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(54) **Titre : METHODE D'ASSEMBLAGE DE COUCHES PREIMPREGNEES SUR DES OUTILS MOULES A L'AIDE D'UN SUPPORT
PELLICULAIRE DEFORMABLE**
(54) **Title: METHOD OF LAYING UP PREPREG PLIES ON CONTOURED TOOLS USING A DEFORMABLE CARRIER FILM**

(57) **Abrégé/Abstract:**

A method of changing the grade of unidirectional prepreg fibers involves adhering the unidirectional prepreg fibers to a deformable carrier film, and increasing the spacing between the prepreg fibers by deforming the film in a direction transverse to the direction of the fibers.

ABSTRACT OF THE DISCLOSURE

A method of changing the grade of unidirectional prepreg fibers involves adhering the unidirectional prepreg fibers to a deformable carrier film, and increasing the spacing between the prepreg fibers by deforming the film in a direction transverse to the direction of the fibers.

METHOD OF LAYING UP PREPREG PLIES ON CONTOURED TOOLS USING A DEFORMABLE CARRIER FILM

This application is divided from Canadian application serial no. 2,878,968, which
5 is divided from Canadian application serial no. 2,751,948 filed on September 12, 2011.

TECHNICAL FIELD

This disclosure generally relates to processes for fabricating composite
structures, and deals more particularly with a method of handling and laying up
10 composite plies, especially on contoured tools.

BACKGROUND

During layup of prepreg plies over a tool, it is sometimes necessary to closely
conform the ply to curves, contours and/or features of the tool in order to assure that
15 the layup is substantially free of voids, wrinkling and/or buckling. Known techniques
for conforming plies to curved tool surfaces involve darting, cutting and/or splitting the
ply during the layup process, and/or extensive hand sweeping to conform the ply to
contoured tool surfaces. These techniques may be time consuming and/or may
provide undesirable mechanical strength of the cured part. Another solution to the
20 problem involves using relatively narrow slit prepreg tape in order to more closely
conform the composite material to contoured tool surfaces. However the use of slit
tape may increase material costs and reduce production rate since laying down slit
tape may be more time consuming.

25 Accordingly, there is a need for a method of laying up a composite ply over a
contoured tool that allows the ply to be deformed as it is applied to the tool in order to
more closely conform the ply to tool contours while the ply remains accurately
positioned. There is also a need for a method of handling and transporting ply
material which allows the material to remain stable during transport and layup.

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SUMMARY

The disclosed embodiments may provide a method of supporting, positioning and deforming a prepreg ply while it is being conformed to simple or complex shapes, contours and features of a tool. The method utilizes a deformable carrier film to support the ply during the layup process in order to prevent the ply from wrinkling and/or buckling as it is being laid up. Use of the carrier film allows the prepreg ply to be accurately positioned and uniformly deformed as needed to conform to contoured tool surfaces. The carrier film may also be used to stabilize the composite ply during handling and transporting. The method may eliminate the need for the use of slit tape, as well as extensive hand working, darting, cutting, and splitting during ply layup. The method may also increase laydown rates of composite material and may facilitate automation of the layup process. Further, the method may improve the accuracy of ply boundaries and provide more uniform deforming of ply material when required, resulting in improvements in both the strength and appearance of cured composite parts.

The disclosure also describes a method of changing the grade of unidirectional prepreg fibers. The method involves adhering the unidirectional prepreg fibers to a deformable carrier film, and increasing the spacing between the prepreg fibers by deforming the carrier film in a direction transverse to the direction of the fibers.

A prepreg fiber ply may involve a fiber grade changed by the above method.

The disclosure also describes a method of laying up composite prepreg over a contoured tool. The method involves placing prepreg material on a carrier film, and using the carrier film to apply the prepreg material to the tool, including deforming the prepreg material by deforming the carrier film.

Placing the prepreg material on the carrier may film involve laying down courses of unidirectional prepreg fiber tape in side-by-side relationship on the carrier film, and may further involve compacting the courses against the carrier film.

The method may further involve removing the carrier film from the prepreg material after the prepreg material has been applied to the tool.

5 Placing the prepreg material on the carrier film may involve compacting the prepreg material against the carrier film.

Carrier film may be deformed to conform the prepreg material to contours on the tool.

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The method may further involve reinforcing at least a portion of the carrier film against deforming.

Reinforcing at least the portion of the carrier film may involve one of increasing
15 the thickness of the carrier film in the portion of the carrier film, embossing the carrier film in the portion of the carrier film, and incorporating reinforcing fibers into the portion of the carrier film.

The method may further involve applying at least one of a release film and a ply
20 doubler on the tool by applying the at least one of the release film and the doubler to the carrier film and using the carrier film to place the at least one of the release film and the doubler on the tool.

The steps of placing prepreg material on a carrier film and using the carrier film
25 to apply the prepreg material to the tool may be repeated to form a multiply part layup.

The disclosure also describes a method of laying up a multi-ply composite part on a tool having contoured surfaces to which the layup is to conform. The method involves: providing a deformable carrier film; reinforcing a portion of the carrier film
30 against deforming, including impregnating the carrier film portion with reinforcing fibers; and placing a composite doubler on a surface of the carrier film. The method

also involves: placing a strip of release film on the surface of the carrier film; placing a composite ply on the surface of the carrier film overlying the doubler and the strip of release film, including laying down a plurality of courses of unidirectional prepreg fiber tape in side-by-side relationship on the surface of the carrier film; and compacting the ply, the doubler and the strip of release film against the carrier film. The method also involves: using the carrier film to transport the ply to a layup tool; using the carrier film to layup the doubler, the strip of release film and the ply on the tool, including deforming the ply by deforming the carrier film to cause the ply to conform to contoured areas of the tool; and peeling away the carrier film from the ply when the ply has been laid up and conformed to the tool.

The disclosure also describes a method involving applying a composite prepreg over a deformable carrier, using the carrier to transport and locate the composite prepreg over a tool, and deforming the composite prepreg by stretching the carrier. Stretching involves changing one of a length or a width of the carrier. The method further involves using the carrier to apply the prepreg to the tool, and removing the carrier from the prepreg.

The disclosure also describes a method of laying up a composite prepreg over a contoured tool. The method involves placing prepreg material on a carrier film and using the carrier film to apply the prepreg material to the tool, including deforming the prepreg material by stretching the carrier film. Stretching involves changing one of a length or a width of the carrier film.

The disclosure also describes a method of laying up a multi-ply composite part on a tool having contoured surfaces to which a layup is to conform. The method involves: providing a deformable carrier film; reinforcing a portion of the carrier film against stretching, including impregnating the portion with reinforcing fibers; placing a composite doubler on a surface of the carrier film; placing a strip of release film on the surface of the carrier film; and placing a composite ply on the surface of the carrier film overlying the doubler and the strip of release film by laying down a plurality of courses

of unidirectional prepreg fiber tape in side-by-side relationship on the surface of the carrier film. The method further involves: compacting the composite ply, the doubler and the strip of release film against the carrier film; using the carrier film to transport the composite ply to a layup tool; and using the carrier film to layup the doubler, the strip of release film and the composite ply on the layup tool, including deforming the composite ply by stretching the carrier film. Stretching involves changing one of a length or a width of the carrier film. The portion of the carrier film reinforced against stretching allows for controlled non-uniform deforming of the composite ply and deforming of the composite ply allows the composite ply to conform to contoured areas of the layup tool. The method further involves peeling away the carrier film from the composite ply when the composite ply has been laid up and conformed to the layup tool.

The disclosure also describes a method of laying up a composite part on a tool. The method involves: providing a composite resin tape reinforced with unidirectional fibers having a substantially zero degree fiber orientation; placing the composite resin tape on a deformable carrier film; forming the composite resin tape and the carrier film onto a first curved surface on a forming tool; forming the composite resin tape and the carrier film about a curved axis onto a second curved surface on the forming tool; and removing the carrier film from the composite resin tape. Forming the composite resin tape and the carrier film includes deforming the composite resin tape and the carrier film by stretching the carrier film. Stretching involves changing one of a length or a width of the carrier film.

The disclosure also describes a method of fabricating a curved composite structure having at least two curved legs. The method involves: providing a composite prepreg tape having unidirectional reinforcing fibers with a substantially zero degree fiber orientation; adhering the composite prepreg tape to a film; forming a first leg of the curved composite structure by forming the film and a first portion of a width of the composite prepreg tape over a first curved surface of a forming tool; forming a second leg of the curved composite structure by forming the film and a second portion of the

width of the composite prepreg tape onto a second curved surface of the forming tool; removing the film from the composite prepreg tape formed over the forming tool; and curing the composite prepreg tape formed over the forming tool. Forming the film and the composite prepreg tape includes deforming the film and the composite prepreg tape by stretching the film. Stretching involves changing one of a length or a width of the film.

The disclosure also describes a method of fabricating a composite stiffener having a curved web and at least one curved flange. The method involves: placing a substantially straight unidirectional prepreg tape on a carrier; forming the at least one curved flange by using the carrier to steer a first portion of the unidirectional prepreg tape onto a first curved tool surface; and forming the curved web by using the carrier to form a second portion of the unidirectional prepreg tape onto a second curved tool surface. Forming the curved web includes deforming the carrier and the unidirectional prepreg tape by stretching the carrier. Stretching involves changing one of a length or a width of the carrier.

The disclosure also describes a method of laying up a multi-ply composite part on a tool having contoured surfaces to which a layup is to conform. The method involves: providing a deformable carrier film; reinforcing a portion of the carrier film against deforming, including impregnating the carrier film with reinforcing fibers; placing a composite doubler on a surface of the carrier film; placing a strip of release film on the surface of the carrier film; and placing a zero degree prepreg ply on the surface of the carrier film overlying the composite doubler and the strip of release film, including laying down a plurality of courses of unidirectional prepreg fiber tape in a side-by-side relationship on the surface of the carrier film. The method further involves: compacting the zero degree prepreg ply, the composite doubler and the strip of release film against the carrier film; using the carrier film to transport the zero degree prepreg ply to tool; and using the carrier film to layup the composite doubler, the strip of release film and the zero degree prepreg ply on the tool, including deforming the zero degree prepreg ply by deforming the carrier film to cause the zero degree prepreg

ply to conform to contoured areas of the tool. Deforming the carrier film includes deforming the carrier film and the zero degree prepreg ply by stretching the carrier film. Stretching involves changing one of a length or a width of the carrier film. The method further involves removing the carrier film from the zero degree prepreg ply
5 when the zero degree prepreg ply has been laid up and conformed to the tool.

The disclosure also describes a method involving: identifying a desired shape of a ply on a tool, in which the ply has a fiber orientation; identifying a cut shape for the ply, in which the cut shape is different than the desired shape; cutting a composite
10 prepreg ply to have the cut shape, the composite prepreg ply having the fiber orientation; applying the composite prepreg ply having the cut shape over a deformable carrier; and deforming the composite prepreg by stretching the deformable carrier. Stretching involves changing one of a length or a width of the deformable carrier. The method further involves using deformable carrier to apply the composite
15 prepreg ply having the cut shape to the tool such that the composite prepreg ply has the desired shape on the tool.

The disclosure also describes a method involving: identifying a desired shape of a ply on a tool, in which the ply has a fiber orientation; identifying a cut shape for the
20 ply, in which the cut shape is different than the desired shape; cutting a composite prepreg ply to have the cut shape, the composite prepreg ply having the fiber orientation; placing the composite prepreg ply having the cut shape on a carrier; and using the carrier to apply the composite prepreg ply to the tool, including deforming the composite prepreg ply by stretching the carrier. Stretching involves changing one of a
25 length or a width of the carrier.

BRIEF DESCRIPTION OF THE ILLUSTRATIONS

FIG. 1 is an illustration of a plan view of a composite prepreg ply held on a deformable carrier film, prior to deforming.

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FIG. 2 is an illustration of a perspective view of a corner of the carrier film viewed from the direction shown as '2' in FIG. 1.

FIG. 3 is an illustration of a view of the ply in direction shown as '3' in FIG. 2.

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FIG. 4 is an illustration of a plan view of the carrier film showing several courses of composite material having been applied to the film.

FIG. 5 is an illustration of the area designated as '5' in FIG. 4.

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FIG. 6 is an illustration similar to FIG. 1 but showing the carrier film and the ply having been deformed.

FIG. 7 is an illustration similar to FIG. 2 showing a corner of the ply and the carrier film after deforming.

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FIG. 8 is an illustration of a sectional view of the deformed ply viewed in the direction shown as '8' in FIG. 7.

FIG. 9 is an illustration of a plan view of a **90** degree ply on a carrier film that
5 has been deformed to stretch the ply into a fan shaped pattern.

FIG. 10 is an illustration of a plan view of a carrier film having a **45** degree ply compacted thereon, prior to deforming.

10 FIG. 11 is an illustration similar to FIG. 10 but showing the carrier film and ply having been deformed in orthogonal directions.

FIG. 12 is an illustration of a sectional view of a carrier film having a ply, a ply doubler and a release film strip applied thereto.

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FIG. 13 is an illustration of a carrier film prior to deforming which includes a substantially non-deformable area containing a fiber reinforcement.

FIG. 14 is an illustration similar to FIG. 13 but showing portions of the carrier
20 film having been deformed.

FIG. 15 is an illustration of a plan view of a carrier film having an isolated area of reinforcement therein.

25 FIG. 16 is an illustration of a sectional view taken along the line **16-16** in FIG. **15**.

FIG. 17 is an illustration of a carrier film having an integrally formed embossment.

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FIG. **18** is an illustration of a flow diagram of a method of laying up a composite structure using a deformable carrier film for ply layup.

FIG. **19** is an illustration of a perspective view of a composite stiffener.

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FIG. **20** is an illustration of diagrammatic views showing the steps of a method for laying up composite plies using the deformable carrier film to form the stiffener section shown in FIG. **19**.

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FIG. **21** is an illustration of a flow diagram of aircraft production and service methodology.

FIG. **22** is an illustration of a block diagram of an aircraft.

