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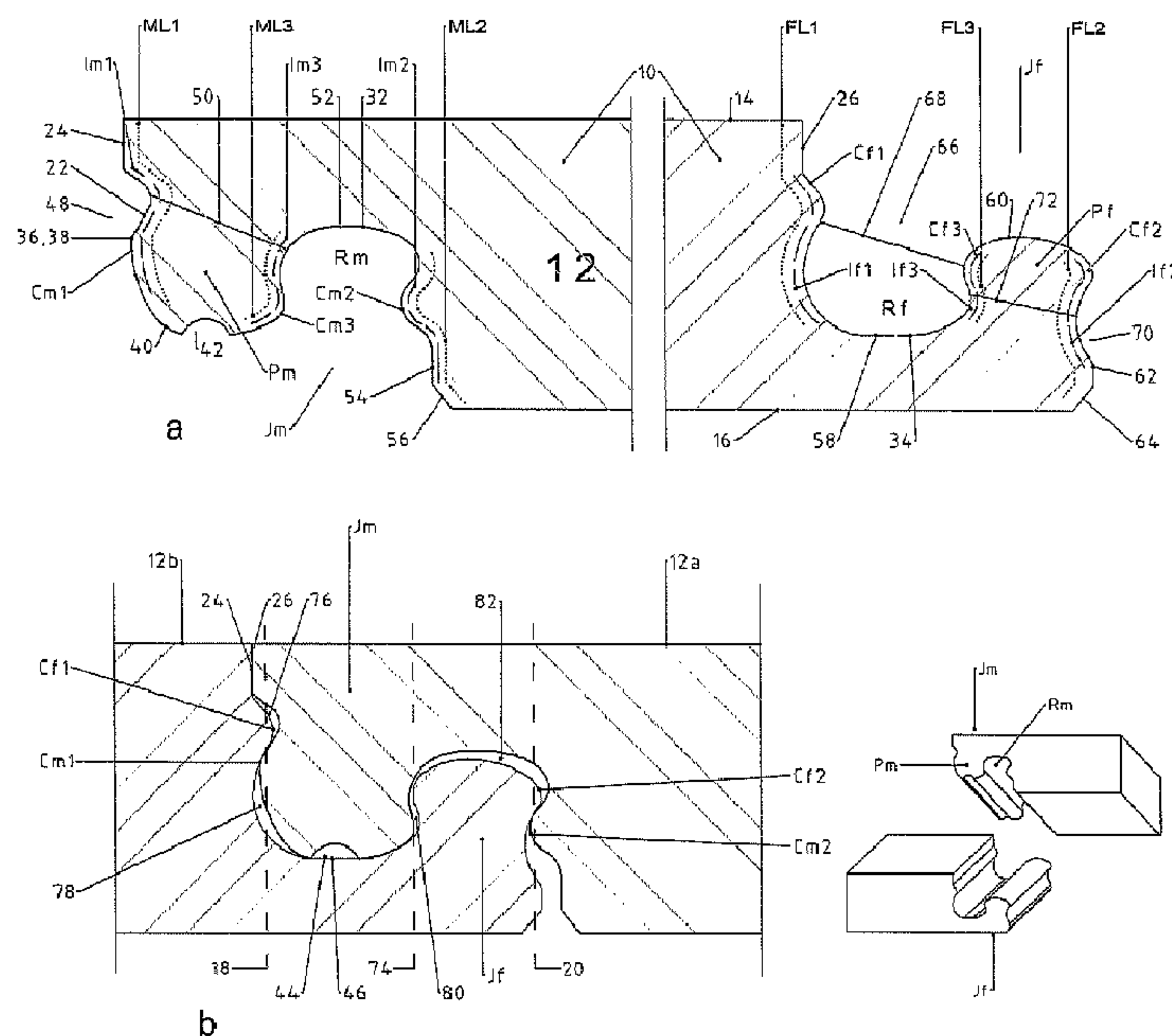
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(54) Titre : SYSTEME DE JOINTS VERTICAUX ET SYSTEME DE REVETEMENT DE SURFACE ASSOCIE
(54) Title: VERTICAL JOINT SYSTEM AND ASSOCIATED SURFACE COVERING SYSTEM



(57) **Abrégé/Abstract:**

A vertical joint system (10) for substrates (12) is formed with joints J_m and J_f which engaged by relative motion in a direction perpendicular to major surfaces (14) and (16) of the substrate (12). The joints are configured to enable relative rotation of up to (3)

(57) Abrégé(suite)/Abstract(continued):

degrees (i.e. clockwise or anticlockwise) while maintaining engagement of the joints. The joints Jm and Jf are further configured to form two locking planes (18, 20) one on each of the inner and outer most sides of the joint. Engagement about the locking planes (18, 20) is provided by transverse outward extending surfaces Cm1, Cm2, Cf1 and Cf2. The surface Cf1 and Cf2 overhang the surfaces Cm1 and Cm2. At least one surface in each pair of engaging surfaces: Cf1 and Cm1; and, Cf2 and Cm2 is smoothly curved. The joints Jm and Jf can be further arranged to provide a third locking plane (74) parallel to and between the locking planes (18, 20). The joints are disengaged by combination of a downward rotation of one joint relative the other then application of a downward force. By virtue of these features flooring with the joint system can be laid on sub-surfaces which have undulations greater than current world industry standards. Additionally replacement of damaged substrates is possible by vertical lifting of damaged substrates without the need to pull up excess flooring from the closest wall to the damaged substrates.

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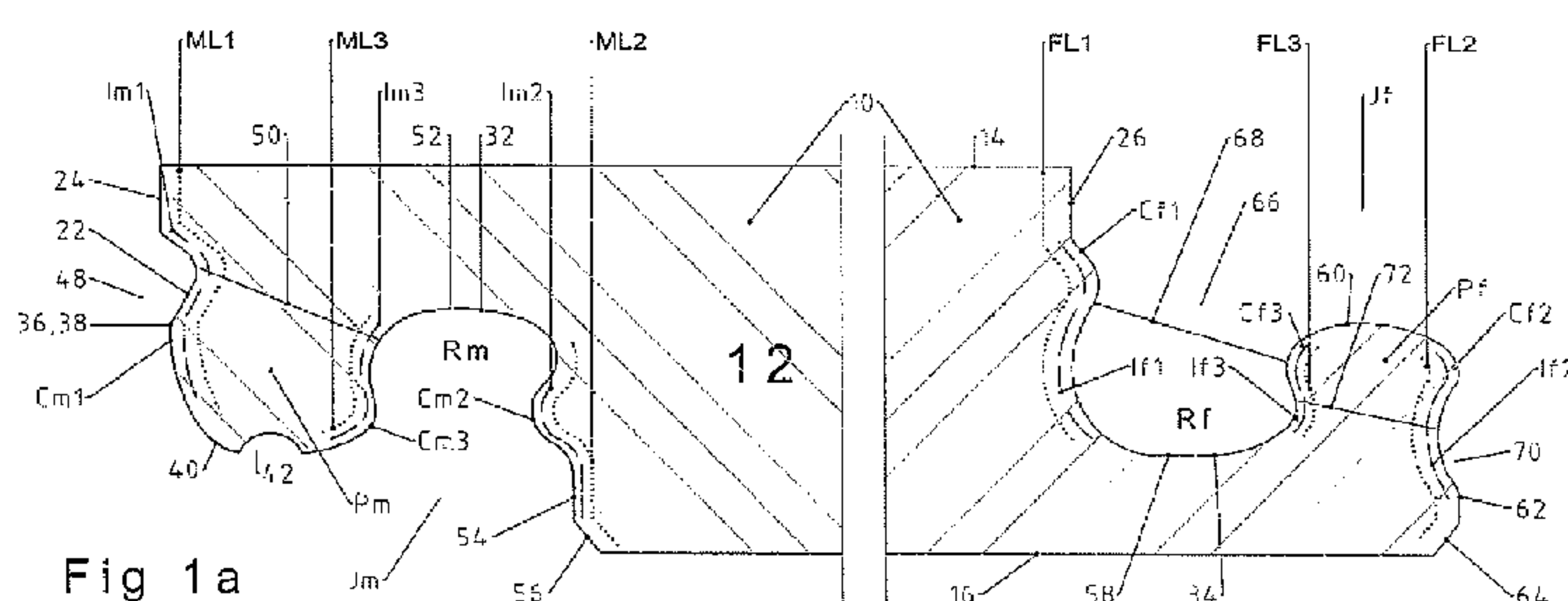


Fig 1a

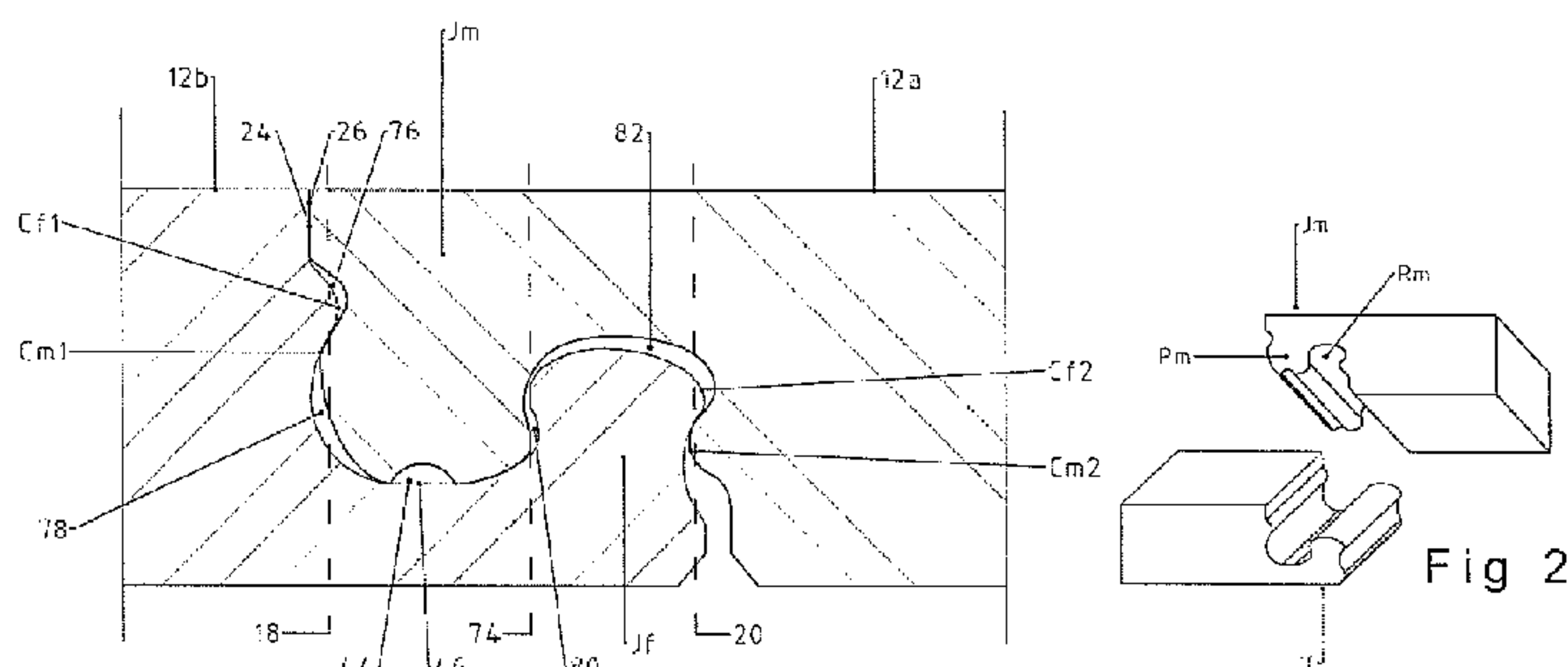


Fig 1b

(57) Abstract: A vertical joint system (10) for substrates (12) is formed with joints Jm and Jf which engaged by relative motion in a direction perpendicular to major surfaces (14) and (16) of the substrate (12). The joints are configured to enable relative rotation of up to (3) degrees (i.e. clockwise or anticlockwise) while maintaining engagement of the joints. The joints Jm and Jf are further configured to form two locking planes (18, 20) one on each of the inner and outer most sides of the joint. Engagement about the locking planes (18, 20) is provided by transverse outward extending surfaces Cm1, Cm2, Cf1 and Cf2. The surface Cf1 and Cf2 overhang the surfaces Cm1 and Cm2. At least one surface in each pair of engaging surfaces: Cf1 and Cm1; and, Cf2 and Cm2 is smoothly curved. The joints Jm and Jf can be further arranged to provide a third locking plane (74) parallel to and between the locking planes (18, 20). The joints are disengaged by combination of a downward rotation of one joint relative the other then application of a downward force. By virtue of these features flooring with the joint system can be laid on sub-surfaces which have undulations greater than current world industry standards. Additionally replacement of damaged substrates is possible by vertical lifting of damaged substrates without the need to pull up ex-

cess flooring from the closest wall to the damaged substrates.

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VERTICAL JOINT SYSTEM AND ASSOCIATED SURFACE COVERING SYSTEMField of the Invention

The present invention relates to a vertical joint system for substrates enabling the
5 substrates to be jointed together side by side. Non-limiting examples of such substrates
include wooden boards or panels which may be used as floor, wall or ceiling covering. The
present invention also relates to a surface covering system utilising substrates which
incorporate the joint system.

10 Background Art

“Click” type floor coverings comprise a plurality of substrates, each provided with
like joint systems to facilitate coupling of adjacent substrates. These joint systems often
comprise first and second joints running along two opposite sides of the substrate. The joints
are configured so that the first joint on one substrate is able to engage the second joint on
15 an adjacent substrate. The joints rely on specific configurations of tongues, grooves,
protrusions, recesses and barbs to effect interlocking engagement.

Joint systems for flooring may be generally categorised as horizontal (or “lay down”)
joint systems or vertical joint systems. Horizontal joint systems require motion in a plane
substantially parallel to a plane containing a major surface of the flooring substrate (i.e. a
20 horizontal plane) in order to effect the engagement of joints on adjacent substrates. Vertical
joint systems on the other hand require motion and/or force in a plane perpendicular to a
major surface of the substrates to effect engagement of the joints. Thus it should be
understood that the expression “vertical” in the context of the present type of joint system,
and as used in this specification, does not mean absolutely vertical but rather perpendicular
25 to a major surface of a substrate. When the substrate is laid on a horizontal surface then
“vertical” in this context is also absolute vertical. But as those skilled in the art will
understand substrates can be laid on surfaces of other dispositions for example on vertical
surfaces such as a vertical wall; or, inclined surfaces such as on a pitched ceiling. In such
situations the vertical joint system holds it’s meaning as a joint system that
30 operates/engages by way of motion and/or force in a plane perpendicular to a major surface
of the substrates

There are also “quasi” vertical joint systems which, while their manufacturer may
claim to be a vertical system, initially require engagement of joints of adjacent panels by a
lateral insertion of one joint into another followed by a rotation of one panel relative to
35 another so that their respective major surfaces are coplanar.

The above references to the background art do not constitute an admission that the
art forms a part of the common general knowledge of a person of ordinary skill in the art.

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The above references are also not intended to limit the application of the joint system as disclosed herein.

Summary of the Invention

5 Aspects of the present invention provide vertical joint systems for substrates. The vertical joint systems facilitate the provision of surface covering system that allow for very easy installation and more particularly repair. To this end repair can be achieved by vertical lifting of damaged panels without the need to pull up excess flooring from the closest wall to the damaged panels.

10 Other aspects of the present invention provide vertical joint systems for substrates wherein engaged substrates can rotate or pivot relative to each other in either positive or negative (i.e. clockwise or anticlockwise) while maintain engagement

In one aspect there is provided vertical joint system for a substrate having an opposed major first and second surfaces, the joint system comprising:

15 first and second non-symmetrical joints extending along opposite sides of the substrate, the first and second joints configured to enable two substrates with like joint systems to engage each other in response to a force applied in an engagement direction which is perpendicular to the major surfaces;

the first and second joints each provided with two laterally spaced transversely

20 extending surfaces configured to enable the first joint of one substrate to engage the second joint of a second substrate with the two transversely extending surfaces of the first joint located relative to the two transversely extending surfaces of the second joint to form respective first and second locking planes on an innermost and an outermost side of each joint, each

25 locking plane lying parallel to the engagement direction and wherein the transversely extending surfaces associated with each locking plane extend laterally toward each other from opposite sides of the locking plane with the transversely extending surfaces of the second joint overhanging the transversely extending surfaces of the first joint to inhibit separation if the

30 engaged joints, wherein in at least one of the transversely extending surfaces associated with each locking plane has a curved profile.

In one embodiment the transversely extending surfaces are configured to enable relative rotation of two engaged substrates by up to 3° while maintaining engagement of the two substrates.

35 In one embodiment the transversely extending surfaces are configured to enable relative rotation of one of the engaged substrates relative to the other by an angle of between 7° to 10° in a direction into a surface of which the substrates are laid while maintaining engagement of the two substrates.

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In one embodiment a void is created on at least one side of each locking plane by virtue of the non-symmetrical configuration of the first and second joints.

In one embodiment at least one of the transversely extending surfaces associated with at least one of the locking planes has a profile of a continuous convex curve.

5 In one embodiment at least one of the locking planes one of the transversely extending surface has a profile of a continuous convex curve and the other has a profile comprising one or more straight lines.

In one embodiment each of the transversely extending surfaces has a profile of a continuous convex curve.

10 In one embodiment two or more of the transversely extending surfaces have profiles of different continuous convex curves.

In one embodiment each joint comprises a protrusion extending in the engagement direction and an adjacent recess formed along a respective side of the substrate; and the transversely extending surfaces are formed on an outermost surface of each protrusion and
15 an inner most surface of each recess.

In one embodiment the protrusion of the first joint has a bulbous profile with a neck of reduced width wherein a portion of the transversely extending surface on the protrusion of the first joint is adjacent an outermost side of the neck.

In one embodiment the recess of the second joint has a bulbous profile with a neck of reduced width wherein a portion of the transversely extending surface on the recess of the
20 second joint is adjacent an outermost side of the neck.

In one embodiment a plane containing a line of shortest distance across the or each neck of is inclined relative to the major surfaces.

In one embodiment a plane containing a line of shortest distance across the or each
25 neck lies in a plane inclined relative to the major surfaces.

In one embodiment the respective lines of shortest distance across each neck are parallel to each other.

In one embodiment the lines of shortest distance across each neck are collinear.

In one embodiment each transversely extending surface constitutes a portion of a
30 respective inflexion surface.

In one embodiment each of the first and second joints is formed with a third transversely extending surface located between the two transversely extending surfaces of that joint, the third transversely extending surfaces relatively located to form a third locking plane disposed intermediate the first and second locking planes and wherein the third
35 transversely extending surfaces associated with the third locking plane extend laterally toward each other from opposites of the third locking plane with the third transversely extending surface of the second joint in alignment with or overhanging the third transversely extending surface of the first joint.

In one embodiment the first and second joints are relatively configured to engage each other about a third locking plane inhibiting separation of the engaged joints in a direction parallel to the engagement direction, the third locking plane being disposed parallel to and between the first and second locking planes.

5 In one embodiment each of the first and second joints comprise a third transversely extending surface wherein the third transversely extending surfaces extend to opposite sides of the third locking plane when in the engaged joint.

In a second aspect there is provided vertical joint system for a substrate having an opposed major first and second surfaces, the joint system comprising:

10 first and second non-symmetrical joints extending along opposite sides of the substrate, the first and second joints configured to enable two substrates with like joint systems to engage each other in response to a force applied in an engagement direction which is perpendicular to the major surfaces;

the first and second joints each provided with two laterally spaced inflexion surfaces
15 configured to enable the first joint of one substrate to engage the second joint of a second substrate with the two inflexion surfaces of the first joint engaging the two inflexion surfaces of the second joint on inner most and outer most sides of each joint to form respective first and second locking planes each of which independently inhibit separation of the engaged joints in a direction parallel to the engagement direction each locking plane lying parallel to
20 the engagement direction and wherein the inflexion surfaces associated with each locking plane lie on both sides of that locking plane and wherein at least one the inflexion surfaces associated with each locking plane has a profile of a continuous curve.

In one embodiment the inflexion surfaces are configured to enable relative rotation of two engaged substrates by up to 3° while maintaining engagement of the two substrates.

25 In one embodiment the inflexion surfaces are configured to enable relative rotation of one of the engaged substrates relative to the other by an angle of between 7° to 10° in a direction into a surface of which the substrates are laid while maintaining engagement of the two substrates.

In one embodiment each joint comprises a third inflexion surface and the respective
30 third inflexion surfaces are relatively configured to engage each other to form a third locking plane disposed between the first and second locking planes.

In one embodiment a void is created on at least one side of each locking plane by virtue of the non-symmetrical configuration of the first and second joints.

In one embodiment one inflexion surface associated with one locking plane has a
35 profile of a continuous curve and the other inflexion of that locking plane has a profile comprising one or more straight lines.

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In one embodiment each of the inflexion surfaces has a profile of a continuous curve.

In one embodiment each joint comprises a protrusion extending in the engagement direction and an adjacent recess formed along a respective side of the substrate; and the
5 inflexion surfaces associated with the first and second locking planes are formed on an outermost surface of each protrusion and an inner most surface of each recess.

In one embodiment the protrusion of the first joint has a bulbous profile having a neck of reduced width wherein a portion of the inflexion surface on the protrusion of the first joint is formed along an outermost side of the neck.

10 In one embodiment the recess of the second joint has a bulbous profile having a neck of reduced width wherein a portion of the inflexion surface on the recess of the second joint is formed along an outermost side of the neck.

In one embodiment a plane containing a line of shortest distance across the or each neck of is inclined relative to the major surfaces.

15 In one embodiment a plane contain a line of shortest distance across the or each neck lies in a plane inclined relative to the major surfaces.

In one embodiment the respective lines of shortest distance across each neck are parallel to each other.

In one embodiment the lines of shortest distance across each neck are collinear.

20 In a third aspect there is provided a vertical joint system for a substrate having an opposed major first and second surfaces, the joint system comprising:

non-symmetrical male and female joints extending along opposite sides of the substrate, the male and female joints configured to enable two substrates with like joint systems to engage each other in response to a force applied in an engagement direction
25 which is perpendicular to the major surfaces;

the male joint comprising a male protrusion extending generally perpendicular from the first major surface toward the second major surface and a male recess formed inboard of the male protrusion; the female joint comprising a female protrusion extending generally perpendicular from the second major surface toward the first major surface and a female
30 recess formed inboard of the female protrusion; the male joint having a first male locking surface formed on a side of its male protrusion most distant from its female recess, a second male locking surface formed on a side of its female recess most distant from its male protrusion and a third male locking surface being a surface common to the male protrusion and male recess; the female joint having a first female locking surface formed on a side of its
35 female recess most distant from its male protrusion, a second female locking surface formed on a side of its male protrusion most distant from its female recess, and a third female locking surface being a surface common to the female protrusion and female recess; the locking surfaces being configured so that when a male and female joint of two substrates are

engaged, the first male and first female locking surfaces engage to form a first locking plane, the second male and second female locking surfaces engage to form a second locking plane, and the third male and third female locking surfaces engage to form a third locking plane located between the first and second locking planes each locking plane inhibiting separation of the engaged joints in a direction parallel to the engagement direction, and wherein at least one of the first male locking surface and the first female locking surface is provided with a smoothly curved transversely extending portion; and at least one of the second male locking surface and the second female locking surface is provided with a smoothly curved transversely extending portion.

10 In one embodiment the locking surfaces are configured to enable relative rotation of two engaged substrates by up to 3° while maintaining engagement of the two substrates.

In one embodiment the locking surfaces are configured to enable relative rotation of one of the engaged substrates relative to the other by an angle of between 7° to 10° in a direction into a surface of which the substrates are laid while maintaining engagement of the two substrates.

15 In one embodiment the other of the first male locking surface and the first female locking surface is provided with a transversely extending portion comprising at least one planar surface.

In one embodiment the other of the second male locking surface and the second female locking surface is provided with a transversely extending portion comprising at least one planar surface.

In one embodiment each of first and second male and female locking surfaces comprises a smoothly curved transversely extending portion.

25 In one embodiment each of the first male locking surface, first female locking surface, second male locking surface and second female locking surface is formed with an inflexion; wherein the inflexions engage each other about the first and second locking planes.

In one embodiment at least one of the third male locking surface and the third female locking surface is formed with an inflexion.

30 In a fourth aspect there is provided a vertical joint system for a substrate having an opposed major first and second surfaces, the joint system comprising:

first and second non-symmetrical joints extending along opposite sides of the substrate, the first and second joints configured to enable two or more substrates with like joint systems to engage each other in response to a force applied in an engagement direction which is perpendicular to the major surfaces and to enable engaged substrates to be disengaged by lifting a first substrate in a direction opposite the engagement direction to facilitate rotation of adjacent engaged substrates along opposite sides of the first substrate to

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lie in planes declined from the first substrate and subsequently applying a force in the engagement direction to the second joints of the engaged substrates.

In one embodiment the first and second joints are each provided with two laterally spaced transversely extending surface portions configured to enable the first joint of one substrate to engage the second joint of a second substrate with the two transversely extending surfaces of the first joint located relative to the two transversely extending surfaces of the second joint to form respective first and second locking planes on an innermost and an outermost side of each joint, each locking plane lying parallel to the engagement direction and wherein the transversely extending portions associated with each locking plane extend laterally toward each other from opposites of the locking plane with the transversely extending portions of the second joint overhanging the transversely extending portions of the first joint.

In one embodiment at least one of the transversely extending surfaces associated with at least one of the locking planes has a profile of a continuous convex curve.

In one embodiment the first and second joints are each provided with two laterally spaced inflexion surfaces configured to enable the first joint of one substrate to engage the second joint of a second substrate with the two inflexion surfaces of the first joint engaging the two inflexion surfaces of the second joint on inner and outer most sides of each joint to form respective first and second locking planes each of which independently inhibit separation of the engaged joints in a direction parallel to the engagement direction each locking plane lying parallel to the engagement direction and wherein the inflexion surfaces associated with each locking plane lie on both sides of that locking plane.

In one embodiment the first joint is a male joint and the second joint is a female joint, the male joint comprising a male protrusion extending generally perpendicular from the first major surface toward the second major surface and a male recess formed inboard of the male protrusion; the female joint comprising a female protrusion extending generally perpendicular from the second major surface toward the first major surface and a female recess formed inboard of the female protrusion; the male joint having a first male locking surface formed on a side of its male protrusion most distant from its female recess, a second male locking surface formed on a side of its female recess most distant from its male protrusion and a third male locking surface being a surface common to the male protrusion and male recess; the female joint having a first female locking surface formed on a side of its female recess most distant from its male protrusion, a second female locking surface formed on a side of its male protrusion most distant from its female recess, and a third female locking surface being a surface common to the female protrusion and female recess; the locking surfaces being configured so that when a male and female joint of two substrates are engaged, the first male and first female locking surfaces engage to form a first locking plane,

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the second male and second female locking surfaces engage to form a second locking plane, and the third male and third female locking surfaces engage to form a third locking plane located between the first and second locking planes each locking plane inhibiting separation of the engaged joints in a direction parallel to the engagement direction.

5 In one embodiment the first and second joints are configured to create three locking planes when mutually engaged, each locking plane lying parallel to the engagement direction and inhibiting separation of engaged joints in a direction opposite the engagement direction.

10 In one embodiment when the substrate is in the configuration of a planar rectangular or square substrate having four sides, the first joint extends for two adjacent sides and the second joint extends for the remaining two adjacent sides.

In a fifth aspect there is provided a surface covering system comprising a plurality of substrates where in each substrate is provided with a vertical joint system in accordance with any one of the first to fourth and tenth aspects.

15 In a sixth aspect there is provided a semi-floating surface covering system comprising:

a plurality of substrates each substrate having a vertical joint system in accordance with any one of the first to fourth and tenth aspects;

a quantity of re-stickable adhesive bonded to the first major surface; and,

20 one or more release strips covering the re-stickable adhesive.

In one embodiment the quantity of re-stickable adhesive is applied in two or more spaced apart lines extending in a longitudinal direction of the substrate.

In one embodiment the quantity of re-stickable adhesive is applied as a continuous strip or bead in at least one of the spaced apart lines.

25 In one embodiment the re-stickable adhesive is applied in a plurality of lines which are evenly spaced from each other and symmetrically disposed about a longitudinal centre line of the substrate.

In one embodiment the re-stickable adhesive has a thickness measured perpendicular to the first major surface of between 1 – 6mm.

30 In one embodiment the re-stickable glue has a thickness of between 2 – 4mm.

In one embodiment the quantity of adhesive comprises a quantity of joint adhesive bonded to the substrate and covered with a release strip, the joint adhesive located in a position wherein when the joint system of one substrate is coupled to the joint system of another substrate with the cover strip removed, the joint adhesive on the one substrate
35 adheres to the joint of the other substrate.

In one embodiment the substrate is made from a material selected from the group consisting of; solid timber, engineered timber, laminate, Bamboo, plastics, and vinyl.

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In a seventh aspect there is provided a method of manufacturing a semi-floating surface covering substrate comprising:

providing a surface covering system in accordance with the fifth aspect;
bonding a quantity of a re-stickable adhesive to the first major surface; and,
5 covering the adhesive with a release strip.

In one embodiment bonding the adhesive comprises applying the adhesive in two or more spaced apart lines extending in a longitudinal direction of the substrate.

In one embodiment the bonding comprises applying the adhesive as a continuous strip or bead in at least one of the spaced apart lines onto the first major surface.

10 In one embodiment the method comprises applying the adhesive with a uniform thickness of between 1 - 6 mm measured in a direction perpendicular to the major surfaces.

In one embodiment the method comprises applying the adhesive with uniform thickness of between 2 - 4 mm.

In one embodiment the method comprises bonding a quantity of re-stickable
15 adhesive to at least a portion of the joint and covering the adhesive in the joints with a release strip, the re-stickable adhesive being applied at a location on a first substrate wherein when the vertical joint systems of the first and a second substrate are coupled together with a release strip covering the adhesive in the joint of the first substrate being removed, the adhesive adheres to the joint of the second substrate.

20 In an eighth aspect there is provided a surface covering system comprising a plurality of substrates, each substrate having: opposite first and second major surfaces wherein the first major surface is arranged to face an underlying support to be covered by the system; and a vertical joint system, the vertical joint system comprising:

first and second non-symmetrical joints extending along opposite sides of a
25 substrate, the first and second joints configured to enable two or more substrates to engage each other in response to a force applied in an engagement direction which is perpendicular to the major surfaces and to enable engaged substrates to be disengaged by: (a) lifting a first substrate in a direction opposite to the engagement direction to facilitate rotation of
30 adjacent engaged substrates along opposite sides of the first substrate to lie in planes declined from the first substrate; and (b) subsequently applying a force in the engagement direction to the second joints of the engaged substrates.

In one embodiment the surface covering system comprises at least one a jack
35 demountably attachable to the first substrate the jack comprising a shaft arranged to pass through a hole formed in the first substrate to bear on the underlying support, the jack being operable to extend the shaft through the hole to thereby lift the first substrate from the underlying support.

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In one embodiment of the surface covering system the vertical joint system is in accordance with any one of the first to fourth and tenth aspects.

In one embodiment the surface covering system comprises a quantity of re-stickable adhesive bonded to the first major surface; and, one or more release strips
5 covering the re-stickable adhesive.

In one embodiment the surface covering system comprises a quantity of re-stickable adhesive bonded to one or both of the first and second joints and respective release strips overlying the re-stickable adhesive bonded on the joints.

In one embodiment the vertical joint system comprises a quantity of re-stickable
10 adhesive bonded to one or both of the first and second joints and respective release strips overlying the re-stickable adhesive bonded on the joints.

In a ninth aspect there is provided a substrate for a surface covering system, the substrate comprising a vertical joint system according to any one of the first to fourth and tenth aspects.

15 In one embodiment the substrate comprises a quantity of re-stickable adhesive bonded to one or both of the first and second joints and respective release strips overlying the re-stickable adhesive bonded on the joints.

In one embodiment of the substrate each joint provided with the bonded re-stickable adhesive is provide with a recess for seating the bonded re-stickable adhesive.

20 In one embodiment the substrate comprises a quantity of re-stickable adhesive bonded to the first major surface; and, one or more release strips covering the re-stickable adhesive on the first major surface.

In one embodiment the vertical joint system comprises a layer of wax being provide on surfaces of the joint which when engaged with a like joint engage to form the first and
25 second locking planes.

In one embodiment of vertical joint system each recess of one substrate is provided with the joint system is configured to elastically open to enable a corresponding protrusion of a second substrate with a like joint system to like to enter and engage the recess.

In a tenth aspect there is provided a vertical joint system for a substrate having an
30 opposed major first and second surfaces, the joint system comprising:

first and second non-symmetrical joints extending along opposite sides of the substrate, the first and second joints configured to enable two substrates with like joint systems to engage each other in response to a force applied in an engagement direction which is perpendicular to the major surfaces;
35 the first and second joints being configured to enable relative rotation of two engaged substrates by up to 3° while maintaining engagement of the two substrates.

In one embodiment of the tenth aspect the first and second joints are each provided with two laterally spaced generally convex surfaces configured to enable the first joint of one substrate to engage the second joint of a second substrate with the two generally convex surfaces of the first joint located relative to the two generally convex surfaces of the second joint to form respective first and second locking planes on an innermost and an outermost side of each joint, each locking plane lying parallel to the engagement direction and wherein the generally convex surfaces associated with each locking plane extend laterally toward each other from opposite sides of the locking plane with the generally convex surfaces of the second joint overhanging the generally convex surfaces of the first joint to inhibit separation if the engaged joints, wherein in at least one of the generally convex associated with each locking plane has a curved profile.

In one embodiment of the tenth aspect each joint comprises a protrusion extending in the engagement direction and an adjacent recess formed along a respective side of the substrate; and the transversely extending surfaces are formed on an outermost surface of each protrusion and an inner most surface of each recess.

In one embodiment of the tenth aspect each recess configured to elastically open to enable a protrusion of a substrate with a like joint system to like to enter and engage the recess.

In one embodiment of the tenth aspect the first and second joints are configured to form a third locking plane intermediate the first and second locking planes.

In an eleventh aspect there is provided a vertical surface covering system comprising a plurality of panels, each panel having an upper major surface and a lower major surface and a plurality of sides disposed between the upper and lower major surfaces, each panel further provided with a joint system configured to enable: (a) a first panel to be engaged on each of its sides with respective other panels to form at least a portion of a surface covering; and (b) the first panel to be disengaged from the other panels by initially lifting the first panel in a direction perpendicular to a plane containing the upper major surface of the first panel surface covering thereby rotating each of two panels engaged on opposite side of the first panel to lie in respective planes declined from the first panel.

In a twelfth aspect there is provided a vertical surface covering system comprising a plurality of panels, each panel having an upper major surface and a lower major surface and a plurality of sides disposed between the upper and lower major surfaces, each panel further provided with a joint system configured to enable a first panel, which is engaged on each of its sides with respective other panels by engagement of respective joint systems on the panels, to be disengaged from the other panels by lifting the first panel in a direction perpendicular to a plane containing the upper major surface of the first panel thereby

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rotating each of two panels engaged on opposite side of the first panel to lie in respective planes declined from the first panel.

In a thirteenth aspect there is provided a vertical surface covering system covering system comprising a plurality of panels, each panel having an upper major surface and a lower major surface and a plurality of sides disposed between the upper and lower major surfaces, each panel further provided with a joint system configured to enable a first panel to be (a) laid in a space between a plurality of previously laid and engaged panels by application of a force in an engagement direction being perpendicular to the major surfaces wherein the joint system of the first panel engages with like joint systems of the previously laid panels adjacent the space; and (b) removed from the previously laid panels by lifting the first panel in a direction opposite the engagement direction.

In a fourteenth aspect there is provided A joint system for a panel of a vertical surface covering system the panel having an upper major surface and a lower major surface and a plurality of sides disposed between the upper and lower major surfaces, the joint system extending along each side of the panel and configured to enable a first panel, which is engaged on each of its sides with respective other panels by engagement of respective joint systems on the panels, to be disengaged from the other panels by lifting the first panel in a direction perpendicular to a plane containing the upper major surface of the first panel thereby rotating each of two panels engaged on opposite side of the first panel to lie in respective planes declined from the first panel.

In a fifteenth aspect there is provided a method of removing a first floor panel from a floor covering formed from a plurality of floor panels which are joined together by joint systems provided on each floor panels, the first floor panel being joined on all sides with the first floor panel by engaged other panels, the method comprising: vertically lifting the first floor panel from the floor covering in manner wherein the first floor panel remains substantially parallel to the floor covering to effect rotation of two of the other panels one of each on opposite sides of the first panel and a partial disengagement of the two other panels.

Brief Description of the Drawings

Notwithstanding any of forms which may fall within the scope of the joint system as set forth in the Summary, specific embodiments will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1a is a section view of a panel incorporating an embodiment of the vertical joint system;

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Figure 1b is a cross section view of a portion of two panels incorporating the vertical joint system in an engaged state;

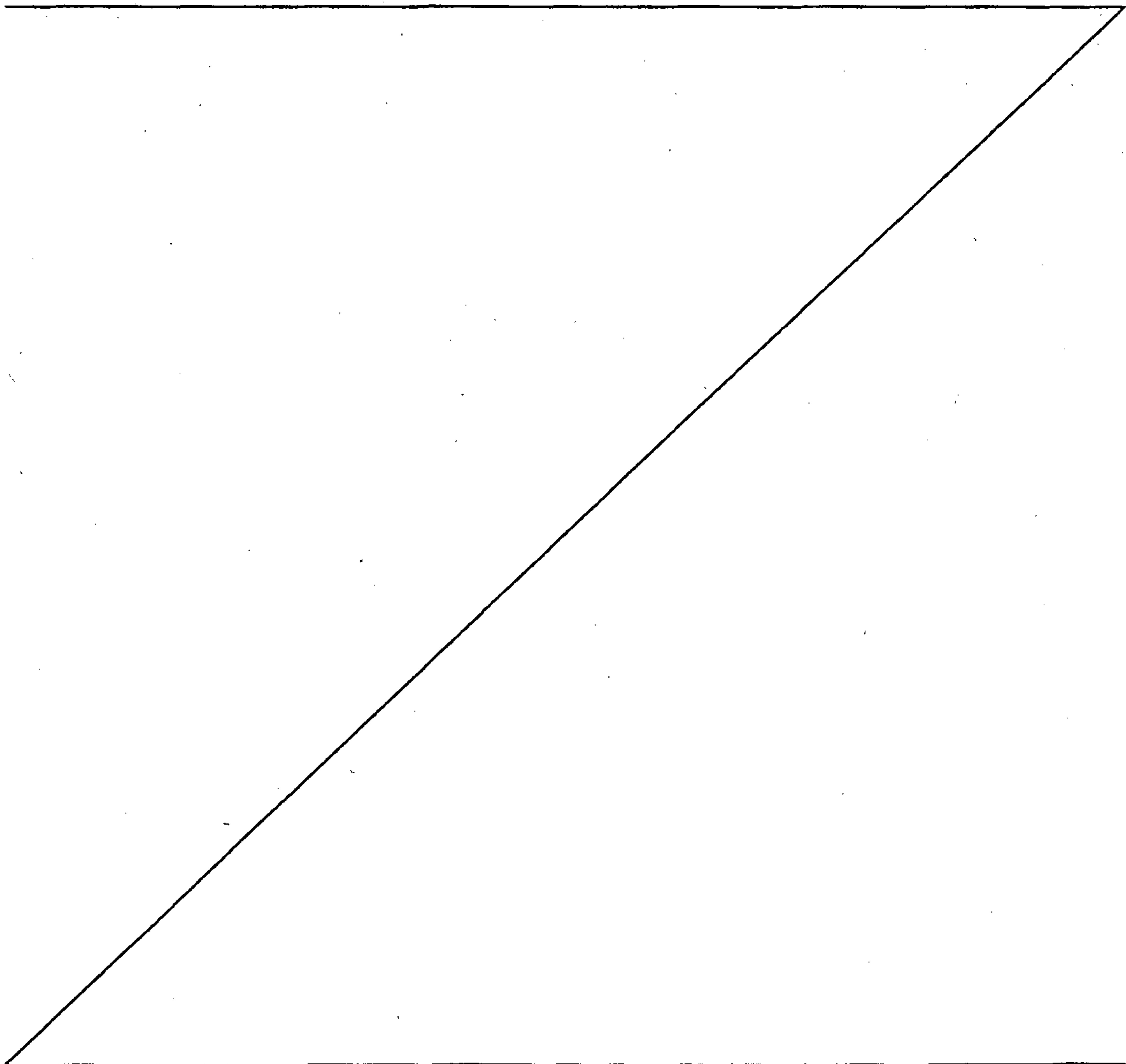
5 Figure 2 is an isometric view of a portion of two panels incorporating the vertical joint system when in a disengaged state;

Figure 3a illustrates the ability of engaged panels incorporating the vertical joint system to rotate in a first direction relative to each other;

Figure 3b illustrates the ability of engaged panels incorporating the vertical joint system to rotate in a second opposite direction relative to each;

10 Figure 4a illustrates the effect of lateral bowing of a substrate overlying a depression or hollow in a supporting surface;

Figure 4b is an enlarged view of detail A marked on Figure 4a;



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Figure 4c illustrates the effect of lateral bowing of a panel when overlying a hump or rise in an underlying surface;

Figure 4d is an enlarged view of detail B marked on Figure 4c;

Figure 4e is a schematic representation providing a comparison in the ability to
5 accommodate surface a hump or rise between prior art joint systems and vertical joint systems in accordance with embodiments of the present invention;

Figure 4f is an enlarged view of detail C marked on Figure 4e;

Figure 4g is a schematic representation providing a comparison in the ability to
10 accommodate surface a hollow or dip between prior art joint systems and vertical joint systems in accordance with embodiments of the present invention;

Figure 4h is an enlarged view of detail D marked on Figure 4g;

Figure 5a is a representation of the relative juxtaposition of panels incorporating the present vertical joint system being ready for engagement;

Figures 5b – 5e depict sequentially the engagement of panels incorporating
15 embodiments of the vertical joint system from a point of initial contact in Figure 5b to complete engagement in Figure 5e;

Figures 5f – 5k depict in sequence a self aligning feature of embodiments of the vertical joint system;

Figures 5l – 5u provides a schematic comparison between the effect of the self
20 aligning feature enabled by embodiments of the present invention and the prior art;

Figure 6a is an elevation view of an area covered by substrates joined together with embodiments of the present vertical joint system and identifying a panel to be removed;

Figure 6b is a view of section A-A from Figure 6a;

Figure 6c is a top elevation of a panel fitted with jacks enabling the removal of the
25 panel;

Figure 6d – 6s depict in sequence steps for the removal and replacement of the highlighted panel in Figure 6a;

Figure 7a is a side elevation of the jack depicted in Figure 6c;

Figure 7b is a top elevation of the jack shown in Figure 6c;

Figure 8a is a side elevation of a wedge used in conjunction with the jack for
30 extracting an engaged panel;

Figure 8b is an elevation view of the wedge shown in Figure 8a;

Figures 9a – 9f depict in sequence the disengagement of joined panels from an initial fully engaged state depicted in Figure 9a to a fully disengaged state shown in Figure
35 9f;

Figure 10a depicts a panel incorporating a second embodiment of the vertical joint system;

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Figure 10b illustrates the engagement of two panels incorporating the second embodiment of the vertical joint system;

Figure 11a depicts a panel incorporating a third embodiment of the vertical joint system;

5 Figure 11b illustrates the engagement of two panels incorporating the third embodiment of the vertical joint system;

Figure 11c illustrates the ability of engaged panels incorporating the joint system of the third embodiment to rotate in a first direction relative to each other;

10 Figure 11d illustrates the ability of engaged panels incorporating the joint system of the third embodiment to rotate in a second opposite direction relative to each;

Figure 12a depicts a panel incorporating a fourth embodiment of the vertical joint system;

Figure 12b illustrates the engagement of two panels incorporating the fourth embodiment of the vertical joint system;

15 Figure 13a depicts a panel incorporating a fifth embodiment of the vertical joint system;

Figure 13b illustrates the engagement of two panels incorporating the fifth embodiment of the vertical joint system;

20 Figure 14a depicts a panel incorporating a sixth embodiment of the vertical joint system;

Figure 14b illustrates the engagement of two panels incorporating the sixth embodiment of the vertical joint system;

Figure 15a depicts a panel incorporating a seventh embodiment of the vertical joint system;

25 Figure 15b illustrates the engagement of two panels incorporating the seventh embodiment of the vertical joint system;

Figure 16a depicts a panel incorporating a eighth embodiment of the vertical joint system;

30 Figure 16b illustrates the engagement of two panels incorporating the eighth embodiment of the vertical joint system;

Figure 17a depicts a panel incorporating a ninth embodiment of the vertical joint system;

Figure 17b illustrates the engagement of two panels incorporating the ninth embodiment of the vertical joint system;

35 Figure 17c schematically illustrates panels of different thickness incorporating the ninth embodiment of the vertical joint system;

Figure 17d illustrates the engagement of two panels shown in Figure 17c;

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Figure 17e provides a series of representations of illustrating the engagement of separate pair of panels of varying thickness the incorporating the ninth embodiment of the vertical joint system

5 Figure 18a depicts a panel incorporating a tenth embodiment of the vertical joint system;

Figure 18b illustrates the engagement of two panels incorporating the tenth embodiment of the vertical joint system;

Figure 19a depicts a panel incorporating a eleventh embodiment of the joint system;

10 Figure 19b illustrates the engagement of two panels incorporating the eleventh embodiment of the vertical joint system;

Figure 20a depicts a panel incorporating a twelfth embodiment of the vertical joint system;

15 Figure 20b illustrates the engagement of two panels incorporating the twelfth embodiment of the vertical joint system;

Figure 21a depicts a panel incorporating a thirteenth embodiment of the vertical joint system;

Figure 21b illustrates the engagement of two panels incorporating the thirteenth embodiment of the vertical joint system;

20 Figure 22 illustrates the engagement of two panels incorporating a fifteenth embodiment of the vertical joint system;

Figure 23a depicts a panel incorporating a fourteenth embodiment of the vertical joint system;

25 Figure 23b illustrates the engagement of two panels incorporating the fourteenth embodiment of the vertical joint system;

Figures 23c - 23i depict in sequence the engagement and disengagement of the fourteenth embodiment of the vertical joint system when incorporating a re-stickable adhesive.

30 Figure 24a depicts a panel provided with incorporating any embodiment of the vertical joint system with the addition of a re-stickable adhesive laid as strips;

Figure 24b is a view of section AA of the panel shown in Figure 24a;

Figure 24c shows the panel of Figures 24a and 24b when adhered to an underlying supporting surface;

35 Figure 25a depicts a panel provided with any embodiment of the vertical joint system with the addition of a re-stickable adhesive laid as beads;

Figure 25b shows the panel of Figure 25a when adhered to an underlying supporting surface;

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Figures 26a-26e depict in sequence the removal of a panel of the type shown in Figures 25a and 25b which is adhered to an underlying supporting;

and,

Figures 27a and 27b depicts a method of laying a floor using jointed panels.

5

Detailed Description of Specific Embodiments

Figures 1a - 2 illustrate a first embodiment of a vertical joint system 10 (hereinafter referred to as "joint system 10") for a substrate. The substrate is shown in cross section view and in this embodiment is in the form of an elongated rectangular panel 12. The substrate or panel 12 has opposed major first and second surfaces 14 and 16 respectively. Each of the surfaces 14 and 16 are planar surfaces and lie parallel to each other. In one orientation the surface 14 is an exposed surface of the panel 12 while the surface 16 bears against a support surface or structure such as but not limited to a concrete, timber, tile or vinyl floor or timber battens. Joint system 10 comprises a first joint Jm and a non-symmetrical second joint Jf. The first joint Jm can be notionally considered to be a male joint while the second joint Jf can be notionally considered to be a female joint. This designation of the joints will be explained shortly.

Assuming the substrate to be in the shape of a quadrilateral the joint Jm extends along two adjacent sides and Jf extend along the remaining two adjacent sides. For example when the substrate is an elongated rectangular floor board as shown in Figures 1b and 1c the joint Jm extends along one longitudinal side and an adjacent transverse side, while the joint Jf extends along the other (i.e. opposite) longitudinal side and the other (i.e. opposite) adjacent transverse side.

Figure 1b illustrates a first joint Jm of a first panel 12a engaged with a second joint Jf of a second panel 12b having an identical joint system 10. For ease of description the panels 12a and 12b will be referred to in general as "panels 12".

As will be explained in greater detail shortly, the first and second joints Jm and Jf are configured to enable two panels 12 (i.e. panels 12a and 12b) to engage each other in response to a pressure or force F (see Figure 5) applied in an engagement direction D which is perpendicular to the major surfaces 14 and 16. When the panels 12 are floor panels the direction D lies in the vertical plane and more particularly is directed downwardly toward a surface on which the panels are laid. This is equivalent to the joints Jm and Jf engaging by virtue of motion of one joint (or substrate) relative to another in a direction perpendicular to a plane containing the major surfaces.

The joint Jm comprises a male protrusion Pm and a male recess Rm, while the joint Jf comprises a female protrusion Pf and a female recess Rf. The first joint Jm is notionally designated as the male joint by virtue of its protrusion Pm depending from the upper surface

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14. The second joint Jf is notionally designated as the female joint by virtue of its recess Rf being configured to receive the protrusion Pm.

When describing features or characteristic common to all protrusions the protrusions will be referred to in general in this specification in the singular as "protrusion P", and in the plural as "protrusions P". When describing features or characteristic common to all recesses the recesses will be referred to in general in this specification in the singular as "recess R", and in the plural as "recesses R". When describing features or characteristic common to all joints the joints will be referred to in general in this specification in the singular as "joint J", and in the plural as "joints J".

The male joint Jm has first, second and third male locking surfaces ML1, ML2 and ML3 respectively (referred to in general as "male locking surfaces ML"). Each of the male locking surfaces ML extends continuously in the general direction perpendicular to the major surfaces. Similarly the female joint Jf has first, second and third female locking surfaces FL1, FL2 and FL3 respectively, (referred to in general as "female locking surfaces FL"). The male and female locking surfaces collectively and generally are referred to locking surfaces L.

Each of the locking surfaces L extends continuously in the general direction perpendicular to the major surfaces. The expression "extend continuously in the general direction perpendicular to the major surfaces" in the context of the male and female locking surfaces is intended to denote that the surfaces extend generally between the opposite major surfaces but continuously so that it extends in one direction only, i.e. always in the direction of the surface 14 to the surface 16 or vice versa and thus does not return upon itself as would be the case for example if the surface included a barb or hook like structure.

The male locking surface ML1 extends from an edge of the major surface 14 adjacent the protrusion Pm and down the adjacent side of the protrusion Pm to a point prior to the surface of the protrusion Pm turning through greater than 45° from the perpendicular to the major surface 14. It will be noted that the locking surface ML1 extends continuously in the general direction perpendicular to the major surface 14, without returning upon itself. Thus every point on the surface ML1 lies on a different horizontal plane. In contrast, in the event that a hook or barb like structure were provided then the corresponding surface would turn upon itself and a plane parallel to the major surface 14 would intersect the surface at three different locations.

The male locking surface ML2 extends from the second major surface 16 up along an adjacent side of the recess Rm to a point prior to the deepest portion of the recess Rm turning through more than 45° toward the protrusion Pm. Finally, the third male surface ML3 extends along a shared or common surface between a protrusion Pm and Rm and denoted by end points prior to the surface turning through more than 45° to the perpendicular at the deepest portion of the recess Rm, or the most distant portion of the protrusion Pm.

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As will be explained shortly, the first and second male and female locking surfaces engage about respective locking planes inhibiting vertical separation of engaged joints Jm and Jf. The third male and female locking planes ML3 and FL3 may also be configured to form a third locking plane. Also, the locking surfaces L in various embodiments comprise
 5 inflexion surfaces which in turn may comprise transverse outward extending surfaces which may take the form of convex or cam surfaces, or bulges. The relationship between the locking surfaces L, inflexion surfaces and transverse outward extending surfaces will be apparent in the following description.

Looking at the configuration of the first and second joints Jm and Jf (referred to in
 10 general as “joints J”) more closely, it will be seen that each of these joints is provided with two laterally spaced apart transversely outward extending surfaces or bulges. The transversely extending surfaces bulges may also be considered and termed as “cam surfaces” as they move across and in contact with each other and at times often with a rolling or pivoting action. The transversely extending surfaces are designated as Cm1 and
 15 Cm2 on the first joint Jm and Cf1 and Cf2 on the joint Jf. In many embodiments transversely extending surfaces are smoothly curved convex surfaces. However as will be apparent from the following description in some embodiments the transversely extending surfaces are of other configurations. For example a transversely extending surface may be generally convex in that the surface is not continuously or smoothly curved for its entire length but is
 20 composed of one or more straight/planar surfaces. For ease of reference the transversely extending surfaces on the male joint Jm will be referred to “surface Cmi” where $i = 1, 2, 3$ and similarly the transversely extending surfaces on the female joint Jf will be referred to “surface Cfi” where $i = 1, 2, 3$.

The surface Cm1 is formed on a protrusion Pm of a first joint Jm while the surface
 25 Cm2 is formed in a recess Rm of joint Jm. Similarly the surface Cf2 is formed on a protrusion Pf on the joint Jf while the surface Cf1 is formed in a recess Rf of the second joint Jf. (For ease of description the surfaces Cm2 and Cm1 will be referred to in general as “surface Cm”; surfaces Cf1 and Cf2 will be referred to in general as “surface Cf”; and collectively the surfaces Cm2, Cm1, Cf1 and Cf2 will be referred to in general as “surfaces
 30 C”).

Figure 1b depicts the joints J in an engaged state. As is evident when the joints J are engaged their respective transversely extending surfaces are located relative to each other to form respective first and second locking planes 18 and 20 which inhibit the separation of the engaged joints in a direction opposite the engagement direction D.

Each locking plane 18, 20 lies parallel to the engagement direction D. The
 35 transversely extending surfaces Cm1, Cf1, Cm2, Cf2 associated with each locking plane extend laterally toward each other from opposite sides of the locking plane with the transversely extending surfaces of the second or female joint (i.e. Cf1 and Cf2) overhanging

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the transversely extending surfaces of the first or male joint (i.e. Cm1 and Cm2). This inhibits separation of the engaged joints Jm and Jf. It will also be noted that at least one of the transversely extending surfaces associated with each locking plane has a curved profile. In this instance the surface Cf1 associated with locking plane 18, and both surfaces Cf2 and Cm2 associated with locking plane 20 have curved profiles.

During the engagement of the joints Jm and Jf the surfaces Cm1 and Cm2 pass and snap over the surfaces Cf1 and Cf2. This action is enabled by one or both of resilient compression of the protrusions Pm and Pf and resilient tension in the recesses Rm and Rf as the surfaces Cm pass the surfaces Cf in response to application of the force F. Whether there is one or both of resilient compression of the protrusions Pm and Pf and resilient tension in the recesses Rm and Rf is dependent on the material from which the panel 12 is made. For example in the case of a panel made from a very stiff or hard material such as strand bamboo there would be very little compression of the protrusions P but tension in the recess R which results in its opening or widening would allow for the engagement. The ability for the protrusions P to enter the recesses R is assisted by the provision of a lubricant such as wax on the joints Jm and Jf. The provision of the lubricant and in particular wax also substantially eliminates joint noise and aids in the ability of adjacent engaged joints J to rotate relative to each other. This rotation motion is describe later in the specification.

Horizontal separation between engaged joints Jm and Jf is inhibited by the seating of the protrusions P in the respective recesses R. The joints Jm and Jf are also provided with respective planar abutment surfaces 24 and 26. The surfaces 24 and 26 extend from opposite edges of and perpendicular to the major surface 14. The respective surfaces Cm and Cf are configured to create lateral compression forces between the surfaces 24 and 26 maintaining them in contact thus preventing the creation of a gap between joined panels 12a and 12b.

Accordingly as described above, the surfaces Cm and Cf co-operate to provide both vertical and horizontal arrestment of panels 12a and 12b when the respective joints Jm and Jf are engaged. However in addition to this the surfaces Cm and Cf enable limited relative rotation between panels 12a and 12b while maintaining engagement of the panels 12. This is depicted in Figures 3a and 3b.

Figure 3a shows the panel 12a being rotated by +3° (3° in an anticlockwise direction) relative to the panel 12b. The rotation is facilitated by pivoting at an upper corner of surface 24 on surface 26. This rotates the protrusion Pm within recess Rf and causes the surface cam Cm2 to ride or roll up, but not past the apex of, the surface Cf2. The projection Pf is now effectively pinched between the surfaces Cm2 and Cm3. In this configuration vertical separation between the substrates 12a and 12b is inhibited by this pinching effect as well as due to the surface Cm1 remaining below surface Cf1. Horizontal arrestment is

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maintained by virtue of the projections Pm and Pf remaining within respective recesses Rm and Rf.

With reference to Figure 3b, the panel 12a is rotated by -3° (3° in a clockwise direction) relative to panel 12b. This is facilitated by the surface Cm2 rolling down and acting
 5 as a pivot or fulcrum point against the side of Joint Jf containing the surface Cm2. This causes separation of the surfaces 24 and 26 creating a gap at the upper major surfaces 14. Nevertheless the panels 12a and 12b remain vertically and horizontally engaged. Vertical arrestment between the substrates is maintained by engagement of the surfaces Cm2 and Cf2; and surfaces Cm1 and Cf1. Horizontal arrestment is provided by the projections Pm
 10 and Pf being maintained in their recess Rf and Rm.

The relative rotation between the panel 12a and 12b is of great assistance in the installation of the substrates particularly on uneven surfaces such as an undulating concrete floor. This is of great importance to the “do-it-yourself” user although benefits also flow
 15 through to the professional layer. Consider for example an uneven undulating surface on which it is desired to lay a click type floor covering having say a prior art joint system where the tongue is inserted laterally or at an inclined angle into a groove or recess. The undulation may be in the form of a concave recess or shallow in a portion of the surface having a width several times greater than the width of the panels. Depending on the degree or slope of the concavity it may be extremely difficult if not impossible to insert a tongue of a
 20 “to be” installed panel into the groove of a previously laid panel. This arises because the two panels do not and will not lie in the same plane, but rather are angled relative to each other due to the concavity.

Additionally, when installing floor boards of a length of about 1m or longer on an uneven surface, banana-ing or lateral bowing occurs of the previously installed floor board
 25 by virtue of an installer kneeling on it when trying to lay the next floor board. The kneeled on board will bow under the weight of the installer due to the uneven underlying surface. This effect is depicted in Figures 4a to 4d. Figures 4a and 4b show lateral bowing of a panel 12x outwardly when the uneven surface is a fall or hollow. Figures 4c and 4d show lateral inward bowing of a panel 12x when the uneven surface is a hump. It will be appreciated that
 30 this bowing makes it very difficult to get full longitudinal engagement with an adjacent panel without gapping. In these circumstances, even professional installers have difficulty in laying the floor and will need to rely on substantial physical exertion and experience. The do-it-yourself installer will often give up and either returns the flooring to the retailer on the basis that it does not “click” together or end up paying for a profession installer.

35 To provide perspective of the effect of the relative rotation capabilities of the joint system 10 in comparison to the prior art reference made to Figures 4e to 4h. Conventional flooring systems are able to accommodate a concavity or a hump in an underlying substrate for example a concrete floor of 3 – 5mm over a length of 1m, being the industry standard.

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Undulations greater than this either prohibit the use of many prior art systems or at least make them very difficult to install. Assuming that they can be installed the undulation can subsequently cause prior art joint systems to disengage horizontally and thus gap excessively. Specifically in the event that the undulation is in the form of a hump or
 5 undulation there is the possibility of either total horizontal separation between the adjacent panels and/or splitting or shearing of the joints. In the event that the undulation is a concavity prior art joints are liable to shear or break due to excessive tensile force being applied to the joints.

In Figures 4e to 4h (which are schematic only and not drawn to scale) the 3 – 5mm
 10 surface undulation which can be accommodated by the prior art system is shown as shaded area 30. Figures 4e and 4f represent an undulation in the form of a rise or hump of 3-5mm, whereas Figures 4g and 4h represent an undulation in the form of a fall or hollow of 3-5mm. In comparison the + or – 3° rotation available by embodiments of the joint system 10 over a 1m length provide a total possible displacement of 52mm. The +3° rotation is illustrated in
 15 Figures 4e and 4f, while the – 3° rotation is illustrated in Figures 4g and 4h. This enables substrates utilising embodiments of the joint system 10 to be successfully laid on floors without horizontal disengagement or separation where the floor may have for example a concave undulation which over a distance of one metre drops by 52mm below adjacent planar surface portion of the floor. Maintaining horizontal engagement maintains the
 20 structural integrity of the floor. This is beneficial in terms of the appearance of the floor which in turn can add value to an associated house.

It will be recognised by those skilled in the art that this enables the laying of a flooring system incorporating the embodiments of the current joint system on substrates that fall outside of 3 – 5mm undulation over a length of 1m dictated by the world industry
 25 standards. This has significant practical and commercial benefits. The practical benefits are that the flooring will be able to be successfully and easily laid by do-it –yourself installers and professional installer on substrates that hitherto were unsuitable for conventional click type flooring. The commercial benefit is that because the flooring systems can be laid they are not returned to the point of sale by disgruntled and frustrated installers requesting a refund
 30 for a system that, in their eye, does not work. The conventional systems will work if the substrate is within the narrow band prescribed as the world industry standard. But the installer is usually unaware of the standard and in any event has not idea as to whether or not their substrate complies. This is not an issue with embodiments of the present invention as it is able to be installed without separation on substrates that fall outside of the world
 35 industry standards.

Returning to Figures 1 and 2, it can be seen that the surfaces Cm and Cf constitute portions of respective inflexion surfaces, which in turn form portions of respective locking surfaces L. Specifically, the surface Cm1 constitutes a part of an inflexion surface Im1

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(indicated by a phantom line) which in turn forms part of first male locking surface ML1 (indicated by broken dot line) of the protrusion Pm. The inflexion surface Im1 extends generally in the direction D from the abutment surface 24.

Similarly surface Cm2 constitutes a portion of inflexion surface Im2 (indicated by a phantom line) which in turn forms part of second male locking surface ML2 (indicated by broken dot line). Surface ML2 is formed on the surface of recess Rm and depends generally in the direction D from near a root 32 of the recess Rm.

The surface Cf2 constitutes part of an inflexion surface If2 (indicated by a phantom line) which in turn forms part of second female locking surface FL2 (indicated by broken dot line) formed on an outer most side of the projection Pf and extending generally in the direction parallel to the direction D.

The surface Cf1 constitutes part of the inflexion surface If1 (indicated by a phantom line) which in turn forms part of first female locking surface FL1 (indicated by broken dot line). Surface FL1 depends from abutment surface 26 and in a direction generally parallel to direction D and toward a root 34 of the recess Rf.

Looking at Figure 1b, it will be seen that the surfaces Cm1, Im1 and ML1 engage the surfaces Cf1, If1 and FL1 respectively; and the surfaces Cm2, Im2 and ML2 engage the surfaces Cf2, If2 and FL2 when the joints Jm and Jf are engaged. The engagement of these surfaces forms or create the first and second locking planes 18, 20. Different portions of the locking L, inflexion I and transversely extending surfaces C operate as arresting and rolling surfaces during various stages of engaging and disengaging of the joints Jm and Jf.

