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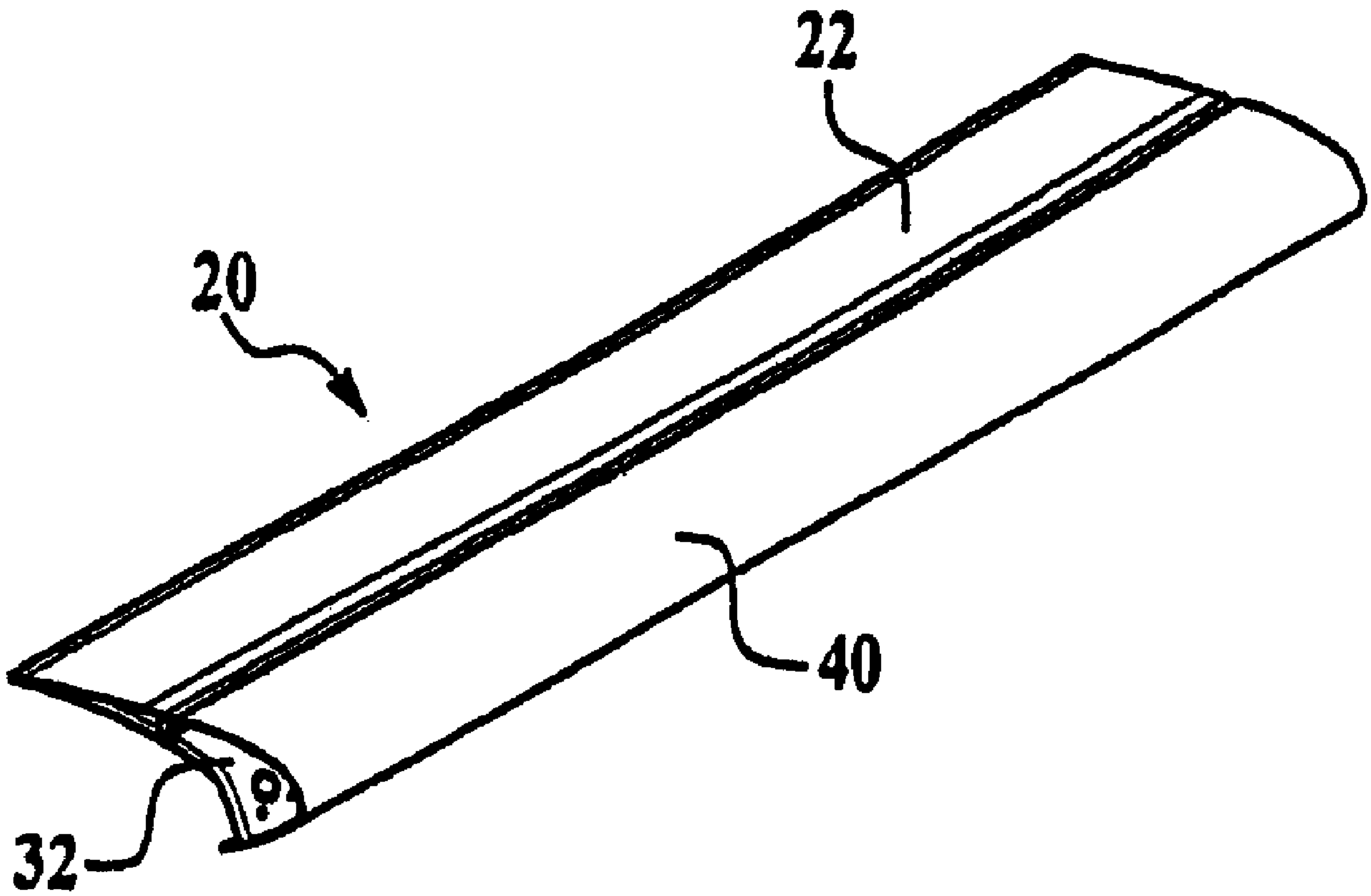
(54) Title: COMPOSITE WING SLAT FOR AIRCRAFT



(57) Abrégé/Abstract:
A composite wing slat for an aircraft includes an upper composite skin, and a lower composite skin including a curved forward edge portion. A pre-formed core is sandwiched between the upper composite skin and a portion of the lower composite skin adjacent the curved forward edge portion, and a plurality of stiffeners are bonded to the lower composite skin. A method for making the composite wing slat is also described.

ABSTRACT OF THE DISCLOSURE

A composite wing slat for an aircraft includes an upper composite skin, and a lower composite skin including a curved forward edge portion. A pre-formed core is sandwiched between the upper composite skin and a portion of the lower composite skin adjacent the curved forward edge portion, and a plurality of stiffeners are bonded to the lower composite skin. A method for making the composite wing slat is also described.

COMPOSITE WING SLAT FOR AIRCRAFT

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention generally relates to structural components for aircraft, and deals more particularly with a wing slat formed of composite materials.

Description of the Related Art

In order to improve the lift characteristics of large commercial and military aircraft, particularly during low speed operation, wings are equipped with high lift, auxiliary devices known as slats. The slats are mounted on the leading edge of the wings so as to pivot or slide outwardly from the leading edge, from a stowed to a deployed position. Typically, leading edge slats are moved downward and forward from the leading edge of the wing using either linear or rotary actuators which move a track or an arm attached to the slat.

In the past, slats have been fabricated using metal and metal alloys using metal-to-metal bonds. Metallic slats suffer from a number of shortcomings, including metal bonding problems which contribute to in-service maintenance, impact damage and corrosion. In addition, metallic slats are fabricated from numerous metal components which must be individually manufactured and assembled, making the slats relatively expensive to manufacture, and adding unnecessary weight to the aircraft.

Accordingly, there is a need for a wing slat construction having a reduced number of parts which is also lighter in weight.

BRIEF SUMMARY OF THE INVENTION

In accordance with one aspect of the invention, there is provided a wing slat apparatus for an aircraft. The wing slat includes an upper composite skin, and a lower composite skin comprising a curved forward edge portion. The wing slat further includes a pre-formed core sandwiched between the upper composite skin and a portion of the lower composite skin adjacent the curved forward edge portion, and a plurality of stiffeners bonded to the lower composite skin.

The apparatus may include a composite spar at a forward end of the pre-formed core and disposed between the upper and lower composite skins.

The composite spar may have first, second and third leg portions, disposed in a C-shape, the first and third leg portions may be generally parallel to each other and the first leg portion of the spar may be in contact with the upper skin and the third leg portion of the spar may be in contact with the lower skin.

The stiffeners may include a plurality of overlapping strips of composite material.

A plurality of longitudinally spaced ribs may be secured to the curved forward edge portion of the lower skin.

A curved forward edge portion of the lower skin may terminate in a trailing edge.

The apparatus may include a nose skin generally extending between the upper skin and the trailing edge of the curved forward edge portion of the lower skin, forming a leading edge of the wing slat.

The upper skin may have a forward edge and the forward edge of the upper skin and a leg of the spar may define a notch and the nose skin may have an upper trailing edge received in the notch such that outer surfaces of the nose skin and the upper skin form a generally flush, continuous surface.

The nose skin may have a heater.

The apparatus may include a plurality of longitudinally spaced ribs secured to the curved forward edge portion of the lower skin, and the nose skin may cover the ribs.

In accordance with another aspect of the invention, there is provided a method of fabricating a composite wing slat for an aircraft. The method involves forming a lay-up by placing a pre-cured upper composite skin in the lay-up mold, placing a pre-cured composite spar in the mold such that a portion of the spar overlies and contacts the upper composite skin and placing a plurality of stiffeners in a portion of the lay-up mold configured to form a curved forward edge of the wing slat. Forming the lay-up further involves placing a lower composite skin over at least the spar and the stiffeners such that a portion of the lower composite skin is in the portion of the lay-up configured to form the curved forward edge of the wing slat. The method further involves compressing the lay-up, and curing the compressed lay-up to form a wing slat subassembly having a curved forward edge in the lower composite skin, which acts as the curved forward edge of the wing slat and wherein the stiffeners are bonded to the curved forward edge and to the lower composite skin.

The method may involve applying a film adhesive to an upper side of the pre-cured upper skin.

The method may involve supporting the spar by a mandrel.

The method may involve placing a first leg portion of the spar in contact with the upper skin and placing a second spaced apart leg portion of the spar on top of the mandrel.

The method may involve placing a preformed core in the mold on the upper skin adjacent the spar before lay-up of the lower skin.

The method may involve loading the preformed core with a foaming adhesive and then applying a film adhesive.

The method may involve placing the lower composite skin further involving placing the lower composite skin over a side of the preformed core.

Placing a plurality of stiffeners may involve placing overlapping strips of composite material in the portion of the lay-up mold configured to form a curved forward edge of the wing slat.

The method may further involve attaching a nose skin to the wing slat subassembly. The nose skin may have a heater.

The method may involve causing a notch to be defined by a forward edge of the upper skin and a leg of the spar and attaching the nose skin may involve causing an upper trailing edge of the nose skin to be received in the notch such that outer surfaces of the nose skin and the upper skin form a generally flush, continuous surface.

Compressing the lay-up may involve placing the lay-up in a vacuum bag and drawing a vacuum on the bag to compress the lay-up.

These and other features, aspects and advantages of the invention will become better understood with reference to the following drawings, description and claims.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

Figure **1** is a perspective view of a composite slat in accordance with the present invention.

Figure **2** is an enlarged, exploded perspective view of the slat shown in Figure **1** with certain parts not shown, for clarity.

Figure **3** is a perspective view of the upper skin of the slat shown in Figure **1**.

Figure **4** is a perspective view of a spar.

Figure **5** is an end view of the spar shown in Figure **4**.

Figure **6** is a perspective view of the lower skin.

Figure **7** is a perspective view of the central core.

Figure **8** is a cross sectional view of a lay-up placed in a lay-up mold used in fabricating parts of the slat shown in Figure **1**.

Figure **9** is a cross sectional view of the lay-up after it has been cured and removed from the lay-up mold shown in Figure **8**.

Figure **10** is a fragmentary, perspective view of a portion of a cured lay-up after it has been removed from the mold shown in Figure **8**.

Figure **11** is a simplified flow diagram of the steps for producing the lay-up shown in Figures **8-10**.

Figures **12-14** are perspective views of ribs used in the slat shown in Figure **1**.

Figure **15** is a perspective view of a composite nose skin forming part of the slat shown in Figure **1**.

Figure **16** is a perspective view of a partially assembled slat, showing the positions of the ribs depicted in Figures **12-14**.