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DETAILED DESCRIPTION

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Referring first to FIGS. **1**, **2** and **3**, a ply **30** of composite material is held in face-to-face contact on a carrier film **32** to form a carrier-ply assembly **34**. The carrier film **32** may be used to transport the ply **30** and/or to apply the ply **30** to a tool (not shown) during a layup process for producing a composite part layup (not shown). In the example illustrated in FIGS. **1-3**, the prepreg ply **30** includes unidirectional reinforcing fibers **40** having a **90** degree orientation, however other plies (not shown) in the part layup may have other fiber orientations based on a predefined ply schedule.

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The fibers **40** are pre-impregnated with a suitable polymer resin **42** which acts as a matrix to hold the fibers **40** in the desired orientation following curing. The resin **42** may be a visco-elastic resin. The composite ply **30** has a length **L1** and a width **W1** prior to being deformed during the layup process, as will be described in more detail below. The ply **30** is adhered to the carrier film **32** by the tackiness of the uncured resin **42** in the ply **30**, however additional tackifiers may be used to provide the necessary adherence between the ply **30** and the carrier film **32**. Following placement of the ply **30** on the carrier film **32**, the ply **30** may be compacted against the carrier

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film **32** to assure that the ply is substantially free of buckling, wrinkles or other irregularities.

The ply **30** may be placed on the carrier film **32** so as to leave one or more edge margins **36**, **38** on the film **32** around the ply **30** to facilitate handling of the film **32** and/or attachment of hardware or equipment (not shown) to the film **32** that may be used to deform, manipulate and/or hold the carrier film **32** during the layup process. As will be discussed below, once compacted on the carrier film **32**, the ply-carrier film assembly **34** can be deformed to fit different contours and shapes of a tool (not shown). The carrier film **32** allows for controlled and uniform or non-uniform deforming of the resin **42**, and may also be used only as a carrier for transporting the prepreg ply **30** from an offline layup station (not shown) to the layup tool (not shown). As used herein, “deform” and “deforming” refer to stretching and/or shearing of a ply material in one or more directions, including simple and compound curves, and within one or more planes.

The carrier film **32** may be deformed in at least one direction, which in the illustrated example, is along an X axis **44**, transverse to the orientation of the fibers **40**. The carrier film **32** may comprise, for example and without limitation, a latex rubber or similar natural or synthetic deformable material having a thickness suitable for the application. The carrier film **32** material may be an elastic material that returns substantially to its original size and shape following deforming. During the layup process, the ply **30** may be deformed by grasping the film at the opposite edge margins **38** and pulling film **32** in opposite directions indicated by the arrows **46**, substantially along the X axis **44**.

Prior to the ply **30** being deformed, the fibers **40** may have an inter-spacing **d1**. The visco-elastic resin **42** (FIG. 3) yields when deformed in a direction perpendicular to the fiber direction (in this case, the Y axis **45**), thereby allowing the fibers **40** to slip or shear substantially simultaneously in a direction parallel to the fiber

direction, i.e. along the X axis **44**, which permits the prepreg ply **30** to conform to the contours of a layup tool (not shown).

Referring to FIGS **4** and **5**, the ply **30** may be applied to the carrier film **32** by placing a plurality of individual courses **48a**, **48b**, **48c** of unidirectional tape on the film **32**, in side-by-side, substantially parallel and abutting relationship either by hand or by using automated fiber placement equipment (not shown). Depending on the application and the particular materials being used, the edges **50** of the courses may overlap slightly or may form gaps **G** between the courses **48**. Deforming of the carrier film **32** may be used to control the size of the overlap or gap **G** between the courses **48** during layup of the ply **30** on a tool (not shown). Furthermore, the carrier film **32** may be used to change the grade of a prepreg material used to form the ply **30**. For example, the grade of a prepreg material may be changed by uniformly deforming the material to a desired grade. Changing the grade of a prepreg material in this manner using the carrier film **32** may be useful in producing interleaved doublers that may reduce part weight, and/or material costs.

FIGS. **6**, **7** and **8** illustrate the ply **30** following deforming along the X axis **44** in the direction of the arrows **46** in FIG. **1**. From FIG. **6** it can be seen that while the width **W1** of the ply **30** remains substantially the same, the ply **30** has been deformed to a greater length **L2** as a result of the deforming of the carrier film **32**. Deforming of the carrier film **32** effectively deforms the **42** resin in the ply **30** which results in an increase in the spacing between the reinforcing fibers to a dimension **d2** which is greater than **d1**. Deforming the ply **30** in this manner may allow the ply **30** to better conform to contours and other features of a tool surface (not shown) during the layup process, and may stabilize the ply material during layup. The carrier film **32** may prevent the prepreg ply **30** from splitting, wrinkling and/or buckling as it is being formed over a tool (not shown), and may allow the ply **30** to be precisely positioned on the tool during the layup process. It should be noted here that generally, when deforming a **90** degree ply **30** as described above in connection with FIGS. **1-8**, the fibers **40** may be expected to deform substantially uniformly along the X axis **44**. However, when

deforming non-90 degree plies 30, the fiber deformation may not be uniform. For example, when deforming a 0 degree ply 30 (not shown) in the direction of the X axis 44, the fibers 40 near the ends 55 (FIG. 6) of the ply 30 may shear at an angle (not shown) relative to the fibers 40 near the center 57 of the ply 30 which retain their 0 degree orientation. This shearing effect may occur gradually, growing increasingly from the center 57 toward the ends 55. Compensation for this shearing deformation may be achieved by cutting the ends 55 of the ply 30 at a pre-selected angle (not shown). When deforming a 45 degree ply 30, both shearing and stretching of the fibers 40 may occur.

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FIG. 9 illustrates the use of the carrier film 32 to deform a 90 degree ply 30 into a radial or fan-like pattern 65 within a single plane, wherein the fiber directions are shown in solid lines. Although not shown in the Figure, this same radial pattern 65 may be deformed into other planes.

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FIGS. 10 and 11 illustrate a prepreg ply 30 having a 45 degree fiber orientation which has a width W_1 and a length L_1 prior to deforming as shown in FIG. 9. In this example, the carrier film 32 is deformed along orthogonal X and Y axes 44, 45, causing the ply 30 to be likewise deformed to both a greater length L_2 . Stretching of the film 32 along the Y axis results in a change in the orientation angle of the fibers 40 to some angle Θ less than 45 degrees. Although the ply examples shown in FIGS. 1-10 are shown being deformed along single axis or two orthogonal axes 44, 45, the ply 30 may be deformed in other directions and within other planes, depending on the requirements of the application and the geometry of the tool (not shown) to which the ply 30 must be conformed. Moreover, as will be discussed below, it may be possible to deform only one or more portions of the carrier film 32 so that only corresponding portions (not shown) of the ply 30 are deformed during layup process.

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In some applications, it may be possible to use the carrier film 32 to pre-position and place additional items of a layup assembly on a tool (not shown), such as without limitation, doublers, release films, and caul plates, along with the ply 30. For example,

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FIG. 12 illustrates a ply 30 placed on a carrier film 32 in which a composite doubler 54 is sandwiched between the ply 30 and the carrier film 32. Similarly, a strip 56 of release film is sandwiched between the ply 30 and the carrier film 32 along the edge margin 36 on the film 32 which may aid in releasing and peeling the carrier film 32 away from the laid up ply 30. Thus, in this example, during the layup process, use of the carrier film 32 allows the ply 30, the doubler 54 and the release film strip 56 to be precisely positioned relative to each other, and to be laid up over a tool (not shown) in a single step.

As previously mentioned, it may be possible or desirable in some applications to deform only a portion of the ply 30 during the layup process. Deforming of the carrier film 32 can be tailored to selectively constrain the elasticity of the ply carrier 32 using any of several techniques that suit part geometry and forming requirements. FIG. 13 illustrates a carrier film 32 having a section 32c that includes a reinforced portion 58 which resists deforming as the film 32 is being deformed during the layup process. In this example, the reinforcement of the film portion 32c is achieved by impregnating unidirectional fibers 60 into the carrier film 32, oriented in the direction that the film 32 is to be deformed, which in this example, is along the X axis 44.

Prior to deforming, carrier film has a length L_1 and the reinforced portion 32c has a width R_1 as shown in FIG. 13. When the carrier film 32 is deformed along the X axis 44, which corresponds to the axial direction of the fibers 60, the fibers 60 do not deform substantially, consequently the width R_1 of the reinforced section 32c remains the substantially same while the overall length of the carrier film 32 deforms to L_2 as a result of the non-reinforced sections 32a, 32b of the film 32 on each side of the reinforced section 32c being allowed to deform. It may also be possible to employ a reinforcement in the reinforced section 32c which allows some degree of deforming of the film 32, but less than other, non-reinforced areas of the film 32. The reinforced portion 32c may comprise, for example and without limitation, cross stitching (not shown) in the film 32. Depending on the type of reinforcement that is used, the width

W of the reinforced portion **32c** may or may not become more narrow when the film **32** is stretched.

In the case of the example shown in FIGS. **13** and **14**, the reinforced area **58** is centrally located within the carrier film **32** and extends across its entire width **W**. FIG. **15** illustrates an example in which the reinforced area **58** is spaced inwardly from the edge margins **36**, **38** of the carrier film **32** and is disposed off-center within the area of the film **32**. As in the example shown in FIGS. **13** and **14**, the reinforced area **58** shown in FIG. **15** also may incorporate reinforcing fibers **60** (see FIG. **14**) into the carrier film **32** which may be unidirectional or multi-directional. For example, the fibers **60** may be woven together and incorporated into the film **32** in a manner that resists deforming in two orthogonal directions, e.g. along the X and Y axes **44**, **45**, that correspond to the orientations of the reinforcing fibers. Similarly, fibers **60** may be placed in additional orientations, e.g. **45** degree orientations, to resist deforming of the film **32** within the reinforced area **58** in other directions. While the reinforced area **58** is shown as being generally square in shape, a variety of other shapes are possible.

Other reinforcing techniques to prevent or reduce local deforming of the film **32** are possible. For example, as shown in FIG. **16**, the substantially non-deformable, reinforced area **58** of FIGS. **13**, **14** and **15** may be achieved by increasing the thickness T_1 of a carrier film to a thickness T_2 in the area **58** of reinforcement. FIG. **17** illustrates another technique for achieving the desired reinforcement, in which the carrier film **32** includes embossed dimples **62** in a desired pattern **63**, in this case, diamonds that resist deforming in one or more directions. In some applications, it may be desirable to employ more than one of the above described techniques to achieve substantially non-deformable areas **58**. For example, and without limitation, a combination of embossed dimples **62**, increased film thickness T_2 and reinforcing fibers **58** may be used. It may also be possible to use one or more of the above reinforcement techniques to achieve differing degrees of film elongation in differing regions of the carrier film **32**.

Attention is now directed to FIG. 18 which broadly illustrates the steps of a method of laying up plies to form a composite part using the deformable carrier film 32 previously described. Beginning at 64, a deformable carrier film 32 is provided having a size and shape suitable for the application and the plies 30 to be laid up. At 66, portions of the deformable carrier film 32 may be reinforced, as desired. At 68, a release film 56 (FIG. 12) may be applied to the deformable carrier film 32, as required, to aid in the removal of the carrier film 32 from the ply 30 following layup. At 70, one or more ply doublers 54 (FIG. 11) or other materials may be applied to the deformable carrier 32, as desired.

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At 72, a prepreg ply 30 is applied to the deformable carrier either manually, or using automated equipment to lay down courses 49 (FIG. 4) of prepreg material in side-by-side, possibly substantially abutting relationship on the carrier film 32. The ply 30 is laid up on the carrier film 32 in a reversed, mirror image-like fashion such that the left and right of the ply 30 are reversed. By reversing the ply 30 on the film 32, the ply 30 will have the proper orientation when transferred from the film 32 to a tool 90 (see FIG. 19). At 74, the ply material, including any doublers and/or release films are compacted against the deformable carrier film 32. This compaction may be performed mechanically with a hand sweep (not shown) or using a vacuum either with or without the application of heat. At 76, the carrier film 32 is deformed in at least one direction, thereby deforming the ply 30 to the desired shape and/or dimensions best suited for layup on the tool 90, including the shape and topography of the tool 90. At 78, with the ply 30 located on the film 32, and positioned between film 32 and the tool 90, the carrier film 32 is used to position and layup the ply 30 onto a tool 90 (see FIG. 19). At 80, following layup of the ply 30 onto the tool 90, the carrier film 32 is removed, as by peeling it away from the laid-up ply 30. At 82, the carrier film 32 may be reused, if desired, or discarded. Steps 68-80 may be repeated until all of the plies 30 of the part layup have been laid up.

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FIG. 20 diagrammatically illustrates the steps of the layup method shown in FIG. 18, in which a curved stiffener 100 shown in FIG. 19 having a L-shaped cross

section and radius of curvature R is laid up on a curved tool **90**. The tool **90** includes two contiguous, curved tool surfaces **90a**, **90b** for respectively forming a web **100a** and a curved flange **100b** of the stiffener **100** shown in FIG. 19. As shown at **84**, courses **48** of unidirectional prepreg material are laid down side-by-side on a deformable carrier film **32** to form a completed **90** degree ply **30** shown at **86**. The completed ply **30** is then compacted onto the film **32**, following which at **88**, the film **32** is then stretched and deformed radially as shown by the arrows **87** to generally match the curvature of the tool surface **90a**. As shown at **89**, the ply **30** is deformed into a fan shape and placed onto the tool surface **90a** using the film **32** to form the curved web **100a** of the stiffener **100**. The carrier film **32** and a peel ply (not shown) may then be removed from the partially formed ply **30**. With the carrier film **32** having been removed, the ply **30** is then formed down over the tool surface **90b** to form the flange **100b** of the stiffener **100**. While the above example illustrates the use of the carrier film **32** to form plies along curves in a single plane, the carrier film **32** may also be used to form plies over tools (not shown) having compound curved surfaces, joggles, etc.