To provide the rolling action between adjacent engaged substrates at least one of the surfaces C and indeed one of inflexion surfaces I in each pair of engaged or related surfaces is formed with a profile of a continuous or smooth curve. For example consider the surfaces Cm1 and Cf1 and corresponding inflexion surfaces Im1 and If1. When the joints Jm and Jf are engaged, surfaces Cm1 and Cf1 are located about or adjacent the first locking plane 18; as are corresponding inflexion surfaces Im1 and If1. In this instance the surface Cf1 and the corresponding inflexion surface If1 has a profile of a continuous or smooth curve. However the surface Cm1 and corresponding inflexion surface Im1 has a profile which comprises a straight line 36. The straight line is relatively short and forms a small ridge or peak 38 on the surface Cm1 and inflexion surfaces Im1. The ridge 38 presents a relatively small contact area against the inflexion surface If1 minimising the friction between the surfaces and the possibility of sticking during relative rotational motion.

In contrast, the surfaces Cm2 and Cf2; and corresponding inflexion surfaces Im2 and If2 which are located about and form the second locking plane 20 each have a profile of a continuous curve. However other embodiments will be described later in which one of the surfaces Cm2/Im2 or Cf2/If2 has a profile comprising one or more straight lines.

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The first and second male locking surfaces ML1 and ML2, and indeed the associated surfaces Cm1 and Cm2 and corresponding inflexion surfaces Im1 and Im2 constitute the extreme (i.e. inner most and outer most) transversely extending and inflexion surfaces of the first (male) joint Jm. The first and second female locking surfaces FL1 and FL2, and indeed the associated surfaces Cf1 and Cf2 and inflexion surfaces If1 and If2 constitute the extreme transversely extending and inflexion surfaces of the second (female) joint Jf. These extreme transversely extending and inflexion surfaces form respective surface pairs which create the extreme (i.e. inner most and outer most) locking planes 18 and 20 in mutually engaged joints Jm and Jf. This is clearly evident from Figure 1b. Specifically the surface pairs are in this embodiment: Im1 and If1, or Cm1 and Cf1; and, Im2 and If2, or Cm2 and Cf2. The above described relative rotation between panels incorporating embodiments of the joint system 10 is facilitated by forming one surface in each of the surface pairs as a smoothly or continuously curved surface.

The surfaces Cm1 and Im1 form part of an outer peripheral surface 40 of the protrusion Pm. The protrusion Pm has a generally ball like or bulbous profile which depends in the direction D from major surface 14. The outer surface 40 after the inflexion surface Im1 curves toward the recess Rm. The surface 40 is provided with a recess 42 at a location most distant the major surface 14. As shown in Figure 1b, when the joints Jm and Jf are engaged the recess 42 forms a reservoir 44 against a lower most portion of surface 46 of the recess Rf. Save for the recess 42 the end of the protrusion Pm facing the bottom of recess Rf1 is rounded or curved. The first male locking surface ML1 comprises the combination of surface 24 and the inflexion surface Im1.

The recess 42 and corresponding reservoir 44 may be used for various different purposes. These include but are not limited to receiving adhesive and/or sealing compound; acting as a reservoir for debris which may have fallen into the recess Rf during installation, or both.. In this regard the recess 42 faces a lowest part of the surface 46 in the recess Rf. It is expected that most debris falling into the recess Rf will collect at the lowest point on the surface 46. As the joints Jm and Jf are engaged by a vertical motion a substantial proportion of any debris is likely to be captured in the subsequently created reservoir 44. In the absence of such a feature, it may be necessary to clean the recess Rf for example by blowing with compressed air, use of a vacuum or a broom to remove debris which may otherwise interfere with the engagement process. The recess 42/reservoir 44 can also accommodate expansion and contraction in the joints J.

The surface 40 after the recess 42 curves around to the recess Rm and incorporates a further inflexion surface Im3. The inflexion surface Im3 is a "shared" surface between the protrusion Pm and recess Rm and includes a surface Cm3. The surface Cm3 transitions the surface 40 from a generally horizontal disposition to a generally vertical

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disposition. The third male locking surface ML3 is substantially co-extensive with the inflexion surface Im3.

It will be noted that the protrusion Pm is formed with a neck 48 having a reduced width in comparison to other portions of the protrusion Pm. It will be seen that the surface Cm1 is adjacent an outer most side of the neck 48. Moreover, a portion of the inflexion surface Im1 adjacent the abutment surface 24 forms the outer most side of the neck 48. Further, a portion of the inflexion surface Im3 forms the opposite side of neck 48. In this embodiment a line 50 of shortest distance across the neck 48 is inclined relative to the major surface 14.

The inflexion surface Im3 leads to surface 52 formed in the root 32 of the recess Rm. The surface 52 curves around to meet with and join inflexion surface Im2. The surface Im2 extends generally in the direction D leading to a surface 54 which extends perpendicular to the major surfaces 14 and 16 and subsequently to a bevelled surface 56 which leads to the major surface 16. The second male locking surface extends from above the inflexion surface Im2 and along the bevelled surface 56 to the major surface 16.

Looking at the configuration of the joint Jf on an opposite side of panel 12, it can be seen that the surface Cf1 and corresponding inflexion surface If1 extend generally in the direction D from the abutment surface 26. The first female locking surface FL1 comprises the combination of surfaces 26 and If1. The inflexion surface If1 leads to the surface 46 at the root 34 of recess Rf. The surface 46 forms a vertical arrestment surface for the protrusion Pm. Moreover the surface 46 includes a centrally located substantially horizontal land 58 which faces the recess 42 when the joint Jm is inserted in the joint Jf. The land 58 lies substantially parallel to the major surfaces 14 and 16. Moving in a direction toward the protrusion Pf, the surface 46 leads to and incorporates a further inflexion surface If3 and corresponding co-extensive third female locking surface FL3. The surfaces If3 and FL3 are shared surfaces between recess Rf and protrusion Pf and extends in a direction generally opposite the direction D.

The inflexion surface If3 leads to an upper arcuate surface portion 60 of the projection Pf which in turn leads to the surface Cf2 and inflexion surface If2. The inflexion surface If2 leads to the planar surface 62 that extends perpendicular to the major surfaces 14 and 16. This surface in turn leads to inclined surface 64 in turn leads to the major surface 16. The second female locking surface comprises the combination of surfaces If2, 62 and 64.

The recess Rf is configured to receive the protrusion Pm. Moreover, the recess Rf is formed with a neck 66. The neck forms a restricted opening into the recess Rf. A line 68 of shortest distance across the neck 66 is in this embodiment inclined relative to the major surfaces 14 and 16. More particularly, the line 66 is inclined at substantially the same angle as the line 50.

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The protrusion Pf like protrusion Pm is of a ball like or bulbous configuration. Further, similar to the protrusion Pm, the protrusion Pf is formed with a neck 70 of reduced width. A line 72 of shortest distance across the neck 70 is inclined to the major surfaces 14 and 16. However in this embodiment the line 70 is inclined at a different angle to the lines
 5 50 and 68.

With reference again to Figure 1b, it is also seen that the shared locking and inflexion surfaces ML3 and FL3; and Im3 and If3 respectively, and indeed their corresponding surfaces Cm3 and Cf3 are located relative to each other to form a third locking plane 74 along which separation of the engaged joints J is inhibited. The third
 10 locking plane 74 is parallel with and between the inner and outer most locking planes 18 and 20.

The joints Jm and Jf are based in part on anatomical joints of the human body and in particular the hip joint and shoulder joint. These joints Jm and Jf are designed to provide horizontal and vertical strength and allow relative rotational motion to a limited extent without
 15 disengagement. In effect the joints Jm and Jf can be considered as ball and socket type joints. The comparison with anatomical joints is enhanced in some embodiments described hereinafter which include a re-stickable flexible, elastic and non curing or non-solidifying adhesive acting between the joints Jm and Jf. In such embodiments the adhesive acts in a manner akin to both a tendon allowing relative motion but maintaining connection, and as
 20 cartilage providing a cushioning effect. Also when wax is provided on the joints can act as a fluid in the joint providing lubrication.

It is further evident from Figure 1b that due to their non-symmetrical nature the joints Jm and Jf are relatively configured so that when they are engaged several spaces or gaps are formed between the engaged joints. A space 76 is formed immediately below the
 25 abutment surfaces 24 and 26 and opposite the surface Cf1. The space 76 may also be described as being a space formed between respective upper portions of the inflexion surfaces Im1 and If1. Space 78 is formed between lower parts of inflexion surfaces Im1 and If1. A generally vertically extending space 80 is formed between the shared inflexion surfaces Im3 and If3; and a generally horizontal space 82 is formed between the root 32 of
 30 recess Rm and arcuate surface portion 60 of the projection Pf. The spaces allow thermal expansion and contraction of the panels 12 without dislocation or fracturing of the joints Jm and Jf as well as assisting in the relative rotation of the panels 12.

The engagement and disengagement of the joints Jm and Jf will now be described in detail with reference to Figures 5a – 9f.

35 Figure 5a depicts a first panel 12a which has already been laid and a second panel 12b which is in the process of being laid. The panels 12a and 12b are supported on an underlying horizontal surface 90. Panel 12a has a joint Jf which is open and ready for connection with the joint Jm of panel 12b. Panel 12b is laid adjacent panel 12a with the joint

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Jm resting on the joint Jf. The edge of panel 12b provided with the joint Jf is simply resting on the surface 90 so that there is a small angle of approximately 1°-3° between the panels 12a and 12b.

From Figure 5b it will be seen that in this position surfaces Cm1 and Cm3 rest on the surfaces Cf1 and Cf3 respectively while the surfaces Cm2 and Cf2 are vertically separated. In this configuration upper portions of the surfaces Cf1 and Cf3 may be considered as cam arresters in that they prohibit the entry of the projection Pm into the recess Rf.

In order to commence engagement of the surfaces Jm and Jf a downward pressure or force F is applied in the direction perpendicular to the major surfaces 14 and directed toward the underlying surface 90. This pressure or force applies compression to the protrusion Pm and tension the recess Rf which depending on the material from which the panels 12 are made will result in one or both of the protrusion Pm compressing and the recess Rf opening or widening so that the surfaces Cm1 and Cm3 can slide past the surfaces Cf1 and Cf3. Again the provision of wax on the joints Jm and Jf assist this sliding action. This results in the protrusion Pm sliding through the neck 66 into recess Rf. The opening the recesses Rm and Rf generates stress in the joints shown by lines T in Figure 5c. This stress is about the curvature at opposite ends of the root of each recess Rf and Rm. The stress is released as the protrusions Pm and Pf pass through the necks of the recesses Rf and Rm providing a spring action closing the recesses onto the protrusions and drawing the protrusions into the recesses. Thus the recesses are able to elastically open and subsequently self close. This action occurs with the other embodiments of the joint system described later in the specification.

The joints in this embodiment are configured so that the respective surfaces Cm and Cf which pass each other do so at slightly different times. In this particular embodiment the surface Cm1 passes the surface Cf1 marginally before the surface Cm3 passes the surface Cf3. Once the surfaces Cm1, Cm3 pass surfaces Cf1, Cf3 the remainder of protrusion Pm is drawn into the recess Rf by an over centre or snap action. This is due to the relative configuration of the inflexion surfaces and the release of compression in the protrusion Pm after the surfaces Cm1 and Cm3 pass through the surfaces Cf1 and Cf3. In effect the respective necks 48 and 66 lay one within the other.

Simultaneously with this action occurring, a similar action is occurring in relation to the protrusion Pf and the recess Rm. The surface Cm2 passes the surface Cf2 marginally after passing of the surfaces Cm3 and Cf3. This is depicted in Figure 5c. As the recess Rm is pushed onto the protrusion Pf, by action of the downward pressure or force F, the protrusion Pf is compressed between the surfaces Cf3 and Cf2. After these surfaces pass the surfaces Cm3 and Cm2 the recess Rf is drawn onto the protrusion Pf by an over centre or snap action.

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While the joints J are engaged by application of pressure or force in a vertical direction (i.e. perpendicular the major surfaces 14, 16) the relative motion between the joints J is not solely vertical. Rather there is a combined vertical motion with lateral displacement. With reference to Figures 5b-5e and the joint Jm, this lateral motion is motion of the joint Jm
 5 is to the left and is highlighted by the closing in the horizontal gap or separation G of the surface 24 and 26 during the engagement process. The horizontal gap G reduces from a maximum gap G1 in Figure 5b to progressively smaller gaps G2 and G3 and finally to a zero gap G4 in figure 5e in which case there is face to face contact between surfaces 24 and 26, when the joints Jm and Jf are fully engaged. Which of the joints Jm and Jf laterally move is
 10 just dependant on which one is least constrained from lateral motion. Indeed both could move laterally toward each other to equal or different degree. This lateral motion is symptomatic of the vertical stability of the engaged joint system

Figure 5d illustrates the joints Jm and Jf marginally before full engagement. Here it can be seen that there is a small gap between the bottom of projection Pm and the recess
 15 Rf and that the major surface 14 of panel 12b is marginally raised relative to the major surface 14 on the panel 12a. The relative downward motion of the panel 12b is halted and the joint fully engaged when the projection Pm hits the arrestment surface 58 on the recess Rf, as shown in Figure 5e. In this configuration the reservoir 46 is formed between the recess 42 and the arrestment surface 58. In this configuration the surfaces Cm1, Cm2, Cm3
 20 on the male joint Jm lay underneath the corresponding surfaces Cf1, Cf2, Cf3 on the female joint.

The aforementioned mentioned ability for the joints Jm and Jf to enable both positive and negative relative rotation without disengagement is able to accommodate for uneven surfaces. Additionally the joints Jm and Jf facilitate self alignment of adjacent panels
 25 12. These features substantially simplify the installation to the extent that a very average home handyperson can easily install panel incorporating embodiments of the joint system 10.

The self aligning aspect of the system 10 arises from the shape and configuration of the joints Jf and Jm and is explained with reference to Figures 5b, and 5f – 5k.

30 Figure 5f shows a panel 12b being roughly positioned for subsequent engagement with panel 12a and prior to the application of any downward force or pressure to engage the panels. The panels 12a and 12b are skewed relative to each other. At one end 85 the protrusion Pm sits on top of recess Rf. The corresponding view in cross section is as shown in Figures 5b and 5j with the joint Jm of panel 12b lying on top of the recess Rf of panel 12a.
 35 At the opposite end 87 the joints are laterally spaced apart. In between, the degree of separation between joints Jm and Jf varies linearly. So at location AA joints Jm and Jf are in contact but protrusion Pm partially rests on protrusion Pf and partially overlies recess Rf and the panels separated by a distance X1 shown in Figure 5i. While at a further location BB

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along the panels the protrusion Pm lies directly above and on protrusion Pf and the panels are separated by a larger distance X2 shown in Figure 5h.

Now a downward pressure or force F is applied at a location between locations 85 and BB to commence engaging the joints and panels. This force is transmitted between the panels for the length along which they are in contact, i.e. essentially between locations 85 and BB. At most points along this length the protrusion Pf is to the left of the apex of protrusion Pf and at least partially overhanging the recess Rf. Also it will be recognised that due to the curvature of surfaces Cm3 and Cf3 there will be a natural tendency for the protrusion Pf to be drawn into the recess Rf.

Consequently the force F when transmitted to the contacting surfaces of joints Jm and Jf will initially resolve into components which include a lateral (transverse) component acting to urge the joint Jf into the recess and thus the panel 12b toward the panel 12a. Accordingly the distance between the panels at end 87 closes. As the location of the application of the force is advanced along the panel 12b toward end 87 the this closing effect continues until the at end 87 the protrusion Pm sits above the recess Rf as shown in Figure 5j and the panels are fully aligned as shown in Figure 5k. Thus the panels self align under application of the downward engaging force. Naturally if the force F is sufficient then in addition to the self alignment, the joints Jm and Jf will also fully engage as shown in Figure 5k. The self aligning effect combined with the engagement of the joints Jm and Jf produces a zipper like effect akin to a snap lock bag.

It should also be understood that floors are often under dynamic tensile and compressive load due to variations in temperature and humidity. They are also under static load from furniture or other household items. Should the tensile load exceed the load carrying capacity of the joints one or both of the protrusions Pm and Pf may fracture or shear. This has several effects. It will release tension in the immediate vicinity of the floor. In addition it will result in a horizontal separation along the fractured panel producing a visible gap. Further depending on the prevailing conditions and circumstance there may also be a vertical displacement of one of the adjacent panels resulting in a height difference.

Once this tension has been released it can be extremely difficult if not virtually impossible to reconnect the disengaged panel or fully connect a new panel. This is because the panels on opposite sides of the fracture, which are still under tension, are being pulled and will move away from each other. To reinstate the floor to its original state one must pull the two sides together. If one merely places a new panel in the space of the previous panel then the gap will remain. This leaves the home owner with the only option of using unsightly filler to make good the gap caused by the separation. This in turn is likely to have a negative impact on the value of the home. The self aligning aspect of the joint system 10 also facilitates the self re-tensioning of say a floor upon replacement of damaged panels as described below.

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The release in tension, subsequent movement of panels and self re-tensioning is described in greater detail in Figures 5l – 5u. Figure 5l illustrates a floor composed of plurality of panels 12. Two of the panels 12a and 12b are being removed and replaced. Assume that there is tension between the panels 12 as described in the preceding paragraph. Once the two panels 12a and 12b are removed leaving a gap 31 there is naturally a release of tension in the floor in the area of the gap 31. Consequently, panels 12 adjacent the gap will shift away from each other as shown by the arrows 33 in Figure 5m. The effect of this is to produce a widening of the gap 31. This widening is illustrated in Figure 5n, and in enlarged view in Figure 5o, and occurs as an additional longitudinal band 35 along a line of abutment which previously existed between panels 12a and 12b prior to their removal. This widening does not only occur within the gap 31. There will also be a separation or at least an increase in tension between remaining adjacent panels along a continuation of the band 35 as there are now fewer panels to accommodate the tension. Figure 5p and corresponding enlarged view of Figure 5q illustrate the effect of replacing the panels with panels having conventional lay down or horizontal locking systems. New panels 12a1 and 12b1 are inserted into the gap 31 and engaged with adjacent panels on either side. However due to the widening of the gap 31, the new installed panels 12a1 and 12b1 cannot be fully engaged with each other. The widening may only be in the order of 0.5 to 2mm but this is sufficient to be easily visible on a floor.

Ordinarily, in the case for example of a tongue and groove type locking system, the tongue will have been sawn off so that there is no mechanical joining between the panels 12a1 and 12b1. A filler will be used to fill the band 35 between the panels 12a1 and 12b1. Significantly the filler is unable to transfer tension across the panels 12a1 and 12b1. Consequently, it is not possible to reinstate the tension within the floor as a whole. Now tension within the floor will act on opposite sides of the filler and the band 35. In time this is likely to lead to the fracturing of the filler and the creation of a new gap 37 shown in Figure 5r and corresponding enlarged view Figure 5s between the panels 12a1 and 12b1.

Figure 5t and enlarged view Figure 5u shows the result in using panels or substrates incorporating joint systems in accordance with embodiments of the present invention. That is assume all of the panels 12 in Figs 5l-5s are provided with say joint system 10. When panels 12a and 12b are removed there is still a widening of gap 31 by creation of band 35. New panel 12a1 is installed and engaged with panels 12c and 12d. Now panel 12b1 is inserted with say its female joint Jf beneath the male joint Jm of panel 12a1 and the male joint Jm of panel 12b1 lying on top of the female joint Jf of adjacent panels 12e and 12f.

Applying downward pressure on the male joint of panel 12a1 where it overlies joint Jf of panel 12b1. This results in these joints and corresponding panels engaging. This will cause a slight motion of the panel 12b1 away from panels 12e and 12f. However this motion

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does not cause a separation greater than the distance X2 shown in Figure 5h. By now applying downward pressure on the male joint Jm of panel 12b1, the panels 12b1 and 12e and 12f are pulled toward each other. Moreover the panels on either side of an interface 39 between panels 12a1 and 12b1 are pulled inwardly toward each other as shown by the
 5 arrows 33 in Figures 5t and 5u. Further the joints Jm and Jf of panels 12b1; and, 12e and 12f are engaged and the entirety of the floor thus re-tensioned and structural integrity re-instated. .

The above describes the situation where the floor is under tension. But equally problems arise in prior art systems when a floor is under compression in which case there
 10 can be a closing in the gap 31. With the prior art systems one must cut the panels to reduce their width to fit in the closed gap. Consequently there will be no full mechanical joint between the newly installed panels and the existing panels. The structural integrity is lost. Embodiments of the present invention can operate in essentially the same manner as described above with reference to Figures 5l-5u but in "reverse" to push the gap open and
 15 mechanically engage all adjacent panels 12 to reinstate full structural integrity. Again this will be effective for gap of up to about the lateral extend of surface Cf1 which may range to about 2mm.

The above self aligning and "zipper" effects also apply when a panel is warped or twisted about its length. . Embodiments of the joint system enable a warped panel to be
 20 aligned and pulled in having the effect of flattening the warp or twist in the panel provided the panel to which it is being engaged is flat and not itself warped or twisted.

When engaging the joints Jm and Jf downward pressure can be applied by a person of a weight of about 70 kilograms or more traversing the joints Jm a small hopping or one legged jumping or small stomping motion. In this way joining of adjacent panels 12 can
 25 be achieved without the need to constantly kneel and stand as is required with prior art systems. The engagement of joint Jm into joint Jf may also be aided by light tapping with a rubber mallet M. The ease of installation not only widely expands the range of do-it-yourself installers by reducing the skill and strength level required it also has significant benefits to all installer including professionals by way of minimising physical stress and exertion. For an
 30 employer or installation company this reduces injury and sick leave to workers. Consequently workers are able to work longer and have increased income and insurance premiums for and compensation claims against the employer can be reduced.

When panels 12 with the joint system 10 are used in large area such as for example in commercial premises a modified compactor can be used to apply the force or pressure to
 35 engage the joints Jm and Jf. The compactor is envisaged as being in the form similar to those used for compacting sand prior to laying pavers, but having a soft smooth non scratch base lining. The lining may comprise but is not limited to a rubber, foam, felt, or cardboard sheet.

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The process of removal of a damaged panel will now be described with particular reference to Figures 6a – 9f. As will become evident from the following description the removal process of a damaged panel relies on the relative rotation enabled between the joined panels by virtue of the configuration of the joint system 10. Figures 6a – 6s depict in sequence various steps in the removal and replacement of a damaged panel. The removal and replacement is facilitated by use of an extraction system which comprises in combination a jack 92 shown in Figures 7a and 7b and a wedge tool 94 shown in Figures 8a and 8b.

The jack 92 is a simple hand screw jack which is applied to a panel being removed. The screw jack 92 is provided with an elongated threaded shaft 96 provided at one end with a cross bar handle 98. The thread of the shank 96 is engaged within a threaded boss 100 formed on a clamp plate 102. The plate 102 is of a square shape with the boss 100 located centrally in the plate 102. The boss 100 overlies a through hole in the plate 102 through which the shaft 96 can extend. Distributed about the plate 102 are four through holes 104 for receiving respective fastening screws 106.

The wedge tool 94 comprises a wedging block 108 coupled at one end to a handle 110. The wedging block 108 is formed with a base surface 112 which in use will bear against a surface on which the panels 12 are installed, and an opposite surface 114 which lies beneath and contacts a major surface 16 of the panel 12 adjacent the panel being removed. The surface 114 includes the relatively inclined portion 116 and a parallel land 118. The inclined portion 116 extends from a leading edge 120 of the wedge block 108 toward the handle 110. The surface 116 is inclined relative to the surface 112, while land 118 lies parallel to the surface 112 and is formed contiguously with the surface 116. The handle 110 is bent so that a free end 122 of the handle 110 lies parallel with but laterally displaced from a distal end 124 which is connected with the wedge block 108.

Figure 6a depicts an area of flooring including a damaged panel 12b which is connected along each side with adjacent panels 12. For the purpose of describing the method of replacing the damaged panel 12b reference will be made only to two of the connected panels 12a and 12c which engage along opposite longitudinal sides of the panel 12b. The three side by side interlocked panels 12a, 12b and 12c are each provided with an embodiment of the joint system 10 and cover a surface 90 as shown in Figure 6b. The central panel 12b has a major surface 14 which is damaged by virtue of a scratch, gash or water damage 126. It should also be understood that unless one of panels 12a or 12c is immediately adjacent a wall then other panels 12 will be interlocked with each of panels 12a and 12c.

In order to replace the damaged panel 12b, a drill 130 (see Figure 6d) is used to drill a hole 128 through the panel 12b for each jack 92 used in the extraction process. The hole 128 is formed of a diameter sufficient to enable the passage of shank 96. The length of

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the panel 12b being removed dictates the number of jacks 92 that may be required. Thus in some instances, extraction can be effected by the use of one jack 92 whereas others may require two or more jacks. In this particular instance two jacks 92 are used as shown in Figure 6c, but for ease of description the extraction process refers to only one of the jacks

5 92.

Upon completion of the hole 128, the clamp plate 102 is placed on the panel 12b with its boss 100 overlying the hole 128 as shown in Figure 6e. The plate 102 is fixed to the panel 12b by way of the four self tapping screws 106 that pass through corresponding holes 104. This is illustrated in Figure 6f. The screws may be screwed in by a DIY battery

10 operated screw driver or using a manual screwdriver.

The next stage in the removal process is shown in Figures 6g and 6h involves engaging the shank 96 with the threaded boss 100 and then screwing down the shaft 96 by use of the handle 98 to lift the panel 12b above the surface 90. It should be immediately recognised that this action requires the relative rotation of the joints Jm and Jf of panel 12b

15 while maintaining their engagement with the joints of adjacent panels 12a and 12c. This rotation is a relative negative rotation as will be explained shortly. However simultaneously there is also a positive rotation of the joints between the panels engaged on either side of panels 12a and 12c opposite the panel 12b.

The jack 92 is operated to lift the damaged panel 12b vertically upward by a

20 distance sufficient to effect a negative rotation between the damaged panel 12b and the adjacent adjoining panels 12a and 12c. The negative rotation is in the order of $7^{\circ} - 10^{\circ}$. This is explained with particular reference to Figure 6h which shows an angle θ_1 between the major surfaces 14 of panels 12a and 12b; and an angle θ_2 between major surfaces 14 of panels 12b and 12c. Prior to lifting of the panel 12d, it should be understood that the angles

25 θ_1 and θ_2 will be 180° assuming that the surface 90 is flat. Formation of a negative angle between adjoined panels 12 is indicative of the angle θ_1 exceeding 180° . The amount by which the angles θ_1 and θ_2 exceed 180° during the disengagement is equated to the negative rotation of the panels during this process. For example if angle θ_1 is say 187° then the relative negative rotation between panels 12a and 12b is 7° .

It will be understood by those skilled in the art that vertically raising of any prior art system having a lateral projection (e.g. a tongue) that seats in a groove or recess of an adjacent panel is virtually impossible without breaking the tongue or fracturing the panel with the groove. Thus this action if attempted with a prior art system is very likely to result in the damaging of one more panels which were not previously damaged or in need of

30 replacement.

The ability for the panels incorporating embodiments of the present joint system to be removed by vertical lifting is a direct result and consequence of the joint system. This provides a lay-down disengagement process of panels being directly opposite to the prior

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art which requires a lay-up disengagement process. As a consequence of the joint system and the ability to disengage without damaging adjacent panels by vertical lifting, repair of a floor can be achieved in a world's best practice manner fully reinstating the integrity of the floor without the need to peel back the entire floor from one wall to the damaged area,
 5 and/or engaging a professional installer.

The jack 92 mechanically lifts and self supports the panel 12b, panels 12a, 12c and panels adjacent to panels 12a and 12c. Thus the installer does not need to rely on their own strength to lift and hold the panels. In contrast some prior art systems use suction cups for example as used by glaziers to hold glass sheets to grip a panel to be removed. The
 10 installer must then use their strength to lift the panel. While this is difficult enough it becomes impossible if the panel is also glued to the surface 90. The jack 92 which provides a mechanical advantage is able to operate in these circumstances. In addition as the jack self supports the panels 12 the installer is free to use both hands in the repair process and indeed is free to walk away from the immediate vicinity of the panel 12b.

The jack 92 is operated to lift the panel 12b vertically upwards to a location where the negative rotation between the panel 12b and adjacent panels 12a and 12c is in the order of 7° to 10° . This is the position shown in Figure 6h and 9d. In this position, there is partial dislocation of the joints Jm and Jf between panels 12a and 12b. This partial dislocation arises from the surface Cm1 rolling over surface Cf1 with the surface 38 snapping past the
 20 apex of surface Cf1 and is denoted by an audible "clunk". Notwithstanding this dislocation the panels remain engaged due to the pinching of protrusion Pf between surfaces Cm2 and Cm3.

The jack 92 can be provided with a scale to give an installer an indication of the when the negative rotation is in the order of 7° to 10° . The scale could comprise for example
 25 a coloured band on the shank 96 which becomes visible above the boss 100 when shank has been screwed down to lift the panel sufficiently to create the above mentioned negative rotation. Several bands could be provided on the shank for panels of different thickness.

In order disengage panel 12b one must first disengage whichever of the panels 12a or 12c has its female joint Jf engaged with panel 12b. In this instance this is panel 12a.
 30 Working above the panels 12 an installer will not immediately know that it is panel 12a. But this can be easily determined by either: lightly tapping on both panels 12a and 12c; or, applying light hand pressure and feeling for joint movement. Due to the orientation of the joints this tapping will result in panel 12a fully disengaging in the vicinity of the tapping. Thereafter as shown in Figure 6i, applying a downward force or pressure on the panel 12a at
 35 other locations along its length will result in a total disengagement of joints Jm and Jf on the panels 12a and 12b.

The interaction between the respective surfaces on the joints Jm and Jf on the panels 12a and 12b from the position where the panels are fully engaged and lie on the

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same plane as shown in Figure 6f to the point of disengagement shown in Figure 6h will be described in more detail with reference to Figures 9a – 9e.

Figure 9a illustrates the panels 12a and 12b prior to operation of the jack 92. This equates the relative juxtaposition of the panels shown in Figures 6a, 6b, and 6d-6g. As the
 5 jack 92 is operated to progressively lift the panel 12b from the surface 90, there is a gradual rotation between the respective joints Jm and Jf. Figure 9b illustrates the joint Jm of panel 12b and joint Jf of panel 12a at relative rotation of approximately -2° . Here the abutment surfaces 24 and 26 commence to separate with the surface Cm1 and in particular the ridge 38 commencing to ride up the surface Cf1. Simultaneously the surface 40 of projection Pm
 10 commences to lift from the surface 46 of recess Rf. There is also now a slight increase in the separation between upper portions of inflexion surfaces and Im3 and If3. Finally, the surface Cm2 rides down the surface Cf2.

Figure 9c shows the effect of continued lifting of the panel 9b to a position where the relative negative rotation between the panels 12a and 12b is about 5° . Here the
 15 separation between abutment surfaces 24 and 26 is more pronounced and the surface Cm1 and in particular ridge 38 reside higher on the surface Cf1 but not yet disengaged from the surface Cf1. There is an increase in the separation between the surfaces 40 and 46 and the surface Cm2 is now seated firmly in a deepest portion of the concavity in inflexion surface If2. This is increasing pressure /force exerted by: surface Cm2 on the neck of protrusion Pf;
 20 and, surface Cm1 on surface Cf1.

Continued operation of the jack 92 further increases the angle between the panels 12a and 12b to approximately -7° as shown in Figure 9d. At this point, the surface Cm1 and ridge 38 have now moved past the surface Cf1 and lie outside of the neck 66 of recess Rf. This would ordinarily be indicated to the installer by an audible “clunk”. However the surface
 25 Cm3 is engaged by and below the surface Cf3; and the surface Cm2 resides below the surface Cf2. More particularly, the protrusion Pf is now being compressed or pinched on opposite sides by the surfaces Cm3 and Cm2. Thus while at this -7° disposition, the joints Jm and Jf are still partially engaged and in the absence of any external force, maintain vertical and horizontal locking of the panels 12a and 12b. Further, during the rotation of the
 30 joints Jm and Jf up to the -7° rotation the surface Cm2 operates as a fulcrum lifting the projection Pm from the recess Rf.

The application of a downward pressure or force on the panel 12a results in one or both of: compressing the projection Pf; or, opening the neck of recess Rm formed by the surfaces Cm3 and Cm2, to enable the projection Pf to escape the recess Rm. Wax in the
 35 joint will reduce friction and now assist in the disengagement of the joints. Now the panel 12a is free to fall back to the surface 90 as shown in Figure 9f and Figure 6i. Thus at this point in time the panels 12a and 12b are fully disengaged.

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However removal of the panel 12b also requires disengagement of the joint Jf of panel 12b from the joint Jm of panel 12c. This process is shown in Figures 6j to 6l.

Immediately after disengagement of panels 12a and 12b, the panel 12b is held above surface 90 by the jack 92. To continue the replacement process the panel 12b is lowered back to the surface 90 by unscrewing shaft 96 from the boss 100 of the clamp plate 102. An installer next grips and lifts the joint Jm of panel 12b to insert the wedge tool 94 between the disengaged joints of the panels 12a and 12b and push it to a position where the land 118 of surface 114 is in contact with the major surface 16 of panel 12c and inside of the joints Jm and Jf. This is shown in Figure 6j. Disengagement of the panel 12b from the panel 12c is now effected by initially rotating the panel 12b by about -7° to -10° to effect a disengagement of the surface Cm1 of panel 12c from the surface Cf1 in the joint Jf of panel 12b. The wedge tool 94 is configured to assist the installer in achieving this rotation. This is also depicted in Figure 6j. Moreover when the wedge block 108 is under the under panel 12c slightly inboard of its joint Jm, and the panel 12b is rotated in the anti-clockwise direction toward the handle 110, the panel 12b will rotate or pivot by 7° to 10° prior to or by the time it abuts the handle 110. The reaching of this position is ordinarily denoted by an audible "clunk" as the surface Cm1 passes from below to above surface Cf1. This juxtaposition of the joints Jm and Jf is as shown in Figure 9d.

Subsequent application of downward pressure or force for example by way of rubber mallet M as shown in Figure 6k will result in total disengagement of the joints Jf and Jm of panels 12b and 12c respectively as shown in Figure 6l. Now the damaged panel 12b is totally disengaged from both adjacent panels 12a and 12c and can be removed.

To replace the damaged panel 12b with a new panel 12b1 an installer now removes the wedge tool 94, lifts the edge of panel 12c by hand and slides a new panel 12b1 beneath the raised panel 12c so that the joint Jm lies above the joint Jf. The opposite side of panel 12b1 rests on panel 12a. This sequence of events is shown in Figures 6m-6p.

The installer now lowers the panel 12c onto the panel 12b1. When this occurs, the male joint Jm of panel 12c rests on the neck 48 of female joint Jf of panel 12b1; and the joint Jm of panel 12b1 will rest on the neck 48 of the joint Jf of previously laid panel 12a. This is shown in Figure 6q.

To fully engage the panel 12b1 downward force or pressure is applied on the male joints Jm of panels 12c and 12b1. This can be done in either order, i.e. panel 12c then panel 12b1 or panel 12b1 then panel 12c. Figure 6q shows the configuration when joint Jm of panel 12c is first engaged with joint Jf of panel 12b1. Figure 6r depicts the joint Jm of panel 12b1 now engaged with joint Jf of panel 12a, reinstating the floor as shown in Figure 6s. The self aligning properties of the joint system as described above with reference to Figures 5f-5k will operate during this process if the panels are initially misaligned.

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The ability to easily remove and replace only the panels 12 which are damaged instead of peeling back the entire floor has enormous practical, commercial and environmental benefits. These are summarised as follows:

The panels can be easily replaced by handypersons of limited skill and with very rudimentary and low cost equipment. This avoid the need for hiring professional installers

The repair is also relatively clean as there is no need to chisel or cut out panels or parts thereof.

As only the damaged panels need be replaced there is no need to move furniture which in itself is often difficult and inconvenient

From the view point of the retailer there is initial benefit in that the retailer should encourage the purchaser to purchase slightly more panels that required to cover a given area to provide spare panels in the event of damage. For example the retailer would explain the benefits in purchasing say an additional one to three square meters of panels. This is much the same as when say a new house in build and the builder leave extra floor and roof tiles or paint for the purposes of repair. A major issue with repair of damaged flooring it the difficultly is sourcing identical panels several years after installation. If identical panel cannot be sourced it may be that an entire level of flooring will need to be replaced when only a small number (e.g. two or three) panels are damaged. For example say the ground floor of a house has three bed rooms a hallway, kitchen and family room all cover by wooden floor panels of the same appearance forming a continuous floor. The entire housing furniture selection and decor is often selected to match with the floor. In such instances when matching replacement panels are not available the entire ground level floors may need to be replaced. Indeed this occurred on a large scale flooring a freak storm in Perth, Western Australia in March 2010. A much more common trigger for this is the spilling overtime of water from refrigerators with water dispensers. Having a small supply of replacement panel at hand avoids the need for full scale floor replacement. A new and growing market for wooden flooring is that uses a relative cheap and plentiful material for the panel and using a bubble jet printer to print a pattern for example the wood grain of exotic trees on the upper major surface 12. It will be appreciated that these patterns can be very complex and trying to rectify a scratch by use of an ink pen is virtually impossible. Again a small supply of additional panels made with the initial purchase of the flooring can potentially save thousands of dollars. A similar situation applies with wooden flooring is that use a relative cheap and plentiful material and are stained on their major surface to mimic the appearance of a more exotic and expensive timber.

The commercial consequence of full floor replacements as described above should not be underestimated. Often this is at the expense of insurance companies. This naturally has a knock effect with insurance premiums increasing and shareholder dividends reducing.

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Also there are timing issue where insurance companies may not be able to have damage assessed and therefore rectified for months.

Now consider the environmental aspects. Typically wooden floor panel are coated with polyurethane or other sealants. Also they may bear adhesives and glues. This often prevents destruction of the damaged boards by incineration due to generation of toxic gases. Consequently they must go to land fill.

The joint 10 depicted in Figures 1-9f is representative of one of a large number of possible embodiments. A small selection of other possible embodiments will now be described. In describing these embodiments the same referencing system will be used as for the joint 10 however each specific embodiment of a joint will be demarcated by the addition of the alphabetical suffix e.g. "a, b, c, ...".

Figures 10a and 10b depict a second embodiment of a joint system 10a incorporated into a substrate 12. The joint system 10a comprises a male joint Jm and female joint Jf along opposite sides. It can be seen that the joint system 10a is of the same general configuration as the joint system 10 shown in Figures 1 and 2. In particular the male joint Jm comprises male locking surfaces ML1, ML2, ML3; inflexion surfaces Im1, Im2, and Im3; as well as surfaces Cm1, Cm2, and Cm3. Likewise the female joint Jf is provided with female locking surfaces FL1, FL2, FL3; inflexion surfaces If1, If2, If3 and surfaces Cf1, Cf2 and Cf3. The relative locations of the locking surfaces, inflexion surfaces and surfaces for the joint system 10a are generally the same as for the joint system 10. However, there are subtle differences in the specific shape and depth of the surfaces. In particular the surface Cm1 in the joint 10a is continuously curved rather than being provided with the ridge 38 of the joint system 10. In addition the mating inflexion surfaces Im1 and If1 are shallower so that the spaces 76 and 78 about the locking plane 18 are smaller than that for the joint system 10. This can be seen by comparison between Figures 10b and Figure 1b. Further, there is a lessening in the depth of the inflexion surfaces Im3 and If3 to the extent that there is no space equivalent to the space 80 of the joint system 10. It can also be seen that the inflexion surfaces Im2 and If2 in the joint system 10a are shallower than the corresponding surfaces in the joint system 10 resulting in a smaller overlap in the surfaces Cf2 and Cm2 when the joints Jm and Jf of adjacent panels 12 are engaged.

The joint system 10a may be used in the same circumstances and with the same materials with the system 10. However due to the slightly shallower depth of the inflexion surfaces I, the joint system 10a is suited to more rigid substrates such as but not limited to bamboo where the compressibility of the projections Pm and Pf2 when passing through the necks of the corresponding recesses Rm and Rf may be limited.

Figures 11a to 11d depict a further embodiment of the joint system 10b provided on opposite sides of the substrate 12. The substantive differences between the joint systems 10b and 10 lie in: (a) the configuration of the immediate inflexion surfaces Im3 and If3; and,

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(b) the removal of the concave recess 42 from the projection Pm and the formation of a similar recess 42f on the surface 58 of recess Rf.

In general, the inflexion surfaces Im3 and If3 are “angularised” in that they are not smoothly or continuously curved for their entire length. Specifically the surface Cm3 (which is part of the inflexion surface Im3) is provided with a narrow ridge 140 similar to the ridge 38 depicted on the protrusion Pm of joint system 10. In addition the inflexion surface Im3 is provided with a “V” shaped gear tooth 142 extending toward the root 52 of the recess R. On the female joint Jf the surface Cf3 is sharpened to form a narrow ridge 144. As depicted in Figure 11b, the apex 145 of gear tooth 142 bears against surface Cf3 below the ridge 144 when joints Jm and Jf are engaged.

The purpose and effect of the variation in configuration of the inflexion surfaces Im3 and If3, and in particular the provision of the gear 142 and variations in the configuration of the surfaces Cf3 and Cm3 is to allow greater relative rotation of up to 5° to 10° or more of between joined while maintaining engagement to assist in installation on undulating surfaces. This is shown in Figures 11c and 11d. The ability to increase the degree of rotation is most pronounced in the positive or upward direction of the male jointed panel 12b relative to panel 12a. This is facilitated by the surface Cm3 bearing against the surface of protrusion Pf in the recess Rf after the apex 145 of gear tooth 142 has passed over the ridge 144. As a consequence the protrusion Pf remains pinched between the surfaces Cm3 and Cm2 thus maintaining horizontal and vertical engagement. The joint system 10b enables a panel to ramp up relative to an adjacent horizontal panel to say a raised cross-over or floor trim piece.

Figures 12a and 12b depict a further embodiment of joint system 10c incorporated in a substrate 12. The joint systems 10c and 10 differ in substance in relation to their aspect ratios. Joint system 10c may be used for substrates of smaller thickness than for joint system 10. As there is less thickness or depth in the substrate 12 the male and female joints Jm and Jf of joint system 10c are shallower but broader. This is most notable by a visual comparison between the protrusion Pm and recess Rf of the joint systems 10c and 10. In joint 10c the protrusion Pm is broader and provided with a flatter bottom surface 42 as is the recess Rf. The broadening of the protrusion Pm also is the effect of sharpening the profile of the Cm3. However, the method of operation and effect of the joint system 10c is the same as for joint system 10. In particular the remains three vertical locking planes 18, 20 and 74 and respective substrates 12 are able to rotate by up to 3 degrees in opposite directions relative to each other.

Figures 13a and 13b depict a further embodiment of the joint system 10d applied to a substrate 12. The substantive differences between the joint system 10d and 10 lies in the depth and relative disposition of the intermediate inflexion surfaces Im3 and If3; and the width of the protrusions P and recesses R. In the joint system 10d, the inflexion surfaces Im3

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and If3 are shallower and are inclined more towards the horizontal i.e. toward a plane containing major surfaces 14 and 16. As a consequence, when the male and female joints Jm and Jf are engaged only inner and outer locking planes 18 and 20 are created; the third locking plane 74 which arises with the earlier embodiments of the joint system being absent.

5 In the joint system 10d, there is no point on the inflexion surface Im3 which is vertically below and laterally inside of a point on the inflexion surface If3. Also the protrusions P and recesses R are broader in the joint system 10d. This provides greater horizontal shear strength along shear planes S1 and S2 which pass through the protrusions Pm and Pf parallel to the major surfaces 14 and 16. This is beneficial with panels of smaller thickness

10 (e.g. say 7mm-3mm) which are otherwise susceptible to shearing along planes S1 and S2. Notwithstanding this, the joint system 10d operates in substantially the same manner as the joint systems 10-10c in that it is a vertical system and adjoining substrates 12 can rotate by 3 degrees relative to each other without disengagement.

Figures 14a and 14b illustrate a further embodiment of the joint system 10e applied

15 to a substrate 12. The joint system 10e embodies the same basic concepts as the joint system 10 and in particular has extreme (or inner and outermost) locking, inflexion and transversely extending surfaces which form respective locking planes 18 and 20 and enable relative rotation between the male and female joints Jf and Jm of joined substrates 12. Also as with all of the embodiments the joint system 10e is a vertical system where joints are

20 engaged by the application of a force or pressure in a direction perpendicular to the major surfaces 14 and 16. However as it is readily apparent from a comparison between the joint system 10e and the joint system 10 there are numerous differences in the specific configuration of the projections P and recesses R on the male or female joints Jf and Jr.

Starting with the male joint Jm, in the system 10e, there is a bevelled surface 146

25 between the major surface 14 and the side surface 24. In addition, between the side surface 24 and the inflexion Im1 the joint system 10e comprises a right angle rebate 148. The protrusion Pm is more symmetrical than in joint system 10 and is provided with a central slot 150 which extends in a direction perpendicular to the major surfaces 14 and 16. Additionally surface 40 of the protrusion Pm is flat rather than arcuate. The slot 150 provides the

30 protrusion Pm with a degree of resilience. This resilience is not in order to effect engagement of the protrusion Pm with recess Rf but rather provides resilience to assist in the rotation of the protrusion Pm within the recess Rf.

The protrusion Pf is more rounded than the corresponding protrusion Pf in system 10 and is also provided with a central slot 152 which extends parallel to the slot 150. Slot

35 152 also provides resilience to the protrusion Pf to assist in its rotation within the socket Rm. Surface 58 at the root 34 of recess Rf is flat and lies parallel with the major surfaces 14 and 16 and also parallel with the surface 40. A square shoulder 154 is formed between the inflexion surface If1 and side surface 26 on the female joint Jf. Shoulder 154 engages the

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rebate 148 when the joints Jf and Jm are engaged as shown in Figure 14b. A further difference in the configuration of joint system 10e is the provision of an inclined surface 156 between the inflexion surface Im2 and the bevelled surface 56 at the joint Jm.

It will be seen from Figure 14b that the joint system 10e has three vertical locking planes 18, 20 and 74 as in the joint system 10. A space 158 is created between the surfaces 40 and 58 when the male joint Jm is engaged with a female joint Jf. This space may be used in the same manner as the void 44 shown in Figure 1b for the collection of debris.

Figures 15a and 15b depict a further embodiment of a joint system 10f incorporated on a substrate 12. In the joint system 10f, the male and female joints Jm and Jf are shallower and squarer than that in the system 10. Male joint Jm comprises an inflexion surface If1 and corresponding surface Cm1 on an outermost surface and an inflexion surface Im2 and corresponding surface Cm2 on an innermost surface. There is also an intermediate surface Cm3 but no intermediate inflexion surface Im3. The female joint Jf is formed with: surfaces Cf1 and Cf2 on inner and outermost surfaces of the joint respectively; and, an inflexion surfaces If2. However, the joint system 10f does not include an intermediate inflexion surface If3 nor an inflexion surface If2 on the outermost surface of the female joint.

Projections P and recesses R in the joint system 10f are squatter than those in the joint system 10. This provides improved shear strength as in the joint system 10d. When substrates 12 incorporated in the joint system 10f are engaged with each other two locking planes 18 and 20 are created by the surface Cf1 and Cm1; and Cf2 and Cm2 respectively. A "quasi" intermediate locking plane is formed by the provision of planar surfaces 25 and 27 on protrusions Pm and Pf respectively. The surfaces 25 and 27 are perpendicular to the major surface 14. When the joints Jm and Jf are engaged the surfaces 25 and 27 abut each other. This provides frictional locking against relative motion between the joints Jm and Jf in the vertical plane. This provides an effect similar to but to less degree than the locking plane 74 in the joint system 10f. Vertical arrestment between the joined substrates 12 is created by the abutment of the surface 40 of projection Pm with the surface 58 in the recess Rf.

A further difference in the configuration between the joint systems 10f and 10 is the omission in the joint system 10f of bevelled surfaces 56 and 64 which lead from the surfaces 50 and 62 respectively to the major surface 16. Thus, in the joint system 10f, the surfaces 54 and 66 extend directly from the respective surfaces Cm2 and Cf2 to the major surface 16.

Figures 16a and 16b depict a further joint system 10g which is suited to panels made of plastics materials such a vinyl or other relatively soft/flexible materials. In the joint system 10g various inflexion surfaces or transversely extending surfaces are formed comprising one or more planar surfaces. However, on each of the extreme locking planes 18 and 20, there remains at least one arcuate transversely outward extending surface to

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facilitate a rolling motion enabling rotation between the joint panels 12. More specifically it can be seen that the projection Pm in the joint system 10f comprises a first locking surface ML1 and having abutment surface 24 and contiguous inflexion surface Im1. The inflexion surface Im1 includes a planar and inwardly sloping surface 160 depending from the surface 24, and an additional planar surface 162 which extends parallel to the surface 24 and is contiguous with the surface 160. Thereafter, the inflexion surface Im1 incorporates an arcuate or a smoothly curved surface Cm1. The surface Cm1 leads to a planar bottom surface 40 of the projection Pm which lies in a plane parallel to the major surfaces 14 and 16. The surface 40 is contiguous with an intermediate and smoothly curved surface Cm3. However the concave recess 42 of earlier embodiments has been replaced with a slot 163 which lies perpendicular to the major surface 14. The slot 163 provides the projection Pm with an increased ability to compress within recess Rm to facilitate rotation during within the recess Rm.

Extending from the surface Cm3 is an inclined planar surface 164 which leads to a planar surface 52 of the recess Rm. The surface 52 lies parallel to the major surfaces 14. The planar surface 164 and the surface Cm3 together form intermediate inflexion surface Im3 and third male locking surface ML3. This is provided with a sharp corner where the surface 164 meets the surface Cm3. The innermost surface ML2 of the male joint Jm includes an angular inflexion surface Im2 and planar surface 56. The inflexion surface Im2 comprises contiguous planar surfaces 166 and 168 which are inclined relative to each other to form a generally concave but angular or sharp corner in the recess Rm. The inflexion surface Im2 further comprises another planar surface 170 which extends perpendicular to the major surfaces 14 and 16. This surface then joins bevelled surface 56 leading to the major surface 16.

The female joint Jf has first female locking surface FL1 comprising abutment surface 26 which extends perpendicular to major surface 14 and contiguous inflexion surface If1. Inflexion surface If1 is composed of planar surface 172 which slopes toward the recess Rf, planar surface 174 which is parallel to surface 26 and a smoothly curved concave surface 176 which leads to the surface 58 at the root of recess Rf. The surfaces 172, 174 and upper portion of surface 176 together form a transversely extending surface in the form of a generally convex cam Cf1. Surface 58 at the root of recess Rf is planar and parallel to the major surface 14. Thereafter, the female joint Jf comprises an intermediate surface If3 which may be considered to be in inverted form of the inflexion surface Im3. To this end the inflexion surface If3 comprises a planar surface 180 which is inclined in a direction toward major surface 14, and a contiguous smoothly curved surface Cf3. The surface Cf3 joins with a planar surface 60 parallel to the major surface 14. The outermost side of the female joint Jf in system 10f is formed with a second female locking surface FL2 having

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smoothly curved surface Cf2 which leads to a planar surface 62 and subsequently to inwardly bevelled surface 64 leading to the major surface 16.

The joints Jm and Jf are engaged by application of a force or pressure in a direction perpendicular to the major surfaces 14 and 16. As is evident from Figure 16d, that joint system 10f results in the provision of three locking planes 18, 20 and 74 as a result of the relative juxtaposition of the surfaces Cf1 and Cm1; Cm1 and Cm2; and Cm3 and Cf3. Further, in the engaged joint, the surfaces Cm1 and Cm3 reside in the angular corners of the recess Rf while smoothly curved surfaces Cf2 and Cf3 reside in the angular corners formed in the recess Rm. In this embodiment it will be noted that there remains on each of the inner and outermost locking planes, an arcuate or smoothly curved surfaces C. Specifically, on locking plane 18, the smoothly curved surface Cm1 is able to roll against the surface of the joint Jf while on the locking plane 20, the arcuate surface Cf2 is able to roll on the surface of the male joint Jm. Also due to the non-symmetrical configuration of the joints Jm and Jf voids or spaces are created between the engaged surface to further assist in the relative rotation between joints and allow for expansion.

Figures 17a and 17b depict a further joint system 10h which is based on and very similar to the joint system 10f. In particular, the system 10h is of the same general shape and configuration of the system 10g with the substantive differences being the omission of the slot 163 and a reduced length in the bevelled surfaces 56 and 64. This reduced length is a function of the thickness of the substrate 12h which is less than that of the substrate 12g. In a non limiting example, the substrate 12g incorporating the joint system 10g may have a thickness in the order of 5.2mm, while the substrate 12h incorporating the joint system 10h may have a thickness in the order of 3.5mm.

In all other respects, the joint system 10h is the same in configuration and function as the joint system 10g.

Figures 17c to 17e illustrate a further feature of embodiments of the joint system relating to the ability to manufacture the system and panels of varying thickness using a single set of tools. Figure 17a and 17b illustrate the joint system 10h formed in panels 12 of a nominal thickness of say 3mm. In Figure 17c and 17d the nominal thickness of 3mm is marked as the innermost horizontal lines 14a and 16a. These lines indicate the major surfaces 14 and 16 of a panel 12. The next adjacent pair of lines 14b and 16b illustrates the major surfaces of the panel 12 if it were made to a thickness of 3.5mm. Continuing in an outward direction line pairs 14c and 16c; 14d and 16d; 14e and 16e; and 14f and 16f; illustrate the major surfaces 14 and 16 for panels 12 made to thicknesses of 4mm, 5mm, 6mm and 7mm respectively. Figure 17e provides perspective for panels 12 made to these different thicknesses. As explained in greater detail hereinafter the ability to manufacture joint systems on panels of varying thickness with a single set of cutting tools provides benefits over the prior art. A further feature of this is that notwithstanding the variation in

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thickness of the panels 12 it will be seen that the physical size of the joints Jm and Jf and the interlocking surfaces remains constant. Thus the strength of the engagement between panels is not compromised by a variation in the thickness of the panels.

Figures 18a and 18b depict a further embodiment of the joint system 10i. The joint system 10i may be viewed as a hybrid combining various features of earlier described joint systems. Both the male and female joints Jf and Jm comprise ball or bulbous like protrusions P, and recesses R having smoothly or continuously curved surfaces. The respective surfaces C of the male and female joints Jf and Jm are arranged to provide three locking planes 18, 20 and 74 when mutually engaged as depicted in Figure 18b. The male and female joints comprise complimentary planar stepped surfaces 148 and 154 which lie parallel to the major surface 14 similar to the joint system 10e. Indeed the joint system 10i may be viewed as a modification of the joint system 10e but with the following differences: broadening of the respective protrusions P and recesses R; a marginal inclining of the surfaces 24 and 26 from the perpendicular of major surface 14; a flattening of a portion of the inflexion surface lf1 between an upper end of surface Cf1 and surface 154; and extension of the bevelled surface 56 so as to extend directly from the Cm2 to the major surface 16. It will be further noted from a comparison between Figures 18b and 14b that a space 82 now exists between the planar surfaces 40 and 52, and there is a space between the surfaces 154 and 148 in the engaged joints Jm and Jf. The joint system 10i operates in the same way as the previously described joint systems in terms of engagement and disengagement and the rolling action between the joints.

Figures 19a and 19b depict a further embodiment of the joint system 10j. The protrusions Pm and Pf are each provided with respective slots 163 and 152 similar to that of the joint system 10e. In the joint system 10j the surfaces Cm1, Cm2, Cm3, Cf1 and Cf3 are each smoothly curved. However the surface Cf2 on the female joint Jf is angular, being composed of a plurality of contiguous planar surfaces. Nevertheless, as shown in Figure 19b, when the joints Jm and Jf are engaged the locking surfaces ML1 and FL1; ML2 and FL2; and ML3 and FL3 create three locking planes 18, 20 and 74 as herein before described. In each of the outermost locking planes 18 and 20, one of the two respective engaged surfaces is continuously curved. Specifically in locking planes 18 and 20 surfaces Cm1 and Cm2 are continuously curved. This maintains the ability of the joints to roll provided the positive and negative relative rotation and the ability to disengage and thus move and replace a damaged substrate in an identical manner as described in relation to the earlier embodiments. The joint system 10j further includes surfaces 146 and 154 similar to the subsystem 10e but in this instance these surfaces are inclined at an acute internal angle relative to the major surface 14. Further the projection Pm and recess Rf are relatively configured to form a relatively large void or space 190 between surfaces 40 and 58. The

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slots 152, 163 provide an internal suspension system enabling compression of the protrusions Pm and Pf to assist in the rolling motion.

Figures 20a and 20b depict a further embodiment of the joint system 10k. The protrusion Pm is formed with continuously curved surfaces Cm1, Cm2 and Cm3. On the female side the protrusion Pf is formed with angular surfaces Cf2 and Cf3, surface Cf1 comprises contiguous planar surfaces 191, 192 and 193. Surface Cf3 comprises contiguous planar surfaces 194, 195 and 196. The surfaces 191 and 194 each lead to the surface 60 of protrusion Pf which lies parallel with major surface 14. Both surfaces 192 and 195 extend perpendicular to the major surface 14 while surfaces 193 and 196 are inclined toward each other surface 193 leads to an oppositely inclined surface 162 which in turn leads to bevelled surface 64 which is cut inwardly but substantially parallel to surface 193. The surface 64 leads to the major surface 16. The route 34 of the recess Rf is formed with planar surface 46 which lies parallel to major surface 14, and to oppositely and outwardly inclined surfaces 197 and 198. Surface 198 leads to an inwardly inclined surface 199 which in turn is formed contiguously with planar surface 200. Surface 200 lies perpendicular to the major surface 14 and joins with surface 154. The combination of surfaces 196 and 197; and surfaces 198 and 199 form respective concave recesses for seating the surfaces Cm1 and Cm3 as shown clearly in Figure 20b.

Looking at the male joint Jm, it will be seen that opposite ends of the surface 52 in the recess Rm lead to contiguous outwardly inclined surfaces 201 and 202. Surface 201 then leads to a planar surface 203 which leads to the surface Cm2. On the opposite side the surface 202 is formed contiguously with a further planar surface 204 which then leads to the surface Cm3. Surfaces 203 and 204 lie perpendicular to the major surface 14. In combination the surfaces 201, 203 and part of the surfaces Cm2 form a concave recess for the surface Cf2. Similarly, the combination of the surfaces 202, 204 and part of the surface Cm3 forms a further concave recess for seating the surface Cf3.

The protrusion Pm is also formed with a planar surface 205 that lies perpendicular to the major surface 14 and extends between the surface Cm1 and the surface 148. When the joints Jm and Jf are engaged, the surfaces 205 and 204 are spaced apart while the respective surfaces 148 and 154; and 26 and 24 are in abutment.

Figures 21a and 21b depict a further embodiment of the joint system 10l. The protrusion Pm has a male locking surface ML1 which, starting from the major surface 14 is initially provided with a small bevelled surface 146 similar to that shown in the joints 10e and 10i and extends downwardly ending in a smoothly curved surface Cm1. The first male locking surface ML1 also comprises an inflexion surface Im1 which includes a planar portion 220 and extends from the bevelled surface 146 toward the surface Cm1.

Protrusion Pm also includes a slot 158 similar to that of the joint system 10e. The protrusion Pm is formed with a curved distal surface 40 and is of a generally symmetrical

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configuration about a centreline passing through the slot 158. To this end the line of shortest distance 50 across the neck 48 of the protrusion Pm lies on a plane parallel to the major surface 14. The slot 158 in the protrusion Pm is outwardly flared near the surface 40 so as to create in effect two prongs or a bifurcation with generally rounded or curved
 5 extremities 221.

The third inflexion surface Im3 and corresponding third male locking plane ML3 on a side of protrusion Pm opposite the inflexion surface IM1 is smoothly curved and leads to a planar surface 52 in the root 32 of recess Rm. The surface 52 lies parallel to the major surface 14. On an opposite side of the recess Rm the joint Jm is formed with a second male
 10 locking surface ML2 which comprises a smoothly curved inflexion surface IM2 which subsequently leads to bevelled surface 56.

The first female locking surface FL1 in the joint Jf comprises a short bevelled surface 155 commencing from the major surface 14 followed by a planar surface portion 222 which extends perpendicular to the major surface 14. Surface 222 leads to inflexion surface
 15 If1 which is smoothly curved and extends toward a root 34 of recess Rf. The root 34 is provided with a planar surface 46 that extends parallel to the major surface 14. The surface 46 in turn leads to third inflexion surface If3 which is smoothly curved and corresponds with the third female locking surface FL3. Distal surface 60 of female protrusion Pf extends
 20 parallel to major surface 14. The second female locking surface FL2 extends continuously toward the major surface 16 beyond the inflection surface IF2 in a smoothly curved manner and subsequently leads to bevelled surface 64.

It will be seen from Figure 21b that each of the respective male and female locking surfaces and the corresponding inflexion surfaces engage about respective locking planes
 25 18, 20 and 74.

In a further variation of the joint system 10l embodiment a bead B (shown in phantom line) of adhesive of the type described in detail shortly can be accommodated in the mouth of the slot 158. This provides additional vertical locking between engaged panels as well as cushioning.

Figure 22 depicts a further embodiment of the joint system 10m with joints Jf and Jm depicted on separate but engaged panels 12a and 12b. The joint system 10m is similar to the joint system 10 depicted in Figures 1a – 2 with the main differences residing in the configuration of the surfaces Cm3 and If3 on the male protrusion Pf. In the joint system 10m the surface Cf3 extends further in the transverse outward direction so as to hook under the
 35 surface Cf3 when the joints Jm and Jf are engaged. This provides greater resistance to vertical separation along the intermediate plane 74 in comparison to that of the joint system 10. Further, the surface Cf3 is provided with small ridge or peak 38' similar in configuration and effect to the peak 38 on the surface Cm1. Due to the configuration of the surface Cf3

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there is an increased grab or pinching of the protrusion Pf between the surfaces Cm3 and Cm2 during the rotation of the joint Jm in a negative sense relative to the joint Jf. The joint Jm is particularly well, but not exclusively, suited for use with panels or substrates made of softer material.

5 Figure 23a and 23b depict a further embodiment of the joint system 10n. The joint system 10m differs from the joint system 10 depicted in Figures 1 – 3b by the provision of additional of three concave recesses, namely concave recesses 42b, which is formed in the root of the recess Rf; concave recess 42c which is formed in the root of the recess Rm; and concave recess 42d formed in the protrusion Pf. The recess 42d is located so that when
10 joints Jm and Jf are engaged the recesses 42 and 42b face each other to form a substantially cylindrical or elliptical void 230. Similarly, the concave recesses 42c and 42d are located to face each other when the joints Jm and Jf are engaged to form a further substantially cylindrical void 232. The void 230 may be used as a dam or void to collect dirt and other debris generated during the laying of substrates 12 provided with the joint system
15 Jm.

Alternately, one of the recesses 42 and 42b may be provided with a pre-laid re-stickable flexible adhesive and configured to extend into the other of the recess 42 and 42b. The expression “re-stickable adhesive” throughout the specification and claims is intended to mean adhesive which is capable of being able to be removed and re-adhered, does not set
20 or cure to a solid rigid mass and maintains long term (e.g. many years) characteristics of flexibility, elasticity and stickiness. The characteristic of being re-stickable is intended to mean that the adhesive when applied to a second surface can be subsequently removed by application of a pulling or shearing force and can subsequently be reapplied (for example up to ten times) without substantive reduction in the strength of the subsequent adhesive bond.
25 Thus the adhesive provides a removable or non-permanent fixing. The characteristics of flexibility and elasticity require that the adhesive does not solidify, harden or cure but rather maintains a degree of flexibility, resilience and elasticity. Such adhesives are generally known as fugitive or “booger” glues and pressure sensitive hot melt glues. Examples of commercially available adhesives which may be incorporated in embodiments of the present
30 invention includes, but are not limited to: SCOTCH-WELD™ Low Melt Gummy Glue; and GLUE DOTS™ from Glue Dots International of Wisconsin.

