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(54) **CLOTH EXHIBITING ACOUSTIC ABSORPTION**

(57) In order to provide a fabric that is lightweight and having sufficient sound-absorption performance, a sound absorbing fabric is three-dimensional and formed of a pair of base fabrics interconnected by connecting yarns; a sound-entrance base fabric has openings (4) in a mesh-work arrangement and non-opening parts; such non-opening part (5) is formed in a dome shape having a curvature (1/R) of 0.1 to 0.7 when radius of the curvature is represented as "R" mm; thickness dimension of the non-opening part (5) from its peak to bottom fringe is 1.5 to 5.0 mm; "DV" value obtained by formula [1] below is 5 to 120; and inlay yarns (6) are knit-wise attached on inner face of non-sound-entrance base fabric (2).

$$DV = \{ 4.2 \times \pi \times A \times W \times c' \} / c \cdots \cdots [1]$$

A: thickness dimension (mm) of the non-opening part;

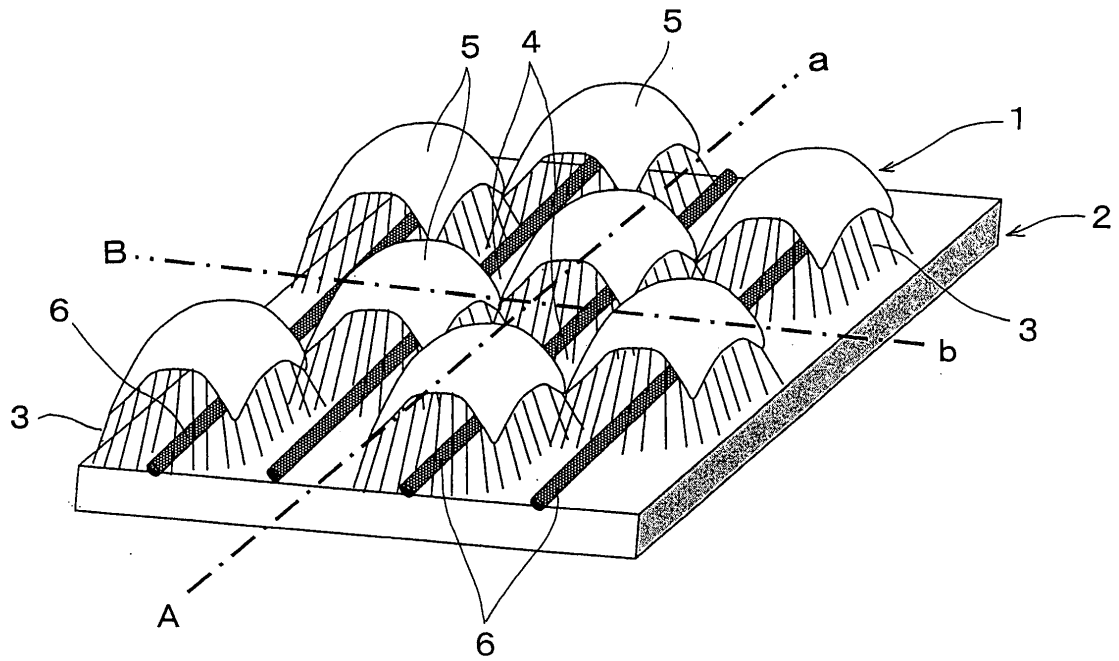
W: course-direction-wise dimension (mm) of the non-opening part;

c': number of loops per one repeat in wale direction, on the non-opening part;

c: course density (number of courses/inch) at completion, of the sound absorbing fabric.

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FIG. 2



**Description**

## Technical Field

5 **[0001]** The invention relates to a sound absorbing fabric. The invention relates more particularly to a sound absorbing fabric having a three-dimensional structure, which has two base fabrics connected by connecting yarns and has mesh openings on sound-entrance base fabric, and in which inlay yarns are knit-wise attached on inner face of non-sound-entrance base fabric.

## 10 Background Art

**[0002]** JP-1984(S59)-1793 Y2 (Japan's examined utility model publication S59-1793) and JP-1989(H01)-150533A (Japan's patent application publication H1-150533) disclose sound absorbing materials; each of which is formed by bonding a cover or top material on a porous materials such as glass wool, urethane foam, felt, polyethylene foam and nonwoven fabric of synthetic fiber; and which are used in building, vehicles and transport machines.

15 **[0003]** These have drawbacks in following. Sound-absorption performance of a porous material is damaged by adhesive used for bonding the cover material. Meanwhile, when rate or amount of application of the adhesive is lowered to curb the damaging in sound-absorption performance, the cover material may become easily separated from the porous material. Further, such bonding of the cover material onto the porous material requires work operation in poor efficiency as to increase work load and thus increase production cost.

20 **[0004]** As to improve the above drawbacks, JP-1992(H04)-53087 U (Japan's utility model application publication H4-53087) discloses a sound absorbing interior finishing material that is formed of a fabric comprised of a pair of base fabrics and connecting yarns. Because the fabric has no openings, the sound-absorption performance would be hardly sufficient. Accordingly, the fabric is required to have a considerably large thickness when to achieve high sound-absorption performance. However, unrestrained increasing of the thickness in accordance with a required level of sound-absorption performance is unrealistic for use in an interior finishing material. Moreover, increasing of thickness induces increase of basis weight, or weight per square meter, of the fabric and thereby causes deterioration in workability and increase of production cost.

## 30 Disclosure of the Invention

## Problems to be solved by the Invention

35 **[0005]** In view of the above drawbacks, it is to provide a fabric that requires no process of bonding with cover material, and exhibits sufficient sound-absorption performance with a light weight construction.

## Means for Solving the Problems

40 **[0006]** The above problems are to be solved by the invention in following manner.

(1) A sound absorbing fabric is a three-dimensional fabric formed of a pair of base fabrics interconnected by connecting yarns, wherein: a front or sound-entrance base fabric has openings in a mesh-work arrangement and non-opening parts; such non-opening part is formed in a dome shape having a curvature (1/R) of 0.1 to 0.7 when radius of the curvature is represented as "R" mm, namely by units of millimeter; a height or thickness dimension of the non-opening part from its peak to bottom fringe is 1.5 to 5.0 mm; "DV" value obtained by formula [1] below is 5 to 120; and inlay yarns are knit-wise attached on inner face of rear or non-sound-entrance base fabric.

$$50 \quad DV = (4.2 \times \pi \times A \times W \times c') / c \cdots \cdots [1]$$

A: thickness dimension (mm) of the non-opening part;

W: course-direction-wise dimension (mm) of the non-opening part;

c': number of loops per one repeat in wale direction, on the non-opening part;

55 c: course density (courses/inch) at completion, of the sound absorbing fabric.

**[0007]** In otherwise, (2) a sound absorbing fabric as constructed as the above (1) is further constructed such that: the non-opening part or dome-shaped part on the sound-entrance base fabric is formed to be 6 to 14 loops per one repeat

in course direction, and be 4 to 24 loops per one repeat in wale direction.

**[0008]** In otherwise, (3) a sound absorbing fabric as constructed as the above (1) is further constructed such that: ratio of inlaying the inlay yarns on inner face of the non-sound-entrance base fabric in course or wale direction is 25 to 100%.

**[0009]** In otherwise, (4) a sound absorbing fabric as constructed as the above (1) is further constructed such that: fineness of base-fabric yarns forming the sound-entrance base fabric is in a range of 167 to 550 dtex.

**[0010]** In otherwise, (5) a sound absorbing fabric as constructed as the above (1) is further constructed such that: fineness of the inlay yarns knit-wise attached on inner face of the non-sound-entrance base fabric is in a range of 167 to 1400 dtex.

**[0011]** In otherwise, (6) a sound absorbing fabric as constructed as the above (1) is further constructed such that: thickness dimension of the sound absorbing fabric is in a range of 2 to 20 mm.

#### Advantageous effect of the Invention

**[0012]** The invention-wise sound absorbing fabric achieves sufficient sound-absorption performance even with light weight construction, requires no process of bonding with a cover material and is applicable as sound absorbing material by itself and preferably for interior finishing material of building or vehicles; because the sound-entrance base fabric has opening and dome-shaped non-opening regions and the inlay yarns are knit-wise attached on inner face of the non-sound-entrance base fabric.

#### Best Mode for Carrying Out the Invention

**[0013]** Embodiments of the present invention will be described in detail in following.

**[0014]** A double raschel knitted fabric is preferably adopted as a three-dimensional fabric to apply the invention, because thickness dimension is easily achieved.

**[0015]** As shown in Figs. 2, 3A and 3B, the invention-wise sound absorbing fabric is a three-dimensional fabric comprised by a pair of base fabrics 1 and 2 and connecting yarns 3 that interconnect the base fabrics. In order to achieve sound-absorption performance even with a light weight construction, openings 4 in a mesh-work arrangement and non-opening parts 5 in a dome-shape having a curvature of 0.1 to 0.7 are provided for the sound-entrance base fabric 1. Thickness dimension ("A" on Fig. 6) from bottom fringe to top of the non-opening part 5 is 1.5 to 5.0 mm; "DV" value obtained by formula [1] shown later is 5 to 120; and inlay yarns 6 are knit-wise attached on inner face of the non-sound-entrance base fabric 2.

**[0016]** For example, some base-fabric yarns forming the sound-entrance base fabric are omitted by an any number when forming the three-dimensional fabric by double raschel knitting. In other words, among yarn guides corresponding interspaces between the knitting needles, an optionally determined number of consecutive yarn guides or one guide are empty of the base-fabric yarns in a manner that such empty yarn guide(s) are repeated in a constant interval, when forming the fabric by the knitting. And, lateral alternate underlapping or shifting of the base-fabric yarns is made by wales in a number same with the number of empty guides. In this way, openings 4 in a mesh-work arrangement are formed on sound-entrance base fabric1. Hence, as compared with conventional sound absorbing materials having a three-dimensional fabric with no openings, incoming sound easily enters inside of the three-dimensional fabric; thus sound-absorption performance is dramatically enhanced. Open area ratio of the sound-entrance base fabric is preferably same with or higher than 10% when for obtaining sufficient sound-absorption performance. When the open area ratio is less than 10%, then incoming sound would become more readily reflected on the sound-entrance base fabric, thus the sound-absorption performance may be deteriorated. When the open area ratio is more than 50%, reflected sound of the sound once having been entered inside of the three-dimensional fabric would more readily propagate through the openings into the air, thus the sound-absorption performance may also be deteriorated. Accordingly, an opening area ratio ranging from 10 to 40% is relatively preferred in view of the sound-absorption performance.

**[0017]** The opening area ratio in accordance with the invention is obtained as follows. The sound-entrance base fabric on a segment of one square inch, of the three-dimensional fabric, is scanned by a scanner and a personal computer; and data thus read out to the computer is binarized in respect of the openings and the other parts, as to calculate percentage of the openings within an area of the one square inch.

**[0018]** In the three-dimensional fabric, the non-opening part 5 in the sound-entrance base fabric 1 is formed in a dome shape by underlapping of yarns forming the base fabric 1. By employing such dome shape, surface area on the sound-entrance base fabric is enlarged so as to improve sound-absorption performance. Further, as shown in Fig. 4, when sound once entered the inside of the three-dimensional fabric is reflected back on the sound-entrance base fabric 1; thus, the reflected sound is rather hard to be diffused to the outside of the three-dimensional fabric. In addition, the sound having entered the inside makes higher number of reciprocate reflecting within the three-dimensional fabric as to induce vibration of fibers and thereby dampening of the sound. Hence, absorption of the sound is enhanced. In the three-

dimensional fabric, the dome-shaped non-opening part 5 is formed so as to have a curvature ( $1/R$ ) of 0.1 to 0.7 when the curvature radius of the non-opening part is represented in units of mm or by "R" mm. The non-opening part is formed to have a thickness dimension of 1.5 to 5.0 mm, and to give the "DV" value of 5 to 120.

**[0019]** The curvature radius "R" of the non-opening part 5 is derived as in Fig. 5, from the base fabric having the dome-shaped non-opening parts. And thereby, the curvature " $1/R$ " is derived.