Figure **17** is an enlarged, fragmentary view of one end of the slat, portions being broken away in section.

DETAILED DESCRIPTION OF THE INVENTION

Referring to the Figures, the present invention broadly relates to an aircraft wing slat **20** formed of composite materials with a minimal number of components. Composite structures and materials are widely used in high performance applications because of their light weight, high strength, high stiffness and superior fatigue resistance. As used herein, "composite materials" refers to materials and structures comprising a combination of dissimilar constituent materials bonded together by a binder, most commonly formed by a thermosetting resin matrix in combination with a fibrous reinforcement such as carbon fiber, typically in the form of a tape, sheet or mat. Multiple plies of the matting are impregnated with a binder such as epoxy plastic resin or polyester resin, and formed into a "lay-up". The plies are arranged so that their respective directions of orientation alternate at differing angles in order to improve the stiffness of the cured laminate. Pressure and heat are applied to the multi-layer part lay-up in order to compress and cure the plies, thereby forming a rigid structure.

The slat **20** broadly comprises an upper composite skin **22**, a lower composite skin **24** and a central core section **26** sandwiched between skins **22** and **24**. A spar **28**, formed of precured composite materials is sandwiched between upper and lower skins **22**, **24** respectively, and is bonded to the leading edge of the central foam core

26. The lower skin **24** extends forwardly beyond the upper skin **22** and includes a downwardly curved section **24**a that terminates in a trailing edge **24**b. A plurality of curved stiffeners **30** formed of composite material extend fore-to-aft and are bonded to the curved section **24**a of the lower skin **24**. As will be discussed later in more detail, a plurality of longitudinally spaced ribs **32** are secured to the curved section **24**a of the lower skin **24**, and a composite nose skin piece **40** is received over the ribs **32** to form the leading edge of the slat **20**.

The upper skin **22** may comprise a pre-cured composite structure, formed for example, of epoxy pre-impregnated carbon fiber fabric. In one example, five plies of carbon fiber fabric alternately arranged in a **0/45/0/-45/0** orientation were found to be satisfactory. A "doubler" comprising five additional plies of the carbon fiber fabric may be added to the underside of forward sections of the upper skin **22** to increase its strength and rigidity. The upper skin **22** is fabricated using normal lay-up techniques, including vacuum bagging and curing. The trailing edge of the upper skin **22** may be machined so as to possess the desired thickness and taper angle.

The material used to lay-up the lower skin **24** may comprise epoxy pre-impregnated carbon fiber tape and fabric arranged in multiple angles relative to the direction of orientation. The number of plies will vary depending upon the desired stiffness in each area of the skin **24**. In one satisfactory example, four plies were found to be satisfactory near the trailing edge of skin **24** while a buildup of ten plies of tape were used in forward portions of the lower skin **24**. A doubler of **4** additional plies was added where the skin **24** contacts the ribs **32**.

As best seen in Figures **4** and **5**, the spar **28** is generally C-shaped in cross section, comprising a lower leg **28**a, a middle leg **28**b and an upper leg **28**c which is wider in width than the lower leg **28**a. The spar **28** extends essentially the entire length of the slat **20** and may be formed using conventional lay-up techniques using multiple plies of epoxy pre-impregnated carbon fiber tape. In one embodiment found to be satisfactory, twenty plies of carbon fiber tape were combined with fiberglass plies in the areas contacting the ribs **32**, wherein the plies were placed in an alternating arrangement of **45/0/0/-45/90/45/0/0/-45/0** relative to the direction of orientation. The lay-up materials forming the spar may be vacuum bagged to compress the plies, following which the compressed lay-up is cured.

The central core section **26** is wedge shaped in cross section and tapers from leading edge **26**a to a trailing edge **26**b. The central core section **26** may be formed from commercially available sheets of either **N636** Kevlar® honeycomb or a honeycomb of NOMEX®. NOMEX® is available from the DuPont Corporation and can be formed into a honeycomb using NOMEX® paper which is a form of paper based on Kevlar®. The initial paper honeycomb is usually dipped in a phenolic resin to produce a honeycomb core that exhibits high strength and very good fire resistance. The formed core **26** can be machined to final dimensions as necessary.

The nose skin **40** may comprise a precured laminate of resin impregnated, alternating fiberglass and carbon fiber plies, in tape form, with a heater blanket (not shown) interposed between least two of the plies in order to provide the slat **20** with a deicing capability. The nose skin **40** is attached to the subassembly **45** using countersunk bolts (not shown) or similar "blind" fasteners, which are received on nutplates (not shown) on the subassembly **45**. The composite nose skin may be formed **40** by laying up composite materials, compressing the composite materials and curing the composite materials.

Referring now particularly to Figures **8** and **11**, a composite subassembly **45** is formed by sequentially laying up materials in a lay-up mold **42**. Beginning at step **48** in Figure **11**, the precured upper skin **22** is first loaded into the mold **42**, following which a film adhesive is applied to the upper side of skin **22**, at step **50**. At step **52**, the pre-cured spar **28** is loaded into the mold **42**, so as to be supported by a mandrel portion **47** of the mold **42**. As can be seen in Figure **8**, a portion of the leg

28c overlies and contacts the upper skin **22**, while leg **28**a is positioned on top of the mandrel portion **47** of the mold **42**. At step **54**, the preformed central core **26** is loaded with a suitable foaming adhesive, following which a film adhesive is applied at **56**. At step **58**, strips of composite material are laid up in the mold **42** to form the stiffeners **30**. Next, at step **60**, the lower skin **24** is loaded into mold **42**, thereby covering and contacting stiffeners **30**, spar **28** and one side of the central core **26**. The mold **42** together with the lay-up is placed in a vacuum bag and a vacuum is drawn to compress the components together. Finally, at step **62**, the lay-up is cured, causing the lower skin **24** and the stiffeners **30** to co-cure. The vacuum bag is removed and the final subassembly is trimmed and drilled to produce necessary openings for fasteners, as required. A seal (not shown) is installed at the ends of the subassembly **45**, between the upper and lower skins **22**, **24**.

The ribs **32** are secured to the forward section of the lower skin **24** by means of screws, rivets or other fasteners, and as previously mentioned, the nose skin **40** is secured by countersunk bolts to a nutplate (not shown) carried on the co-cured subassembly **45**. As best seen in Figures **9**, **10** and **17** the upper trailing edge of the nose skin **40** is received within a notch **66** defined by the forward edge of upper skin **22** and the upper leg **28**a of the spar **28**. The notch **66** allows the outer surfaces of nose skin **40** and upper skin **22** to form a flush, continuous surface in order to reduce turbulence. An end rib **36** (Figures **14** and **17**) seals the outer end of the nose skin **40**. As shown in Figure **17**, an upper, spanwise bulb seal **68**, and a lower, spanwise flex skirt **64** are attached to the rear of the slat **20** and function to seal the spar **20** against the fixed leading edge of a wing (not shown) when the slat **20** is in its stowed position during normal flight.

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

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

1. A wing slat apparatus for an aircraft, comprising:

an upper composite skin;

a lower composite skin comprising a curved forward edge portion;

a pre-formed core sandwiched between the upper composite skin and a portion of the lower composite skin adjacent said curved forward edge portion; and

a plurality of stiffeners bonded to the lower composite skin.

2. The apparatus of claim **1** further comprising a composite spar at a forward end of the pre-formed core and disposed between said upper and lower composite skins.

3. The apparatus of claim **2** wherein the composite spar has first, second and third leg portions, disposed in a C-shape, wherein the first and third leg portions are generally parallel to each other and wherein the first leg portion of the spar is in contact with the upper skin and the third leg portion of the spar is in contact with the lower skin.

4. The apparatus of any one of claims **1** to **3**, wherein said stiffeners comprise a plurality of overlapping strips of composite material.

5. The apparatus of any one of claims **1** to **4** further comprising a plurality of longitudinally spaced ribs secured to said curved forward edge portion of said lower skin.

6. The apparatus of any one of claims **1** to **5** wherein said curved forward edge portion of said lower skin terminates in a trailing edge.

7. The apparatus of any one of claims **1** to **6** further comprising a nose skin generally extending between the upper skin and the trailing edge of the curved forward edge portion of said lower skin, forming a leading edge of the wing slat.

8. The apparatus of claim **7** wherein the upper skin has a forward edge and wherein said forward edge of the upper skin and a leg of said spar define a notch and wherein said nose skin has an upper trailing edge received in said notch such that outer surfaces of the nose skin and the upper skin form a generally flush, continuous surface.

9. The apparatus of claim **7** or **8** wherein said nose skin has a heater.

10. The apparatus of any one of claims **7** to **9** further comprising a plurality of longitudinally spaced ribs secured to said curved forward edge portion of said lower skin, wherein said nose skin covers said ribs.

11. A method of fabricating a composite wing slat for an aircraft, comprising the steps of:

forming a lay-up by:

placing a pre-cured upper composite skin in the lay-up mold;

placing a pre-cured composite spar in the mold such that a portion of the spar overlies and contacts the upper composite skin;

placing a plurality of stiffeners in a portion of the lay-up mold configured to form a curved forward edge of the wing slat;

placing a lower composite skin over at least the spar and the stiffeners such that a portion of the lower composite skin is in said portion of the lay-up configured to form said curved forward edge of the wing slat;

compressing the lay-up;

curing the compressed lay-up to form a wing slat subassembly having a curved forward edge in the lower composite skin, which acts as said curved forward edge of said wing slat and wherein said stiffeners are bonded to said curved forward edge and to said lower composite skin.

12. The method of claim **11** further comprising applying a film adhesive to an upper side of said pre-cured upper skin.

13. The method of claim **11** or **12** further comprising supporting said spar by a mandrel.

14. The method of claim **13** further comprising placing a first leg portion of the spar in contact with the upper skin and placing a second spaced apart leg portion of the spar on top of the mandrel.

15. The method of any one of claims **11-14**, further comprising placing a preformed core in the mold on the upper skin adjacent the spar before lay-up of the lower skin.

16. The method of claim **15** further comprising loading the preformed core with a foaming adhesive and then applying a film adhesive.

17. The method of claim **15** or **16** wherein placing the lower composite skin further comprises placing the lower composite skin over a side of the preformed core.

18. The method of any one of claims **11** to **17**, wherein placing a plurality of stiffeners comprises placing overlapping strips of composite material in said portion of the lay-up mold configured to form a curved forward edge of the wing slat.

19. The method of any one of claims **11** to **18** further comprising attaching a nose skin having a heater to said wing slat subassembly.