It is noted that manufacturers of re-stickable glue/adhesive may advise that the adhesive is not suitable for particular materials for example wood. However when the joint system is incorporated in wooden or wood based panels this does not preclude the use of
35 such adhesives. This is because wooden or wood based panels are usually, and if not can be, coated with a polymer sealant or other coating. Thus provided the adhesive is recommended for use with polymer surfaces can be used on polymer coated wooded or wood based panels.

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Alternately, both recesses 42 and 42b may be provided with the re-stickable adhesive so as to engage each other when the joints Jm and Jf are engaged.

In a similar manner, one or both of the concave recesses 42c and 42d may be provided with a bead of re-stickable adhesive of the type described hereinafter. When only one of the two recesses 42c and 42d is provided with the adhesive the adhesive is configured in a bead so as to extend into the other of the recesses 42c and 42d. However when both are provided with adhesive, the adhesive material while still in the form of a bead may be formed of a smaller thickness or depth.

Provision of the adhesive material has multiple effects. Firstly, it acts to assist in minimising the possibility of vertical or horizontal separation during the normal service life of the substrates 12. In addition the adhesive may act as a seal against moisture passing either from the major surfaces 14 through a joint to the major surface 16, or in a reverse direction in the event of moisture seeping up through a surface in which the substrates 12 are laid. The provision of the re-stickable adhesive however does not interfere with the ability to remove and replace one or more damaged substrates 12 due to the unique removal system described herein above. As the adhesive is re-stickable and in particular does not set or cure, the removal system remains effective for the removal of one or more panels 12 without damage to the joint of adjoining adjacent panels 12 which are not removed.

One further feature of the joint system 10n is that the locking surfaces ML3 and FL3 are each provided with planar surfaces 210 and 212 which lie parallel to the locking plane 74. These surfaces are pressed together when the joints Jm and Jf are engaged. Provided no wax is placed on these surfaces they will in effect provide a frictional intermediate locking plane 74. Such frictional intermediate locking planes can be incorporated in other of the above described

In one embodiment as shown in Figures 23c-23i adhesive is applied to both of the recesses in the male joint Jm only and not in the female joint Jf. In such an embodiment, due to the nature of the re-stickable adhesive, when a substrate 12 is removed from adjacent adjoining substrates, the adhesive remains in the recesses 42 and 42c of the removed substrates. Moreover, the nature of the adhesive is such that it remains in the recess in which it is originally provided. This is depicted in Figures 23c-23i which progressively show the disengagement of joints Jm and Jf of the joint system 10n

Figure 23c shown joints Jm and Jf prior to engagement. Recesses 42 and 42c are each provided with respective beads B1 and B2 of re-stickable adhesive 300 covered with release strips R1 and R2. There is no adhesive in the recesses 42b and 42d.

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Figure 23d shows the joints Jm and Jf fully engaged with the release strips R1 and R2 removed so that the re-stickable adhesive 300 in beads B1 and B2 adhere to the surface of the recesses 42b and 42d.

Figures 23e -23i show the typical disengagement process of joints Jm and Jf in
 5 embodiments of any joints system with initially the joint Jm being rotated in a negative (clockwise) direction relative to joint Jf to release protrusion Pm from recess Rf, and the subsequent application of downward pressure on the female joint Jf. The re-stickable adhesive is able to flex and move during the separation process to allow the rotation and subsequently is pulled from the recesses 42b and 42d to remain in recesses 42 and 42c.

10 The adhesive beads B bonded to a joint J may also act to absorb debris that lies in a recess into which the bead B is to be adhered. For example a bead B bonded in recess 42 can absorb debris in the recess 42b into which the bead B is adhered. The debris will initially adhere to the outside surface of the bead B. As the panels 12 move in normal use there will also be some movement and rolling of the bead B. It is believed that this will have
 15 the effect of drawing the debris into the adhesive so that the adhesive envelops the debris and provides a fresh adhesive surface to stick to the recess 42b.

One or more adhesive beads can be provided in each of the previously described embodiments to provide added vertical and horizontal locking strength while still allowing the full operation and benefits of the embodiments. This may be achieved for example by the
 20 provision of one or more recesses 42 in one of the joints Jm or Jf to seat a bead of the re-stickable adhesive. Depending on the thickness of the bead a receiving recess may or may not be required on the other joints Jm and Jf. The provision of the re-stickable adhesive can be seen as providing an additional locking plane to the joint system.

Typically, as in the above example, the adhesive is laid in only one of two mutually
 25 facing recesses 42. The bond when the adhesive is initially placed in that recess is stronger than the bond when that adhesive contacts a surface of the opposed recess in another substrate. Thus when a substrate is removed, the adhesive originally applied to that substrate remains with that substrate.

In all of the above described the embodiments of the joint system 10, it will be noted
 30 that the protrusions Pm and Pf are not of the same configuration, i.e. cannot be transposed over each other. Similarly the recesses Rm and Rf are not of the same configuration, i.e. cannot be transposed over each other. More particularly the respective engaging protrusions and recesses are not of a complementary configuration. Thus the protrusions Pm and Pf; the recesses Rm and Rf ; and joints Jm and Jf are asymmetrical. As a
 35 consequence when a protrusion P is engaged in a recess R gaps or spaces are created between the male and female locking surfaces ML1, FL1 and ML2, FL2 at the inner and outer locking planes 18 and 20. This assists in providing the ability of embodiments of the joint system to roll or rotate in opposite directions by up to 3° by providing space into which

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the protrusion can roll without disengaging. In turn this aids in the ability of the joint system to be used easily and with success on undulating floors. This will be recognised by those in the art as filling a need particularly in the do it yourself market for flooring system which hitherto has endured systems that require high quality underlying surfaces for successful
5 installation.

As a result of the specific configuration of the joint systems in accordance with embodiments of the present invention, and in particular as they are true vertical systems it is possible for manufacturers to manufacture panels with a wide range of thickness with a single set of cutting tools. For example for manufactured or natural wood substrates a single
10 set of cutting tool can produce joint systems on panel ranging from 20mm to 8mm with the only adjustment required being a simple one of cutting depth. Similarly with plastics panels such LVT a single set of cutting tool can produce joint systems on panel ranging from 7mm to 3mm as shown and previously described with reference to Figures 17c-17e. This is of significant commercial benefit giving rise to reduced production costs which can be passed
15 on to the consumer.

The range in cost for set of cutting tools for cutting a joint system is typically between US\$30,000 to US\$50,000. Usually a set of cutting tools used for prior art joints can be used for two different thicknesses. For example one set is used for joints on panels of thickness of 7mm-6mm; and a second set for thickness of 5mm-4mm. It also takes about 3
20 hours to replace a set of cutting tools then several additional hours to set up the cutting machine with the new set of tool. Subsequently several test runs are made and products evaluated to fine tune the tool and machine setting before full scale production can recommence. If the only adjustment required is to change the depth of cut then there is no cost for new cutting tools and the downtime is reduced to a total of about 1 hour. A further
25 benefit of this is that relative small manufactures and able to afford to produce relative small production runs of at low cost and thus compete with larger manufactures. This may increase competition and thus in turn benefit the consumer.

With reference to Figures 24a-26e a semi floating/semi direct stick surface covering system may be provided by a plurality of substrates 12 incorporating any one of the joints
30 systems 10 as hereinbefore described and further incorporating a quantity of the re-stickable adhesive 300 bonded to the first major surface 16. The re-stickable adhesive 300 is used in conjunction with a sealant or sealing membrane (not shown) which is applied to an underlying surface onto which the adhesive 300 is to be bonded. Many sealants are commercially available which may perform this function. Such sealants may include for
35 example BONDCRETE™ or, CROMMELIN™ concrete sealer. The type of sealant used is simply dependent on the type of surface onto which the semi-floating surface covering system is to be used. The purpose is to prevent the generation of dust which may otherwise interfere with the bonding strength of the blue adhesive 300.

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Others have in the past used glues to adhere substrates to floors. In particular adhesives have been used to glue wooden floor boards to an underlying surface. However to the best of the inventor's knowledge, all such systems use glues which are specifically designed to set or cure to a solid unyielding bonded layer. In the art of timber or wooden
5 flooring, this is known as "direct stick" flooring. Some have proposed to utilize adhesives which take up to an hour or two to set or cure to enable installers to move the flooring panels during installation to ensure correct alignment. Indeed others propose using adhesives which may take up to 28 days to fully cure or harden.

Some consumers prefer direct stick flooring to floating flooring as it provides a
10 harder more solid feel and significantly does not provide bounce when being walked on and does not generate noise such as creaking or squeaking. A disadvantage however of the direct stick flooring is that it is very messy to apply, and once the adhesive has cured, which it is specifically designed to do, removal and/or repair of one or more damaged panels is problematic. The removal of a direct stick panel generally requires the use of power tools to
15 initially cut through a section of the panel, and then much hard labour in scraping the remainder of the plank and adhesive from the underlying subsurface. This generates substantial dust and noise and of course usually comes at substantial expense due to the associated time required.

Use of the re-stickable adhesive as described hereinabove with substrates 12
20 incorporating the joint system 10 provides a semi-floating surface covering system having the benefits of both traditional floating surface coverings and direct stick coverings but without the substantial disadvantages of direct stick surface coverings. Specifically, the use of the re-stickable adhesive 300 eliminates bounce and noise often found with conventional floating flooring, but still provides a degree of cushioning due to the flexible and elastic
25 characteristics of the adhesive which does not set or cure. Further the characteristics of the adhesive also enable movement of substrates/panels 12 due to changes in environmental condition such as temperature and humidity. This is not possible with direct stick flooring. Indeed recently, the world market has been having problems with direct sticking of compressed bamboo substrates due to the completely rigid and inflexible bond created by
30 the traditional adhesives. Accordingly, should the compressed bamboo need to move or expand due to variations in environmental conditions it is restricted from doing so by the direct stick adhesive. Consequently it has been suggested by multiple flooring associations around the world that compressed bamboo should not be direct stuck to substrates but limited to application in floating floor systems which enable it to move in response to
35 dynamic seasonal changes.

The provision of the re-stickable adhesive also enables for the take up of undulations or variations in the underlying surface to which it is applied. This is facilitated by providing the adhesive 300 in beads or strips of a thickness measured perpendicular to the

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major surfaces 14, 16 of between 1 – 6mm and more particularly 2 – 4mm. In addition to taking up variations in the underlying surface, the adhesive as mentioned above also provides acoustic benefits in: (a) eliminating noise and squeak which may otherwise arise from the bounce or deflection in traditional floating floors; (b) dampening vibrations (i.e. noise) transmission between adjacent panels; and (c) dampening vibrations (i.e. noise) transmission in multi-storey buildings from an upper level to an immediately adjacent lower level. This again is to be contrast with direct stick glues which due to their curing into a rigid bond, do not in any way dampen vibration or noise transmission.

The benefits and advantages of the use of re-stickable adhesive as herein before described in their own right give rise to a floor covering systems comprising substrates which may be tessellated and on which the adhesive is applied. Such systems do not necessarily require vertical joints systems of the type described hereinabove and may also be used with other types of joints systems. Indeed in certain circumstances, it is believed that the re-stickable adhesive concept gives rise to a surface covering system with joint-less substrates. Thus in one embodiment there would be provided a semi-floating surface covering system which comprises a plurality of substrates each substrate having first and second opposite major surfaces, the first major surface arranged to lie parallel to and face a surface to be covered; a quantity of re-stickable adhesive as herein before described bonded to the first major surface; and one or more release strips covering the removal adhesive.

It is envisaged in one embodiment that the adhesive 300 will be applied at the time of manufacture of the substrate 12. Thus in this embodiment a commercial product would comprise for example boxes of substrates 12 provided with one or more lines of adhesive material 300 covered with release strips 302. Installers are then able to simply install a surface covering by applying, if it does not already exist, a sealing coat or membrane to the surface 304, removing the release strip 302 and pressing the substrate 12 onto an underlying surface 304. In the event that the substrate also includes a joint system such as, but not limited to, the joint systems 10 et al as described herein above, then the installer would engage joints of adjacent panels during the installation process

In one example it is envisaged that the adhesive material 302 may be applied by rolling a strip or bead of hot melt pressure sensitive adhesive onto the major surface 16. Figures 24a-24c illustrate the adhesive 300 applied as strips of adhesive, while Figures 25a and 25b illustrate the adhesive 300 applied as beads B of adhesive. In embodiments where the re-stickable adhesive is provided by say GLUE DOTSTM adhesive dots, the dots can be applied by machine 16.

In the present embodiments the quantity of re-stickable adhesive 300 is applied in three spaced apart lines extending in a longitudinal direction L of a panel 12. However as will be explained in greater detail below, the adhesive material 300 may be applied in different configurations. The re-stickable adhesive material 300 is covered by one or more

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release strips 302. In the depicted embodiment a separate release strip 302 is applied individually to each individual line of adhesive material 300. However in an alternate embodiment, a single release strip having dimensions substantially the same as dimensions of the major surface 16 may be applied to the quantity of re-stickable adhesive 300. In that instance, when using the substrate 12, an installer need peel off only one release strip 302 rather than a number of separate release strips.

Figures 24c and 25b depict the use of the adhesive based surface covering systems on an underlying surface 304 which may, for example, be a concrete pad. In order to apply the panel 12 the release strips 302 are removed and the panel 12 is applied with surface 16 directed toward or facing the surface 304. By contacting the adhesive material 300 to the surface 304 and applying downward pressure, the panel 12 is adhered to the surface 304. Additional panel 12 can be likewise adhered to a surface 304 and tessellated to form a surface covering. The adhesive material 300 is sufficiently tacky and strong to adhere to the surface 304 with sufficient force to prevent lifting or separation between the panel 12 and surface 304 under normal use conditions. It is believed that providing the adhesive in the form of beads B (Figures 25a and 25b) may provide greater horizontal movement which typically occurs with changes in environmental conditions (e.g. temperature and humidity). This stems from the rounded nature of the beads B which may facilitate an easier rolling or shear rolling effect than the strips of adhesive.

Removal of a damaged panel (either with no joint system or with joint system of a type described herein above, i.e. a vertical joint system) can be performed in the same manner as described herein above in relation to Figures 6a-6s. That is, a damaged panel is removed vertically by use of one or more jacks 92. Figures 26a – 26e depict in part the removal of a damaged panel 12b of a semi-floating surface covering system which includes adjoining panels 12a and 12c. Each of the panels in the semi-floating floor system is formed with a joint system 10 which may be in accordance with any one of the embodiments of the joint system described above. In addition beads B of adhesive material 300 adhere the panels 12 to the underlying surface 90. In this particular embodiment there are no beads of adhesive material in between the joints Jm and Jf of the joint system 10. However in alternate embodiments such adhesive material may be provided. In terms of the process for removal of the panel 12b the provision of additional adhesive between the joints Jm and Jf is of no consequence. That is, the removal process remains the same as irrespective of whether or not adhesive material exists between the joints Jm and Jf.

Figures 26b – 26e show sequentially the steps of attaching a jack 92 to the damaged board 12b and subsequently operating the jack to lift the panel 12b from the surface 90. The sequence of steps and the method of their performance are identical to that described herein above in relation to Figures 6d – 6h. However in this instance due to the provision of the beads B of adhesive 300 the operation of the jack 92 to vertically lift the

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panel 12b also has the effect of initially flexing and stretching the beads B and subsequently causing the beads B to detach and lift from the underlying surface 90. This will occur generally in sequence as a jack is operated to lift the panel 12b from a region in the vicinity of the jack 92 outwardly to lower lying regions. Thus the first beads B to detach from surface
 5 90 will be those on either side of or otherwise closest to the shaft 96 of the jack 92. As the jack 92 progressively lifts the panel 12b the beads B of adhesive 300 nearest the most recently detached beads will now lift off the surface 90 and so on.

Generally, the entirety of the bead B will lift from the surface 90 and thus remain bonded to the substrate 12. In some instances, very small portions of the adhesive 300 may
 10 remain on the underlying surface 90. Once the jack 92 has been operated to the extent to lift the panel 12b so that all of the adhesive beads B have been detached, the remainder of the normal removal process as described in relation to Figures 6g – 6i; and indeed the entirety of the replacement processes shown and described in relation to Figures 6j – 6o is be employed to reinsert a fresh undamaged panel.

15 It will be noted that some of the beads B of adhesive 300 have separated from the adjacent panels 12a and 12c. During the reinstatement process, these beads which remain on the panels 12a and 12c will re-adhere to the underlying surface 90. In addition, of course when a fresh panel is joined to the panels 12a and 12c, the adhesive 300 on that fresh panel will now also adhesively bond to the surface 90.

20 As will be understood by those skilled in the art, this represents a huge advantage over direct stick flooring systems in terms of the ability to properly repair a damaged floor. The accepted industry standard for optimal repair of a damaged floor is to peel back all of the panels from the closest wall to the damaged panel or panels. With direct stick systems, this is such a difficult task, that generally repairers take shortcuts and simply attempt to
 25 remove and replace only the damaged panels. This makes it impossible to reconnect mechanical joints between panels. In the event of any dimensional variation in the panels either due to environmental expansion or contraction, or simply due to the inability to source dimensionally equivalent fresh panels, installation will generally also require the use of fillers to make good any gap between the existing panels and the newly instated panel.

30 A further feature of substrates incorporating having embodiments of the joint system 10 is the ability to reverse lay. Reverse laying has two meanings in the art. One meaning refers to the ability to lay from both sides of a panel. For example consider a first panel approximately midway between parallel walls in a room. The ability to reverse lay enables two installers (or two teams of installers) to lie in opposite directions away from the
 35 first panel. This naturally greatly reduces the installation time. This is used with direct stick panels and has the benefit of enabling run out to be amortised between opposing walls of a room to provide a superior visual appeal. Reverse laying with direct stick is possible because a layer can fix with glue a first panel in an optimum position in or near the middle of

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the room to minimise run out near the walls. Additional panels can be stuck down form opposite side of the first panel. This cannot be done with floating floors because a first panel placed in an optimum position is not fixed, it floats, and thus cannot be used as a base to lay in opposite directions.

5 The other meaning of reverse lay refers to the ability to engage panels 12 which extend perpendicular (or some orientation other than parallel) to each other. This enables for example the ability to lay in say a herring bone pattern.

Current prior art, even with direct stick, makes it reasonably difficult to reverse lay flooring because traditionally one must lay from the female joint away. This is because in
10 the prior art lay down process the male joint is traditionally 50+% shorter than the female joint thus creating a less extreme angle needed or not needed to engage the male portion into the female portion into a locked horizontal plane. As the present joint system 10 is vertical, there is no lay down process. Rather the vertical nature of the joint system 10 makes it exceptionally easy to engage panels from either side, either placing a male joint on
15 an exposed female joint, in order to lay in one direction, or sliding the female joint under a male joint of a previously laid panel in order to lay in the reverse direction.

Figures 27a and 27b illustrate the above aspects or meaning of reverse laying pictorially. Figure 27a shows a floor plan 400 of a building in which a floor comprising a plurality of panels 12 is laid. Figure 27b illustrates in enlarged view detail A of Figure 27a
20 encompassing a portion of a passageway of the building. Consider the laying a traditional floating floor in the building. The layer would choose a wall for example wall 402 in a room 403 as a starting wall against which a first panel 12a is laid. It is well known that walls in buildings are never perfectly parallel or square to each other and may be out of alignment by up to 100mm or more. In the current floor plan, wall 404 runs generally but not exactly
25 parallel to a wall 402 and may be out of alignment by a length of say 100mm between opposite ends of the walls 402 and 404. Thus as the layer lays additional panels 12b, 12c, etc up to panel 12p the misalignment or divergence between the walls 404 and 402 becomes apparent as the edge of panel 12p does not abut the wall 404. Rather, there is a divergence between the edge of panel 12p and wall 404 requiring the provision of obliquely
30 cut panels 12q laid end to end to make up the gap between the panels 12p and wall 404. (It should be explained that it would be unusual for a single panel to be of a length sufficient to extend for the full length of the room 403. Thus reference to panels 12a, 12b etc is made solely for the purposes of ease of description. Ordinarily for example panels 12a, 12b etc shown in room 403 would comprise a plurality of panels joined end to end.)

35 The substantial misalignment between the walls 402 and 404 is highlighted by the obliquely cut panel 12q. It will be also seen in Figure 27a that there are openings 406 and 408 for example as doorways in wall 404 into room 410 and hallway 412. The panels laid in room 410 and 412 follow the same direction and alignment with the panels 12 in the room

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403. This then continues on the degree of misalignment between the panels and the walls of the house.

It will also be seen however that in other areas for example rooms 414, 416, and hallway 418 the panels 12 are laid generally perpendicular to the panels laid in the other rooms. This is provided as an illustration of the second form or type of reverse laying.

With the use of the semi-floating semi-direct stick floor system as described above in relation to Figures 24a – 25b, a layer can now utilise a centre line 420 of say room 401 as a starting point for the laying of the first panel and then reverse lay in opposite directions. By doing so the misalignment between the walls 402 and 404 from a visual perspective can be minimised by amortising the run out in the panels 12 immediately adjacent the walls 402 and 404. This can be seen by the center line 420 passing obliquely through the panels 12i and 12j which are shown in positions provided by traditional laying practice for floating floors.

Now that embodiments of the vertical joint system and surface covering system have been described in detail it will be apparent to those skilled in the art that numerous modifications and variations can be made without departing from the basic inventive concepts. For example embodiments are decided in relation to wooden flooring panels. However the systems are applicable to many different materials and may also be applied to surfaces or structures other than floors. For example panels incorporating the joint system may be made from plastics material to treat the LVT (“luxury vinyl tile”) market or may be provided on base substrates made of plastics materials to which are attached face panels of other material such as carpet or ceramic tiles. In this embodiment the resultant panel has a laminate type structure where the base includes embodiments of the joint system and the face panel is provides a consumer with the desired finish. It will also be apparent many of the features of different embodiments are interchangeable or can be additionally applied. For example the recess 42 can be applied to each and every embodiment of the joint system. As can: an opposing recess of the type shown as recess 42b in Figure 22a; or indeed additional recesses 42b, 42c and 42d. Further the re-stickable adhesive 300 may be applied to such recesses. Also the jack 92 is described as a screw jack. However other types of jacks or lifting system can be used such as lever jack or pneumatic or hydraulic operated systems. Further the joint systems 10 are largely described in application to elongated rectangular panels. However they can be applied to panels of any shape that can tessellate. For example the joint system may be applied to square, hexagonal or triangular panels. Also there is no need for the panels to be of identical shape and/or size. All such modifications and variations together with others that would be obvious to persons of ordinary skill in the art are deemed to be within the scope of the present invention the nature of which is to be determined from the above description and the appended claims.

Claims

1. A vertical joint system for a substrate having an opposed major first and second surfaces, the joint system comprising:

5 first and second non-symmetrical joints, the first joint extending along two adjacent sides of the substrate and the second joint extending along two further adjacent sides of the substrate, the first and second joints configured to enable two or more substrates with like joint systems to engage each other in response to a force applied in an engagement direction which is perpendicular to the major surfaces and to enable engaged substrates to be disengaged by lifting a first
10 substrate in a direction opposite the engagement direction to facilitate rotation of adjacent engaged substrates along opposite sides of the first substrate to lie in planes declined from the first substrate and subsequently applying a force in the engagement direction to the second joints of the engaged substrates,

wherein the first and second joints are each provided with two laterally spaced
15 transversely extending surface portions configured to enable the first joint of one substrate to engage the second joint of a second substrate with the two transversely extending surfaces of the first joint located relative to the two transversely extending surfaces of the second joint to form respective first and second locking planes on an innermost and an outermost side of each joint to
20 inhibit separation of the engaged joints in a direction opposite the engagement direction,

wherein the first joint extends in the direction of insertion from an edge of the first major surface of the substrate toward the second major surface, and

wherein each of the transversely extending surfaces of the first joint lie inboard of
25 the edge.

2. The vertical joint system according to claim 1, wherein the first and second joints are further configured to enable the adjacent engaged substrates to rotate by up to 7° to 10° downward from the first substrate without disengaging or damage.

30 3. The vertical joint system according to claim 1 or 2, wherein the transversely extending surfaces are each provided as respective inflexion surfaces configured to enable the first joint of one substrate to engage the second joint of a second substrate with the two inflexion surfaces of the first joint engaging the two inflexion surfaces of the second joint on inner and outer most sides of each joint to form
35 respective first and second locking planes each of which independently inhibit separation of the engaged joints in a direction parallel to the engagement direction each locking plane lying parallel to the engagement direction and wherein the inflexion surfaces associated with each locking plane lie on both sides of that locking plane.

40 4. The vertical joint system according to claim 1 or 2, wherein the first joint is a male joint and the second joint is a female joint,

the male joint comprising a male protrusion extending generally perpendicular from the first major surface toward the second major surface and a male recess formed inboard of the male protrusion;

5 the female joint comprising a female protrusion extending generally perpendicular from the second major surface toward the first major surface and a female recess formed inboard of the female protrusion;

10 the male joint having a first male locking surface formed on a side of its male protrusion most distant from its female recess, a second male locking surface formed on a side of its female recess most distant from its male protrusion and a third male locking surface being a surface common to the male protrusion and male recess, wherein the first and second male locking surfaces comprise respective transversely extending surfaces of the first joint;

15 the female joint having a first female locking surface formed on a side of its female recess most distant from its male protrusion, a second female locking surface formed on a side of its male protrusion most distant from its female recess, and a third female locking surface being a surface common to the female protrusion and female recess, wherein the first and second female locking surfaces comprise respective transversely extending surfaces of the second joint;

20 the locking surfaces being configured so that when a male and female joint of two substrates are engaged, the first male and first female locking surfaces engage to form a first locking plane, the second male and second female locking surfaces engage to form a second locking plane, and the third male and third female locking surfaces engage to form a third locking plane located between the first and second locking planes each locking plane inhibiting separation of the engaged joints in a direction parallel to the engagement direction.

30 5. The vertical joint system according to claim 4, wherein each protrusion has a distal end surface and each recess has a root surface, wherein when respective joints of two substrates are engaged the distal end surface of the protrusions face the root surface of the recesses, and wherein the distal end surface of at least one of the protrusions has a generally convex configuration.

6. The vertical joint system according to claim 5, wherein the distal end surface of each of the protrusions has a generally convex configuration.

7. The vertical joint system according to claim 5 or 6, wherein the distal end surface of each of the protrusions has smoothly curved corners.

35 8. The vertical joint system according to any one of claims 1 to 3, wherein the first and second joints are configured to create three locking planes when mutually engaged, each locking plane lying parallel to the engagement direction and inhibiting separation of engaged joints in a direction opposite the engagement direction.

9. The vertical joint system according to any one of claims 1 to 8, wherein the protrusions and recesses are configured to facilitate self-alignment of two substrates when one of the substrates is joined to another of the substrates.
10. The vertical joint system according to any one of claims 1 to 9, wherein the first and second joints are arranged to engage by applying a downward force while traversing along the two substrates.
11. The vertical joint system according to any one of claims 1 to 10, further comprising a lubricant provided on surfaces of one or both of the first and second the joints.
12. The vertical joint system according to any one of claims 1 to 11, wherein the first and second joints are arranged so that when a first joint is engaged with a second joint by the application of the force in the engagement direction the force causes a relative lateral motion of the joints toward each other.
13. A surface covering system comprising a plurality of substrates, each substrate having:
- opposite first and second major surfaces, wherein the first major surface is arranged to face an underlying support to be covered by the system; and
- a vertical joint system, the vertical joint system comprising:
- i. first and second non-symmetrical joints extending along opposite sides of a substrate, the first joint extending from the first surface toward the second surface and second joint extending from the second surface toward the first surface, a first joint locking surface being provided on an outermost side of the first joint, the first joint locking surface being arranged to engage with a second joint locking surface provided on an innermost side of the second joint and wherein the first joint locking surface does not extend laterally beyond an edge of the first major surface of a side of the substrate along which the first joint extends;
- ii. the first and second joints being configured to enable two or more substrates to engage each other in response to a force applied in an engagement direction which is perpendicular to the major surfaces and to enable engaged substrates to be disengaged by:
- (a) lifting a first substrate in a direction opposite to the engagement direction to facilitate rotation of adjacent engaged substrates along opposite sides of the first substrate to lie in planes declined from the first substrate; and
- (b) subsequently applying a force in the engagement direction to the second joints of the engaged substrates.
14. The vertical joint system according to any one of claims 1 to 12, wherein the transversely extending surfaces comprise cam surfaces arranged to facilitate the rotation of the adjacent engaged substrates.

15. A surface covering system comprising a plurality of substrates where in each substrate is provided with a vertical joint system in accordance with any one of claims 1 to 12.
- 5 16. The surface covering system according to claim 13 or 15, wherein the substrate is made from a material selected from the group consisting of solid timber, engineered timber, manufactured wood laminate, Bamboo, plastics, and vinyl.
17. The surface covering system according to any one of claims 13, 15 and 16, wherein the substrates are rectangular, square, triangular or hexagonal in shape.
- 10 18. The vertical joint system according to any one of claims 4 to 12, wherein the first and second joints are arranged such that, when two substrates are juxtaposed in a skewed manner so that near one end of the two substrates the first joint of one substrates overlies the second joint of the other substrate, and at an opposite end the joints are laterally spaced apart, the two substrates are brought together to facilitate the self-alignment by application of downward force at a first location between the one end and a location where the joints are arranged so that the male protrusion lies directly above the female protrusion.
- 15 19. The surface covering system according to claim 13, 16 or 17, further comprising:
- 20 at least one a jack demountably attachable to the first substrate the jack comprising a shaft arranged to pass through a hole formed in the first substrate to bear on the underlying support, the jack being operable to extend the shaft through the hole to thereby lift the first substrate from the underlying support.
- 25 20. The surface covering system according to claim 13, wherein the joint locking surfaces comprise cam surfaces arrange to facilitate the rotation of the adjacent engaged substrates.
21. The surface covering system according to claim 13, wherein the vertical joint system is in accordance with any one of claims 1 to 12.
- 30 22. A wall or ceiling covering system comprising a surface covering system according to any one of claims 13, 15-17, and 19.
23. A wall or ceiling covering comprising a plurality of panels, each panel provided with a joint system according to any one of claims 1 to 12.
- 35 24. A method of removing a first floor substrate from a floor covering formed from a plurality of floor substrates which are joined together by joint systems provided on each of the floor substrates, the first floor substrate being joined on all sides with the other floor substrates in the floor covering, the method comprising:
- vertically lifting the first floor substrate from the floor covering by applying a lifting force directly on the first substrate in manner wherein the first floor substrate initially lies parallel to the floor covering and remains substantially parallel to the

floor covering during the vertical lifting to effect rotation of the other substrates on the sides of the first substrate and a partial disengagement of the other substrates.

25. The method according to claim 24, further comprising:

- 5 applying a downward force on a first of the other substrates to fully disengage the first other substrate from the first substrate.

26. The method according to claim 25, comprising:

applying a downward force on the first substrate to fully disengage a second of the other substrates.

- 10 27. The method according to claim 26, comprising:

prior to applying the downward force on the first substrate, supporting the second of the other substrates.

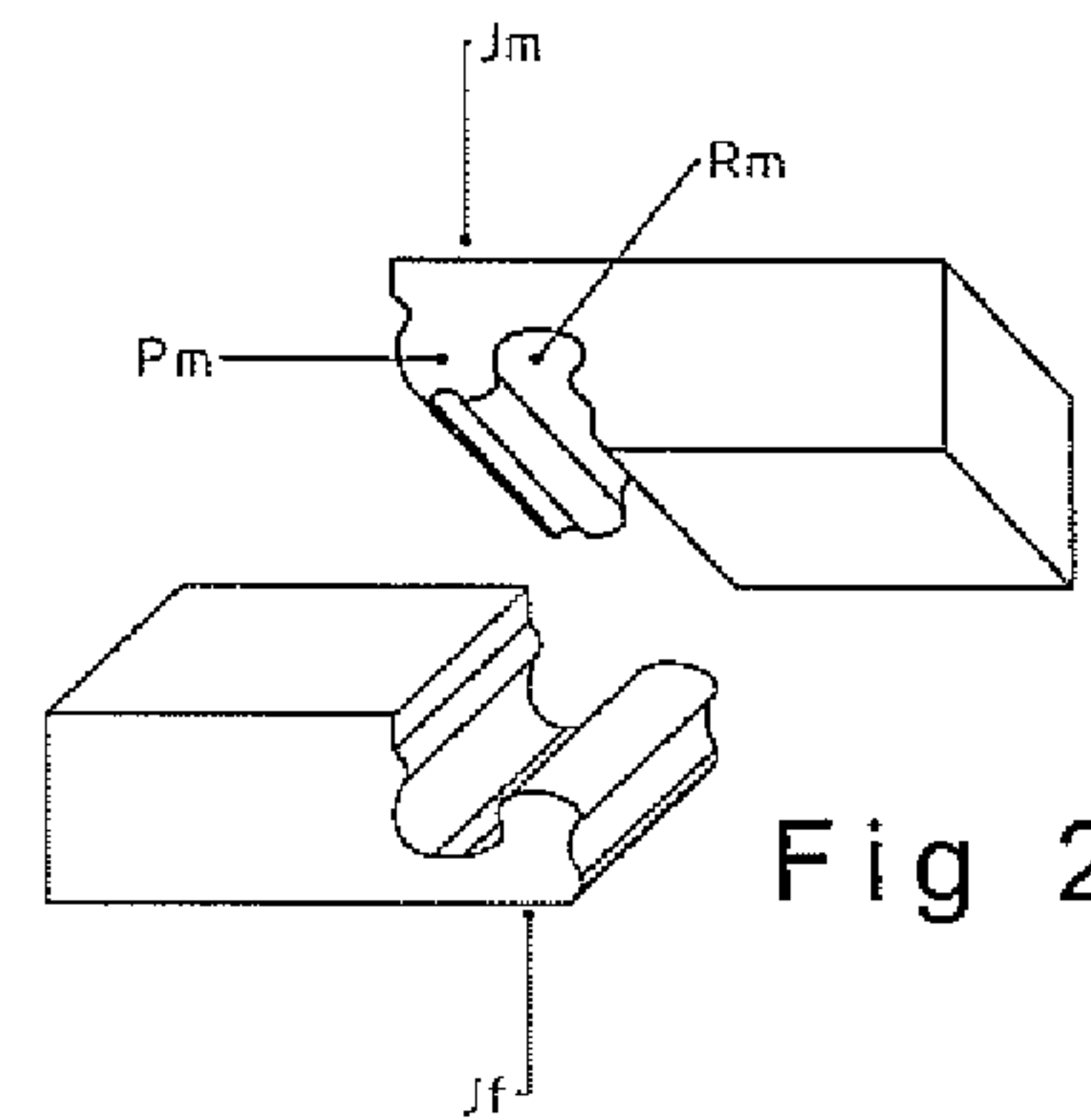
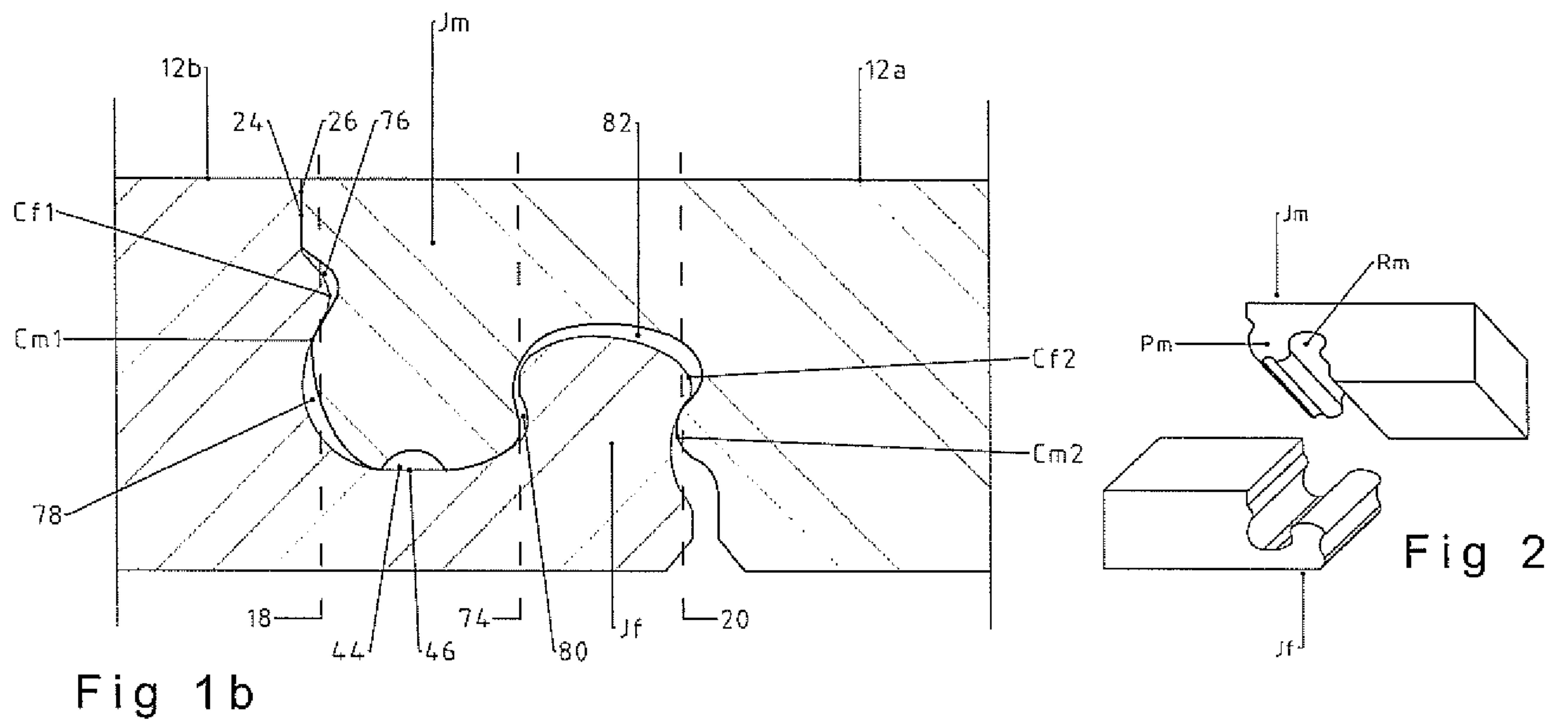
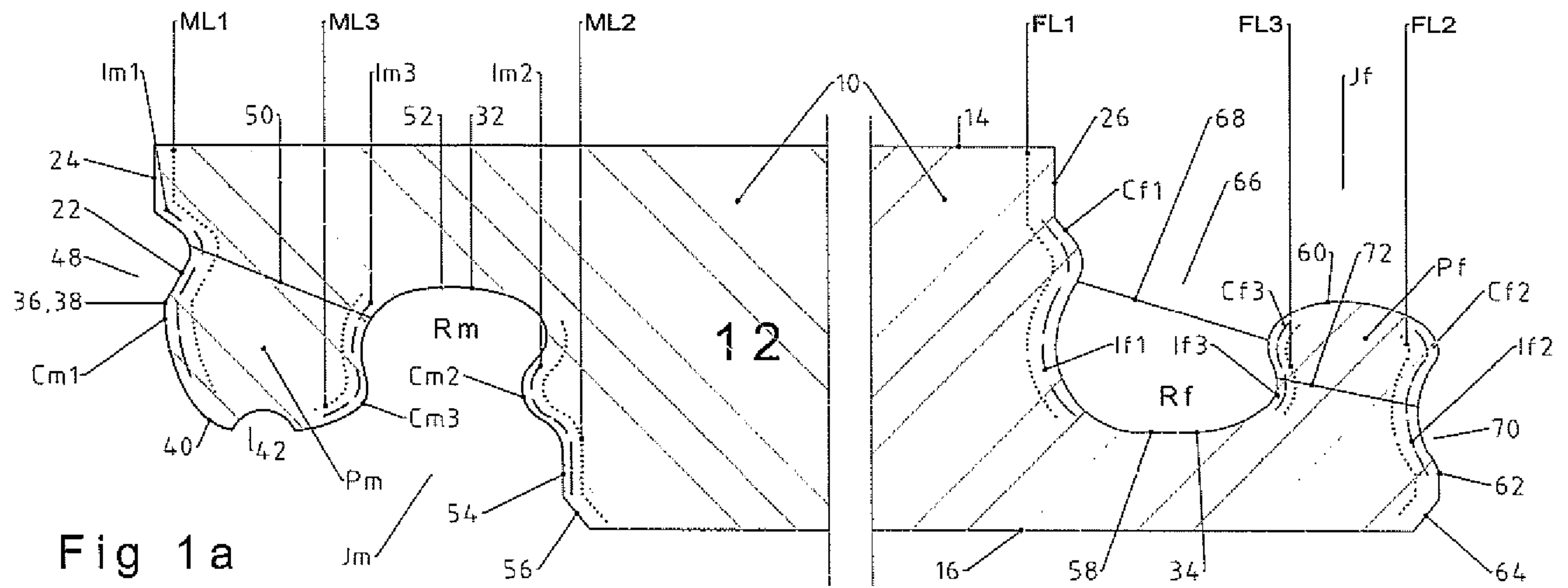
- 15 28. The method according to claim 27, wherein supporting the second of the other substrates comprises locating one or more blocks between the second of the other substrates and a support on which the floor is laid.

29. The method according to claim 28, further comprising:

attaching a lifting device to the first substrate operable to lift the first substrate vertically, the lifting device arranged to self-support the first substrate when the first substrate is vertically lifted.

- 20 30. The method according to claim 29, further comprising:

forming a hole in the first substrate and locating a portion of the lifting device to extend through the hole and bear against a support on which the floor is laid.



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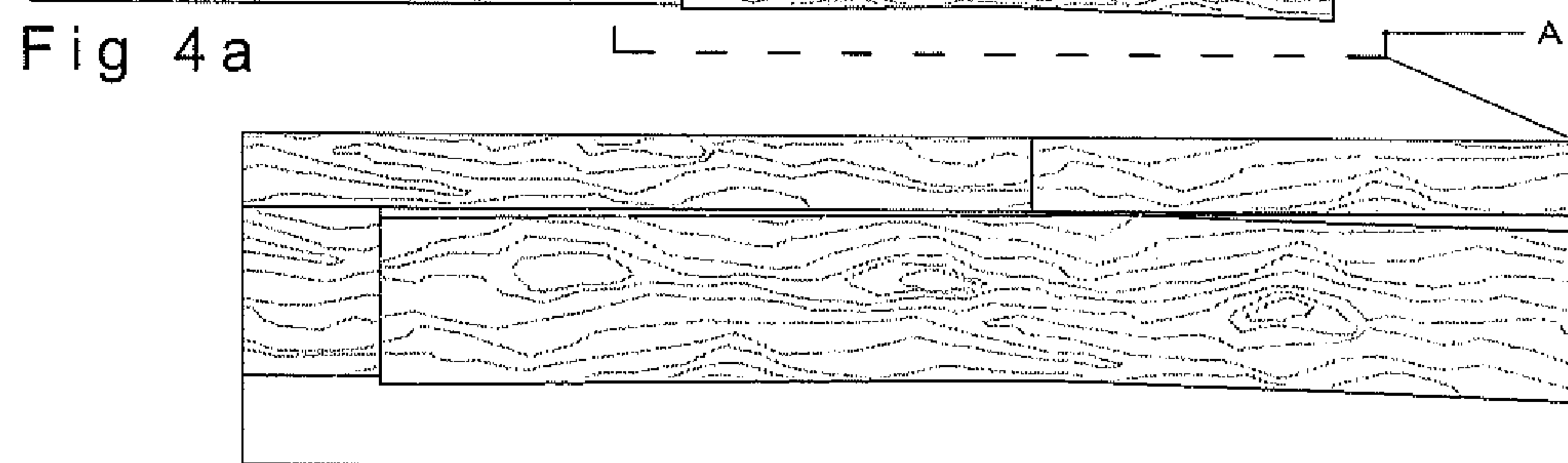
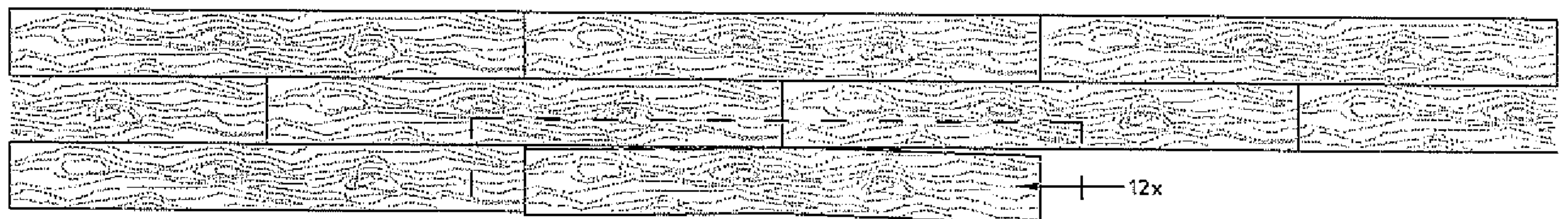
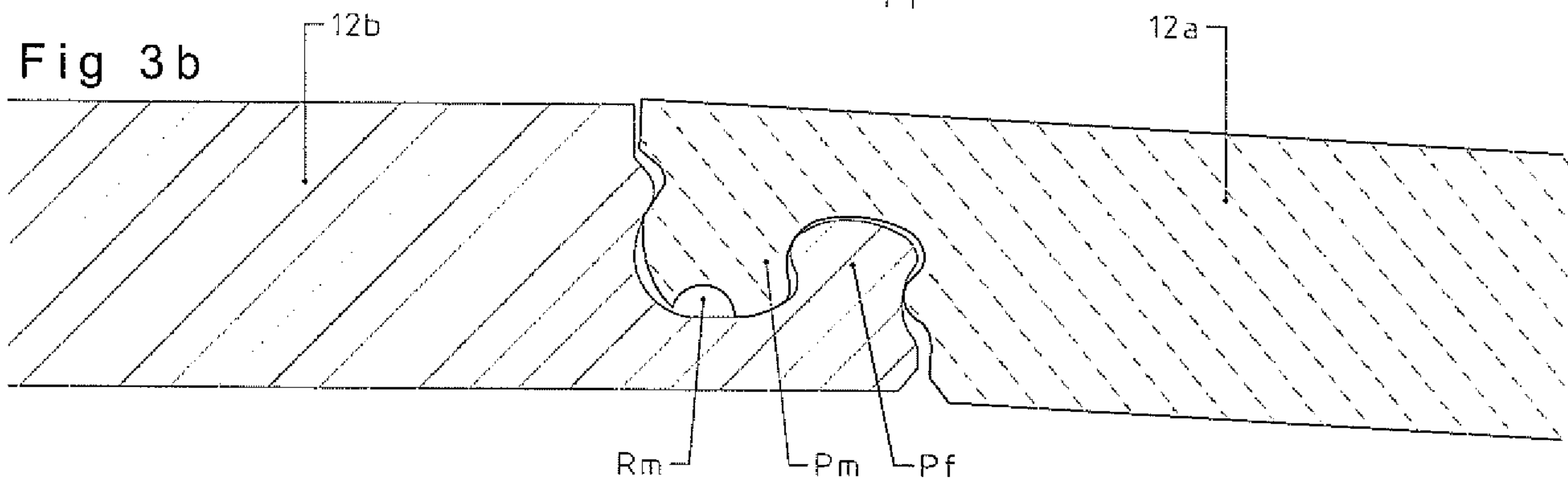
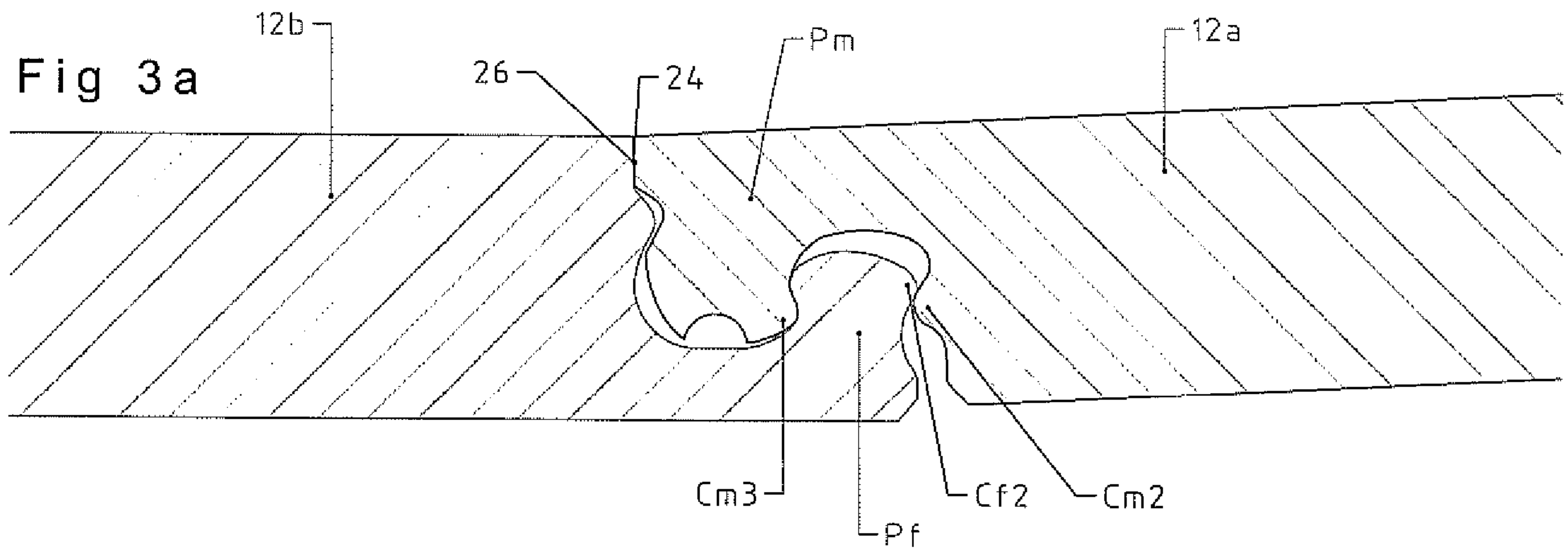