**[0020]** The thickness dimension "A" of the non-opening part 5 is as in Fig. 6, a difference given by subtracting a thickness dimension "C" up to bottom fringes of the non-opening parts 5, from whole thickness "B" of the fabric. Thus, thickness dimension (mm) of the non-opening part  $A = B - C$ .

**[0021]** The "DV" value is an approximate volume within the non-opening part, which is obtained by assuming the part as a semi-elliptical sphere, by use of a following formula giving volume of an elliptical sphere:  $V = 4/3 \cdot \pi \cdot a \cdot b^2$ . Accordingly, the "DV" value of the non-opening part is obtained as follows.

**[0022]**  $DV \text{ value} = 4/3 \times \pi \times [\text{wale-direction-wise dimension of the non-opening part}/2] \times [\text{thickness dimension of the non-opening part}] \times [\text{course-direction-wise dimension of the non-opening part}/2] \times 1/2$ .

**[0023]** In respect of the non-opening part, wale-direction-wise and course-direction-wise dimensions as well as thickness dimension are calculated as follows.

- Wale-direction-wise dimension (mm) of the non-opening part = [number of loops "c'" within one repeat in wale direction, of the non-opening part] / [course density "c" (number of courses/inch) at completion, of the sound absorbing fabric]  $\times 2.54 \times 10$ .

- Thickness dimension "A" (mm) of the non-opening part: actual measurement obtained by; measuring such dimension at arbitrary three points on an electron microscopic picture; and calculating an average value.

- Course-direction-wise dimension "W" (mm) of the non-opening part: actual measurement obtained by; measuring such dimension of the bottom fringe on a course-direction-wise cross section passing the peak of the non-opening part, at arbitrary three points on an electron microscopic picture; and calculating an average value.

**[0024]** Calculation and measurement as the above are integrated to give the formula [1] below.

$$\cdot DV = (4.2 \times \pi \times A \times W \times c') / c \cdots \cdots [1]$$

**[0025]** When the curvature is 0.1 or less, the thickness dimension is less than 1.5 mm, or the "DV" value is less than 5, sound-absorption performance may become insufficient because the dome shape is not of a remarkable curvature.

**[0026]** The non-opening part 5 of the sound-entrance base fabric preferably has 6 to 14 loops for one repeat in the course direction ("w'" in Fig. 3B), and 4 to 24 loops for one repeat in the wale direction ("c'" in Fig. 3A). With regard to number of loops, less than 6 loops in the course direction, or less than 4 loops in the wale direction hardly gives a dome shape; and 15 loops or more in the course direction, or 25 loops or more in the wale direction results in a small opening part. Thus, these cases may not give a sufficient sound-absorption performance.

**[0027]** In the invention-wise fabric, the base-fabric yarns forming the sound-entrance base fabric may be suitably selected from known yarns of synthetic fibers and natural fibers; however, it is preferable in view of durability to adopt those of synthetic fibers, and polyester fibers among others. In respect of type of the yarns, it is preferable to adopt those having a small apparent density such as spun yarns and textured yarns. Selection of such yarns leads to make an acoustic impedance on surfaces of the base fabric approach the acoustic impedance of air, thereby allowing the incoming sound to enter the inside more easily.

**[0028]** An acoustic impedance is a value specific to a medium propagating sounds and is represented by: [density of the medium]  $\times$  [sound velocity]. A larger difference in the acoustic impedance between media results in a higher reflectivity of the incoming sounds; and a smaller difference in the acoustic impedance between media allows the incoming sounds to enter the inside of the medium more easily to facilitate a sound-absorption performance. Therefore, when yarns having a small apparent density such as spun yarns and textured yarns are used for forming the sound-entrance base fabric, its acoustic impedance become similar with that of a medium of sound source, or of air; and thus, the incoming sounds become easy to enter the inside of the medium or the base fabric, thereby enhancing a sound-absorption performance. Use of yarns having large surface areas relative to their volume, such as multifilament yarns having a small apparent density, is also preferable because a sound-absorption performance for the incoming sounds is enhanced. Fineness of yarns forming the base fabric preferably ranges from 167 to 550 dtex. A fineness of less than 167 dtex may excessively decrease thickness dimension of overlapping of yarns forming the non-opening part of the base fabric; thereby making it difficult to give a dome shape sufficient for facilitating a sound-absorption performance. Meanwhile, yarns more than 550 dtex may balloon basis weight, and production cost.

**[0029]** The base-fabric yarns forming the non-sound-entrance base fabric may also be suitably selected from known

yarns of synthetic fibers and natural fibers; however, it is preferable in view of durability to adopt those of synthetic fibers, and polyester fibers among others. Fineness of yarns forming the base fabric is 84 to 330 dtex, preferably 110 to 220 dtex. In respect of type of the yarns, it is preferable to adopt spun yarns, textured yarns or multifilament yarns. When fineness of the yarns is less than 110 dtex, the density of the base fabric is not sufficiently high, and thus sound-absorption performance may be deteriorated. Yarns more than 220 dtex may balloon the basis weight and production cost.

**[0030]** Densities of the non-sound-entrance base fabric at completion are in a range from 30 to 60 courses/inch and from 18 to 40 wales/inch, and preferably from 33 to 50 courses/inch and from 20 to 36 wales/inch. Density of the non-sound-entrance base fabric falling short of such range makes small density on sound-entrance base fabric, and thus, may make insufficient sound-absorption performance. Density of the non-sound-entrance base fabric exceeding such range may balloon the basis weight and production cost.

**[0031]** The incoming sounds enter into the sound absorbing fabric from the base fabric that has the openings and low apparent density, and then propagate through interspaces having the connecting yarns to reach the base fabric having no openings and having higher apparent density. In this way, the incoming sounds go through parts having larger and larger density as go further from the sound-entrance base fabric to the other base fabric; and as a result of such construction, reflection of sounds decreases and a high sound-absorption performance is achievable.

**[0032]** The invention-wise sound absorbing fabric satisfies following formulae in respect of wale-direction-wise and course-direction-wise cross-sections that include the peaks of the non-opening parts.

$D > E > F$ ,  $D' > E' > F'$  where;

D: interval between the peaks of two non-opening parts adjacent to each other in the wale direction;

E: interval between the bottom fringes of two non-opening parts adjacent to each other in the wale direction;

F: interval in the wale direction between knit-wise attaching sites of the connecting yarns on the non-sound-entrance base fabric;

D' : interval between the peaks of two non-opening parts adjacent to each other in the course direction;

E' : interval between the bottom fringes of two non-opening parts adjacent to each other in the course direction; and

F' : interval in the course direction between knit-wise attaching sites of the connecting yarns on the non-sound-entrance base fabric.

**[0033]** When the above formulae are satisfied, each of the interspaces formed by the non-opening parts and the opening parts makes a tapered shape gradually decreasing in size as approaches to the inner face of the non-sound-entrance base fabric from the sound-entrance fabric. Thus, the incoming sounds are repeatedly reflected in the tapered part and the sound is converted to thermal energy, whereby the sound-absorption performance is enhanced.

**[0034]** As shown in Figs. 2, 3A and 3B, inlay yarns 6 are knit-wise attached on the inner face of the non-sound-entrance base fabric 2 in the invention-wise sound absorbing fabric. Thus, density of the non-sound-entrance base fabric is enhanced so as to enhance sound-absorption performance of the three-dimensional fabric.

**[0035]** The knit-wise attaching of the inlay yarns for the invention indicates following, in the double raschel knitted fabric for example. When the inlay yarns are inlaid in the wale or knitting direction, the inlay yarns form loops on the inner face of the non-sound-entrance base fabric in an interval of any optionally adopted number of courses. When the inlay yarns are inlaid in the course or knitting-width direction, the inlay yarns underlapping by any optionally adopted number of wales are held by base fabric structure or base-fabric yarns, on the inner face of the non-sound-entrance base fabric.

**[0036]** In the invention-wise fabric, the inlay yarns may be suitably selected from yarns of known synthetic fibers and natural fibers; however, it is preferable in view of durability to adopt those of synthetic fibers, and polyester fibers among others. In respect of type of the yarns, it is preferable to adopt those having a small apparent density such as spun yarns, textured yarns and multifilament yarns. Selection of such yarn enhances sound-absorption performance within the fabric. Yarns used as the inlay yarns preferably has a fineness ranging from 167 to 1400 dtex. When the fineness is less than 167 dtex, sound-absorption performance may be deteriorated because density on the non-sound-entrance base fabric is not sufficiently enhanced; and yarns more than 1400 dtex may balloon the basis weight and production cost.

**[0037]** An inlay ratio of the inlay yarns relative to the course density or the wale density of the non-sound-entrance base fabric (that is, a percentage where inlaying for every course or every wale is taken as 100%) is preferably 25 to 100%. When the inlay ratio is less than 25%, density of the non-sound-entrance base fabric is not sufficiently enhanced by the inlay yarns thus the sound-absorption performance is not sufficiently enhanced by the inlay yarns.

**[0038]** The inlay ratio is calculated by following manner.

(1) For inlaying in the wale or knitting direction

**[0039]**

$$\text{Inlay ratio (\%)} = X/c \times 100;$$

where

X: number of the inlay yarns within one inch (inlay yarns/inch) in the course direction at completion, of the sound absorbing fabric; and

c: course density (courses/inch) at completion, of the sound absorbing fabric.

(2) For inlaying in the course or knitting-width direction

**[0040]**

$$\text{Inlay ratio (\%)} = Y/(c \times w) \times 100;$$

where

Y: loop number of inlay yarns knit-wise attached to one inch square of the non-sound-entrance base fabric (loop/inch<sup>2</sup>);

c: course density (courses/inch) at completion, of the sound absorbing fabric; and

w: wale density (wales/inch) at completion, of the sound absorbing fabric.

**[0041]** The connecting yarns in the invention-wise fabric may be suitably selected from known yarns of synthetic fibers and natural fibers; however in view of durability, it is preferable to adopt yarns of synthetic fibers, and of polyester fibers among others. In respect of type of yarns, it is preferable in view of the sound-absorption performance, to adopt blend yarns in which monofilament yarns are blended with multifilament yarns, spun yarns or textured yarns in accordance with situation arisen. By adopting monofilament yarns, retained are thickness of the three-dimensional fabric and interspaces in connecting part between the base fabrics. Thus, numbers of repeating of reciprocal transmission and reflection of the sound within the three-dimensional fabric is increased as to increase vibration of fibers and thereby facilitating the damping and absorption of the sound. The sound-absorption performance is enhanced when the monofilament yarns are blended with multifilament yarns, spun yarns or textured yarns having larger surface areas and thereby smaller apparent densities as compared with monofilaments having same fineness; because thereby absorption of the incoming sound within the sound absorbing fabric is facilitated.

**[0042]** Ratio of monofilament yarns relative to the whole weight of connecting yarns is preferably 40% or more, and particularly preferably 50% or more. A blending ratio of less than 40% may deteriorate retaining of thickness dimension of the three-dimensional fabric as well as spacing at connecting part between the base fabrics; and thus induce insufficient sound-absorption performance.

**[0043]** Fineness of the connecting yarns preferably ranges from 22 to 330 dtex. When the connecting yarns are less than 22 dtex, the thickness dimension or the spacing of the three-dimensional fabric may not be retained. When the connecting yarns are more than 330 dtex, the connecting yarns may stick out from the base fabrics.

**[0044]** When the multifilament yarns are used in the connecting yarns, fineness of filaments consisting the yarns is preferably 2 dtex or more. When the fineness of the filaments is less than 2 dtex, thickness dimension or the spacing of the three-dimensional fabric may not be retained.

**[0045]** Thickness dimension of the sound absorbing fabric that has two base fabrics preferably ranges from 2 to 20 mm. When the thickness dimension is less than 2 mm, an non-opening part in a dome shape is hardly formed on the sound-entrance base fabric, and sufficient sound-absorption performance may not be obtained. When thickness dimension is more than 20 mm, even though sound-absorption performance is achieved, the basis weight increases to induce increase of production cost or the like problem.

**[0046]** An apparent density calculated according to the following formula for the sound absorbing fabric is preferably 0.3 g/cm<sup>3</sup> or less. When the apparent density is larger than 0.3 g/cm<sup>3</sup>, sufficient spacing may not be obtained; and thus, a sound-absorption performance based on diffused reflection of the sounds within the fabric may not be sufficient.

$$\text{Apparent density} = Z/(1000 \times B)$$

where

Z: weight (g) per square meter of the sound absorbing fabric; and

B: thickness (mm) of the sound absorbing fabric.