Referring next to FIGS. **21** and **22**, embodiments of the disclosure may be used in the context of an aircraft manufacturing and service method **102** as shown in FIG. **21** and an aircraft **104** as shown in FIG. **22**. During pre-production, exemplary method **102** may include specification and design **106** of the aircraft **104** and material procurement **108**. During production, component and subassembly manufacturing **110** and system integration **112** of the aircraft **104** takes place. During step **110**, the disclosed method and apparatus may be employed to fabricate composite parts such as fuselage frame sections and stiffeners which are then assembled at step **112**. Thereafter, the aircraft **104** may go through certification and delivery **114** in order to be placed in service **116**. While in service by a customer, the aircraft **104** may be scheduled for routine maintenance and service **118** (which may also include modification, reconfiguration, refurbishment, and so on).

30

Each of the processes of method **102** may be performed or carried out by a system integrator, a third party, and/or an operator (e.g., a customer). For the purposes of this description, a system integrator may include without limitation any number of aircraft manufacturers and major-system subcontractors; a third party may
5 include without limitation any number of vendors, subcontractors, and suppliers; and an operator may be an airline, leasing company, military entity, service organization, and so on.

As shown in FIG. **22**, the aircraft **104** produced by exemplary method **102** may
10 include an airframe **120** with a plurality of systems **122** and an interior **124**. The disclosed method and apparatus may be employed to fabricate frame sections and stiffeners which form part of the airframe **120**. Examples of high-level systems **122** include one or more of a propulsion system **126**, an electrical system **128**, a hydraulic system **130**, and an environmental system **132**. Any number of other systems may be
15 included. Although an aerospace example is shown, the principles of the invention may be applied to other industries, such as the automotive industry.

The apparatus embodied herein may be employed during any one or more of the stages of the production and service method **102**. For example, components or
20 subassemblies corresponding to production process **110** may be fabricated or manufactured in a manner similar to components or subassemblies produced while the aircraft **104** is in service. Also, one or more apparatus embodiments may be utilized during the production stages **110** and **112**, for example, by substantially expediting assembly of or reducing the cost of an aircraft **104**. Similarly, one or more
25 apparatus embodiments may be utilized while the aircraft **104** is in service, for example and without limitation, to maintenance and service **118**.

Although the embodiments of this disclosure have been described with respect to certain exemplary embodiments, it is to be understood that the specific
30 embodiments are for purposes of illustration and not limitation, as other variations will occur to those of skill in the art.

EMBODIMENTS IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A method of changing the grade of unidirectional prepreg fibers, comprising:

adhering the unidirectional prepreg fibers to a deformable carrier film;
and

increasing the spacing between the prepreg fibers by deforming the
carrier film in a direction transverse to the direction of the fibers.

2. A prepreg fiber ply having a fiber grade changed by the method of claim 1.

3. A method of laying up composite prepreg over a contoured tool, comprising:

placing prepreg material on a carrier film; and

using the carrier film to apply the prepreg material to the tool, including
deforming the prepreg material by deforming the carrier film.

4. The method of claim 3, wherein placing the prepreg material on the carrier film
includes:

laying down courses of unidirectional prepreg fiber tape in side-by-side
relationship on the carrier film, and

compacting the courses against the carrier film.

5. The method of claim **3** or **4**, further comprising:

removing the carrier film from the prepreg material after the prepreg material has been applied to the tool.

5

6. The method of claim **3**, wherein placing the prepreg material on the carrier film includes compacting the prepreg material against the carrier film.

7. The method of any one of claims **3** to **6**, wherein carrier film is deformed to conform the prepreg material to contours on the tool.

10

8. The method of any one of claims **3** to **7**, further comprising:

reinforcing at least a portion of the carrier film against deforming.

15

9. The method of claim **8**, wherein reinforcing at least the portion of the carrier film comprises one of:

increasing the thickness of the carrier film in the portion of the carrier film,

20

embossing the carrier film in the portion of the carrier film, and

incorporating reinforcing fibers into the portion of the carrier film.

10. The method of any one of claims **3** to **9**, further comprising:

25

applying at least one of a release film and a ply doubler on the tool by applying the at least one of the release film and the doubler to the carrier film and using the carrier film to place the at least one of the release film and the doubler on the tool.

30

11. The method of any one of claims **3** to **10**, wherein the steps of placing prepreg material on a carrier film and using the carrier film to apply the prepreg material to the tool are repeated to form a multiply part layup.

5 **12.** A method of laying up a multi-ply composite part on a tool having contoured surfaces to which the layup is to conform, comprising:

providing a deformable carrier film;

10 reinforcing a portion of the carrier film against deforming, including impregnating the carrier film portion with reinforcing fibers;

placing a composite doubler on a surface of the carrier film;

15 placing a strip of release film on the surface of the carrier film;

placing a composite ply on the surface of the carrier film overlying the doubler and the strip of release film, including laying down a plurality of courses of unidirectional prepreg fiber tape in side-by-side relationship on the surface of the carrier film;

20

compacting the ply, the doubler and the strip of release film against the carrier film;

25 using the carrier film to transport the ply to a layup tool;

using the carrier film to layup the doubler, the strip of release film and the ply on the tool, including deforming the ply by deforming the carrier film to cause the ply to conform to contoured areas of the tool; and

30

peeling away the carrier film from the ply when the ply has been laid up and conformed to the tool.

13. A method comprising:

5

applying a composite prepreg over a deformable carrier;

using the carrier to transport and locate the composite prepreg over a tool;

10

deforming the composite prepreg by stretching the carrier, stretching comprising changing one of a length or a width of the carrier;

using the carrier to apply the prepreg to the tool; and

15

removing the carrier from the prepreg.

14. The method of claim **13**, wherein:

20

applying the prepreg over the carrier includes compacting the prepreg against the carrier; and

the carrier is removed from the prepreg after the prepreg has been applied to the tool.

25

15. The method of claim **13**, wherein applying the composite prepreg includes:

applying courses of unidirectional prepreg tape in side-by-side relationship on the carrier.

30

16. The method of claim **15**, wherein stretching the carrier controls a size of an overlap or a gap between the courses while applying the prepreg to the tool.

17. The method of any one of claims **13** to **16**, further comprising:

applying at least one of a release film and a ply doubler on the carrier before the composite prepreg is applied to the carrier.

18. The method of any one of claims **13** to **17**, further comprising:

reinforcing a portion of the carrier against stretching in a first direction.

19. The method of claim **18**, wherein reinforcing the portion of the carrier includes at least one of:

increasing a thickness of the carrier in the portion of the carrier;

embossing the carrier in the portion of the carrier; and

incorporating reinforcing fibers into the portion of the carrier.

20. The method of claim **18**, wherein the portion of the carrier reinforced against stretching allows for controlled non-uniform deforming of the prepreg material.

21. The method of claim **18**, wherein a corresponding portion of the composite prepreg overlying the portion of the carrier reinforced against stretching is not deformed during the stretching of the carrier.

22. The method of any one of claims **13** to **21**, wherein stretching the carrier is performed as the prepreg is being applied to the tool.

23. The method of claim **13**, wherein deforming the composite prepreg by stretching the carrier comprises increasing a spacing between unidirectional prepreg fibers by stretching the carrier in a first direction transverse to a second direction of the fibers.

5

24. The method of any one of claims **13** to **23**, wherein the carrier comprises an elastic material that returns substantially to its original size and shape following stretching.

10 25. The method of any one of claims **13** to **24**, wherein:

the composite prepreg is placed on the carrier so as to leave one or more edge margins on the carrier around the composite prepreg; and

15 wherein the one or more edge margins facilitate at least one of handling of the carrier and attachment of hardware or equipment to the carrier.

26. The method of claim **25**, wherein the hardware or equipment may be used to deform, manipulate and/or hold the carrier during layup.

20

27. The method of claim **13**, wherein deforming the composite prepreg by stretching the carrier includes stretching the carrier such that a width of the composite prepreg remains substantially the same, while a length of the composite prepreg is deformed to a greater length as a result of the stretching of the carrier.

25

28. The method of any one of claims **13** to **27** further comprising:

30 cutting at least one end of the composite prepreg at a pre-selected angle to compensate for a shearing effect in the composite prepreg during deformation.

29. The method of claim **13**, wherein stretching the carrier along an Y axis results in a change in an orientation angle of fibers of the composite prepreg.
- 5 30. The method of any one of claims **13** to **29**, wherein the carrier is configured to prevent wrinkling of the prepreg during deformation of the prepreg.
31. The method of claim **13**, wherein deforming the composite prepreg includes deforming the composite prepreg radially.
- 10 32. A method of laying up a composite prepreg over a contoured tool, comprising:
- placing prepreg material on a carrier film; and
- 15 using the carrier film to apply the prepreg material to the tool, including deforming the prepreg material by stretching the carrier film, stretching comprising changing one of a length or a width of the carrier film.
- 20 33. The method of claim **32**, wherein placing the prepreg material on the carrier film includes:
- laying down courses of unidirectional prepreg fiber tape in side-by-side relationship on the carrier film; and
- 25 compacting the courses against the carrier film.
- 30 34. The method of claim **32** or **33**, wherein the steps of placing prepreg material on the carrier film and using the carrier film to apply the prepreg material to the tool are repeated to form a multiply part layup.

35. The method of any one of claims 32 to 34, wherein deforming the prepreg material includes stretching the carrier film in a direction traverse to an orientation of fibers in the composite material.

5 36. A method of laying up a multi-ply composite part on a tool having contoured surfaces to which a layup is to conform, comprising:

providing a deformable carrier film;

10 reinforcing a portion of the carrier film against stretching, including impregnating the portion with reinforcing fibers;

placing a composite doubler on a surface of the carrier film;

15 placing a strip of release film on the surface of the carrier film;

placing a composite ply on the surface of the carrier film overlying the doubler and the strip of release film by laying down a plurality of courses of unidirectional prepreg fiber tape in side-by-side relationship on the surface of the carrier film;

compacting the composite ply, the doubler and the strip of release film against the carrier film;

25 using the carrier film to transport the composite ply to a layup tool;

using the carrier film to layup the doubler, the strip of release film and the composite ply on the layup tool, including deforming the composite ply by stretching the carrier film, stretching comprising changing one of a length or a width of the carrier film, the portion of the carrier film reinforced against stretching allows for controlled non-uniform deforming of the

composite ply, wherein deforming of the composite ply allows the composite ply to conform to contoured areas of the layup tool; and

peeling away the carrier film from the composite ply when the composite ply has been laid up and conformed to the layup tool.

37. A method of laying up a composite part on a tool, comprising:

providing a composite resin tape reinforced with unidirectional fibers having a substantially zero degree fiber orientation;

placing the composite resin tape on a deformable carrier film;

forming the composite resin tape and the carrier film onto a first curved surface on a forming tool;

forming the composite resin tape and the carrier film about a curved axis onto a second curved surface on the forming tool; and

removing the carrier film from the composite resin tape;

wherein forming the composite resin tape and the carrier film includes deforming the composite resin tape and the carrier film by stretching the carrier film, stretching comprising changing one of a length or a width of the carrier film.

38. The method of claim **37**, wherein placing the composite resin tape on the carrier film includes compacting the composite resin tape against the carrier film.

39. The method of claim **37** or **38**, further comprising:

contouring at least one edge of the composite resin tape along its length.

5 **40.** The method of claim **39**, wherein contouring the at least one edge of the composite resin tape is performed by cutting the composite resin tape along the edge.

10 **41.** The method of any one of claims **37** to **40**, wherein deforming the carrier film is performed as the composite resin tape and the carrier film are being formed onto the second curved surface of the forming tool.

42. A method of fabricating a curved composite structure having at least two curved legs, comprising:

15

providing a composite prepreg tape having unidirectional reinforcing fibers with a substantially zero degree fiber orientation;

adhering the composite prepreg tape to a film;

20

forming a first leg of the curved composite structure by forming the film and a first portion of a width of the composite prepreg tape over a first curved surface of a forming tool;

25

forming a second leg of the curved composite structure by forming the film and a second portion of the width of the composite prepreg tape onto a second curved surface of the forming tool;

30

removing the film from the composite prepreg tape formed over the forming tool; and

curing the composite prepreg tape formed over the forming tool;

wherein forming the film and the composite prepreg tape includes deforming the film and the composite prepreg tape by stretching the film, stretching comprising changing one of a length or a width of the film.

43. The method of claim **42**, wherein forming the second leg is performed by pressing the film and shearing the second portion of the width of the composite prepreg tape about a curved bend line onto the second curved surface of the forming tool.

44. The method of claim **42**, further comprising:

contouring at least one edge of the composite prepreg tape along its length.

45. The method of claim **44**, wherein contouring the at least one edge of the composite prepreg tape is performed by cutting the tape along the at least one edge.

46. A method of fabricating a composite stiffener having a curved web and at least one curved flange, comprising:

placing a substantially straight unidirectional prepreg tape on a carrier;

forming the at least one curved flange by using the carrier to steer a first portion of the unidirectional prepreg tape onto a first curved tool surface; and

forming the curved web by using the carrier to form a second portion of the unidirectional prepreg tape onto a second curved tool surface;

wherein forming the curved web includes deforming the carrier and the unidirectional prepreg tape by stretching the carrier, stretching comprising changing one of a length or a width of the carrier.

5

47. The method of claim **46**, wherein forming the curved web includes deforming the carrier as the second portion of the unidirectional prepreg tape is being formed onto the second curved tool surface.

10 **48.** The method of claim **46** or **47**, wherein:

steering the first portion of the unidirectional prepreg tape includes a steering a first portion of a width of the unidirectional prepreg tape, and forming the second portion of the unidirectional prepreg tape includes forming a second portion of the width of the unidirectional prepreg tape.

15

49. The method of claim **46** or **47**, wherein a single width of the unidirectional prepreg tape is used to form the at least one curved flange and the curved web.

20 **50.** The method of claim **46** or **47**, wherein forming the curved web includes shearing a portion of a width of the unidirectional prepreg tape about a curved bend line onto the second curved tool surface.

51. The method of any one of claims **46** to **50**, further comprising:

25

removing the carrier from the unidirectional prepreg tape after the curved web and the at least one curved flange have been formed; and

curing the unidirectional prepreg tape.

30

52. The method of any one of claims **46** to **51**, further comprising:

clamping the at least one curved flange against the first curved tool surface, and wherein forming the curved web is performed while the at least one curved flange is clamped against the first curved tool surface.

