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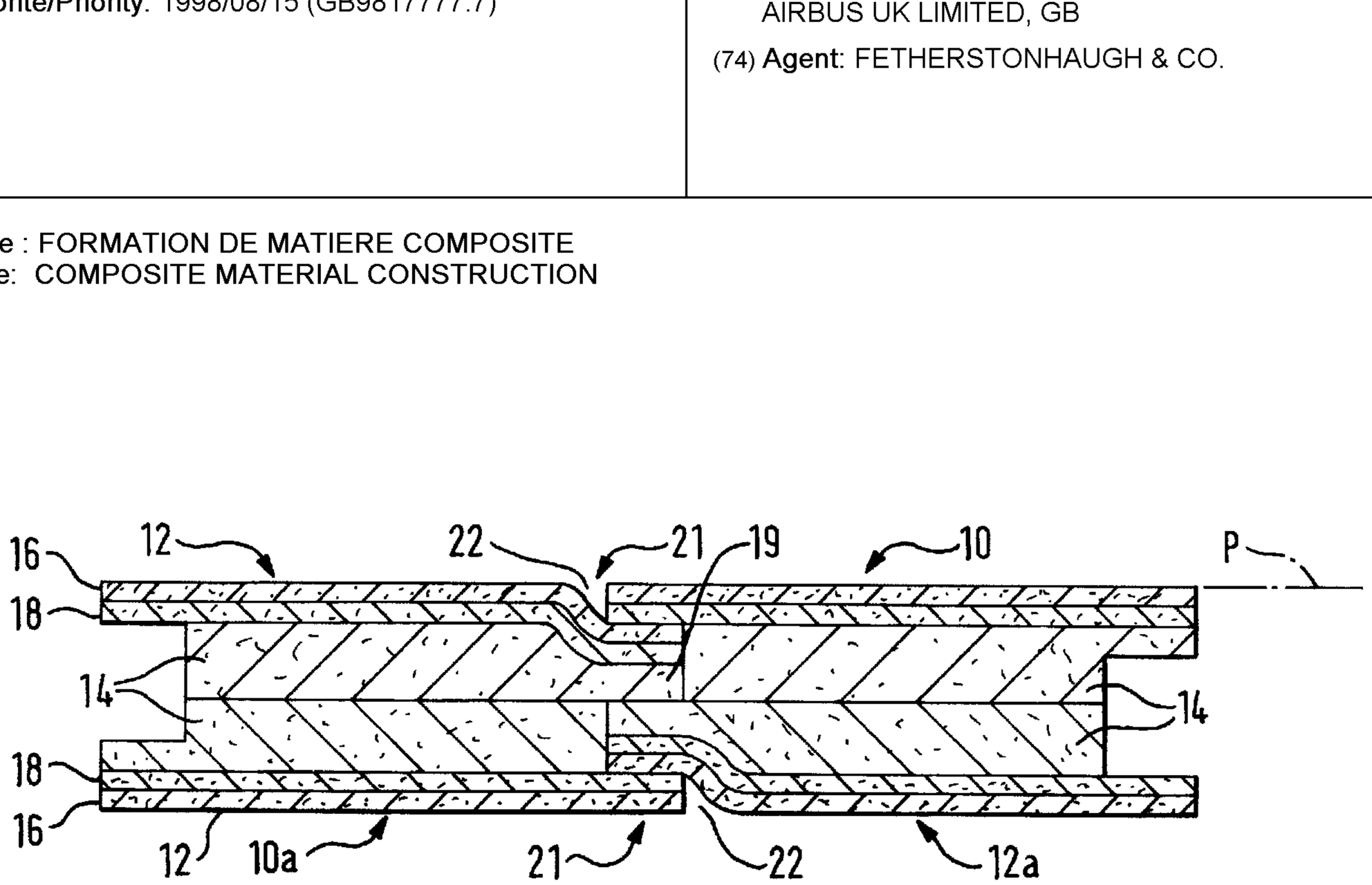


(57) Abrégé/Abstract:
A method for constructing a composite material which comprises a laminate of plies comprising a warp dominated ply and a weft dominated ply, includes arranging first and second pieces (10, 12) of material alongside each other with a recess (20) being defined at least partly by a warp dominated ply (14) so that parts (16, 18) thereof form a lap joint (21) which is received at least partly in a recess (20) formed in or by a warp dominated or other ply, and arranging at least part (12a) of one of said first and second pieces of material (10, 12) in said recess (20) so as to form lap joint (21) with part (10a) of the other of the first and second pieces of material (10, 12). The parts (10a, 12a) of said first and second pieces of material include weft dominated plies (16, 18).

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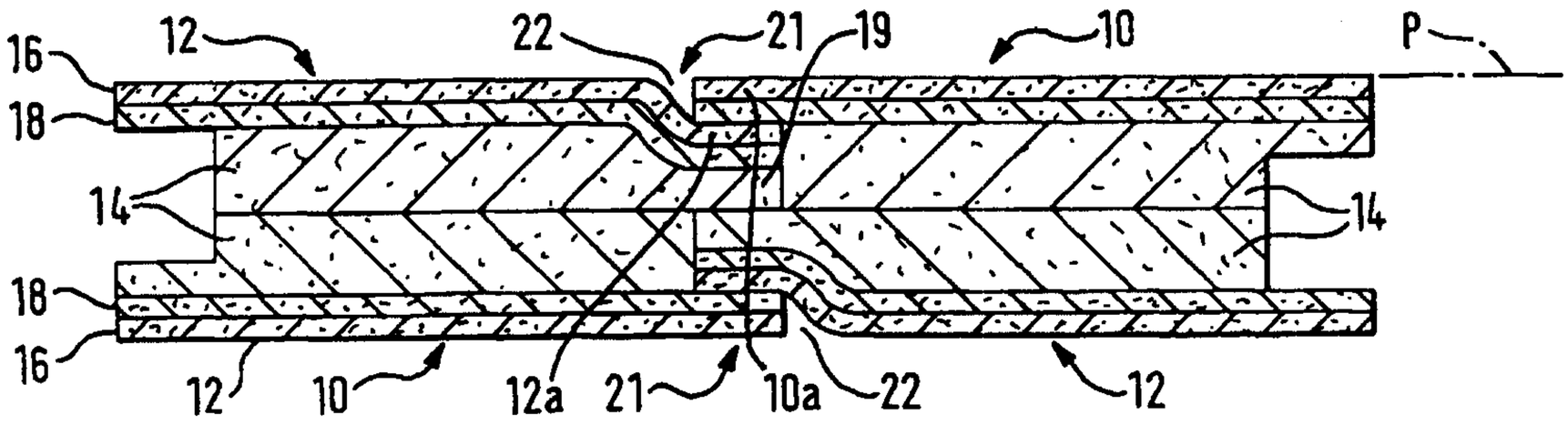
(54) Title: COMPOSITE MATERIAL CONSTRUCTION




(57) Abstract

A method for constructing a composite material which comprises a laminate of plies comprising a warp dominated ply and a weft dominated ply, includes arranging first and second pieces (10, 12) of material alongside each other with a recess (20) being defined at least partly by a warp dominated ply (14) so that parts (16, 18) thereof form a lap joint (21) which is received at least partly in a recess (20) formed in or by a warp dominated or other ply, and arranging at least part (12a) of one of said first and second pieces of material (10, 12) in said recess (20) so as to form lap joint (21) with part (10a) of the other of the first and second pieces of material (10, 12). The parts (10a, 12a) of said first and second pieces of material include weft dominated plies (16, 18).