Fig 4 b

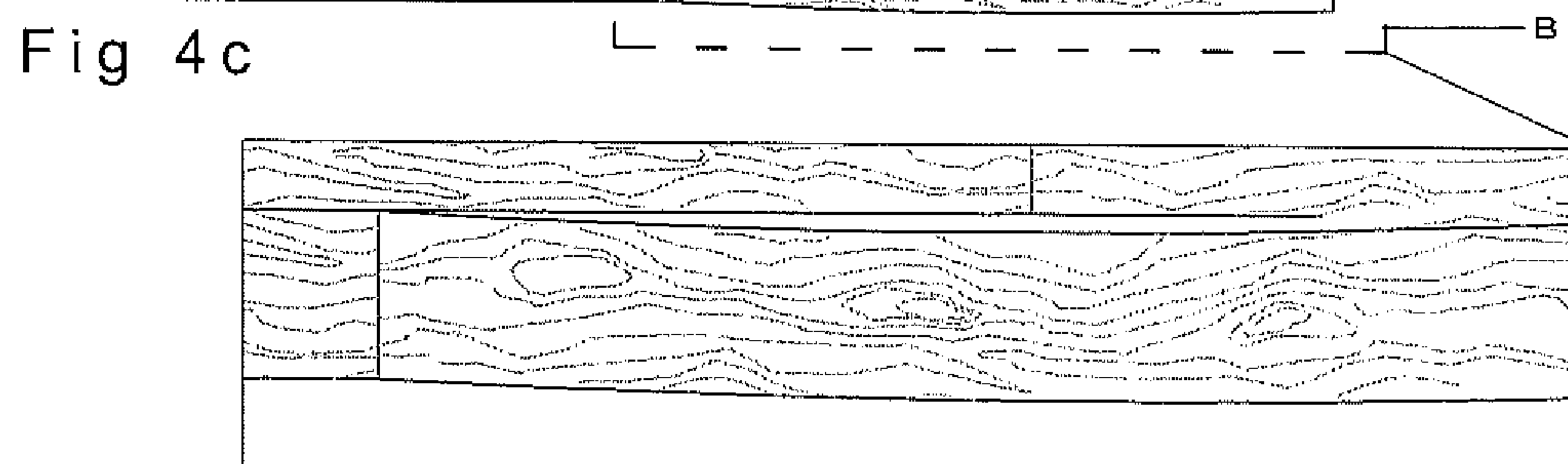
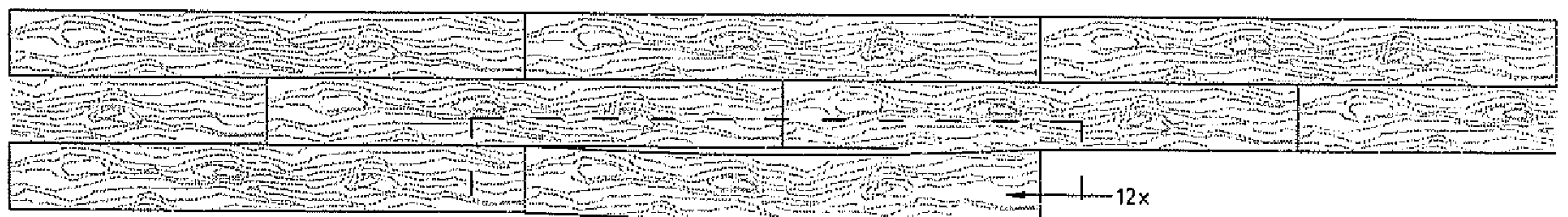
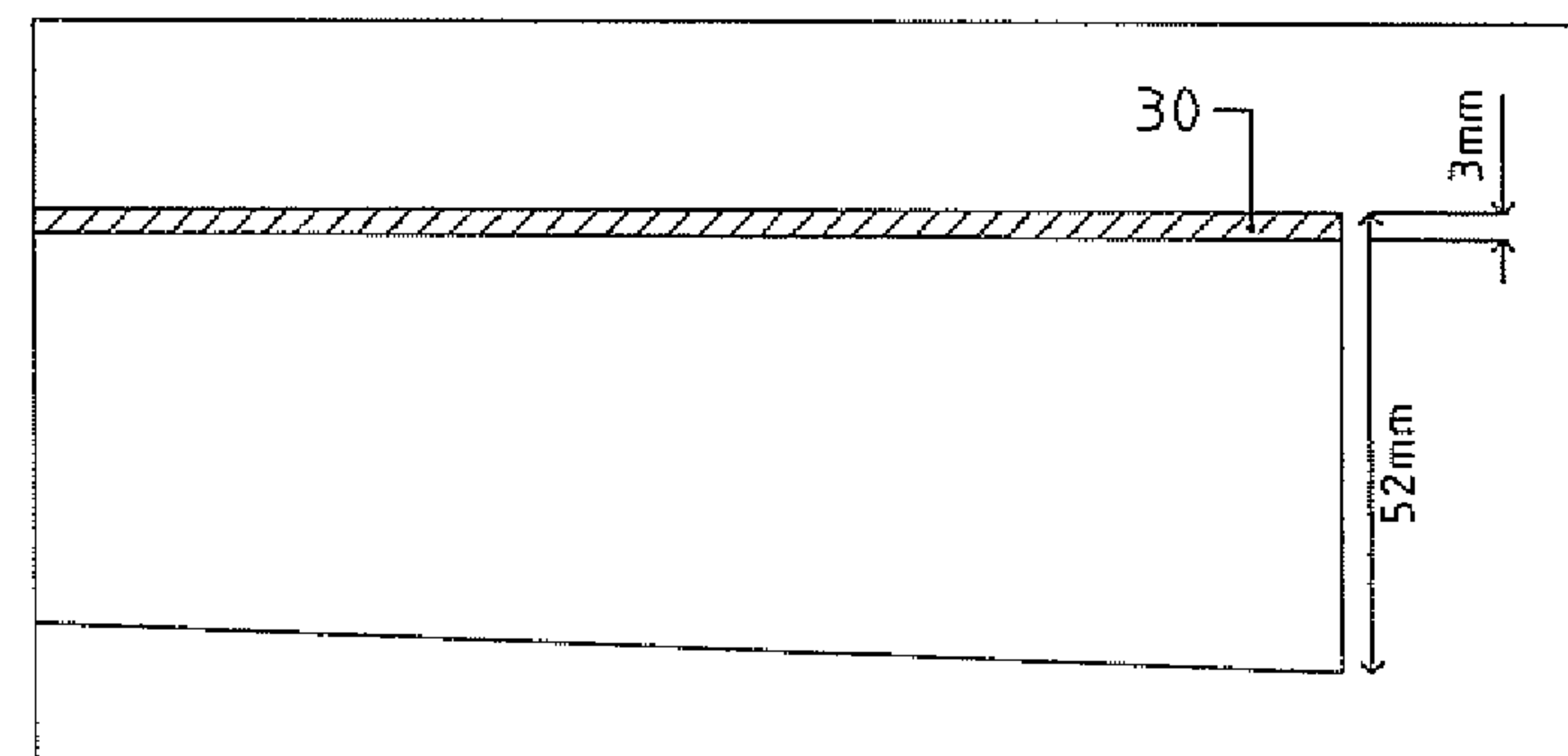
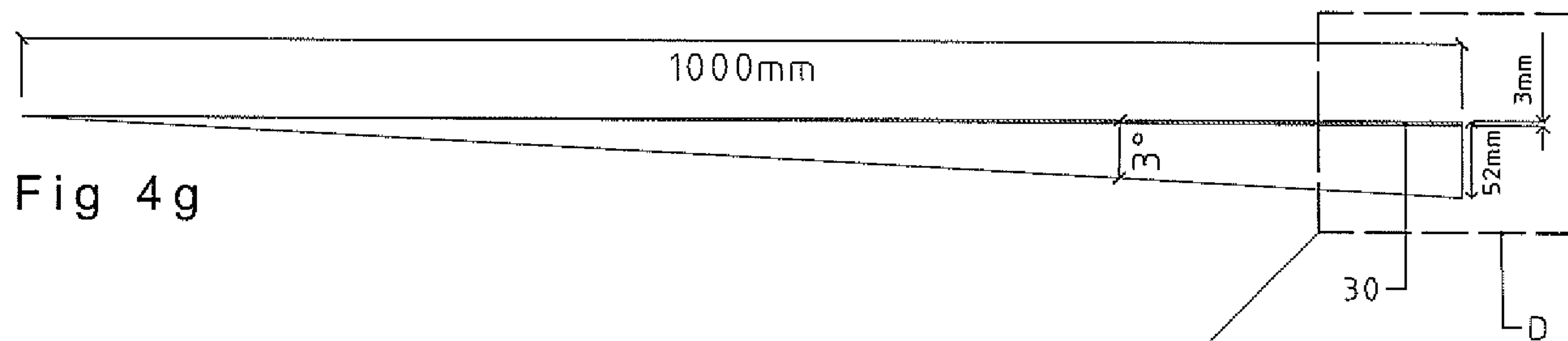
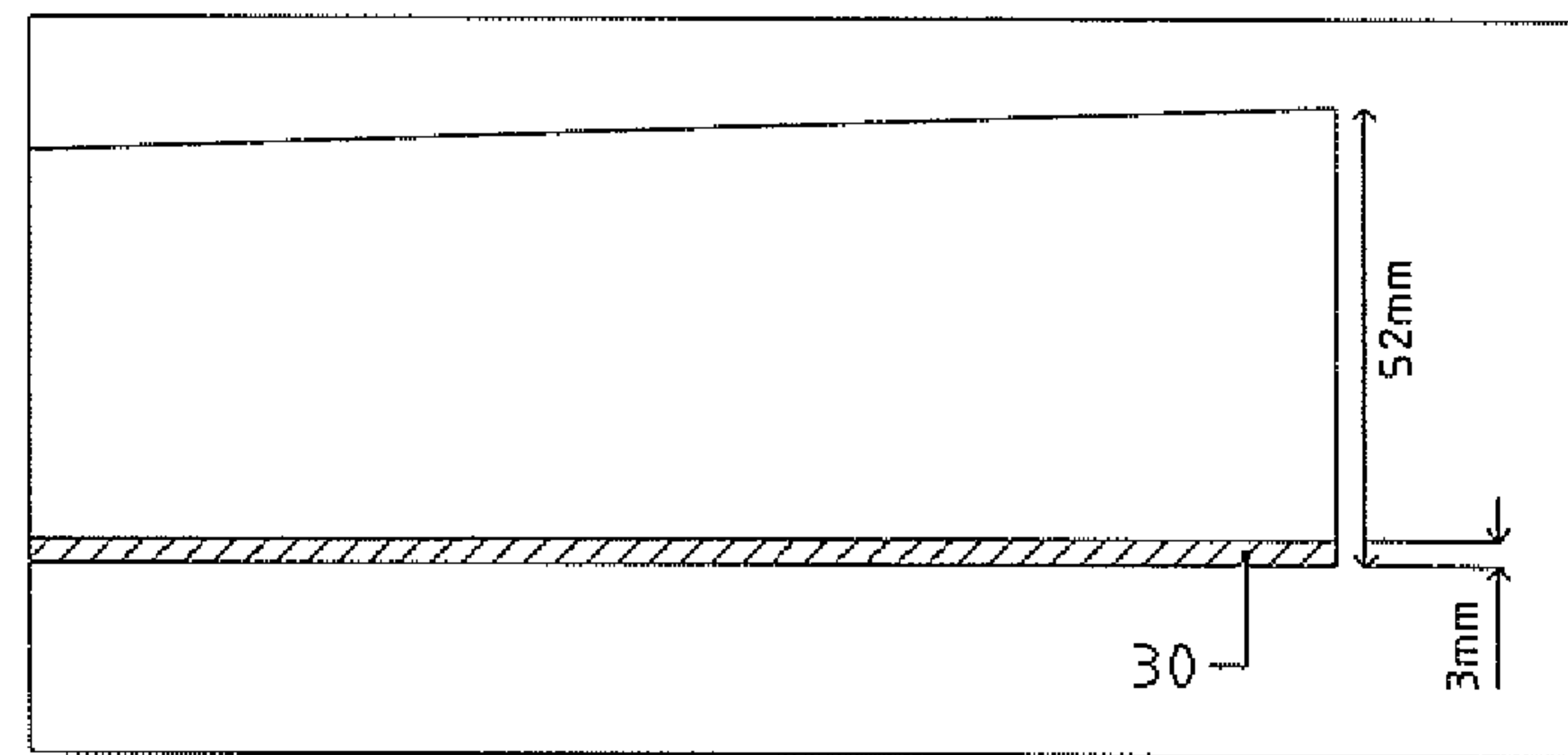
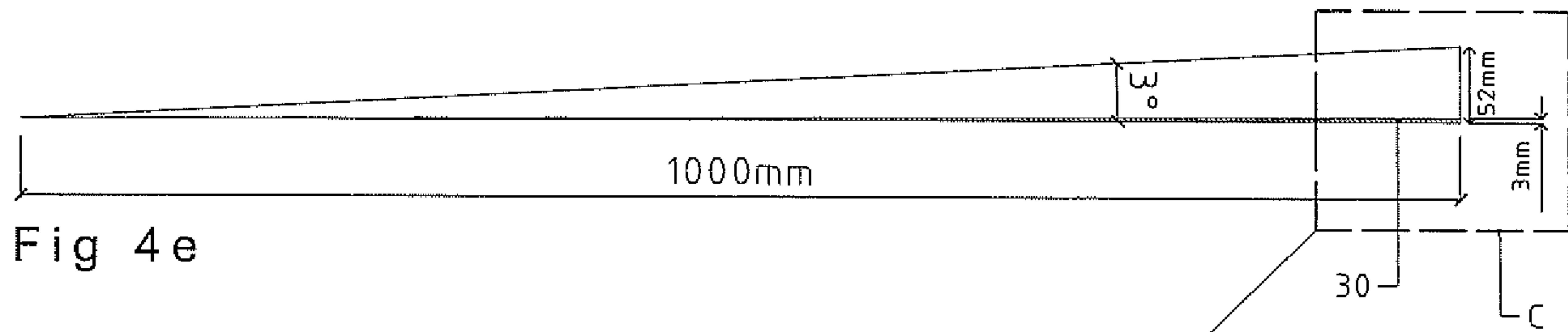
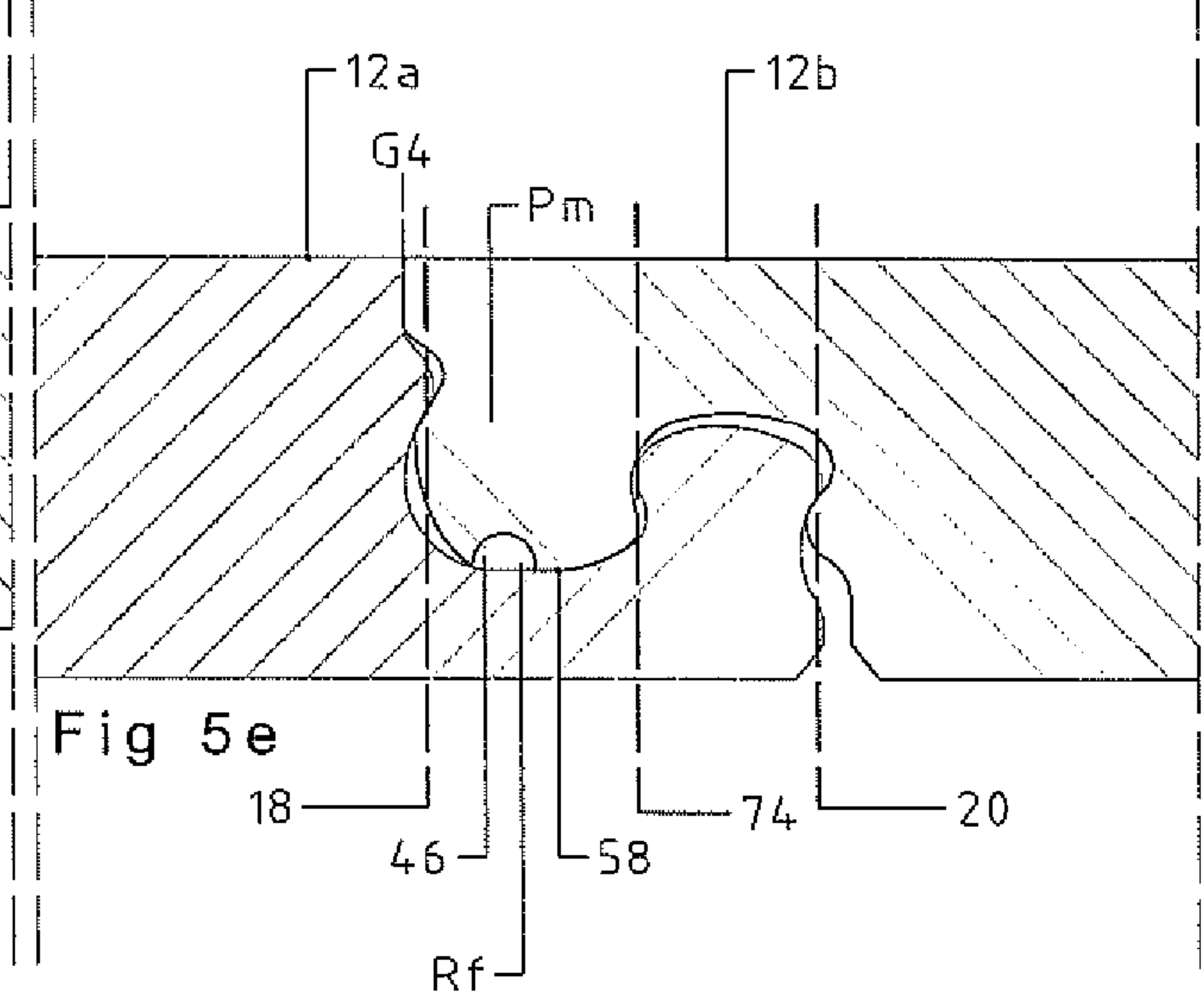
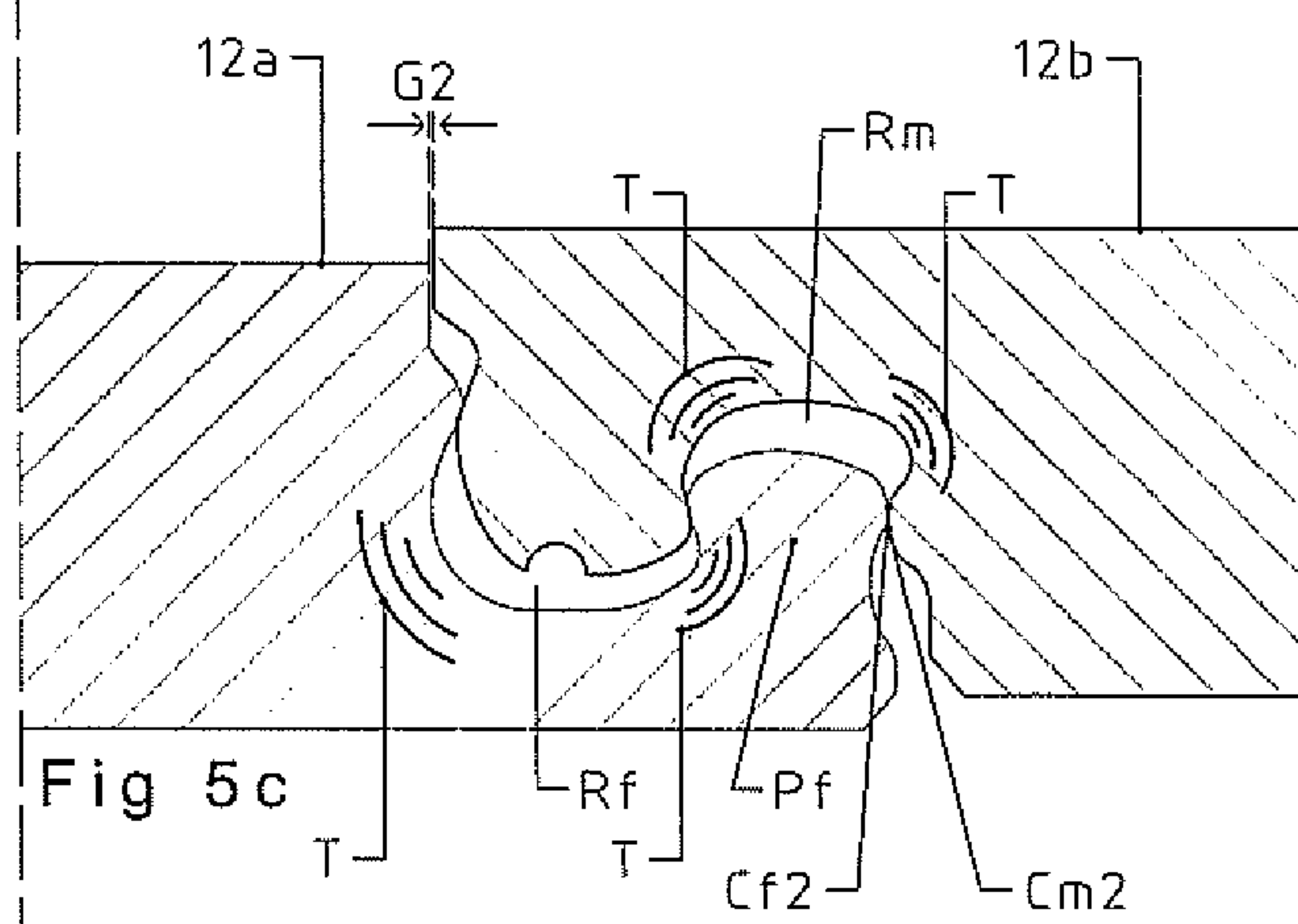
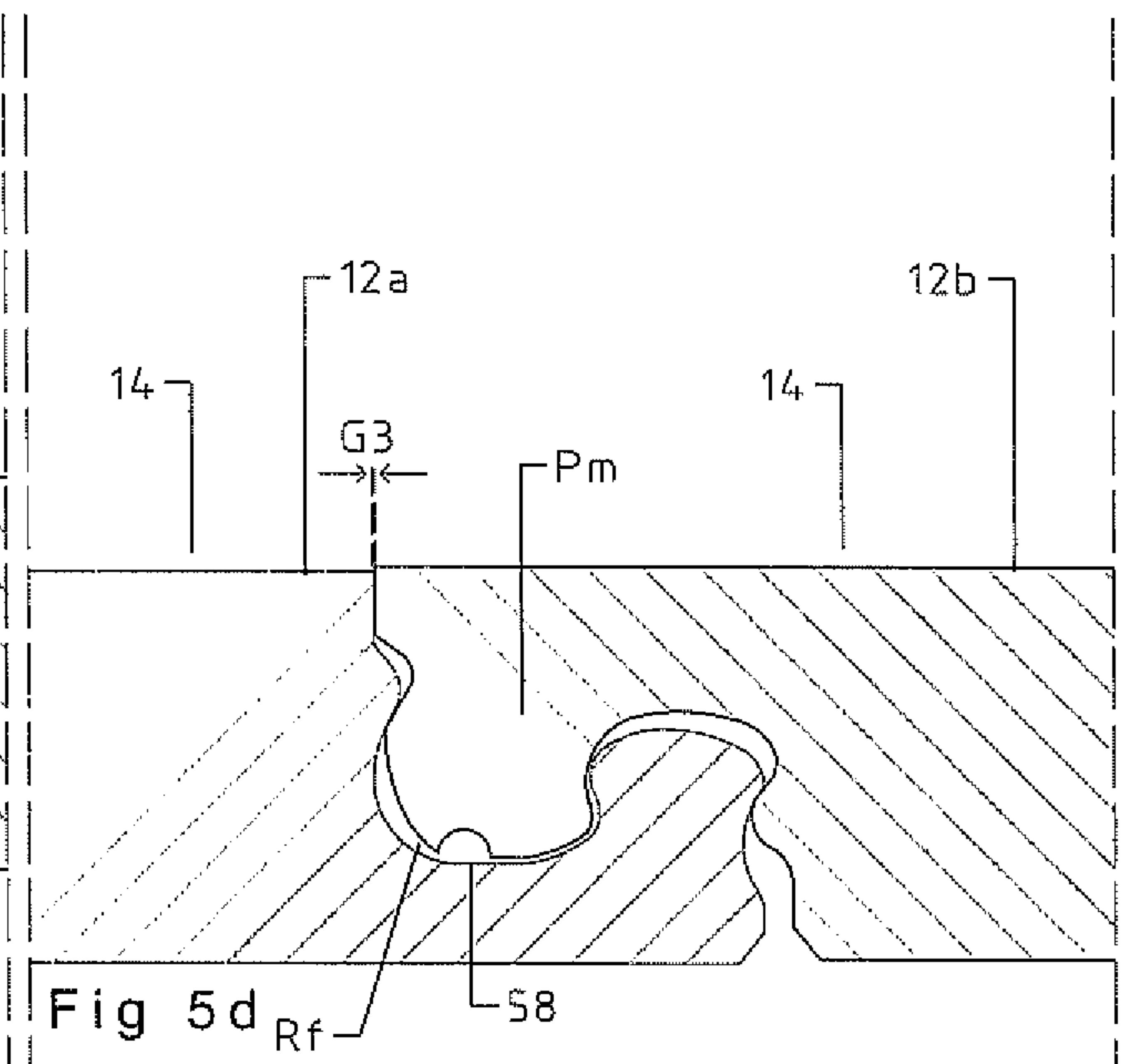
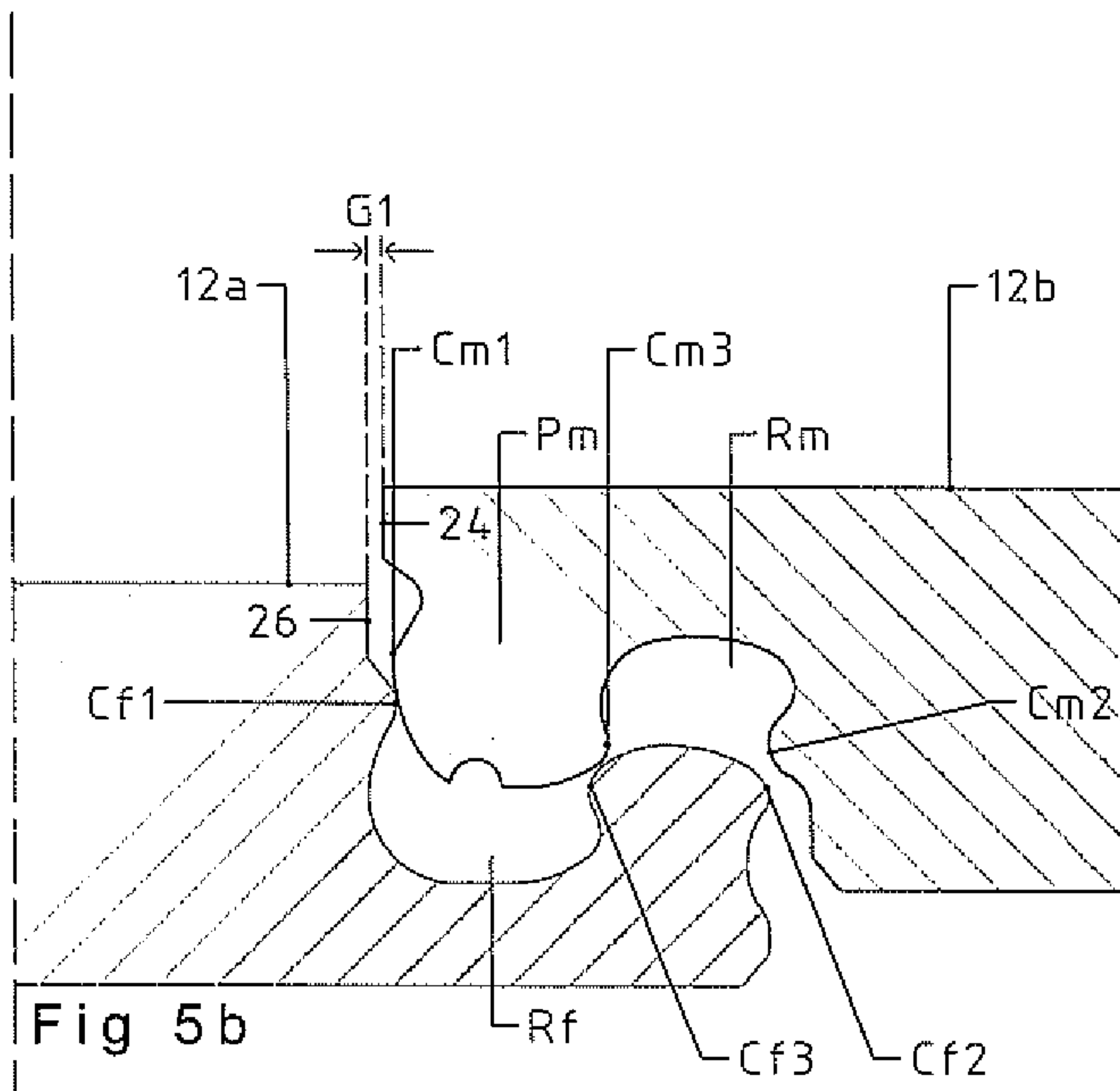
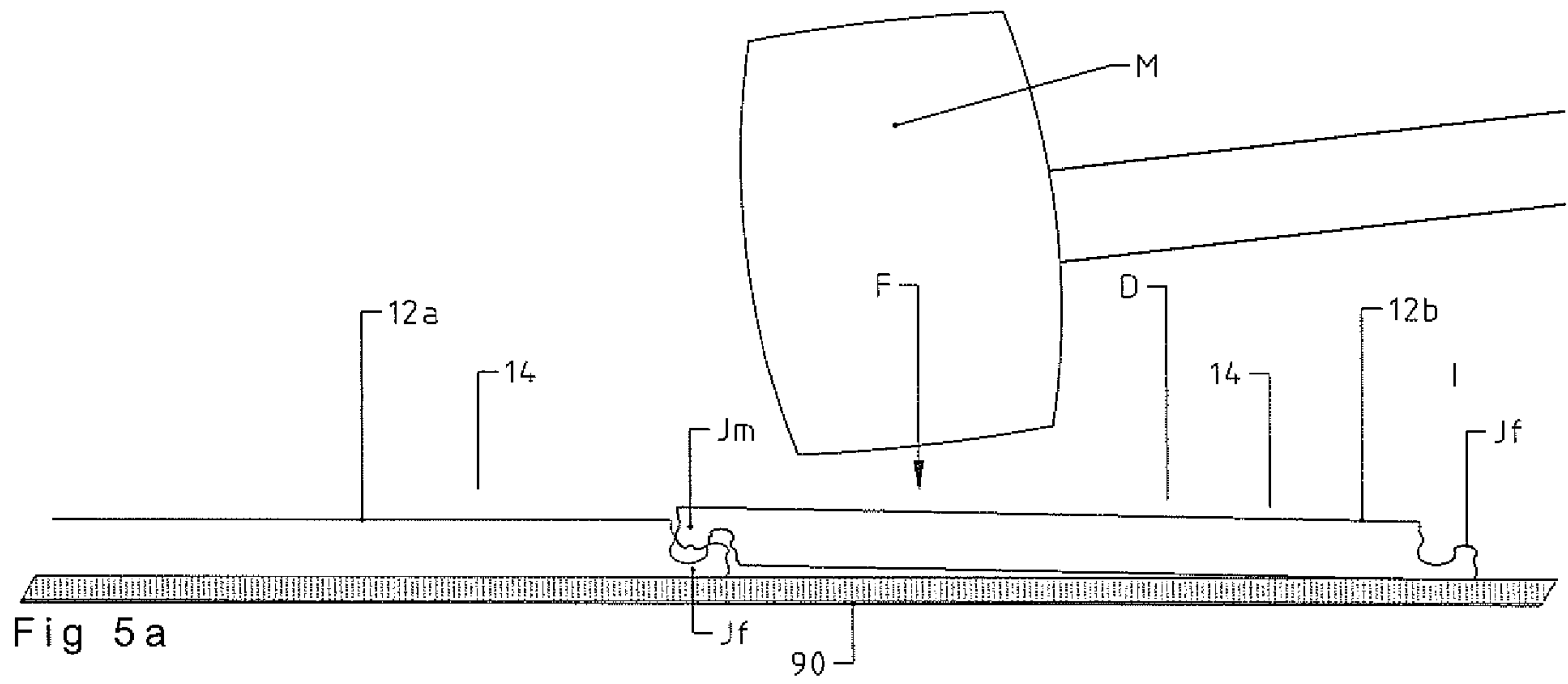


Fig 4d

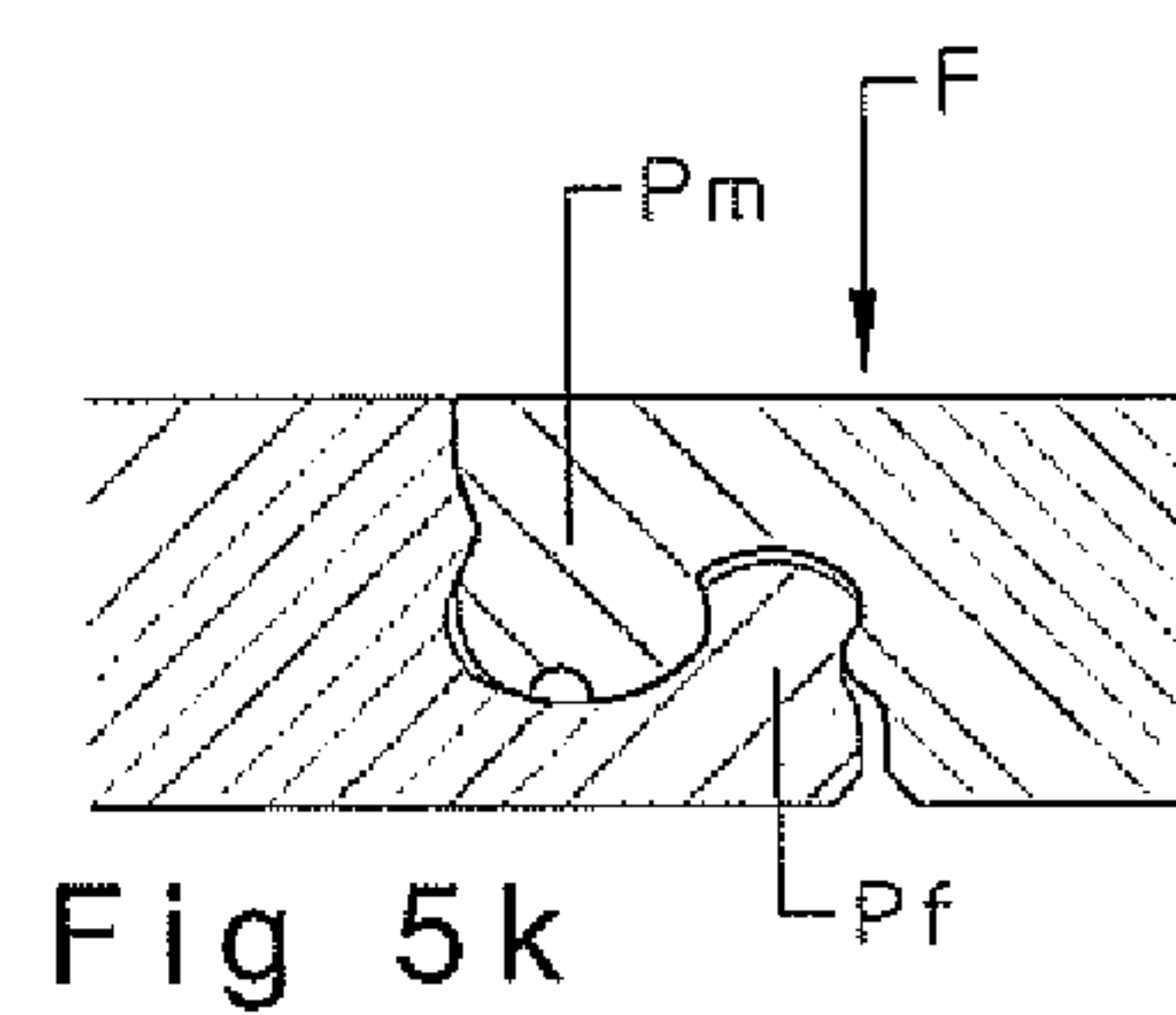
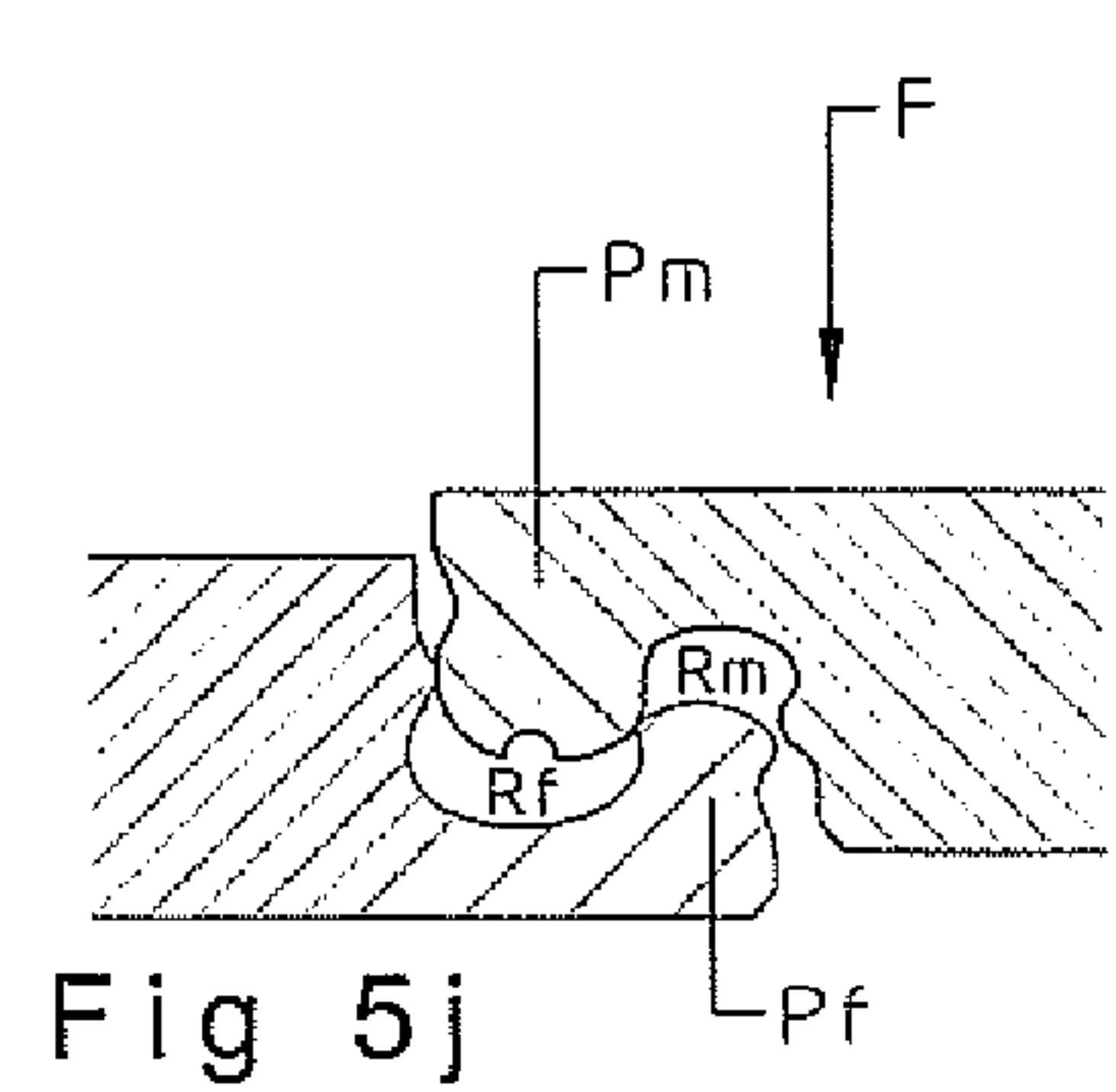
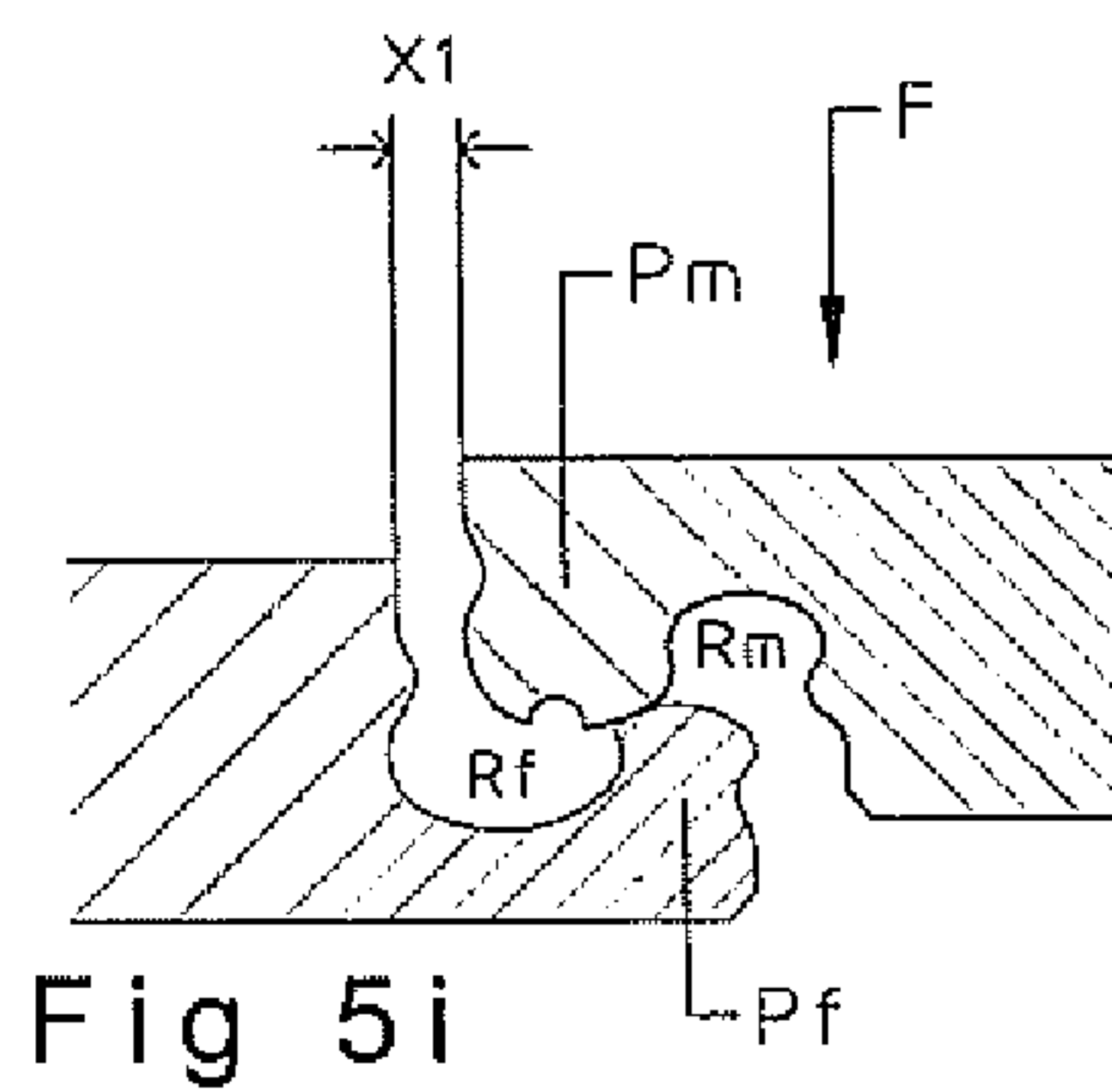
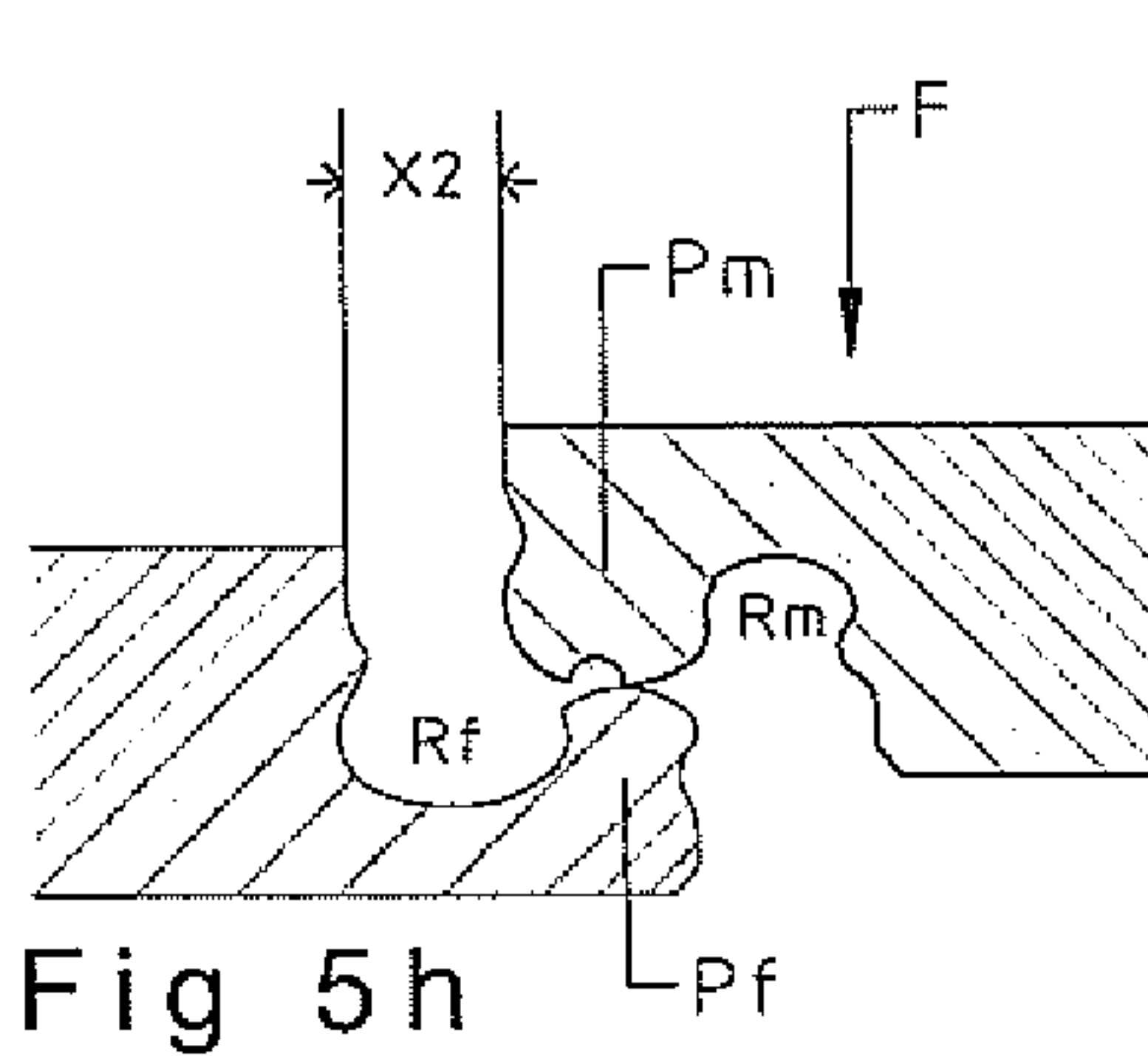
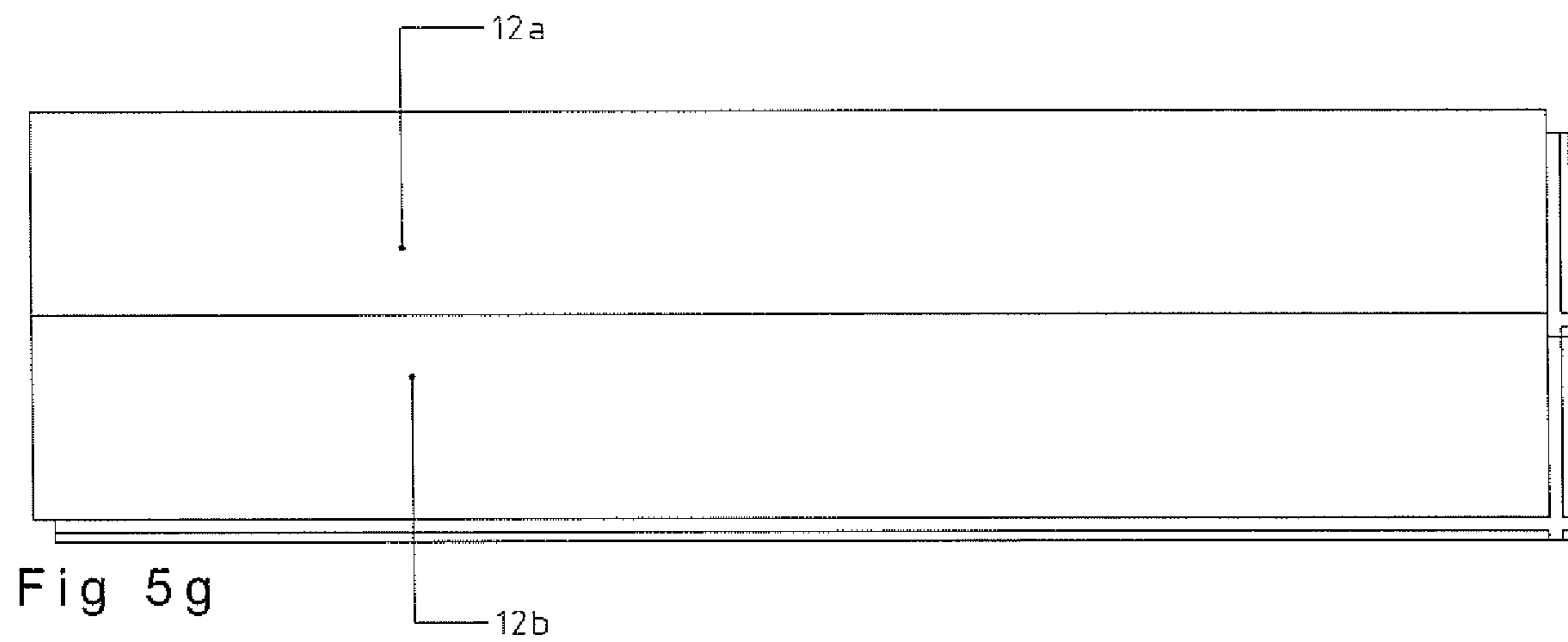
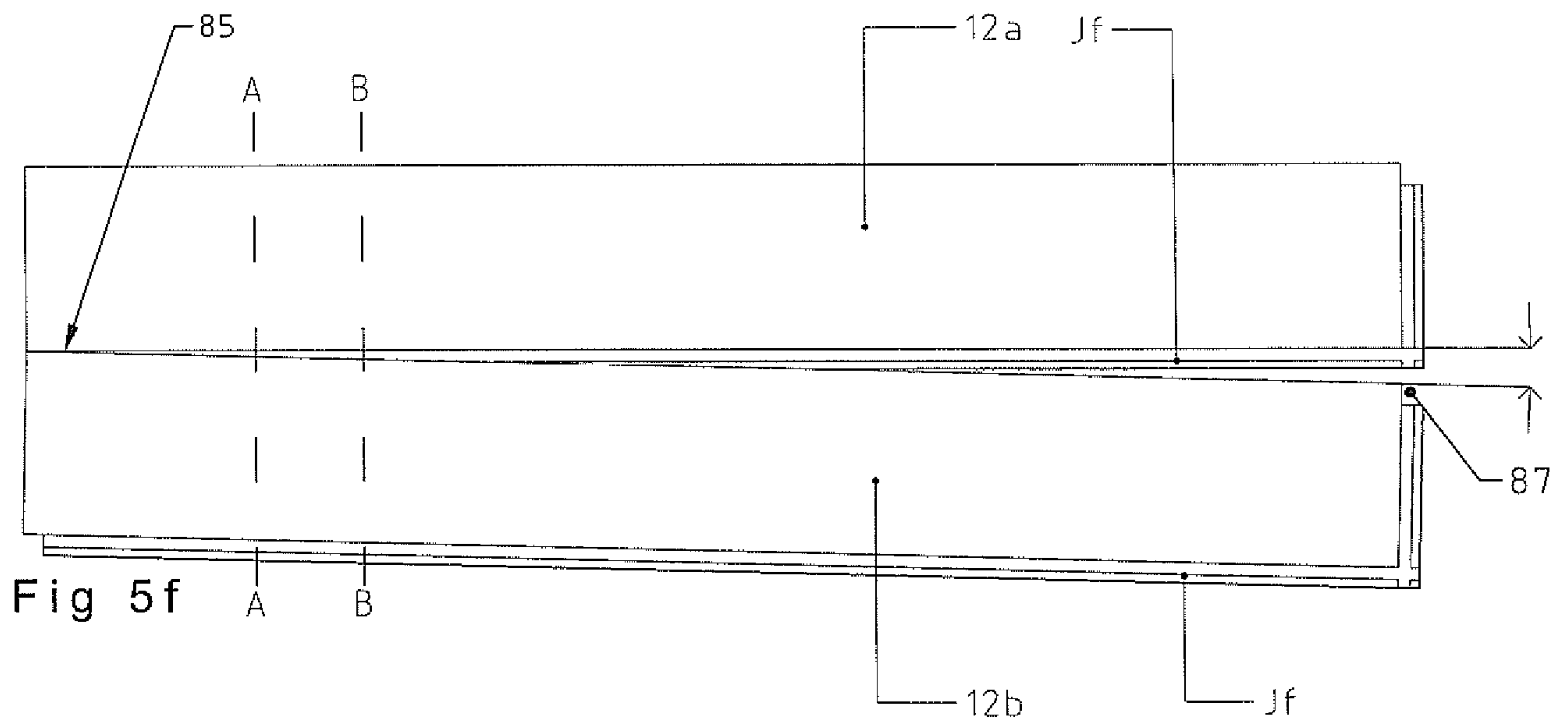
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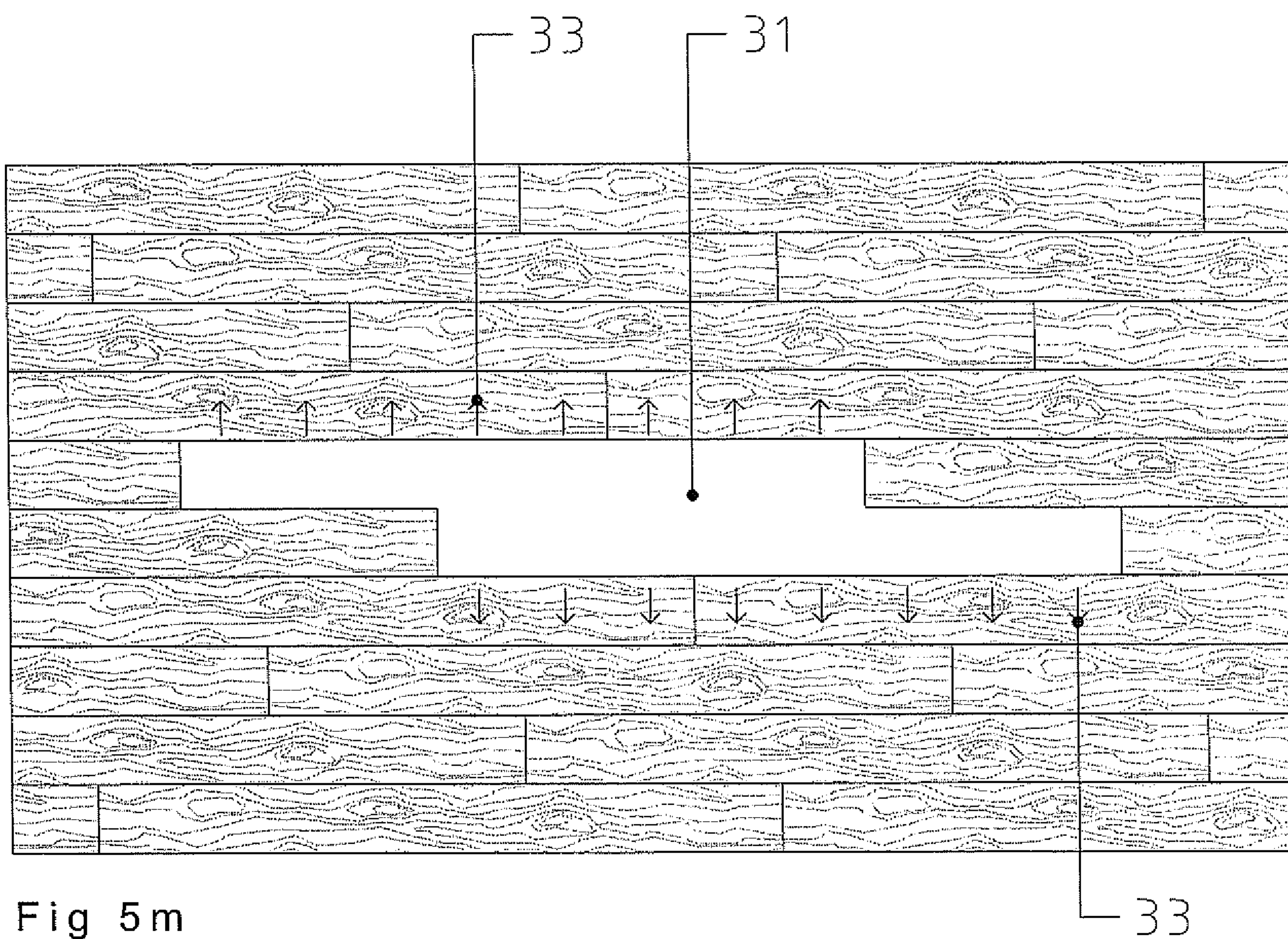
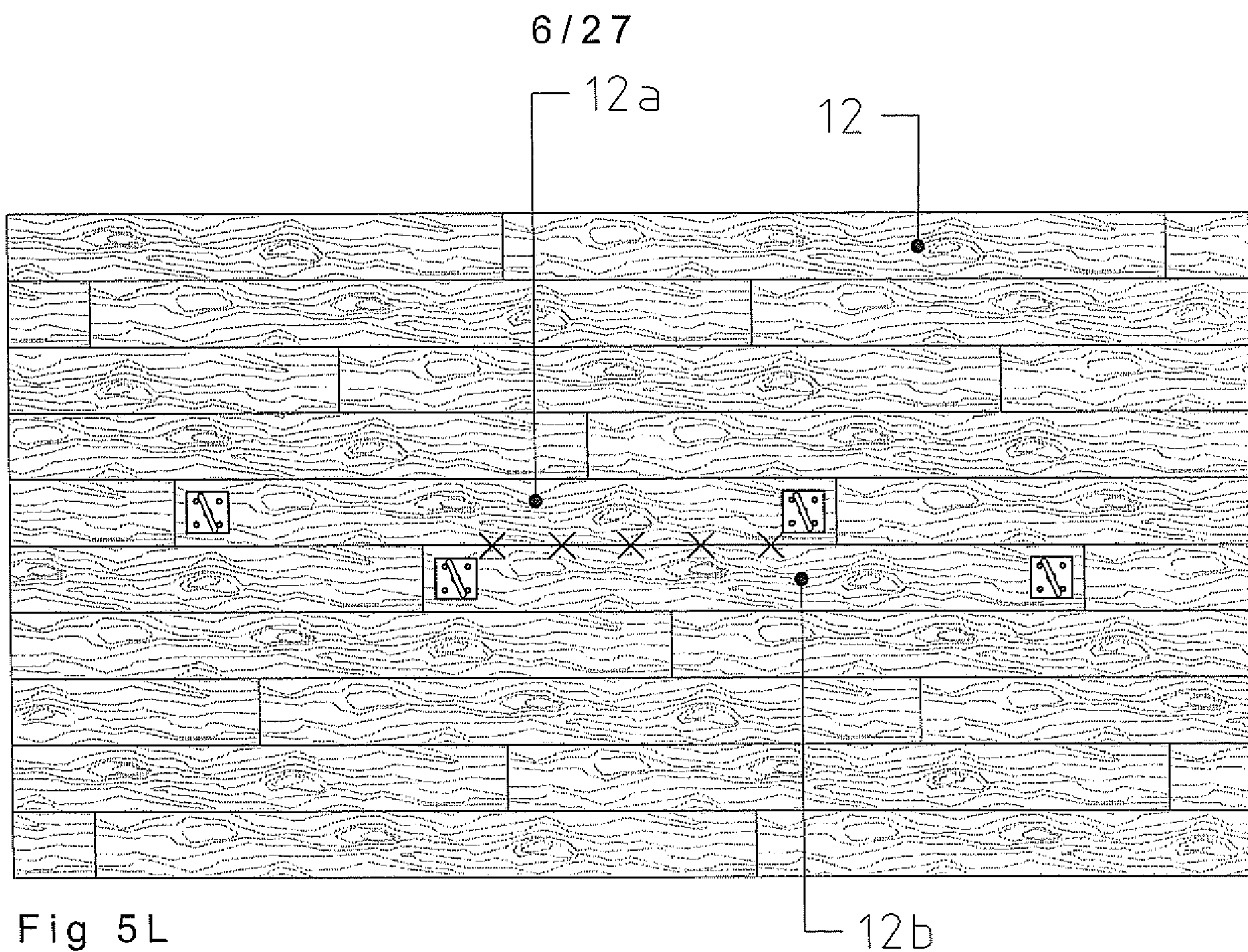


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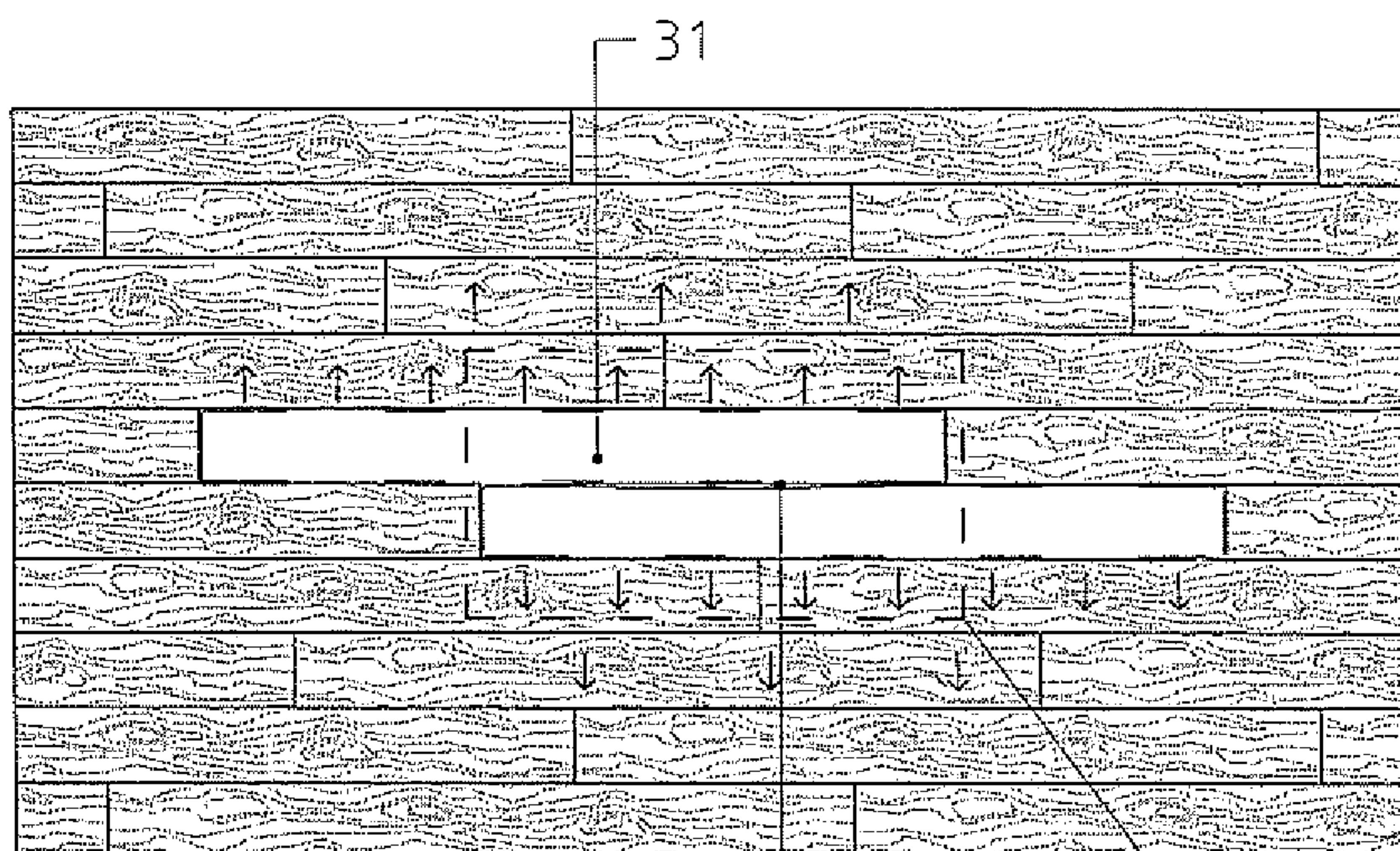