53. The method of any one of claims **46** to **52**, wherein placing the unidirectional prepreg tape on the carrier includes forming overlapping segments of the unidirectional prepreg tape on the carrier by sequentially forming offset segments of the unidirectional prepreg tape on the carrier.

54. The method of claim **53**, wherein placing the unidirectional prepreg tape on the carrier includes overlapping the segments.

55. The method of any one of claims **46** to **54**, further comprising:

contouring an edge of the unidirectional prepreg tape along its length before the at least one curved flange and the curved web are formed.

56. A method of laying up a multi-ply composite part on a tool having contoured surfaces to which a layup is to conform, comprising:

providing a deformable carrier film;

reinforcing a portion of the carrier film against deforming, including impregnating the carrier film with reinforcing fibers;

placing a composite doubler on a surface of the carrier film;

placing a strip of release film on the surface of the carrier film;

placing a zero degree prepreg ply on the surface of the carrier film overlying the composite doubler and the strip of release film, including laying down a plurality of courses of unidirectional prepreg fiber tape in a side-by-side relationship on the surface of the carrier film;

5

compacting the zero degree prepreg ply, the composite doubler and the strip of release film against the carrier film;

using the carrier film to transport the zero degree prepreg ply to tool;

10

using the carrier film to layup the composite doubler, the strip of release film and the zero degree prepreg ply on the tool, including deforming the zero degree prepreg ply by deforming the carrier film to cause the zero degree prepreg ply to conform to contoured areas of the tool wherein deforming the carrier film includes deforming the carrier film and the zero degree prepreg ply by stretching the carrier film, stretching comprising changing one of a length or a width of the carrier film; and

15

removing the carrier film from the zero degree prepreg ply when the zero degree prepreg ply has been laid up and conformed to the tool.

20

57. A method comprising:

identifying a desired shape of a ply on a tool, in which the ply has a fiber orientation;

25

identifying a cut shape for the ply, in which the cut shape is different than the desired shape;

cutting a composite prepreg ply to have the cut shape, the composite prepreg ply having the fiber orientation;

30

applying the composite prepreg ply having the cut shape over a deformable carrier;

5 deforming the composite prepreg by stretching the deformable carrier, stretching comprising changing one of a length or a width of the deformable carrier; and

10 using deformable carrier to apply the composite prepreg ply having the cut shape to the tool such that the composite prepreg ply has the desired shape on the tool.

58. The method of claim **57**, further comprising:

15 using the carrier to transport and locate the composite prepreg ply over the tool.

59. The method of claim **57** or **58**, further comprising:

20 removing the carrier from the composite prepreg ply.

60. The method of claim **57** or **58**, wherein:

25 applying the composite prepreg ply over the carrier includes compacting the composite prepreg ply against the carrier; and

the carrier is removed from the composite prepreg ply after the composite prepreg ply has been applied to the tool.

61. The method of any one of claims **57** to **60**, further comprising:

applying at least one of a release film and a ply doubler on the carrier
before the composite prepreg ply is applied to the carrier.

5

62. The method of any one of claims **57** to **59**, wherein applying the composite
prepreg ply over the carrier includes:

10

laying down courses of unidirectional prepreg fiber tape in side-by-side
relationship on the carrier; and

compacting the courses against the carrier.

15

63. The method of any one of claims **57** to **62**, wherein the fiber orientation is a **45**
degree orientation.

64. The method of any one of claims **57** to **62**, wherein the fiber orientation is a **0**
degree orientation.

20

65. The method of any one of claims **57** to **64**, wherein stretching the carrier is
performed as the composite prepreg ply is being applied to the tool.

25

66. The method of any one of claims **57** to **65**, wherein the carrier comprises an
elastic material that returns substantially to its original size and shape following
stretching.

30

67. The method of any one of claims **57** to **66**, wherein the cut shape compensates
for a shearing effect in the composite prepreg ply while applying the composite
prepreg ply to the tool.

68. The method of any one of claims **57** to **66**, wherein the cut shape compensates for a fanning effect in the composite prepreg ply.

69. A method comprising:

5

identifying a desired shape of a ply on a tool, in which the ply has a fiber orientation;

10

identifying a cut shape for the ply, in which the cut shape is different than the desired shape;

cutting a composite prepreg ply to have the cut shape, the composite prepreg ply having the fiber orientation;

15

placing the composite prepreg ply having the cut shape on a carrier; and

using the carrier to apply the composite prepreg ply to the tool, including deforming the composite prepreg ply by stretching the carrier, stretching comprising changing one of a length or a width of the carrier.

20

70. The method of claim **69**, wherein placing the composite prepreg ply on the carrier comprises:

25

laying down courses of unidirectional prepreg fiber tape in side-by-side relationship on the carrier; and

compacting the courses against the carrier.

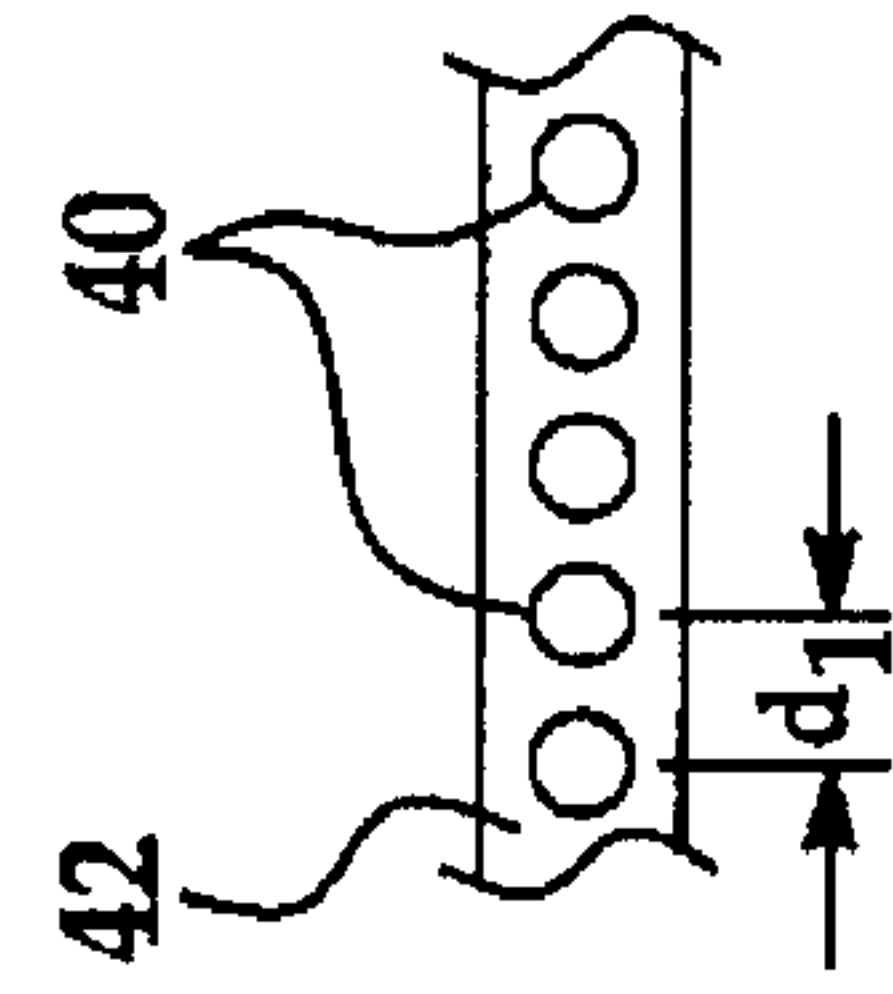
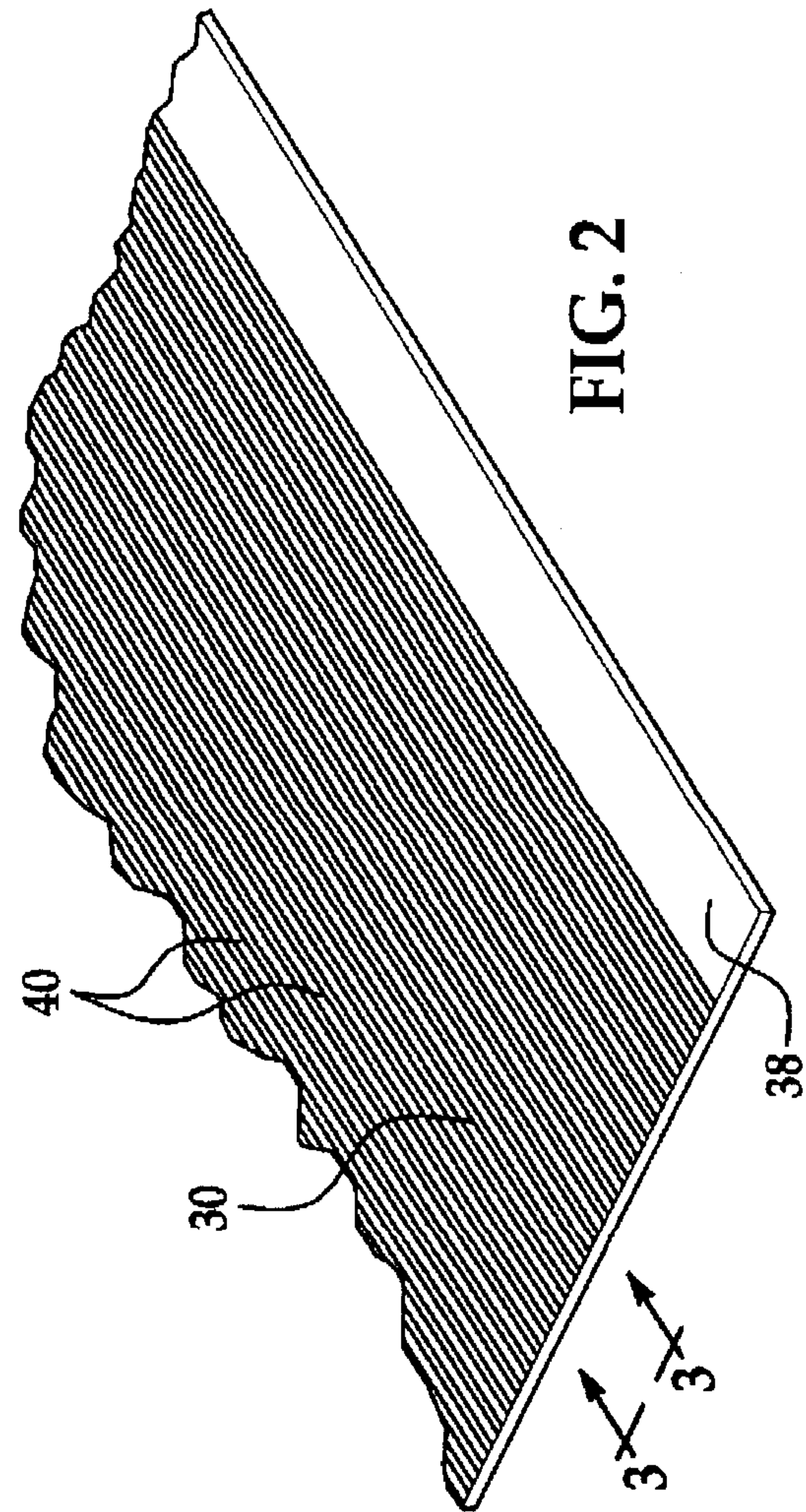
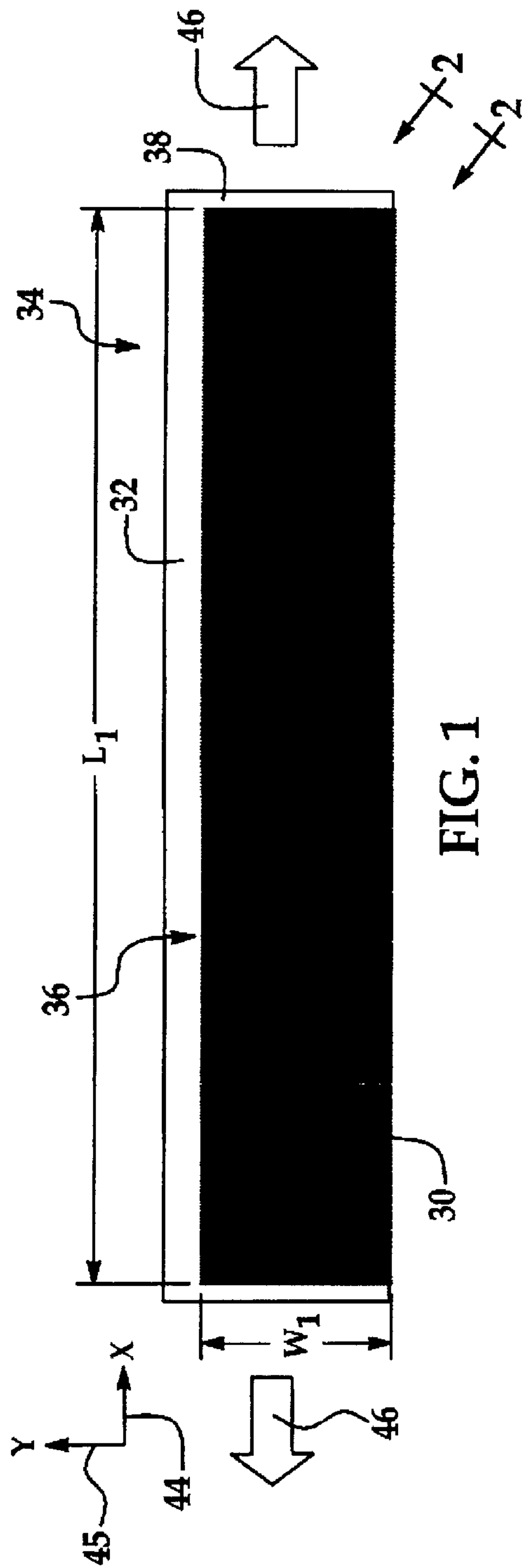
30

71. The method of claim **69** or **70**, wherein placing composite prepreg ply on the carrier and using the carrier to apply the composite prepreg ply are repeated to form a multiple ply part layup.