# COMPOSITE MATERIAL CONSTRUCTION

The invention relates to a composite material construction. In particular, the invention relates to a method of joining pieces of material so as to form a composite material and to a composite material made by such a method primarily for use in aircraft construction.

It is known to produce wing skins from composite laminae formed from multi-axial fibres such as non-crimp or warp knitted fabric. Such skins are produced by laying several layers of fabric into a stack of required thickness. The term "Multi-axial" means that alternate layers of fibre will be constructed in several different directions to produce a fabric with optimum strength in required directions. Commonly used directions for wing skin manufacture are 0° (spanwise for the wing) +45°,-45° and 90° (substantially chordwise). An example of such a skin is described in our Patent Application EP-A- 0 826 488 where the +45° and -45° plies form an overlap on the 90° plies. Normally the 0° plies are warp dominated and the remaining plies weft dominated. The term "Non-crimp" refers to fabrics where warp and weft dominated fibres are laid one upon the other in non-woven fashion up to a required thickness. The fibre layers are then interconnected by a warp knitting process.

Where a multi-axial composite material is to be produced, utilising non-crimp fabrics, current machines can construct fabrics containing multi-axial layers only up to a width of 1.72 m. Structures wider than 1.72 m require two or more pieces of such fabric to be joined together using a joint for the ±45° layers. An overlap joint fulfilling such a requirement is described in the above patent application.

The present application is concerned with a composite material construction involving the joining of material with alternative forms of joints in which the disruption to component thickness is minimised.

According to a first aspect of the invention there is provided a method of constructing a composite material which comprises a laminate of plies comprising warp dominated and weft dominated plies, the method being characterised by including arranging first and second pieces of material for use in the construction alongside each other with a recess being defined at least partly by a warp dominated or other ply, and arranging at least part of one of said first and second pieces of material in said recess so as to form lap joint with part of the other of the first and second pieces of material, the said parts of said first and second pieces of material including weft dominated plies.

By allowing part of one of the first and second pieces of material to be received in the recess, the disruption to component thickness resulting from the joint is minimised.

In one embodiment, each of the first and second pieces of material comprises a laminate of plies comprising a warp dominated ply and a weft dominated ply, the method including arranging the two pieces of material alongside each other with edges of the warp dominated ply of each piece extending in the same direction and with the weft dominated plies forming the lap joint. With such a method, the warp dominated ply forms part of the pieces of material to be joined together enabling a wide composite material to be built up from smaller sections of composite material.

With the arrangement disclosed in the immediate proceeding paragraph, the method may include forming the recess in an edge of the first said piece of composite material.

The corresponding edge of the second piece of composite material may be formed in the same way. The method may include forming the recess by setting one set edge of the warp dominated ply of the first piece back from an adjacent edge of the weft dominated ply forming part of the lap joint. Such an arrangement will provide a particularly simple way of defining the recess.

Where the recess is formed in an edge of the first piece of composite material, the method may include reducing the thickness of the warp dominated ply of the second piece of material adjacent its said edge to enable the weft dominated ply and a remainder part of the warp dominated ply to enter the recess when forming the lap joint. The method may include forming the corresponding edge of the first piece of the material in the same way.

The method may include bringing an edge of the remainder part of the warp dominated ply of the second piece into abutment with the edge of the warp dominated ply of the first piece when forming the lap joint.

In another embodiment, the method may include forming the recess by providing or forming between the edges of warp dominated plies or within a width of a warp dominated ply a length of thinner warp dominated material. In either case, the length of the thinner warp dominated material is preferably formed from higher filament count or higher modulus fibres compared to fibres used to construct the warp dominated plies. The lap joint may be formed so that part of the weft dominated ply of only one of the pieces lies in the recess with part of the other weft dominated ply of the other piece overlapping at least a portion of it.

The method may include placing a layer of warp dominated material on the outside of a lap joint. By doing that, it is possible to compensate for any reduction in strength which may arise due to the use of the thinner warp dominated material.

In a further embodiment, the method may include forming the recess as a groove in one surface of the warp dominated ply and providing a further weft dominated ply on the opposite surface of the warp dominated ply. The recess may be formed in, for example, a centre section of the warp dominated ply although it may be formed at other positions.

Conveniently, two pieces of material to be joined together may be fed to a machine so as to form the lap joint, the warp dominated ply and the further weft dominated ply as a single laying-up operation. As will be appreciated, such a method forms a convenient way of joining together the pieces of material by machine. Moreover, the method enables a machine previously used for bi-axial laying-up to be used to produce a multi-axial composite material much wider than would be possible on normal multi-axial laying-up machines.

With any of the foregoing embodiments in accordance with the invention, it is possible to form two layers of the jointed material with one layer inverted relative to the other with the weft dominated plies forming outer surfaces of the two layers.

Alternatively, the inversion can take place so that the warp dominated plies form the outer surfaces of the two layers.

According to a second aspect of the invention, there is provided an aerofoil having a skin formed from materials joined by the method according to the first aspect of the invention or any of the consistory clauses relating thereto.

According to a third aspect of the invention, there is provided an aircraft skin panel formed from material joined by the method according the first aspect of the invention or any of the consistory clauses relating thereto.

According to a fourth aspect of the invention there is provided a method of constructing a composite material which comprises a laminate of plies comprising a warp dominated ply and a weft dominated ply, the method including arranging first and second pieces of material for use in the construction alongside each other so that parts thereof form a lap joint which is received at least partly in a recess formed in or by a warp dominated or other ply, the said parts of said first and second pieces of material including weft dominated plies.

According to a fifth aspect of the invention there is provided a composite material construction which comprises a laminate of plies comprising warp dominated and weft dominated plies, characterised in that the construction comprises first and

second pieces of material arranged alongside each other, a recess being defined at least partly by a warp dominated or other ply, part of one of said pieces of material being received in the recess and forming a lap joint with a part of the other piece of material, the said parts of the first and second pieces of material including weft dominated plies.