Fig 5n

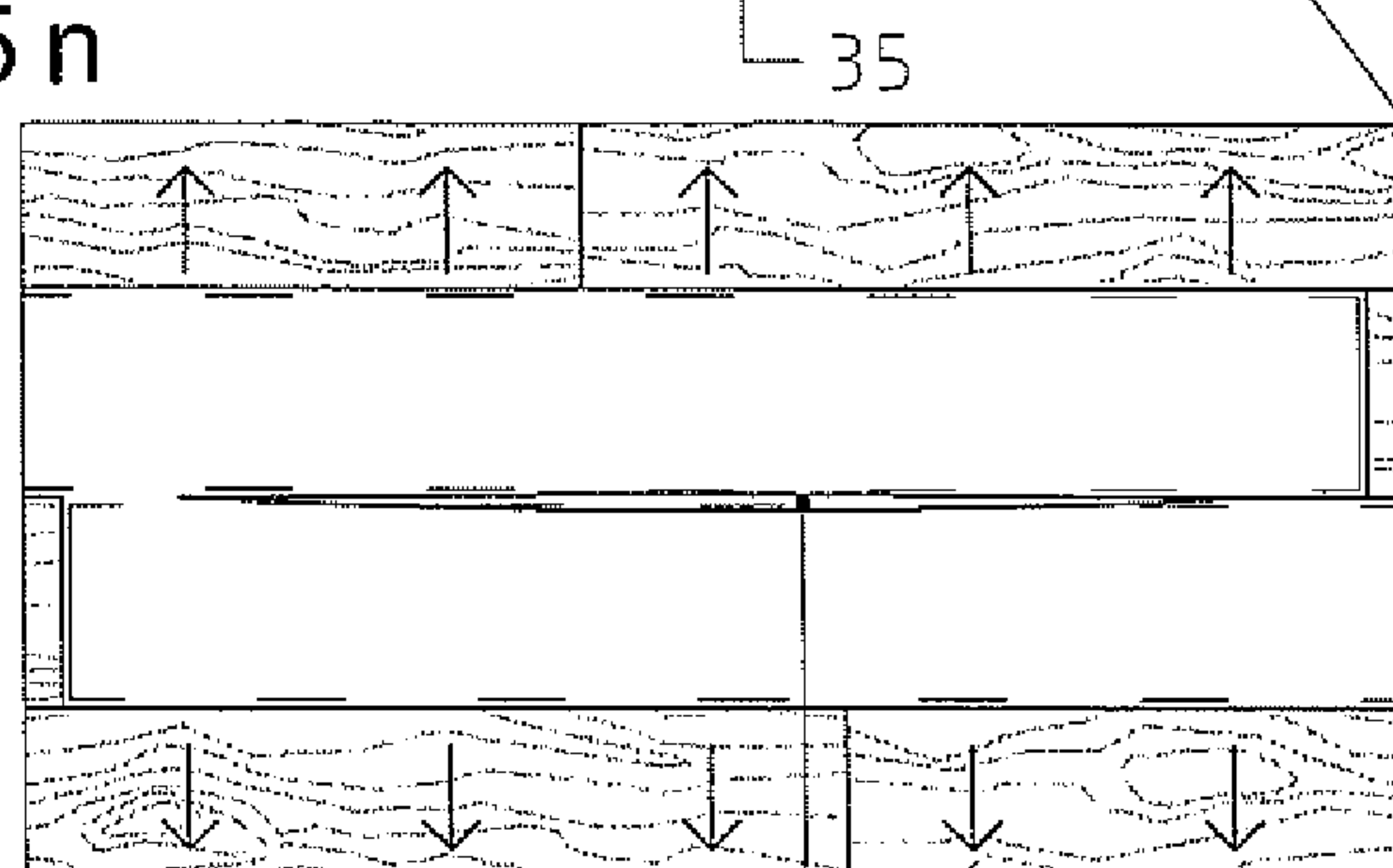


Fig 5o

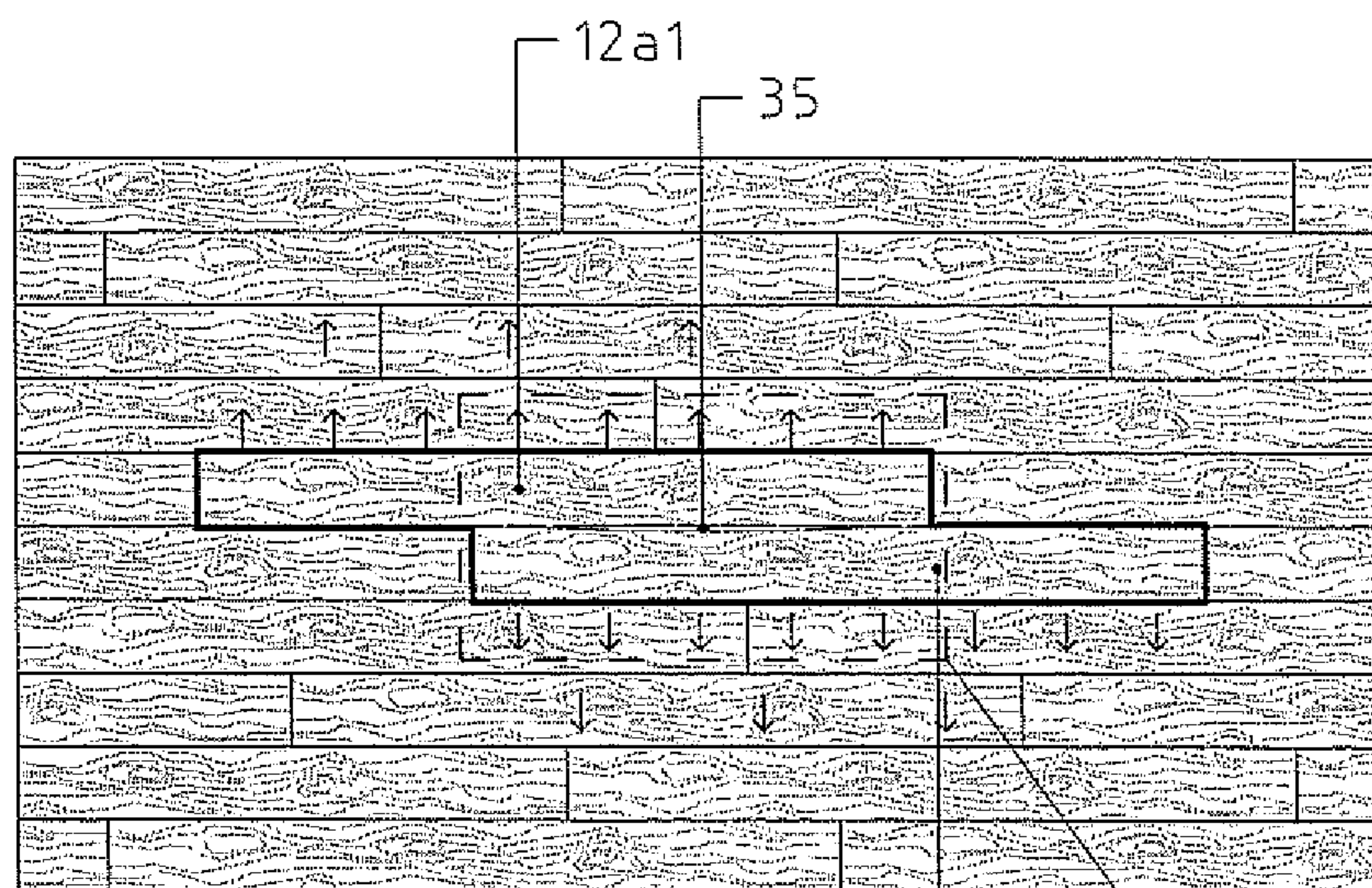


Fig 5p

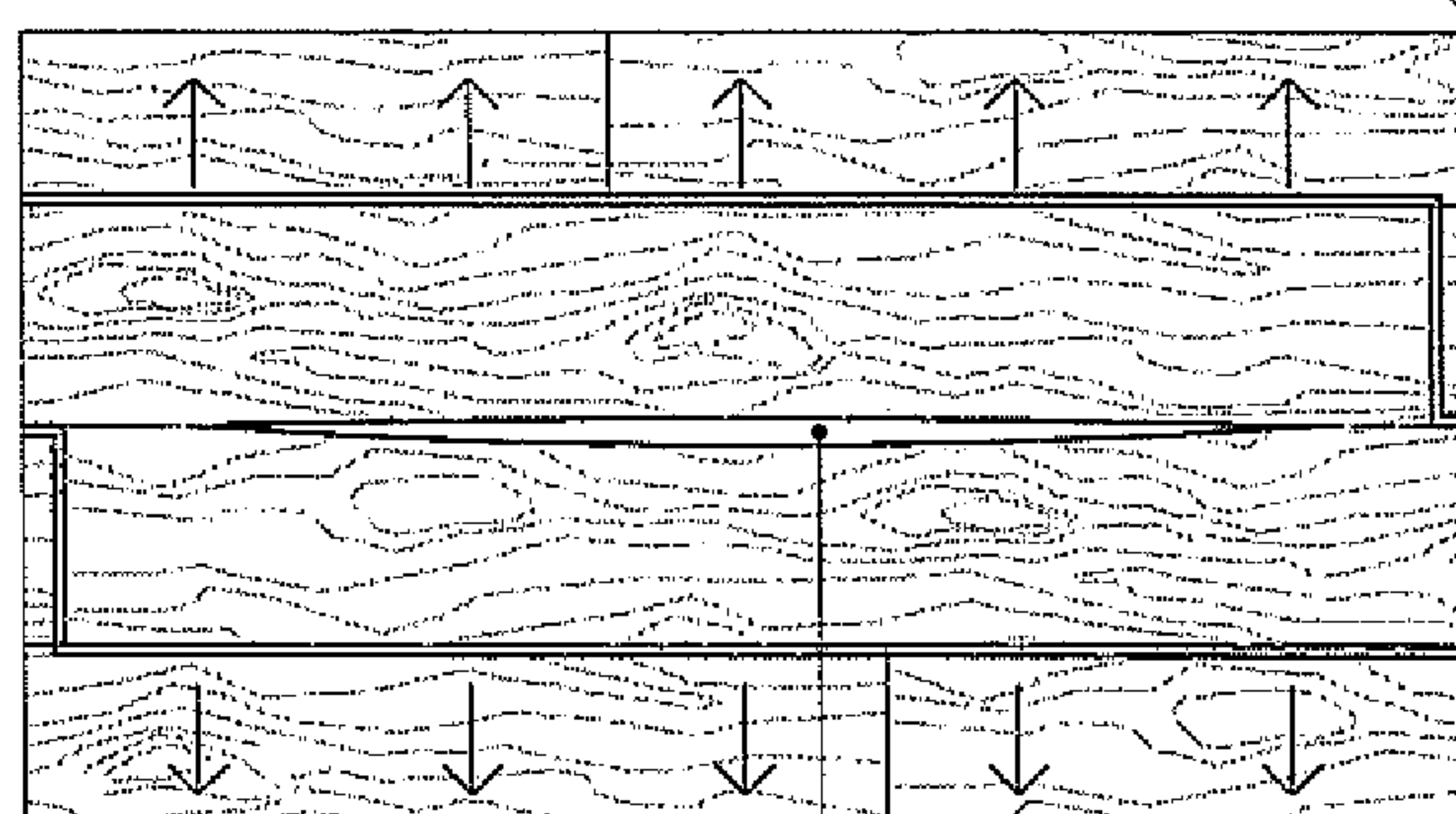
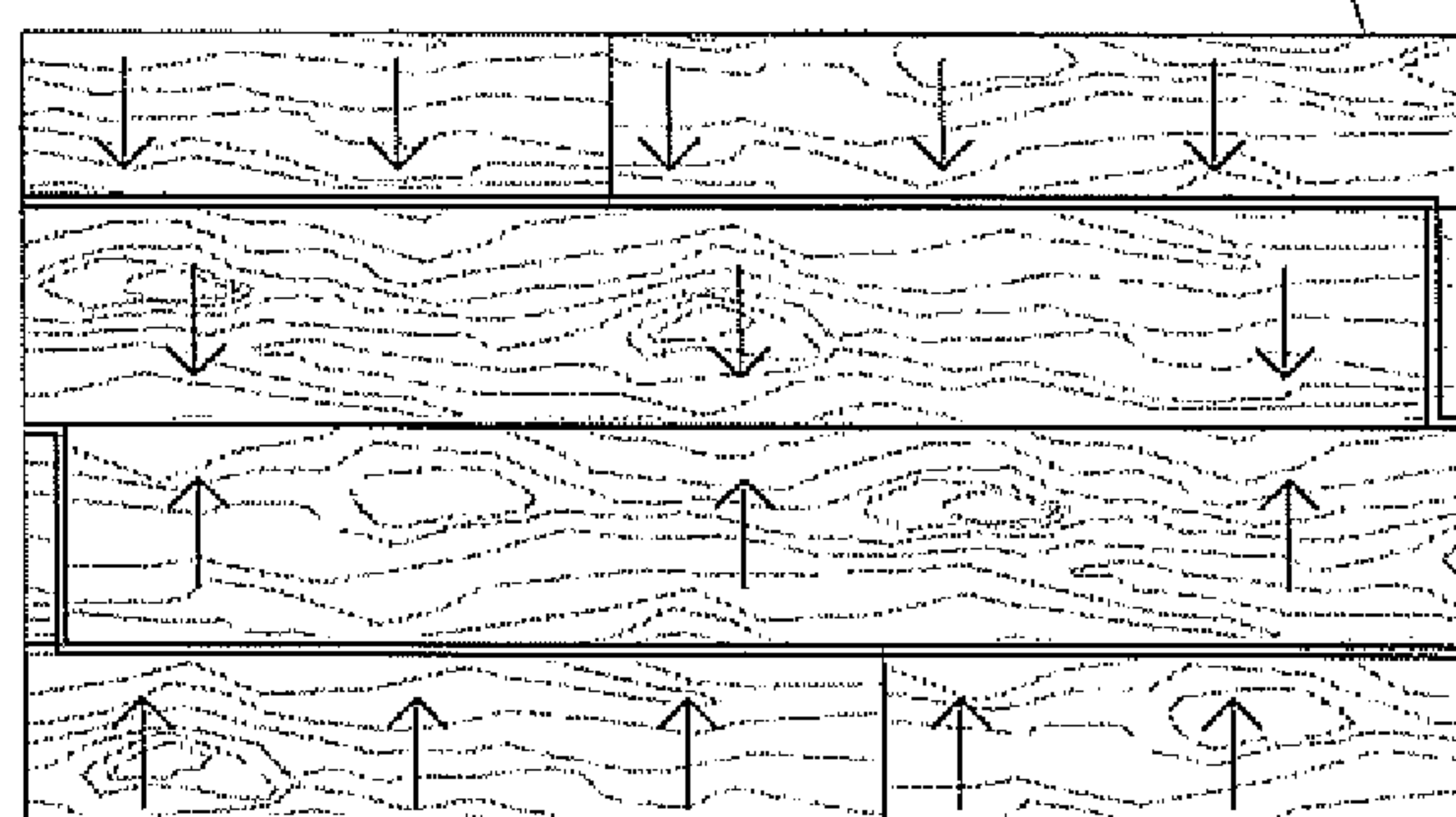
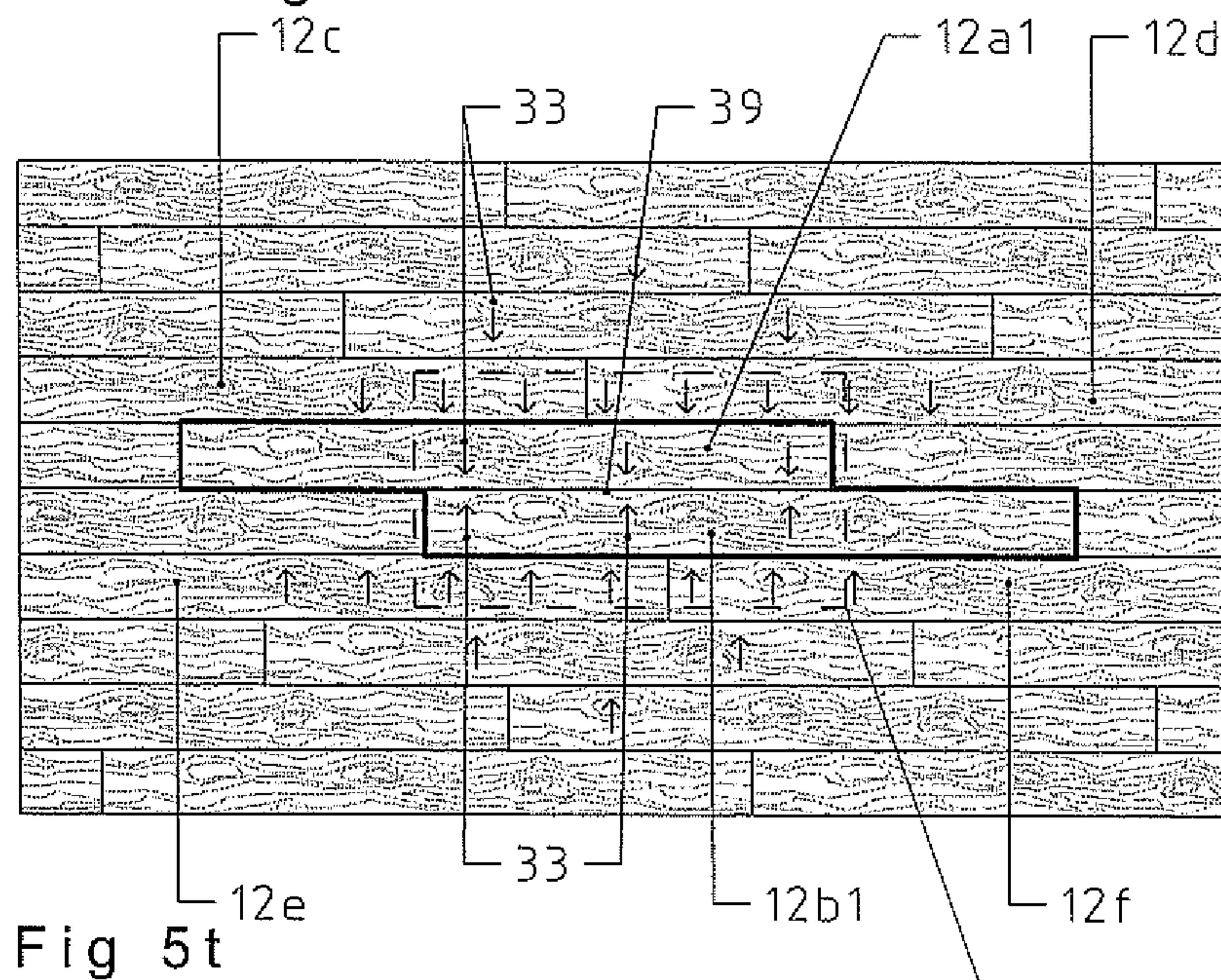
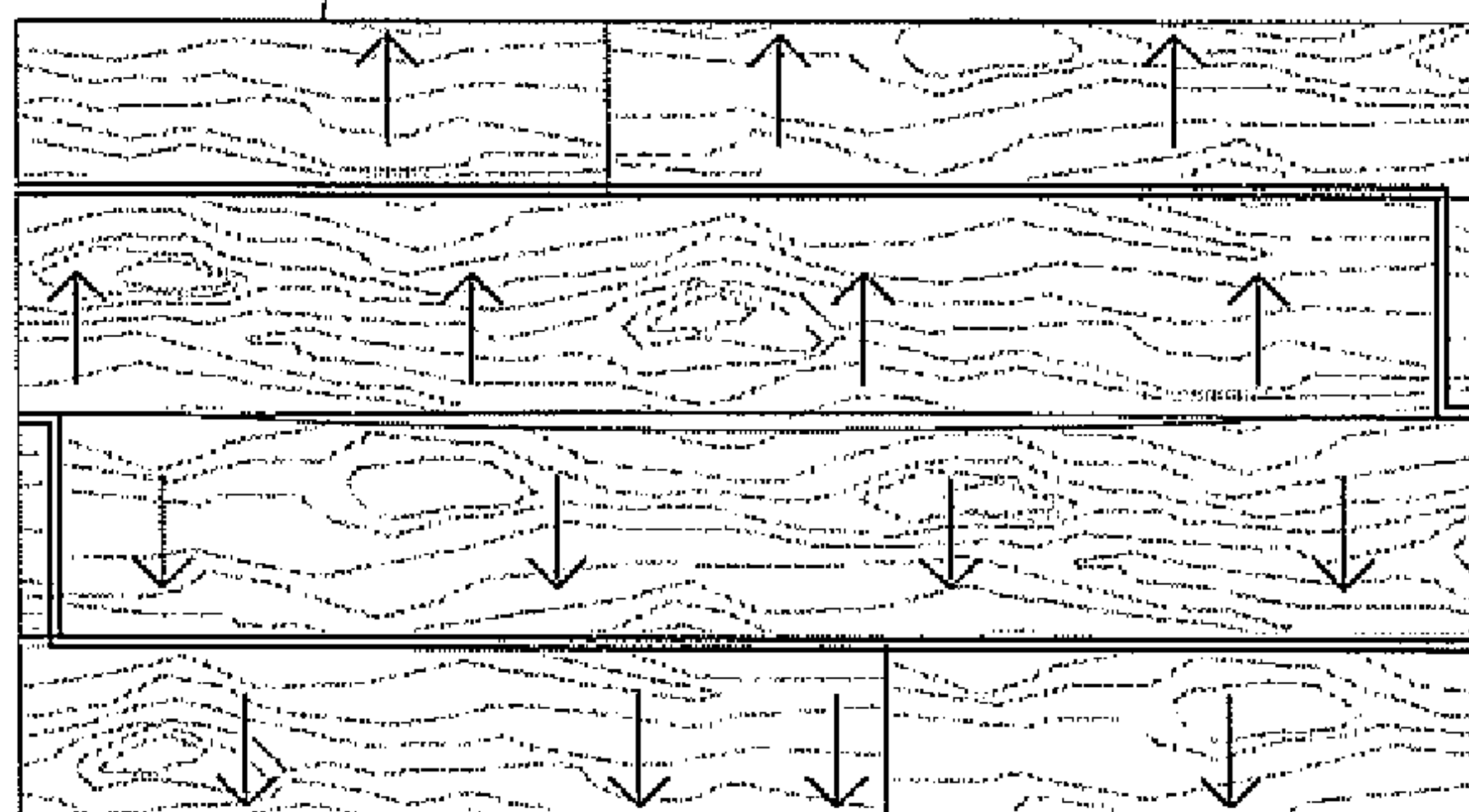
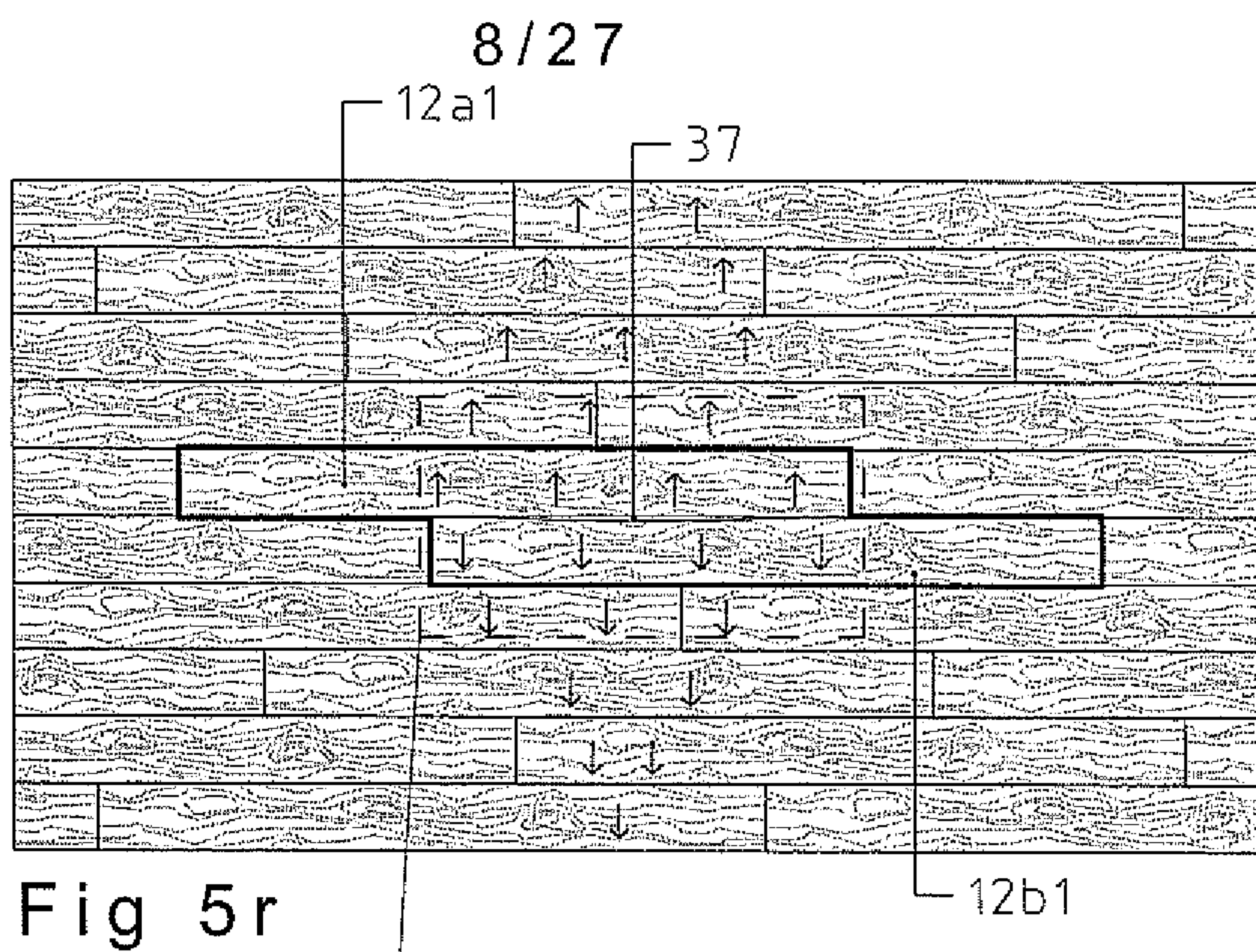


Fig 5q



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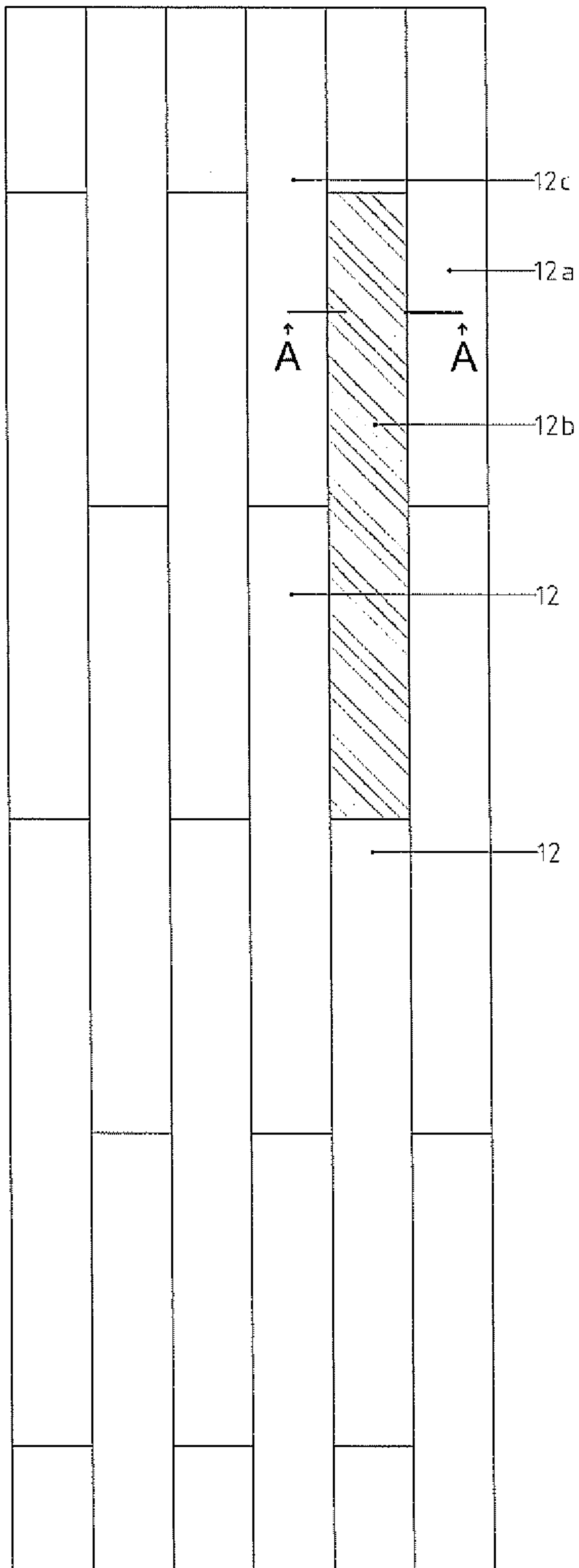


Fig 6a

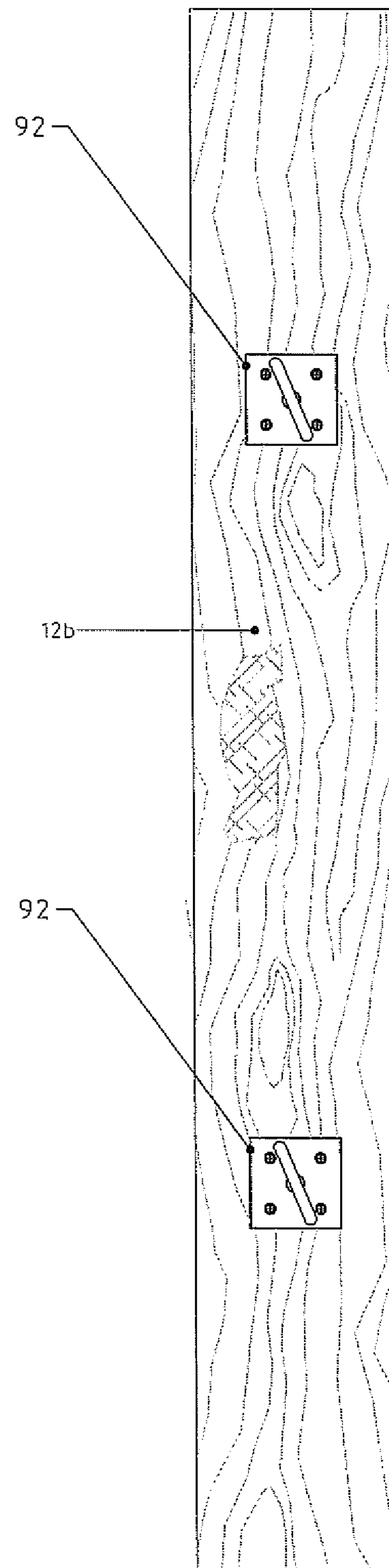


Fig 6c

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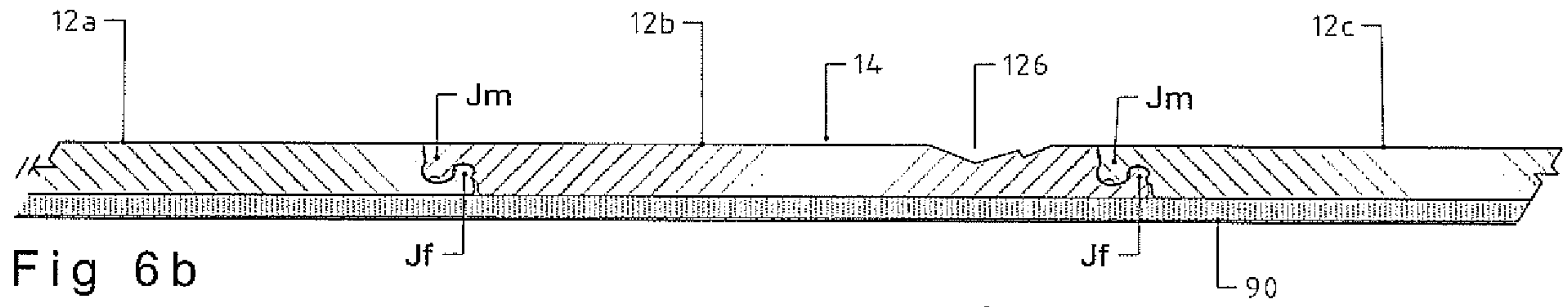


Fig 6b

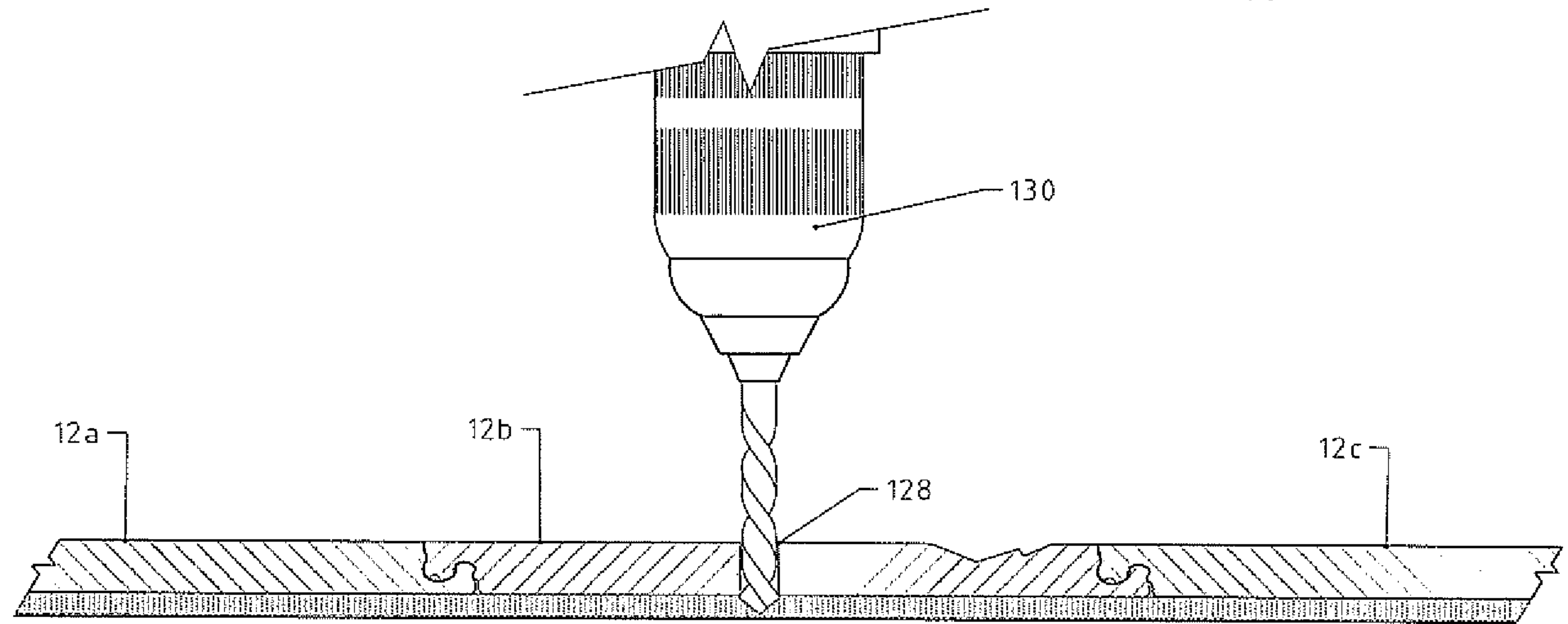


Fig 6d

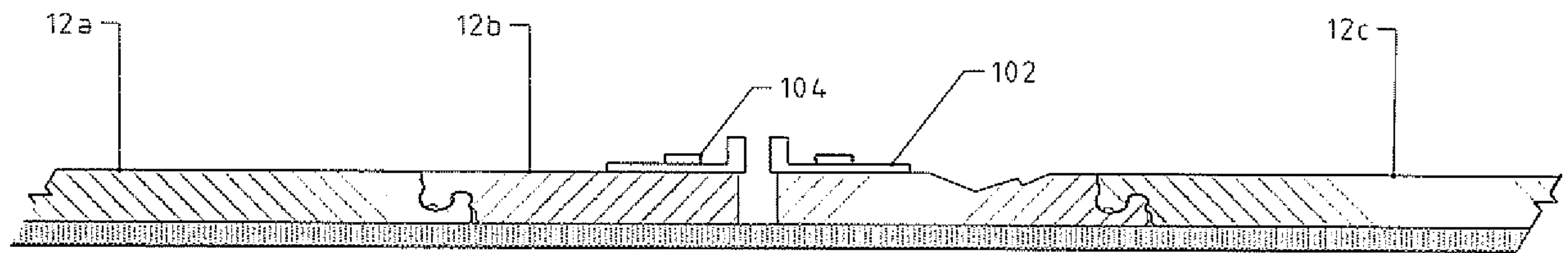


Fig 6e

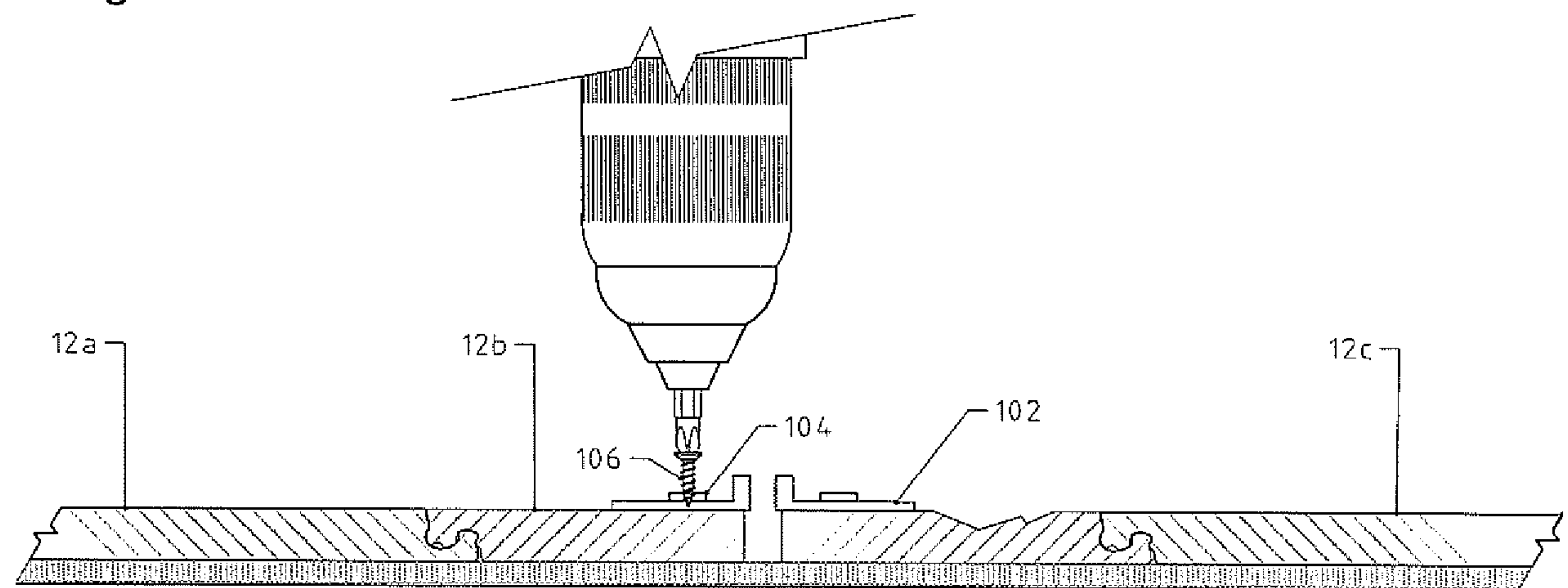


Fig 6f

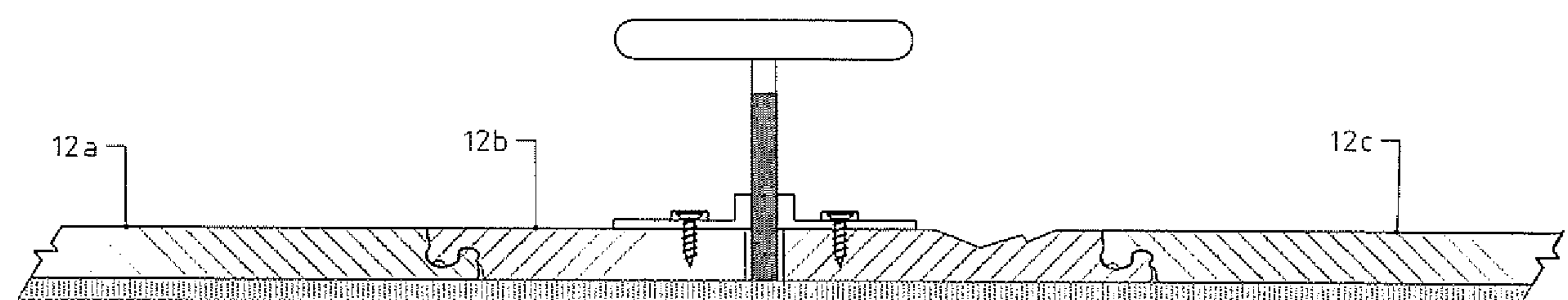


Fig 6g

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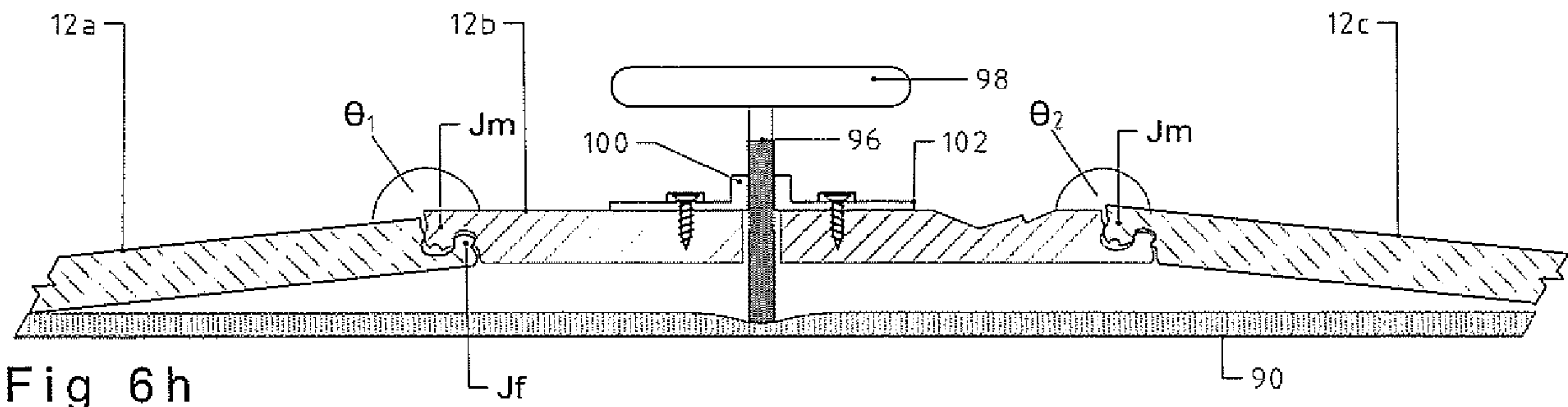


Fig 6h

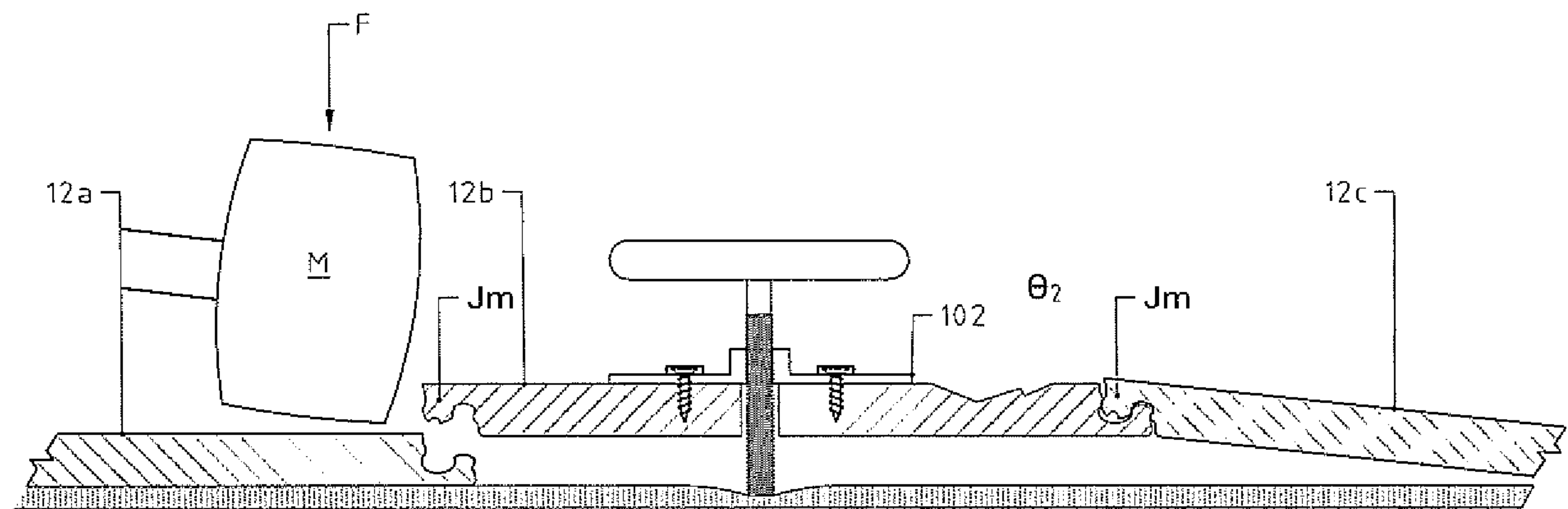


Fig 6i

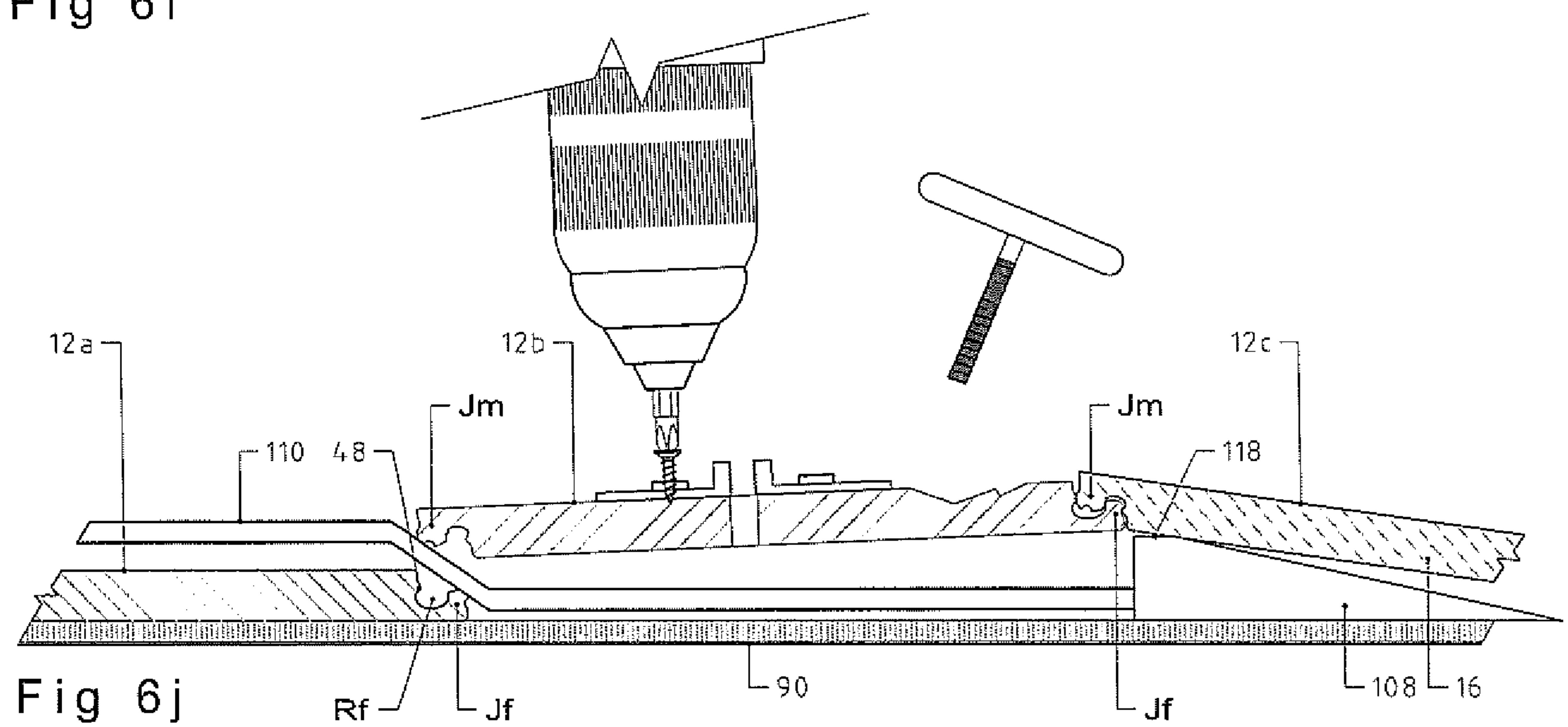


Fig 6j

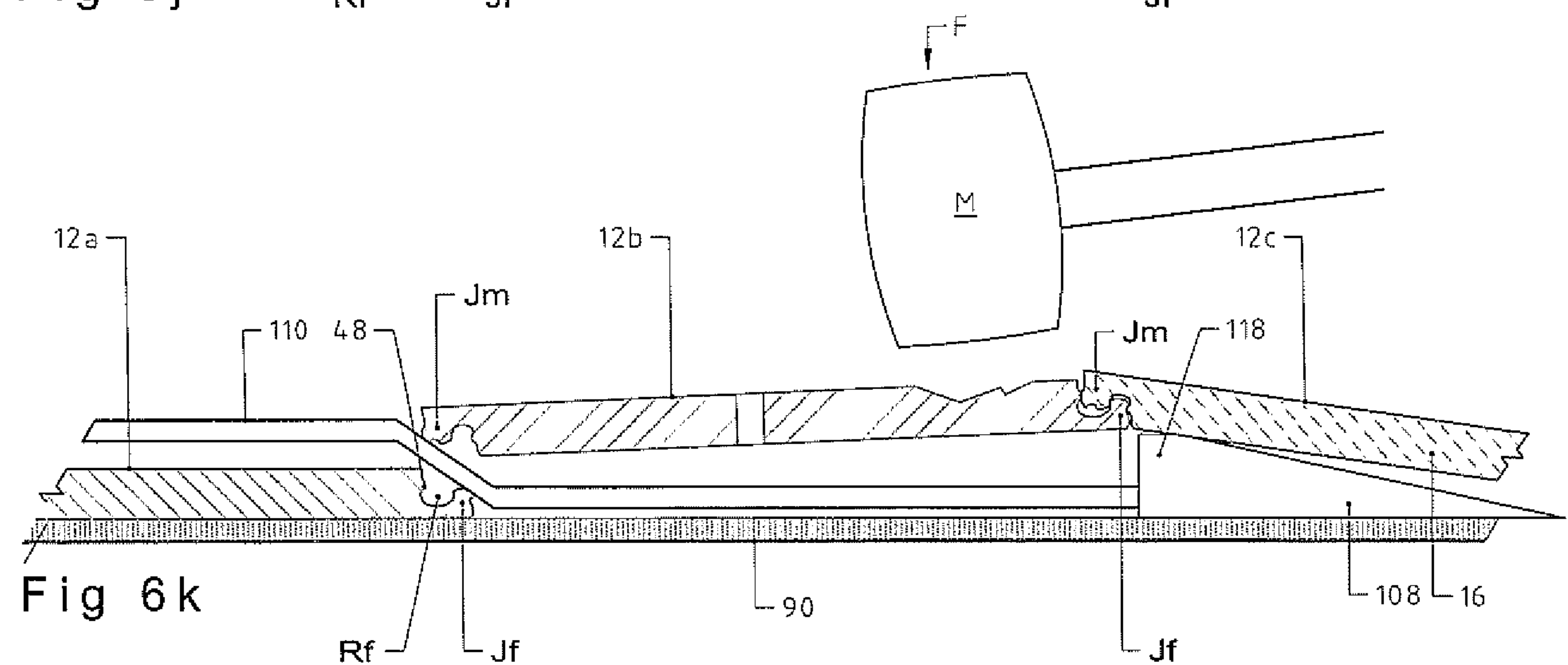
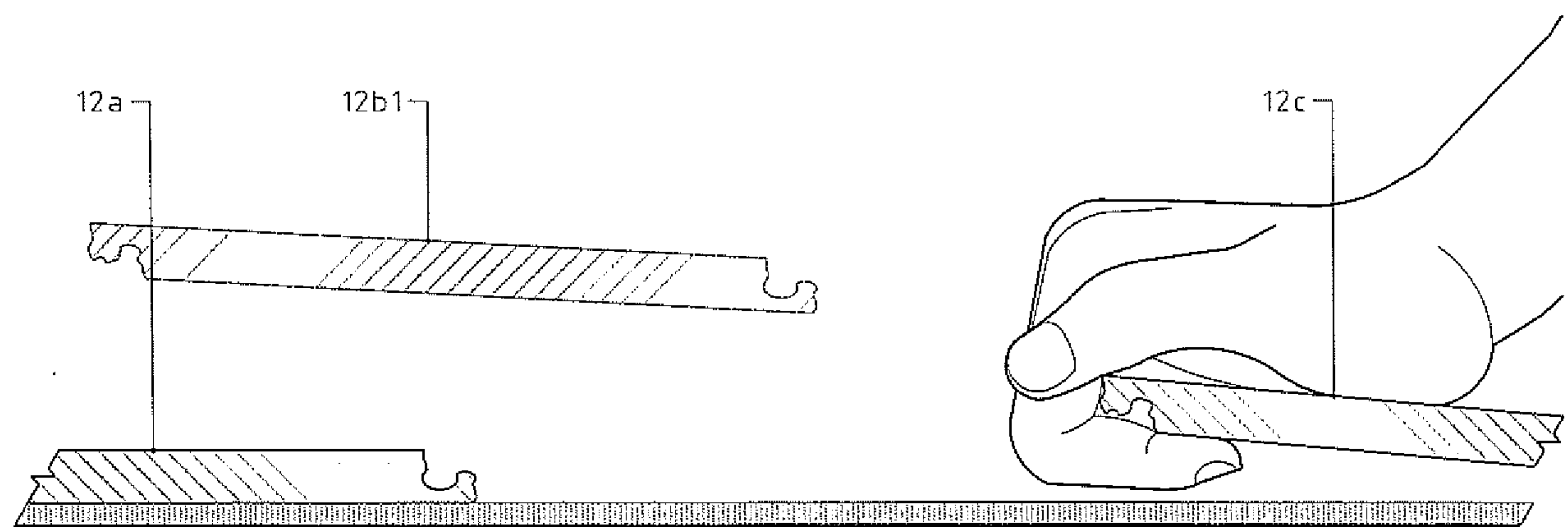
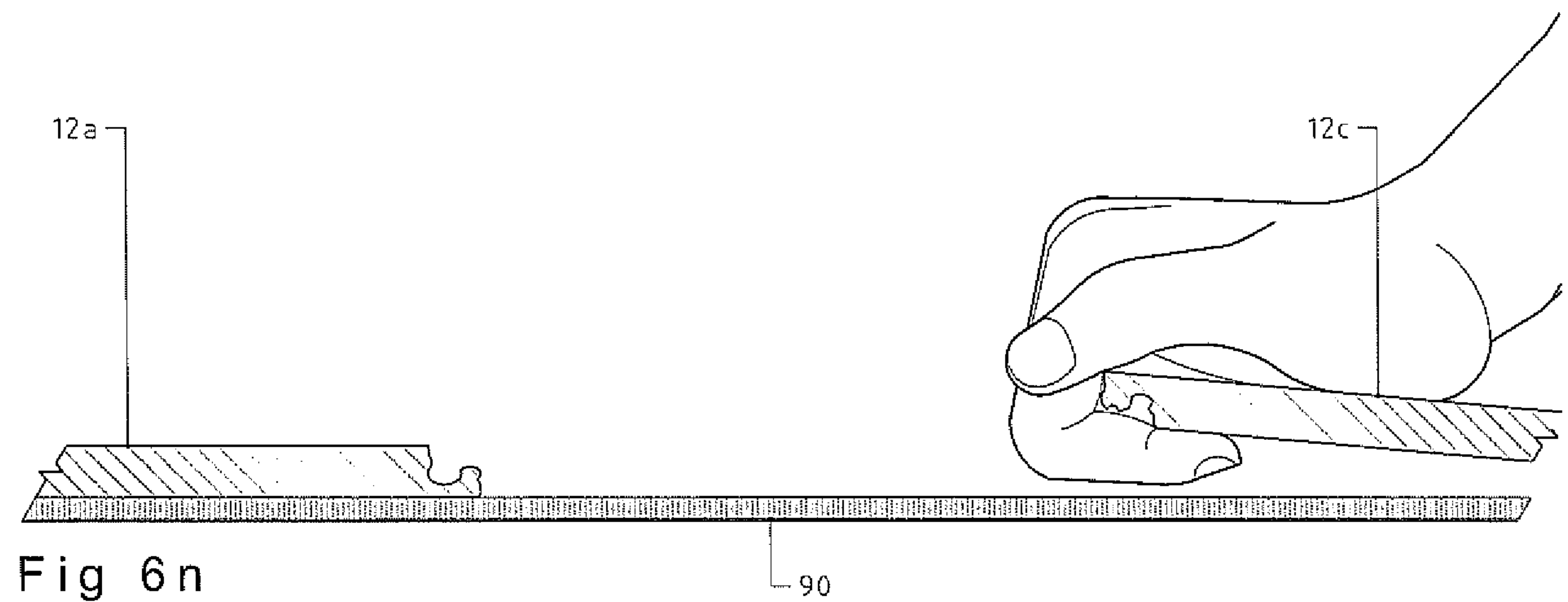
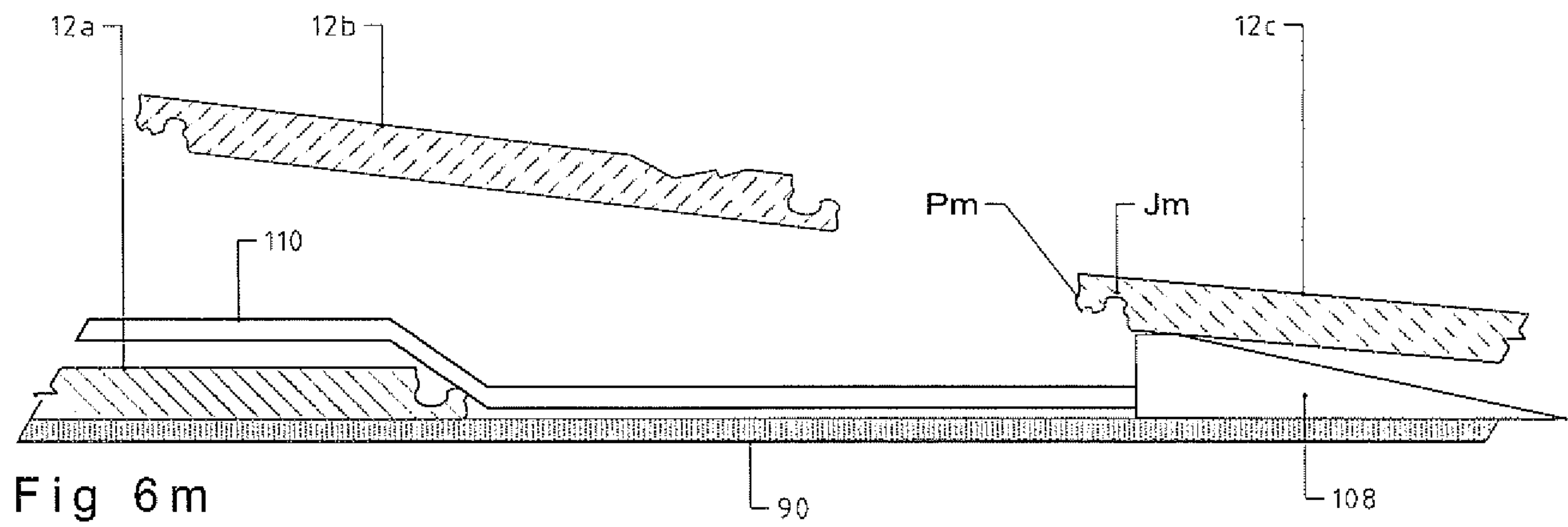
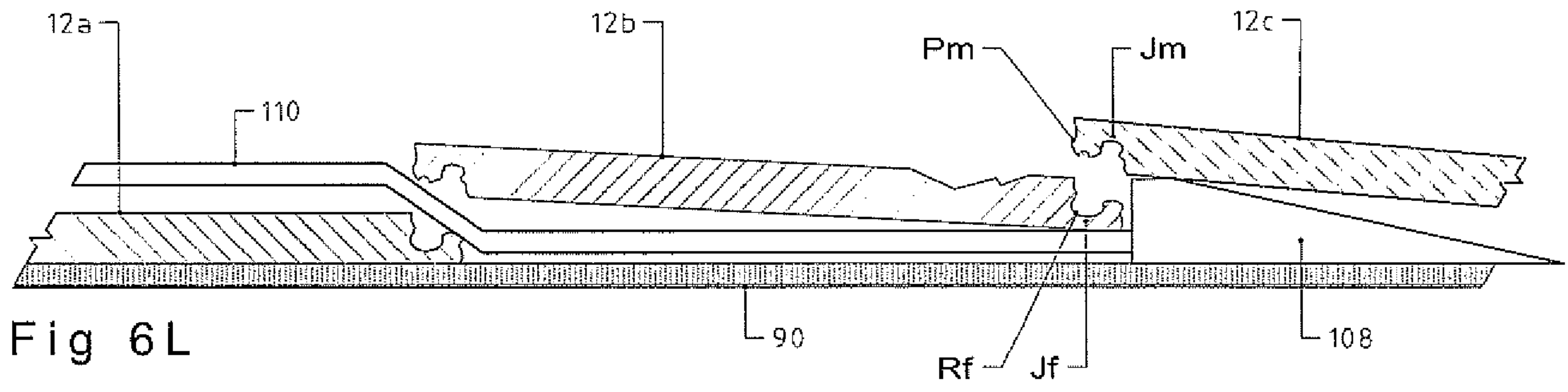


Fig 6k

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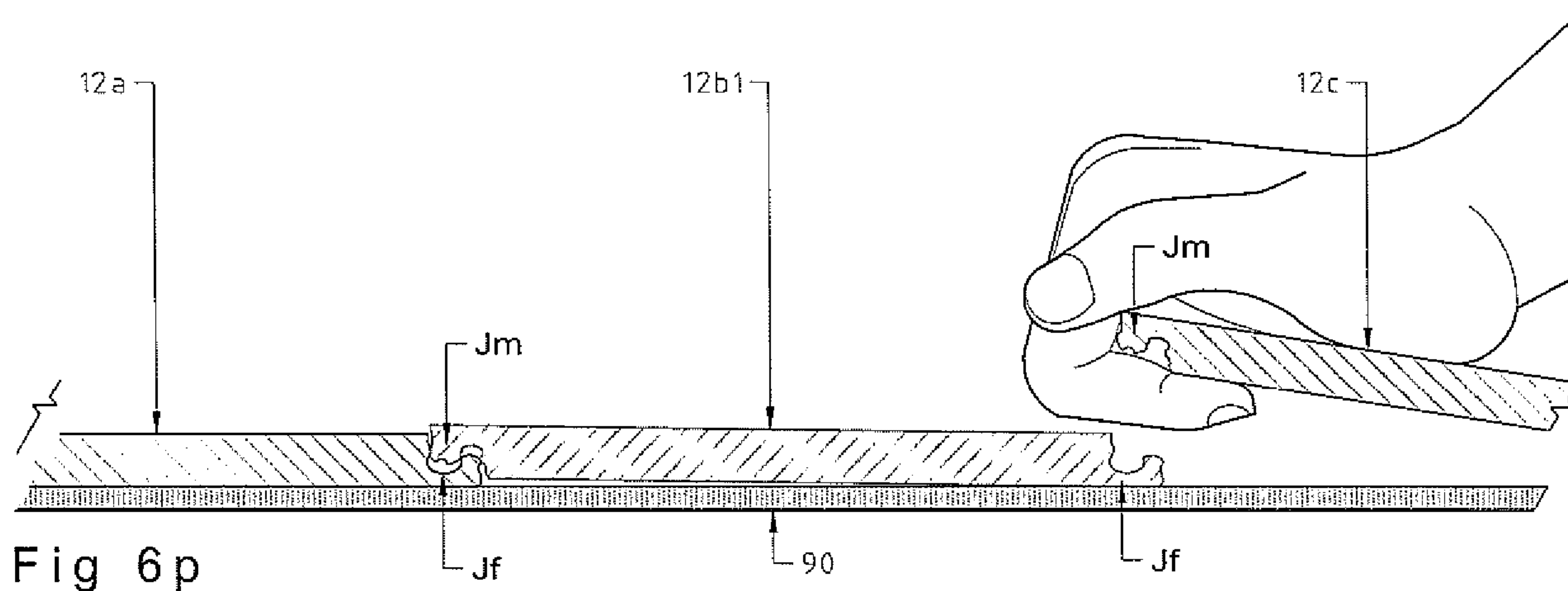


Fig 6 p

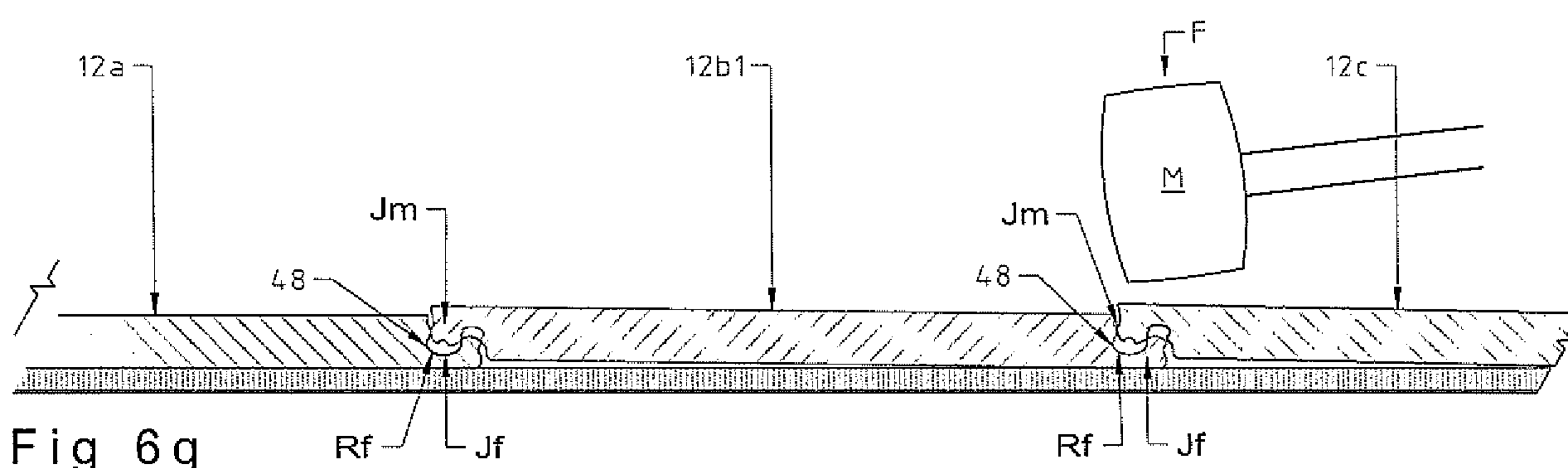


Fig 6q

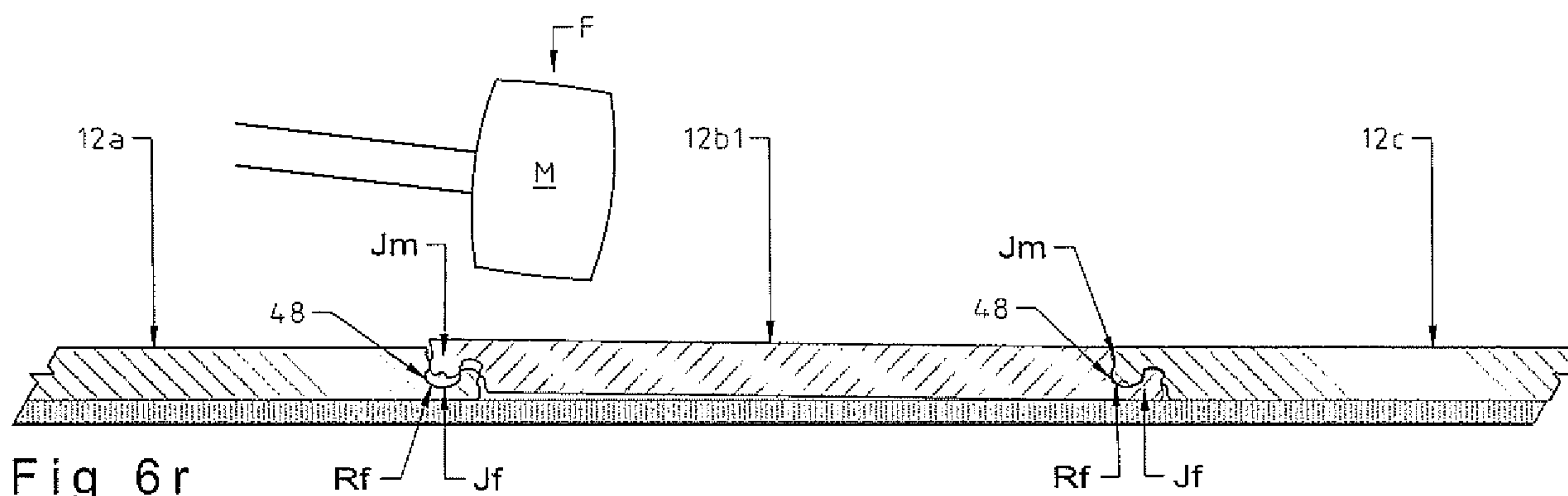


Fig 6r

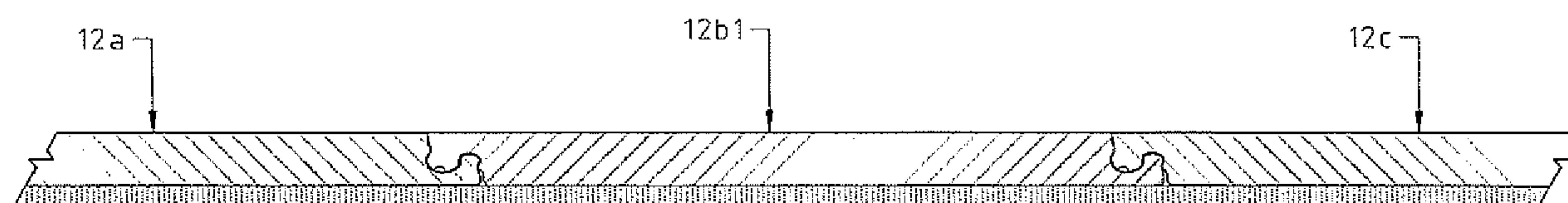
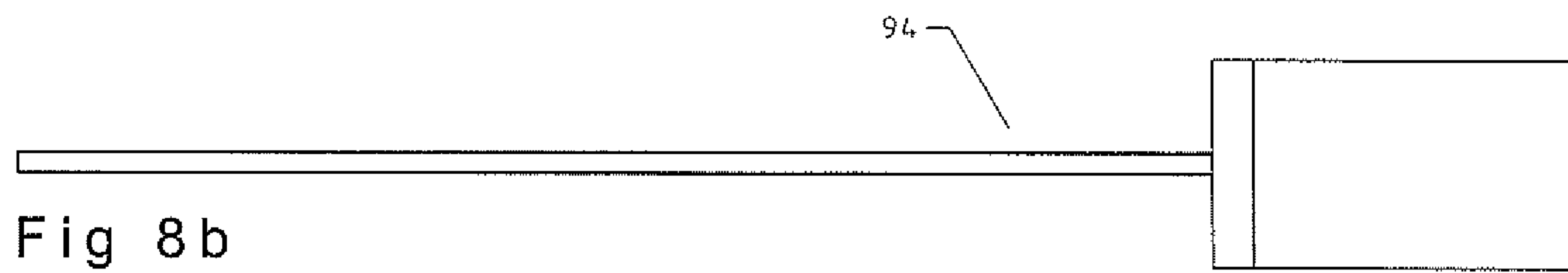
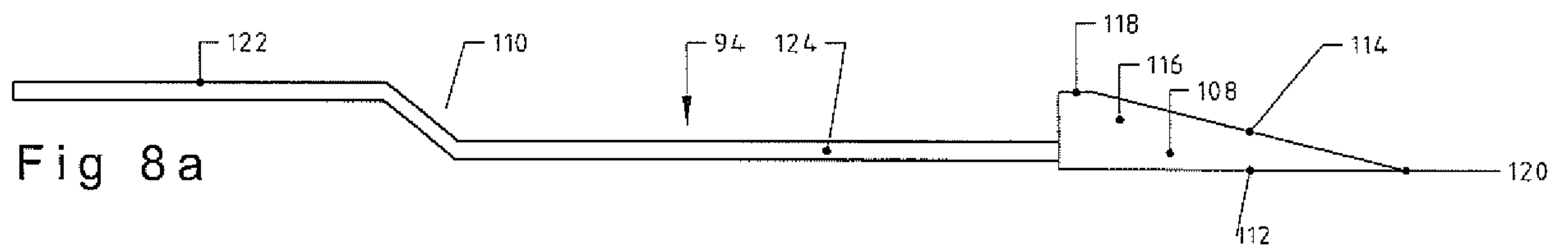
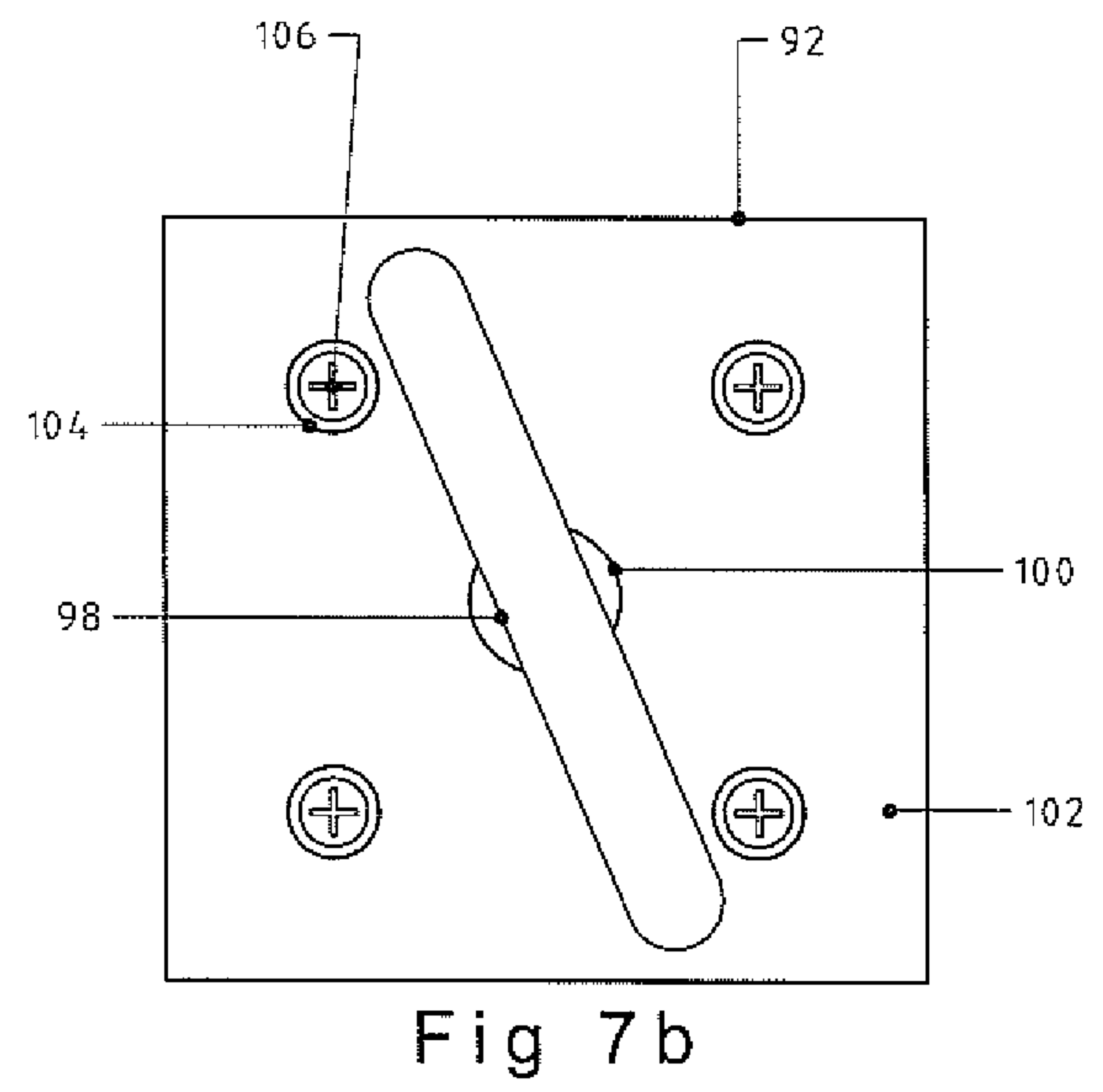
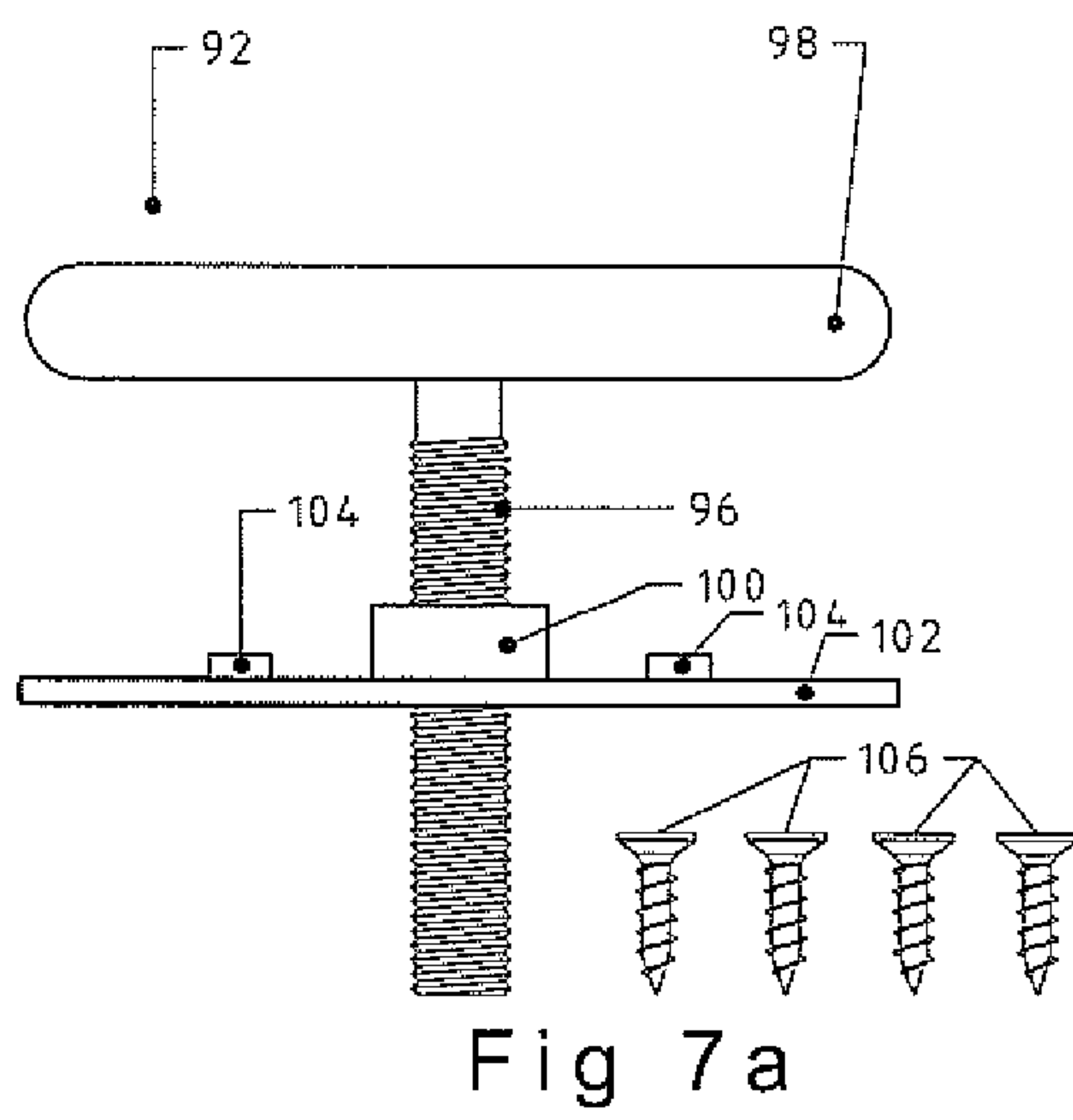