72. The method of any one of claims **69** to **71**, wherein deforming the composite prepreg ply includes:

5 stretching the carrier in a direction transverse to the fiber orientation of the composite prepreg ply.

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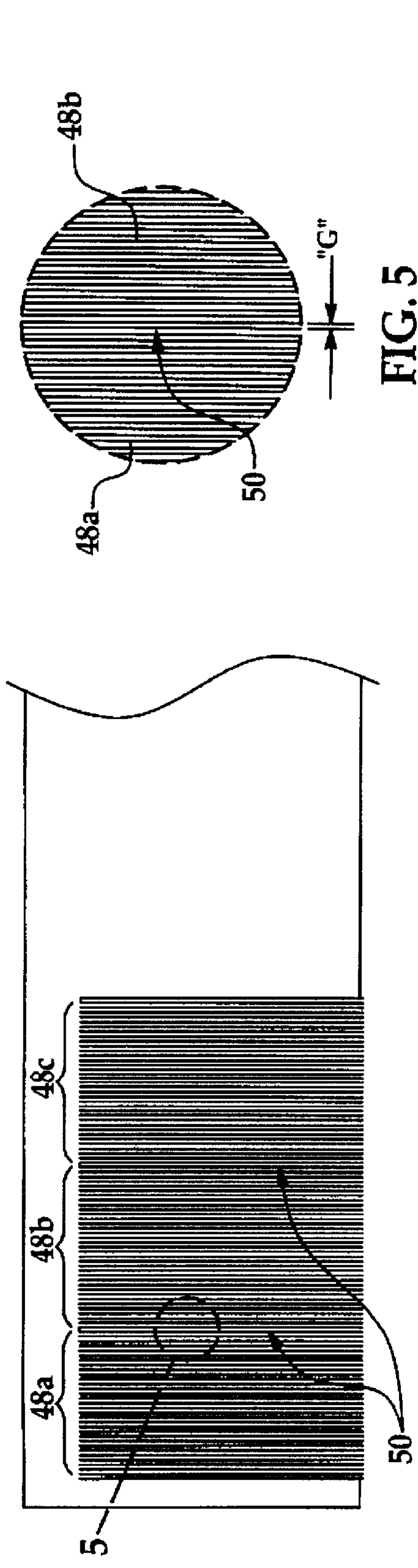


FIG. 5

FIG. 4

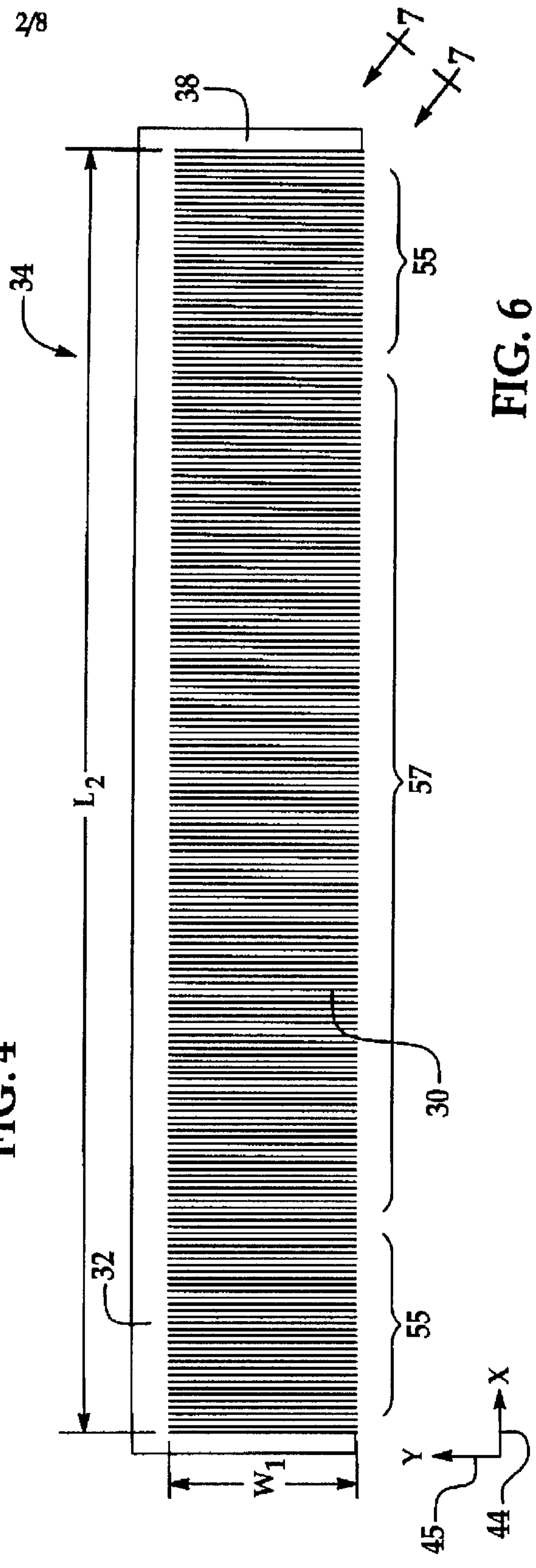


FIG. 6

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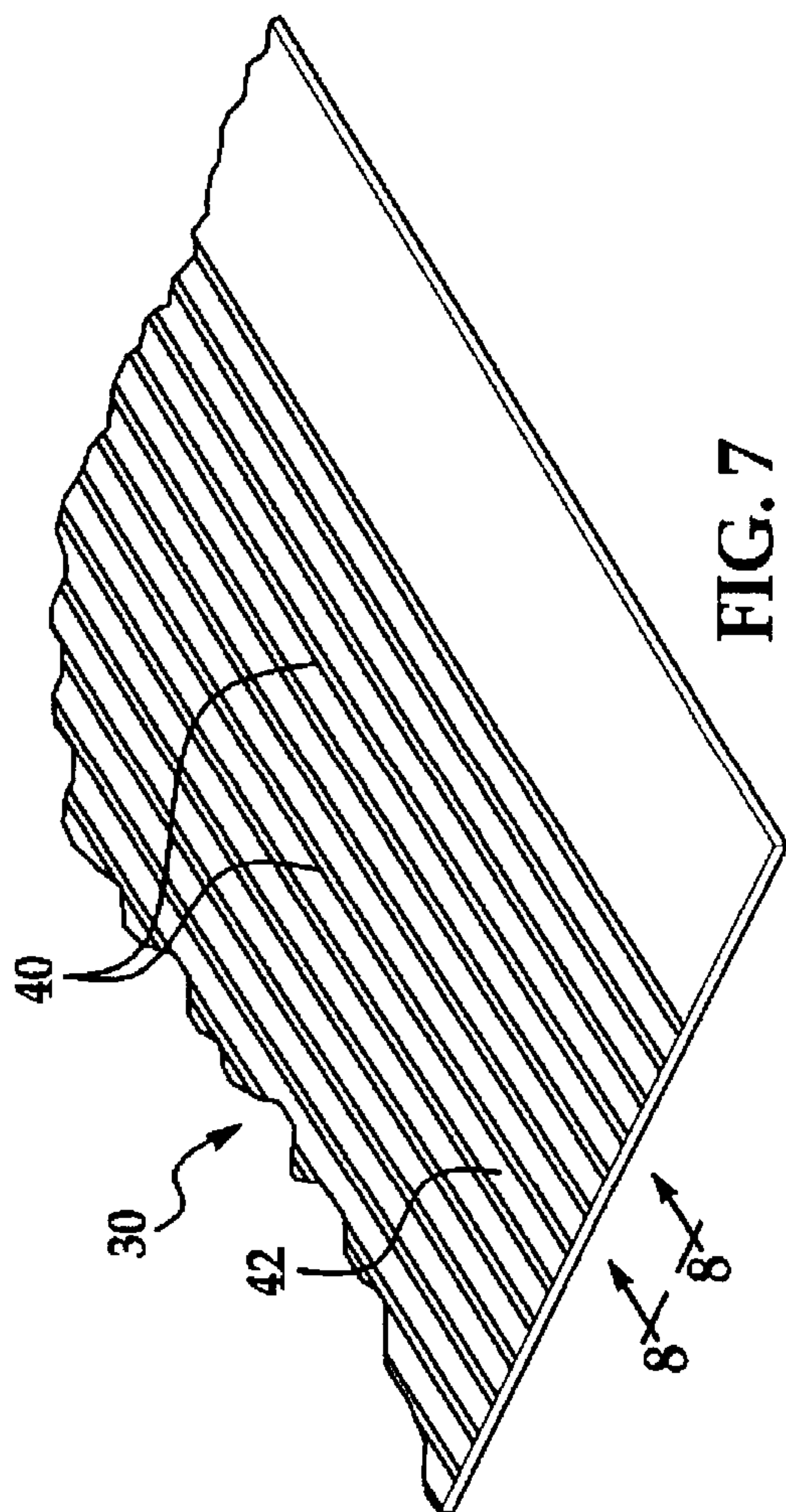


FIG. 8

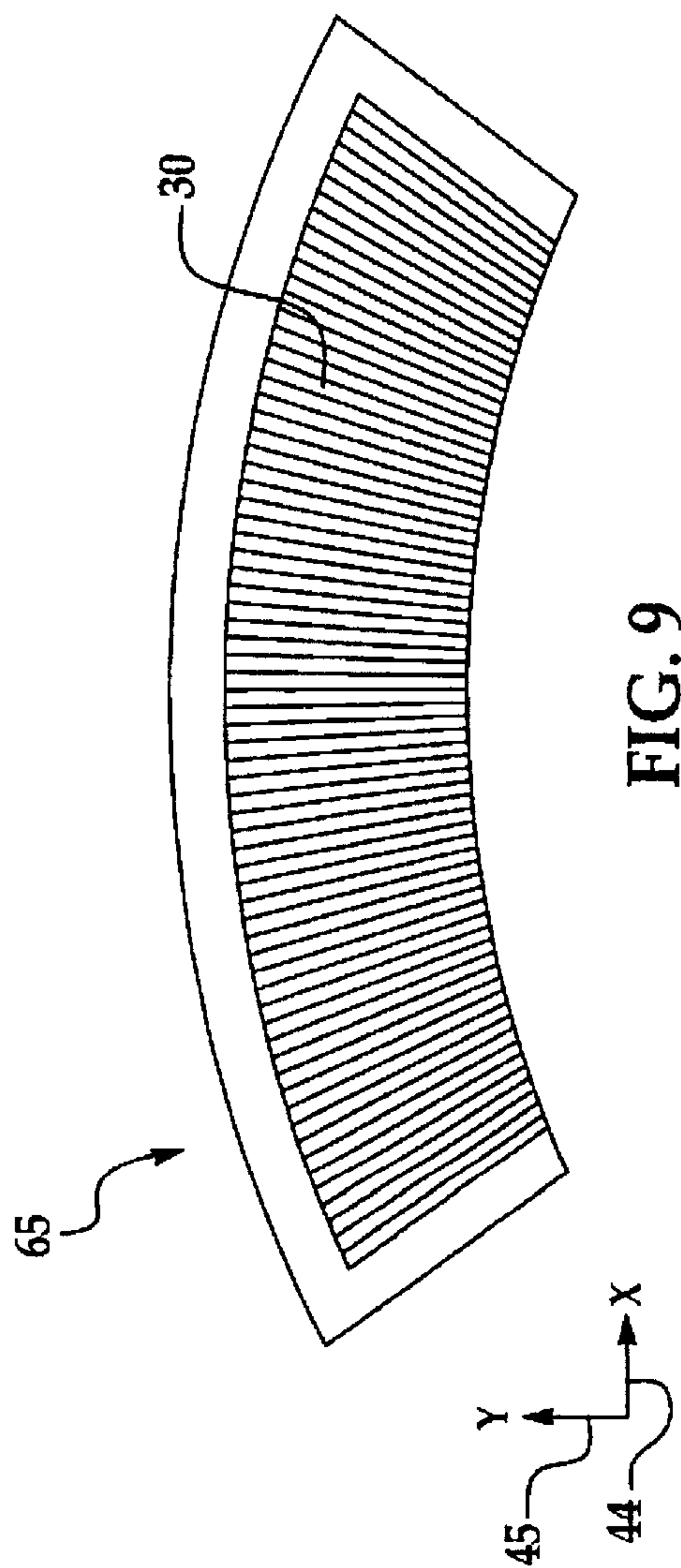
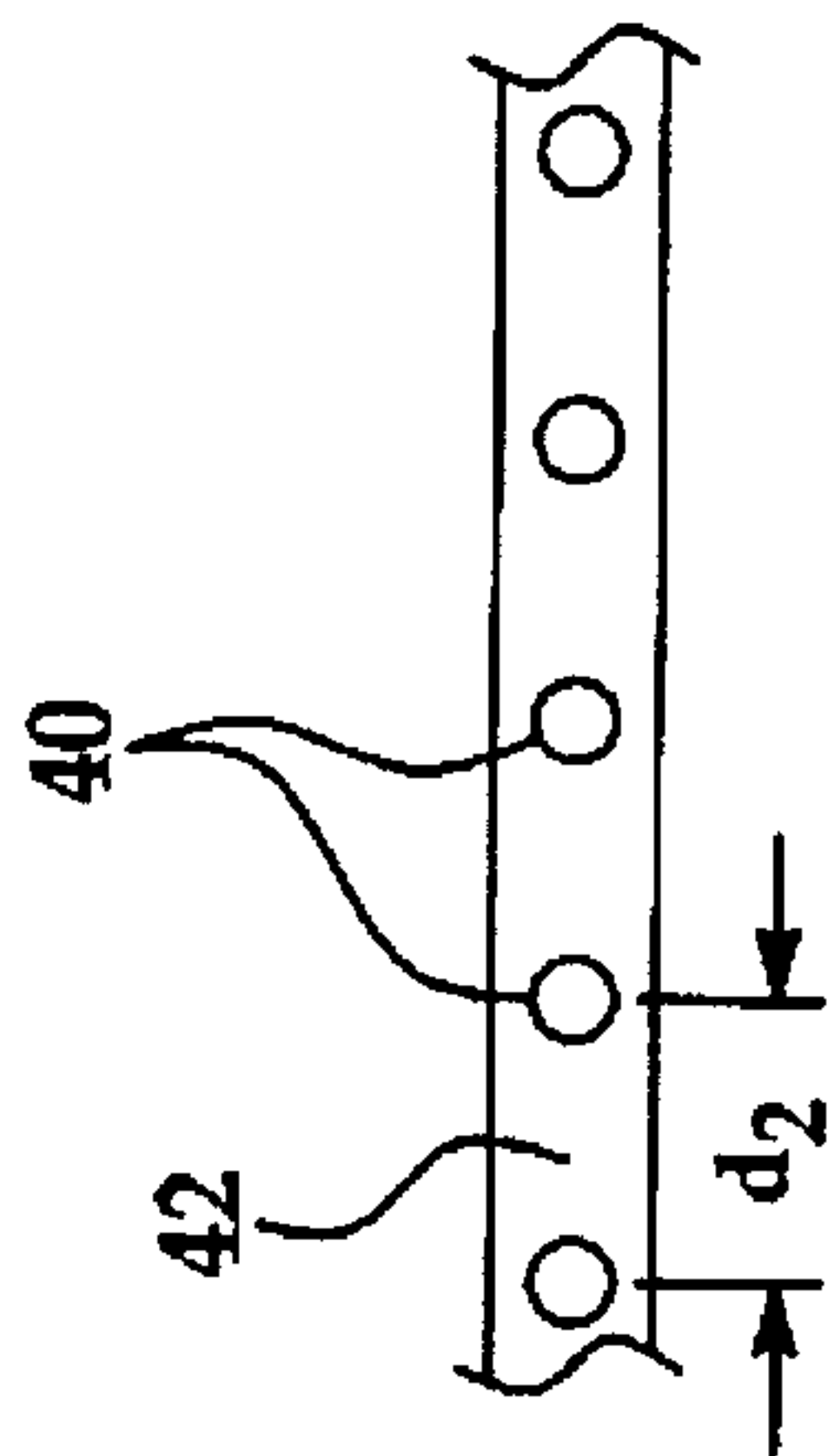