According to a sixth aspect of the invention there is provided a composite material construction which comprises a laminate of plies comprising a warp dominated ply and a weft dominated ply, a recess being defined at least partly by the warp dominated ply and parts of the weft dominated ply being arranged alongside each other so as to form a lap joint at least part of which is received in the recess.

The material used in the composite material construction may have the features of the material set out in the first aspect of the invention or any consistory clause relating thereto.

According to one aspect of the present invention, there is provided a method of constructing a composite material which comprises a laminate of plies that includes a warp dominated ply and a weft dominated ply, the method being characterised by forming a recess in an outer surface of a piece of material which recess is at least partly defined by a warp dominated ply of the construction, arranging a first piece of material of the construction alongside a second piece of material of the construction with at least a part of the second piece of material in the recess and overlapping at least a part of the first piece of material to form a lap joint wherein the part of the second piece of material in the recess and the overlapped part of the first piece of material include weft dominated plies.

According to another aspect of the present invention, there is provided a composite material construction which comprises a laminate of plies that includes a warp dominated ply and a weft dominated ply, characterised in that the construction comprises a recess defined at least partly by a warp dominated ply of the construction, and a first piece of material arranged alongside a second piece of material with at least a part of the second piece of material being received within the recess and with the first part of the second piece of material in the recess overlapping at least a part of the first piece of material to form a lap joint wherein the recessed part of the second piece of material in the recess and the overlapped part of the first piece of material include weft dominated plies.

Composite material construction in accordance with the invention will now be described by way of example with reference to the accompanying drawings in which:

Figure 1 is a diagrammatic cross-section through two pieces of composite material to be joined together by a method in accordance with the invention;

Figure 2 shows diagrammatically the way in which an edge of the second piece of material is pressed down prior to mating with the other piece;

Figure 3 shows the way in which the pieces of material join together;

Figure 4 shows diagrammatically different method of joining material together to form a composite material;

Figure 5 shows a modification of the method shown in Figure 4;

Figure 6 shows diagrammatically a cap used in the method of Figures 4 and 5;

Figure 7 shows diagrammatically a further method of joining material to form a composite where the warp dominated layer defines a groove-like recess in one surface; and

Figure 8 is a diagrammatic perspective view of an aircraft having a wing which includes a material joined together by a method in accordance with the invention.

Referring to Figures 1 to 3, first and second pieces of material 10,12 are substantially identical in construction and each one comprises a warp dominated ply

14 (referred to herein as a 0° ply) and two weft dominated plies 16,18. The weft dominated plies 16,18 are arranged at +45° and -45° relative to the 0° ply 14.

It will be noted that the right hand edge of each 0° ply 14 as viewed in the drawings is reduced in thickness by a distance x which corresponds substantially to the thickness of the ±45° plies 16, 18 thereby forming a thinned area 19. The left-hand edge of each piece 10,12 is formed so that the 0° ply is set back from the left-hand edge of the ±45° plies. In that way, a recess 20 is formed at the left-hand edge of each piece 10,12 defined by the weft dominated ply 18 and the warp dominated ply 14.

As shown in Figure 2, the right-hand edge of the second piece 12 is pressed down before the two pieces are brought together manually or by machine. The pressing down is facilitated by the thinning of the right-hand edge of the second piece 12. Finally, the two pieces 10, 12 are mated together as shown in Figure 3 so that the right hand edge of the second piece 12 is received within the recess 20 of the first piece 10 with the 0° ply 14 of each piece 10,12 in edge to edge abutment and parts 10a, 12a of the two ±45° plies 16,18 of the pieces 10,12 form a lap joint 21. Advantageously, the upper surfaces of the pieces 10, 12 formed by ±45° plies lie substantially in the same plane P with virtually no disruption to the component thickness.

Once the materials have been put together, a suitable bonding matrix is applied to impregnate the material so as to bind the plies together and to fill the joint 21 and the gap 22, shown in Figure 3. The composite material is then placed in an autoclave where the matrix is cured under heat and pressure.

As shown in Figure 3, further first and second pieces 10a, 12a can be inverted and placed against the first and second pieces 10, 12, prior to curing in the autoclave, to double the thickness of the composite material, again without any significant disruption to the overall component thickness due to the lap joint 21. By arranging the pieces 10,12, 10a, 12a in the manner shown in Figure 3, a balanced lay-up is achieved which is a desirable feature. In the case illustrated, looking from bottom to top in Figure 3, the layers balance as follows:

+45°, -45°, 0°, 0°, -45°, +45°

Two or more balanced lay-ups, as shown in Figure 3, can be placed one upon the other, if desired, to provide a composite to skin of increased thickness which is then cured under heat and pressure.

The production of the reduced thickness right-hand edge of each piece 10, 12 and the production of the recess 20 is preferably carried out as part of the lay-up process for the pieces 10, 12. On existing multi-axial fabric making machines, the maximum width of each piece 10, 12, that can be made is 1.7 m. Aircraft surfaces

such as wings can commonly require fabrics having a greater width than 1.7 m. The only way of achieving greater widths is, therefore, by joining two pieces together and the methods shown in Figures 1 to 3 provide a method resulting in minimal disruption to component thickness. If no more than two pieces 10,12 are joined together, the respective right and left-hand ends of those pieces need not be shaped as shown but could simply be left plain as shown in broken lines in Figure 2.

Looking next at Figure 4, the first and second pieces 10,12 are formed differently. Instead of forming a thinned area 19 at the edge of the second piece 12, both pieces 10,12 have their 0° plies 14 spaced apart by a section of thinner warp dominated material 24 (again preferably of 0°). The thinner section 24 is formed of higher filament count fibres or higher modulus fibres. In that way, although the section 24 is thinner than the 0° plies of the pieces 10, 12, the nature of the material 24 is such that it at least partially compensates for the absence of the thicker warp dominated material absent from that position. The use of the thinner section 24 effectively produces a recess 26 defined by the thinner section 24 and the 0° plies 14 of the pieces 10,12. If desired, the thinner 0° section of material 24 can be formed on the edge of one piece of material 10 and brought into abutment with the edge of the second piece of material 12 to form the recess 26.

As shown in Figure 4, the ±45° plies 16, 18 of the second piece 12 include a portion which substantially fills the recess 26 leaving a step 30. Part 10b of the ±45°

plies 16, 18 of the first piece 10 occupies the step 30 and forms an overlap joint 32 with the portion 12b. In the event that the thinner 0° section 24 does not fully compensate for absence of the thicker 0° ply as described above, a 0° ply cap 34 can be placed on the top surfaces of the ±45° plies to provide full compensation as shown in Figure 4. It should be stressed that Figure 4 is diagrammatic and the 0° ply cap 34 will normally have sloping sides 35 as shown diagrammatically in Figure 6 typically arranged at a gradient of 1:20.