## Examples

## &lt;Example 1&gt;

**[0047]** A knitting machine (RD6DPLM-77E-22G) manufactured by Karl Mayer GmbH was used. As shown in Fig. 7, yarns of 110dtex/48f were introduced to guide bars L-1 and L-2 to knit-wise form a rear or non-sound-entrance base fabric; yarns of 167dtex/48f were introduced to guide bars L-5 and L-6 to knit-wise form a front or sound-entrance base fabric having openings; and monofilament yarns of 33 dtex were introduced to a guide bar L-3 as connecting yarns to connect the front and rear base fabrics. Two-ply yarns of 167dtex/48f were introduced to a guide bar L-4 as inlay yarns in an arrangement of "1-in, 2-out", so that each inlaying is made at wale-direction-wise interval of five courses, onto the rear base fabric by knit-wise attaching from its inner face.

**[0048]** Yarns for the front base fabric were underlapped by three needle stitches or sway-wise laterally shifted in a range across three needles. The ranges of underlapping of the base-fabric yarns were shifted by three needle stitches, alternately in course-wise opposite directions, at wale-direction-wise interval of six courses, in a manner to form the openings.

**[0049]** Thus obtained knitted fabric was subjected to preset processing at 190°C for 1 minute, then dyeing at 130°C, drying and a finishing set at 150°C for 1 minute. At completion, the knitted fabric is a three-dimensional fabric of 36 courses/inch and 23 wales/inch and 3.0 mm in thickness. Details of the fabric are shown in Table 1.

## &lt;Example 2&gt;

**[0050]** The knitting machine (RD6DPLM-77E-22G) manufactured by Karl Mayer GmbH was used. As shown in Fig. 8, yarns of 110dtex/48f were introduced to guide bars L-1 and L-2 to knit-wise form a rear or non-sound-entrance base fabric; two-ply yarns of 167dtex/48f were introduced to guide bars L-5 and L-6 to knit-wise form a front or sound-entrance base fabric having openings; and monofilament yarns of 33 dtex were introduced to a guide bar L-3 as connecting yarns to connect the front and rear base fabrics. Two-ply yarns of 167dtex/48f were introduced to a guide bar L-4 as inlay yarns in an arrangement of "2-in, 1-out", so that each inlaying is made at wale-direction-wise interval of five courses, onto the rear base fabric by knit-wise attaching from its inner face.

**[0051]** Yarns for the front base fabric were underlapped by six needle stitches in course direction. The ranges of underlapping of the base-fabric yarns were shifted by six needle stitches, alternately in course-wise opposite directions, at wale-direction-wise interval of six courses, in a manner to form the openings.

**[0052]** Thus obtained knitted fabric was subjected to preset processing at 190°C for 1 minute, then dyeing at 130°C, drying and a finishing set at 150°C for 1 minute. At completion, the knitted fabric is a three-dimensional fabric of 36 courses/inch and 23 wales/inch and 4.0 mm in thickness. Details of the fabric are shown in Table 1.

## &lt;Example 3&gt;

**[0053]** The knitting machine (RD6DPLM-77E-22G) manufactured by Karl Mayer GmbH was used. As shown in Fig. 9, textured yarns of 110dtex/48f were introduced to guide bars L-1 and L-2 to knit-wise form a rear or non-sound-entrance base fabric; yarns of 167dtex/48f were introduced to guide bars L-5 and L-6 to knit-wise form a front or sound-entrance base fabric having openings; and monofilament yarns of 33 dtex were introduced to a guide bar L-3 as connecting yarns to connect the front and rear base fabrics. Two-ply yarns of 167dtex/48f were introduced to a guide bar L-4 as inlay yarns in an arrangement of "1-in, 2-out", so that each inlaying is made at wale-direction-wise interval of eleven courses, onto the rear base fabric by knit-wise attaching from its inner face.

**[0054]** Yarns for the front base fabric were underlapped by three needle stitches in course direction. The ranges of underlapping of the base-fabric yarns were shifted by three needle stitches, alternately in course-wise opposite directions, at wale-direction-wise interval of twelve courses, in a manner to form the openings.

**[0055]** Thus obtained knitted fabric was subjected to preset processing at 190°C for 1 minute, then dyeing at 130°C, drying and a finishing set at 150°C for 1 minute. At completion, the knitted fabric is a three-dimensional fabric of 36 courses/inch and 23 wales/inch and 4.0mm in thickness. Details of the fabric are shown in Table 1.

## &lt;Example 4&gt;

**[0056]** The knitting machine (RD6DPLM-77E-22G) manufactured by Karl Mayer GmbH was used. As shown in Fig. 10, yarns of 110dtex/48f were introduced to guide bars L-1 and L-2 to knit-wise form a rear or non-sound-entrance base fabric; yarns of 167dtex/48f were introduced to guide bars L-5 and L-6 to knit-wise form a front or sound-entrance base fabric having openings; and monofilament yarns of 33 dtex in an arrangement of "7-in, 3-out" as well as textured polyester yarns of 33 dtex/6f in an arrangement of "3-in, 7-out" were introduced to a guide bar L-3 as connecting yarns, as to



connect the front and rear base fabrics. Two ply yarns of 167dtex/48f were introduced to a guide bar L-4 as inlay yarns in an arrangement of "1-in, 2-out", so that each inlaying is made at wale-direction-wise interval of five courses, onto the rear base fabric by knit-wise attaching from its inner face.

**[0057]** Yarns for the front base fabric were underlapped by three needle stitches in course direction. The ranges of underlapping of the base-fabric yarns were shifted by three needle stitches, alternately in course-wise opposite directions, at wale-direction-wise interval of six courses, in a manner to form the openings.

**[0058]** Thus obtained knitted fabric was subjected to preset processing at 190°C for 1 minute, then dyeing at 130°C, drying and a finishing set at 150°C for 1 minute. At completion, the knitted fabric is a three-dimensional fabric of 36 courses/inch and 23 wales/inch and 3.0 mm in thickness. Details of the fabric are shown in Table 1.

<Example 5>

**[0059]** The knitting machine (RD6DPLM-77E-22G) manufactured by Karl Mayer GmbH was used. As shown in Fig. 11, yarns of 167dtex/48f were introduced to a guide bar L-1 and yarns of 110dtex/48f were introduced to a guide bar L-4 in an arrangement of "1-in, 2-out" to knit-wise form a rear or non-sound-entrance base fabric. Yarns of 1200dtex/210f were introduced to a guide bar L-2 as inlay yarns, so that inlaying is made every course continuously as to be attached by yarns from the guide bar L-4, onto the rear base fabric from its inner face. Yarns of 167dtex/48f were introduced to guide bars L-5 and L-6 to knit-wise form a front or sound-entrance base fabric having openings; and monofilament yarns of 33 dtex were introduced to a guide bar L-3 as connecting yarns to connect the front and rear base fabrics.

**[0060]** Yarns for the front base fabric were underlapped by three needle stitches in course direction. The ranges of underlapping of the base-fabric yarns were shifted by three needle stitches, alternately in course-wise opposite directions, at wale-direction-wise interval of six courses, in a manner to form the openings.

**[0061]** Thus obtained knitted fabric was subjected to preset processing at 190°C for 1 minute, then dyeing at 130°C, drying and a finishing set at 150°C for 1 minute. At completion, the knitted fabric is a three-dimensional fabric of 36 courses/inch and 23 wales/inch and 3.0mm in thickness. Details of the fabric are shown in Table 1.

<Comparative example 1>

**[0062]** The knitting machine (RD6DPLM-77E-22G) manufactured by Karl Mayer GmbH was used. As shown in Fig. 12, yarns of 167dtex/48f were introduced to guide bars L-1 and L-2 to knit-wise form a rear or non-sound-entrance base fabric; yarns of 110dtex/48f were introduced to guide bars L-5 and L-6 to knit-wise form a front or sound-entrance base fabric having openings; and monofilament yarns of 33 dtex were introduced to a guide bar L-3 as connecting yarns to connect the front and rear base fabrics.

**[0063]** Yarns for the front base fabric were underlapped by three needle stitches in course direction. The ranges of underlapping of the base-fabric yarns were shifted by three needle stitches, alternately in course-wise opposite directions, at wale-direction-wise interval of six courses, in a manner to form the openings.

**[0064]** Thus obtained knitted fabric was subjected to preset processing at 190°C for 1 minute, then dyeing at 130°C, drying and a finishing set at 150°C for 1 minute. At completion, the knitted fabric is a three-dimensional fabric of 36 courses/inch and 23 wales/inch and 3.0 mm in thickness. Details of the fabric are shown in Table 1.

<Comparative example 2>

**[0065]** The knitting machine (RD6DPLM-77E-22G) manufactured by Karl Mayer GmbH was used. As shown in Fig. 13, yarns of 167dtex/48f were introduced to guide bars L-1 and L-2 to knit-wise form a rear or non-sound-entrance base fabric; yarns of 167dtex/48f were introduced to guide bars L-5 and L-6 to knit-wise form a front or sound-entrance base fabric having openings; and monofilament yarns of 33 dtex were introduced to a guide bar L-3 as connecting yarns to connect the front and rear base fabrics.

**[0066]** Yarns for the front base fabric were underlapped by one needle stitch in course direction. The ranges of underlapping of the base-fabric yarns were shifted by one needle stitch, alternately in course-wise opposite directions, at wale-direction-wise interval of six courses, in a manner to form the openings.

**[0067]** Thus obtained knitted fabric was subjected to preset processing at 190°C for 1 minute, then dyeing at 130°C, drying and a finishing set at 150°C for 1 minute. At completion, the knitted fabric is a three-dimensional fabric of 36 courses/inch and 23 wales/inch and 3.0 mm in thickness. Details of the fabric are shown in Table 1.

<Comparative example 3>

**[0068]** The knitting machine (RD6DPLM-77E-22G) manufactured by Karl Mayer GmbH was used. As shown in Fig. 14, yarns of 167dtex/48f were introduced to guide bars L-1 and L-2 to knit-wise form a rear base fabric; yarns of 167dtex/

48f were introduced to guide bars L-5 and L-6 to knit-wise form a front base fabric; and monofilament yarns of 33 dtex were introduced to a guide bar L-3 as connecting yarns to connect the front and rear base fabrics.

**[0069]** Thus obtained knitted fabric was subjected to preset processing at 190°C for 1 minute, then dyeing at 130°C, drying and a finishing set at 150°C for 1 minute. At completion, the knitted fabric is a three-dimensional fabric of 36 courses/inch and 23 wales/inch and 3.0 mm in thickness. Details of the fabric are shown in Table 1.

<Comparative example 4>

**[0070]** The knitting machine (RD6DPLM-77E-22G) manufactured by Karl Mayer GmbH was used. In a manner similar to a knitting pattern diagram shown in Fig. 13, yarns of 167dtex/48f were introduced to guide bars L-1 and L-2 to knit-wise form a rear or non-sound-entrance base fabric; two-ply yarns of 167dtex/48f were introduced to guide bars L-5 and L-6 to knit-wise form a front or sound-entrance base fabric having openings; and monofilament yarns of 33 dtex were introduced to a guide bar L-3 as connecting yarns to connect the front and rear base fabrics.

**[0071]** Yarns for the front base fabric were underlapped by six needle stitches in course direction. The ranges of underlapping of the base-fabric yarns were shifted by six needle stitches, alternately in course-wise opposite directions, at wale-direction-wise interval of 18 courses, in a manner to form the openings.

**[0072]** Thus obtained knitted fabric was subjected to preset processing at 190°C for 1 minute, then dyeing at 130°C, drying and a finishing set at 150°C for 1 minute. At completion, the knitted fabric is a three-dimensional fabric of 36 courses/inch and 23 wales/inch and 4.5 mm in thickness. Details of the fabric are shown in Table 1.