FIG. 9

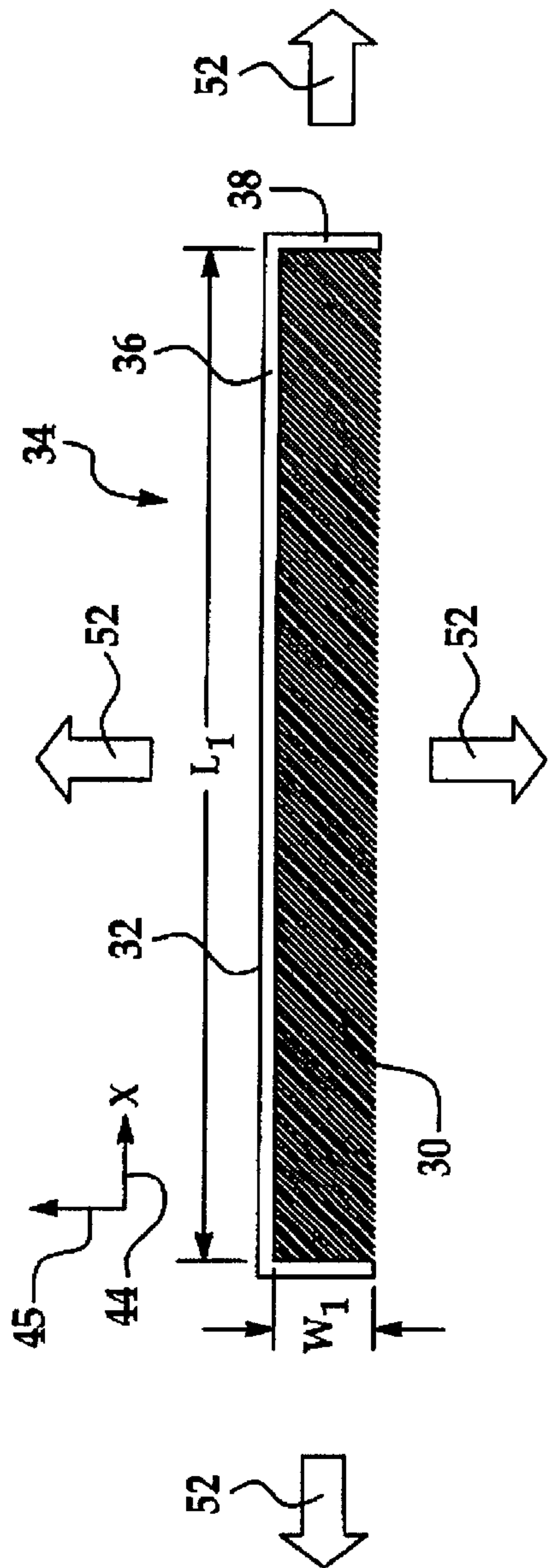


FIG. 10

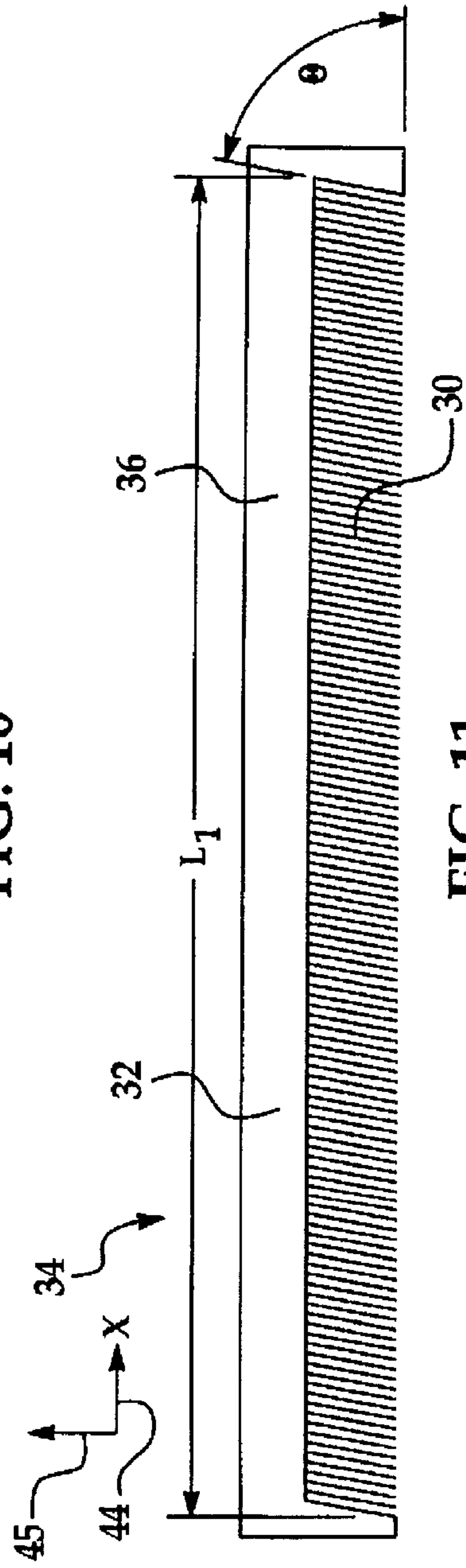


FIG. 11

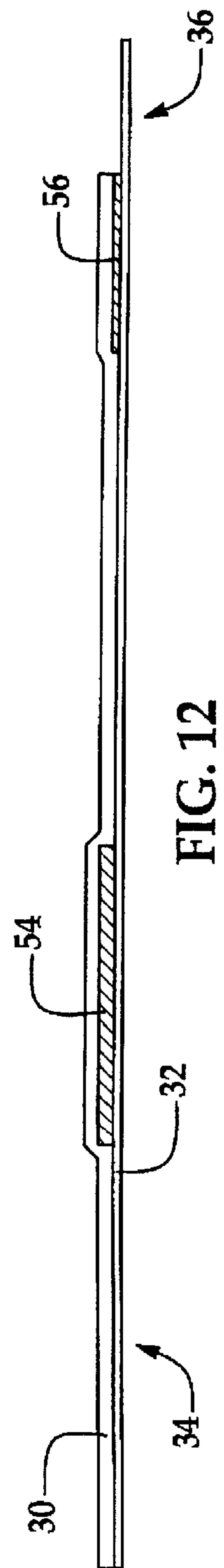


FIG. 12

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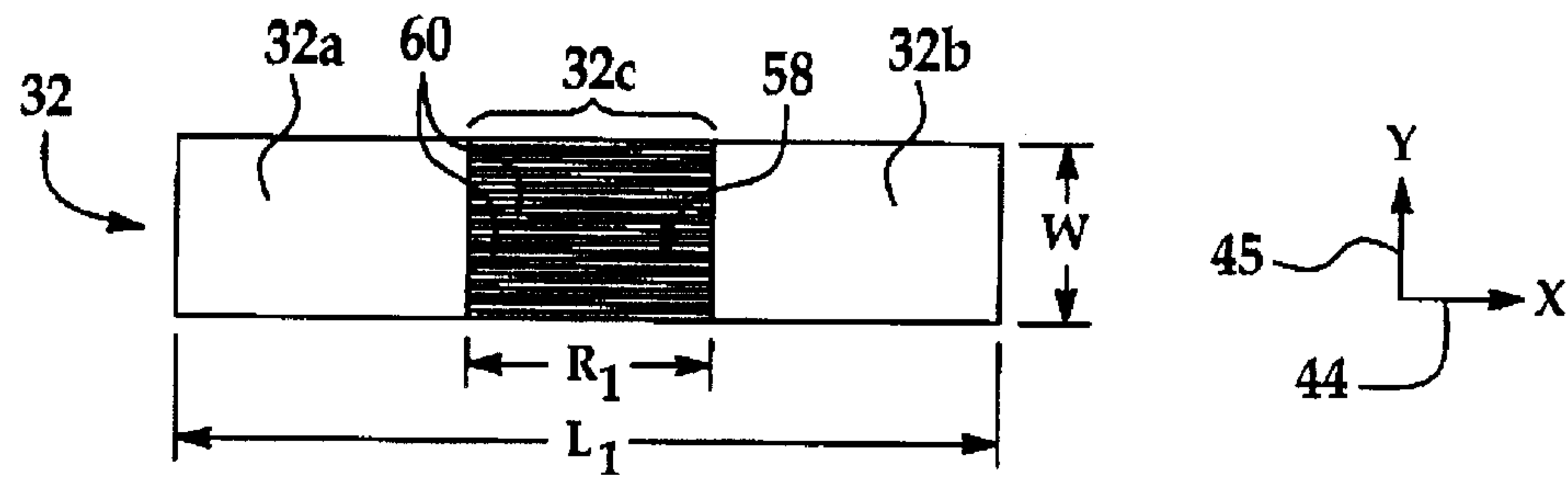


