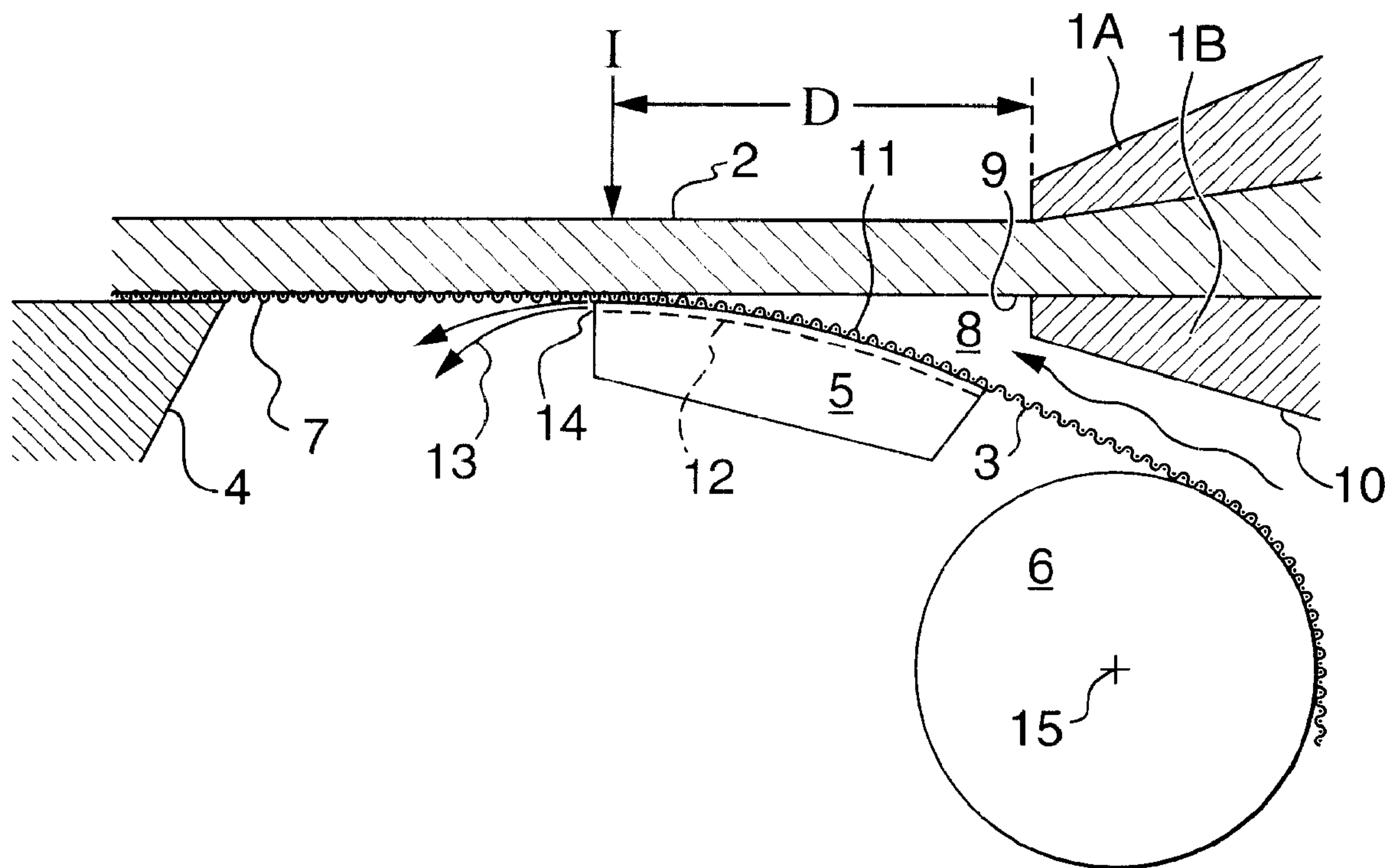




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(54) Titre : LAME MAITRESSE VENTILEE  
 (54) Title: VENTED LEAD BLADE



(57) **Abrégé/Abstract:**

A vented lead blade to be located in a papermaking machine so that the stock jet impinges the forming fabric at, or near to, its trailing edge, serves to bend the forming fabric before it enters the forming section, has grooves to vent a substantial proportion of any air trapped in the wedge shaped space between the surface of the forming fabric and the surface of the stock jet, and at least some of any liquid carried with the air. The vented lead blade enables the forming fabric to be positioned so that the angle of impingement of the stock jet onto the forming fabric can be minimized to substantially zero; facilitates reduction of the unsupported length of the stock jet; and can be used in an open surface forming section with a single forming fabric, or in the forming section of a two fabric papermaking machine.

ABSTRACT

A vented lead blade to be located in a papermaking machine so that the stock jet impinges the forming fabric at, or near to, its trailing edge, serves to bend the forming fabric before it enters the forming section, has grooves to vent a substantial proportion of any air trapped in the wedge shaped space between the surface of the forming fabric and the surface of the stock jet, and at least some of any liquid carried with the air. The vented lead blade enables the forming fabric to be positioned so that the angle of impingement of the stock jet onto the forming fabric can be minimized to substantially zero; facilitates reduction of the unsupported length of the stock jet; and can be used in an open surface forming section with a single forming fabric, or in the forming section of a two fabric papermaking machine.

1007-374

**VENTED LEAD BLADE****Field of the Invention**

This invention concerns a vented lead blade for use in a paper making machine.

**Background of the Invention**

In the initial portion of the forming section of either a single or two fabric papermaking machine, an unsupported jet of highly aqueous stock is ejected from the head box slice onto the surface of a moving forming fabric. The unsupported jet will typically traverse a distance of from about 6 cm to about 40 cm before impinging the surface of the forming fabric at the point of impingement. The angle of impingement,  $\alpha$ , formed between the stock jet and the plane of the forming fabric at the point of impingement will typically be from about  $4^{\circ}$  to about  $10^{\circ}$ . It is well known that improved paper formation can be obtained by minimizing both the angle  $\alpha$  and the length of the unsupported free jet.

As the angle  $\alpha$  increases, the magnitude of the pressure exerted by the jet on the surface of the forming fabric also increases.

For a forming fabric moving at a speed of 20 m/sec and a jet of pure water, the impingement pressure  $I$  in kPa can be shown to be given by the following relationship:

$$I = 200 \sin \alpha.$$

Typical peak impingement pressures for different values of the angle  $\alpha$  are shown in Table 1.

TABLE 1: Peak Impingement Pressure

<u>Angle of Impingement, <math>\alpha^\circ</math></u>	<u>Pressure (I, kPa)</u>
1	3.49
2	6.98
4	13.95
6	20.90
8	27.83
10	34.73

Impingement angles greater than about  $5^\circ$  will create peak impingement pressures that may cause sheet marking, low retention of paper making fines and fillers, and plugging of the forming fabric. Therefore, the angle  $\alpha$  should be made as small as possible so that, ideally, the unsupported stock jet impinges on the fabric substantially tangentially.

As the length of the stock jet increases, its outside surface begins to break up into ridges and furrows, which will eventually cause sheet basis weight variations. Further, finely dispersed fibers in the stock start to reflocculate rapidly in the unsupported jet prior to the point of impingement. Therefore, the unsupported stock jet should be made as short as possible to minimize these effects.

Due to the competing space requirements of both the head box slice lip structure and the adjacent upstream rolls such as a breast roll, it is difficult to shorten the unsupported stock jet length without increasing the angle  $\alpha$ . Even if the head box slice lips can be located so that the angle  $\alpha$  is very small, and the free jet is nearly tangential to the forming fabric, air that is trapped in the small wedge shaped space between the surface of the forming fabric and the surface of the unsupported stock jet

becomes entrained into the stock forming bubbles which are detrimental to sheet formation.