<Comparative example 5>

**[0073]** The knitting machine (RD6DPLM-77E-22G) manufactured by Karl Mayer GmbH was used. In a manner similar to a knitting pattern diagram shown in Fig. 13, yarns of 167dtex/48f were introduced to guide bars L-1 and L-2 to knit-wise form a rear or non-sound-entrance base fabric; two-ply yarns of 167dtex/48f were introduced to guide bars L-5 and L-6 to knit-wise form a front or sound-entrance base fabric having openings; and monofilament yarns of 33 dtex were introduced to a guide bar L-3 as connecting yarns to connect the front and rear base fabrics.

**[0074]** Yarns for the front base fabric were underlapped by three needle stitches in course direction. The ranges of underlapping of the base-fabric yarns were shifted by three needle stitches, alternately in course-wise opposite directions, at wale-direction-wise interval of two courses, in a manner to form the openings.

**[0075]** Thus obtained knitted fabric was subjected to preset processing at 190°C for 1 minute, then dyeing at 130°C, drying and a finishing set at 150°C for 1 minute. At completion, the knitted fabric is a three-dimensional fabric of 36 courses/inch and 23 wales/inch and 3.0 mm in thickness. Details of the fabric are shown in Table 1.

<Comparative example 6>

**[0076]** The knitting machine (RD6DPLM-77E-22G) manufactured by Karl Mayer GmbH was used. In a manner similar to a knitting pattern diagram shown in Fig. 13, yarns of 167dtex/48f were introduced to guide bars L-1 and L-2 to knit-wise form a rear or non-sound-entrance base fabric; yarns of 84dtex/36f were introduced to guide bars L-5 and L-6 to knit-wise form a front or sound-entrance base fabric having openings; and monofilament yarns of 33 dtex were introduced to a guide bar L-3 as connecting yarns to connect the front and rear base fabrics.

**[0077]** Yarns for the front base fabric were underlapped by seven needle stitches in course direction. The ranges of underlapping of the base-fabric yarns were shifted by seven needle stitches, alternately in course-wise opposite directions, at wale-direction-wise interval of eight courses, in a manner to form the openings.

**[0078]** Thus obtained knitted fabric was subjected to preset processing at 190°C for 1 minute, then dyeing at 130°C, drying and a finishing set at 150°C for 1 minute. At completion, the knitted fabric is a three-dimensional fabric of 36 courses/inch and 23 wales/inch and 3.0 mm in thickness. Details of the fabric are shown in Table 1.

| Table 1               |                                     |                                        |            |                      |                                              |                        |                                              |                                  |                                      |
|-----------------------|-------------------------------------|----------------------------------------|------------|----------------------|----------------------------------------------|------------------------|----------------------------------------------|----------------------------------|--------------------------------------|
|                       | Curvature of dome-shaped part "1/R" | Thickness of dome-shaped part "A" (mm) | "DV" value | Inlaying density (%) | Thickness of sound-absorbing fabric "B" (mm) | Opening area ratio (%) | Width of bottom of dome-shaped part "w" (mm) | Basis weight (g/m <sup>2</sup> ) | Apparent density (g/m <sup>3</sup> ) |
| Example 1             | 0.42                                | 2.14                                   | 18.12      | 33%                  | 3.0                                          | 35                     | 4.00                                         | 485                              | 0.162                                |
| Example 2             | 0.17                                | 2.60                                   | 53.77      | 66%                  | 4.0                                          | 13                     | 9.77                                         | 596                              | 0.149                                |
| Example 3             | 0.45                                | 2.41                                   | 41.93      | 33%                  | 4.0                                          | 31                     | 4.11                                         | 477                              | 0.119                                |
| Example 4             | 0.42                                | 2.14                                   | 18.09      | 33%                  | 3.0                                          | 35                     | 4.00                                         | 483                              | 0.161                                |
| Example 5             | 0.45                                | 2.09                                   | 36.89      | 33%                  | 3.0                                          | 34                     | 4.17                                         | 509                              | 0.170                                |
| Comparative example 1 | 0.49                                | 1.40                                   | 10.28      | -                    | 3.0                                          | 40                     | 3.35                                         | 480                              | 0.160                                |
| Comparative example 2 | 0.21                                | 0.61                                   | 1.43       | -                    | 3.0                                          | 44                     | 1.11                                         | 538                              | 0.179                                |
| Comparative example 3 | -                                   | -                                      | -          | -                    | 5.0                                          | -                      | -                                            | 601                              | 0.120                                |
| Comparative example 4 | 0.20                                | 3.54                                   | 226.89     | -                    | 4.5                                          | 22                     | 9.72                                         | 655                              | 0.145                                |
| Comparative example 5 | 0.49                                | 1.68                                   | 4.92       | -                    | 3.0                                          | 27                     | 4.00                                         | 477                              | 0.159                                |
| Comparative example 6 | 0.09                                | 1.88                                   | 56.25      | -                    | 3.0                                          | 15                     | 10.21                                        | 460                              | 0.153                                |

**[0079]** In order to evaluate the sound-absorption performance of the sound absorbing fabrics obtained in the examples, sound-absorption performance or ratios of absorbed sound was measured substantially in accordance with JIS A 1405. These results are shown in Table 2 and Fig. 1, which is a graph plotted with the values in the table.

Table 2

|      | Ex. 1 | Ex. 2 | Ex. 3 | Ex. 4 | Ex. 5 | Comp<br>Ex. 1 | Comp.<br>Ex. 2 | Comp.<br>Ex.3 | Comp.<br>Ex. 4 | Comp.<br>Ex. 5 | Comp.<br>Ex. 6 |
|------|-------|-------|-------|-------|-------|---------------|----------------|---------------|----------------|----------------|----------------|
| 100  | 0.019 | 0.019 | 0.019 | 0.020 | 0.019 | 0.020         | 0.020          | 0.020         | 0.020          | 0.020          | 0.020          |
| 125  | 0.020 | 0.019 | 0.019 | 0.020 | 0.019 | 0.019         | 0.020          | 0.015         | 0.018          | 0.020          | 0.020          |
| 160  | 0.038 | 0.029 | 0.031 | 0.038 | 0.032 | 0.031         | 0.031          | 0.033         | 0.030          | 0.032          | 0.032          |
| 200  | 0.038 | 0.037 | 0.038 | 0.038 | 0.043 | 0.039         | 0.038          | 0.038         | 0.041          | 0.040          | 0.040          |
| 250  | 0.042 | 0.043 | 0.046 | 0.043 | 0.043 | 0.047         | 0.047          | 0.038         | 0.044          | 0.048          | 0.048          |
| 315  | 0.048 | 0.050 | 0.050 | 0.048 | 0.048 | 0.047         | 0.047          | 0.048         | 0.047          | 0.048          | 0.048          |
| 400  | 0.057 | 0.059 | 0.060 | 0.058 | 0.057 | 0.057         | 0.057          | 0.054         | 0.057          | 0.058          | 0.058          |
| 500  | 0.080 | 0.090 | 0.081 | 0.084 | 0.077 | 0.078         | 0.078          | 0.079         | 0.082          | 0.081          | 0.081          |
| 630  | 0.093 | 0.106 | 0.094 | 0.097 | 0.093 | 0.091         | 0.088          | 0.089         | 0.096          | 0.095          | 0.095          |
| 800  | 0.110 | 0.137 | 0.111 | 0.116 | 0.108 | 0.105         | 0.102          | 0.102         | 0.091          | 0.109          | 0.109          |
| 1000 | 0.123 | 0.176 | 0.127 | 0.132 | 0.122 | 0.116         | 0.111          | 0.111         | 0.102          | 0.120          | 0.120          |
| 1250 | 0.159 | 0.252 | 0.166 | 0.171 | 0.158 | 0.148         | 0.140          | 0.135         | 0.130          | 0.151          | 0.151          |
| 1600 | 0.209 | 0.370 | 0.219 | 0.228 | 0.208 | 0.188         | 0.171          | 0.162         | 0.166          | 0.189          | 0.189          |
| 2000 | 0.289 | 0.547 | 0.303 | 0.321 | 0.287 | 0.249         | 0.221          | 0.203         | 0.223          | 0.248          | 0.248          |
| 2500 | 0.410 | 0.748 | 0.428 | 0.458 | 0.407 | 0.341         | 0.295          | 0.266         | 0.311          | 0.336          | 0.336          |
| 3150 | 0.574 | 0.914 | 0.596 | 0.637 | 0.572 | 0.472         | 0.404          | 0.359         | 0.434          | 0.463          | 0.463          |
| 4000 | 0.731 | 0.966 | 0.752 | 0.789 | 0.731 | 0.630         | 0.554          | 0.495         | 0.630          | 0.616          | 0.616          |
| 5000 | 0.762 | 0.902 | 0.781 | 0.800 | 0.764 | 0.707         | 0.647          | 0.604         | 0.667          | 0.691          | 0.691          |
| 6300 | 0.742 | 0.834 | 0.760 | 0.770 | 0.747 | 0.725         | 0.688          | 0.657         | 0.691          | 0.709          | 0.709          |

**[0080]** As clear from the Table 2, sound-absorption performance of the Example 5 is almost equal to that of the Example 1; and thus, in the graph of Fig. 1, plot curves of these examples overlap with each other. And, sound-absorption performance of the Comparative example 6 is almost equal to that of the Comparative example 5; and thus, in the graph of Fig. 1, plot curves of these comparative examples overlap with each other.

**[0081]** As clear from the Table 2 and Fig. 1, as compared with fabrics in Comparative examples 1 to 3, the sound-absorption performance in high frequency range of no less than 800 Hz is significantly improved in each of the fabrics of Examples 1 to 5. In particular, the sound-absorption performance of the Examples in the high frequency range is superior to that of the Comparative example 3, which has no openings on the front base fabric nor inlay yarns. The sound-absorption performances of the Examples are superior to those of Comparative examples 1 and 2, in which thickness dimension of the dome-shaped non-opening parts is less than 1.5 mm even though the openings are provided on the front base fabric.

#### Brief Description of the Drawings

**[0082]**

Fig. 1 is a graph showing sound-absorption performance of the invention-wise fabric.

Fig. 2 is a partial perspective view schematically showing an example of the invention-wise sound absorbing fabric.

Fig. 3A is a schematical cross-sectional view of the fabric shown in Fig. 2 along its A-a line.

Fig. 3B is a schematical cross-sectional view of the fabric shown in Fig. 2 along its B-b line.

Fig. 4 is an explanatory view showing propagation of the incoming sound within the fabric Shown in Fig. 2.

Fig. 5 is an explanatory view indicating a curvature radius of the dome shape in the fabric shown in Fig. 2.  
 Fig. 6 is an explanatory view indicating a thickness dimension of the dome shape in the fabric shown in Fig. 2.  
 Fig. 7 is a knitting pattern diagram for Example 1.  
 Fig. 8 is a knitting pattern diagram for Example 2.  
 Fig. 9 is a knitting pattern diagram for Example 3.  
 Fig. 10 is a knitting pattern diagram for Example 4.  
 Fig. 11 is a knitting pattern diagram for Example 5.  
 Fig. 12 is a knitting pattern diagram for Comparative example 1.  
 Fig. 13 is a knitting pattern diagram for Comparative example 2.  
 Fig. 14 is a knitting pattern diagram for Comparative example 3.

## Reference Numerals

### [0083]

1 front or sound-entrance base fabric;  
 2 rear or non-sound-entrance base fabric; 3 connecting yarn;  
 4 opening; 5 non-opening part (dome-shaped part);  
 6 inlay yarn.

## Claims

1. A sound absorbing fabric, which is a three-dimensional fabric formed of a pair of base fabrics interconnected by connecting yarns, wherein: a sound-entrance base fabric has openings in a mesh-work arrangement and non-opening parts; such non-opening part is formed in a dome shape having a curvature (1/R) of 0.1 to 0.7 when radius of the curvature is represented as "R" mm; thickness dimension of the non-opening part from its peak to bottom fringe is 1.5 to 5.0 mm; "DV" value obtained by formula [1] below is 5 to 120; and inlay yarns are knit-wise attached on inner face of non-sound-entrance base fabric.

$$DV = (4.2 \times \pi \times A \times W \times c') / c \dots \dots [1]$$

A: thickness dimension (mm) of the non-opening part;  
 W: course-direction-wise dimension (mm) of the non-opening part;  
 c' : number of loops per one repeat in wale direction, on the non-opening part;  
 c: course density (number of courses/inch) at completion, of the sound absorbing fabric.