Looking at Figure 5, it will be seen that the section 24 is not as wide as shown in Figure 4 and part 10c of the ±45° plies 16, 18 of the first piece 10 steps on to the top of the ±45° layers 16, 18 of a part 12c of the second piece 12 to form a lap joint 33. The part 10c helps to compensate for any loss of strength due to the use of the thinner 0° section 24. If any further compensation is required a ply cap 34a, thinner than the cap 34 shown in Figure 4 can be applied. It is envisaged that the cap 34a will taper downwardly somewhat as shown in Figure 6. If desired, several layers of joined materials can be built up and then a single capping piece applied to a surface of the ±45° plies as desired. As shown in Figure 6, the capping 34 may be brought up by several plies 37 of 0° material where the same number of plies of composite material have been built up to produce the full component thickness.

Where the joined composite material is to be used, say as a wing skin for an aircraft, it is important that there is minimum disruption at the outer surface of the skin.

Therefore, if possible, the component forming the wing skin should have the cap 34 or 34a directed towards the inside of the wing leaving the 0° plies to provide a substantially uninterrupted surface ply forming the outer surface of the wing skin.

In Figures 4 and 5 , the 0° plies 14, 24 can be made in one piece by a single operation in a laying-up machine and two separate ±45° plies are subsequently fed to the machine to form the lap joints 32, 33. In that way, two separate pieces of composite material 10, 12 are not required although two separate ±45° layers are provided and fed to the laying-up machine so as to produce the overlap joint 32.

Machines are known which will produce bi-directional laying-up of fibres, for example, 0° and 90°. Those machines will produce fabric in widths of up to 5 m. Therefore, by using a method as described in respect to Figures 4 and 5 where two ±45° plies are fed to such a machine, the machine can be used to produce multi-axial fabrics having a width substantially greater than 1.7 m.

Looking now at Figure 7, a warp dominated 0° ply 14 is produced on a bi-axial laying-up machine along with a weft dominated 90° ply 40. It will be noted that the 0° ply 14 is formed during the lay-up process with a groove-like recess 47. Two ±45° plies 44, 46 comprising plies 16,18 are formed on a multi-axial laying-up machine are fed to the bi-axial laying-up machine so that they overlap as shown in Figure 7 to form a lap joint 48. The addition of the 90° ply and the overlapping of

the two ±45° plies 44, 46 help to compensate for the thinning of the 0° ply where formed with the recess 26. However, if desired, a capping as described above may be provided over the joint 48.

In Figure 8 an aircraft 50 has wings 52 each of which is provided with a skin 54 made from a composite material joined by a method in accordance with the invention. The joint is indicated at 21 in Figure 8 and three plies 14, 16 and 18 are indicated. Typically the 0° fibres of the warp dominated ply 14 will extend spanwise of the wings 52 with the fibres of plies 16, 18 at $\pm$ 45°.

It will be appreciated that a method in accordance with the invention enables a machine which is used for manufacturing bi-axial fabrics of up to 5 metres in widths to be used to construct a multi-axial fabric of similar widths. Hitherto, that has not been possible.

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CLAIMS:

1. A method of constructing a composite material which comprises a laminate of plies that includes a warp dominated ply and a weft dominated ply, the method being characterised by forming a recess (20; 26; 47) in an outer surface of a piece of material which recess is at least partly defined by a warp dominated ply (14) of the construction, arranging a first piece of material (10) of the construction alongside a second piece (12) of material of the construction with at least a part (12a; 12c) of the second piece of material (12) in the recess (20; 26; 47) and overlapping at least a part (10a; 10b; 10c) of the first piece of material (10) to form a lap joint (21; 32; 33; 48) wherein the part (12a; 12c) of the second piece of material (12) in the recess (20; 26; 47) and the overlapped part (10a; 10b; 10c) of the first piece of material include weft dominated plies.

2. A method according to claim 1 characterised in that in which each of the first and second pieces of material (10, 12) comprises a laminate of plies comprising a warp dominated ply (14) and a weft dominated ply (16, 18), the method including arranging the two pieces of material (10, 12) alongside each other with edges of the warp dominated ply (14) of each piece extending in the same direction.

3. A method according to claim 2 characterised by forming the recess (20) in an edge of the first said piece (10) of composite material.

4. A method according to claim 3 characterised by forming corresponding edge of the second piece of composite material (12) in the same way.

5. A method according to claim 3 or 4 characterised by forming the recess (20) by setting a said edge of a warp dominated ply (14) of the first piece (10) back from an adjacent edge of a weft dominated ply (16, 18) forming part of the lap joint (21).

6. A method according to claim 3, 4 or 5 characterised by reducing the thickness of the warp dominated ply (14) of the second piece of material (12) adjacent its said edge to enable the weft dominated ply (16, 18) and a remainder part of the warp dominated ply (14) to enter the recess (20) to form the lap joint (21).

7. A method according to claim 6 characterised by forming the corresponding edge of the first piece of material (10) in the same way.

8. A method according to claim 6 or 7 characterised by bringing an edge of the remainder part of the warp dominated ply (14) of the second piece (12) into abutment with the edge of the warp dominated ply (14) of the first piece (10) when forming the lap joint (21).

9. A method according to claim 1 or 2 characterised by forming the recess (26) by positioning a length of thinner warp dominated material (24) between the edges of the warp dominated plies (14) or within a width of a warp dominated ply (14).

10. A method according to claim 9 when appendant to claim 2 including providing the thinner length of warp dominated material (24) on the edge of the warp dominated ply (14) of the first piece of material (10) and abutting the

thinner length (24) against the edge of the warp dominated ply (14) of the second piece of material (12).

11. A method according to claim 9 or 10 characterised in that the length of thinner warp dominated material (24) is formed from higher filament count or higher modulus fibres compared to fibres used to construct the warp dominated ply or plies (14).

12. A method according to any of claims 9 to 11 characterised by forming the lap joint (32) so that part ( 12c) of the weft dominated ply (16, 18) of only one of the pieces (12) lies in the recess (26) with part (10b; 10c) of the other weft dominated ply (16, 18) of the other piece overlapping at least a portion of it.

13. A method according to claim 12 characterised by arranging the said part (10c) of the other weft dominated ply (16, 18) of the other piece (10) to overlap all of that part (12c) of the weft dominated ply (16, 18) of the said one piece of material (12).

14. A method according to any of claims 9 to 13 characterised by placing a layer (34, 34a) of warp dominated material on the outside of the lap joint (32, 33).

15. A method according to claim 1 characterised by forming the recess (47) as a groove in one surface of the warp dominated ply (14) and providing a further weft dominated ply (40) on the opposite surface of the recessed warp dominated ply (14).