20. The method of claim **19** wherein the nose skin has a heater.

21. The method of claim **19** or **20** further comprising causing a notch to be defined by a forward edge of the upper skin and a leg of said spar and wherein attaching said nose skin comprises causing an upper trailing edge of said nose skin to be received in said notch such that outer

surfaces of the nose skin and the upper skin form a generally flush, continuous surface.

22. The method of any one of claims **11-21** wherein compressing comprises placing the lay-up in a vacuum bag and drawing a vacuum on the bag to compress the lay-up.

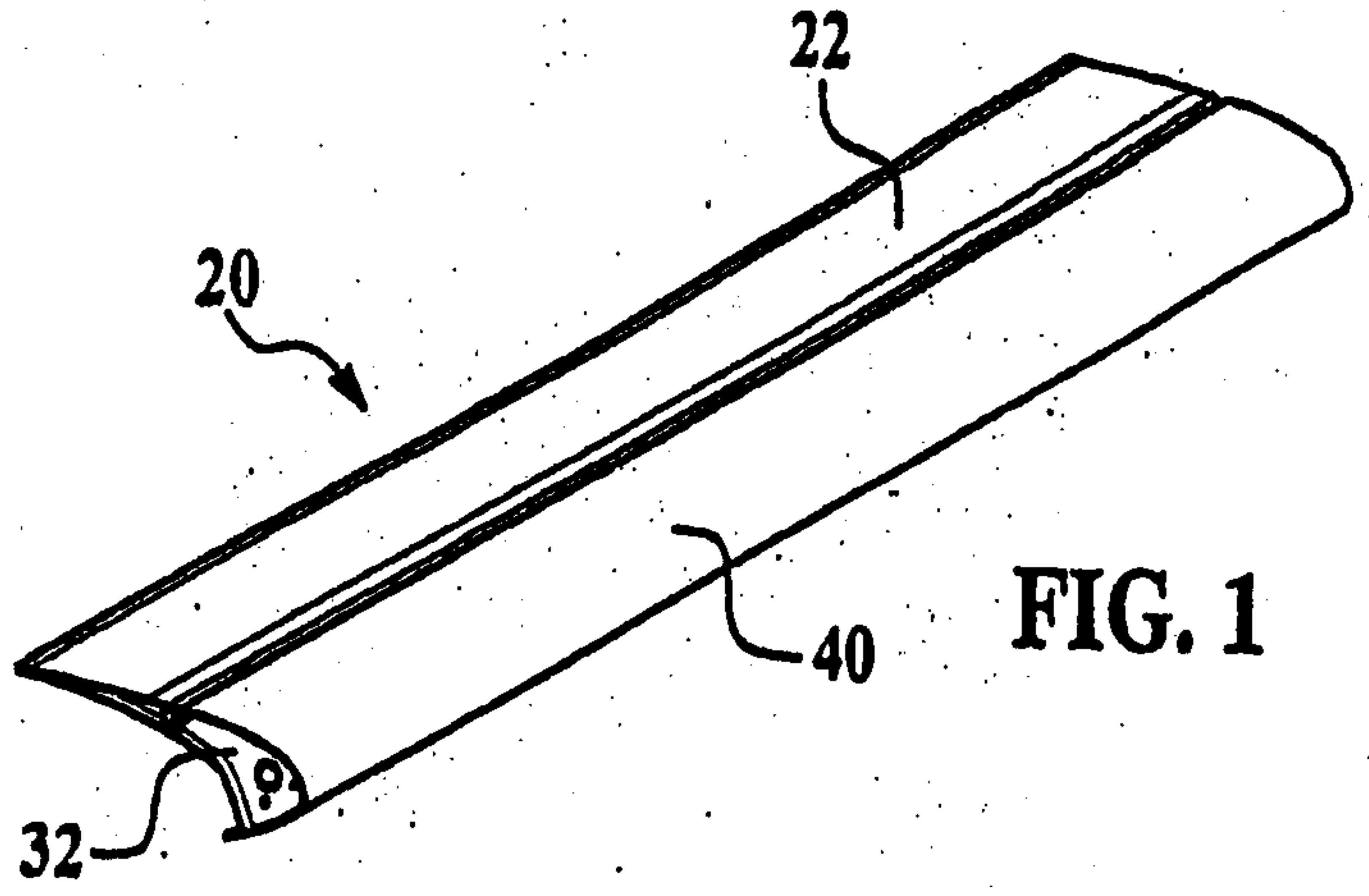


FIG. 1

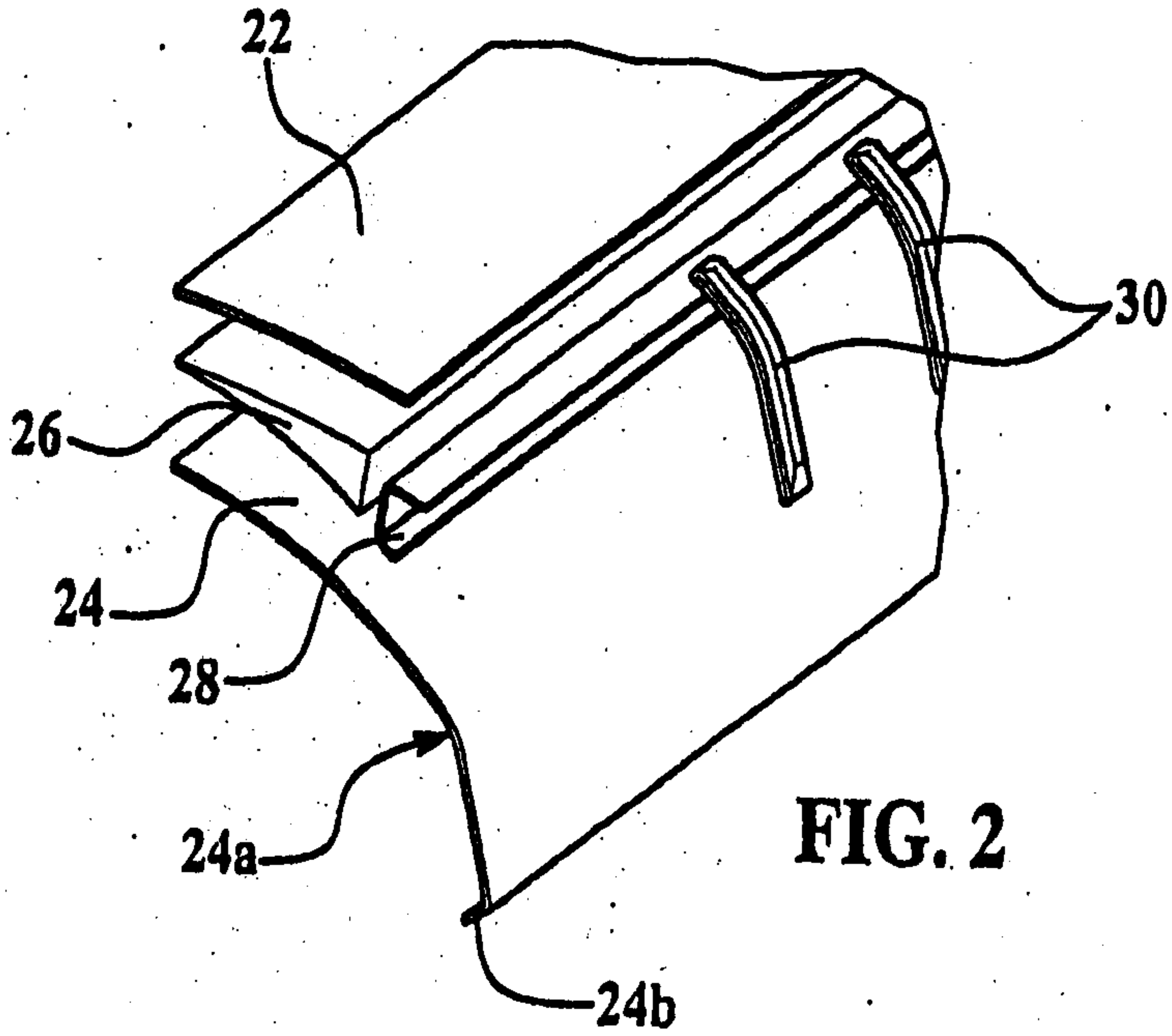


FIG. 2

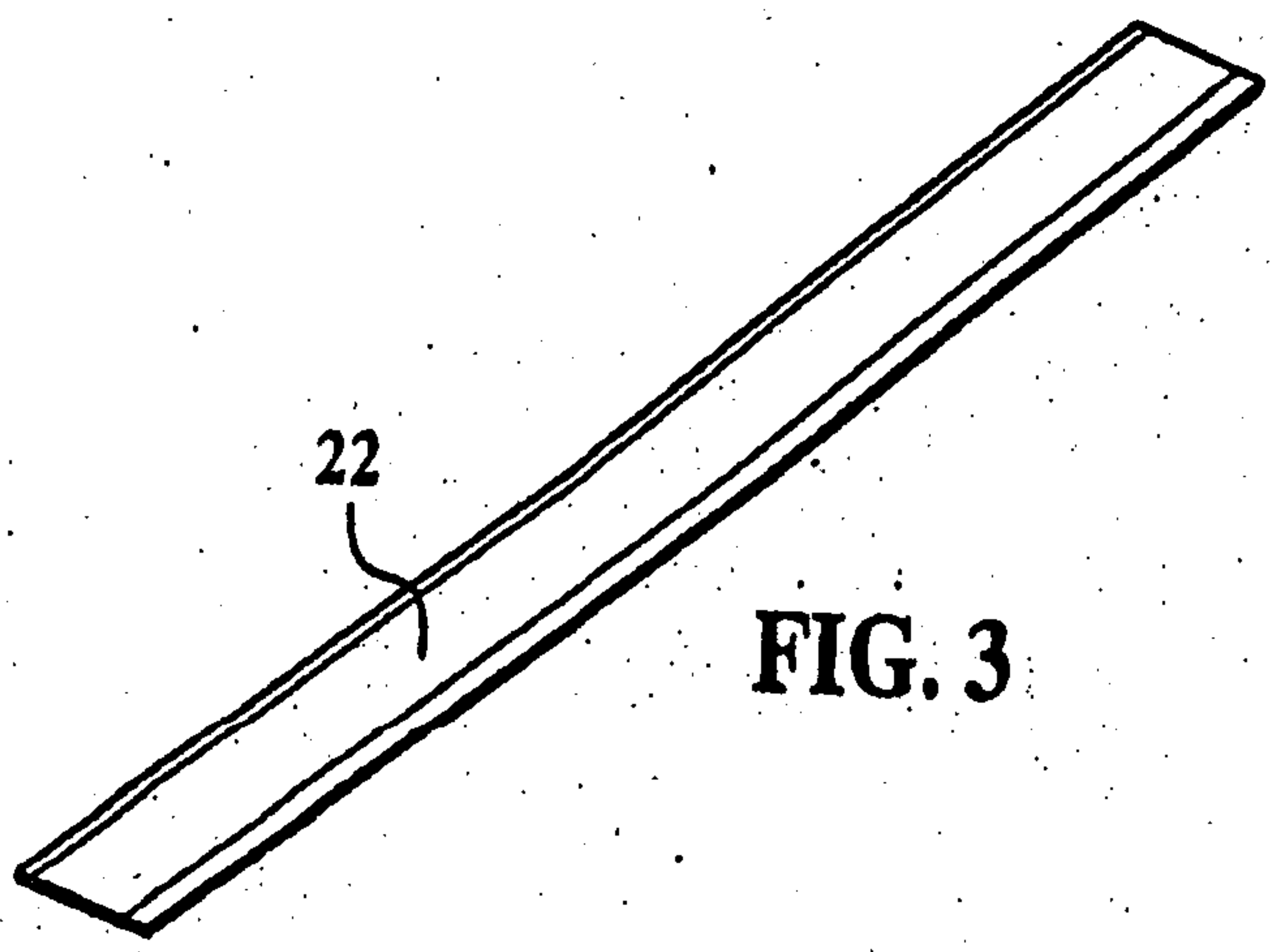


FIG. 3

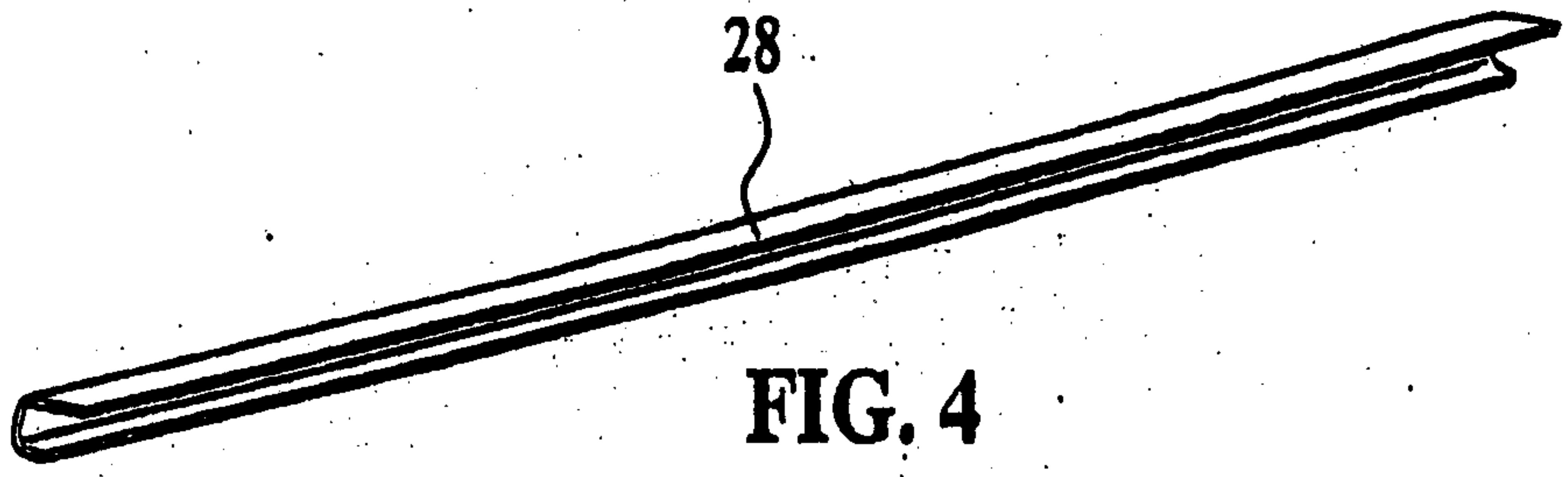