2. A sound absorbing fabric according to claim 1, wherein the non-opening part or dome-shaped part on the sound-entrance base fabric is formed to be 6 to 14 loops per one repeat in course direction, and be 4 to 24 loops per one repeat in wale direction.
3. A sound absorbing fabric according to claim 1, wherein ratio of inlaying the inlay yarns on inner face of the non-sound-entrance base fabric in course or wale direction is 25 to 100%.
4. A sound absorbing fabric according to claim 1, wherein fineness of base-fabric yarns forming the sound-entrance base fabric is in range of 167 to 550 dtex.
5. A sound absorbing fabric according to claim 1, wherein fineness of the inlay yarns knit-wise attached on inner face of the non-sound-entrance base fabric is in range of 167 to 1400 dtex.
6. A sound absorbing fabric according to claim 1, wherein thickness dimension of the sound absorbing fabric is in a range of 2 to 20 mm.

FIG. 1

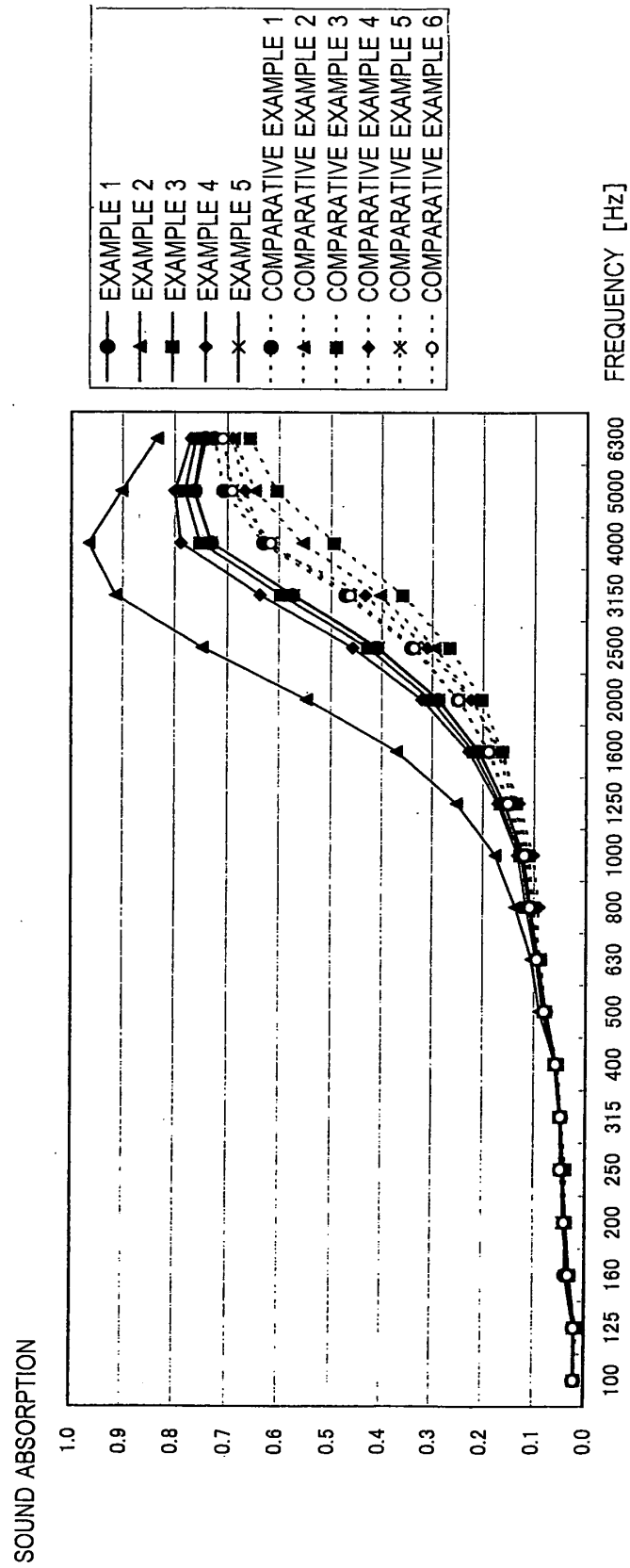


FIG. 2

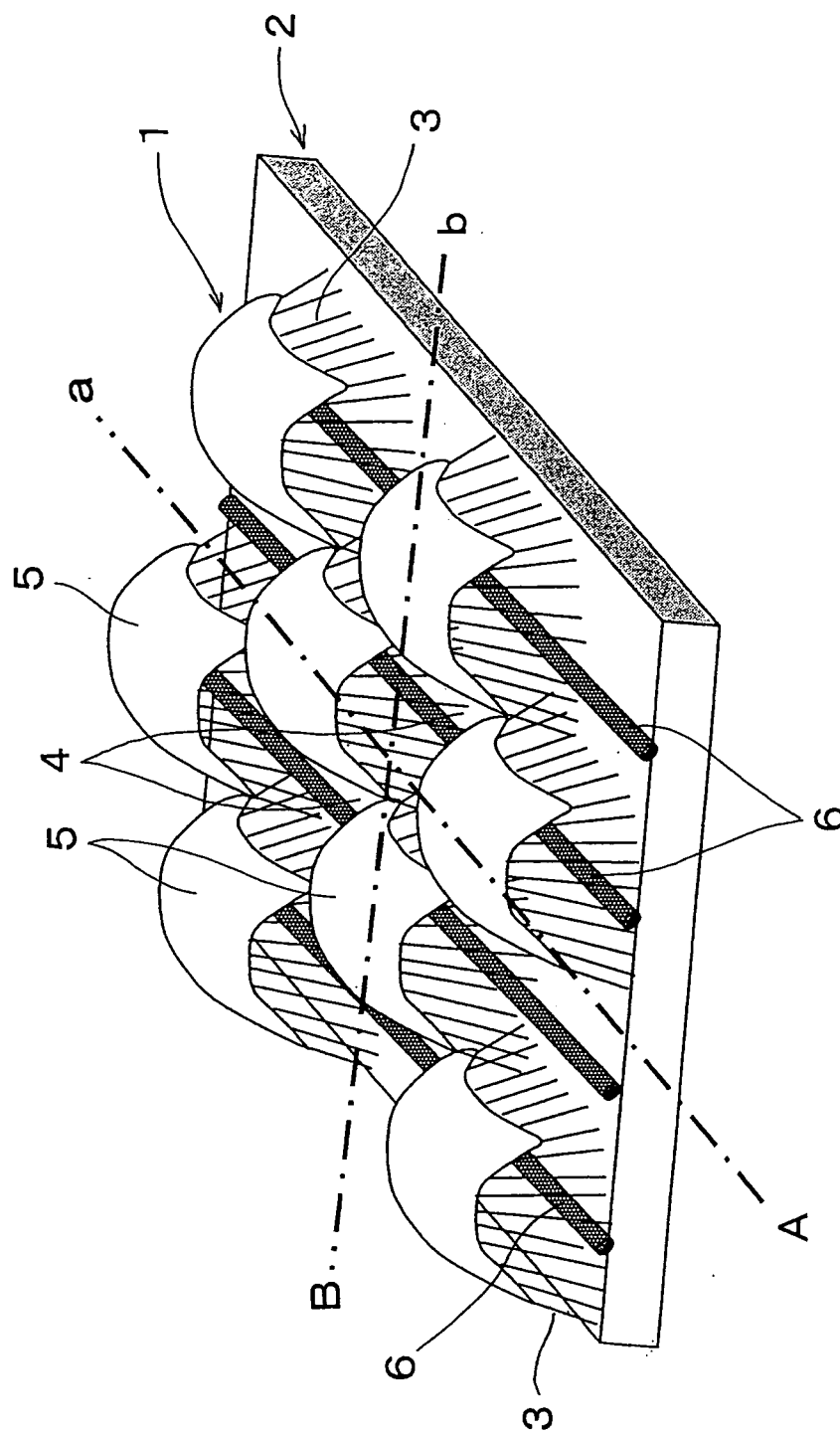


FIG. 3A

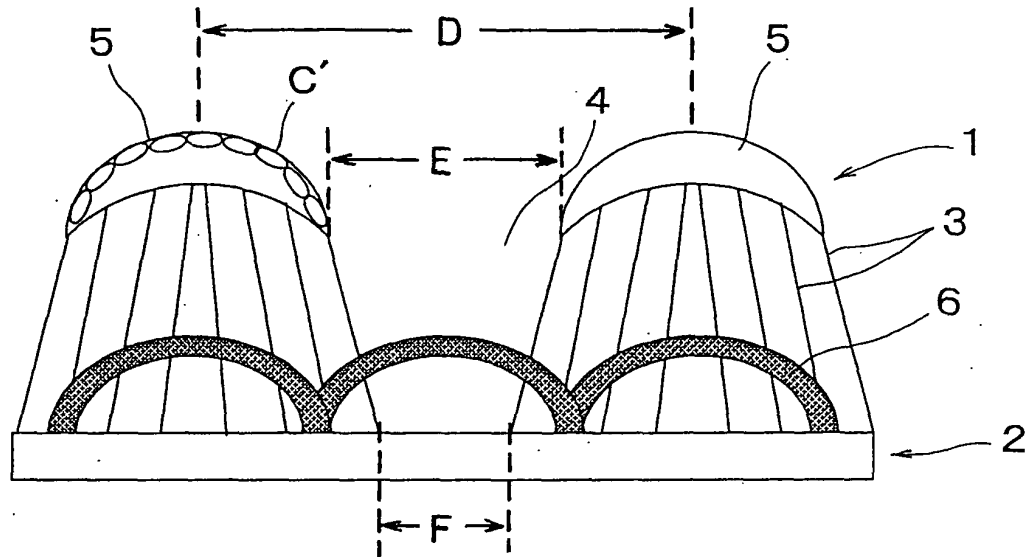


FIG. 3B

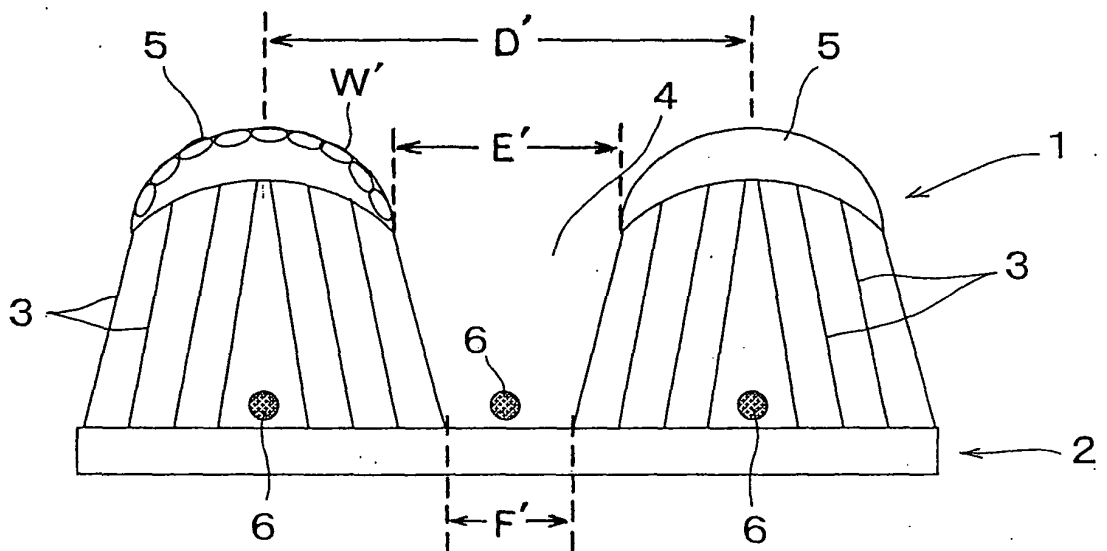




FIG. 4

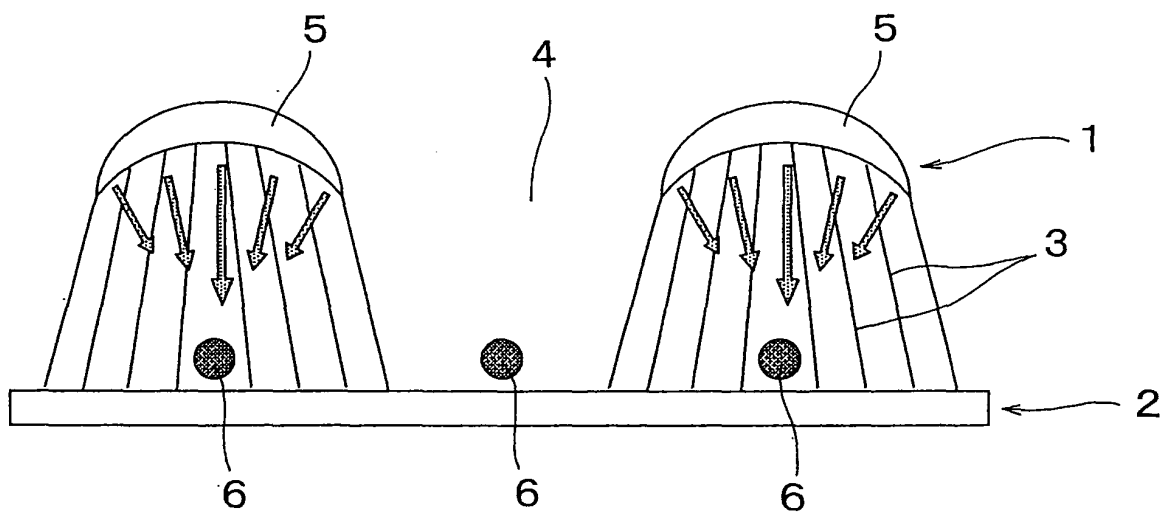


FIG. 5

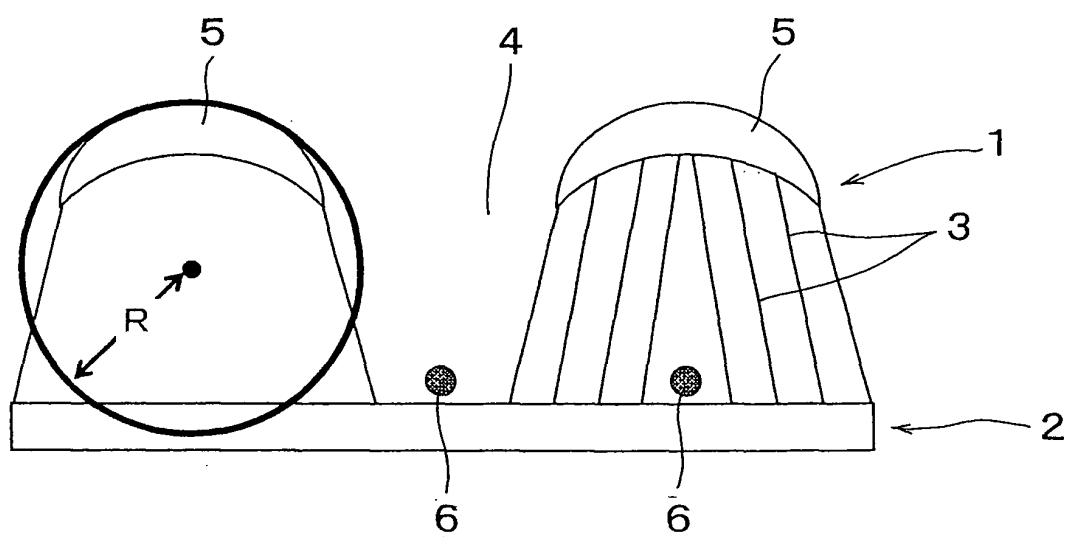


FIG. 6

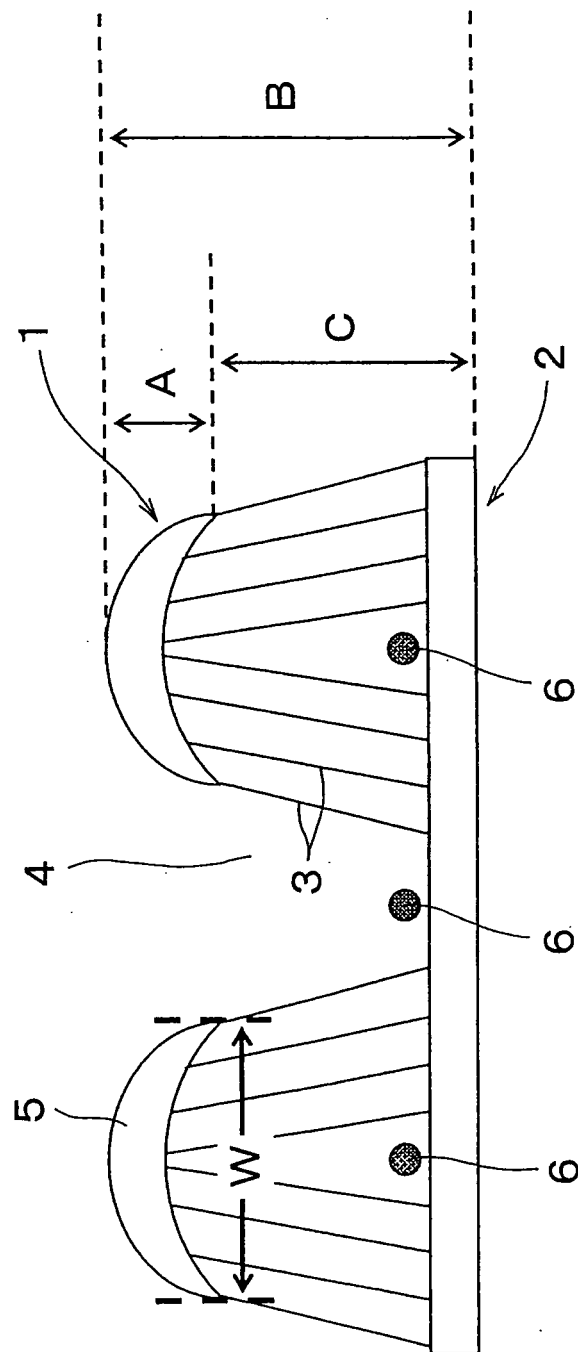


FIG. 7

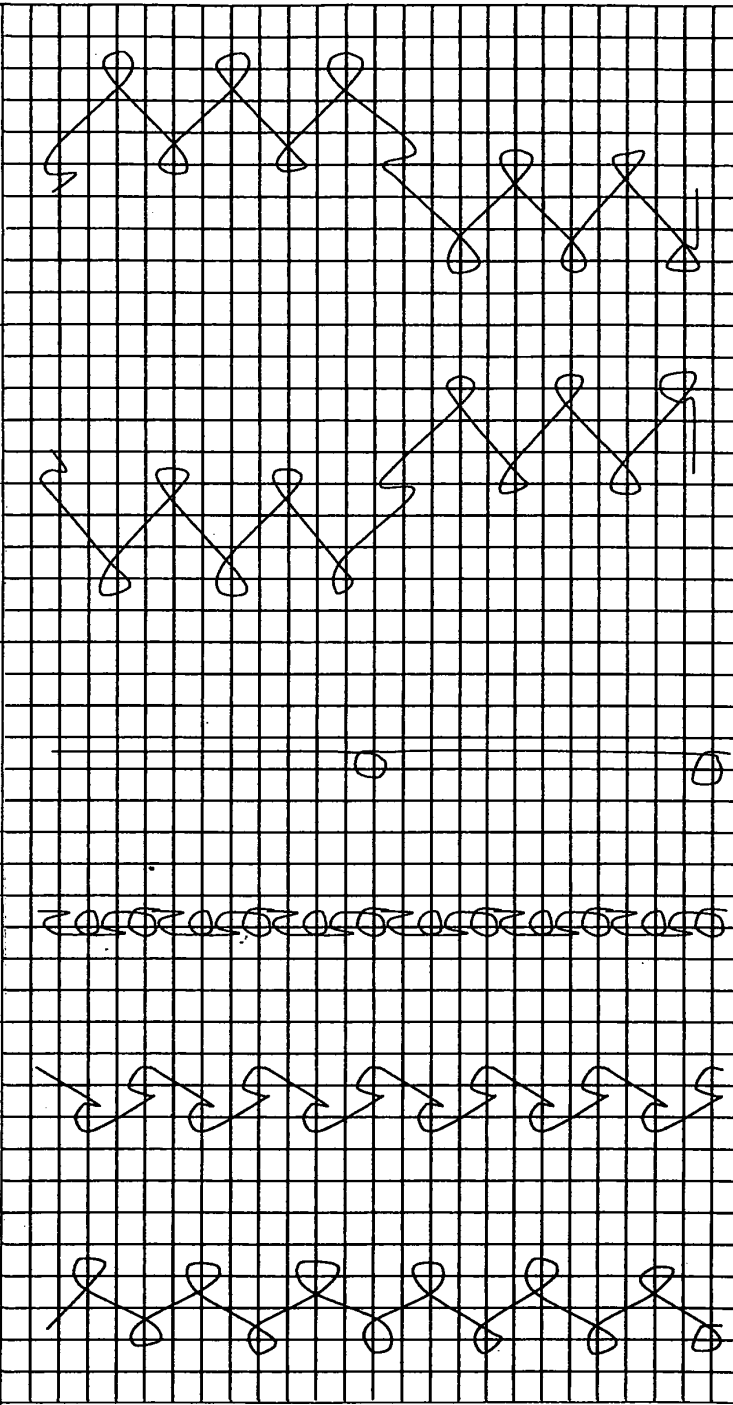
|                                                   |                                                                                     |                           |                         |                                          |                           |                           |                    |  |
|---------------------------------------------------|-------------------------------------------------------------------------------------|---------------------------|-------------------------|------------------------------------------|---------------------------|---------------------------|--------------------|--|
| KNITTING MACHINE<br>MEASUREMENTS AT<br>COMPLETION | RD-6DPLM-77 (22G)                                                                   |                           |                         |                                          |                           |                           | THICKNESS: 3.0mm   |  |
|                                                   | WIDTH: 135 cm                                                                       |                           |                         |                                          |                           |                           | COURSE/WALE: 36/23 |  |
| TYPE OF YARN                                      | POLYESTER:<br>110dtex/48f                                                           | POLYESTER:<br>110dtex/48f | POLYESTER:<br>33dtex/1f | POLYESTER:<br>167dtex/2f<br>TWO-PLY YARN | POLYESTER:<br>167dtex/48f | POLYESTER:<br>167dtex/48f |                    |  |
| GUIDE BAR NO.                                     | L-1                                                                                 | L-2                       | L-3                     | L-4                                      | L-5                       | L-6                       |                    |  |
| KNITTING PATTERN                                  |  |                           |                         |                                          |                           |                           |                    |  |
|                                                   |                                                                                     |                           |                         |                                          |                           |                           |                    |  |