16. A method according to claim 15 characterised by feeding the two pieces of material (10, 12) to a machine so as to form the lap joint (21; 32; 33), the warp dominated ply (14) and the further weft dominated ply (40) by means of a single laying-up operation.

17. A method according to any one of claims 1 to 16 characterised by forming two layers of the jointed material (10, 12) with one layer inverted relative to the other and the weft dominated plies (16, 18) forming outer surfaces of the two layers.

18. A method according to any one of claims 1 to 16 including forming two layers of the jointed material (10, 12) with one layer inverted relative to the other and the warp dominated plies (14) forming outer surfaces of the two layers.

19. A method according to any one of claims 1 to 18 characterised in that the weft dominated plies (16, 18) comprise plies arranged at +45 degrees and -45 degrees in relation to the warp dominated ply (14).

20. A method according to claim 15 characterised in that the further weft dominated ply (40) comprises a ply at 90 degrees to the warp dominated ply.

21. A method according to any one of claims 1 to 20 characterised in that the composite material made by the method has a width dimension at right angles to the warp dominated ply in excess of 1.7 metres.

22. A method according to any one of claims 1 to 21 characterised by the composite material forming a skin panel for an aerofoil.

23. A method according to any one of claims 1 to 21 characterised by the composite material forming a skin panel for an aircraft.

24. A composite material construction which comprises a laminate of plies that includes a warp dominated ply and a weft dominated ply, characterised in that the construction comprises a recess (20; 26; 47) defined at least partly by a warp dominated ply (14) of the construction, and a first piece of material (10) arranged alongside a second piece of material (12) with at least a part (12a; 12c) of the second piece of material (12) being received within the recess (20; 26; 47) and with the first part (12a; 12c) of the second piece of material (10) in the recess overlapping at least a part (10a; 10b; 10c) of the first piece of material (10) to form a lap joint (21; 32; 33; 48) wherein the recessed part (12a; 12c) of the second piece of material (12) in the recess and the overlapped part of the first piece of material (10) include weft dominated plies.

25. A composite material construction according to claim 24 characterised in that each of the two pieces of material (10, 12) includes warp dominated plies (14) and weft dominated plies (16, 18), the edges of the warp dominated plies of each piece of material (10,12) extend in the same direction.

26. A composite material construction according to claim 24, characterised in that the recess (20) is formed in an edge of the first piece of material (10).

27. A composite material construction according to claim 26 characterised in that the recess (20) is formed by setting a said edge of a warp dominated ply (14) of the first

piece (10) back from an adjacent edge of a weft dominated ply (16, 18) forming part of the lap joint (21).

28. A composite material construction according to claim 24 characterised in that a thinner warp dominated material (24) is positioned between the edges of the warp dominated plies (14) or within a width of a warp dominated ply (14) to form the recess (26).

29. A composite material construction according to any of claims 25 to 28 characterised in that the recess (47) is in the form of a groove in one surface of the warp dominated ply (14) and a further weft dominated ply (40) is arranged on the opposite surface of the warp dominated ply (14).

30. A composite material construction according to any of claims 24 to 29 wherein the width of the overlap of the first and second pieces of material (10, 12) is spanned by a warp dominated ply or warp dominated plies (14; 24).

31. A composite material construction according to any of claims 24 to 30 characterised in that the construction has a width dimension at right angles to the warp dominated ply in excess of 1.7 metres.

32. A composite material construction of any of claims 24 to 30 forming a skin for an aerofoil.

33. A composite material construction of any of claims 24 to 30 forming a skin panel for an aircraft.

FETHERSTONHAUGH & CO.