FIG. 13

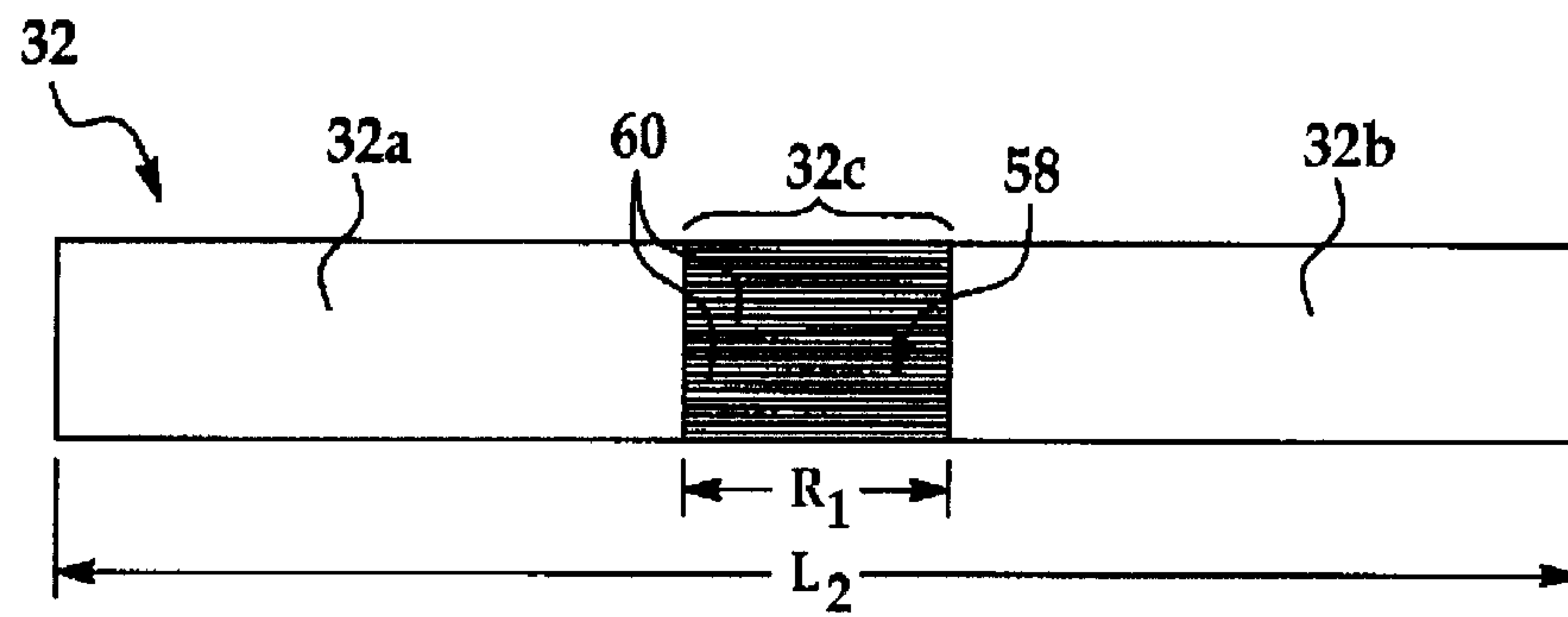


FIG. 14

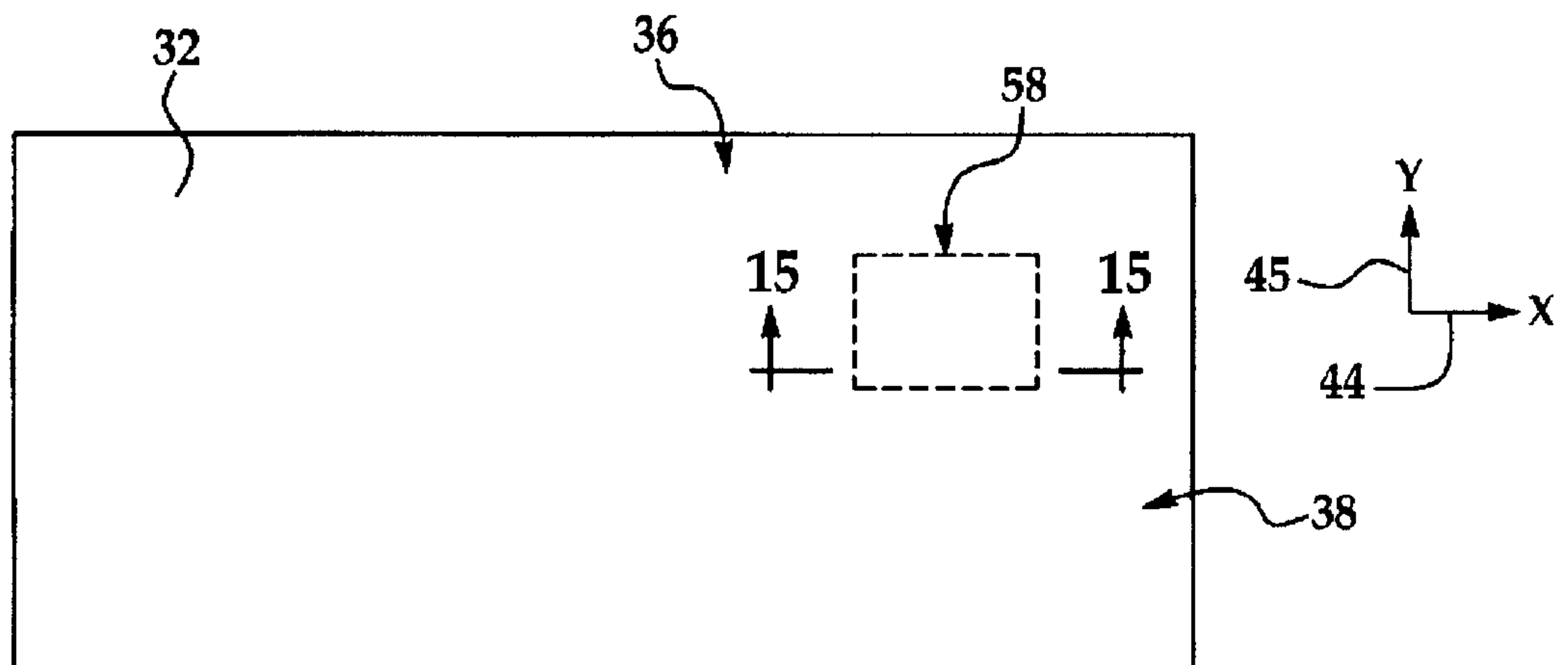


FIG. 15

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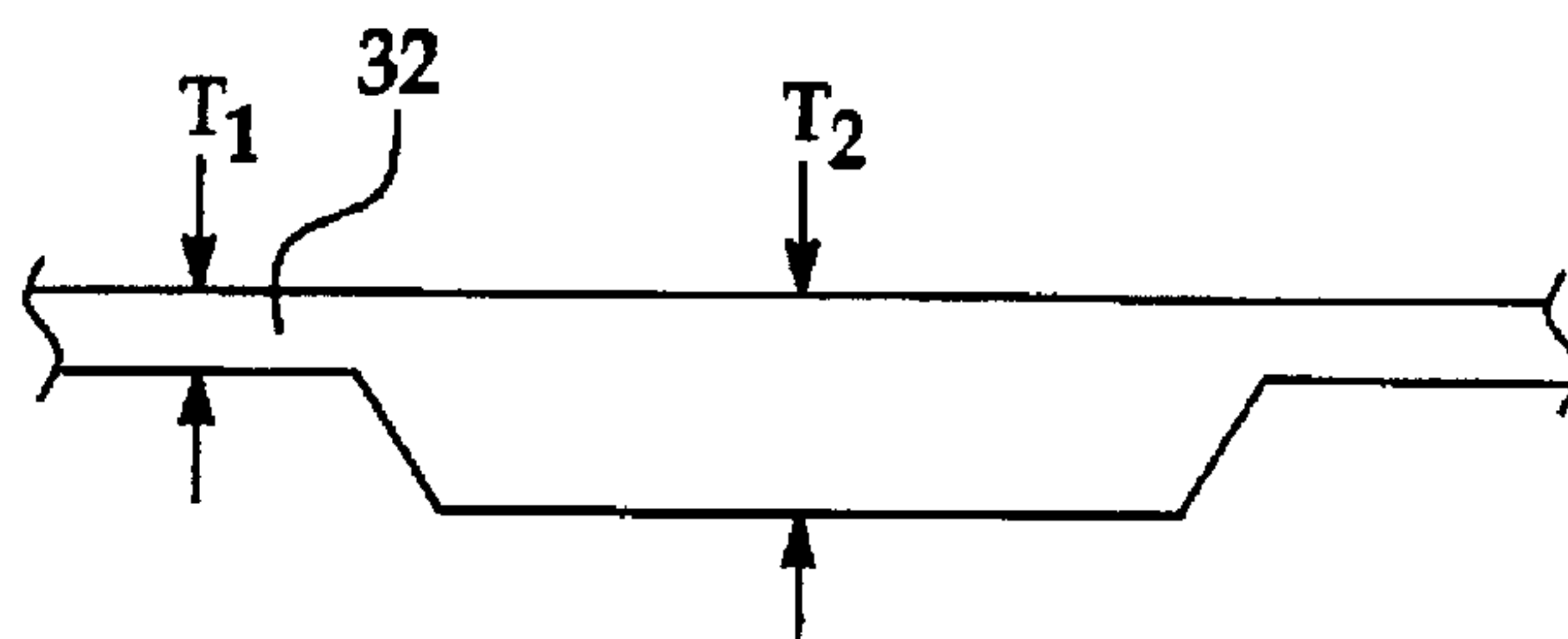