Fig 6s

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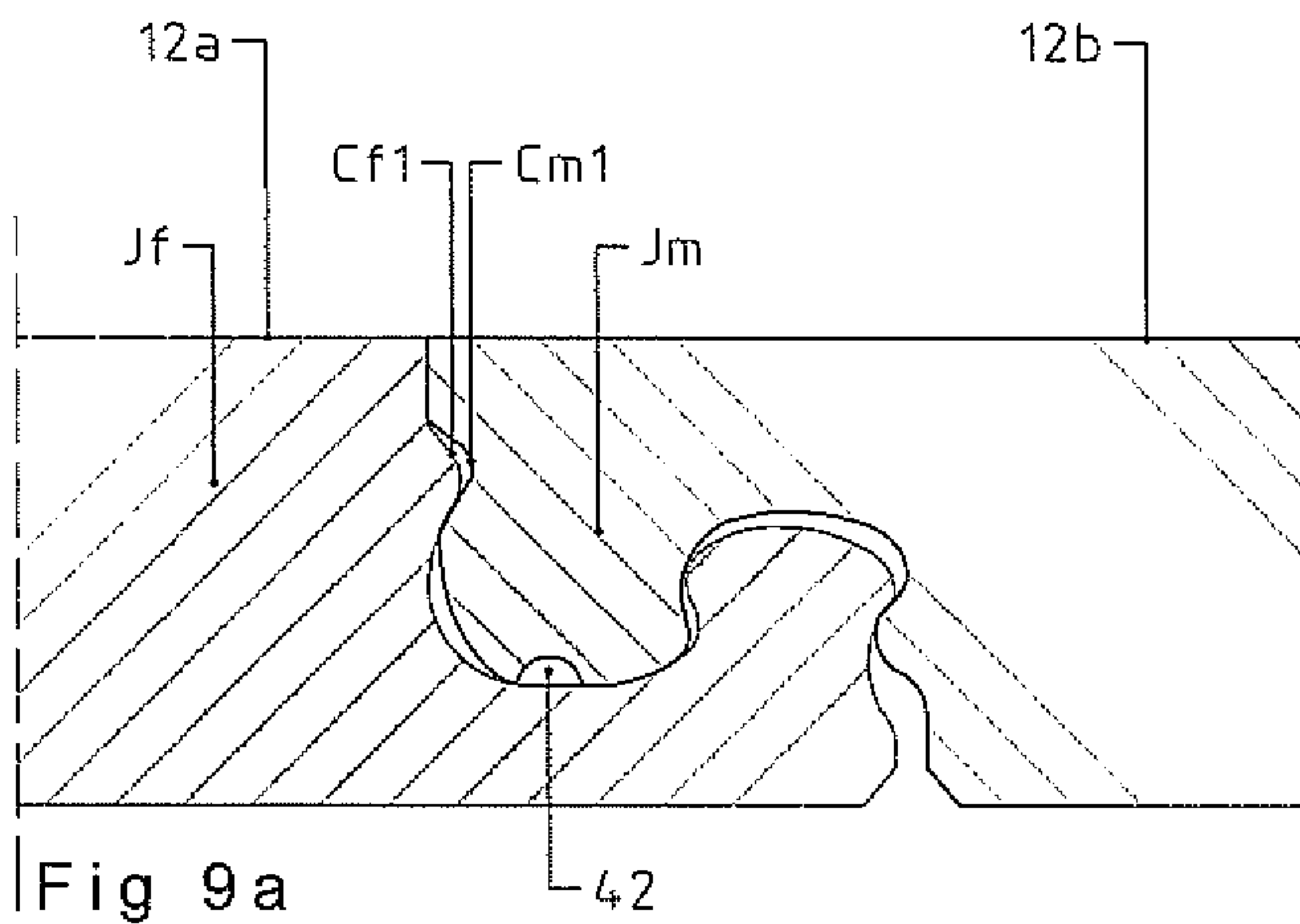


Fig 9a

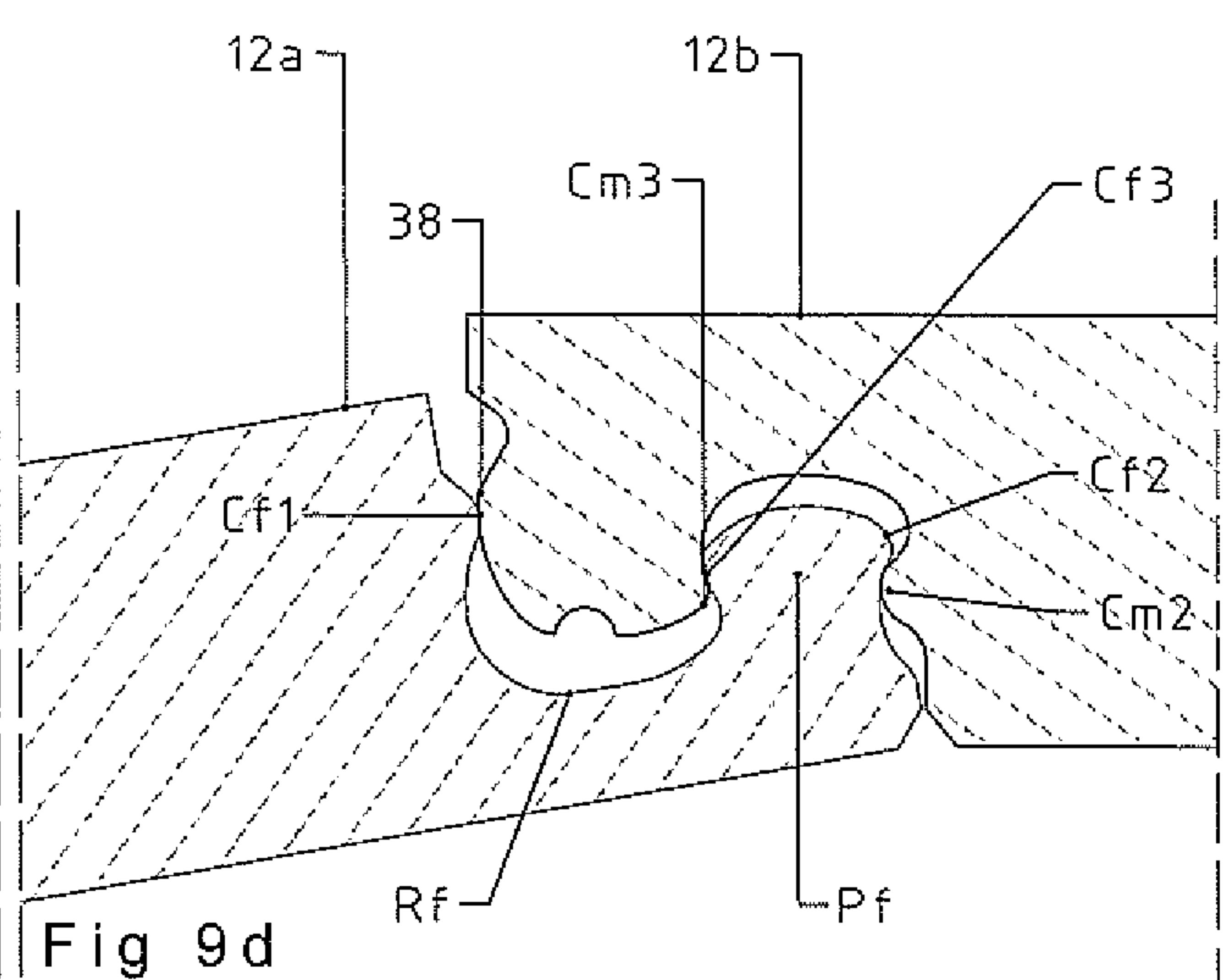


Fig 9d

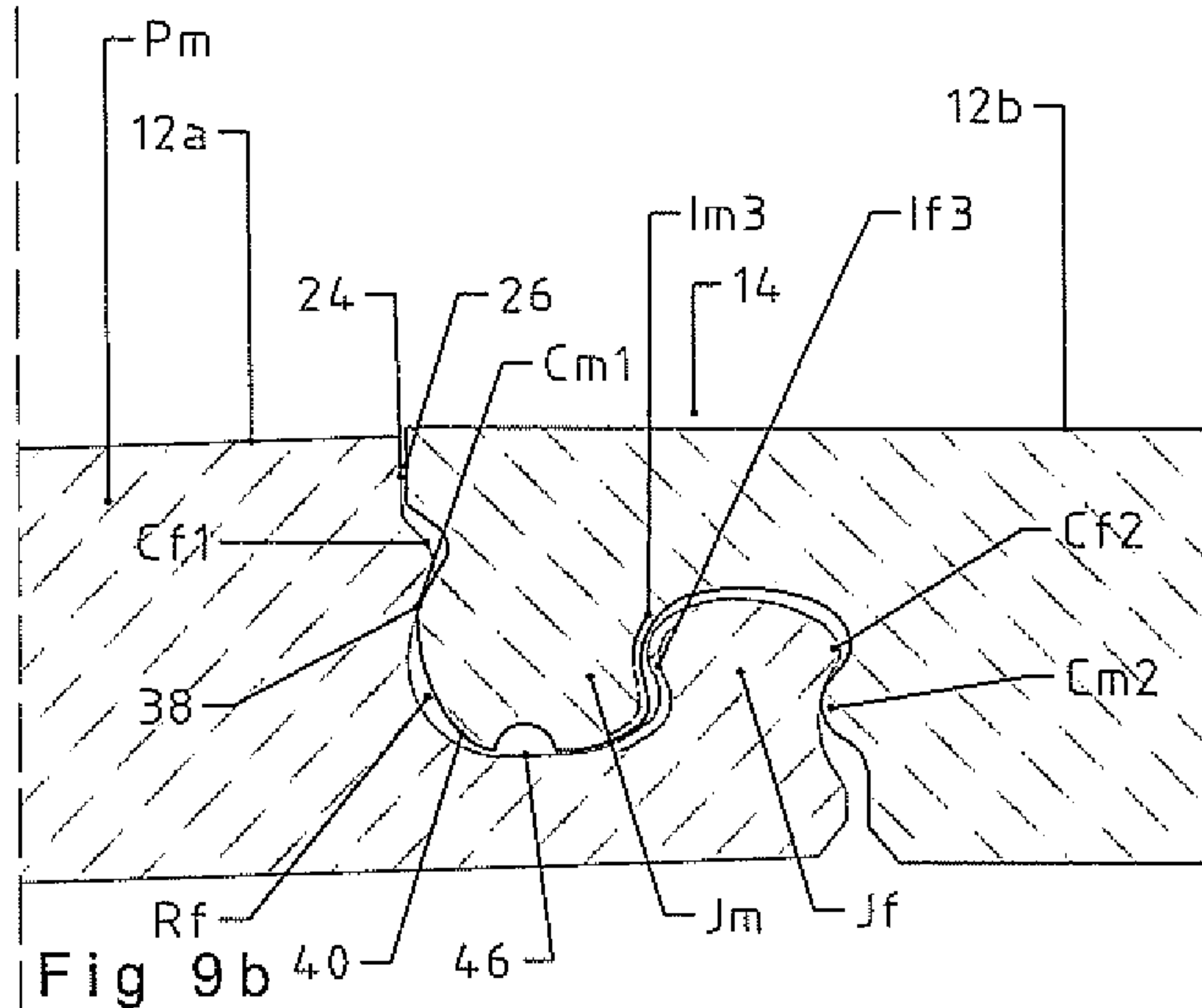


Fig 9b

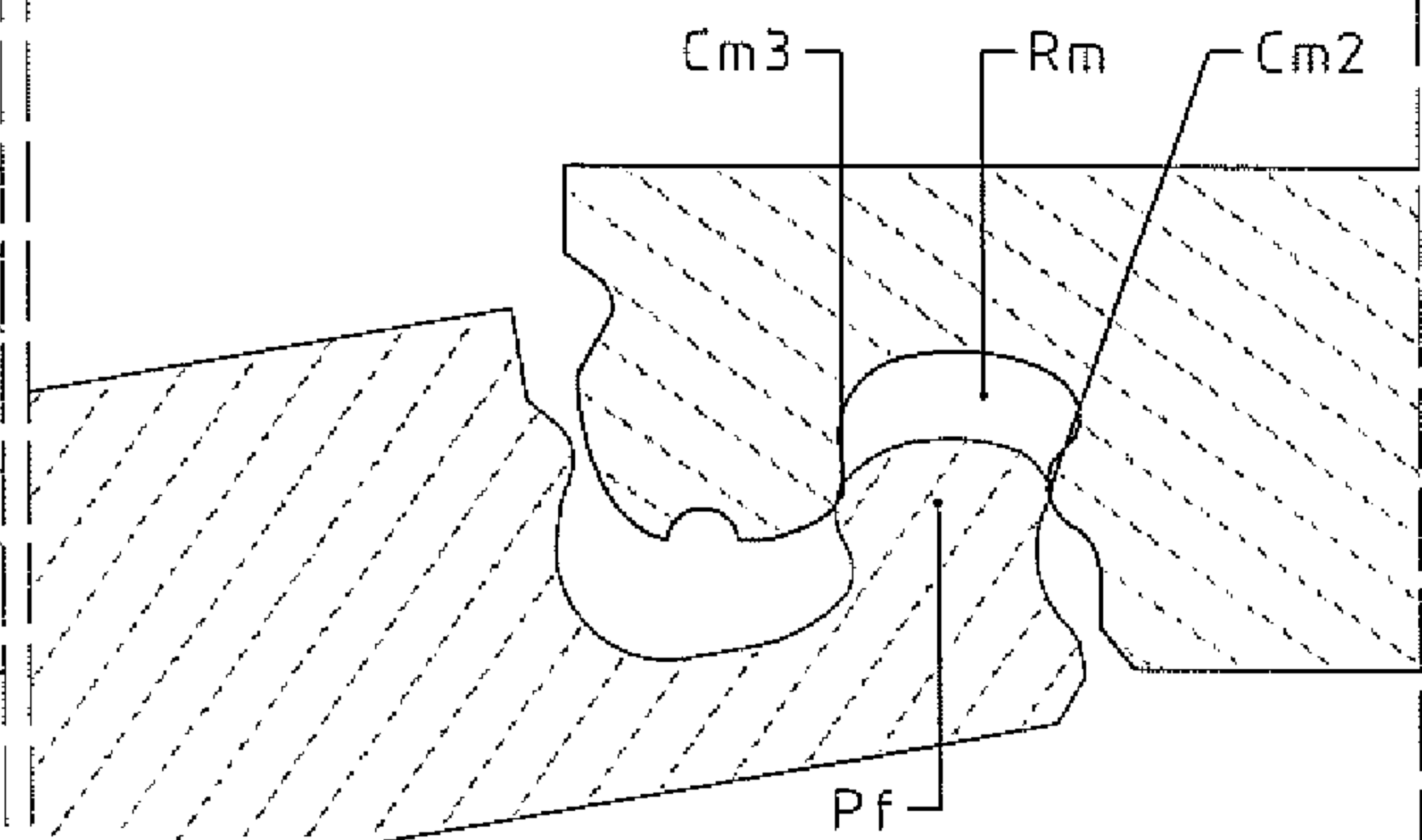


Fig 9e

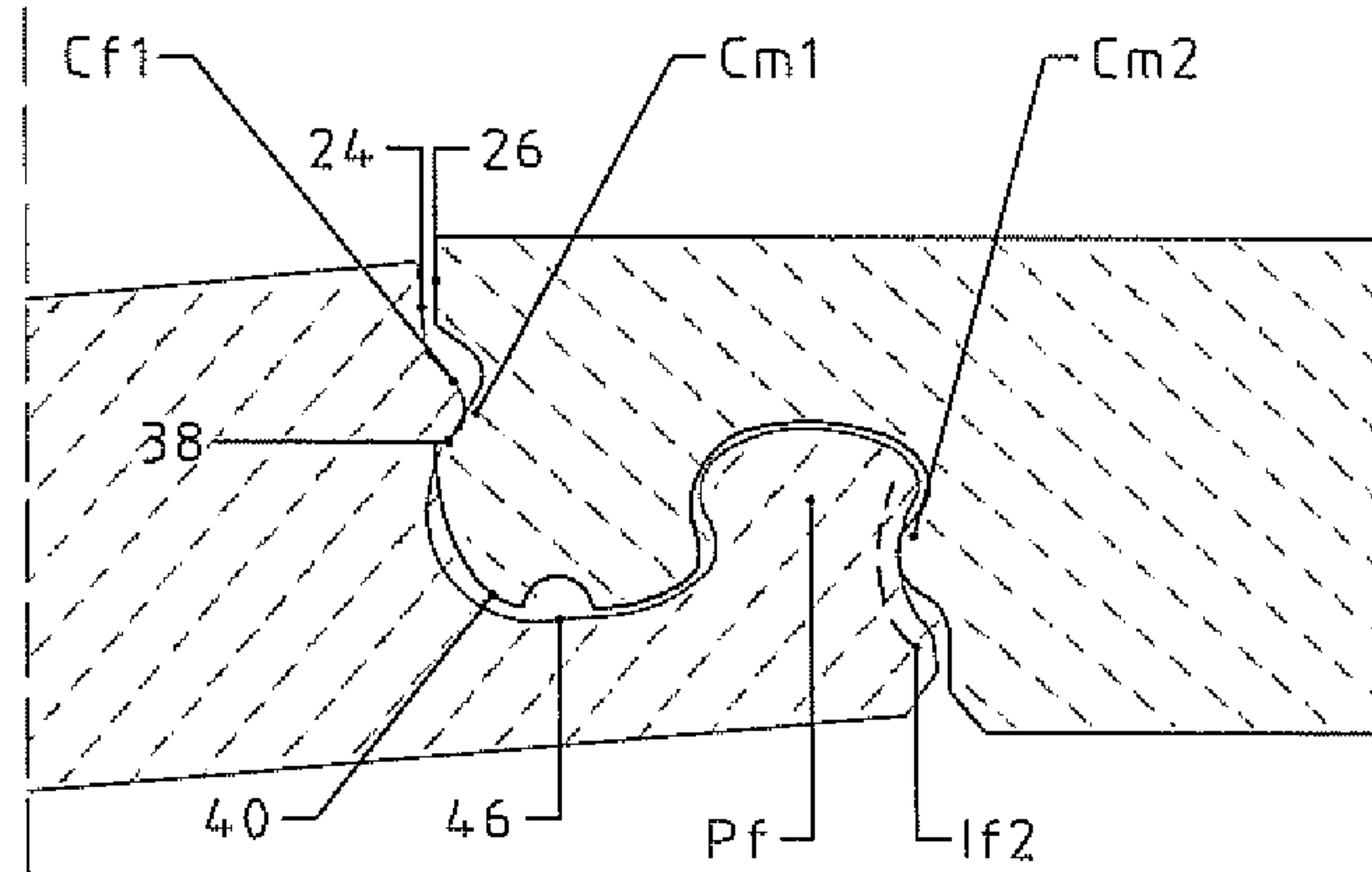


Fig 9c

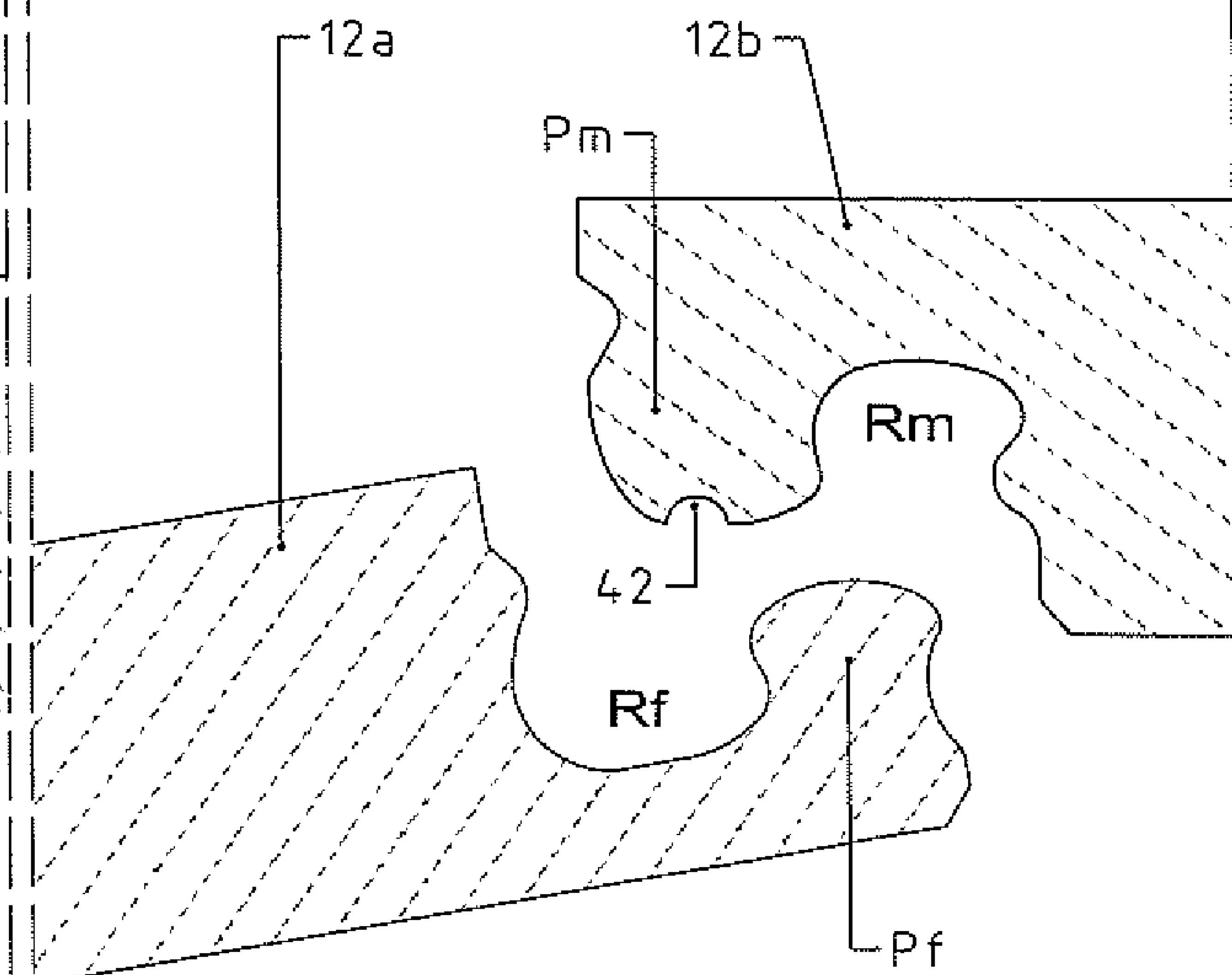


Fig 9f

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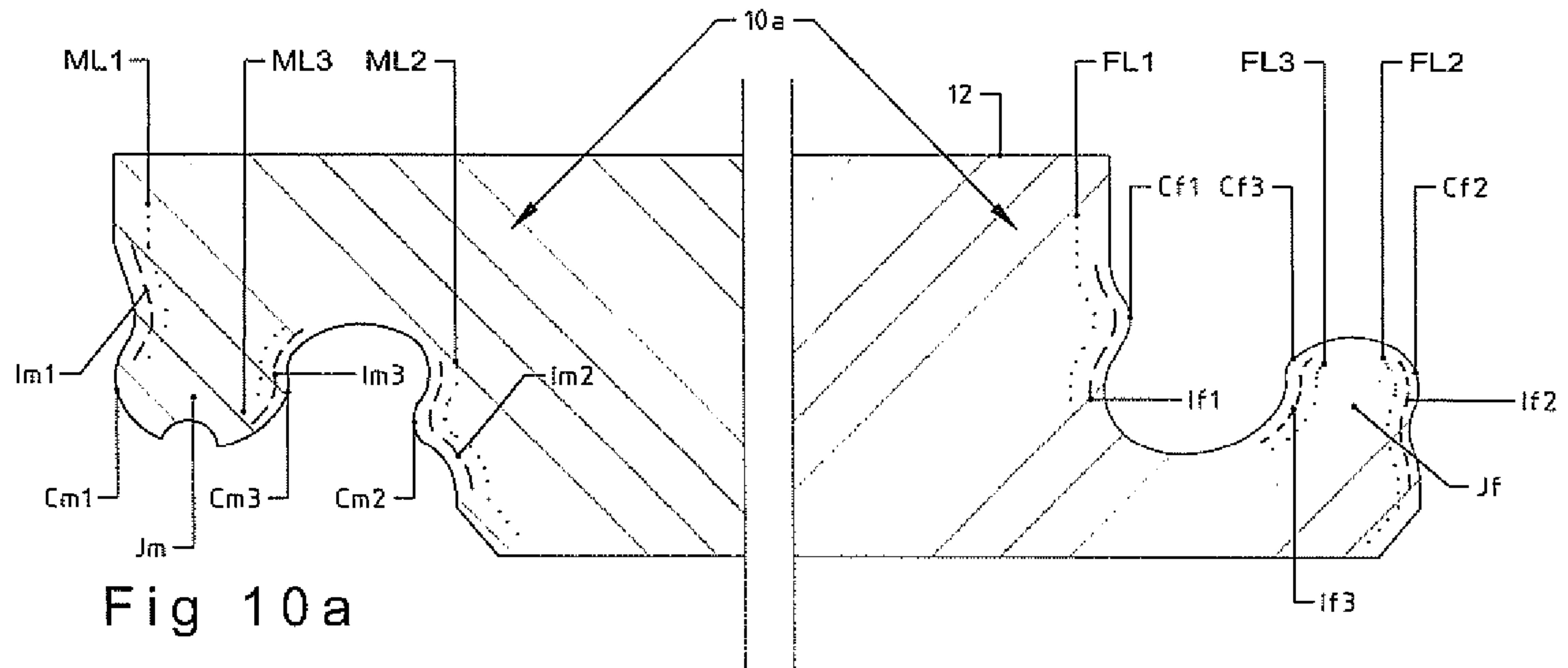


Fig 10a

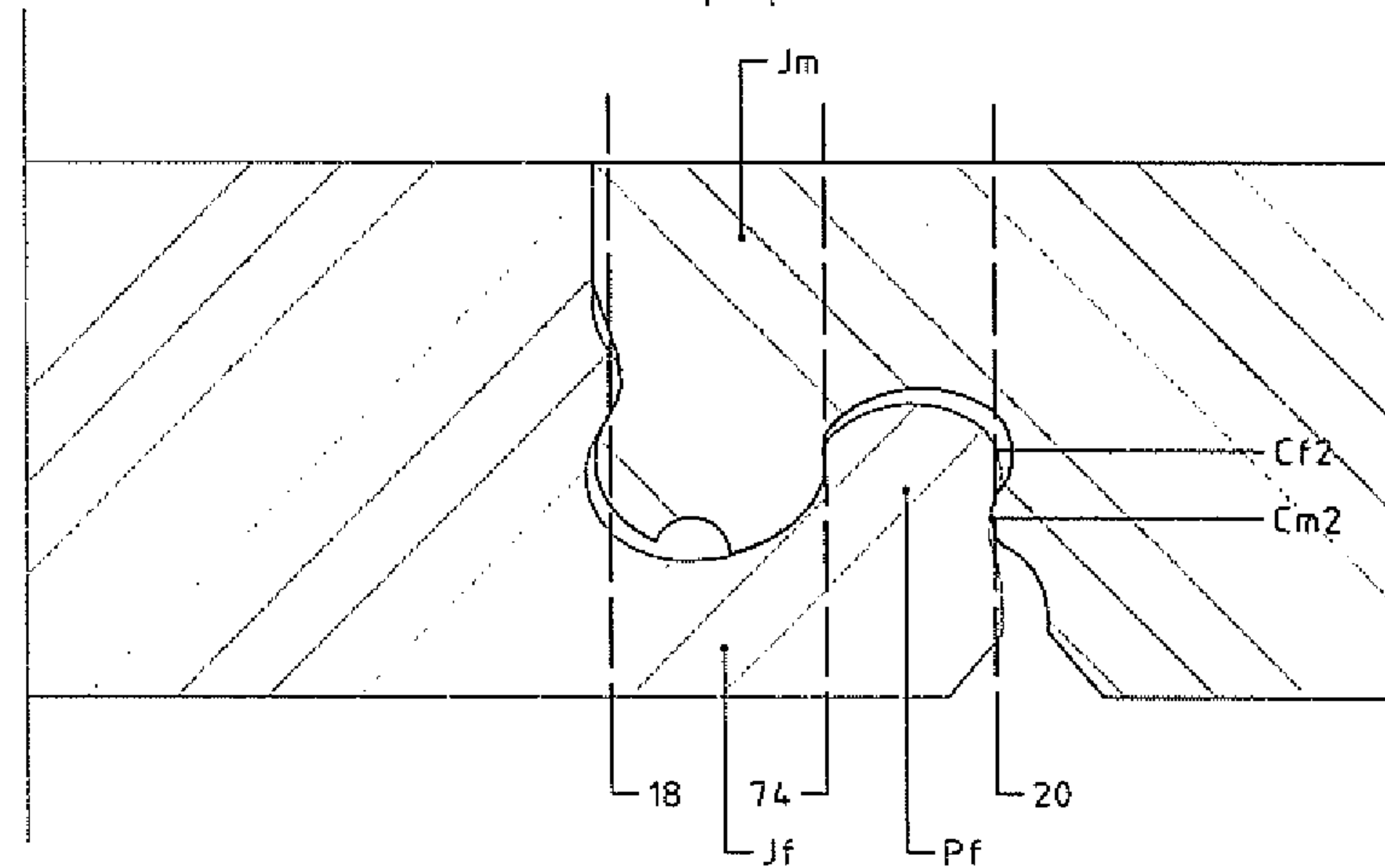


Fig 10b

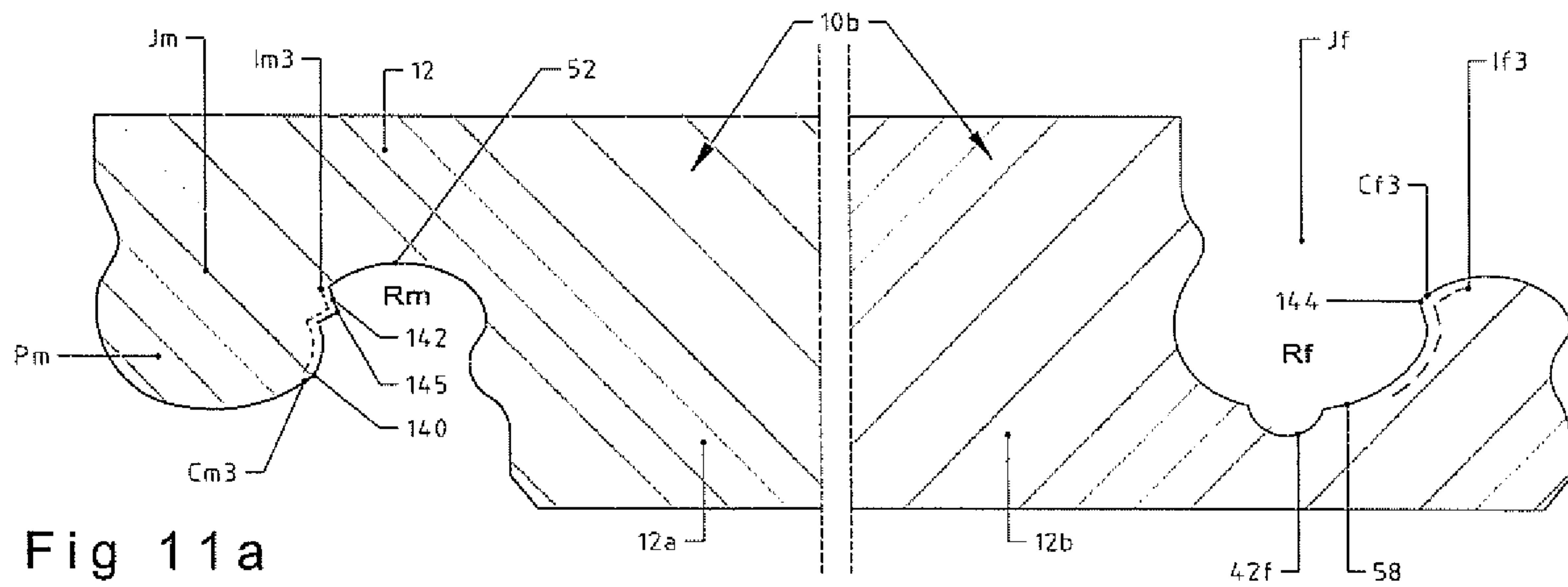


Fig 11a

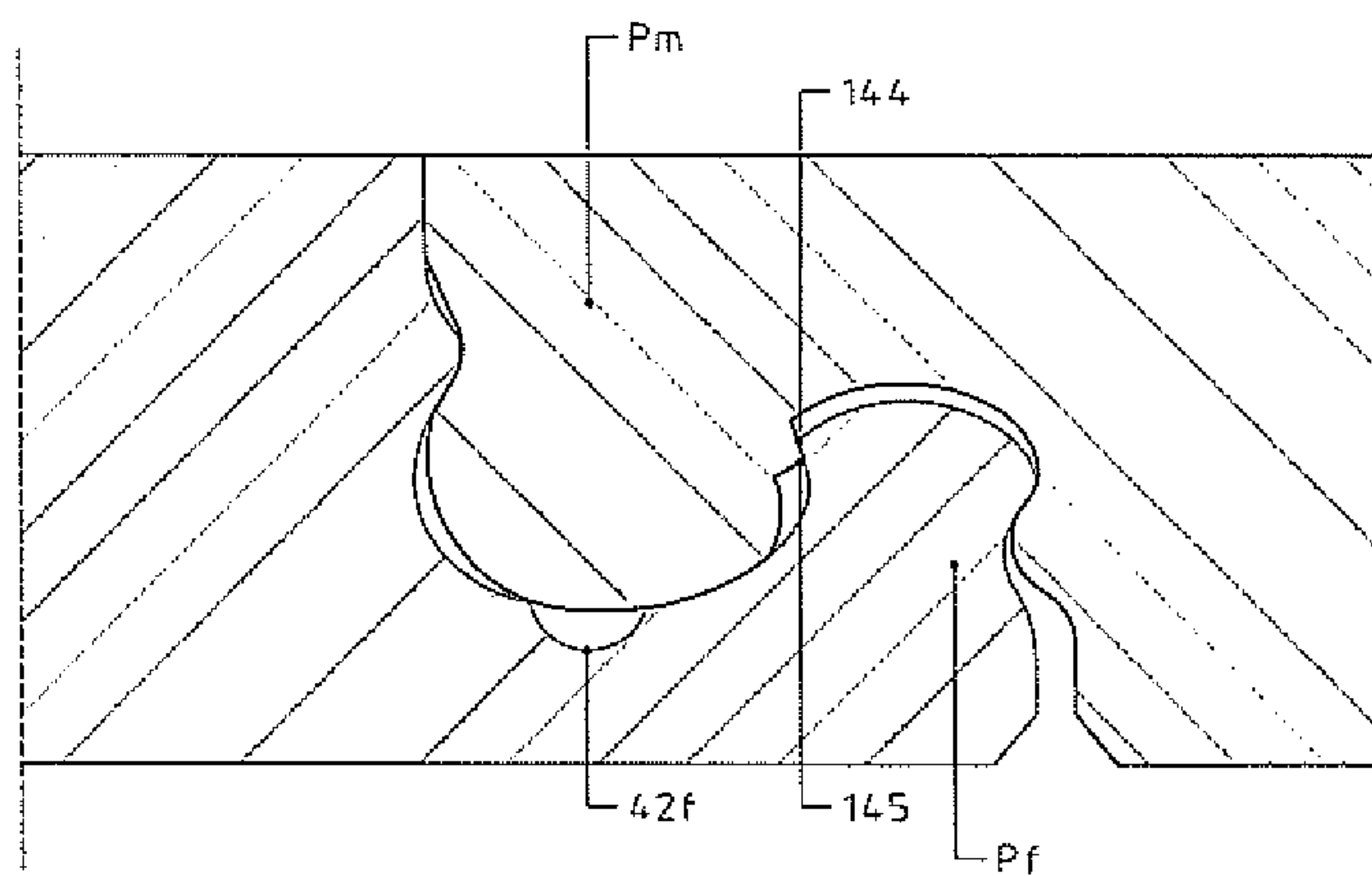


Fig 11b

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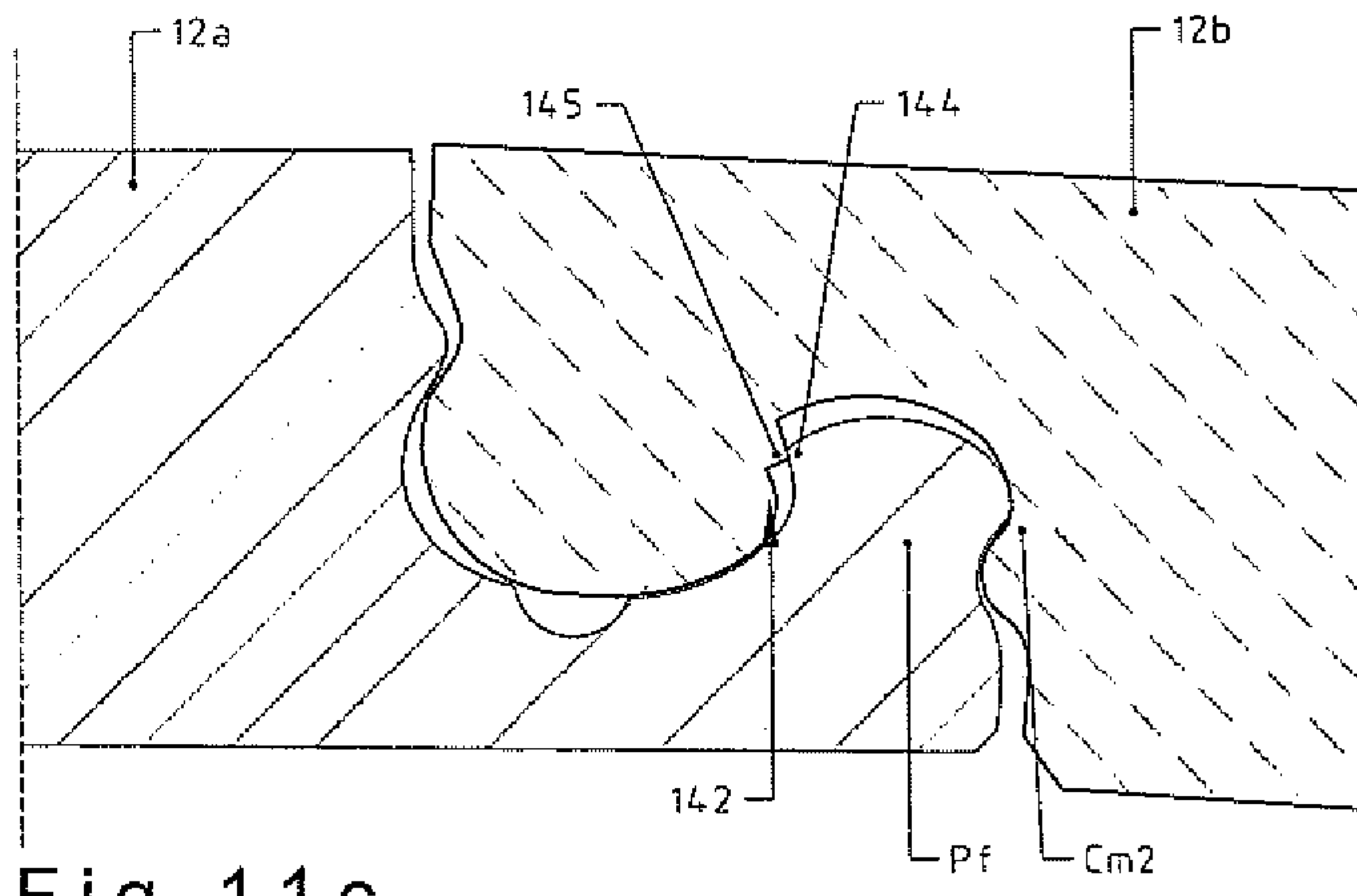


Fig 11c

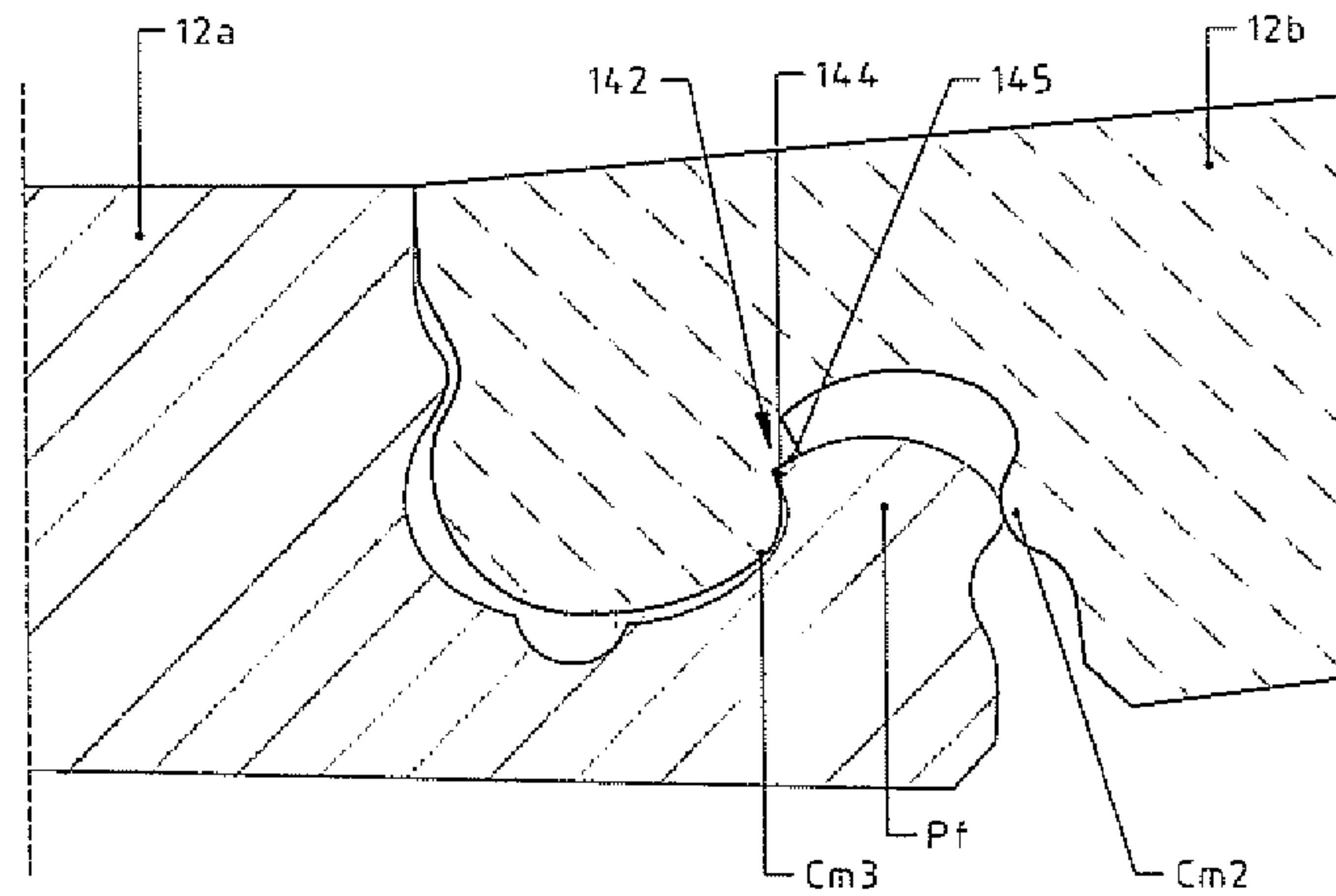


Fig 11d

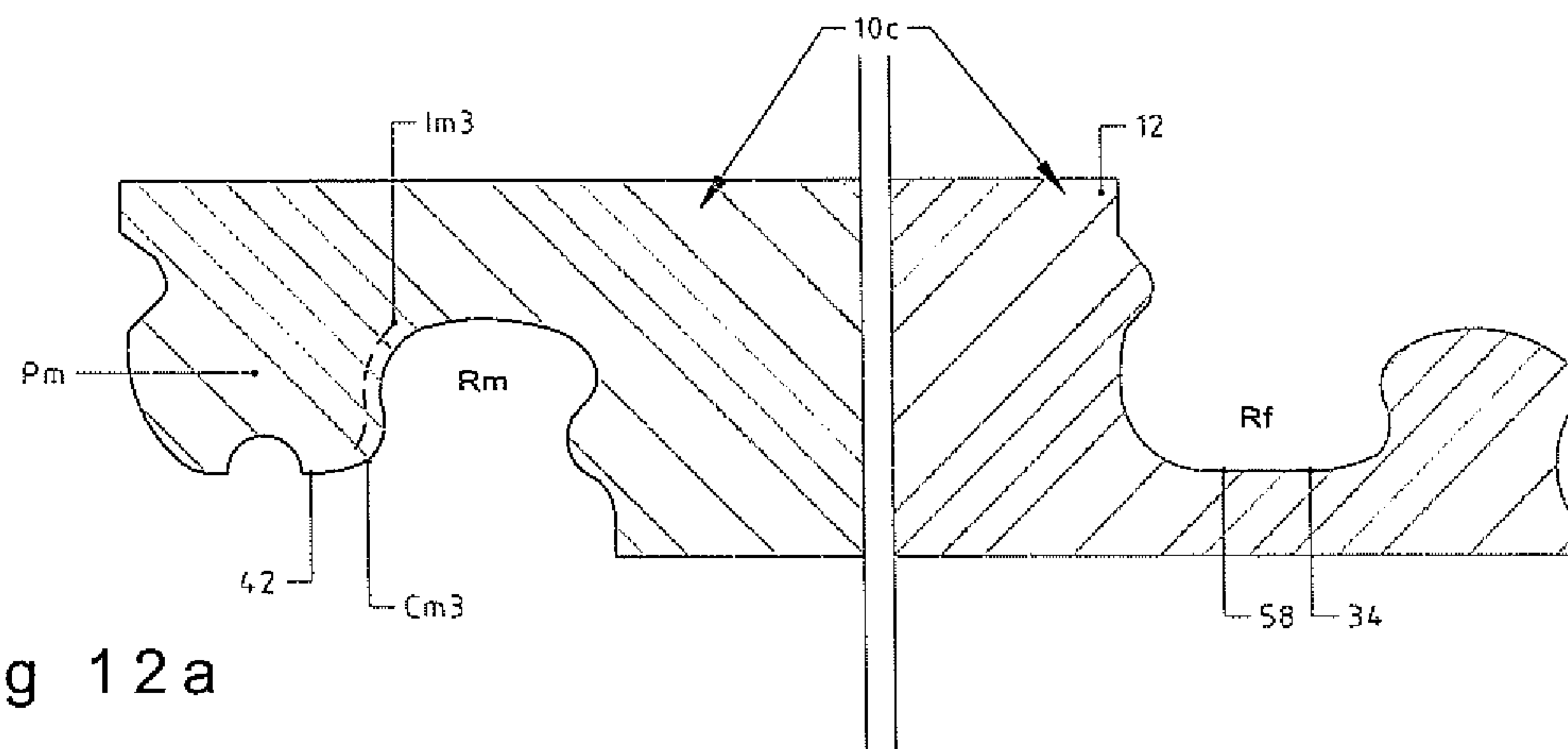


Fig 12a

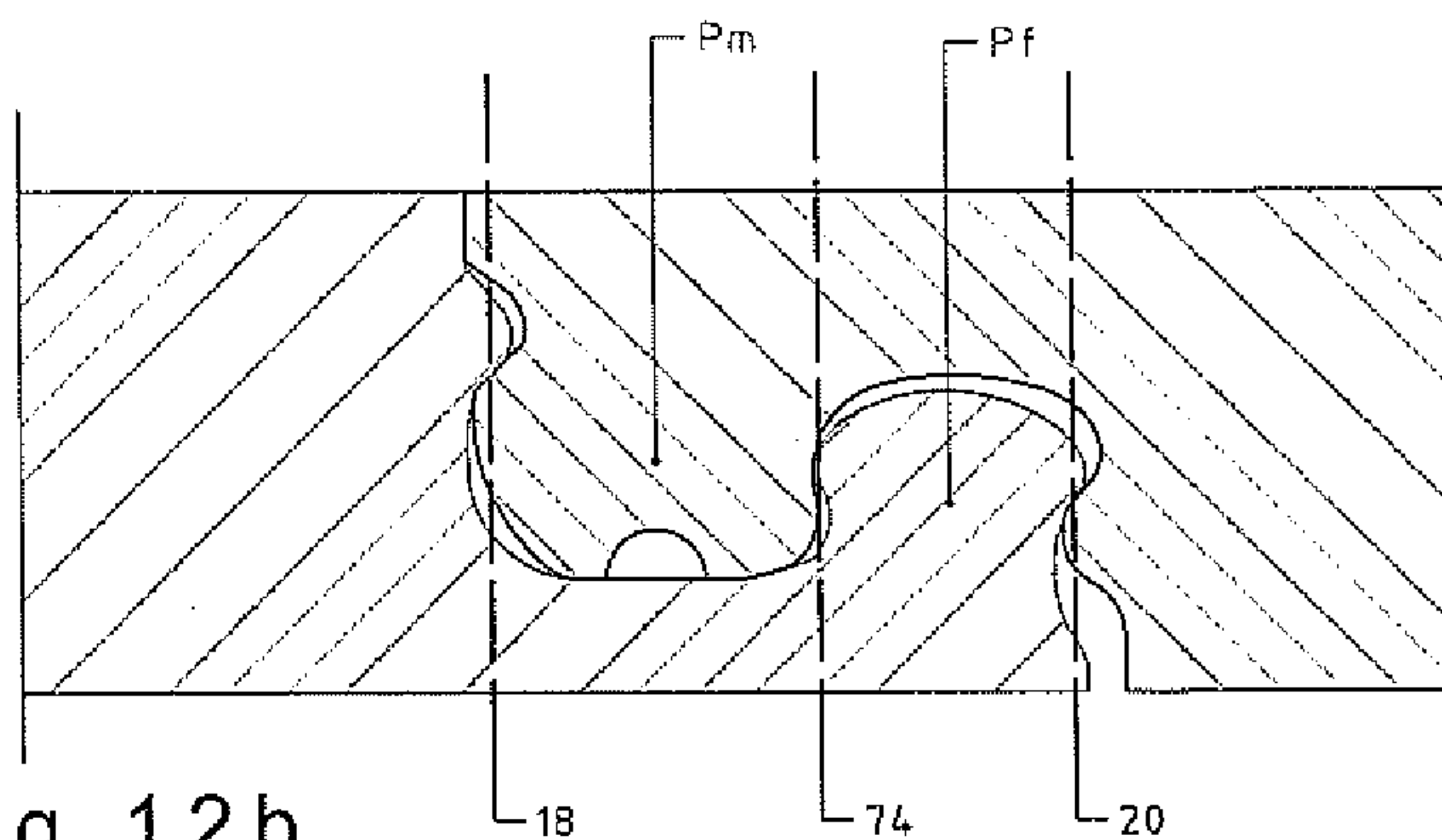


Fig 12b

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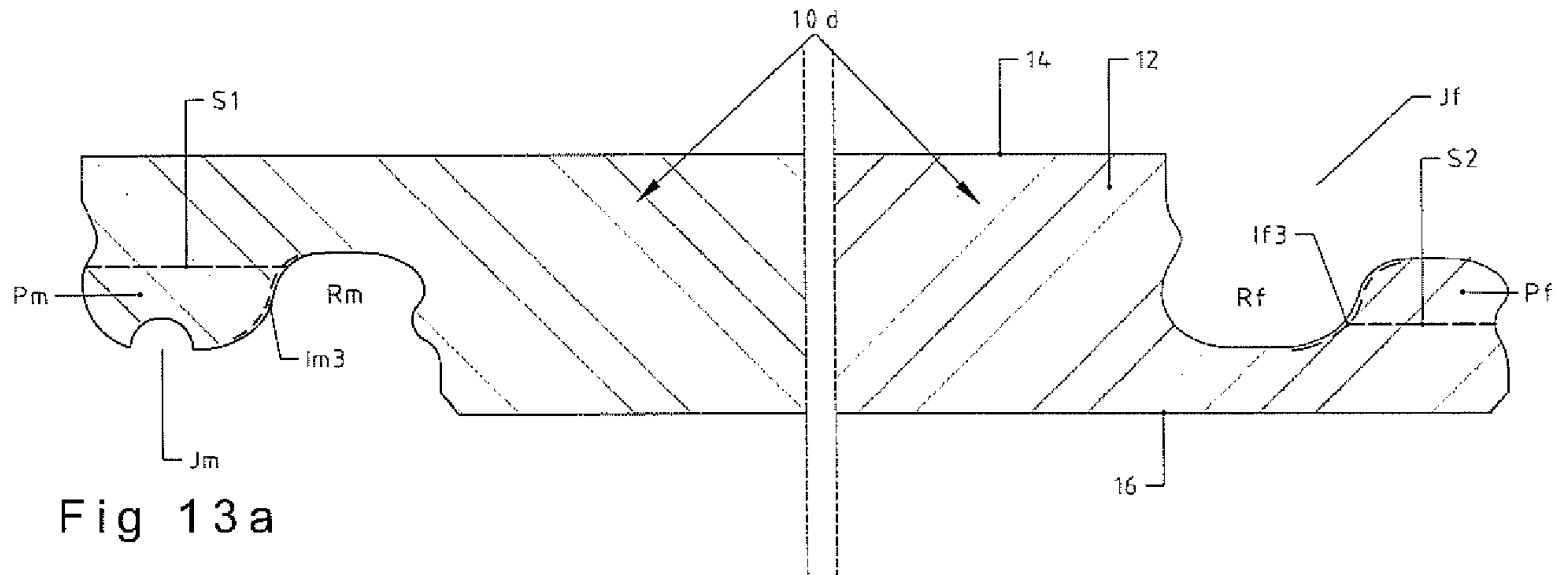