Several proposals have been made to overcome these difficulties. Nelson et al, US 3,440,136 discloses a method of avoiding air entrainment by evacuating the air from the forming zone, and flooding this area with water. However this proposal has been found to be difficult to realize in practice. Irwin et al., US 4,734,164, disclose a forming board for a single fabric machine in which the first blade is slightly curved to permit the breast roll to be lowered slightly. The difficulty with this proposal is that air is trapped in the shallow wedge space between the jet and the forming fabric as it passes over the curved first blade. This air is forced into the stock as bubbles which cause formation defects. Malashenko, US 4,802,954, discloses a lead-in blade located ahead of the curved blade element proposed by Irwin et al., which is said to reduce the amount of fluid pumped by the forming fabric into the wedge shaped space between the jet and the fabric. However, a small wedge shaped air space remains. The pressure in this space is controlled by a vacuum pump to reduce the jet disturbance. Ewald in US 5,084,138 addresses the problem of excessive free jet length by using curved turning bars to replace large diameter breast rolls and a solid curved blade, but does not avoid air entrapment at the wedge between the jet and the fabric.

The present invention seeks to provide a lead blade for use in the forming shoe or forming board of a high speed paper making machine which will eliminate or at least substantially reduce all of the aforementioned deficiencies of the prior art by means of a construction and arrangement which at least in part adopts these recommendations.

**Summary of the Invention**

This invention seeks to provide a vented lead blade for use downstream of the breast roll, between the breast roll and the fabric supporting elements in the forming section, and located so that the stock jet impinges the forming fabric at, or near to, its trailing edge. The vented lead blade does two things. First, it serves to bend the forming fabric before it enters the forming section. Second, it serves to vent at least a substantial proportion of any air which becomes trapped in the wedge shaped space between the surface of the forming fabric and the surface of the stock jet. The vented lead blade of this invention thus enables the forming fabric to be positioned so that the angle  $\alpha$  can be minimized, and, if desired, by allowing the breast roll to be repositioned to create space into which the head box can be moved, thus reducing the unsupported length of the stock jet. The vented lead blade of this invention can be used in both an open surface forming section with one forming fabric, or in the forming zone of a two fabric paper making machine.

Thus in a first broad embodiment this invention seeks to provide a curved vented lead blade for use in a paper making machine upstream of, and immediately adjacent to, the point of impingement of a stock jet ejected from a head box slice onto a moving forming fabric carrying an amount of liquid, which lead blade has a leading edge, a shaped trailing edge portion, including a trailing edge, and a convexly curved surface located between the leading edge and the trailing edge portion, over which the forming fabric moves in sliding contact and wraps through an angle of wrap  $\theta$ , the convexly curved surface and the trailing edge portion including a plurality of grooves which begin at the leading edge and end at the trailing edge

constructed and arranged to vent at the lead blade trailing edge at least a substantial proportion of any air trapped in the forming fabric from a wedge shaped space between the stock jet and the forming fabric surface, and at least some of the liquid carried by the forming fabric.

In a second broad embodiment this invention seeks to provide a papermaking machine, having a machine direction and a cross machine direction, which includes:

a forming fabric moving in the machine direction;

a head box including a head box slice which provides a jet of paper making stock which impinges at an angle of impingement onto the forming fabric at a point of impingement;

a roll, having a cylindrical surface whose axis is in the cross machine direction, about which the forming fabric passes, and which is located upstream of the head box slice;

a forming section, located downstream of the point of impingement, including static support elements which define a fabric path through which the forming fabric passes; and

a vented lead blade, located upstream of, and immediately adjacent to, the point of impingement of a stock jet ejected from a head box slice onto a moving forming fabric, about which a forming fabric wraps through a wrap angle  $\theta$ ;

wherein the vented lead blade has a leading edge, a shaped trailing edge portion including a trailing edge and a convexly curved surface, located between the leading edge and the trailing edge portion, over which the forming fabric moves in sliding contact and wraps through an angle of wrap  $\theta$ , the convexly curved surface and the trailing edge portion including a plurality of grooves which begin at the leading edge and end at the trailing edge constructed and arranged to vent at the lead blade trailing edge at least a substantial proportion of any air trapped in the

forming fabric from a wedge shaped space between the stock jet and the lead blade curved surface, and at least some of the liquid carried by the forming fabric.

In a third broad embodiment this invention seeks to provide a papermaking machine, having a machine direction and a cross machine direction, which includes:

a first and a second forming fabric each moving in the machine direction;

a head box including a head box slice which provides a jet of paper making stock which impinges at an angle of impingement onto at least one of the forming fabrics at a point of impingement;

two rolls, each having a cylindrical surface whose axis is in the cross machine direction, about each of which one of the forming fabric passes, and which are located adjacent the head box slice;

a forming section, located downstream of the point of impingement, including static support elements which define a fabric path through which the forming fabric passes; and

two vented lead blades, each located upstream of, and immediately adjacent to, the point of impingement of the stock jet, about the first of which the first forming fabric wraps through a wrap angle  $\theta_1$ , and about the second of which the second forming fabric wraps through a wrap angle  $\theta_2$ ;

wherein each vented lead blade has a leading edge, a shaped trailing edge portion including a trailing edge and a convexly curved surface, located between the leading edge and the trailing edge portion, over which the forming fabric moves in sliding contact and wraps through an angle of wrap, the convexly curved surface and the trailing edge portion including a plurality of grooves which begin at the leading edge and end at the trailing

edge constructed and arranged to vent at the lead blade trailing edge at least a substantial proportion of any air trapped in the forming fabric from a wedge shaped space between the stock jet and the lead blade curved surface, and at least some of the liquid carried by the forming fabric.

Preferably, the convexly curved surface is essentially circular, with a constant radius. More preferably, the shaped trailing edge portion conforms to the convexly curved surface. Alternatively, the convexly curved surface is not circular, and the radius of curvature increases towards the trailing edge. Conveniently, the convexly curved surface is not circular, the radius of curvature increases towards the trailing edge, and the shaped trailing edge portion is essentially flat.

Preferably, the convexly curved surface has an effective radius of curvature that is from about 50% to about 100% of the radius of the adjacent upstream roll. The radius of curvature will not generally be greater than that of the adjacent upstream roll.

Preferably, the angle  $\theta$ ,  $\theta_1$  or  $\theta_2$  through which the forming fabric wraps the lead blade is from about  $10^\circ$  to about  $40^\circ$ . More preferably, the angle of wrap is from about  $15^\circ$  to about  $30^\circ$ . Most preferably, the angle of wrap is from about  $20^\circ$  to about  $25^\circ$ .

Preferably, in a paper making machine having two forming fabrics, the two vented lead blades are the same, and their convexly curved surfaces are the same shape. Alternatively, in a paper making machine having two forming fabrics, the two vented lead blades are not the same, and their convexly curved surfaces are not the same shape.

Preferably, in a paper making machine having two forming fabrics, the two vented lead blades are the same, the angles  $\theta_1$  and  $\theta_2$  are the same, and their convexly curved surfaces are the same shape. Alternatively, in a paper making machine having two forming fabrics, the two vented lead blades are not the same, the angles  $\theta_1$  and  $\theta_2$  are not the same, and their convexly curved surfaces are not the same shape.

The invention will now be described with reference to the attached schematic drawings in which:

Figure 1 shows part of an open surface paper making machine including a vented lead blade;

Figures 2 and 3 show parts of two different twin fabric paper making machines;

Figures 4, 5 and 6 show the effects of wrap angle and vented lead blade effective radius;

Figures 7, 8 and 9 show three different groove arrangements for the vented lead blade top surface; and

Figure 10 shows four different groove shapes.

In Figures 1 - 6 only the parts of the paper making machine required for an understanding of this invention are shown.