FIG. 4

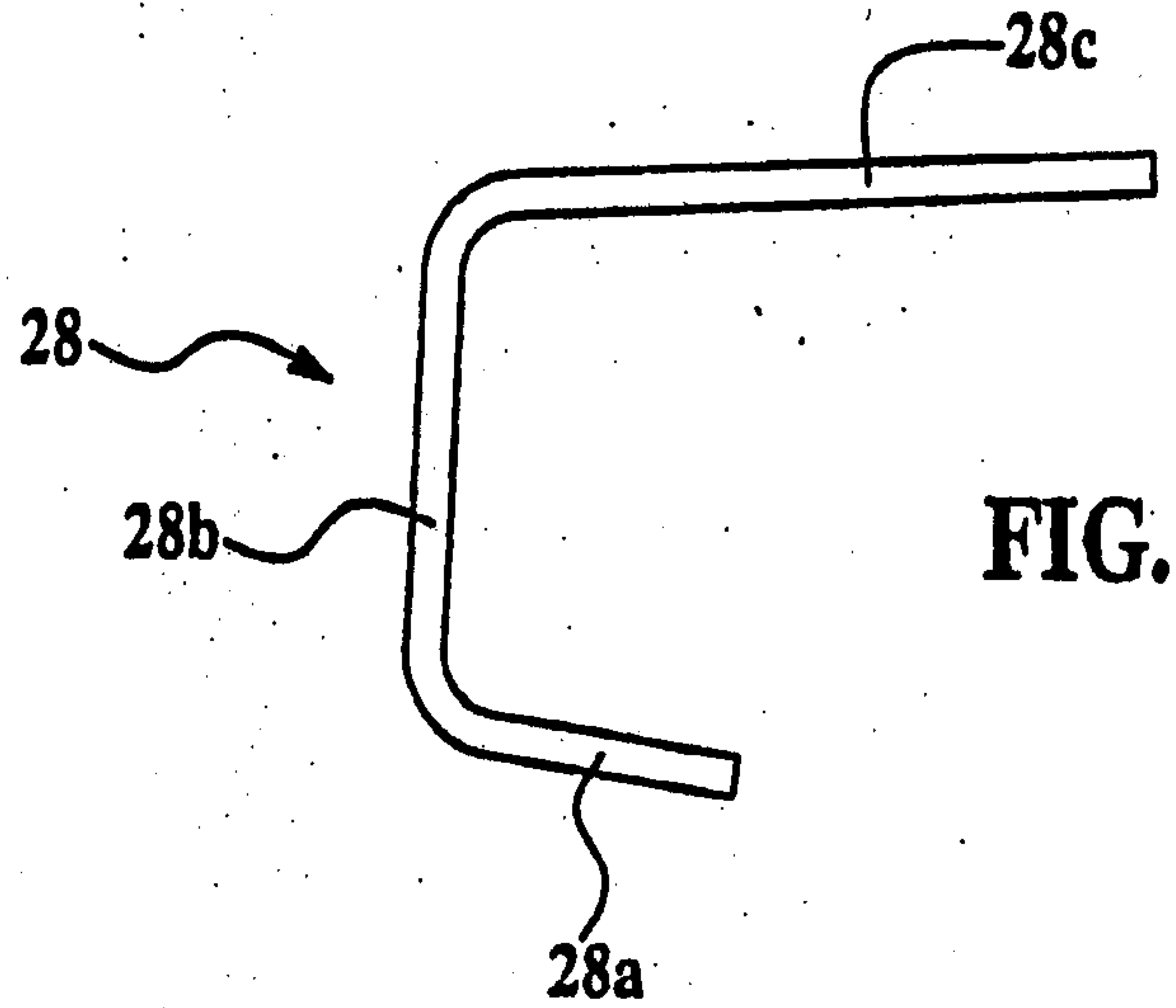


FIG. 5

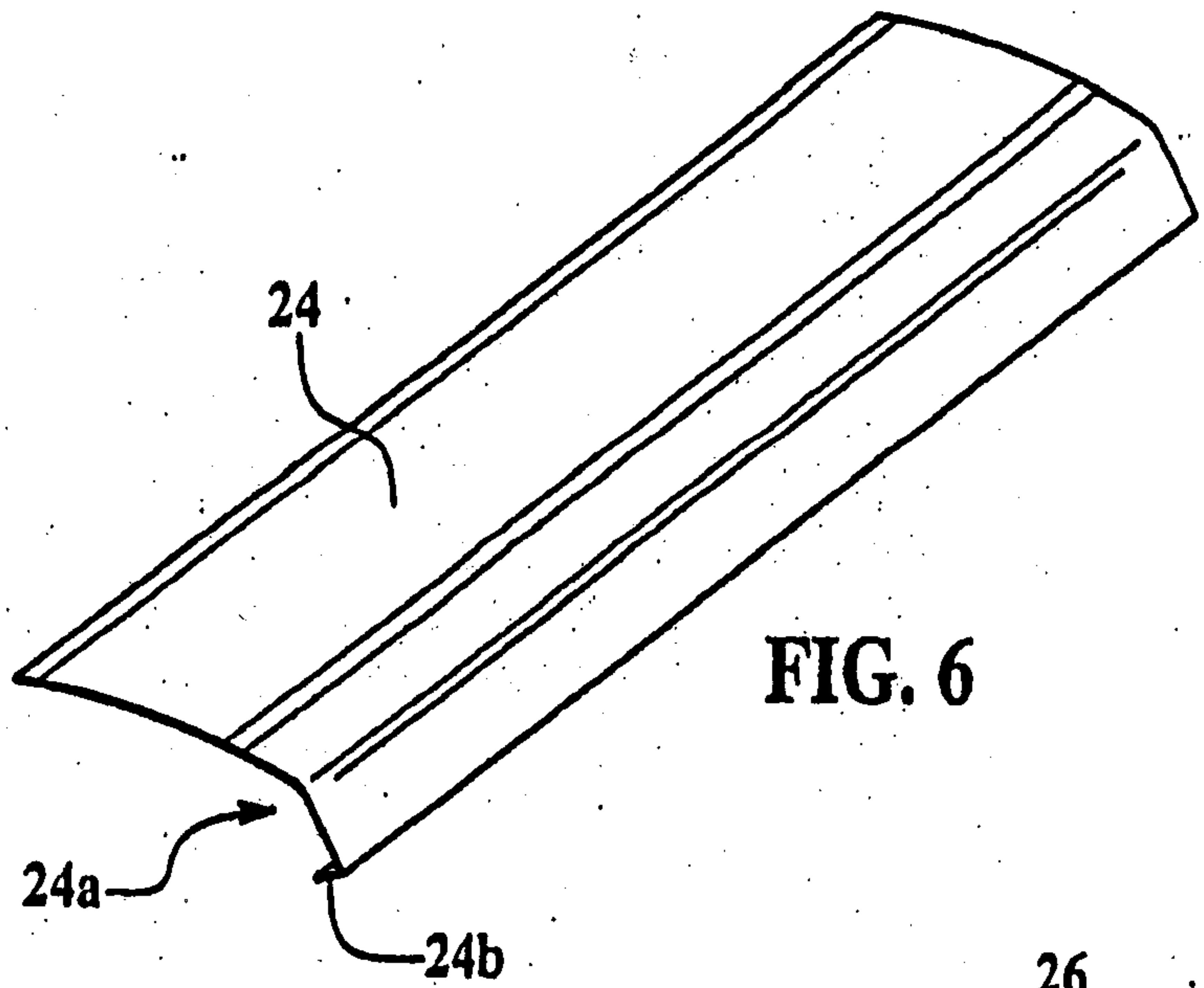


FIG. 6

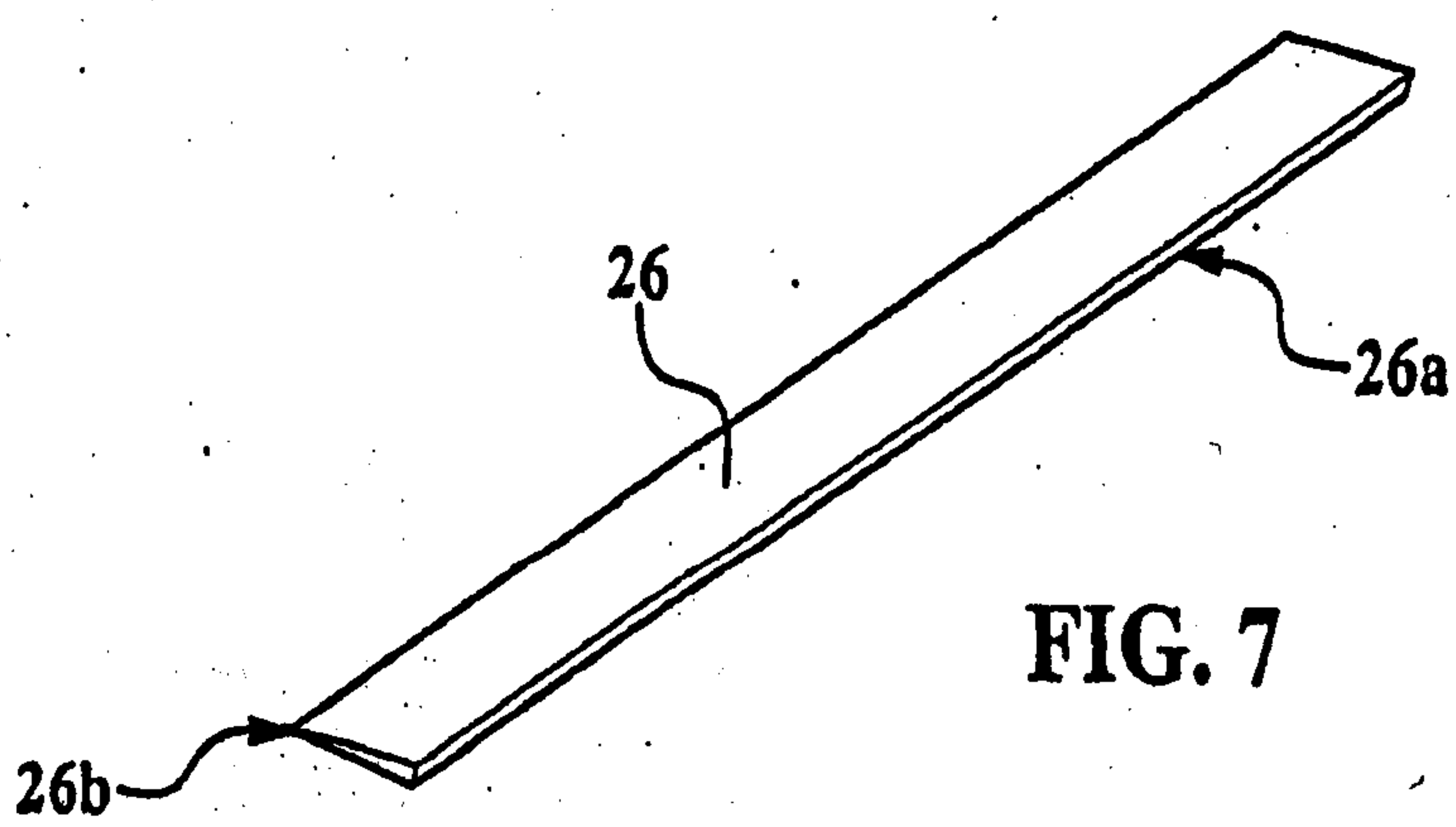


FIG. 7

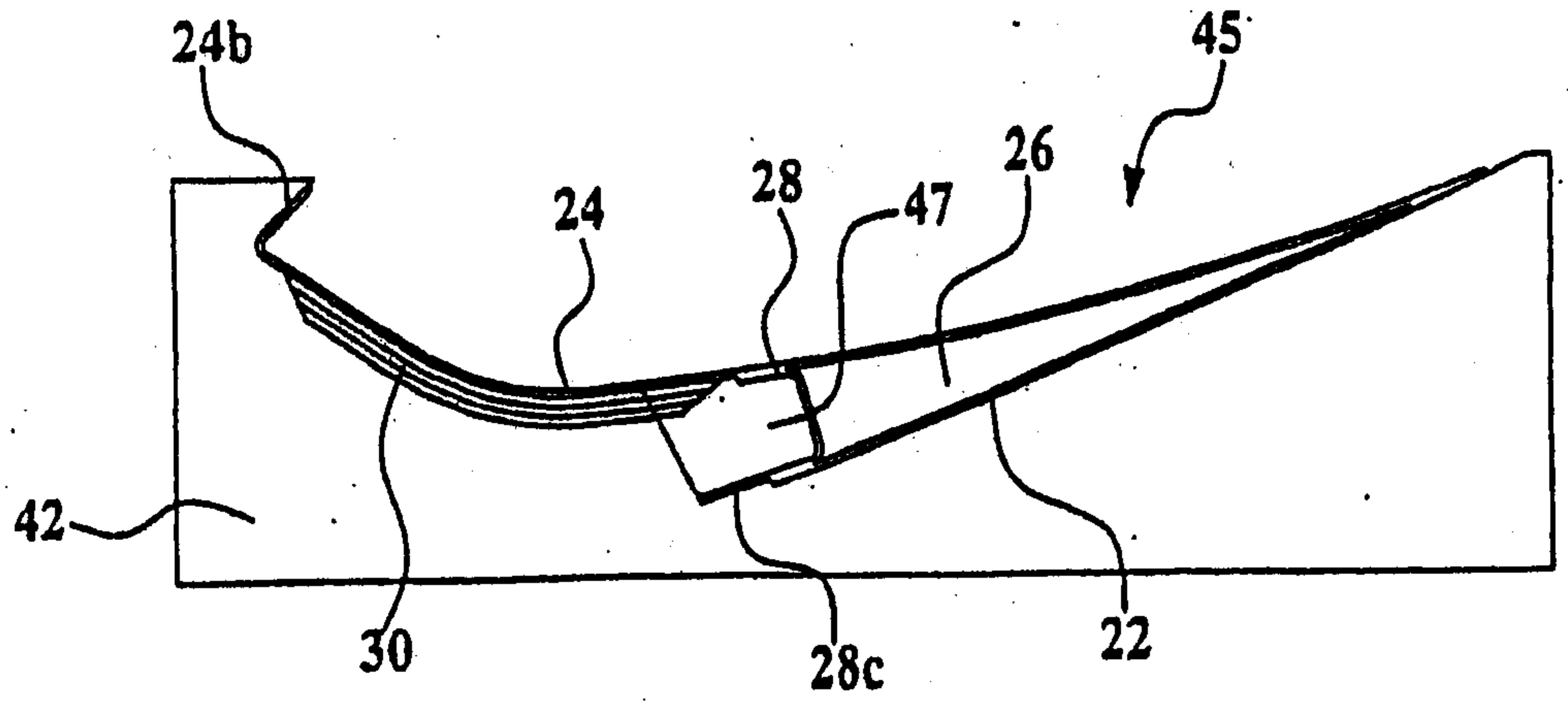


FIG. 8

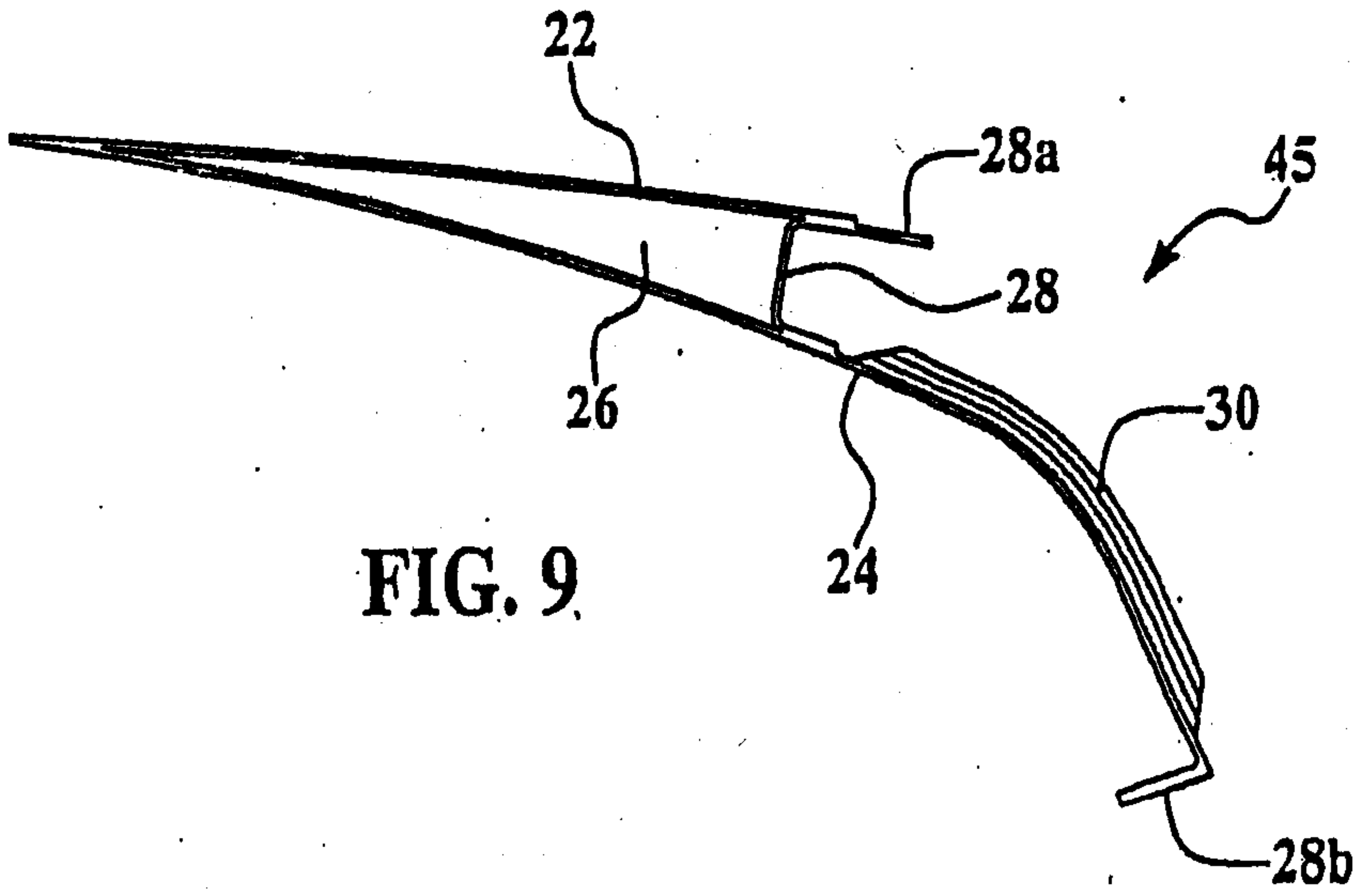