Fig 13a

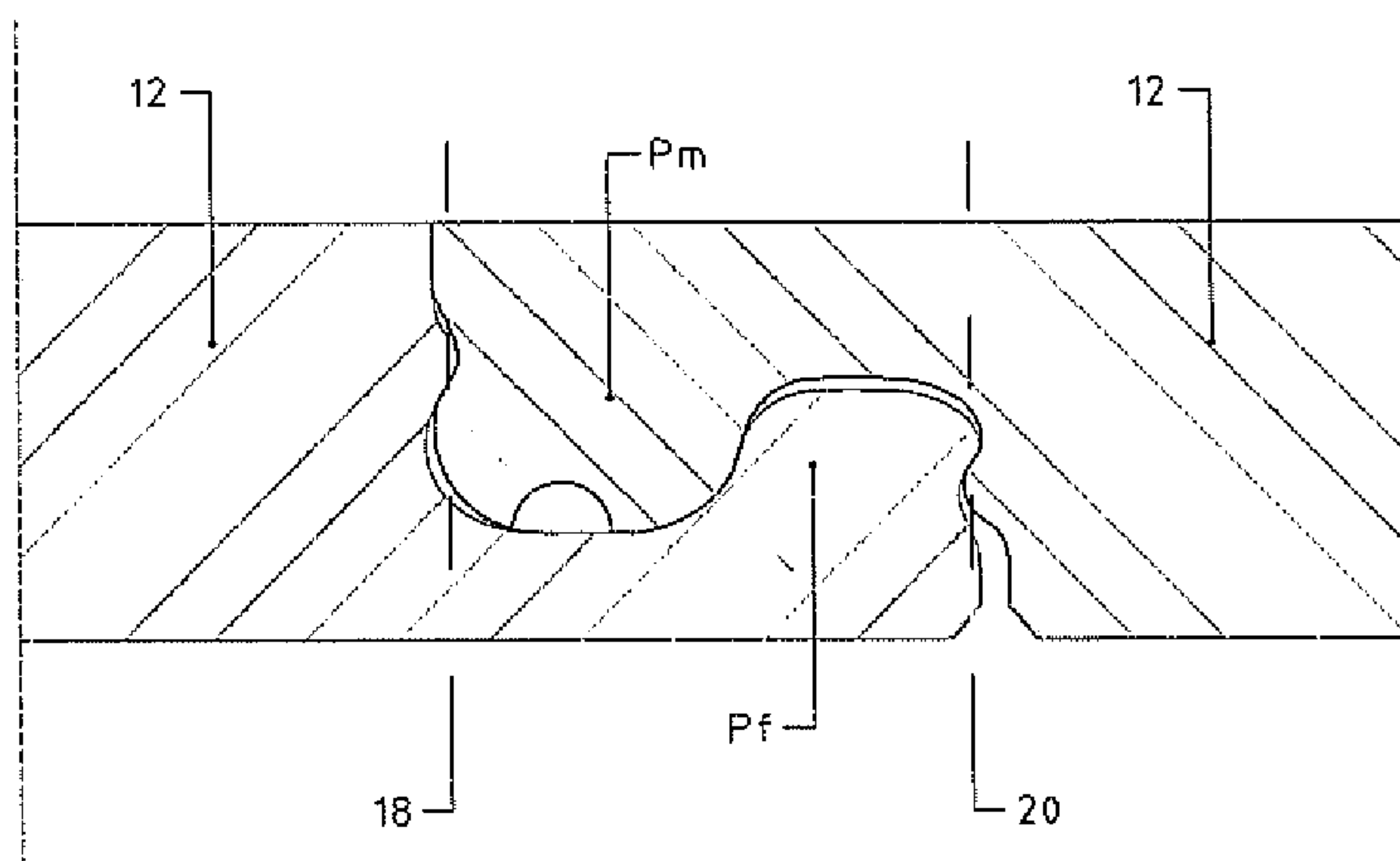


Fig 13b

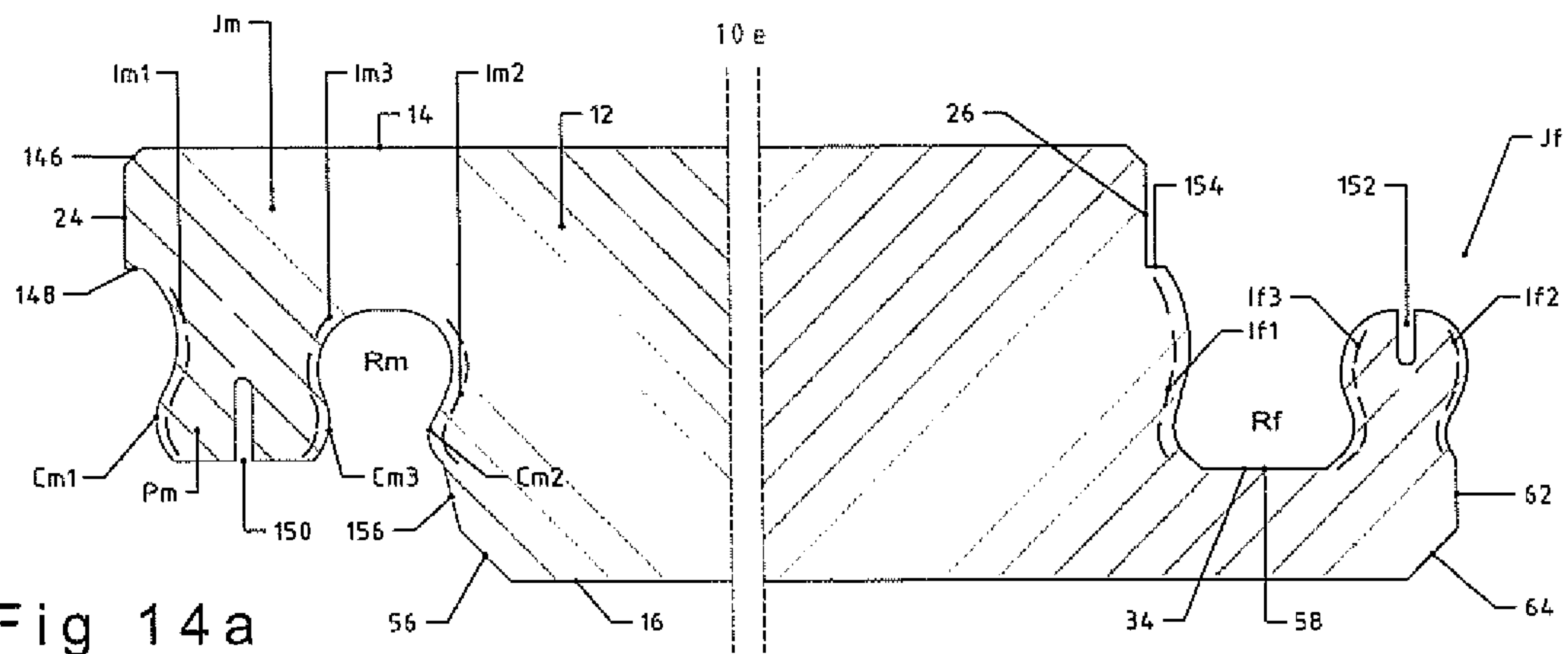


Fig 14a

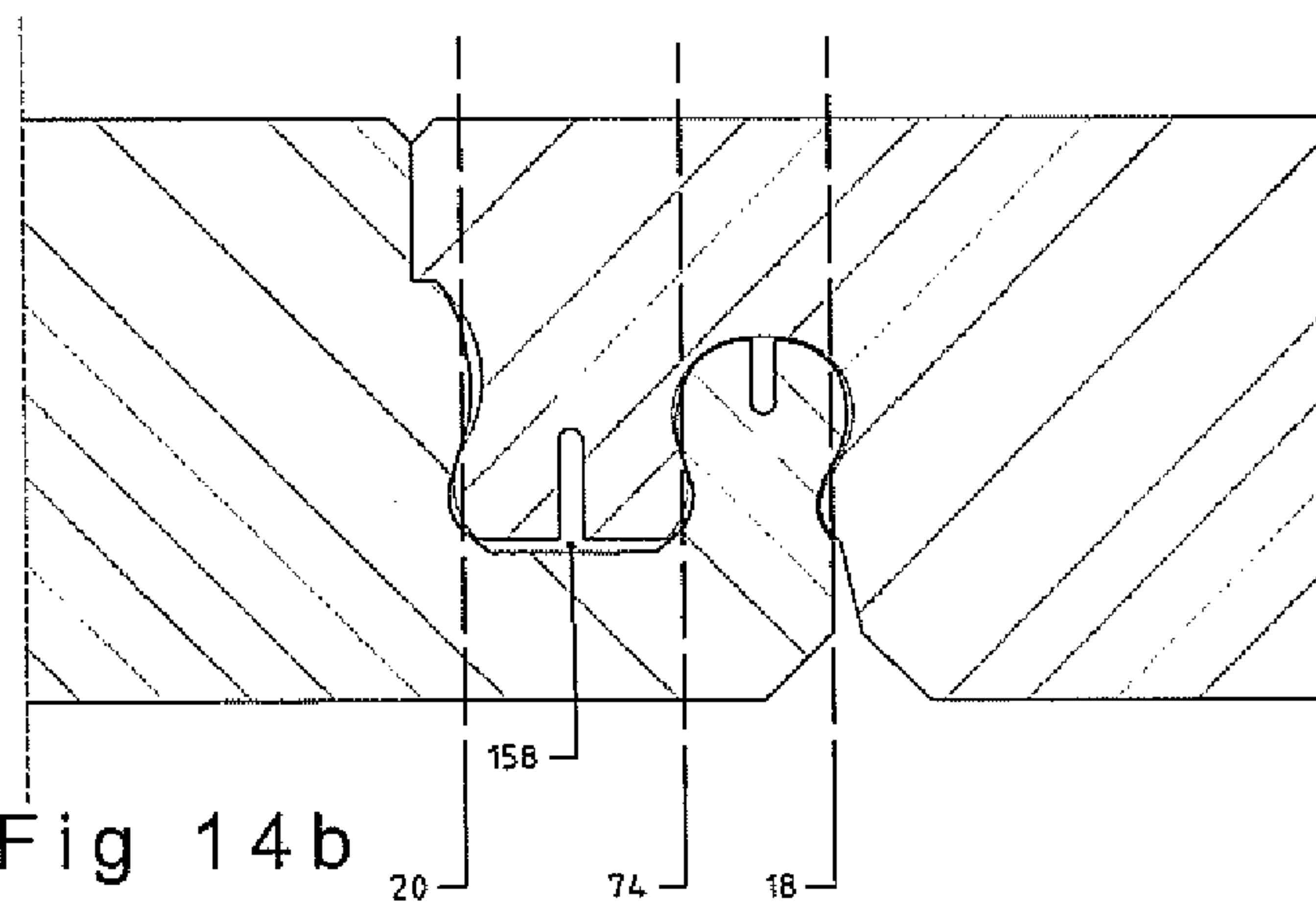


Fig 14b

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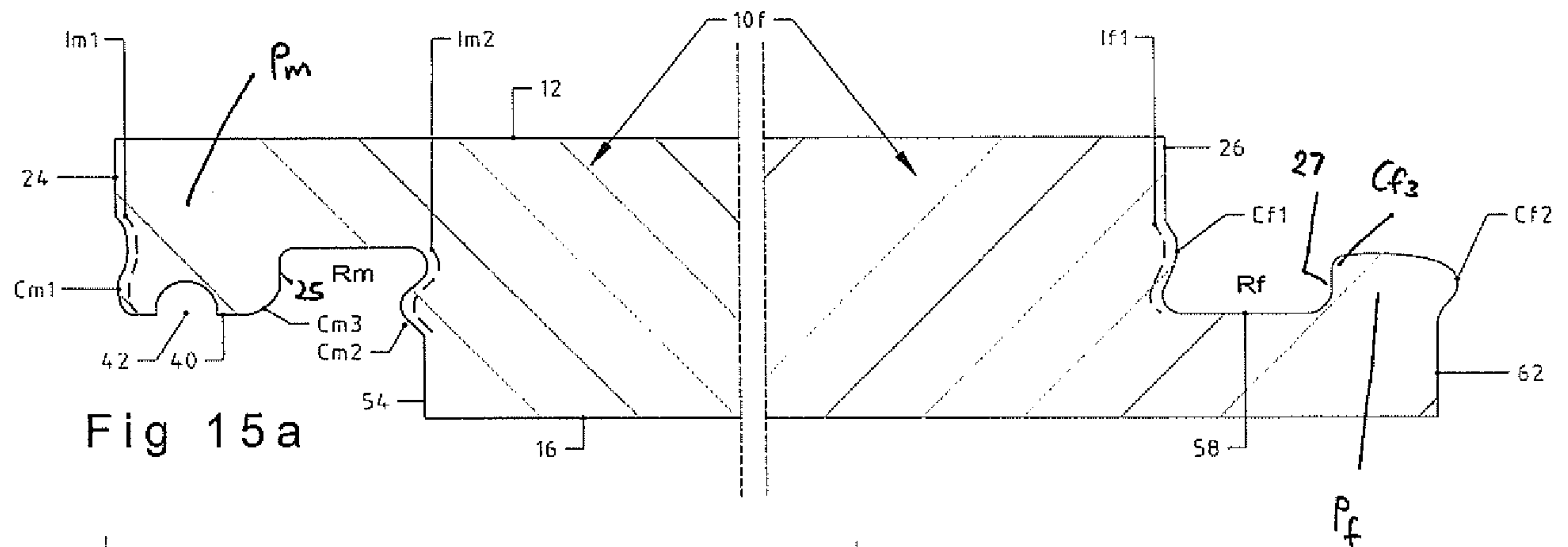


Fig 15a

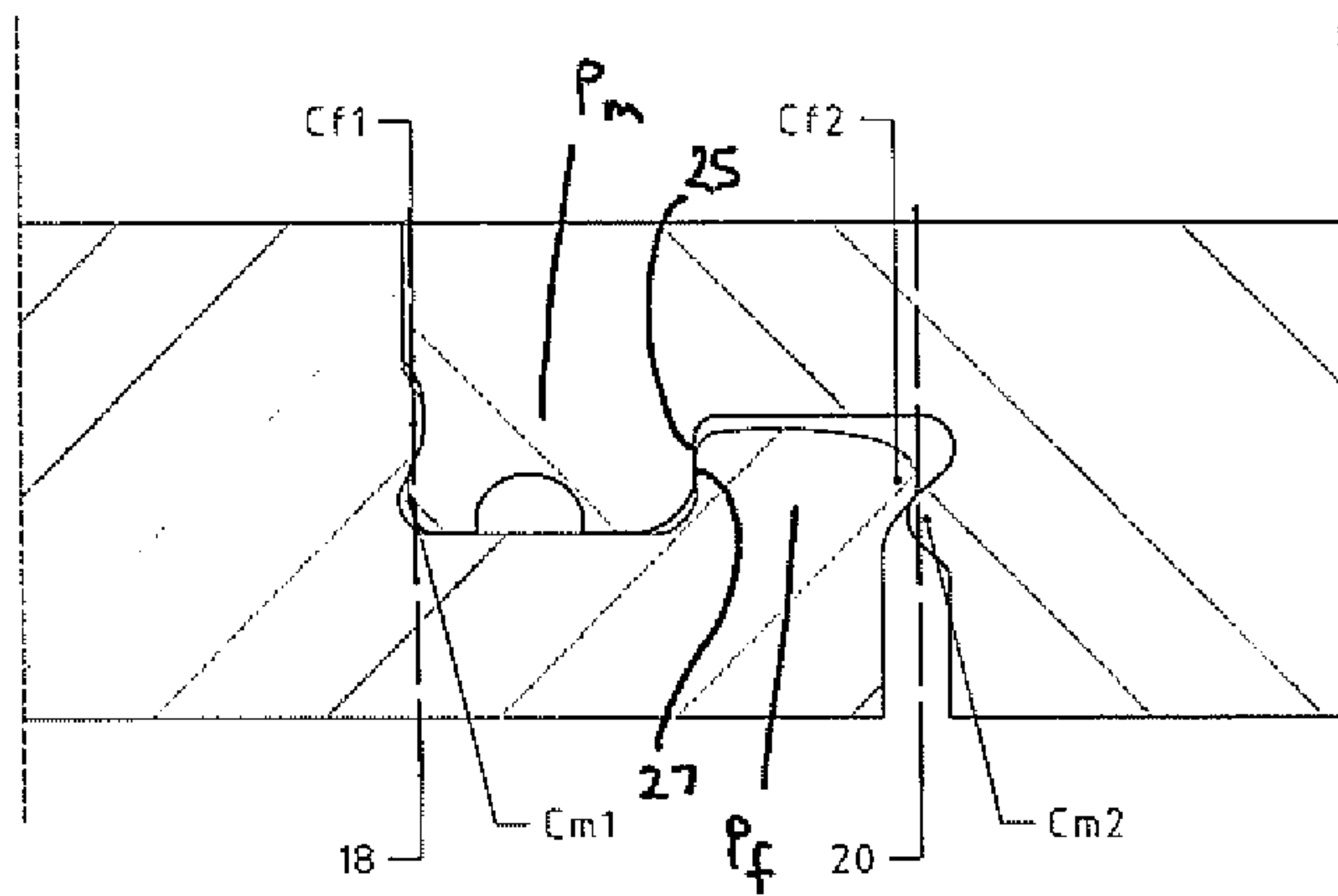


Fig 15b

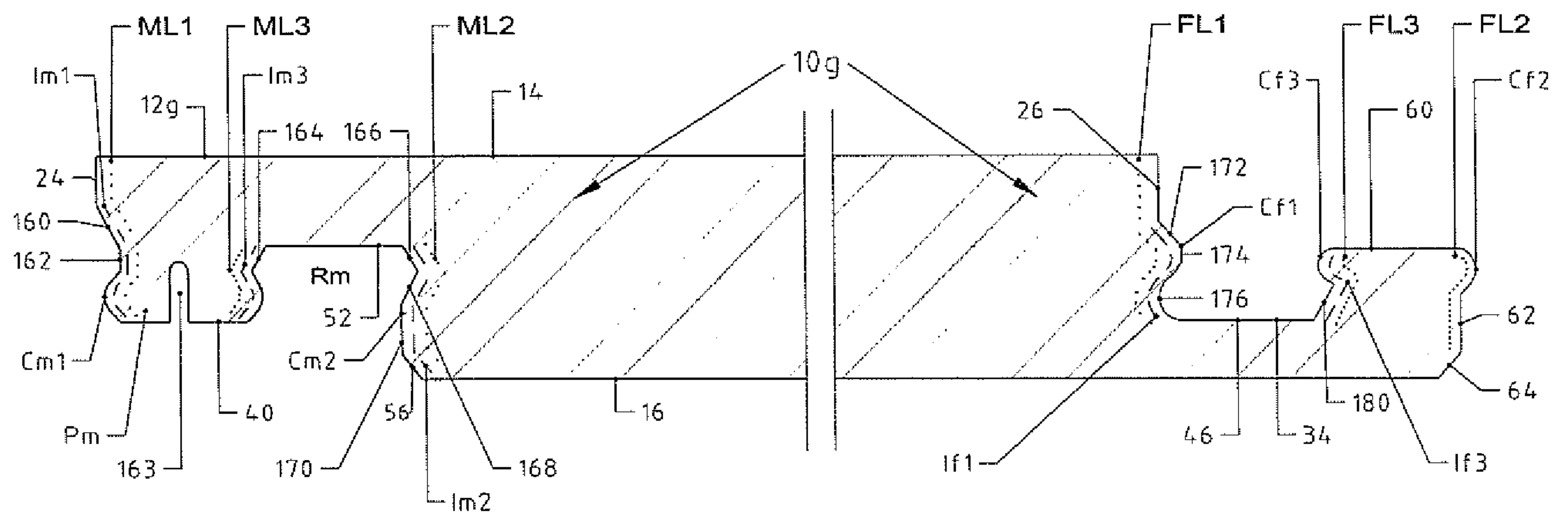


Fig 16a

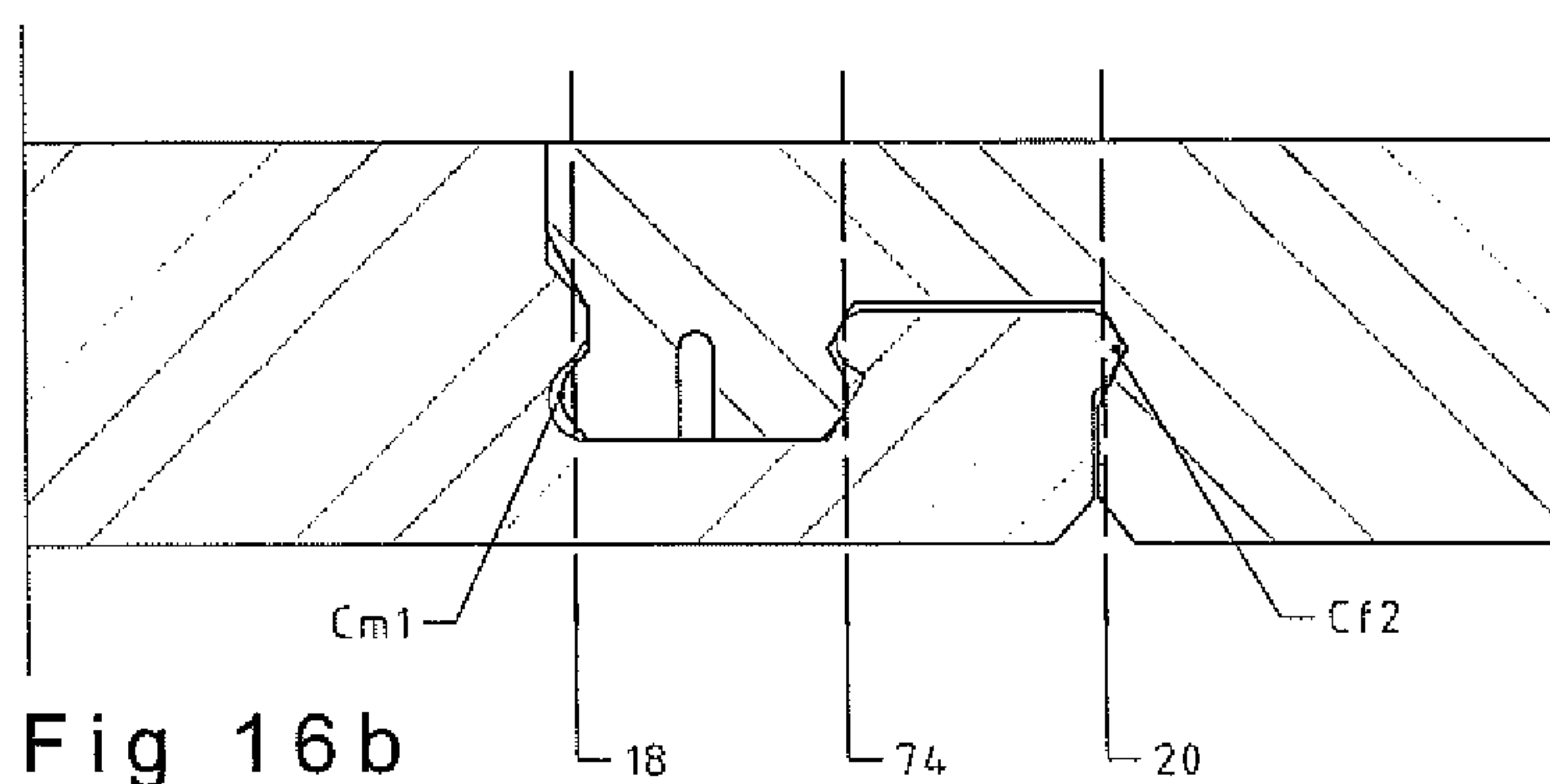
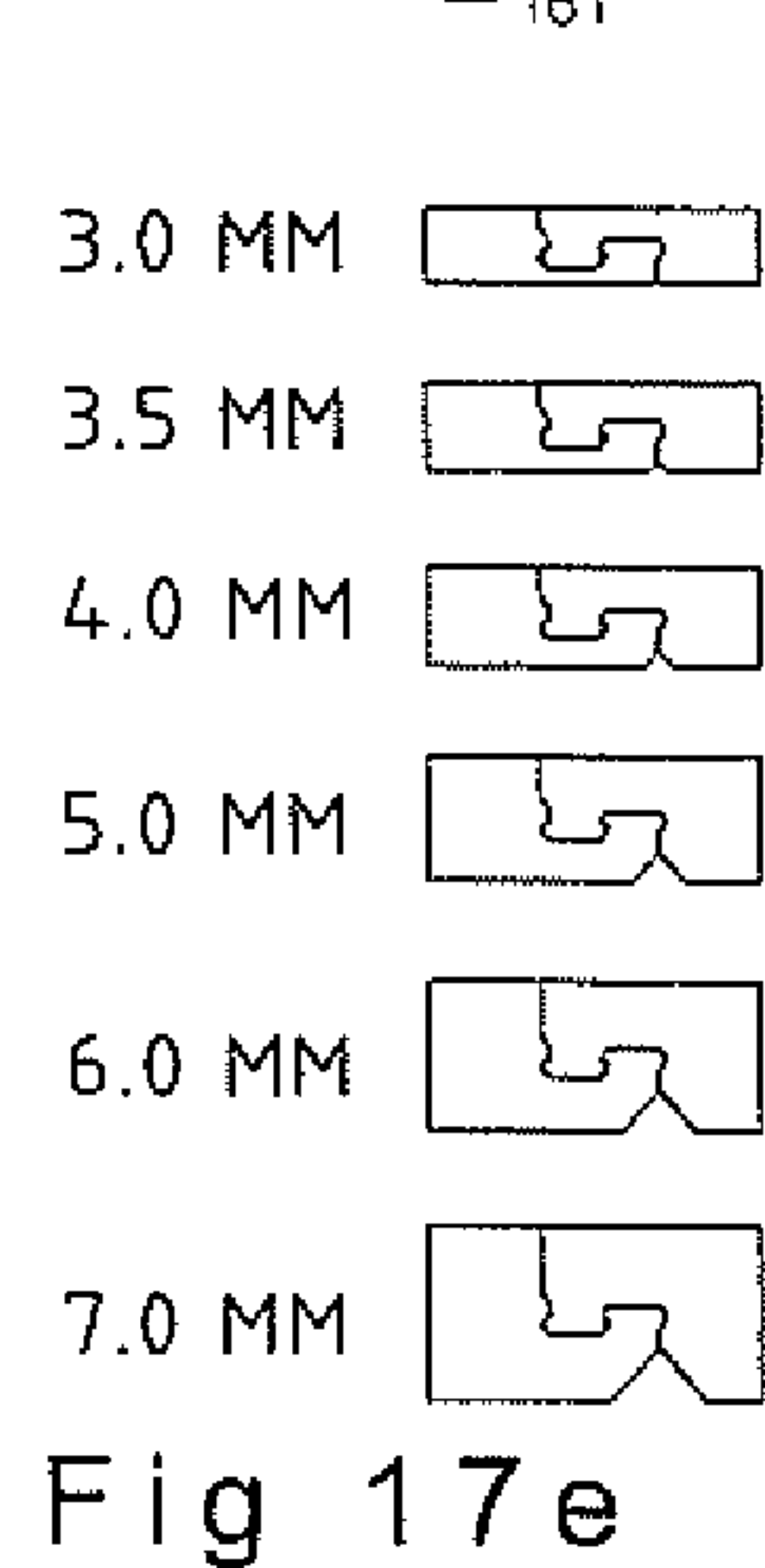
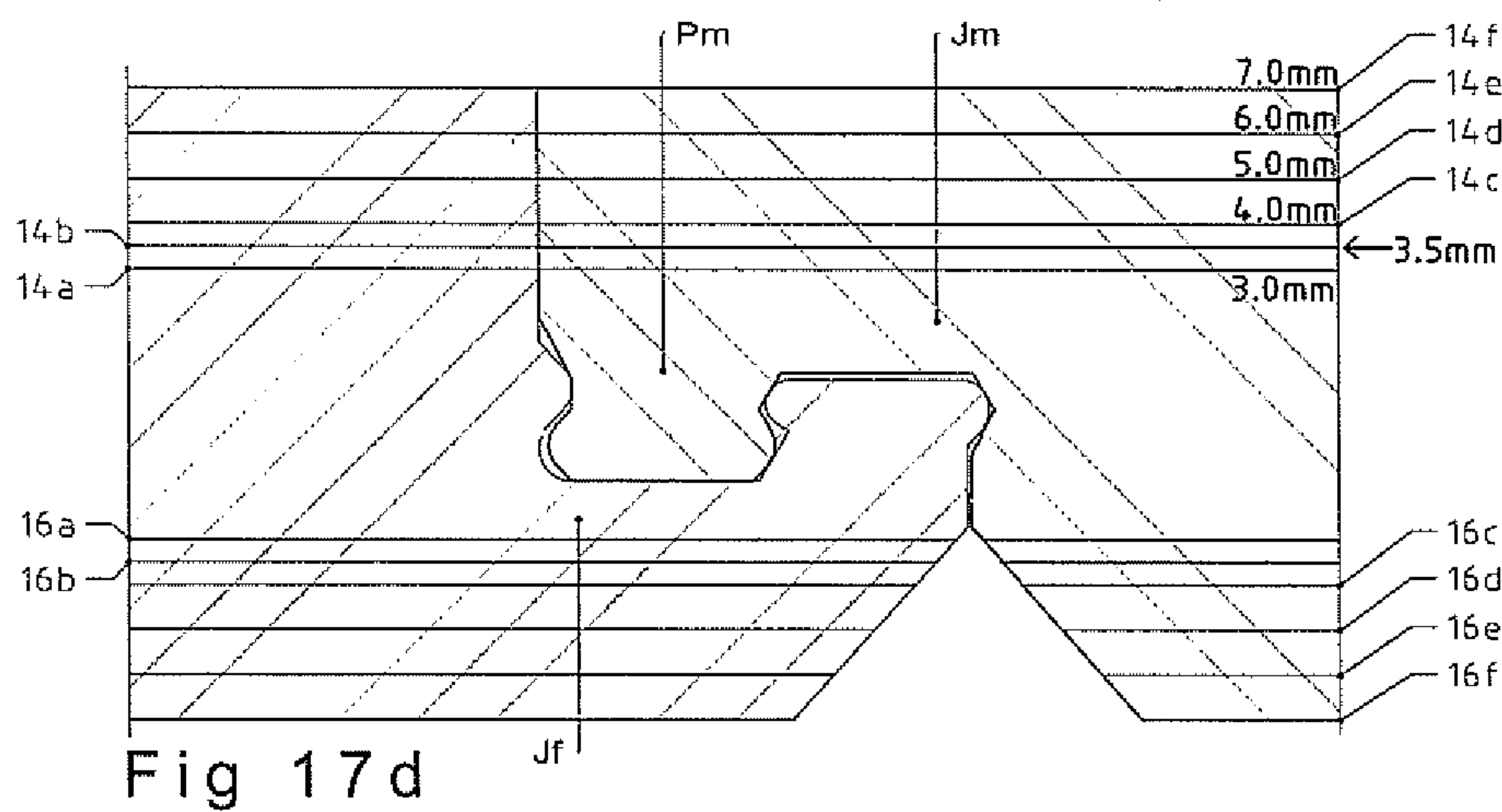
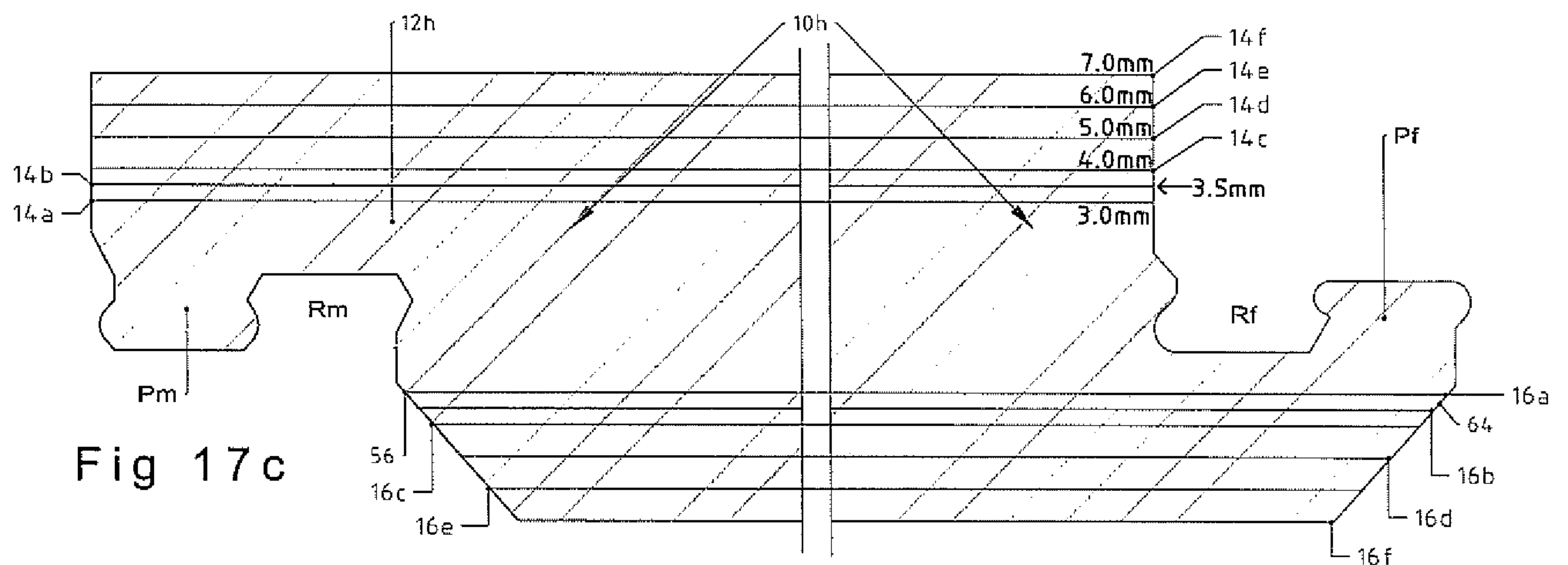
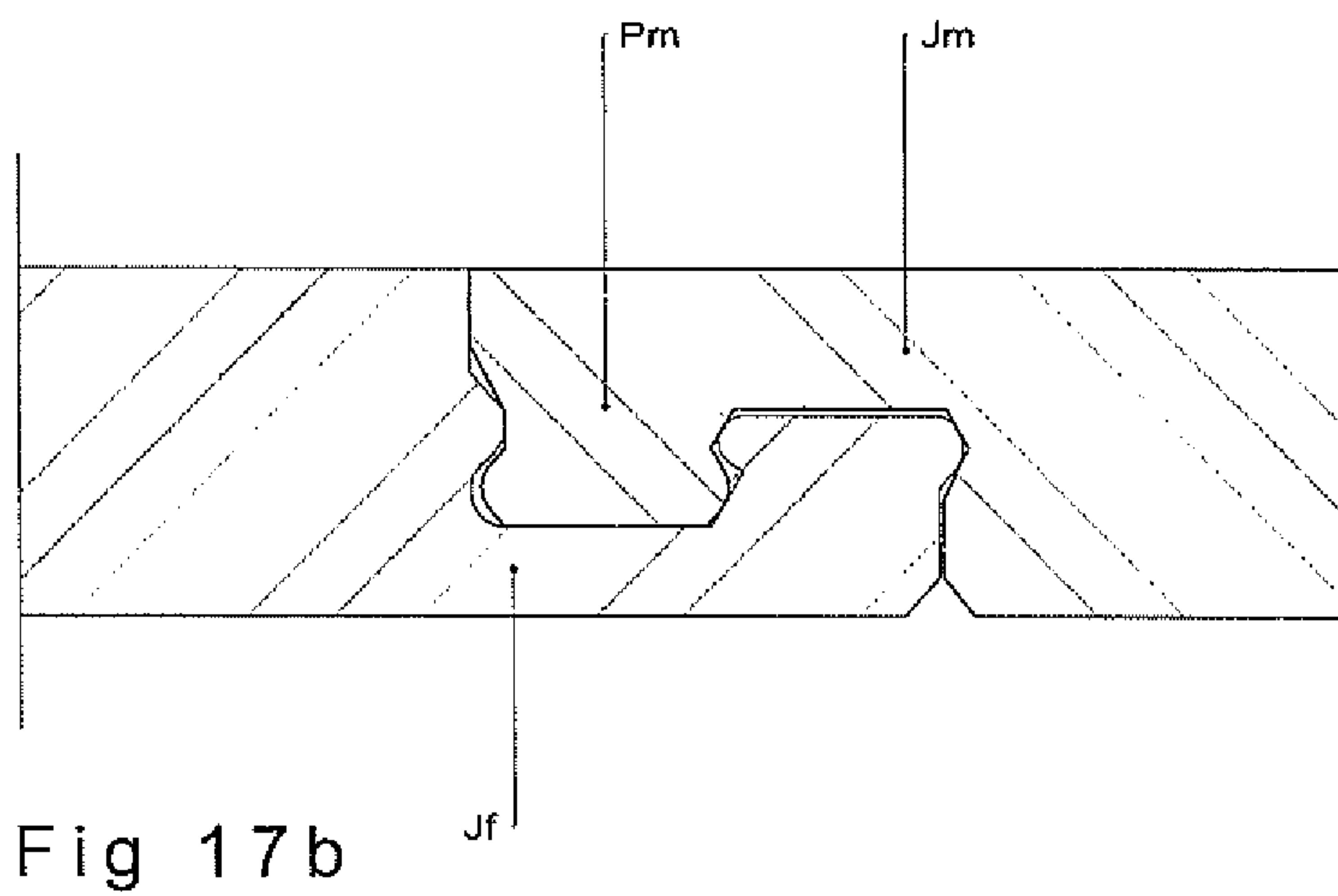
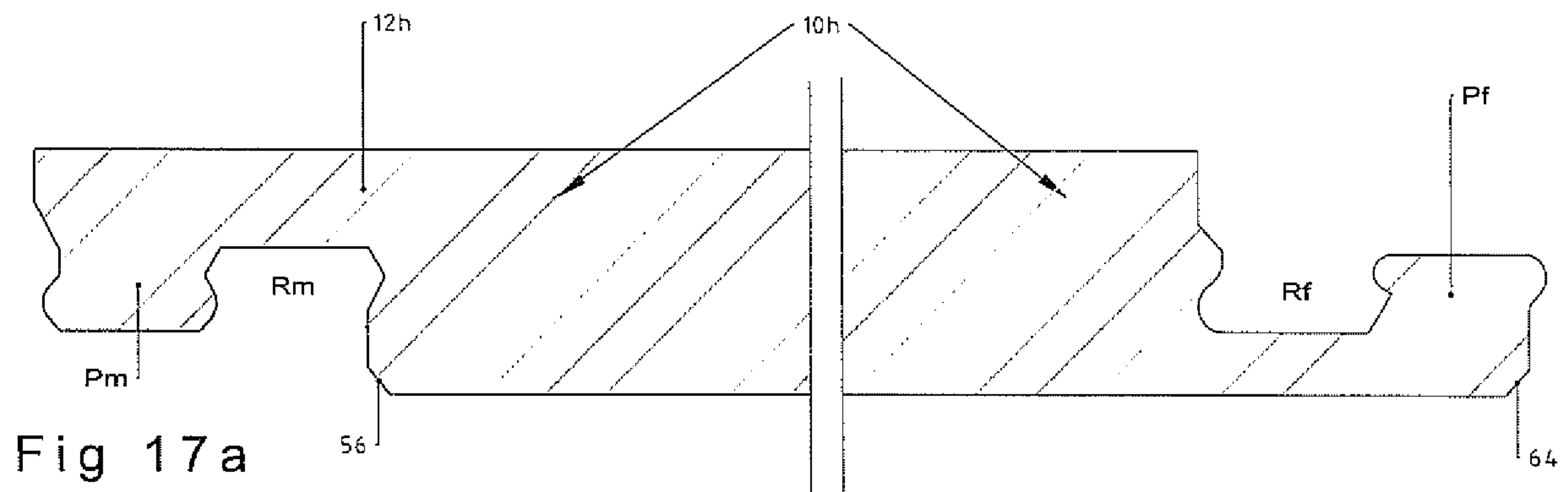
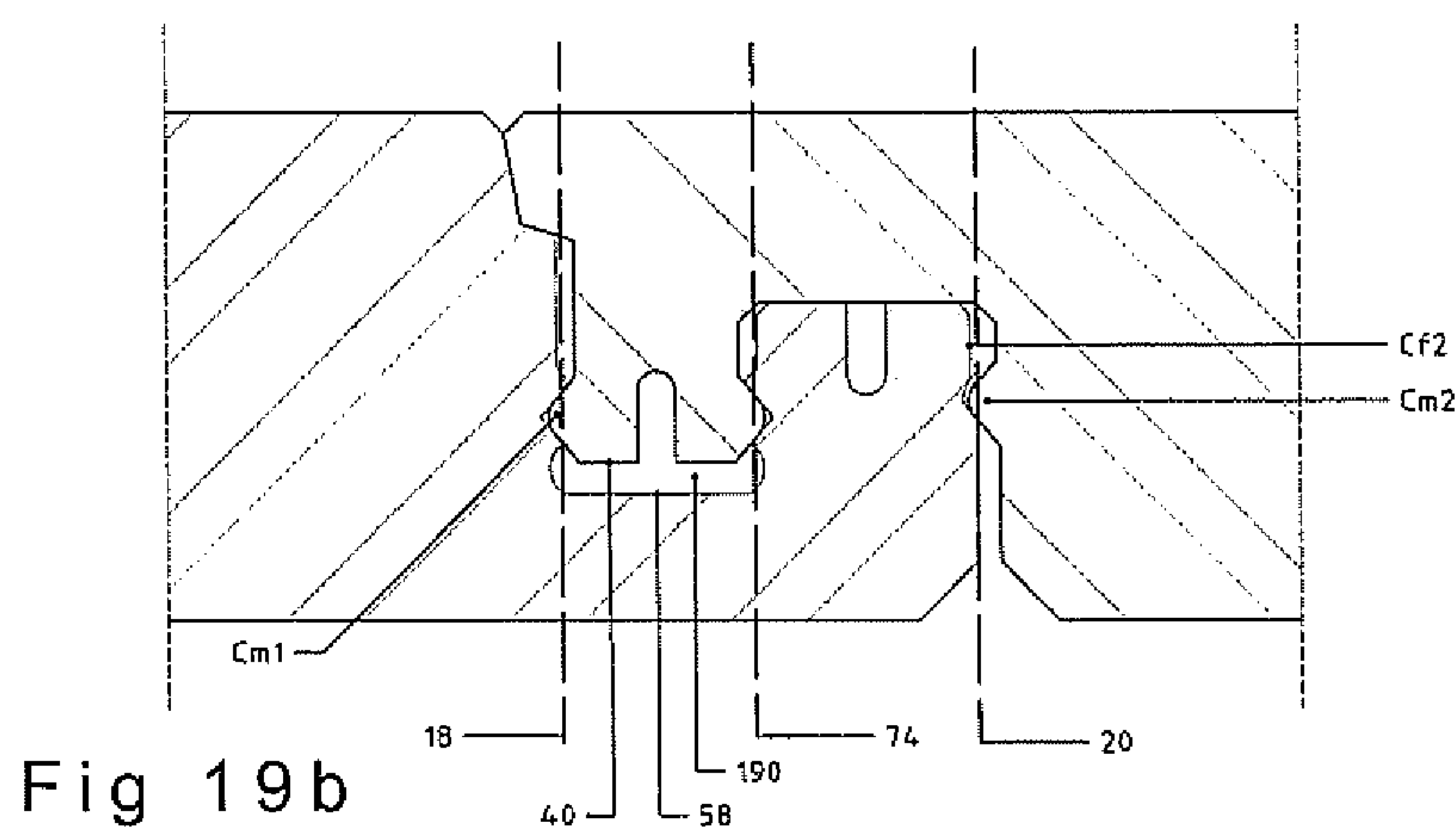
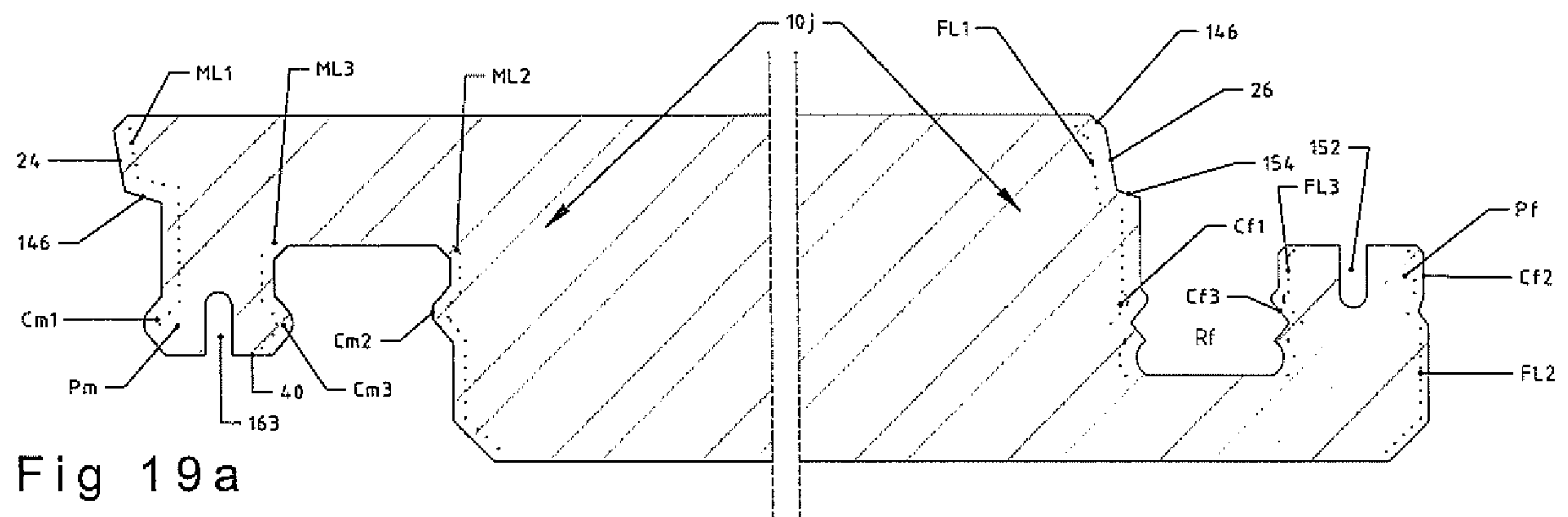
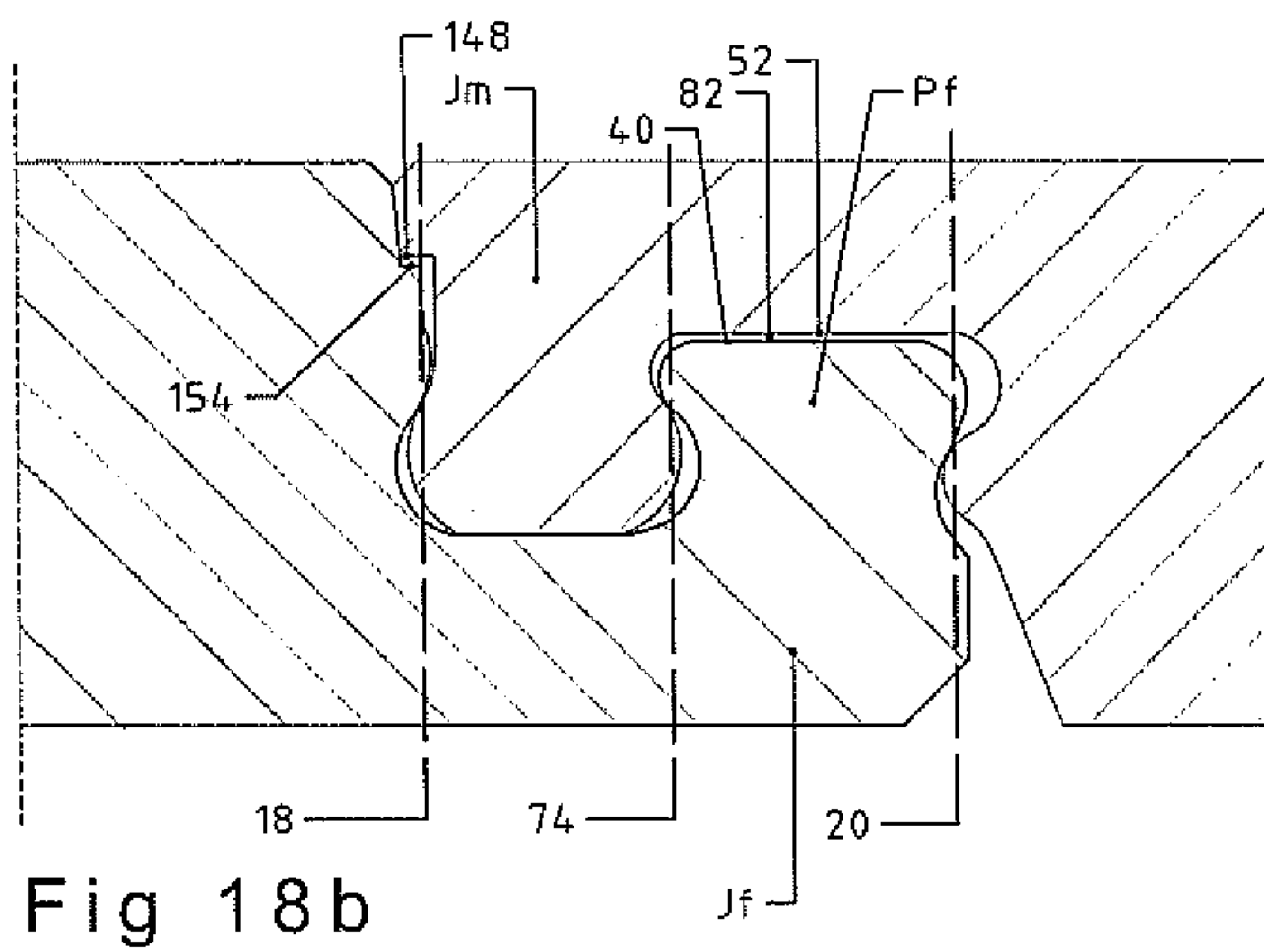
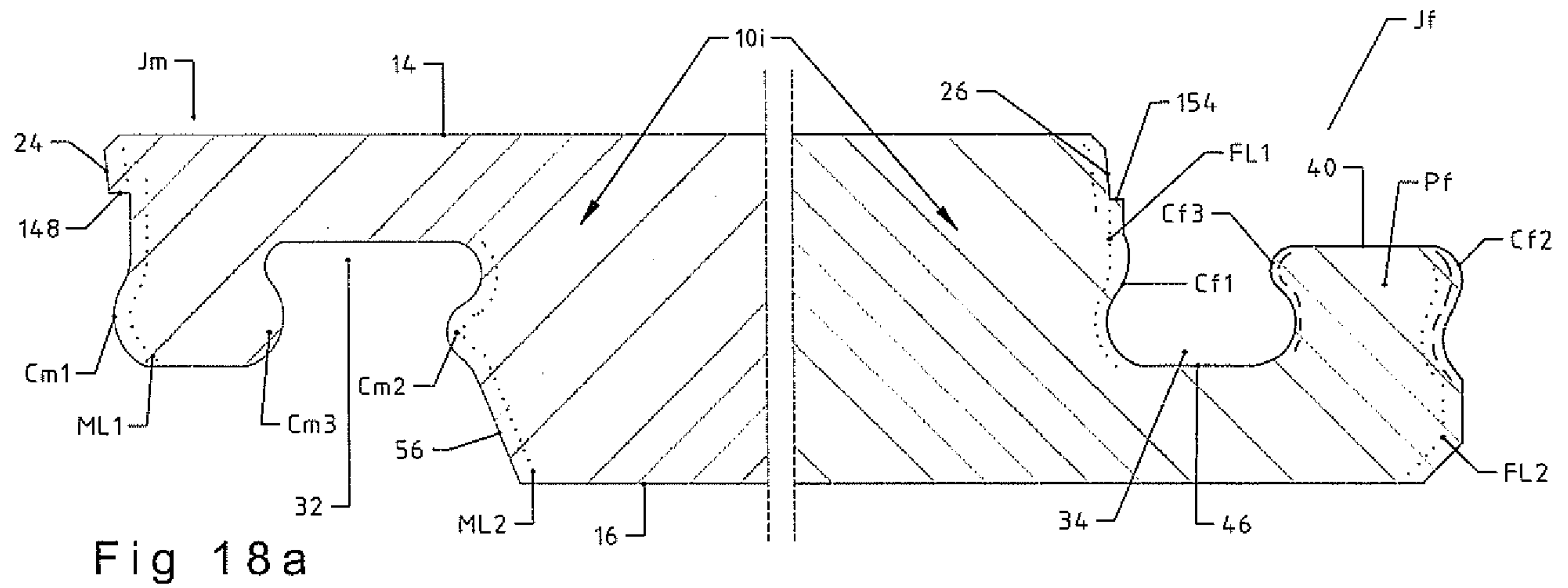


Fig 16b

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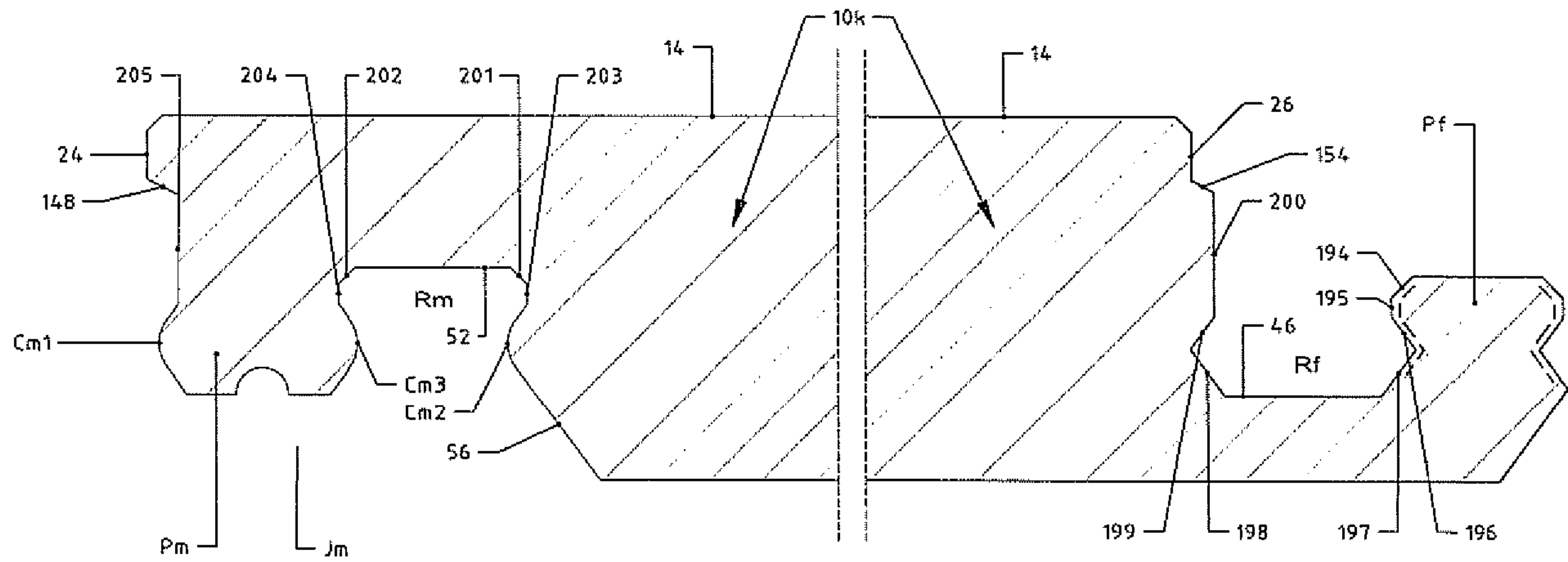


Fig 20a

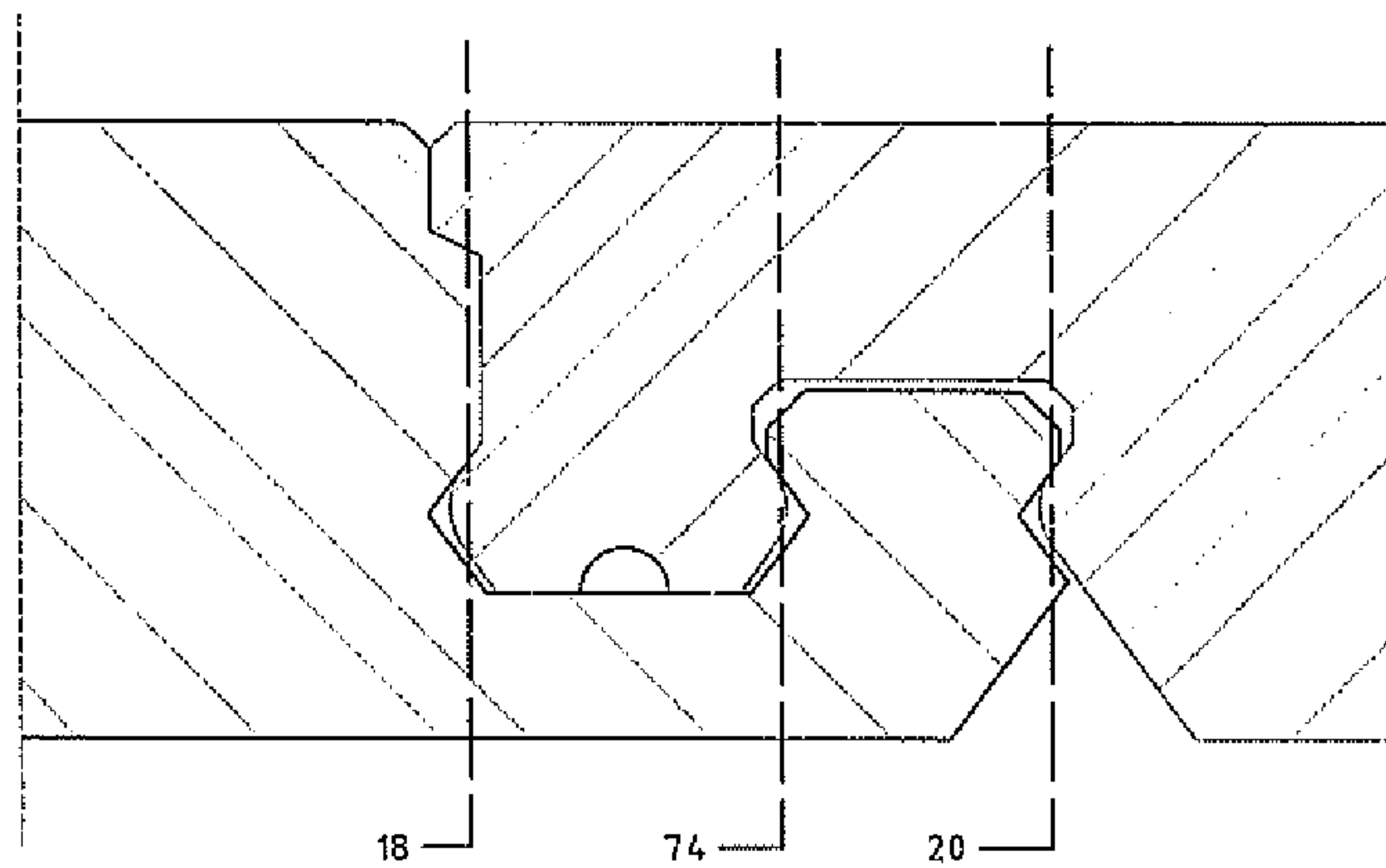


Fig 20b

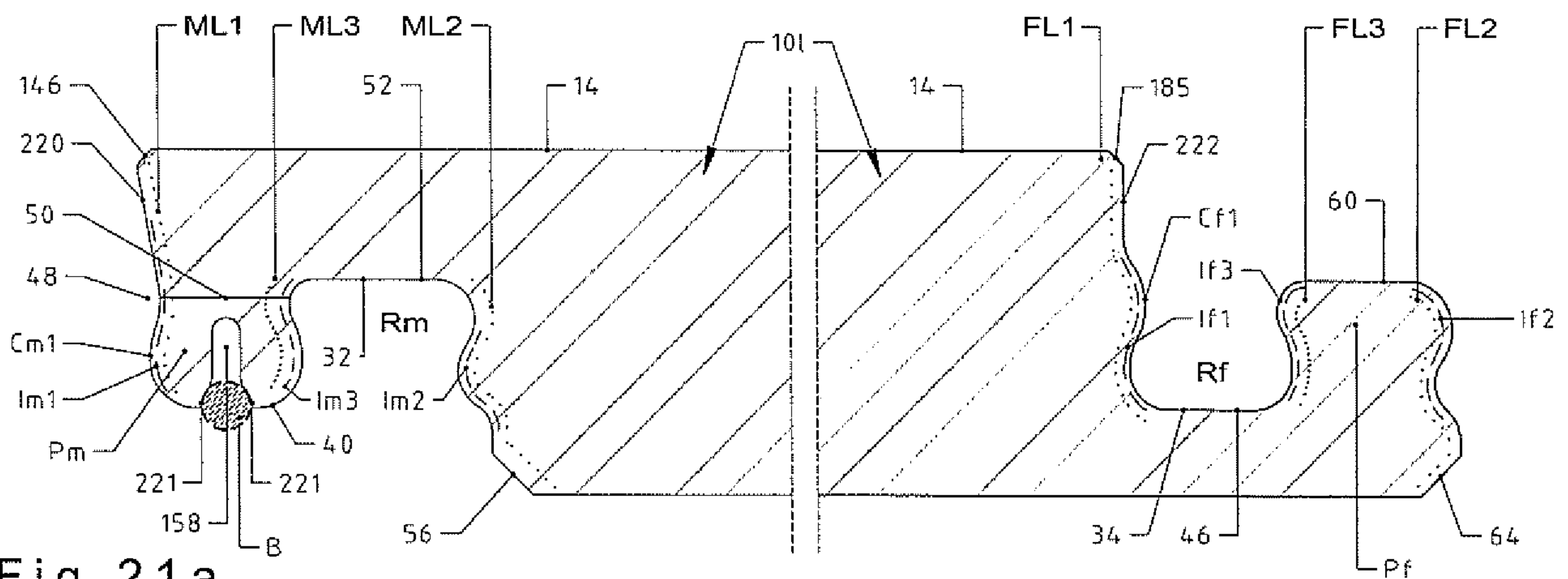


Fig 21a

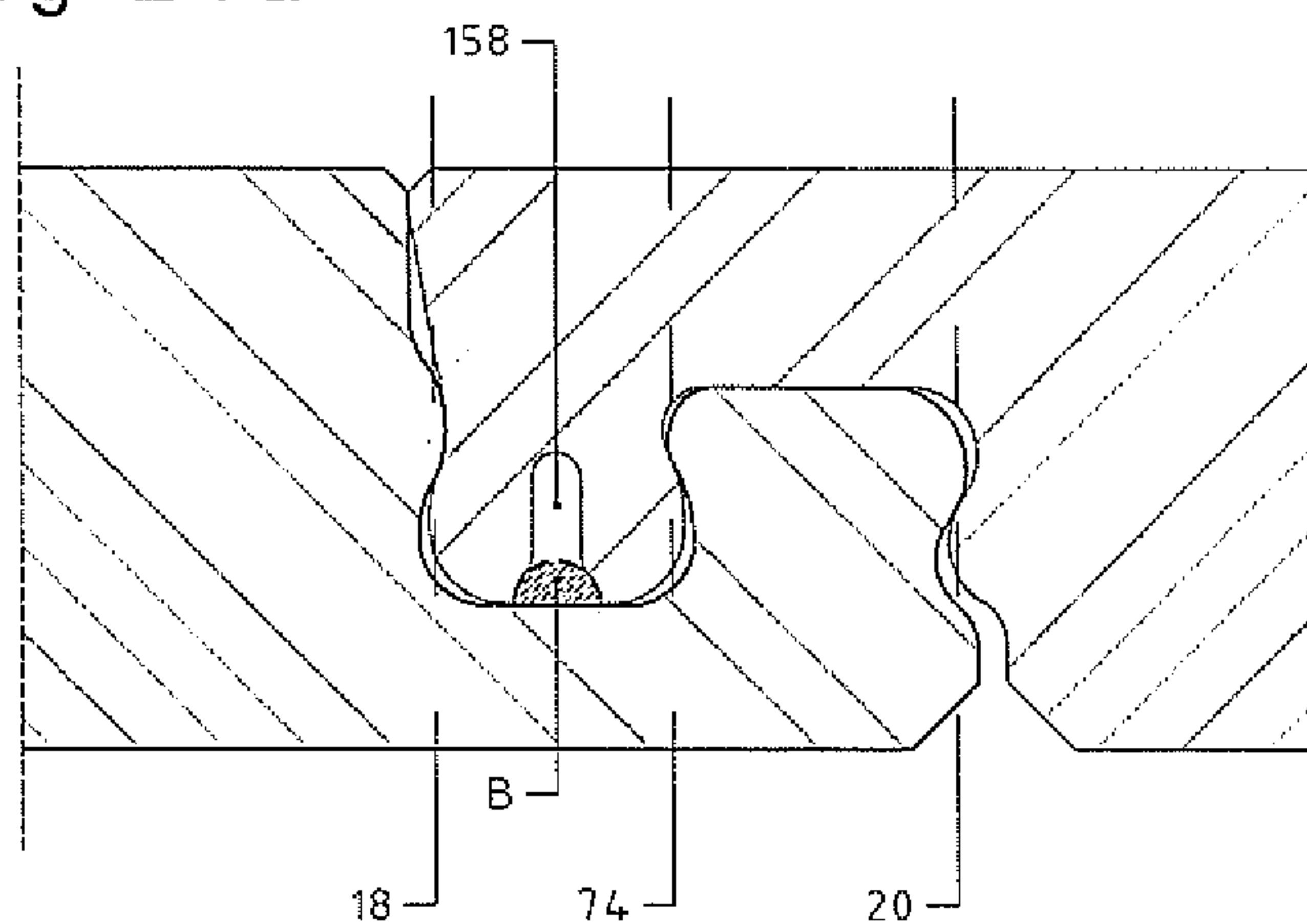


Fig 21b

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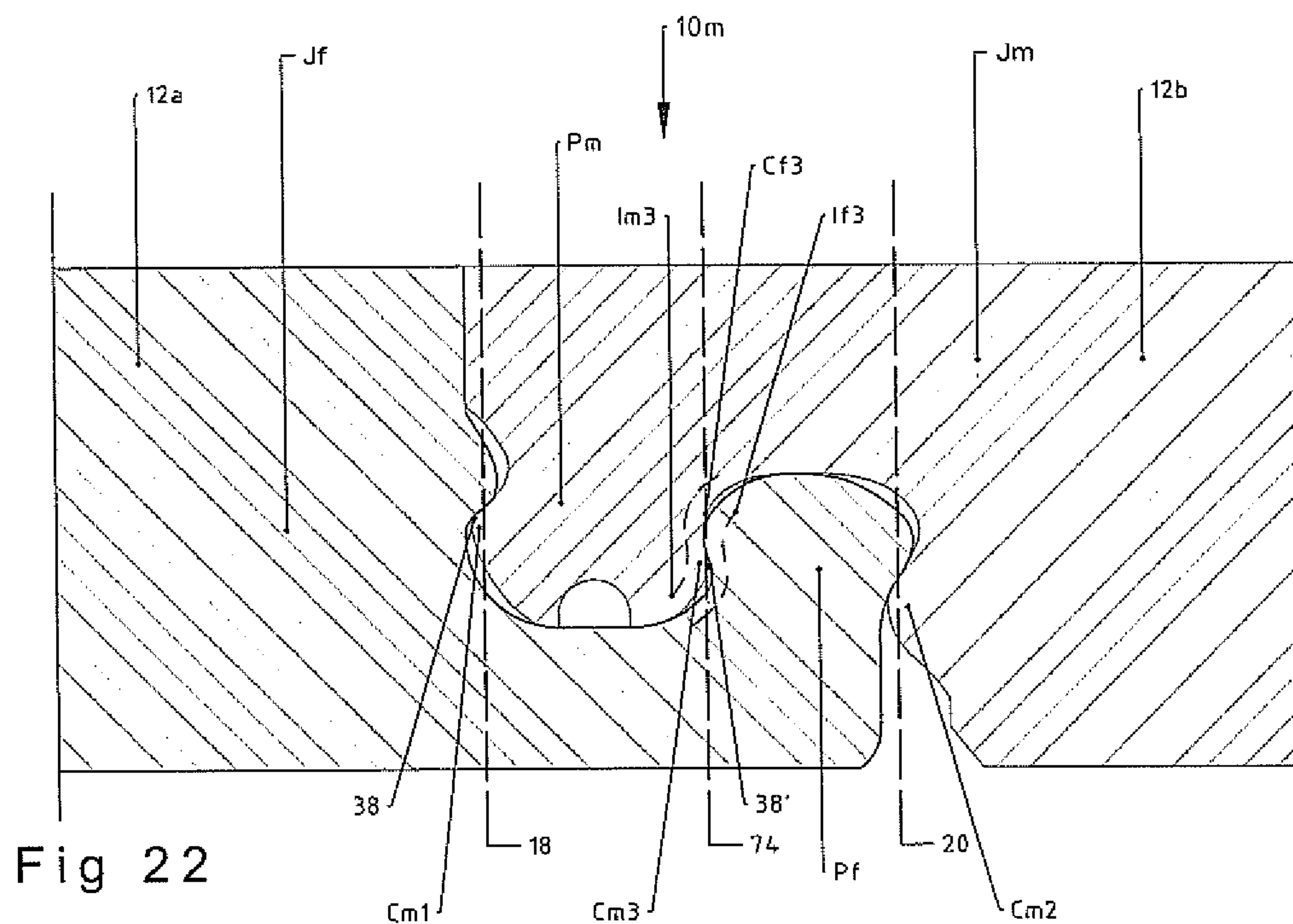