Figure 1 shows a paper making machine which includes a vented lead blade according to the teachings of this invention. The slice lips 1A and 1B of the head box deliver a jet of stock 2 onto the forming fabric 3 at the impingement point I. The forming fabric 3 passes around the roll 6, wraps the vented lead blade 5, and then passes over the first static support element 4 in the forming section. As the moving forming fabric 3 and the stock jet 2 converge, air 8 in the wedge shaped space between the surface of the stock jet 9, the surface 10 of the head box lip

1B, and the surface of the forming fabric 11 becomes trapped and enters the forming fabric 3. This air, together with some of the liquid in the forming fabric at this point, passes through the forming fabric 3 into the grooves 12 in the top surface of the vented lead blade 5.

In this arrangement, since the axis 15 of the roll 6 is now located out of the fabric path 7, and since the vented lead blade 5 occupies far less space than the roll, it is possible to maintain the angle of impingement close to zero, and to shorten the unsupported length D of the stock jet 2 significantly. Further, since the trailing edge 14 of the vented lead blade 5 is closely adjacent the impingement point I, the trapped air is prevented from interfering in the formation process within the stock in the forming section. The grooves 12 are located and dimensioned so that at least a substantial proportion, and preferably all, of the air passing through the forming fabric, together with any liquid carried with the air from the liquid on the forming fabric at this point, is vented as at 13 from the vented lead blade at its trailing edge 14.

Figures 2 and 3 show a paper making machine which has two forming fabrics, and which incorporates two vented lead blades according to the teachings of this invention. In describing these two Figures the terms "upper" and "lower" refer only to the orientation shown: in practice in a twin fabric machine the forming section is often oriented vertically, or at some angle thereto.

Referring first to Figure 2, the slice lips 1A and 1B deliver a jet of stock 2 onto the lower forming fabric 31 at the impingement point I. The forming fabric 31 wraps the lower

vented lead blade 51. As the moving forming fabric 31 and the stock jet 2 converge, air 81 in the wedge shaped space between the surface of the stock jet 91, the surface 101 of the head box lip 1B, and the surface of the forming fabric 111 becomes trapped and enters the forming fabric 31. This air 81, together with some of the liquid in the forming fabric 31 at this point, passes through the forming fabric 31 into the grooves 121 in the lower vented lead blade 51. The accumulated air and liquid 131 is vented from the lower vented lead blade 51 at its trailing edge 141. The construction as regards the lower forming fabric 51 is thus essentially the same as Figure 1. Downstream of the impingement point I a second forming fabric 32 converges with the upper side 92 of the stock 2 on the lower forming fabric 31. Further air is trapped in the space 82 between the lower face 112 of the upper forming fabric 32 and the surface 92 of the stock 2. This additional air, and some of the liquid in the forming fabric 52, passes through the forming fabric 52 into the grooves 122 and is vented at the trailing edge 142 of the upper vented lead blade 52.

Figure 3 shows an alternative arrangement to that of Figure 2. The arrangement of the lower forming fabric 31 is the same. The upper forming fabric 32 converges with the stock jet 2 at the same point as the lower forming fabric 31, more or less at the impingement point I. For the upper forming fabric air is now trapped in the space bounded by the upper surface 92 of the stock jet, the lower surface 112 of the upper forming fabric 32, and the upper surface 102 of the head box lip 1A. All of the trapped air, together with some of the liquid in the two forming fabrics, is vented through the grooves 121, 122 at the trailing edges 141, 142 of the two vented lead blades 51, 52.

In both of these twin fabric machines, the two vented lead blades will often be the same, and have the same convexly curved shape. However in some circumstances it may be desirable to use two different vented lead blades, which may have different convexly curved shapes. It is also then possible that the two wrap angles  $\theta_1$  and  $\theta_2$  will likely be similar, they may not be the same.

Figures 4, 5 and 6 show the relationship between the angle  $\theta$  through which the forming fabric 3 wraps about a vented lead blade, the effective radius of curvature of the vented lead blade, and the radius of the adjacent upstream roll. Each of these Figures uses the same numbers as Figure 1, and thus considers a single fabric machine. Similar considerations apply to a twin fabric machine.

In each of these Figures, the convexly curved surface 16 of the vented lead blade 5 has a constant radius, the forming fabric 3 is received tangentially from the adjacent upstream roll 6, and the impingement point I is adjacent the trailing edge 14 of the vented lead blade 5. These three Figures are also shown to essentially the same scale.

In Figure 4, the radius  $R_4$  of the vented lead blade surface 16 is the same as the radius  $R_1$  of the roll 6, which is some distance from the head box slice lips 1A, 1B. The vented lead blade 5 then has to be relatively wide in order to bend the forming fabric 3 into the forming path 7. If  $R_1$  and  $R_4$  are both approximately 46 cm, the angle of wrap  $\theta_4$  is about  $18^\circ$ . This large radius also implies that the length  $D_4$  of the unsupported stock jet 2 cannot be shortened very much.

In Figure 5, the radius  $R_5$  of the vented lead blade surface 16 is smaller than the radius  $R_1$  of the roll 6, which is still some distance from the head box slice lips 1A, 1B. The vented lead blade 5 then still has to be relatively wide in order to bend the forming fabric 3 into the forming path 7. If  $R_1$  is approximately 46 cm, and  $R_5$  is approximately 23 cm, the angle of wrap  $\theta_5$  is about  $36^\circ$ . This smaller radius  $R_5$  allows the length  $D_5$  of the unsupported stock jet 2 to be shortened.

In Figure 6, the radius  $R_6$  of the vented lead blade surface 16 is smaller than the radius  $R_1$  of the roll 6, which is now closer to the head box slice lips 1A, 1B. The vented lead blade 5 is much narrower in order to bend the forming fabric 3 into the forming path 7. If  $R_1$  is approximately 46 cm, and  $R_6$  is approximately 23 cm, the angle of wrap  $\theta_6$  is about  $18^\circ$ . This smaller radius  $R_5$  allows the length  $D_6$  of the unsupported stock jet 2 to be shortened still further.

It can thus be seen that the vented lead blade of this invention provides considerable flexibility in the geometry of the machine wet end.

The curved surface of the lead in blade is vented by means of grooves which begin at the extreme upstream edge of the blade and are continuous to its downstream edge. Three groove arrangements are shown in Figures 7, 8 and 9. In each Figure, the forming fabric moves in the direction of the arrow A. In Figure 7, the grooves 17 are regularly spaced the same distance apart, and are essentially parallel to the arrow A. The disadvantage with this arrangement is that there is some risk of the forming fabric tracking across the blade. This is avoided in Figure 8, where although the grooves 18 are still regular and

parallel, they are at an angle  $\beta$  to the arrow A. Alternatively, two sets of angled grooves 18A, 18B can be used as shown in Figure 9. Within each set, the grooves are parallel to each other and regularly spaced, and each set is at an angle  $\beta$  to the arrow A. Typically, the angle  $\beta$  in Figures 8 and 9 will be from about  $2^\circ$  to about  $30^\circ$ .

The purpose of the grooves in the vented lead blade surface is to provide spaces through which at least a substantial proportion of the air is vented which enters the forming fabric from the wedge shaped space essentially between the forming fabric and the jet surface. At the same time, at least some of the liquid in the forming fabric as it enters the forming section will also be vented.

Figure 10 shows four possible groove structures for this purpose. For simplicity, the blade surface 17 has been shown flat; in practice it will be curved. Groove 19 is of constant width for its entire length from the leading edge 17A to the trailing edge 17B. As the fabric passes over the vented lead blade surface 17, air is continuously entering the forming fabric. It is thus often advantageous to use a groove with an increasing cross section, such as the groove 20 which widens, or the groove 21 which deepens, or the groove 22 which both widens and deepens, in each case from the leading edge 17A to the trailing edge 17B. Typically, the grooves 19, 20, 21 and 22 are from 2 - 8 mm in width, and 1 - 8 mm in depth.