FIG. 8

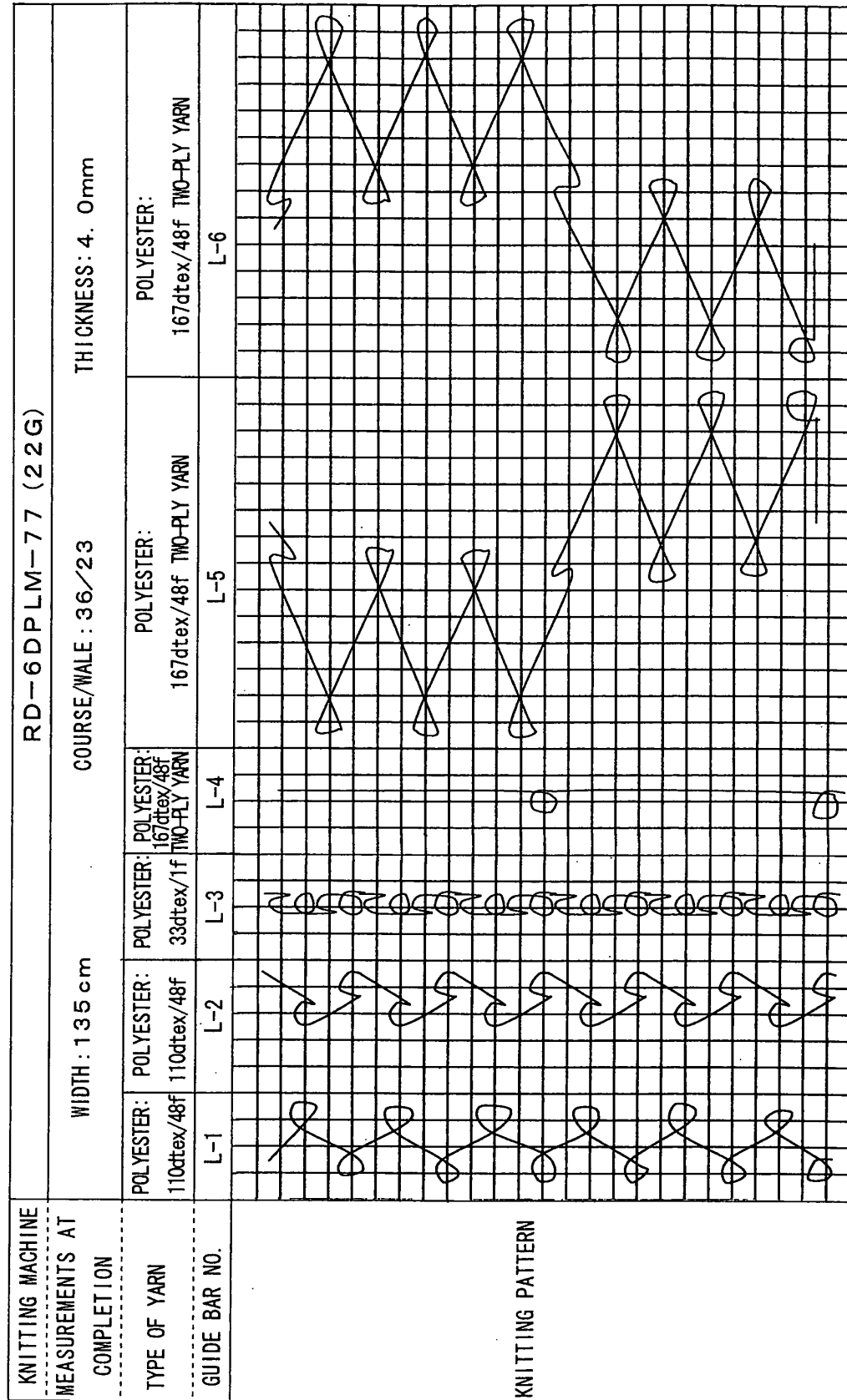


FIG. 9

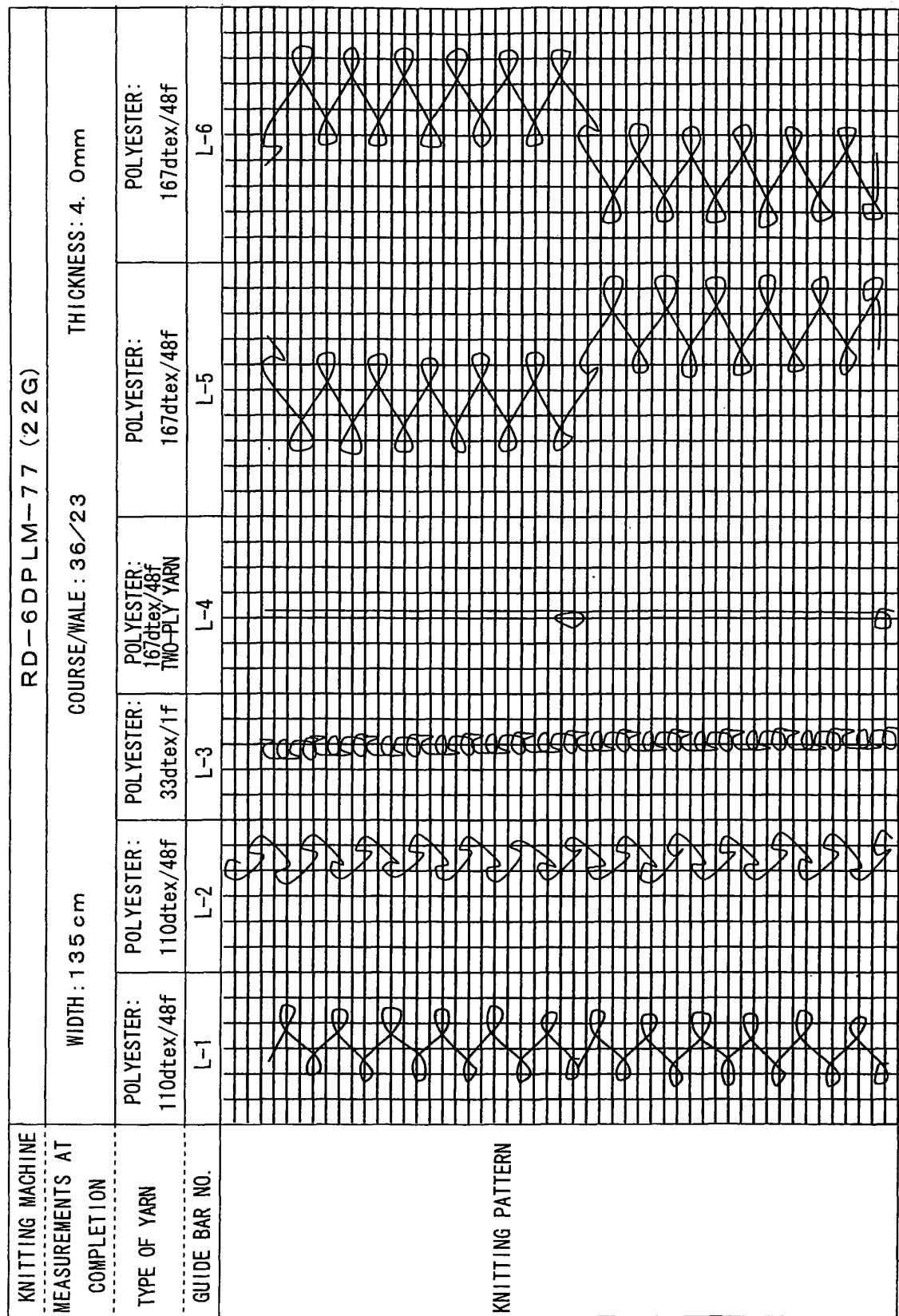


FIG. 10

| KNITTING MACHINE<br>MEASUREMENTS AT<br>COMPLETION | RD-6DPLM-77 (22G)         |                           |                                              |                                           |                           |                           |
|---------------------------------------------------|---------------------------|---------------------------|----------------------------------------------|-------------------------------------------|---------------------------|---------------------------|
|                                                   | WIDTH : 135 cm            |                           | COURSE/WALE : 36/23                          |                                           | THICKNESS : 3.0 mm        |                           |
| TYPE OF YARN                                      | POLYESTER:<br>110dtex/48f | POLYESTER:<br>110dtex/48f | POLYESTER:<br>33dtex/1f 70%<br>33dtex/6f 30% | POLYESTER:<br>167dtex/48f<br>TWO-PLY YARN | POLYESTER:<br>167dtex/48f | POLYESTER:<br>167dtex/48f |
| GUIDE BAR NO.                                     | L-1                       | L-2                       | L-3                                          | L-4                                       | L-5                       | L-6                       |
| KNITTING PATTERN                                  |                           |                           |                                              |                                           |                           |                           |
|                                                   |                           |                           |                                              |                                           |                           |                           |