Fig 22

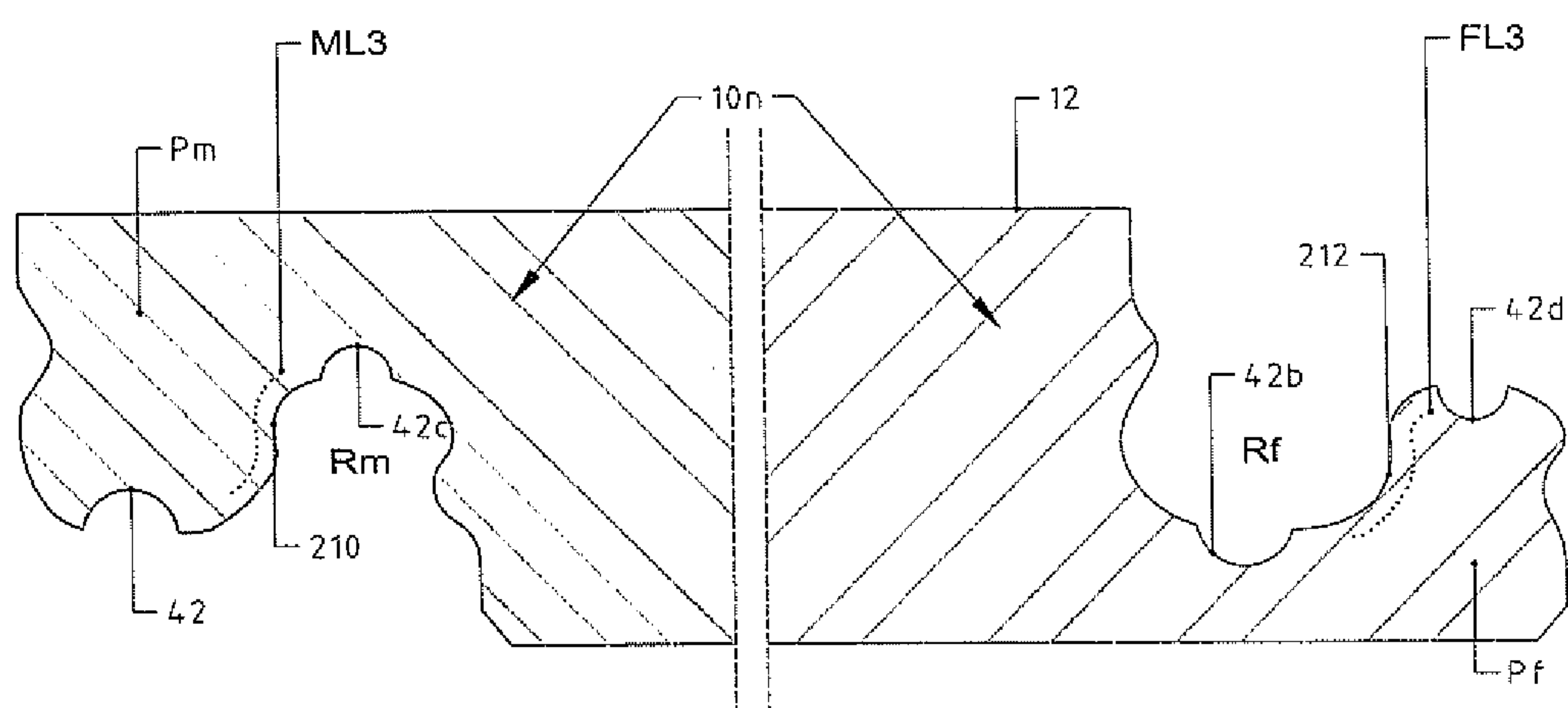


Fig 23a

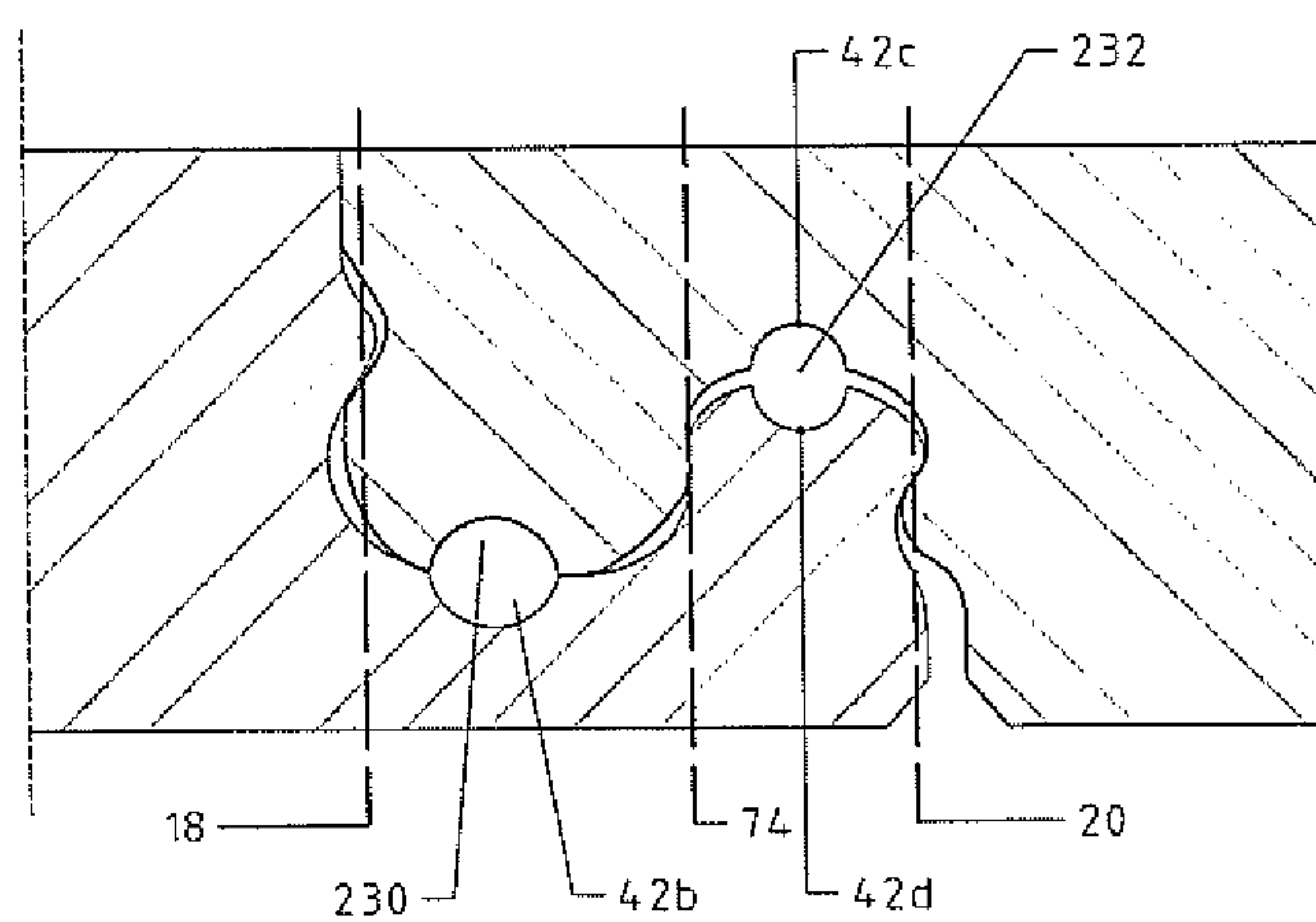


Fig 23 b

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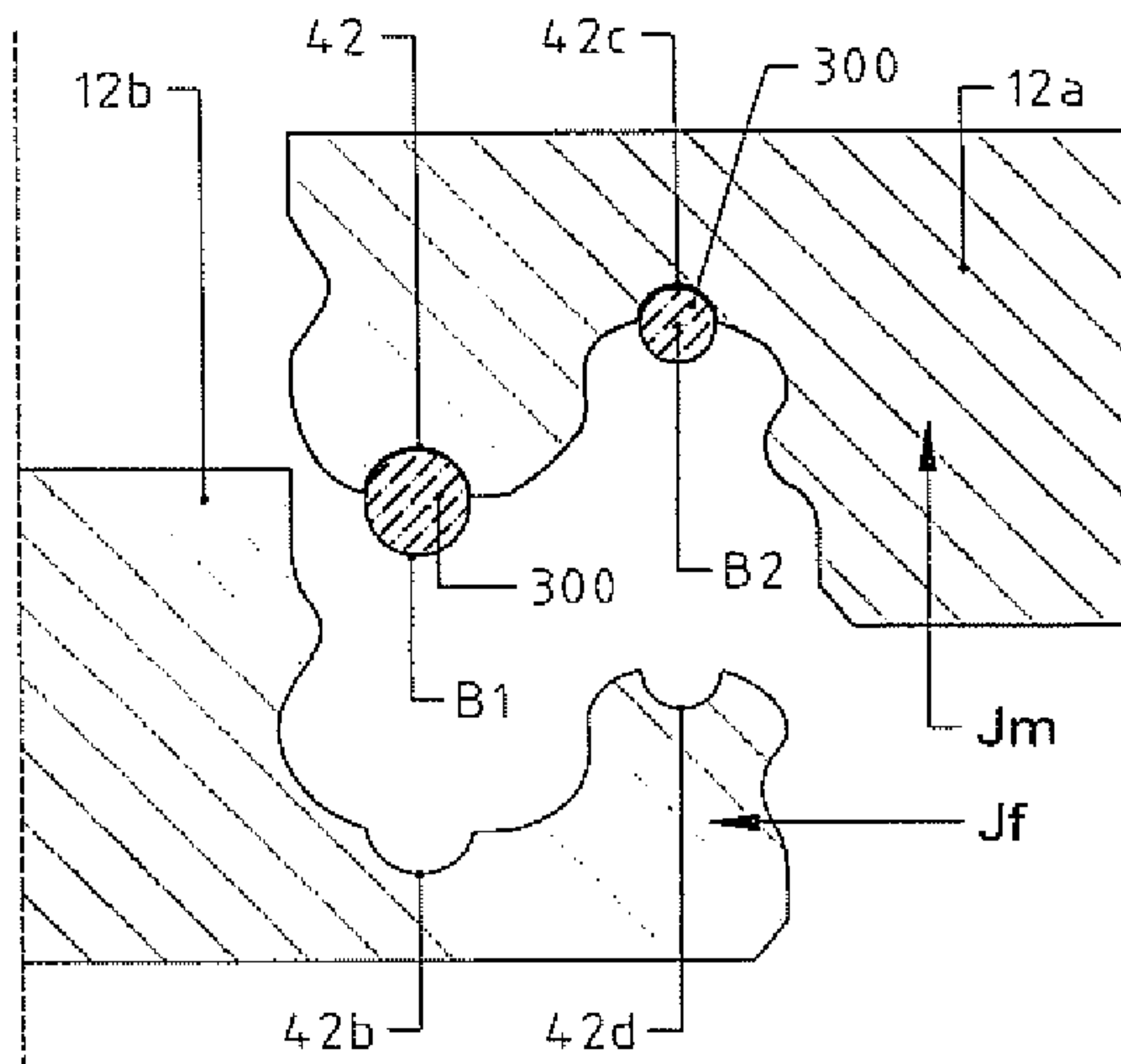


Fig 23c

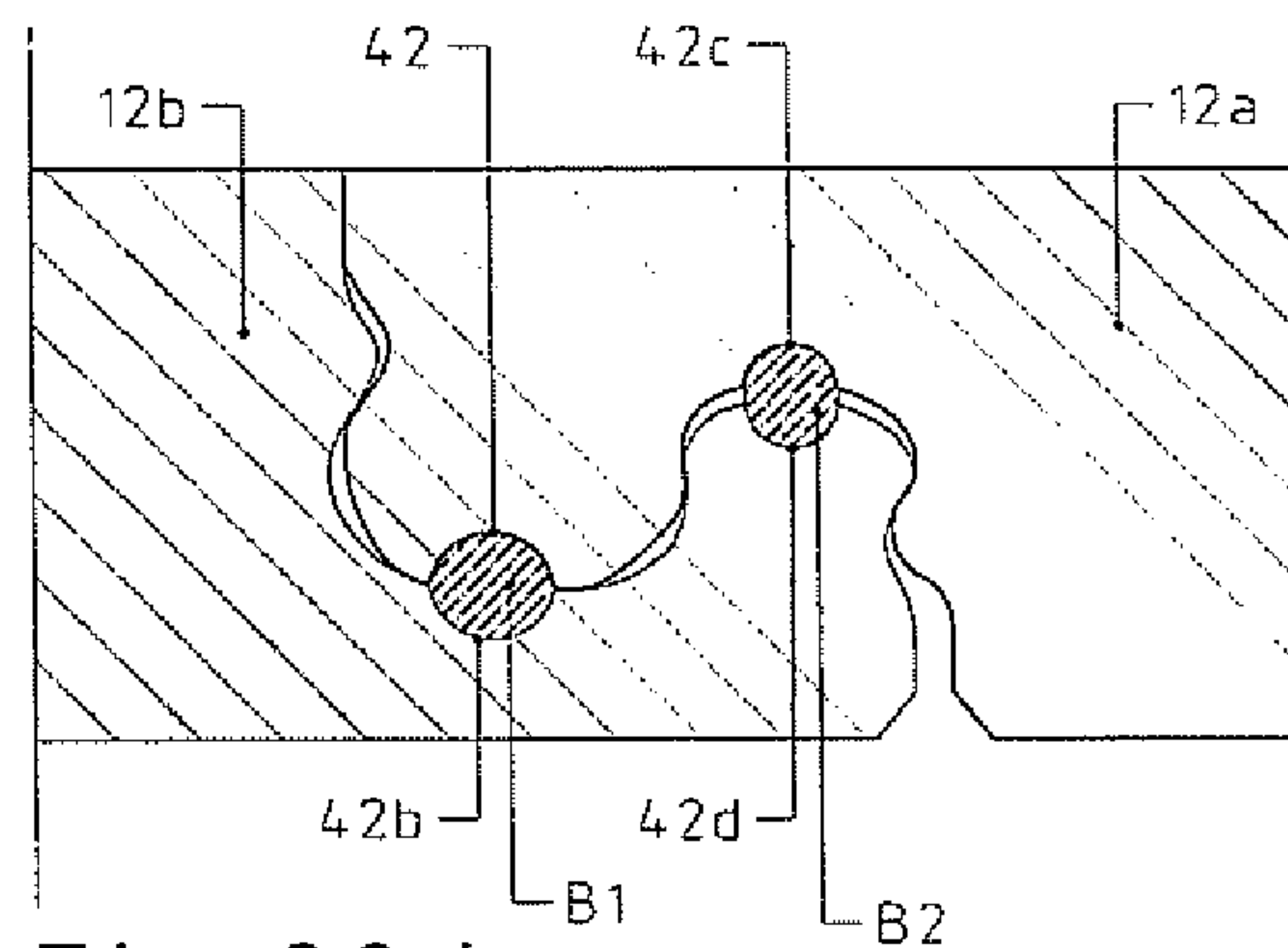


Fig 23d

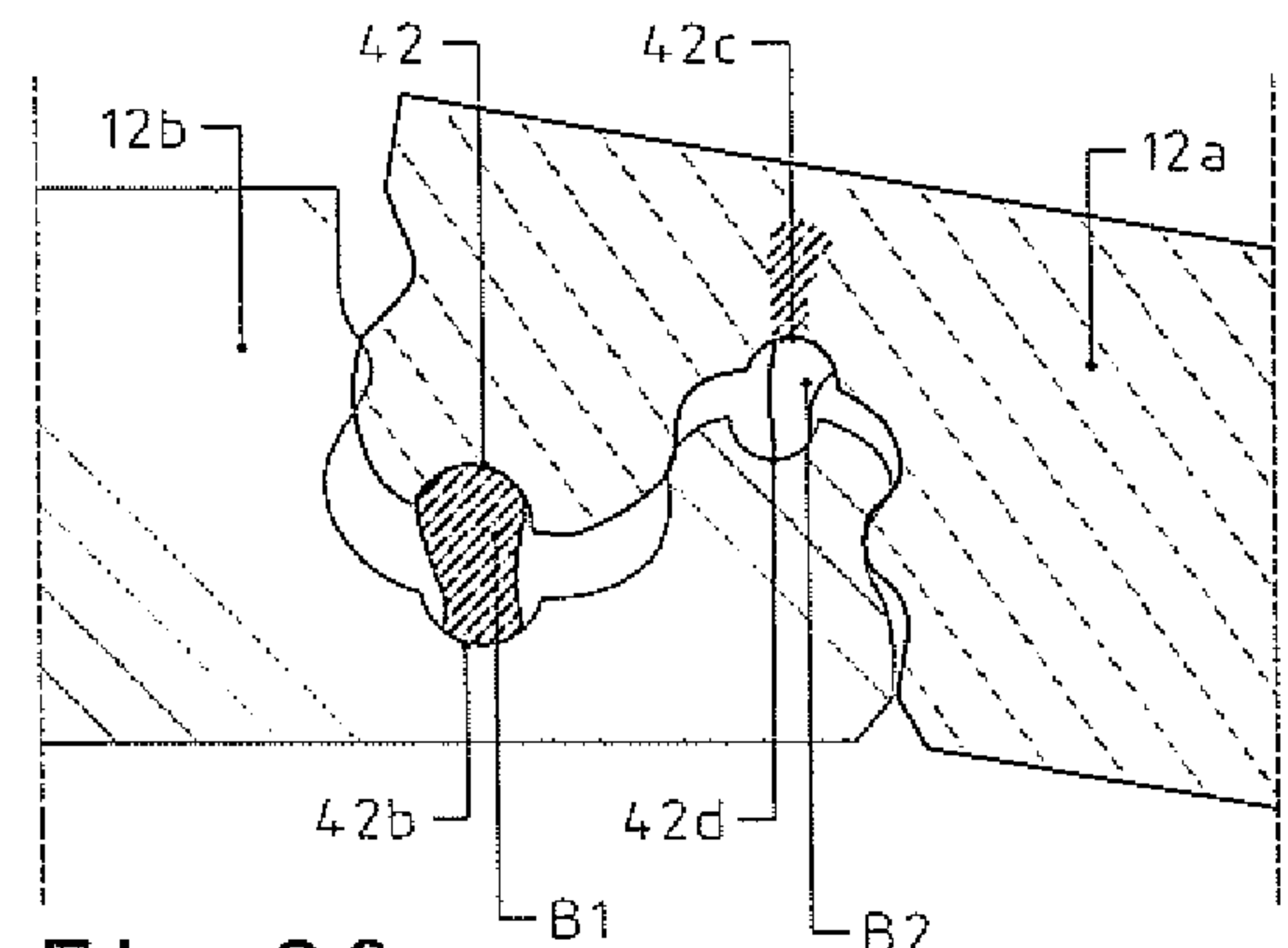


Fig 23g

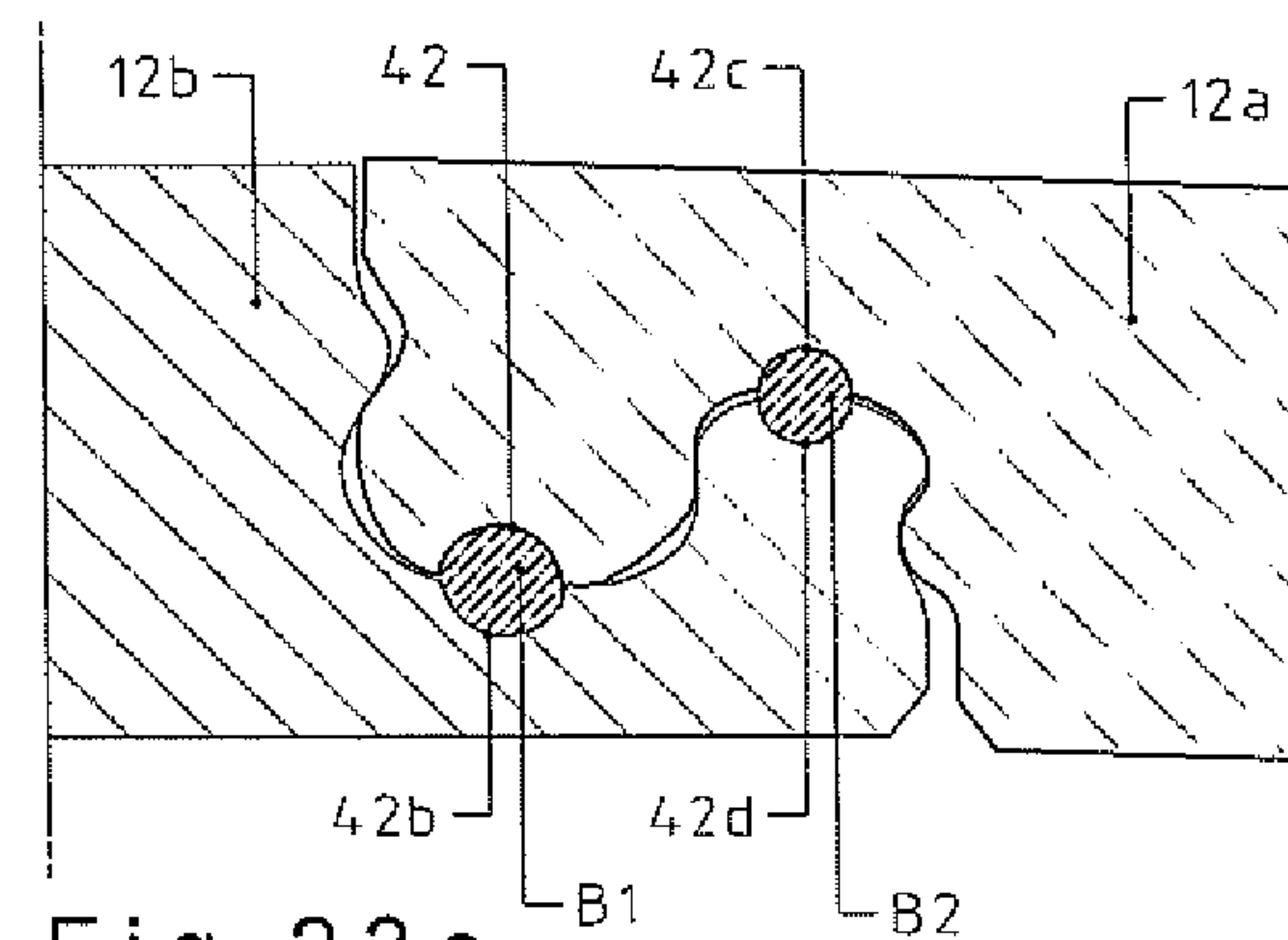


Fig 23e

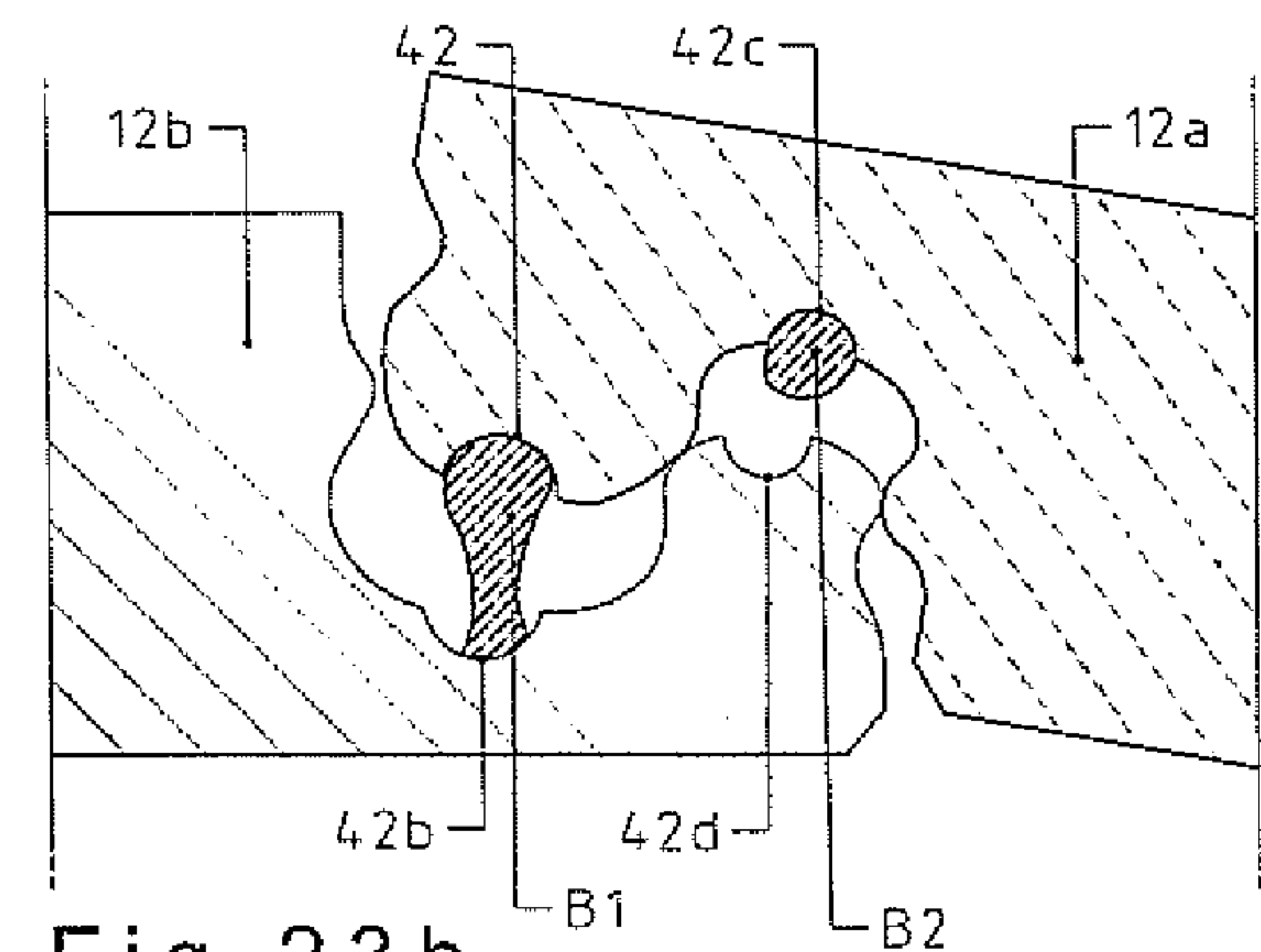


Fig 23h

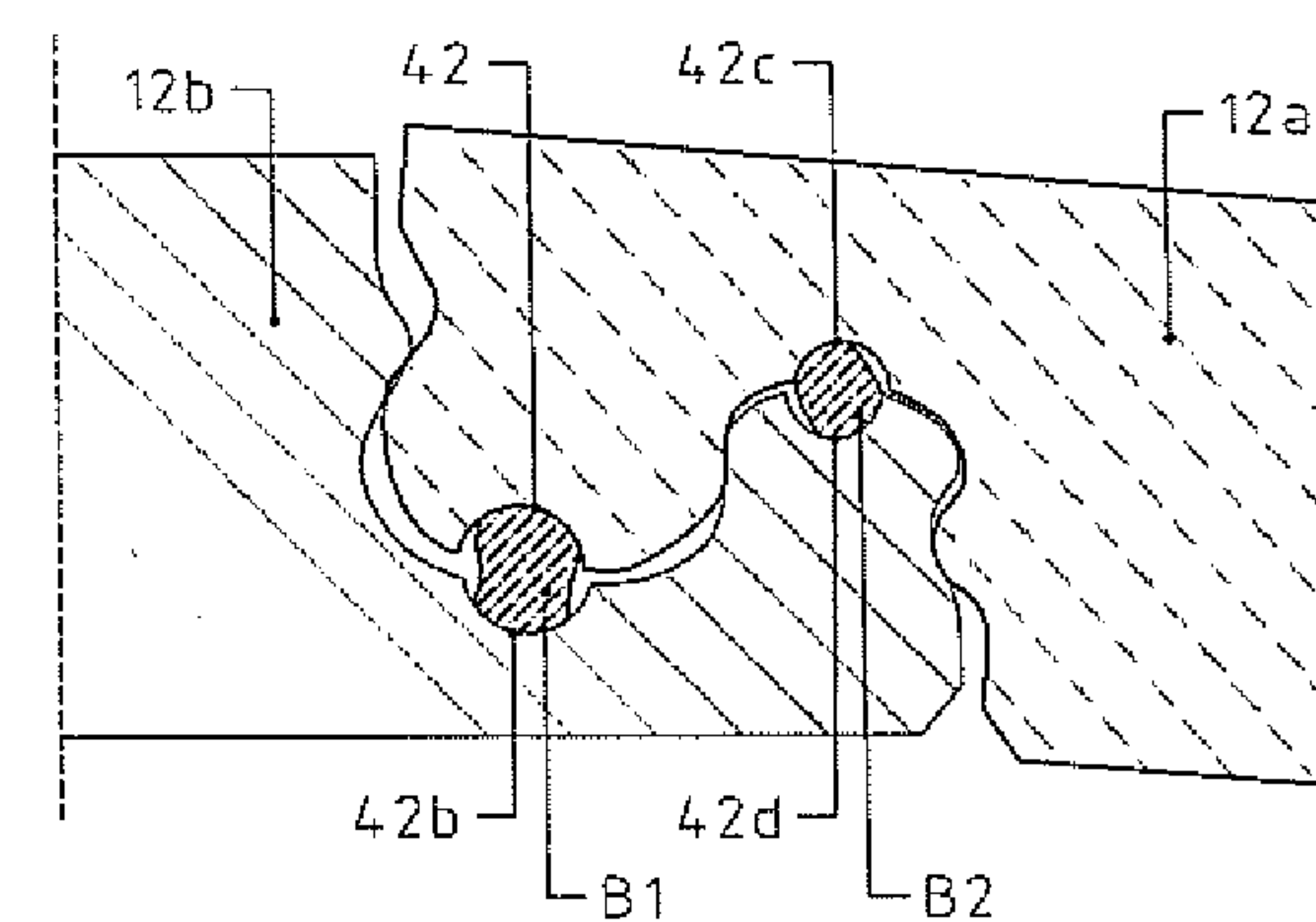


Fig 23f

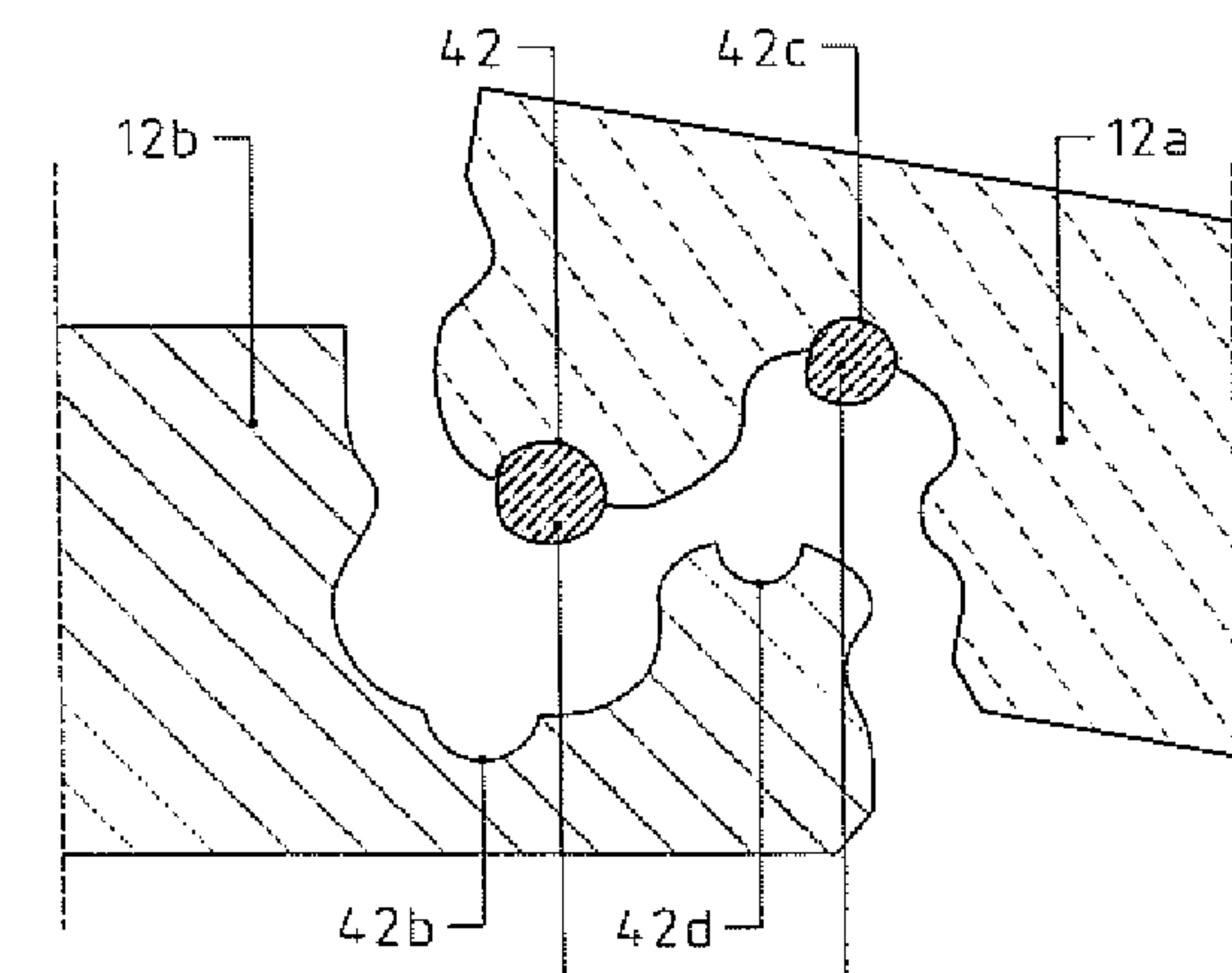
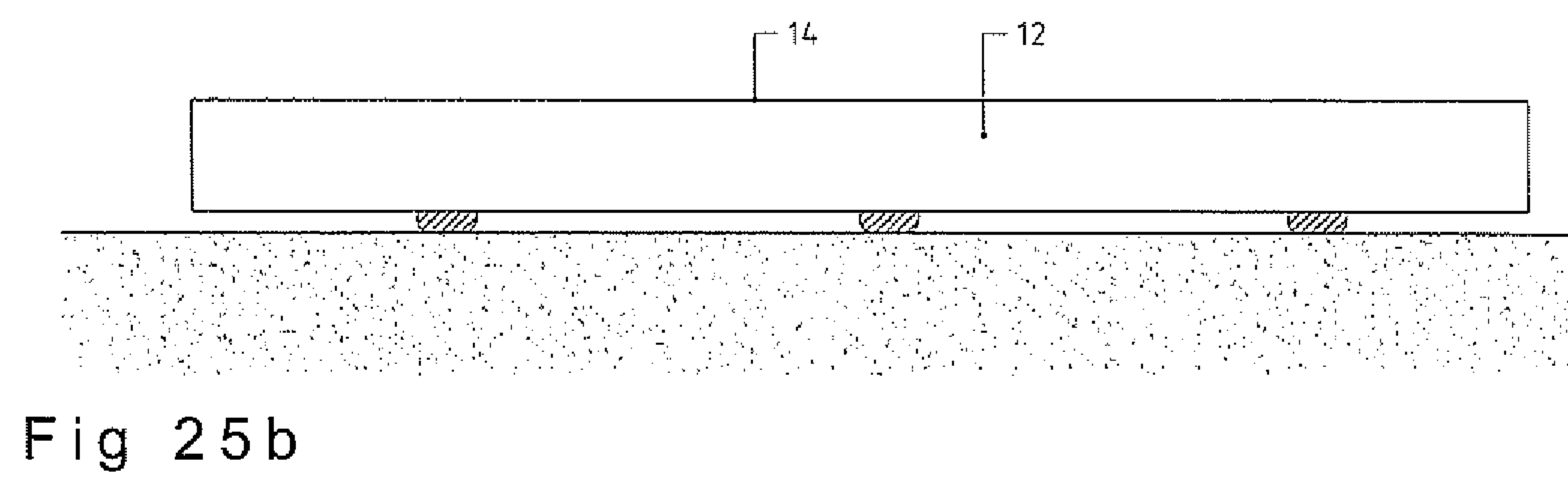
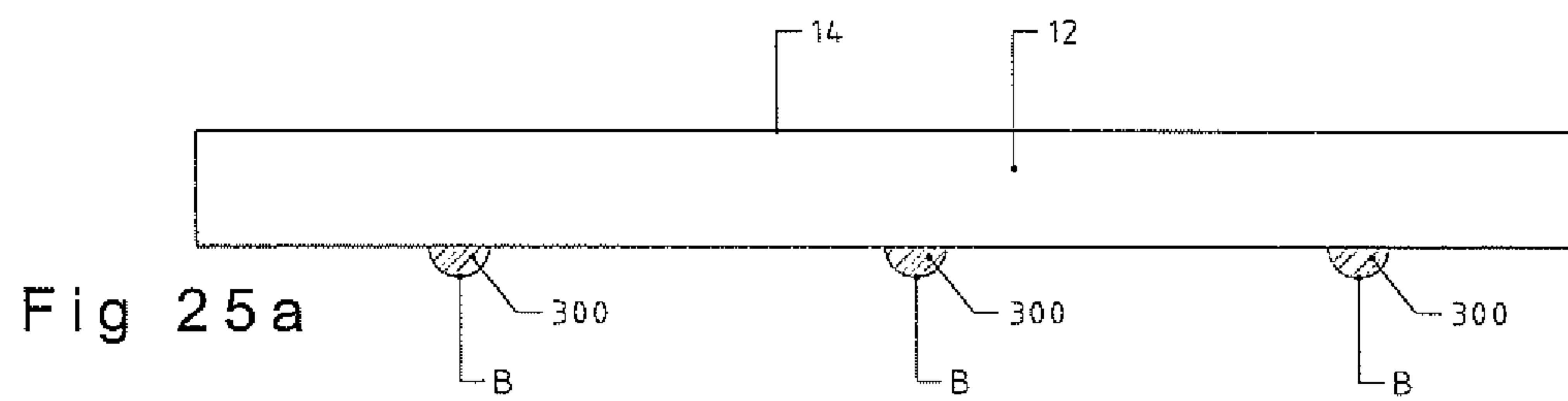
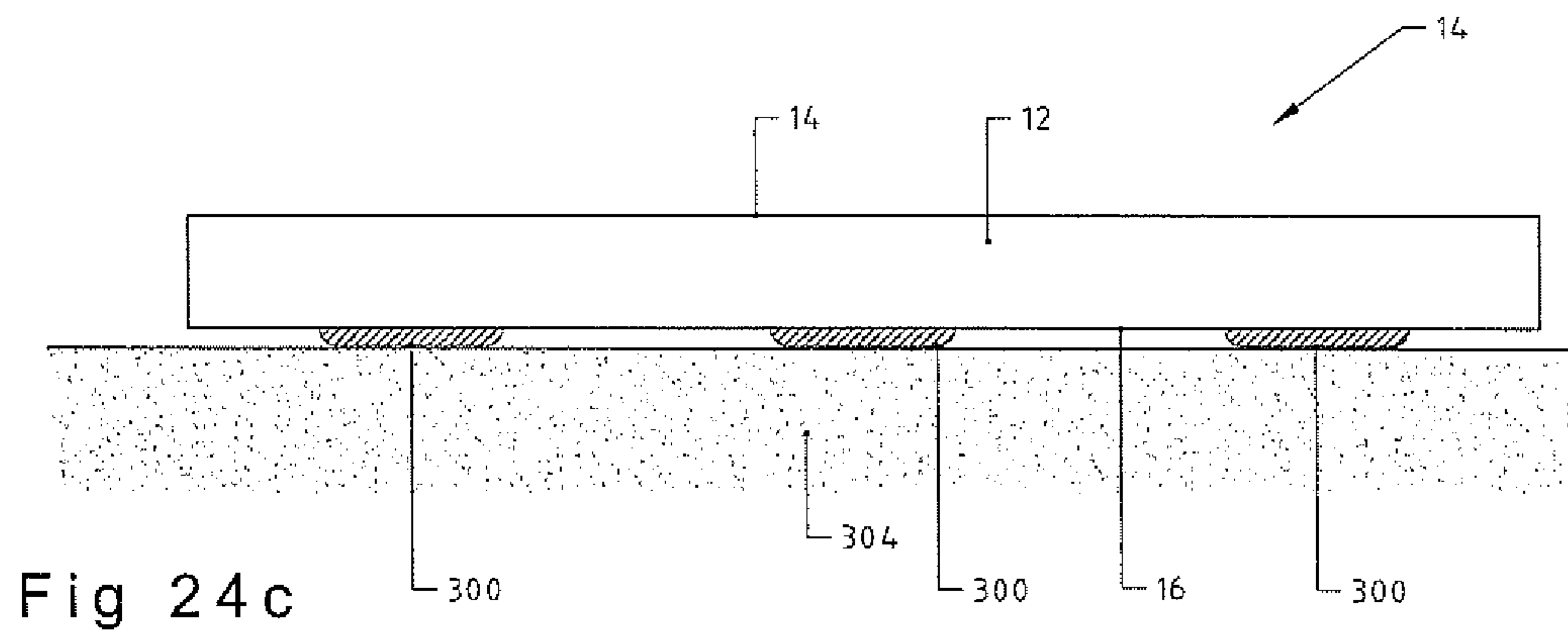
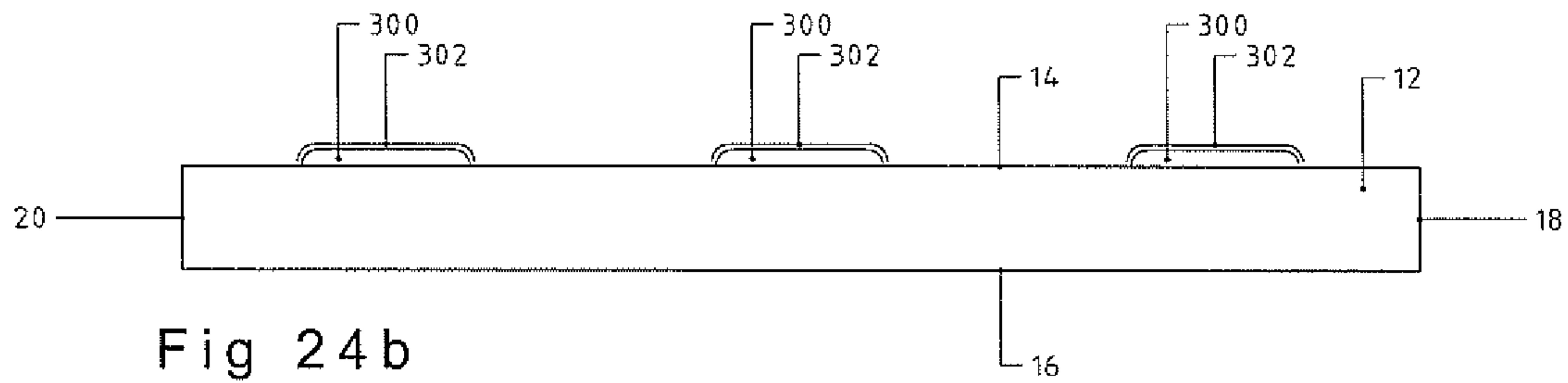
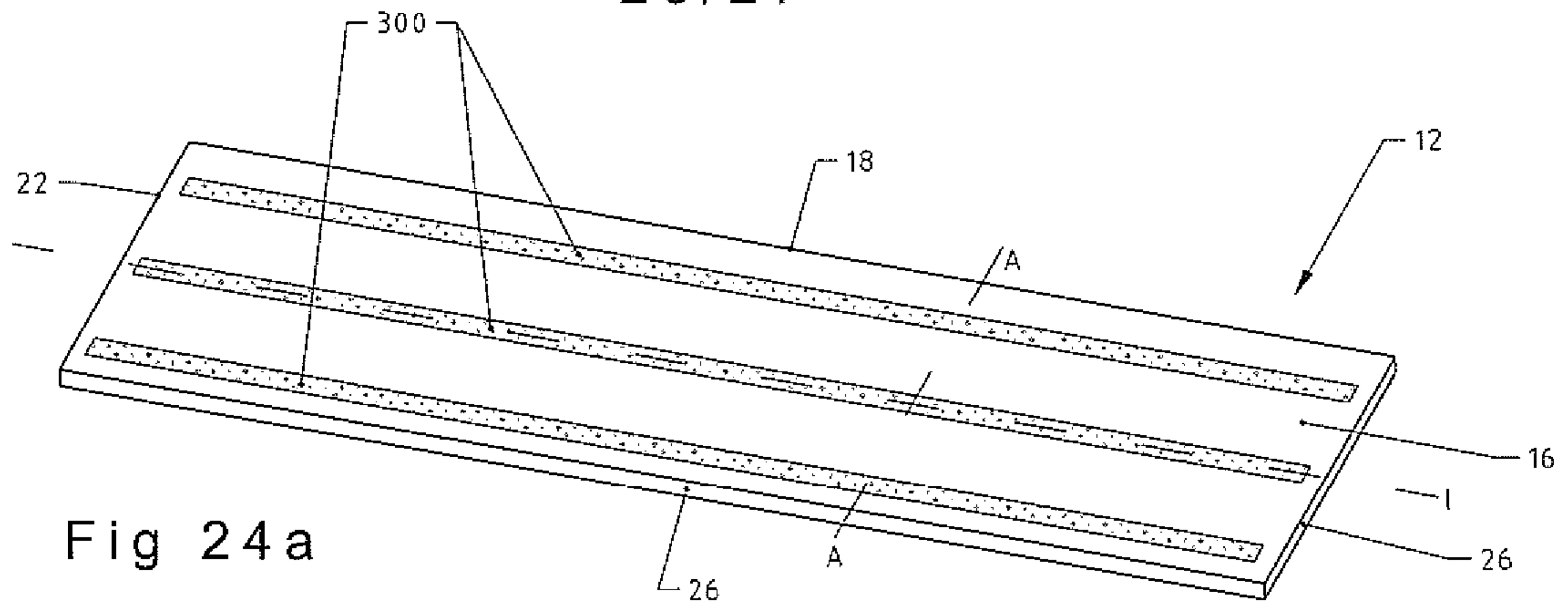


Fig 23i

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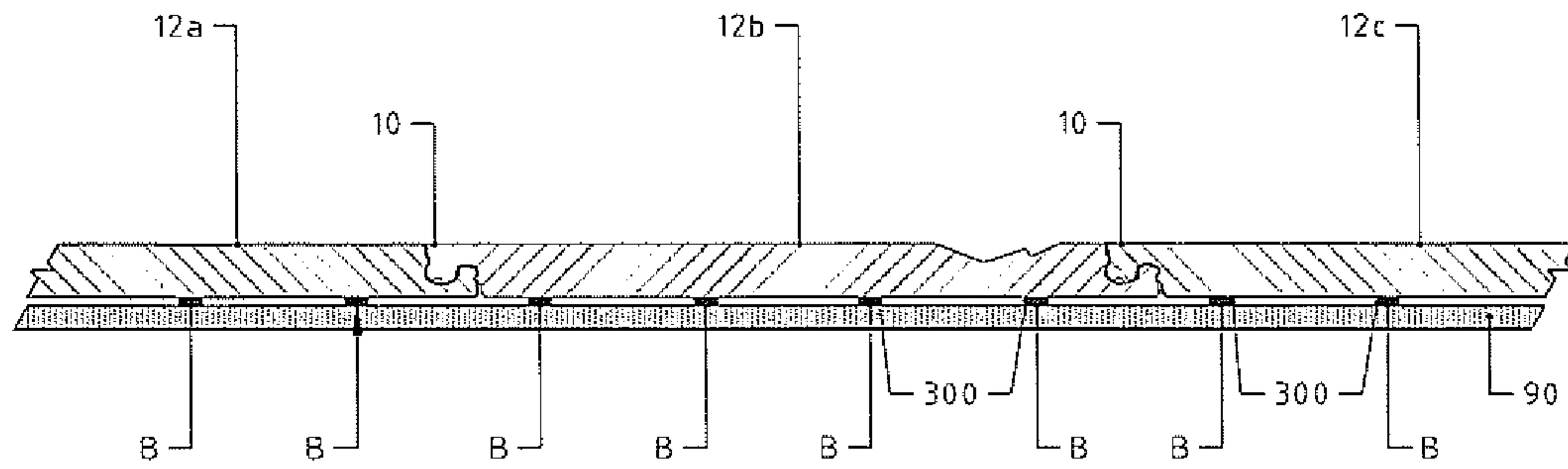


Fig 26a

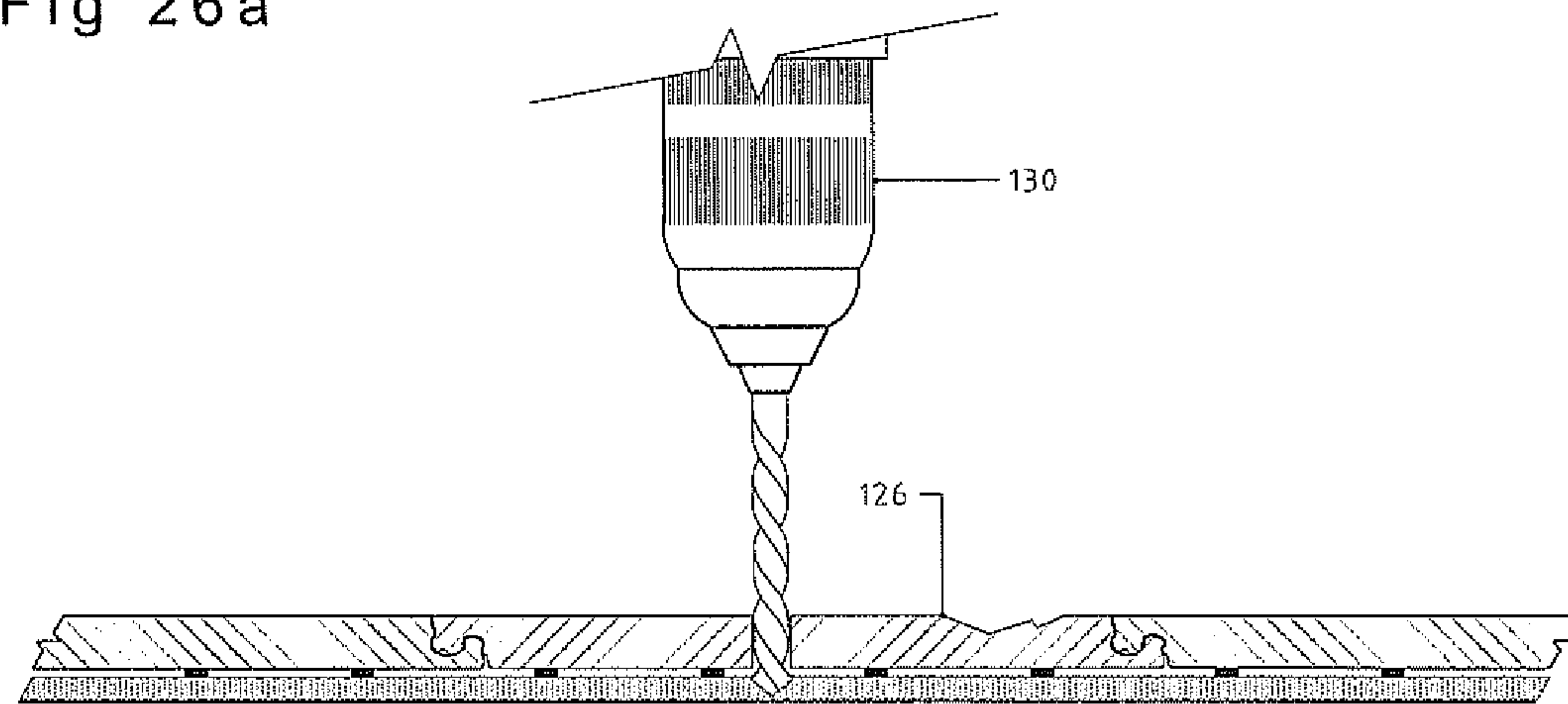


Fig 26b

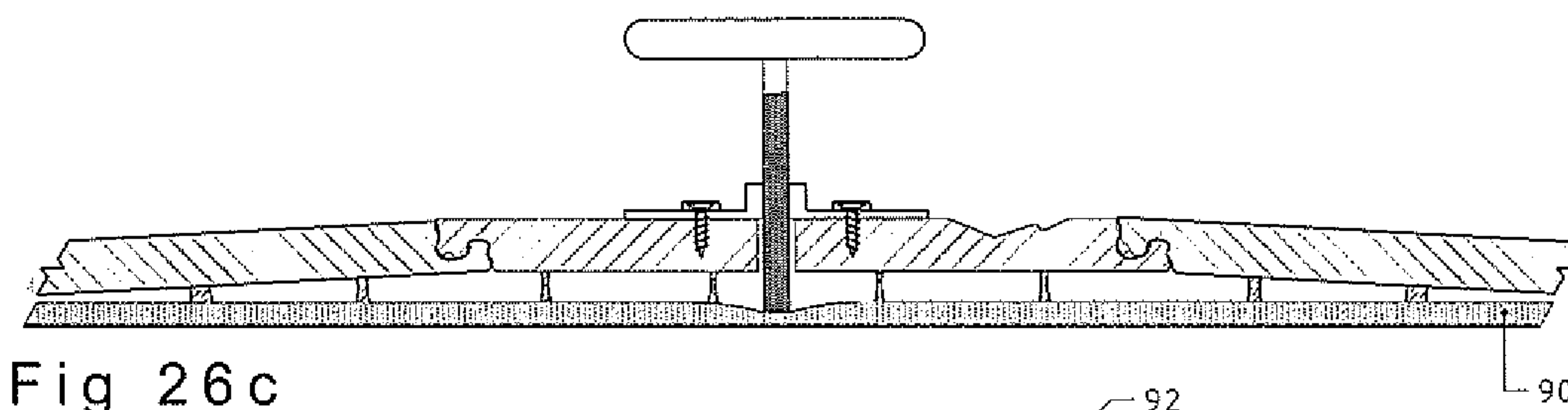


Fig 26c

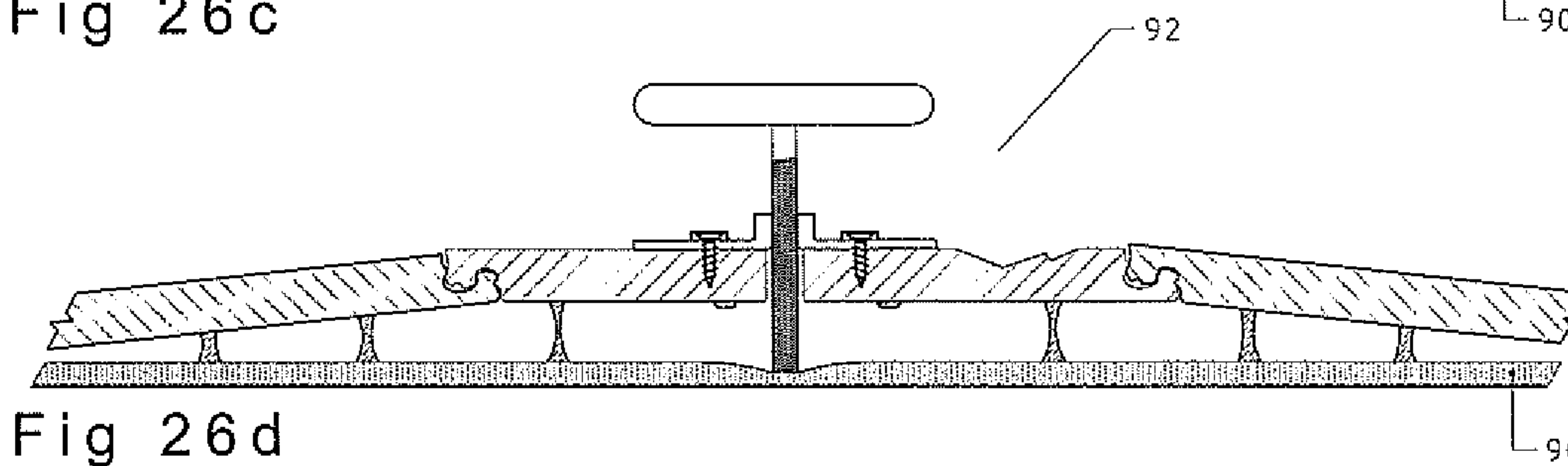


Fig 26d

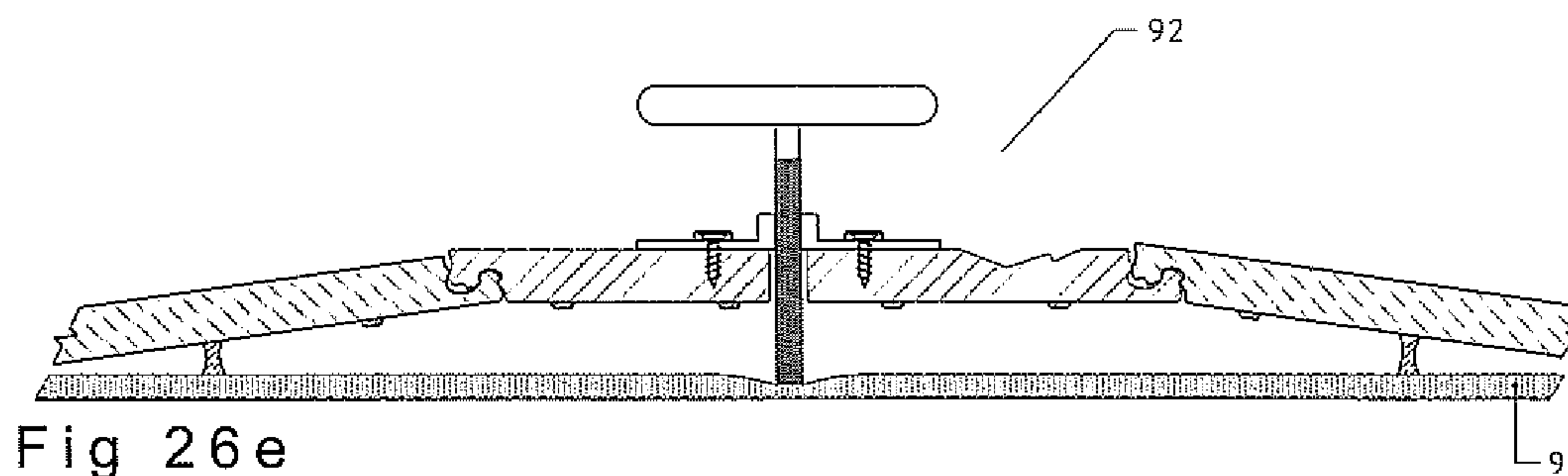


Fig 26e

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