OTTAWA, CANADA

PATENT AGENTS

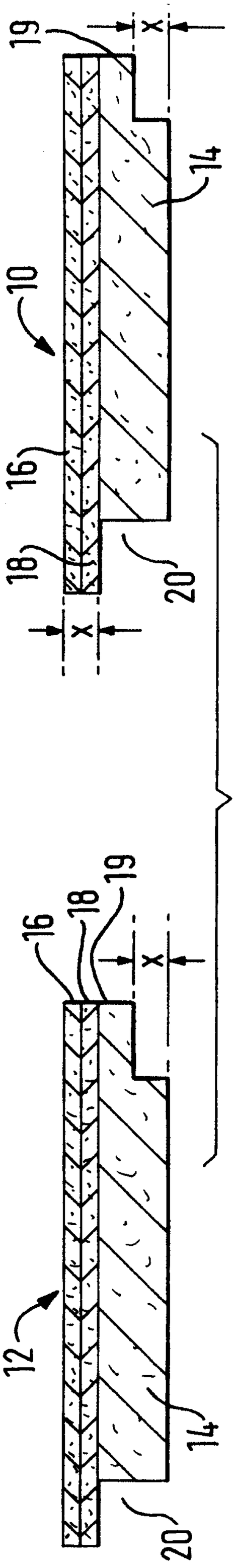



FIG. 1

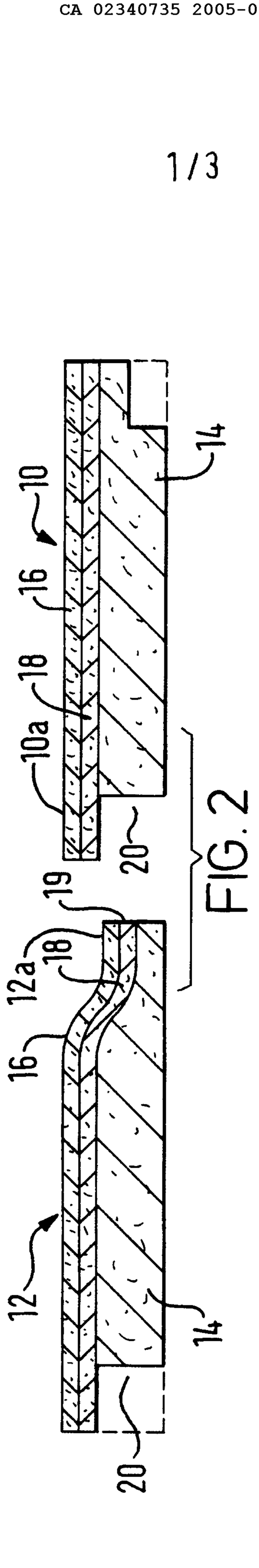



FIG. 2

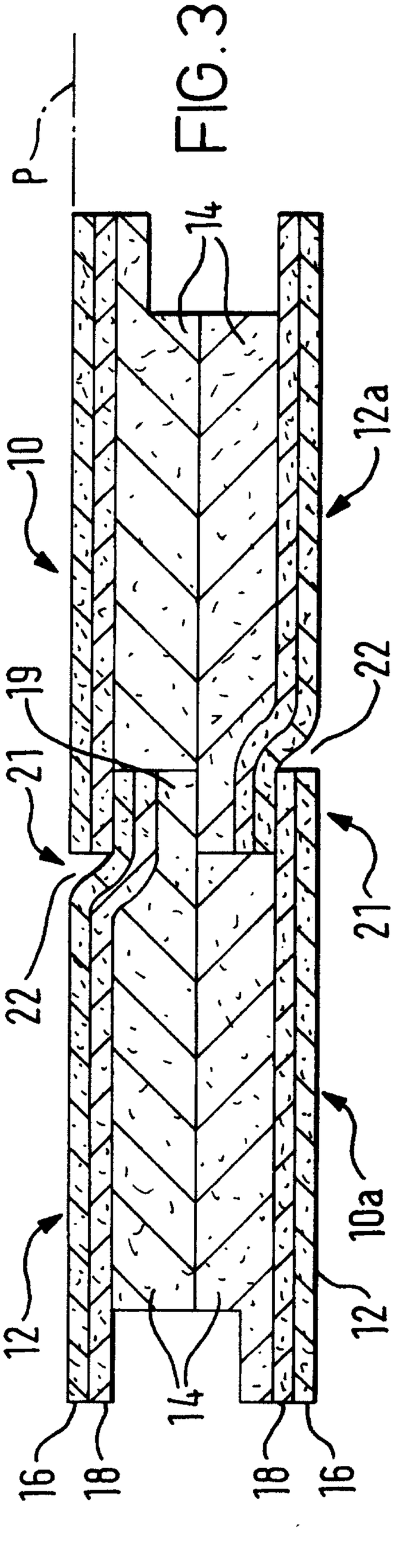