In operation, the forming fabric moves in sliding contact as it wraps the vented lead blade. At the point of contact of the forming fabric with the upstream leading edge of the lead blade, for example at 17A in Figure 10, the fabric may form a small

contact angle that is ideally  $0.5^\circ$  or less. It is preferred that the forming fabric is tangential to the vented lead blade surface at this point. The leading edge of the blade can be curved to minimize any frictional effects at this point; a suitable edge radius is from about 0.0025 mm to about 0.0065 mm. The forming fabric should exit the vented lead blade tangentially to the trailing edge portion of the blade surface, substantially in the path defined by the downstream fabric support elements. The downstream path of the forming fabric should be parallel to and in the same plane as the underside of the stock jet, so that the angle of impingement of the stock jet onto the forming fabric is substantially zero.

What Is Claimed Is:

1. A curved vented lead blade for use in a papermaking machine upstream of, and immediately adjacent to, the point of impingement of a stock jet ejected from a head box slice onto a moving forming fabric carrying an amount of liquid, which lead blade has a leading edge, a shaped trailing edge portion, including a trailing edge, and a convexly curved surface located between the leading edge and the trailing edge portion, over which the forming fabric moves in sliding contact and wraps through an angle of wrap  $\theta$ , the convexly curved surface and the trailing edge portion including a plurality of grooves which begin at the leading edge and end at the trailing edge constructed and arranged to vent at the lead blade trailing edge at least a substantial proportion of any air trapped in the forming fabric from a wedge shaped space between the stock jet and the forming fabric surface, and at least some of the liquid carried by the forming fabric.

2. A papermaking machine, having a machine direction and a cross machine direction, which includes:

a forming fabric moving in the machine direction;

a head box including a head box slice which provides a jet of paper making stock which impinges at an angle of impingement onto the forming fabric at a point of impingement;

a roll, having a cylindrical surface whose axis is in the cross machine direction, about which the forming fabric passes, and which is located upstream of the head box slice;

a forming section, located downstream of the point of impingement, including static support elements which define a fabric path through which the forming fabric passes; and

a vented lead blade, located upstream of, and immediately adjacent to, the point of impingement of a stock jet ejected from a head box slice onto a moving forming fabric, about which a forming fabric wraps through a wrap angle  $\theta$ ;

wherein the vented lead blade has a leading edge, a shaped trailing edge portion, including a trailing edge, and a convexly curved surface located between the leading edge and the trailing edge portion, over which the forming fabric moves in sliding contact and wraps through an angle of wrap  $\theta$ , the convexly curved surface and the trailing edge portion including a plurality of grooves which begin at the leading edge and end at the trailing edge constructed and arranged to vent at the lead blade trailing edge at least a substantial proportion of any air trapped in the forming fabric from a wedge shaped space between the stock jet and the lead blade curved surface, and at least some of the liquid carried by the forming fabric.

3. A papermaking machine, having a machine direction and a cross machine direction, which includes:

a first and a second forming fabric each moving in the machine direction;

a head box including a head box slice which provides a jet of paper making stock which impinges at an angle of impingement onto at least one of the forming fabrics at a point of impingement;

two rolls, each having a cylindrical surface whose axis is in the cross machine direction, about each of which one of

the forming fabric passes, and which are located adjacent the head box slice;

a forming section, located downstream of the point of impingement, including static support elements which define a fabric path through which the forming fabric passes; and

two vented lead blades, each located upstream of, and immediately adjacent to, the point of impingement of the stock jet, about the first of which the first forming fabric wraps through a wrap angle  $\theta_1$ , and about the second of which the second forming fabric wraps through a wrap angle  $\theta_2$ ;

wherein each vented lead blade has a leading edge, a shaped trailing edge portion, including a trailing edge, and a convexly curved surface located between the leading edge and the trailing edge portion, over which the forming fabric moves in sliding contact and wraps through an angle of wrap, the convexly curved surface and the trailing edge portion including a plurality of grooves which begin at the leading edge and end at the trailing edge constructed and arranged to vent at the lead blade trailing edge at least a substantial proportion of any air trapped in the forming fabric from a wedge shaped space between the stock jet and the lead blade curved surface, and at least some of the liquid carried by the forming fabric.

4. A curved vented lead blade according to Claim 1 wherein the convexly curved surface is essentially circular, with a constant radius.

5. A curved vented lead blade according to Claim 1 wherein the shaped trailing edge portion conforms to the convexly curved surface.

6. A curved vented lead blade according to Claim 1 wherein the convexly curved surface is not circular, and the radius of curvature increases towards the trailing edge.

7. A curved vented lead blade according to Claim 1 wherein the convexly curved surface is not circular, the radius of curvature increases towards the trailing edge, and the shaped trailing edge portion is essentially flat.

8. A curved vented lead blade according to Claim 1 wherein the convexly curved surface has an effective radius of curvature that is from about 50% to about 100% of the radius of the adjacent upstream roll.

9. A curved vented lead blade according to Claim 1 wherein the angle  $\theta$  is between  $10^\circ$  and  $40^\circ$ .

10. A curved vented lead blade according to Claim 9 wherein the angle  $\theta$  is between  $15^\circ$  and  $30^\circ$ .

11. A curved vented lead blade according to Claim 10 wherein the angle  $\theta$  is between  $20^\circ$  and  $25^\circ$ .

12. A papermaking machine according to Claim 3 wherein the two vented lead blades are the same, and their convexly curved surfaces are the same shape.

13. A papermaking machine according to Claim 3 wherein the two vented lead blades are not the same, and their convexly curved surfaces are not the same shape.

14. A papermaking machine according to Claim 3 wherein the two vented lead blades are the same, the angles  $\theta_1$  and  $\theta_2$  are the same, and the convexly curved surfaces are the same shape.

15. A paper making machine according to Claim 3 wherein the two vented lead blades are not the same, the angles  $\theta_1$  and  $\theta_2$  are not the same, and the two convexly curved surfaces are not the same shape.

16. A papermaking machine according to Claim 2 wherein the convexly curved surface of the vented lead blade is essentially circular, with a constant radius.

17. A papermaking machine according to Claim 2 wherein the shaped trailing edge portion of the vented lead blade conforms to the convexly curved surface.

18. A papermaking machine according to Claim 2 wherein the convexly curved surface of the vented lead blade is not circular, and the radius of curvature increases towards the trailing edge.

19. A papermaking machine according to Claim 2 wherein the convexly curved surface of the vented lead blade is not circular, the radius of curvature increases towards the trailing edge, and the shaped trailing edge portion is essentially flat.

20. A papermaking machine according to Claim 2 wherein the convexly curved surface of the vented lead blade has an

effective radius of curvature that is between 50% and 100% of the radius of the adjacent upstream roll.

21. A papermaking machine according to Claim 2 wherein the angle  $\theta$  is between  $10^\circ$  and  $40^\circ$ .

22. A papermaking machine according to Claim 21 wherein the angle  $\theta$  is between  $15^\circ$  and  $30^\circ$ .

23. A papermaking machine according to Claim 22 wherein the angle  $\theta$  is between  $20^\circ$  and  $25^\circ$ .

24. A papermaking machine according to Claim 12 wherein the convexly curved surface of each vented lead blade is essentially circular, with a constant radius.

25. A papermaking machine according to Claim 13 wherein the convexly curved surface of at least one vented lead blade is essentially circular, with a constant radius.

26. A papermaking machine according to Claim 12 wherein the shaped trailing edge portion of each vented lead blade conforms to the convexly curved surface.

27. A papermaking machine according to Claim 12 wherein the convexly curved surface of each vented lead blade is not circular, and the radius of curvature increases towards the trailing edge.

28. A papermaking machine according to Claim 12 wherein the convexly curved surface of each vented lead blade is not

circular, the radius of curvature increases towards the trailing edge, and the shaped trailing edge portion is essentially flat.

29. A papermaking machine according to Claim 13 wherein the shaped trailing edge portion of at least one vented lead blade conforms to the convexly curved surface.

30. A papermaking machine according to Claim 13 wherein the convexly curved surface of at least one vented lead blade is not circular, and the radius of curvature increases towards the trailing edge.