FIG. 9

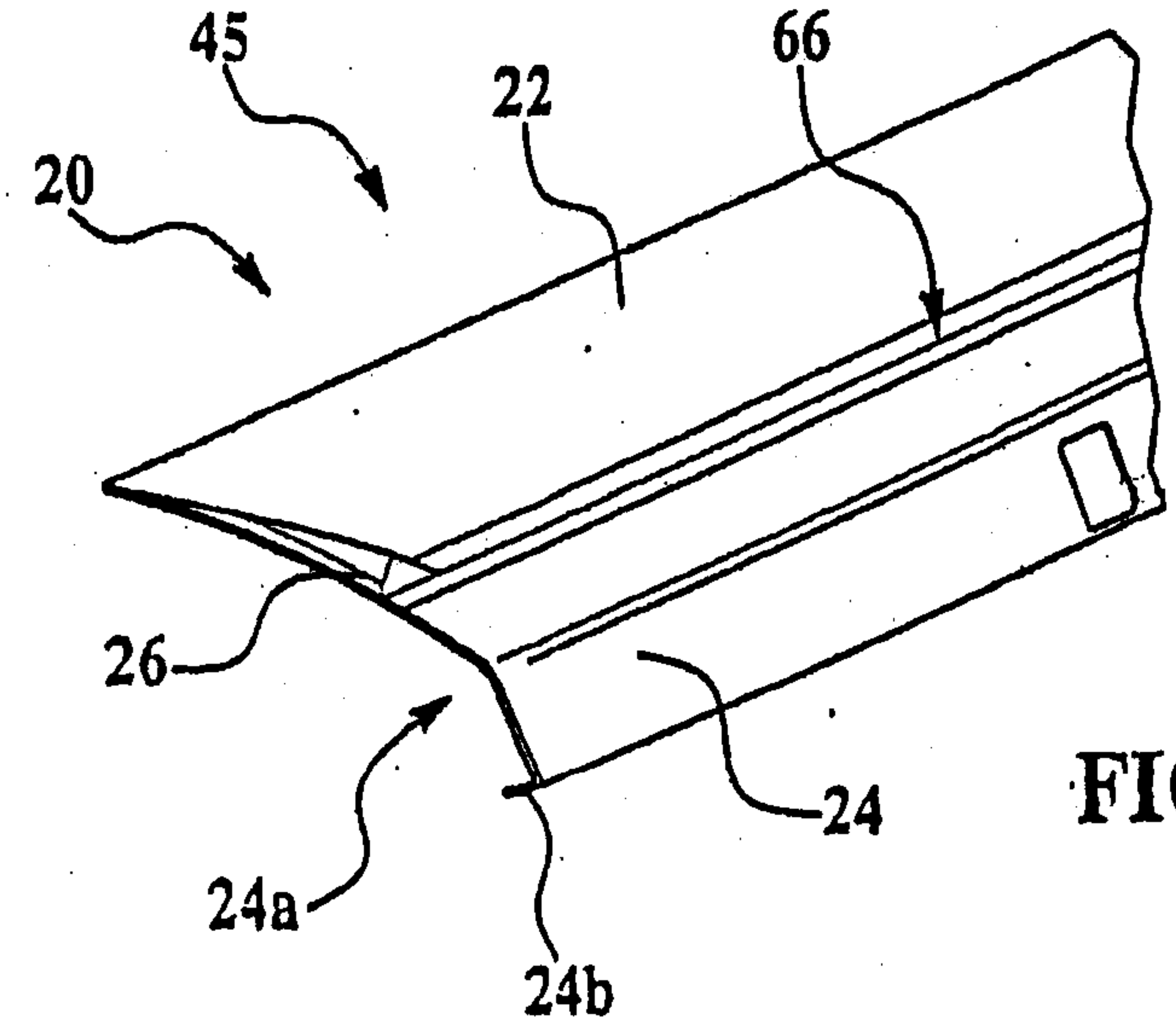


FIG. 10

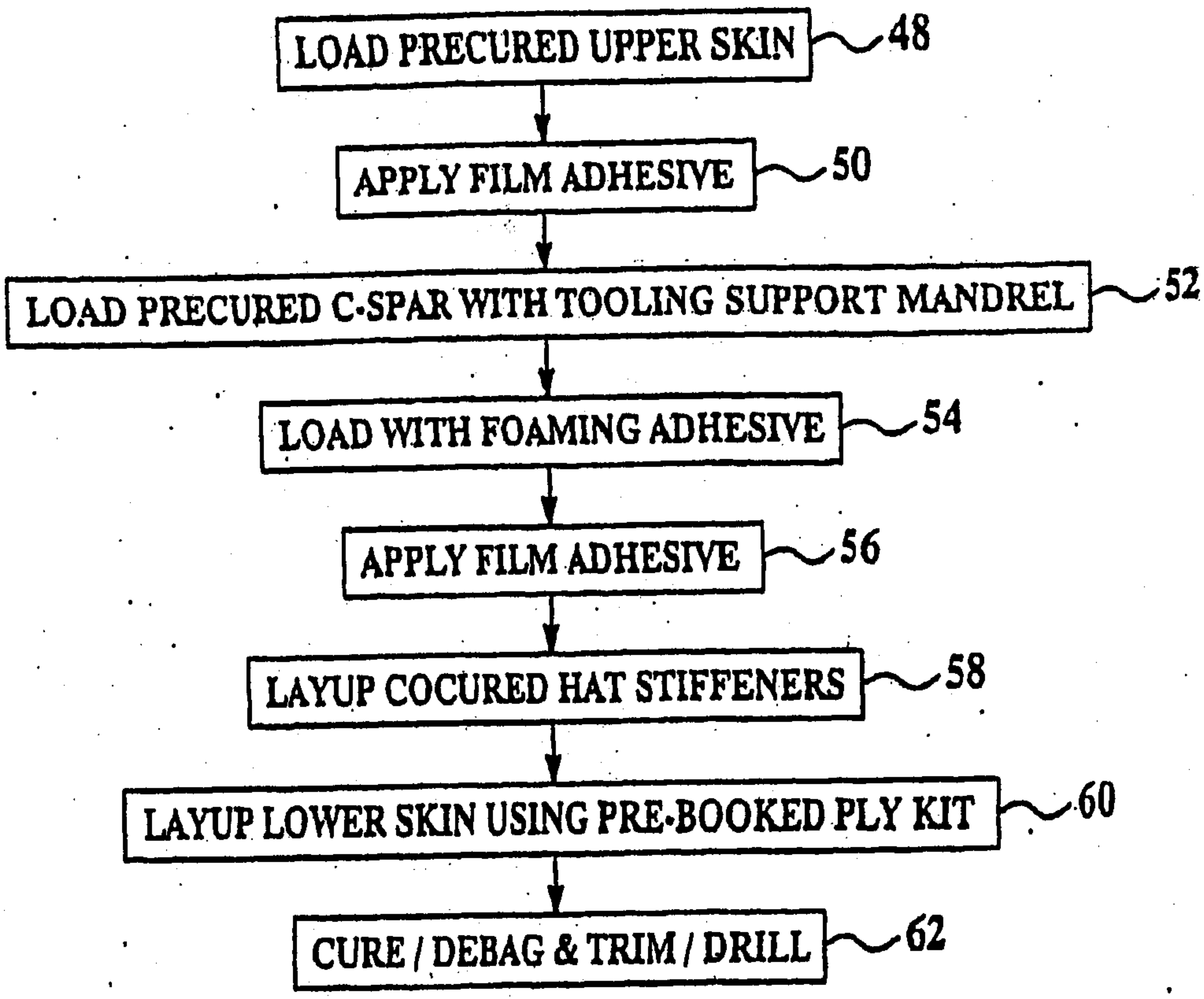


FIG. 11

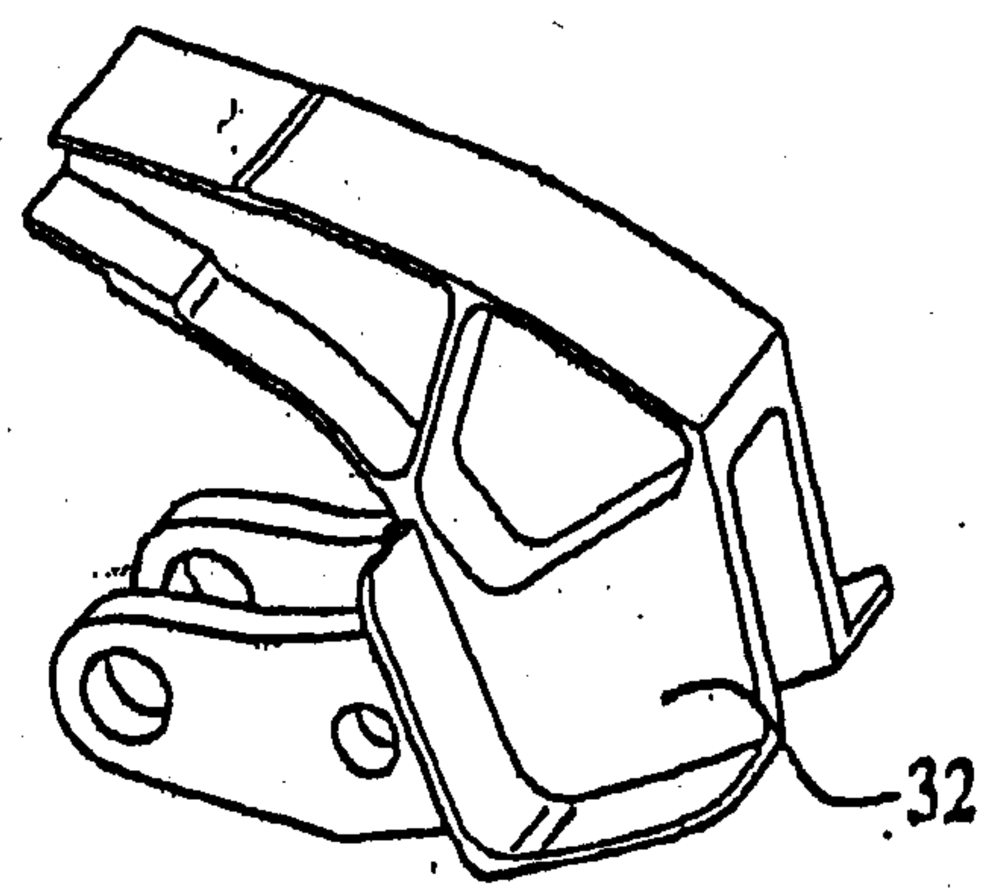


FIG. 12

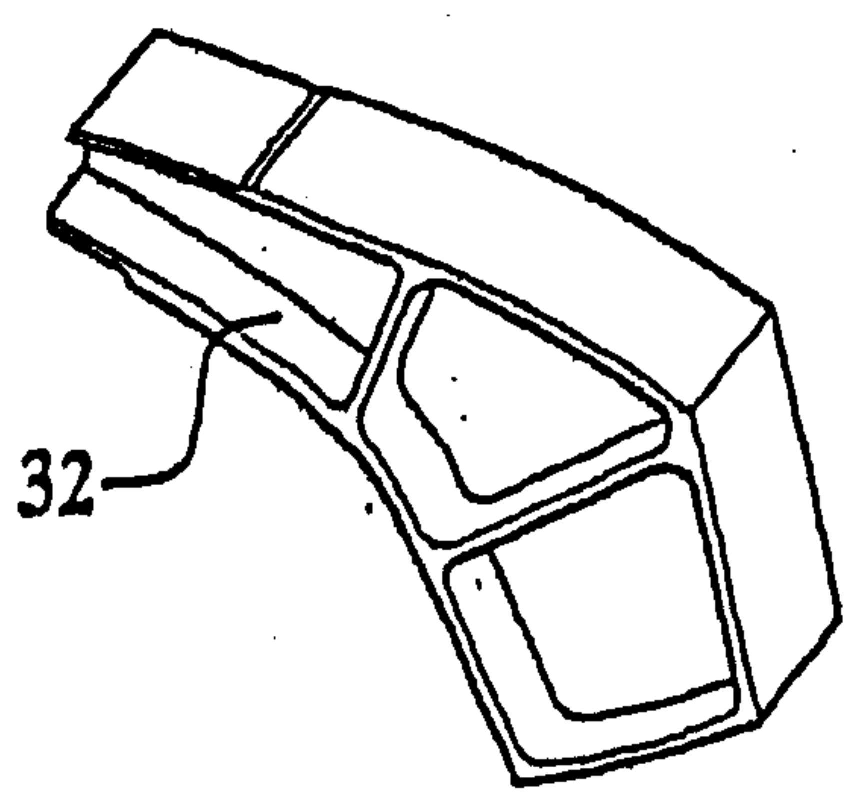


FIG. 13

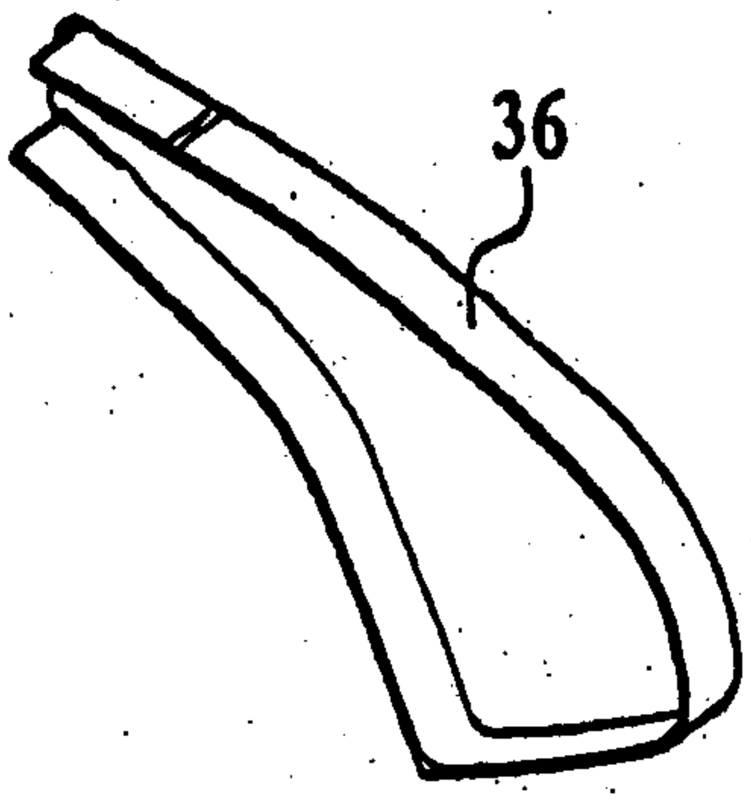