FIG. 16

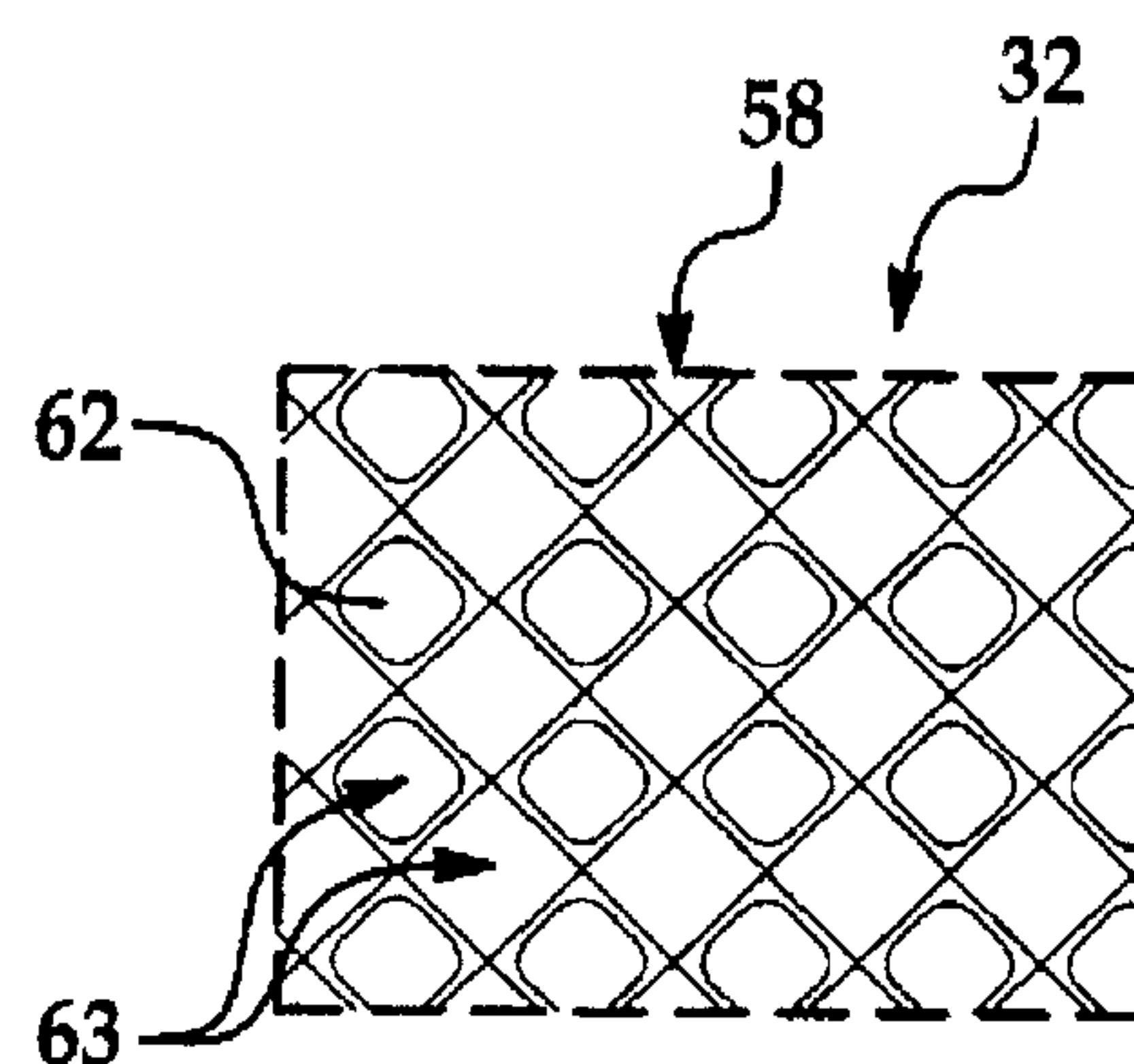


FIG. 17

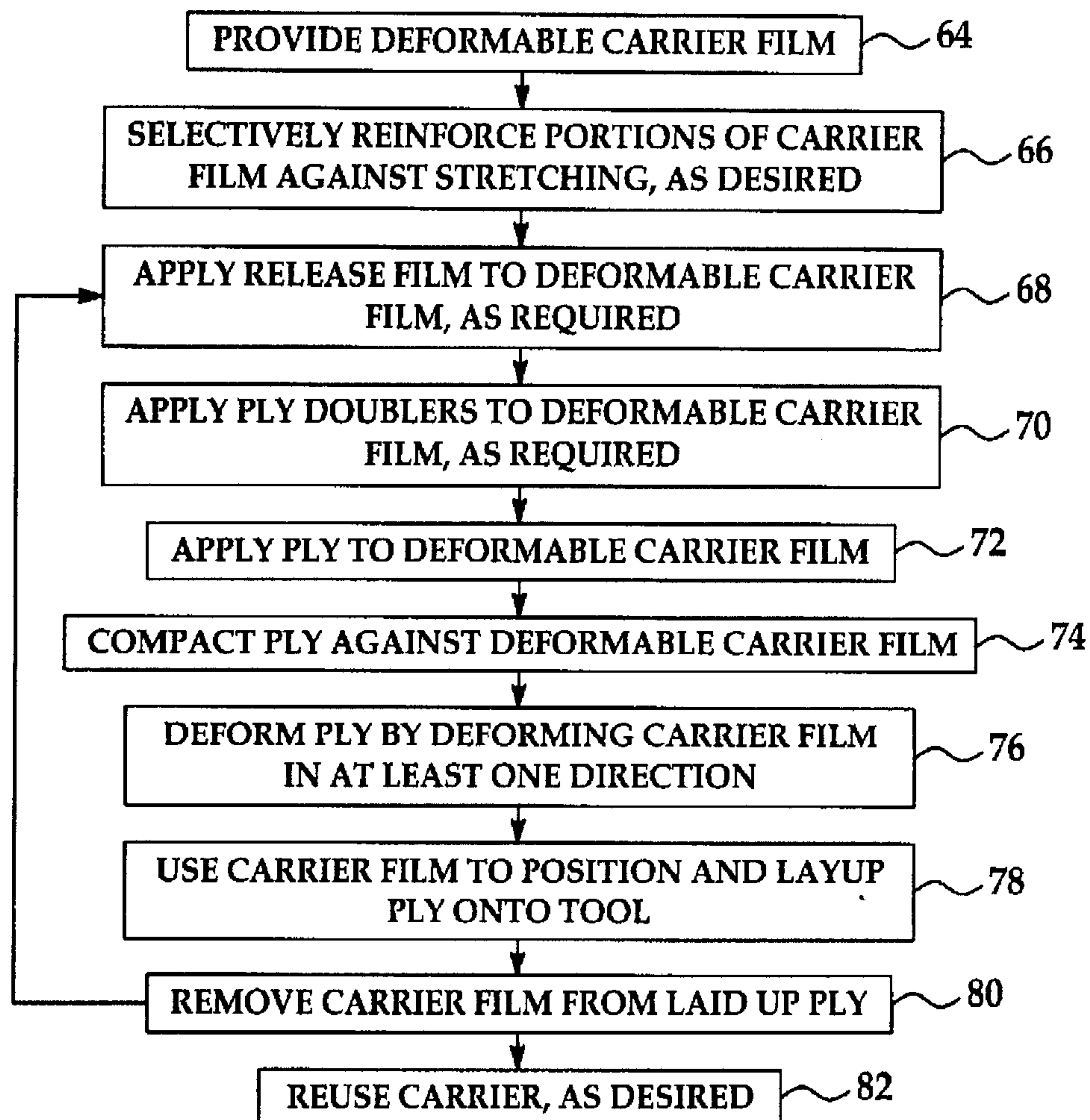


FIG. 18

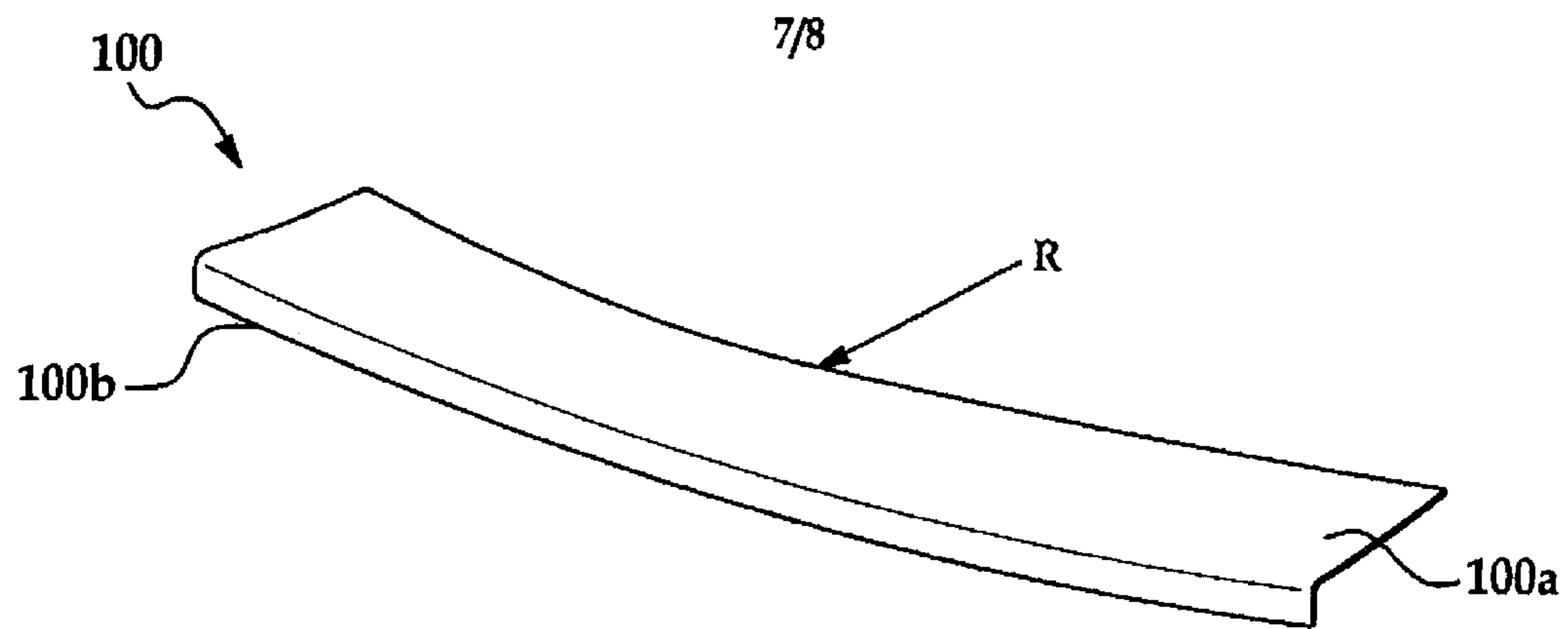


FIG. 19

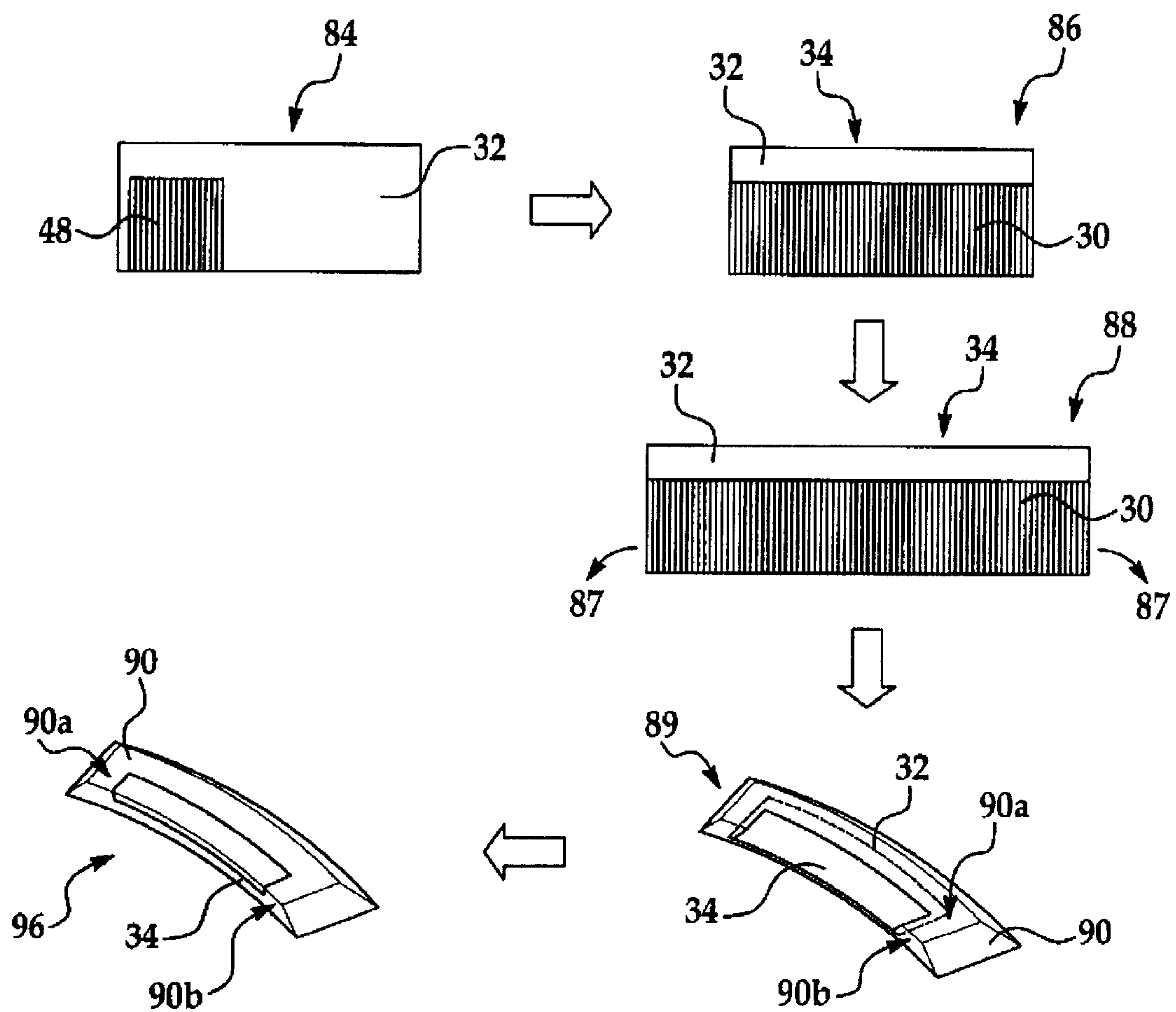


FIG. 20

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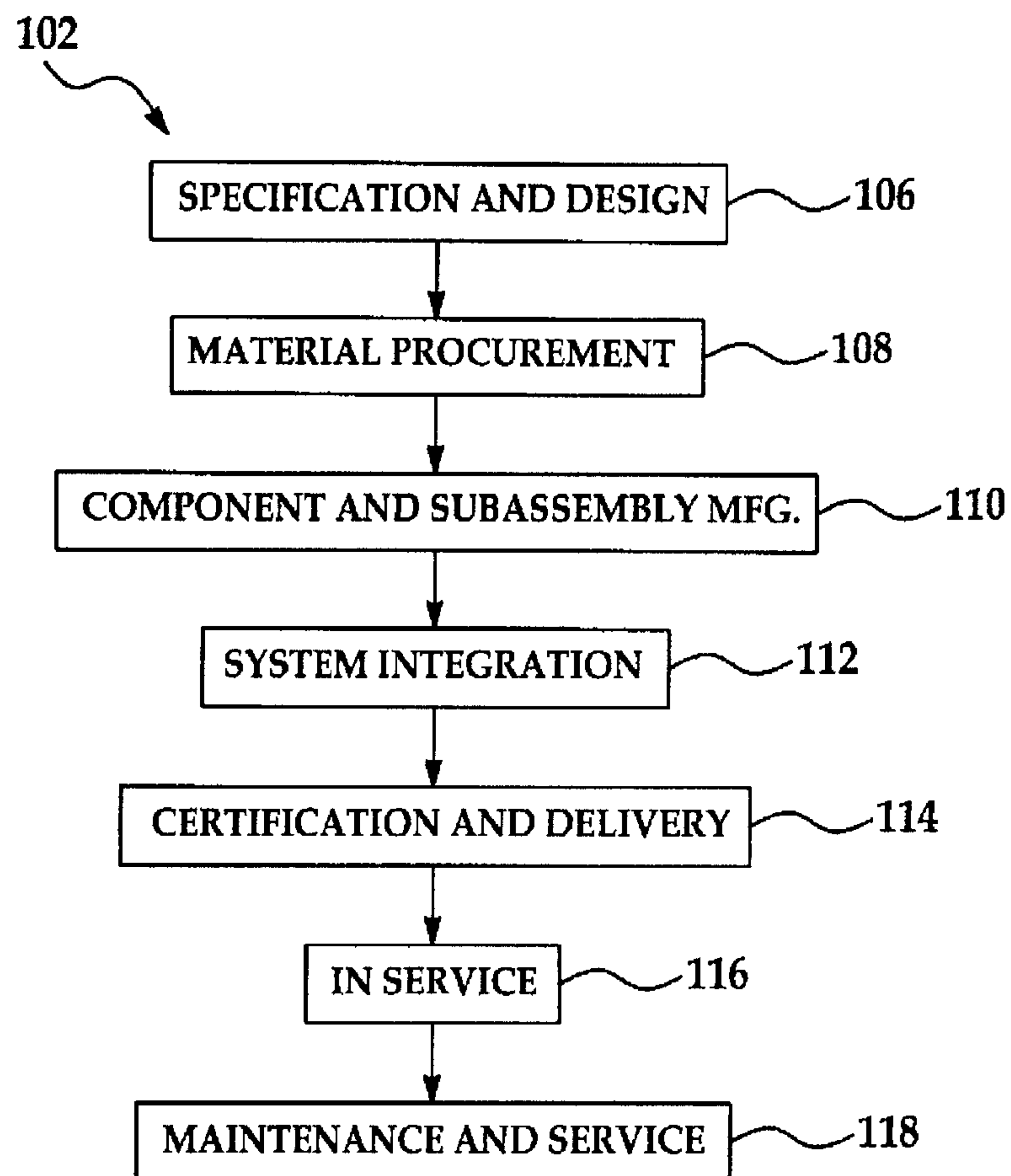


FIG. 21

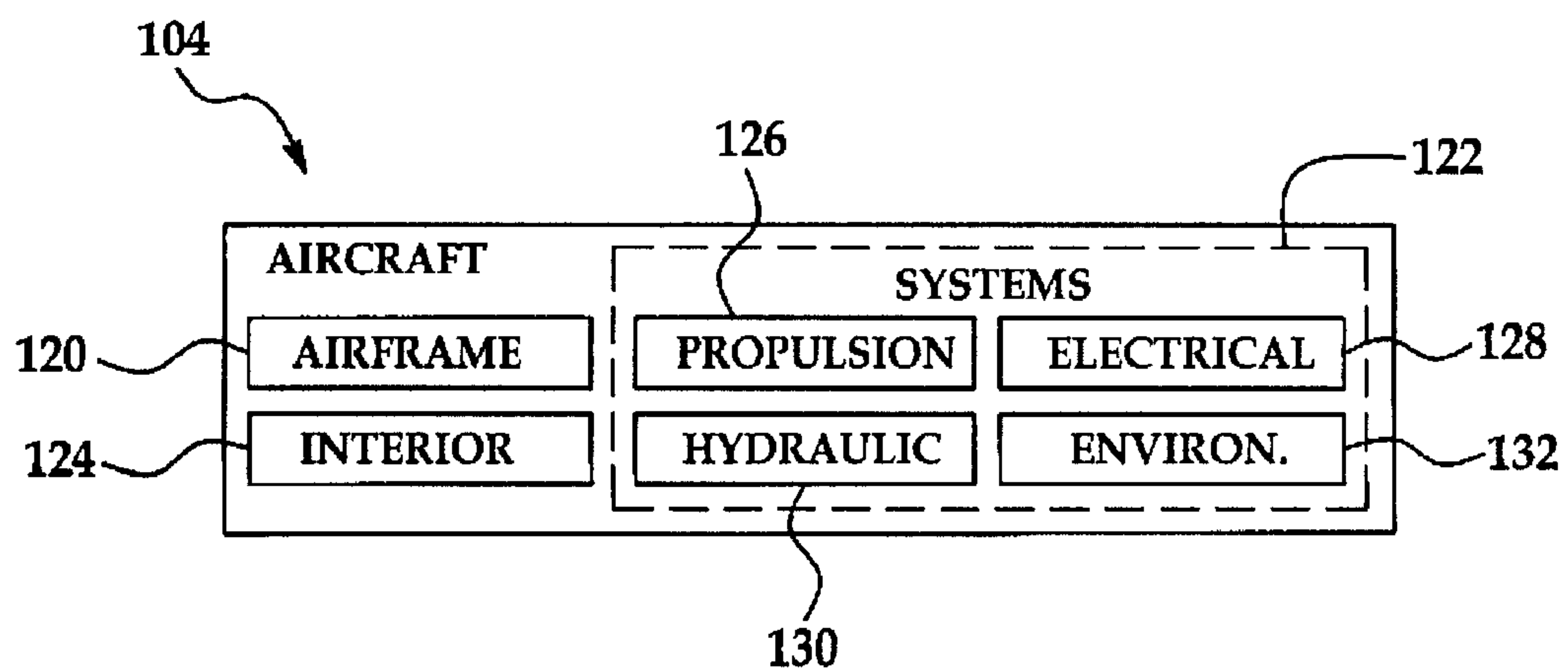


FIG. 22