31. A papermaking machine according to Claim 13 wherein the convexly curved surface of at least one vented lead blade is not circular, the radius of curvature increases towards the trailing edge, and the shaped trailing edge portion is essentially flat.

32. A papermaking machine according to Claim 3 wherein the convexly curved surface of each vented lead blade has an effective radius of curvature that is between 50% and 100% of the radius of the adjacent upstream roll.

33. A papermaking machine according to Claim 3 wherein the angle  $\theta_1$  is between  $10^\circ$  and  $40^\circ$ .

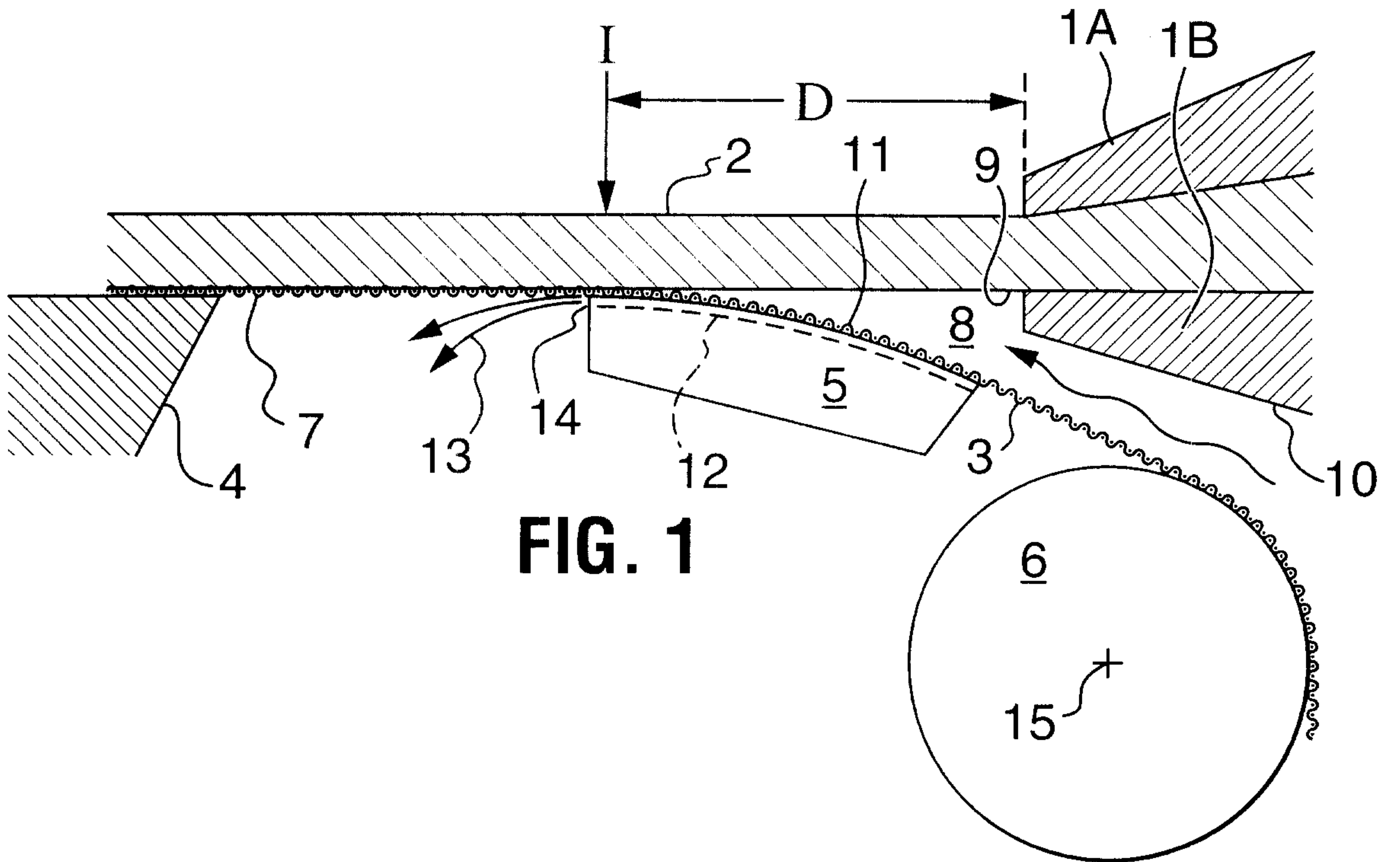
34. A papermaking machine according to Claim 3 wherein the angle  $\theta_1$  is between  $15^\circ$  and  $30^\circ$ .

35. A papermaking machine according to Claim 3 wherein the angle  $\theta_1$  is between  $20^\circ$  and  $25^\circ$ .

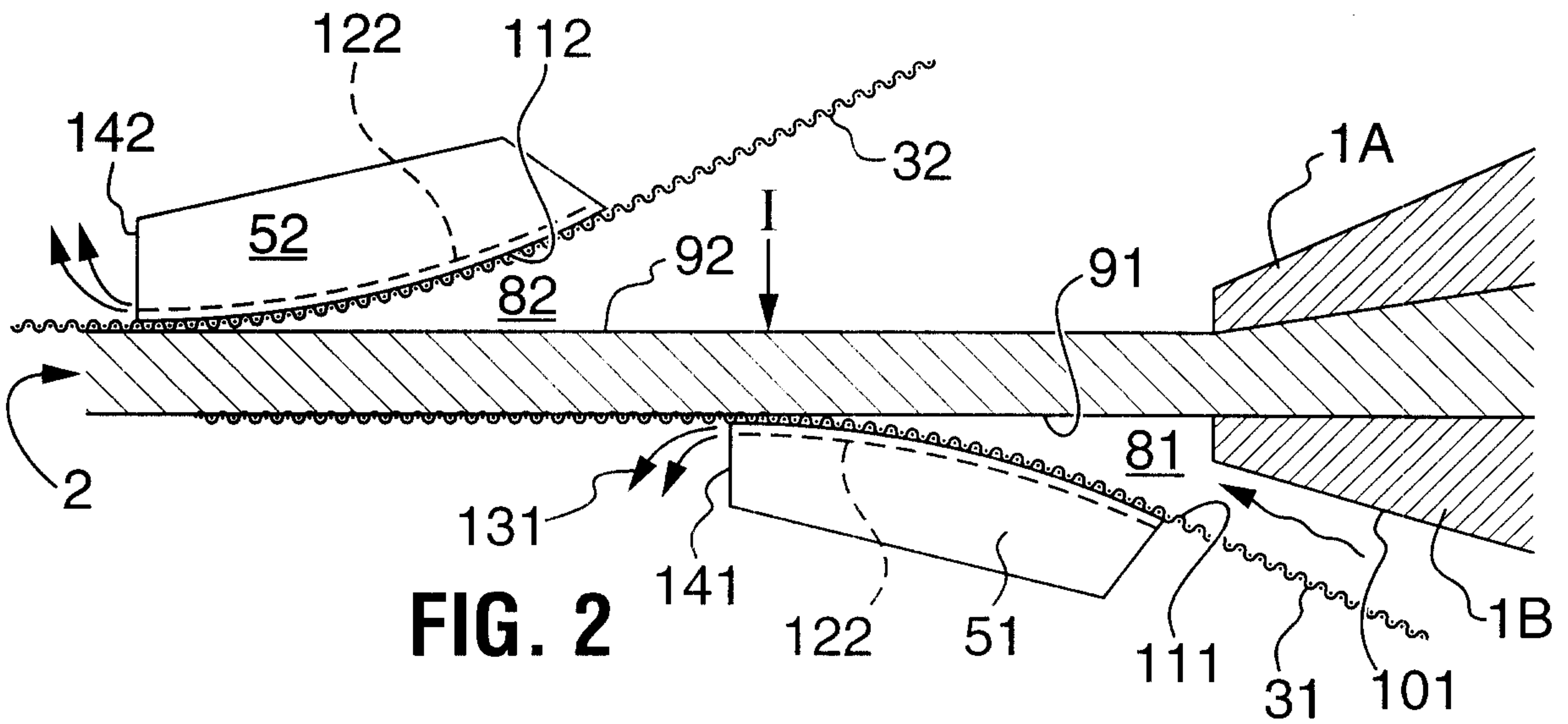
36. A papermaking machine according to any one of Claims 3, 33, 34 or 35 wherein the angle  $\theta_2$  is between  $10^\circ$  and  $40^\circ$ .