FIG. 14

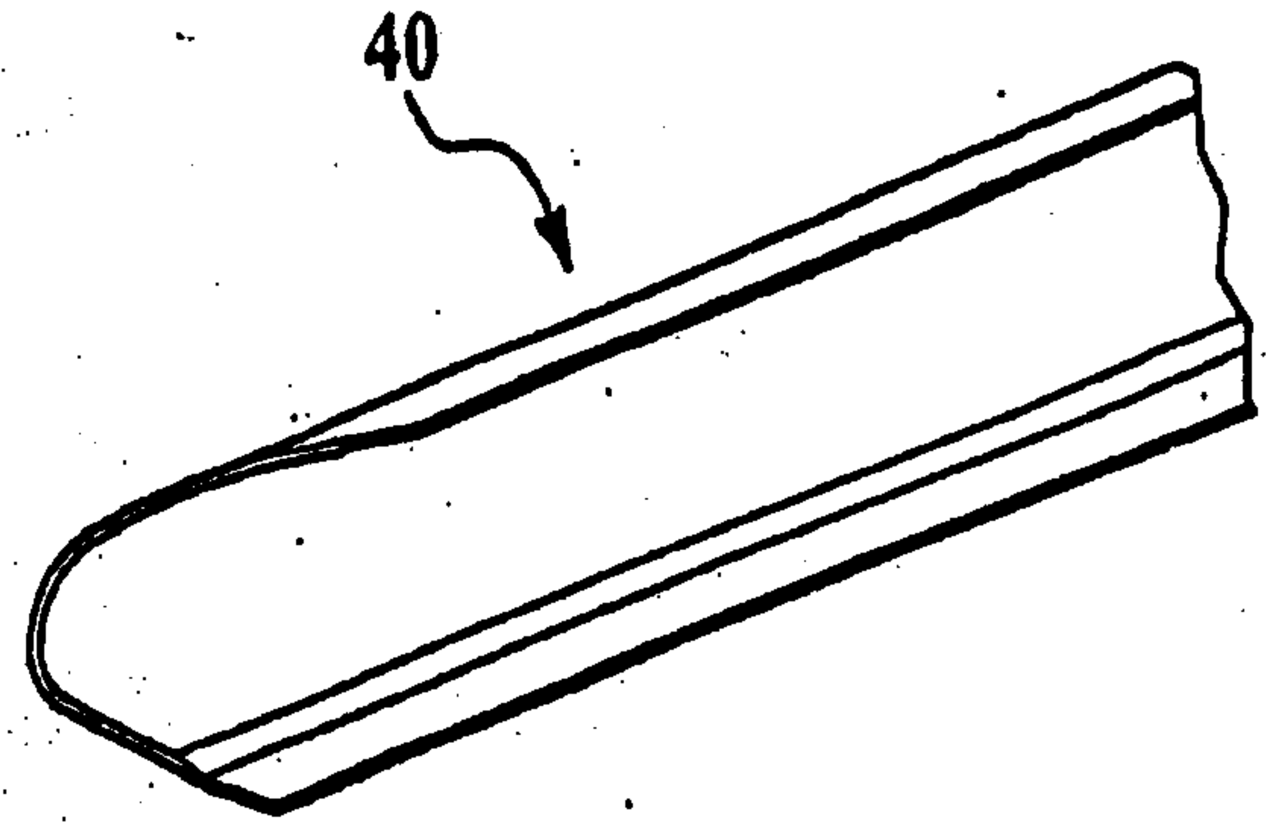


FIG. 15

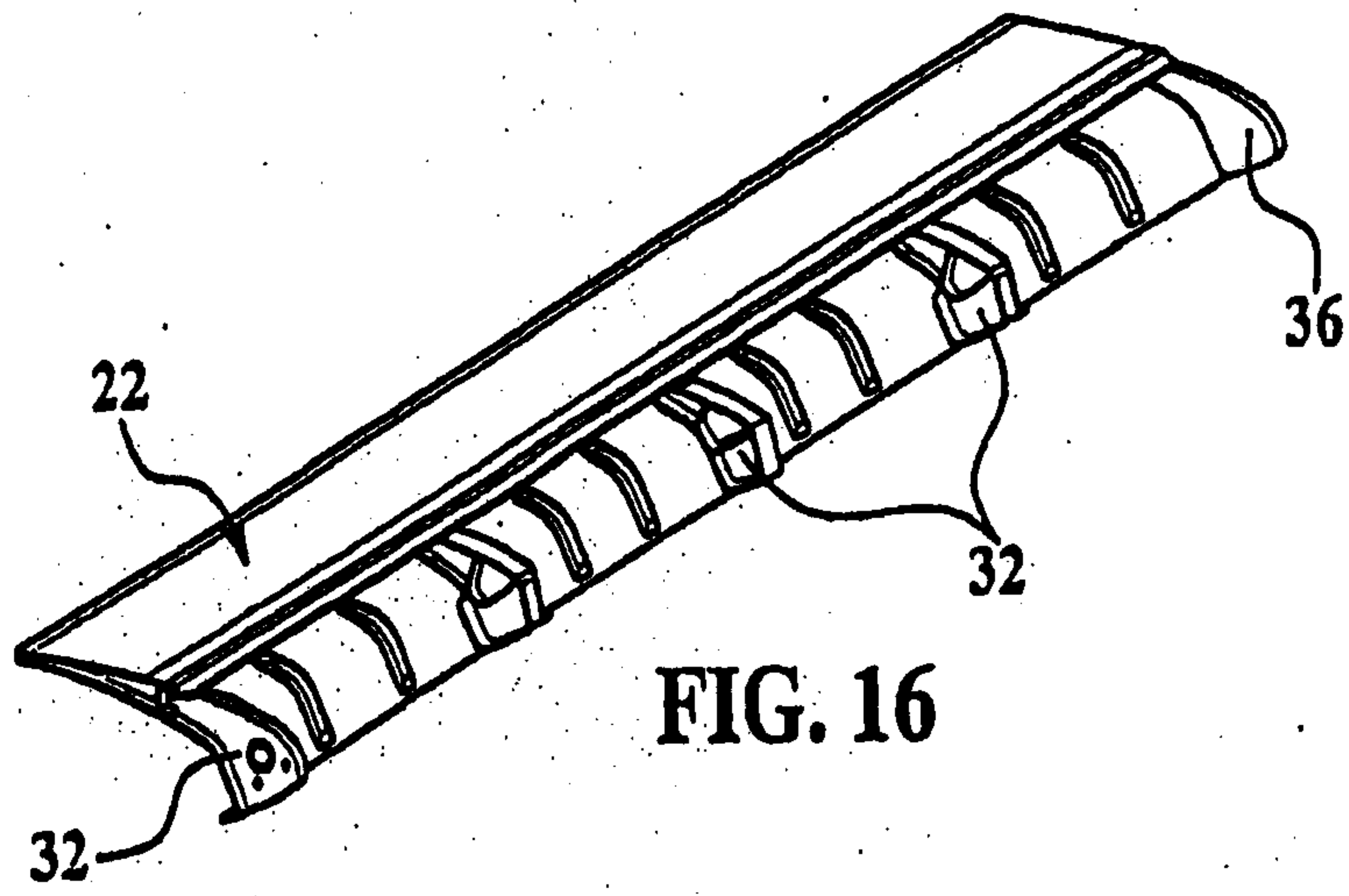


FIG. 16

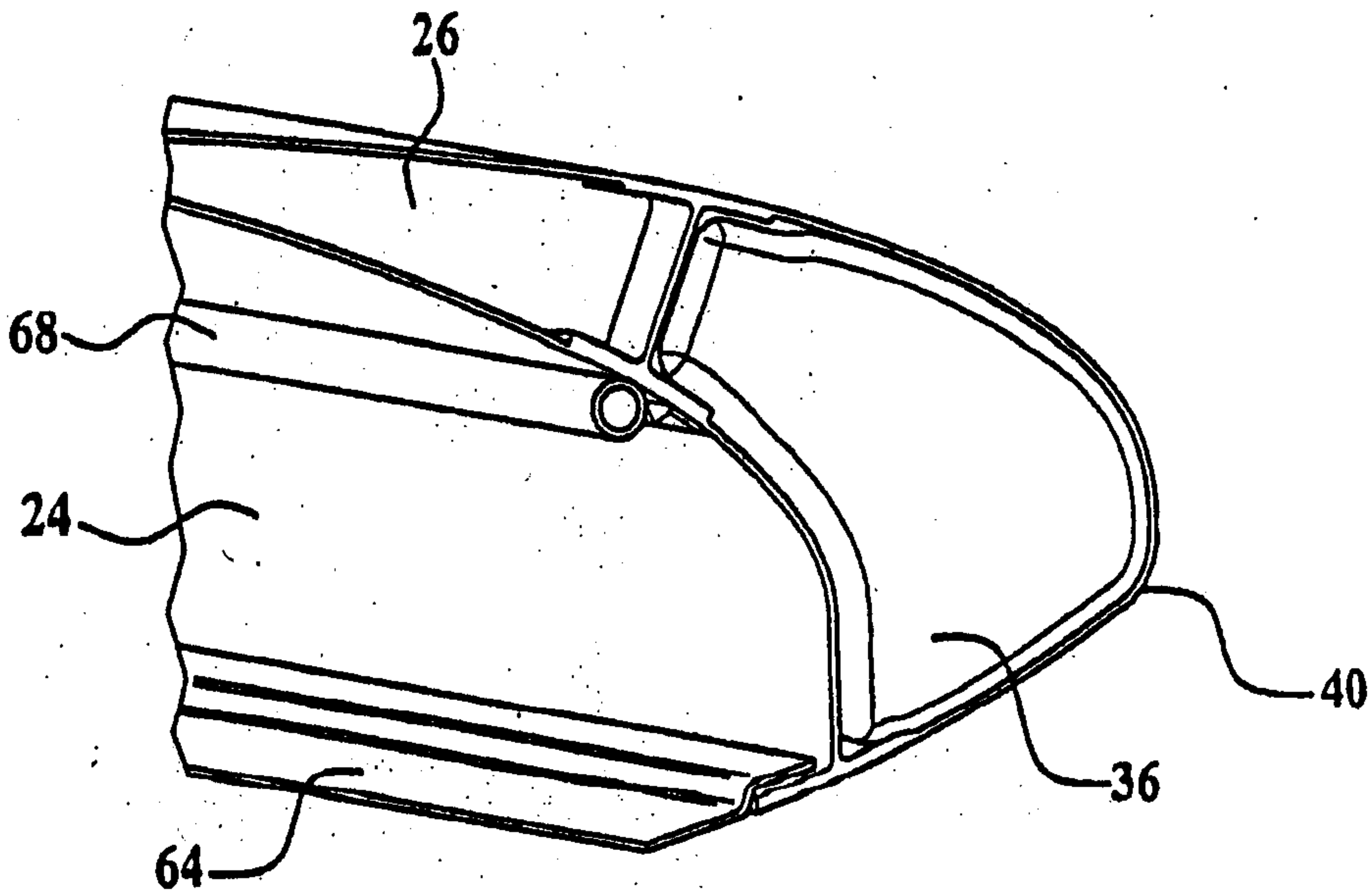
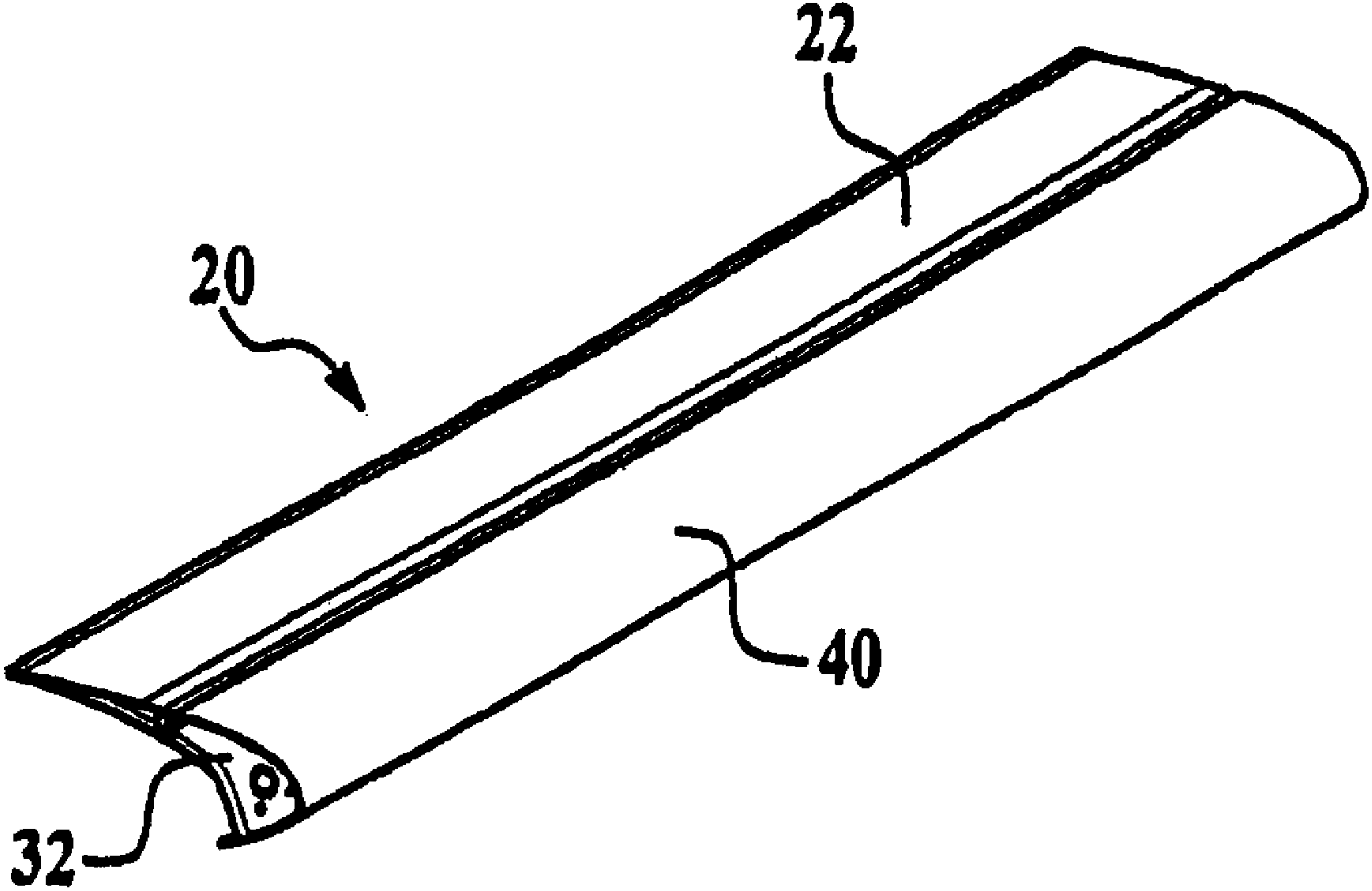


FIG. 17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