FIG. 3

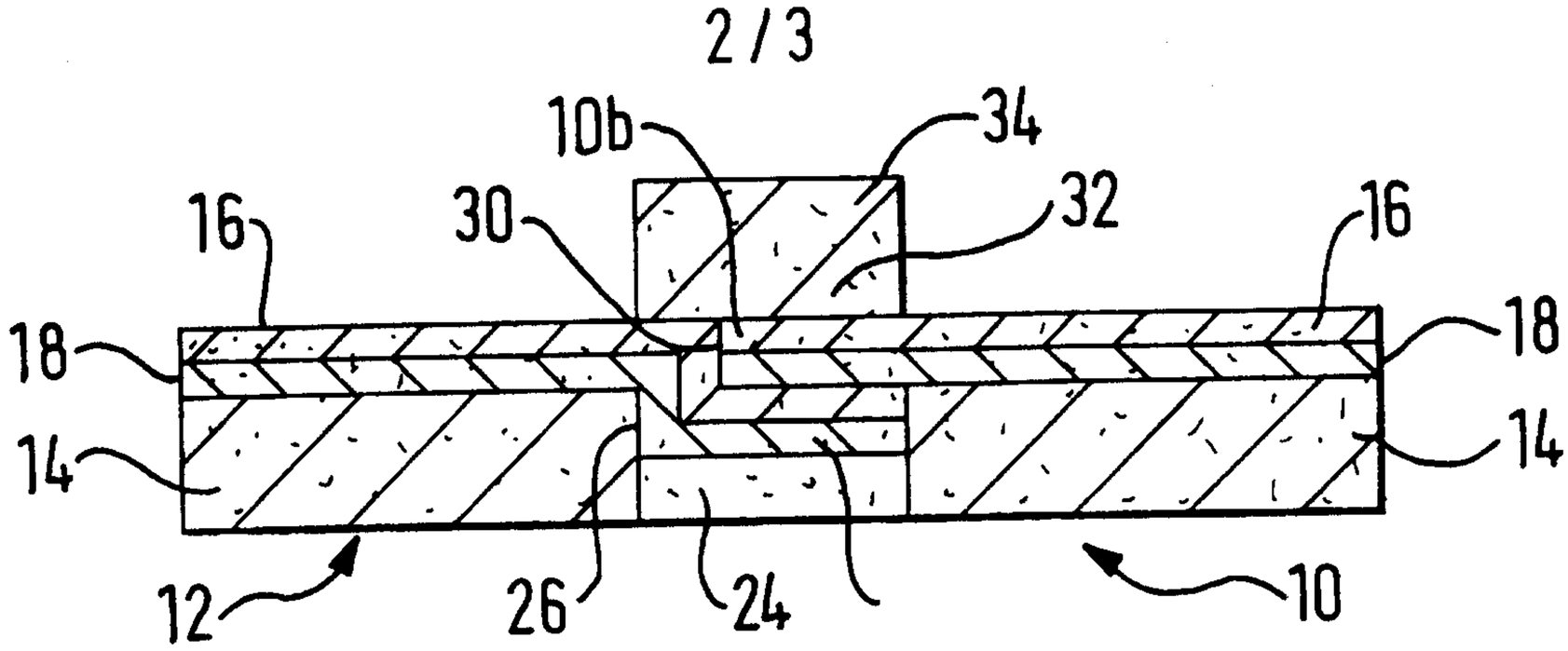



FIG. 4

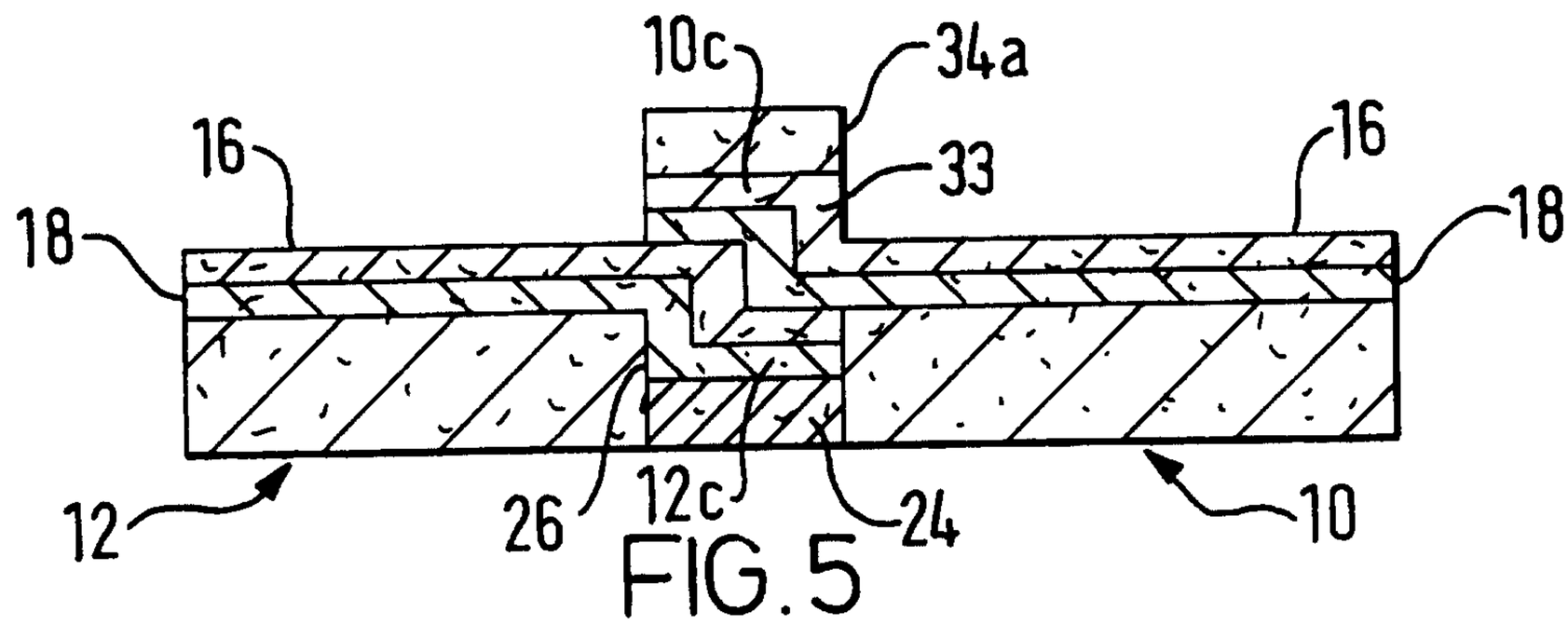



FIG. 5

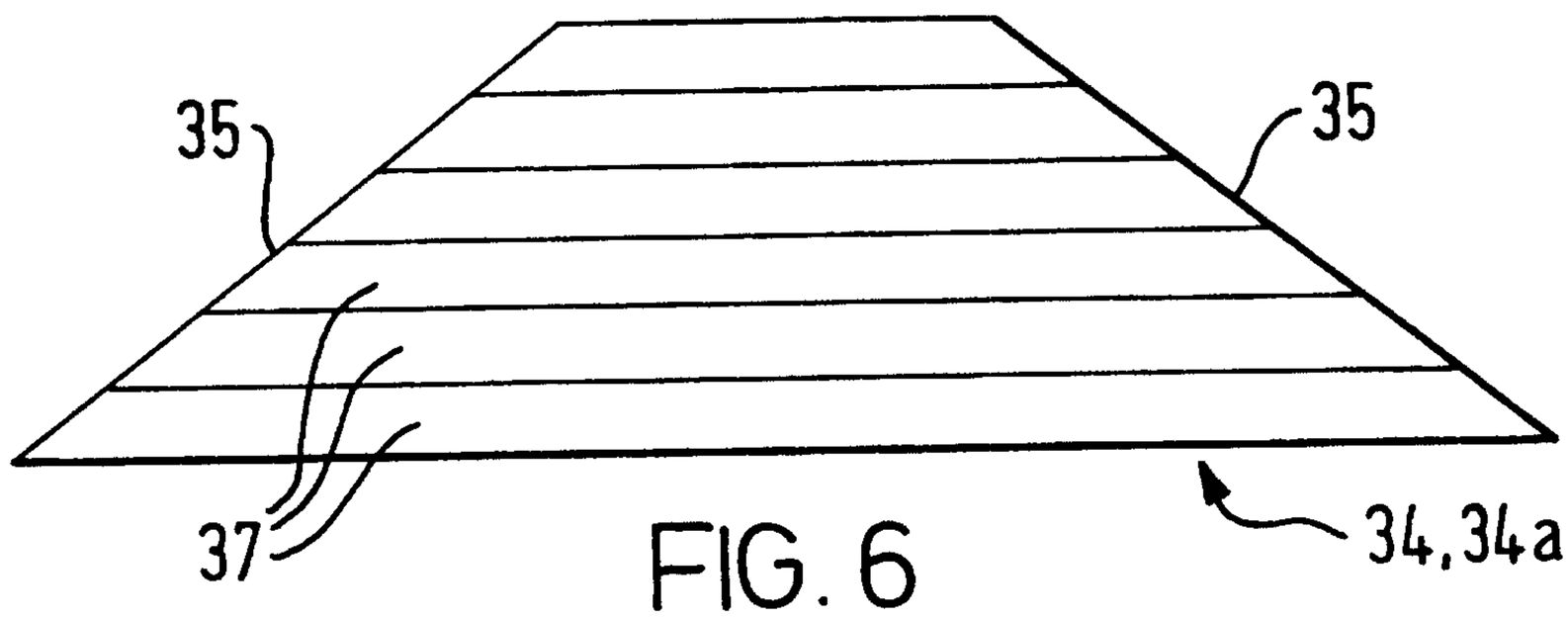



FIG. 6