37. A papermaking machine according to Claim 36 wherein the angle  $\theta_2$  is between  $15^\circ$  and  $30^\circ$ .

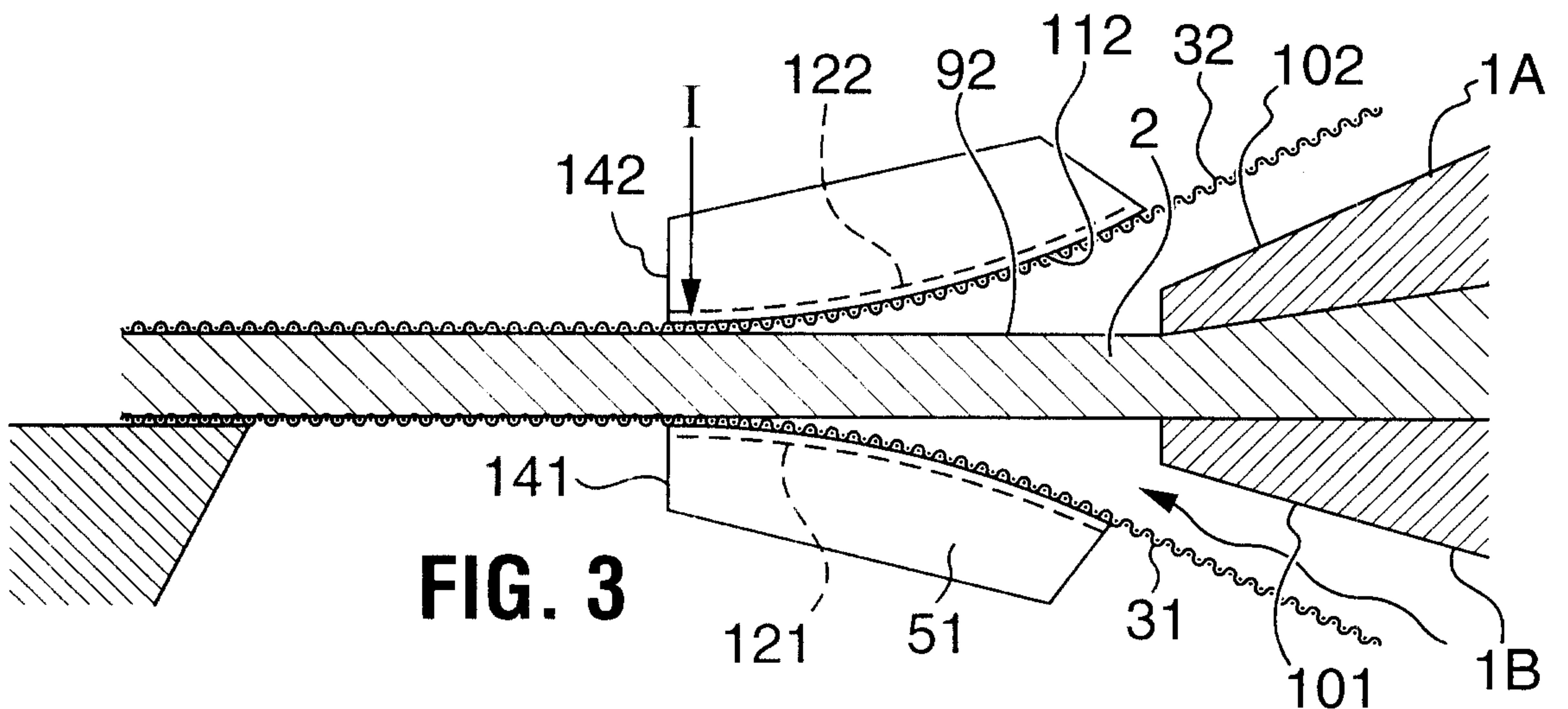
38. A papermaking machine according to Claim 36 wherein the angle  $\theta_2$  is between  $20^\circ$  and  $25^\circ$  degrees.