FIG. 11

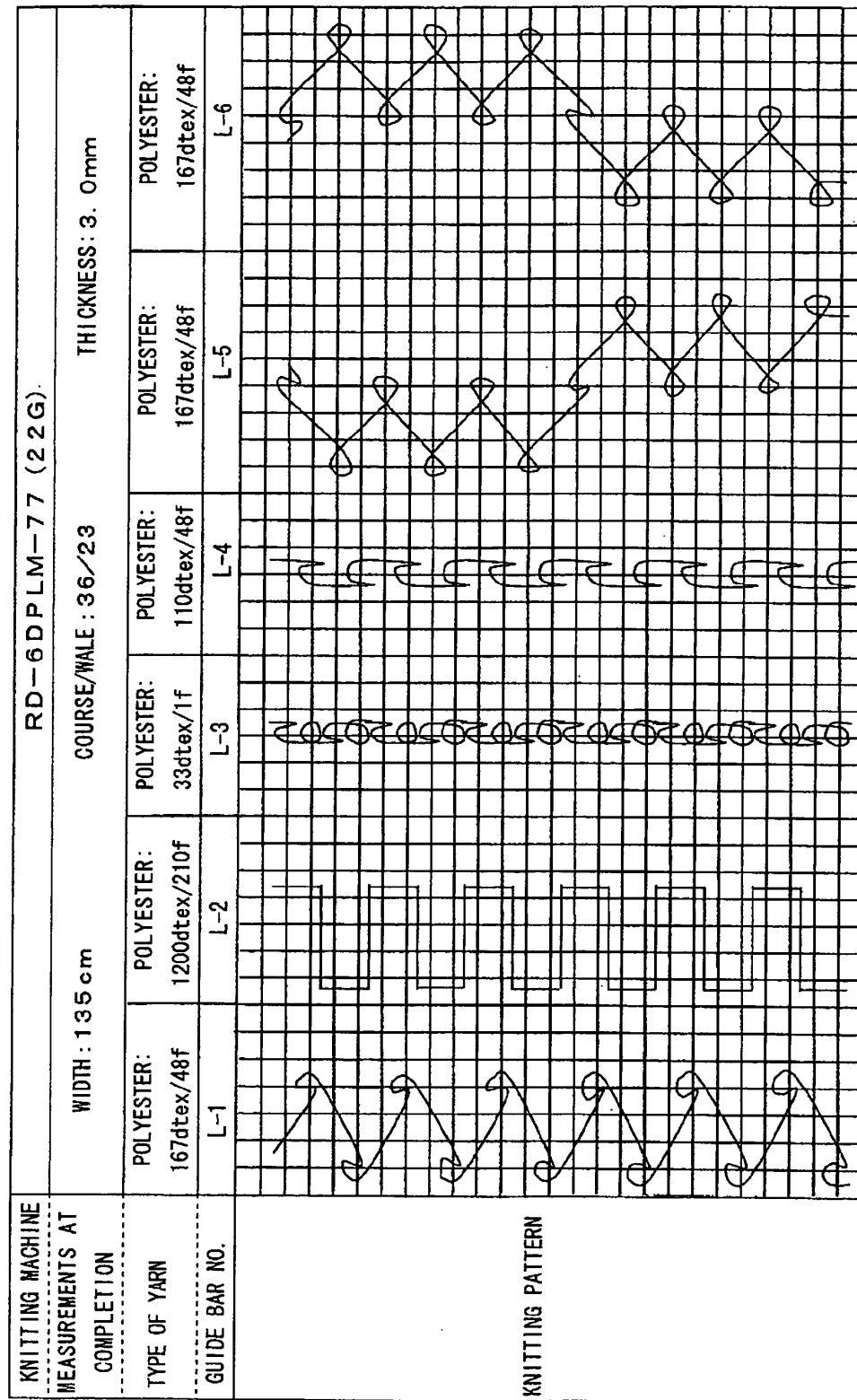


FIG. 12

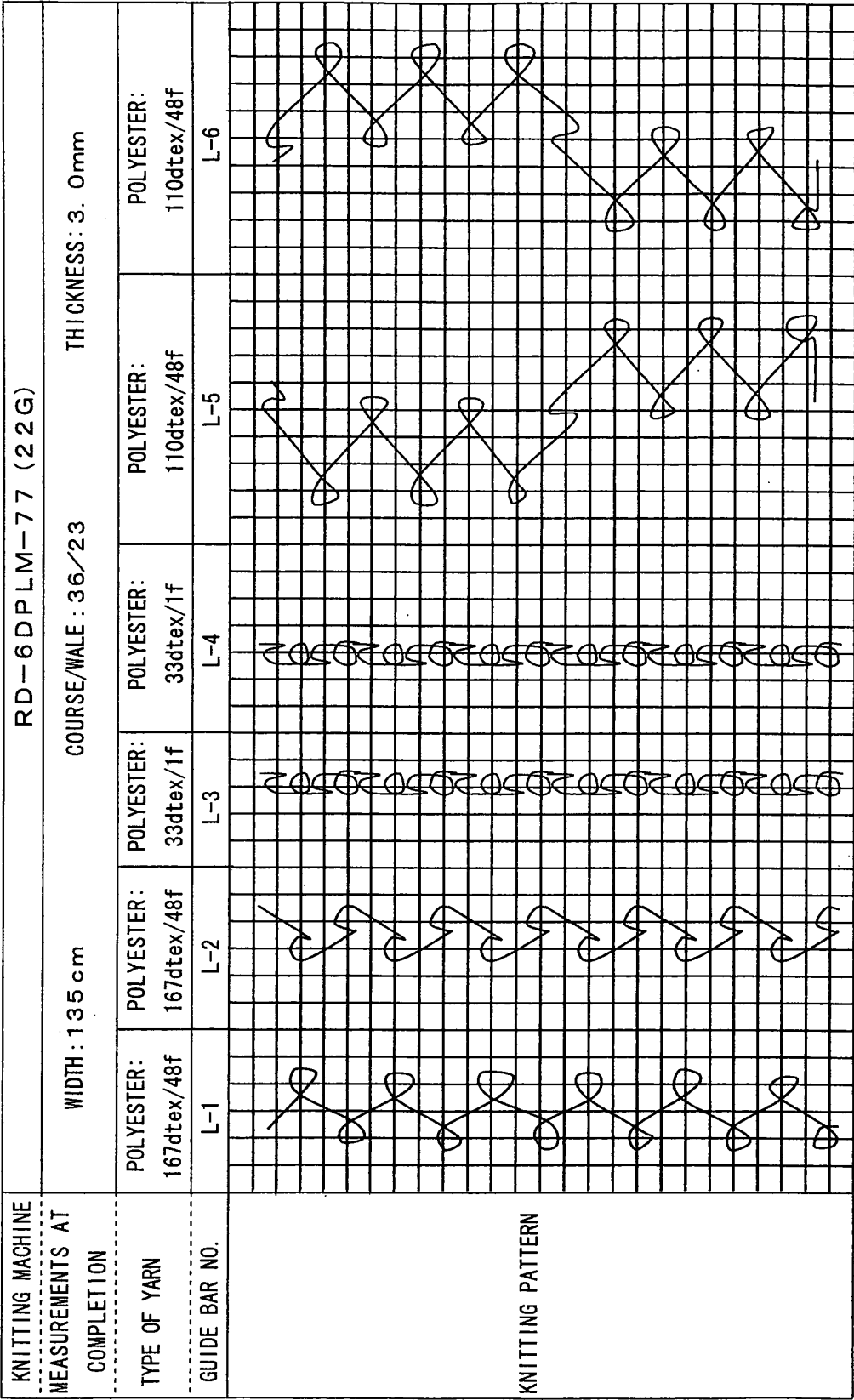




FIG. 13

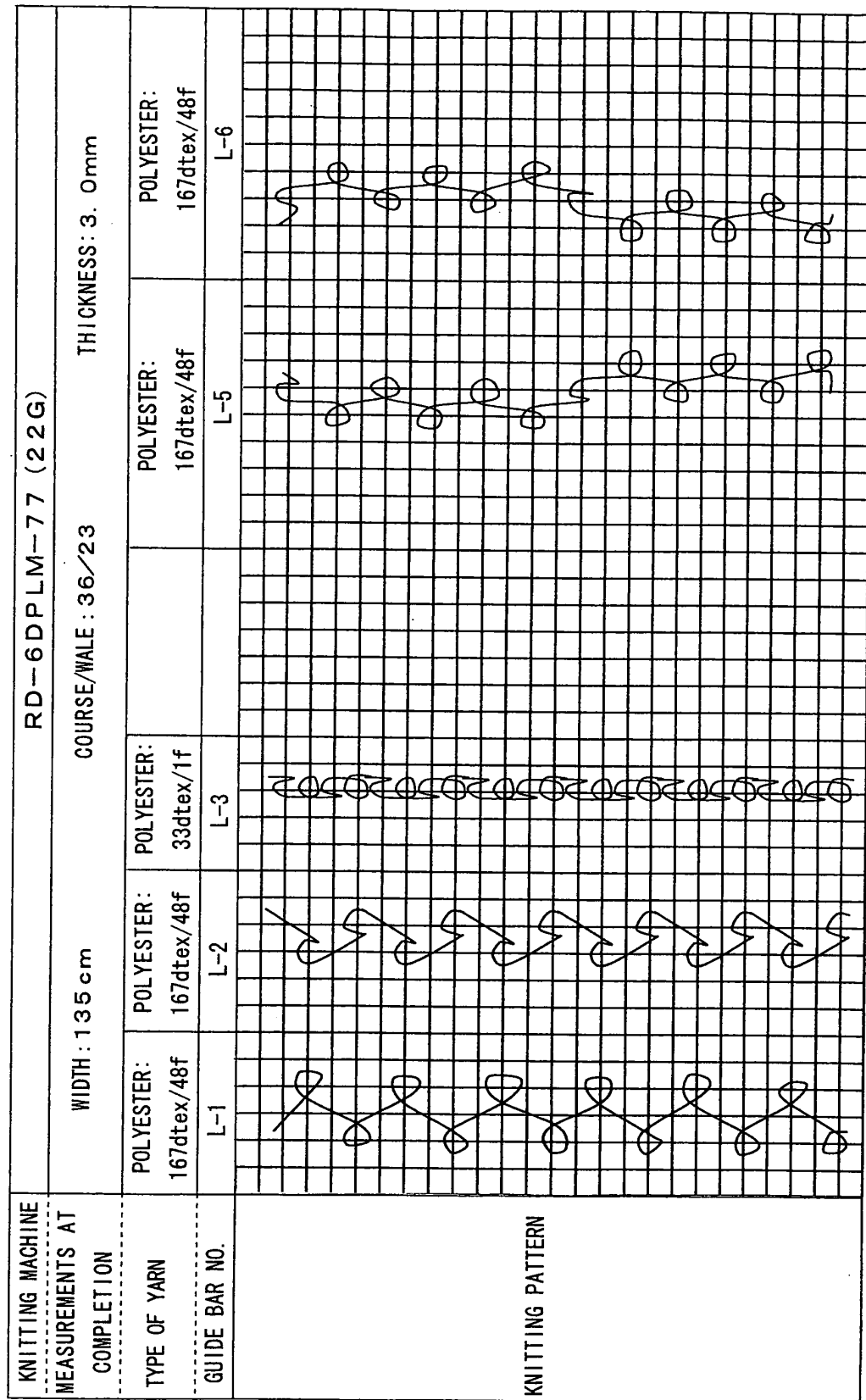
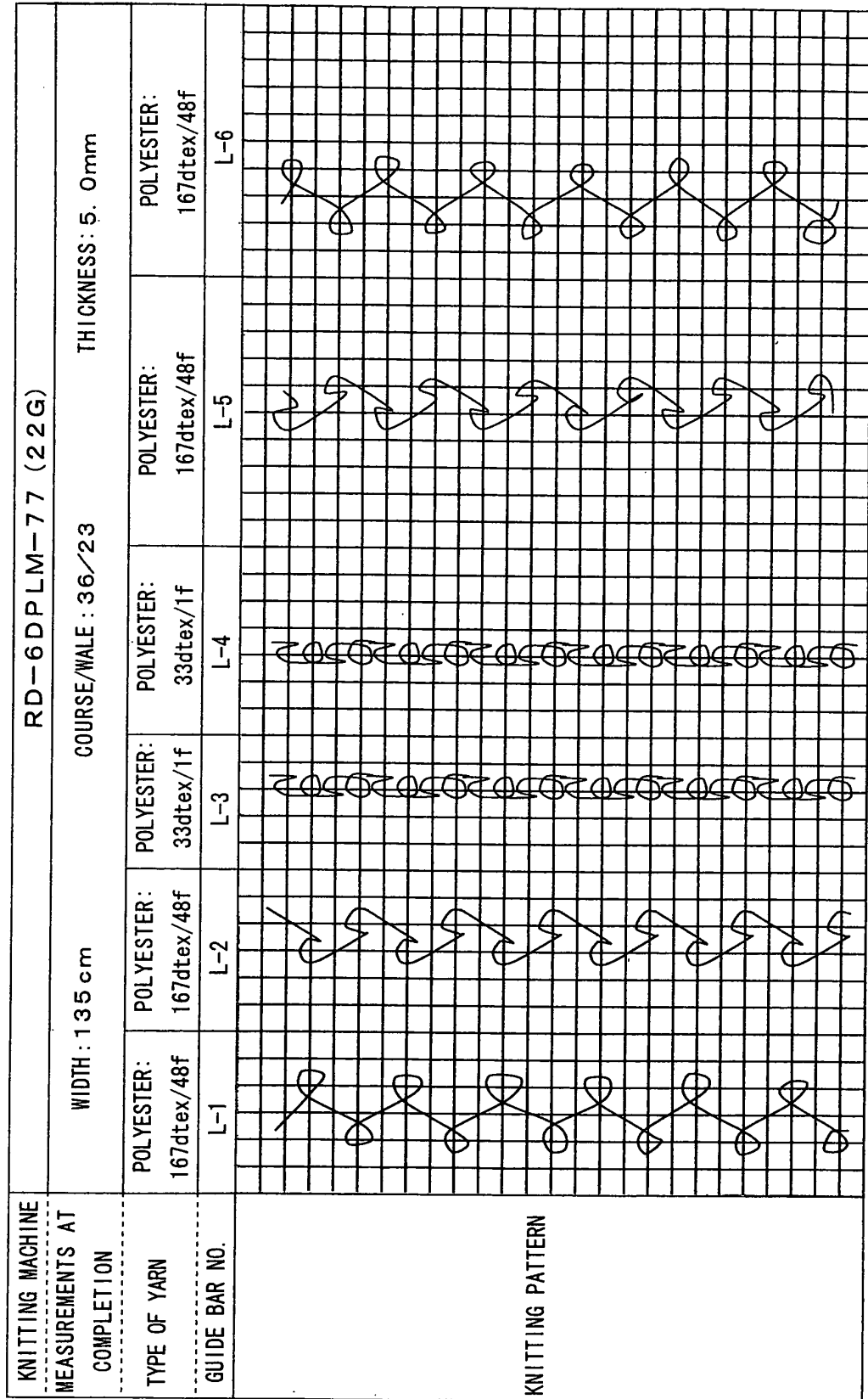


FIG. 14



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2006/306946

## A. CLASSIFICATION OF SUBJECT MATTER

D04B21/14 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

D04B21/00-21/20, G10K11/00-13/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

|                           |           |                            |           |
|---------------------------|-----------|----------------------------|-----------|
| Jitsuyo Shinan Koho       | 1922-1996 | Jitsuyo Shinan Toroku Koho | 1996-2006 |
| Kokai Jitsuyo Shinan Koho | 1971-2006 | Toroku Jitsuyo Shinan Koho | 1994-2006 |

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                                                        | Relevant to claim No. |
|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| A         | JP 2002-294539 A (Seiren Co., Ltd.),<br>09 October, 2002 (09.10.02),<br>Claims 1, 4; example 4; Figs. 5, 6, 10<br>(Family: none)                          | 1-6                   |
| E, A      | JP 2005-104620 A (Seiren Co., Ltd.),<br>20 April, 2006 (20.04.06),<br>Claims 1 to 5; example 5; comparative<br>examples 1; Figs. 15, 16<br>(Family: none) | 1-6                   |
| P, A      | JP 2005-126884 A (Seiren Co., Ltd.),<br>19 May, 2005 (19.05.05),<br>Claims 1 to 4; comparative example 2;<br>Fig. 14<br>(Family: none)                    | 1-6                   |

☒ Further documents are listed in the continuation of Box C.☐ See patent family annex.

\* Special categories of cited documents:

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Date of the actual completion of the international search  
14 June, 2006 (14.06.06)Date of mailing of the international search report  
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## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2006/306946

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                                             | Relevant to claim No. |
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**REFERENCES CITED IN THE DESCRIPTION**

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