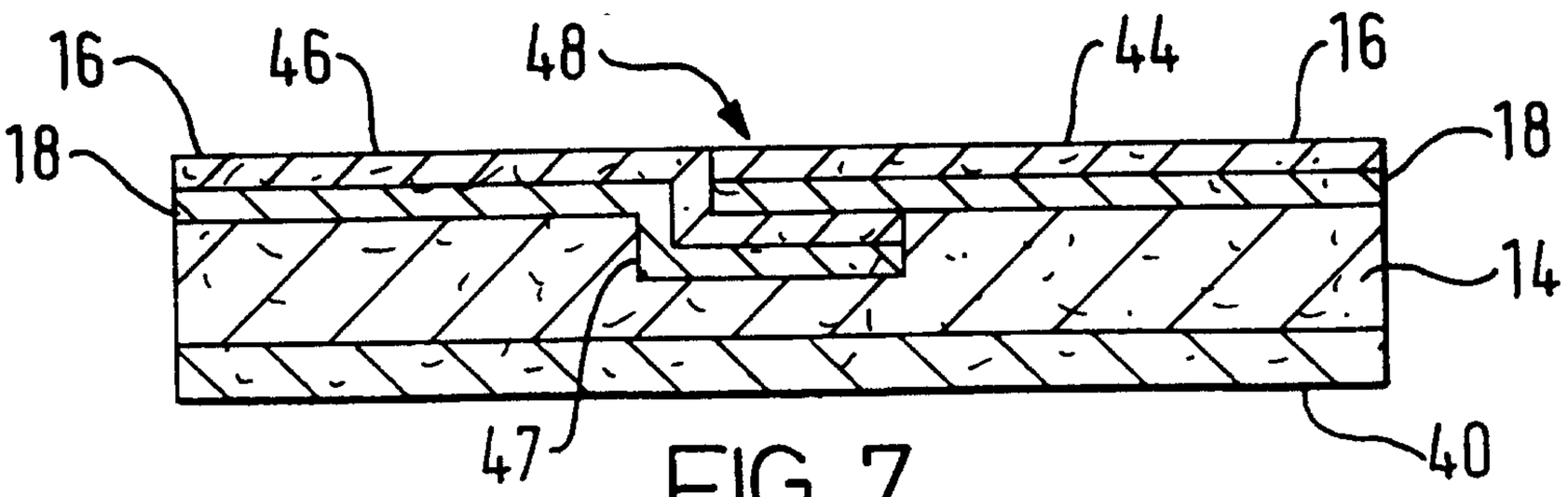



FIG. 7

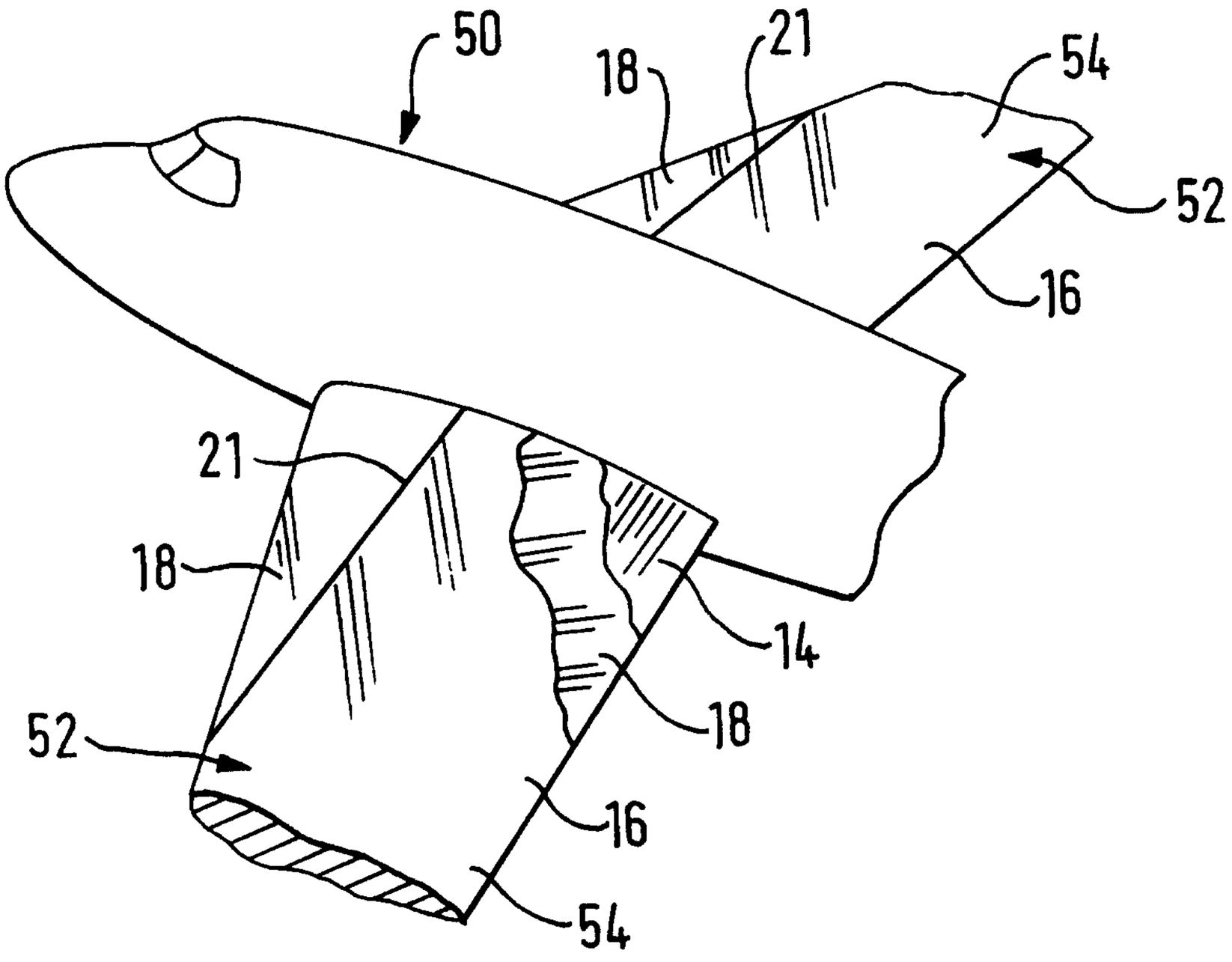
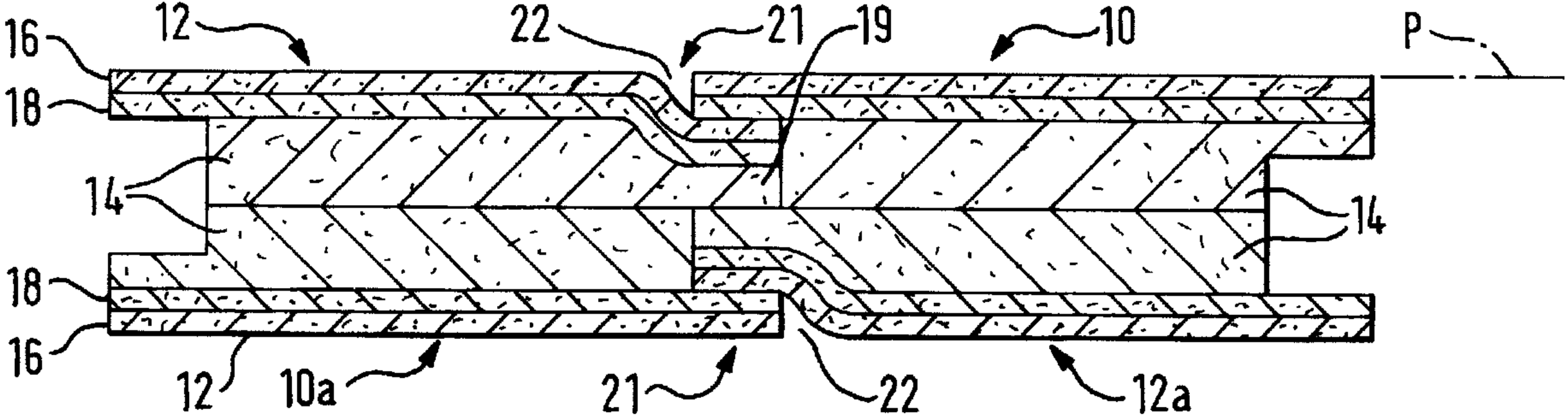



FIG. 8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