**FIG. 1**



**FIG. 2**



**FIG. 3**

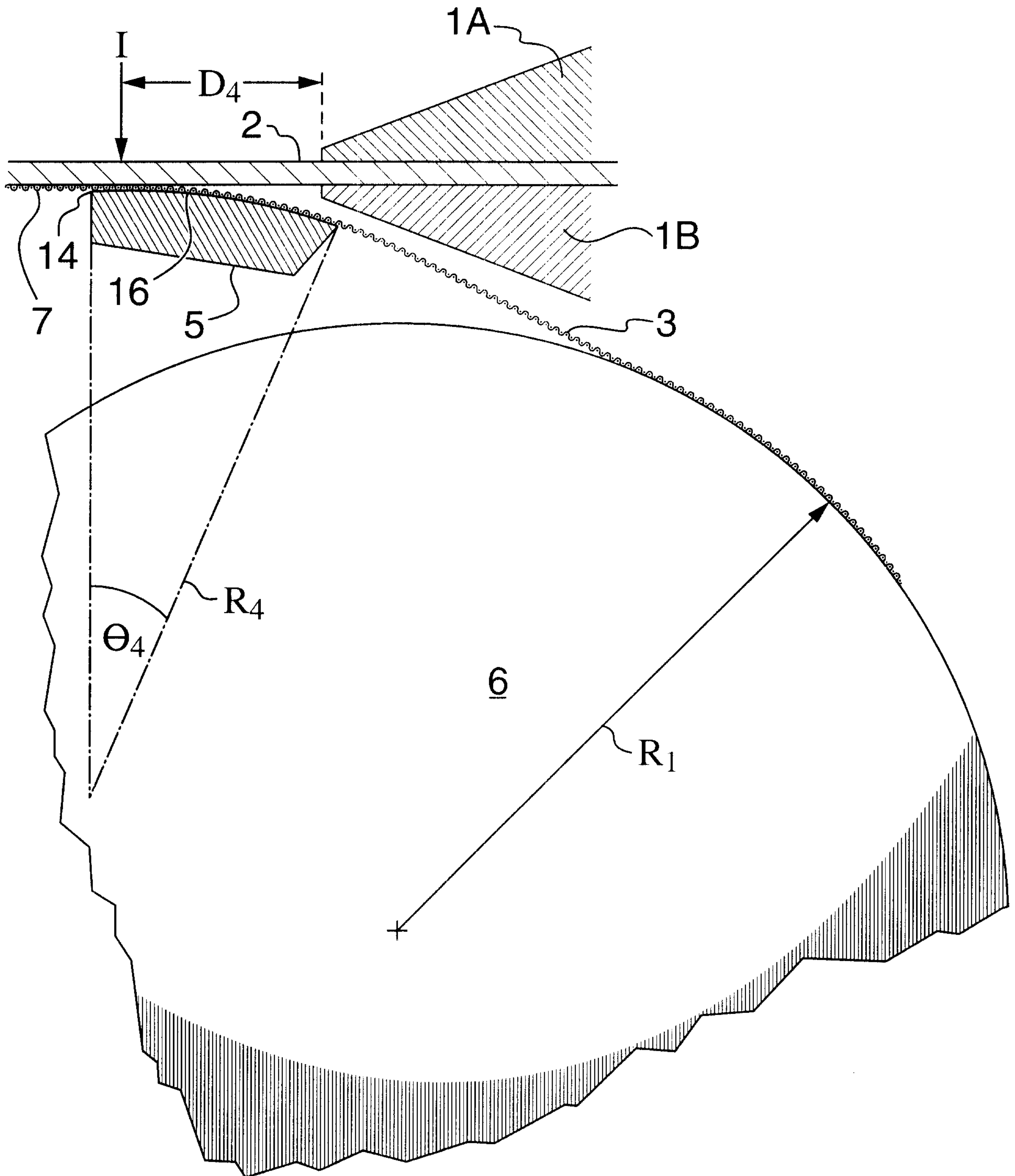
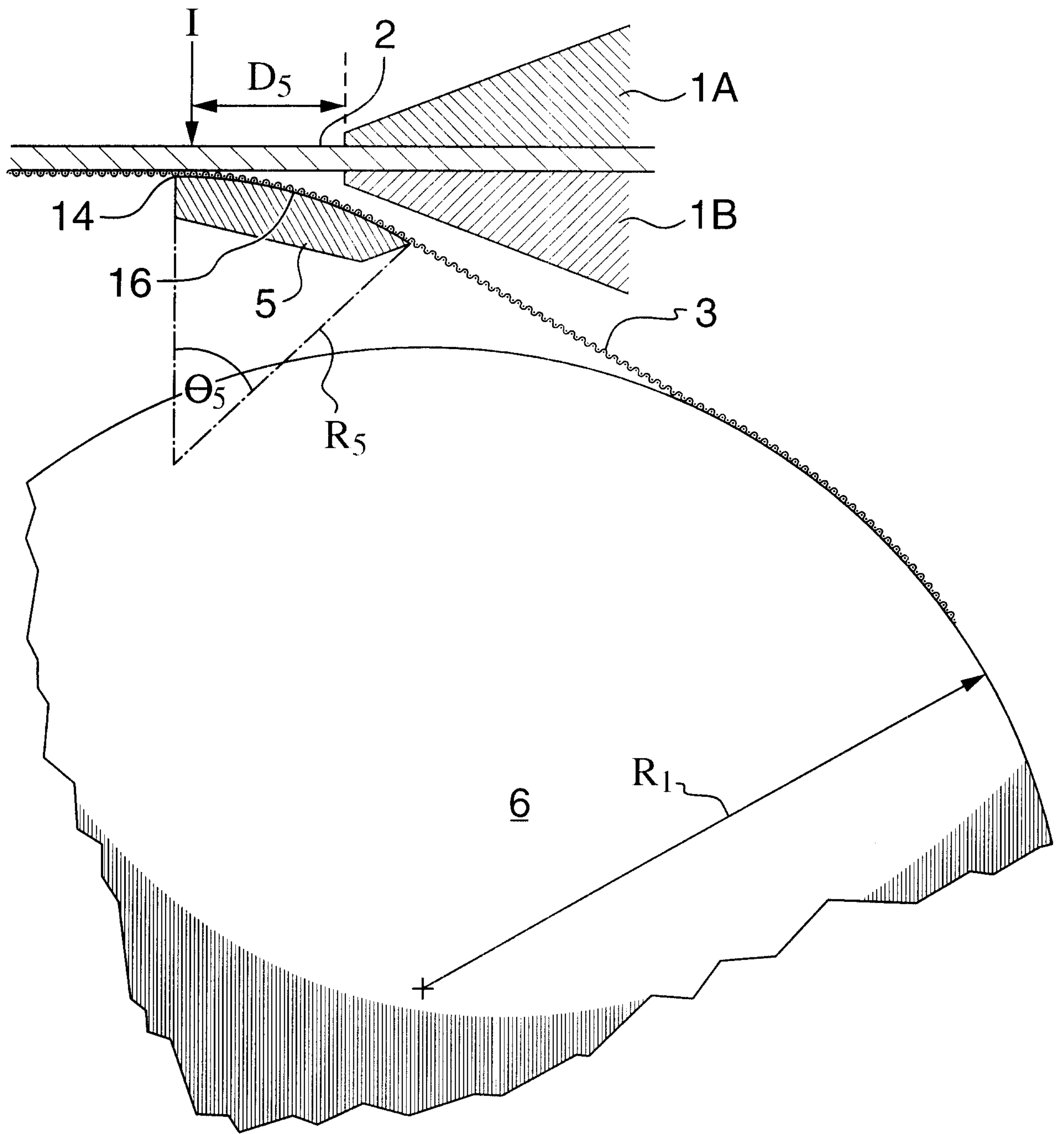
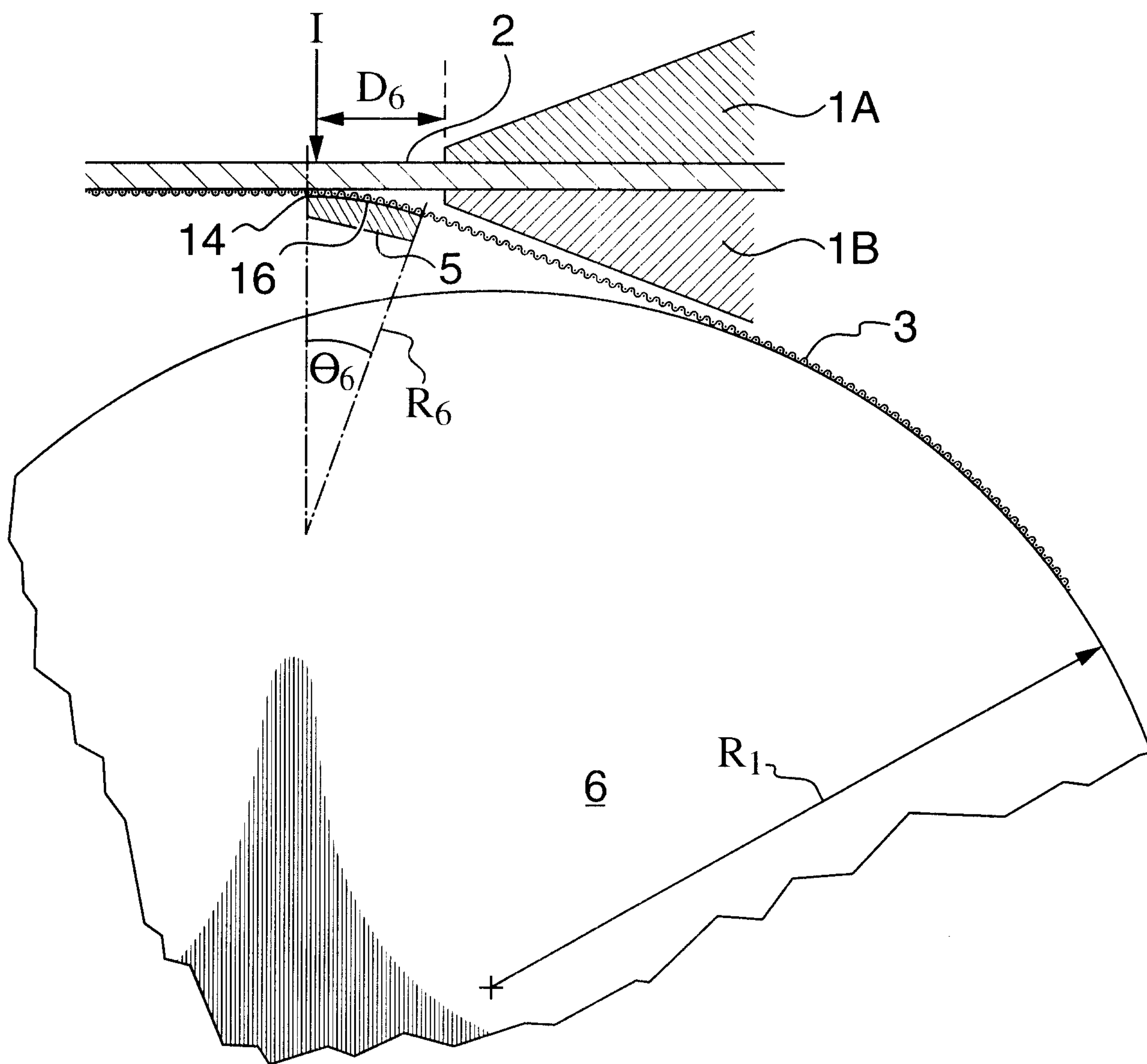


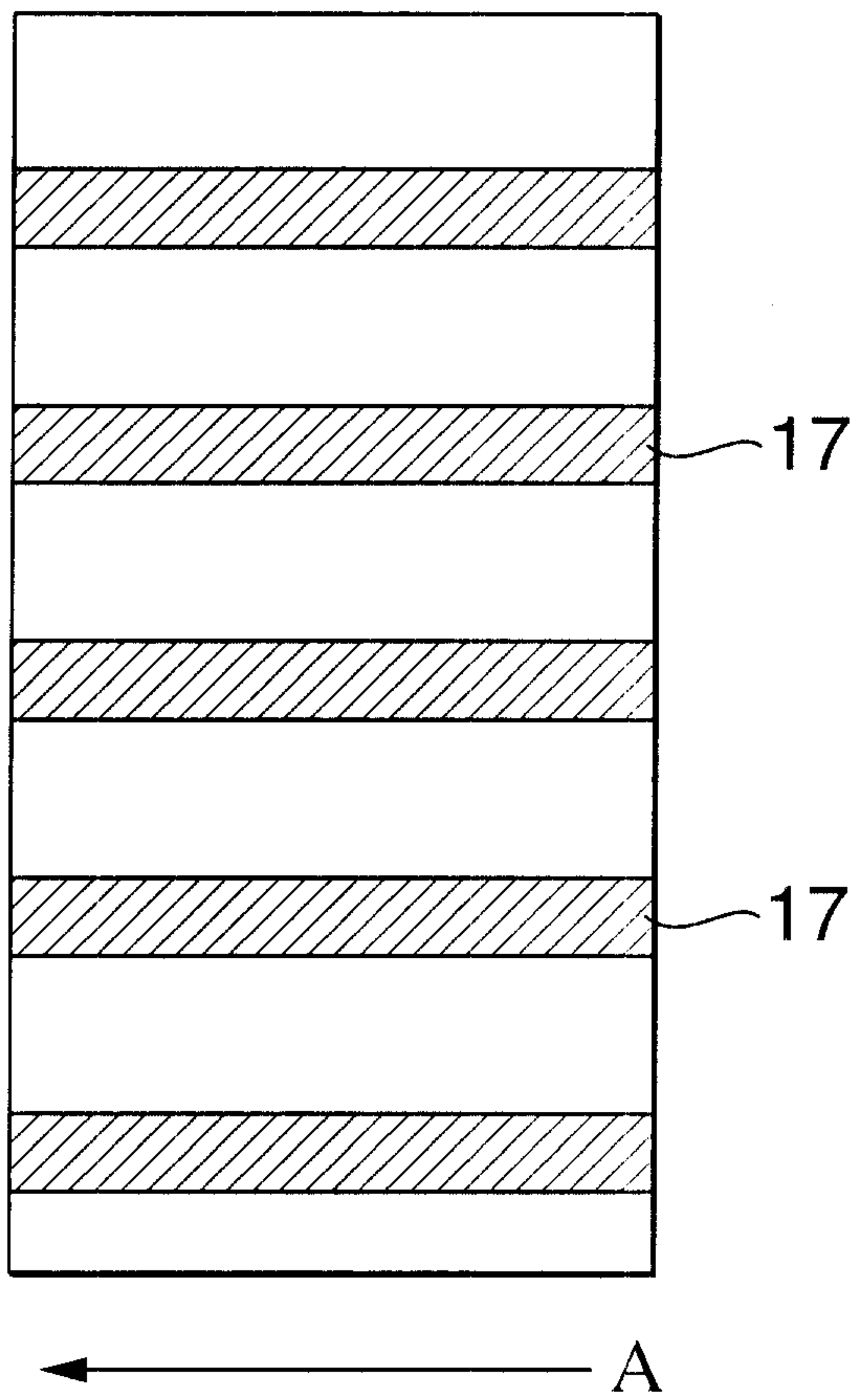
FIG. 4



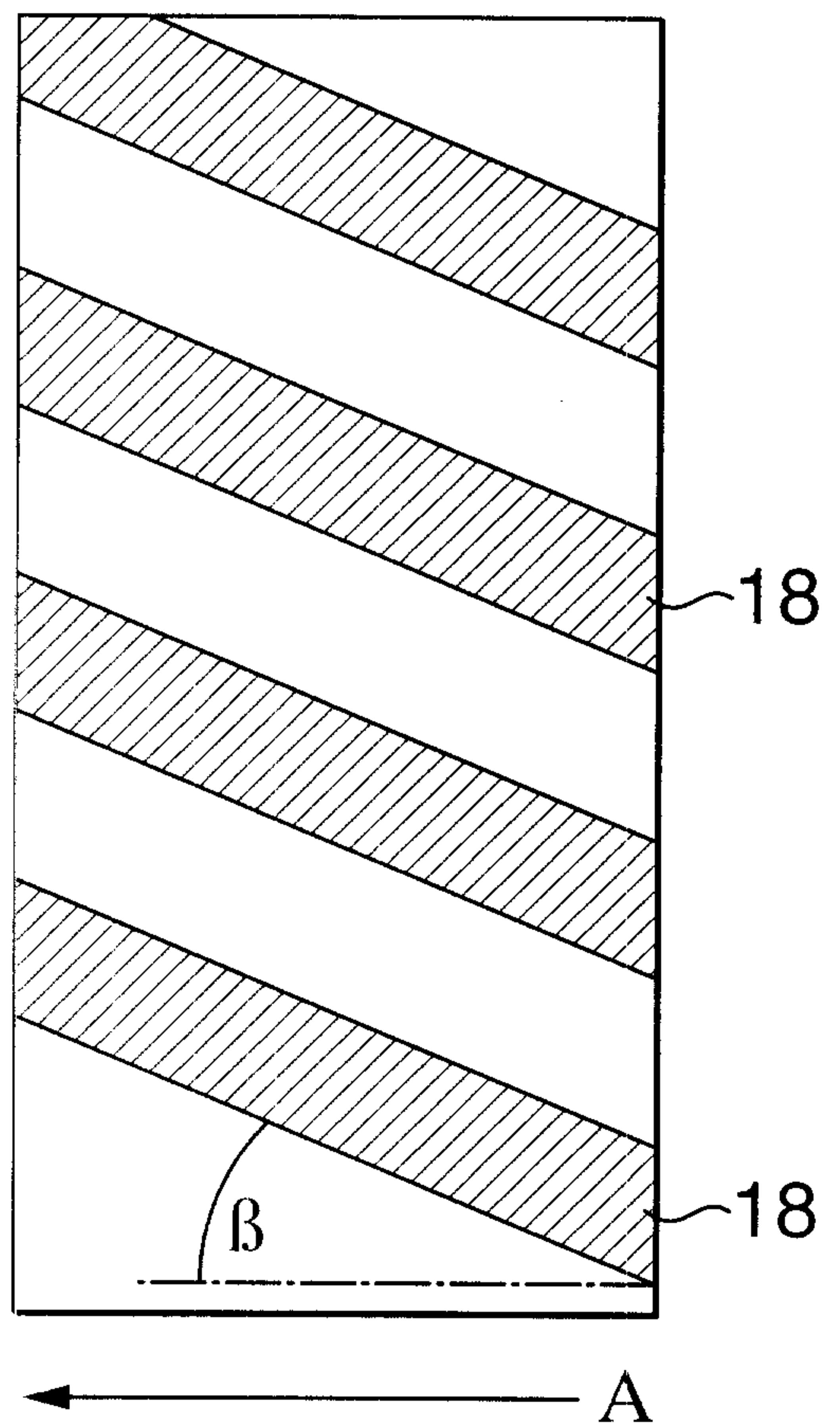
**FIG. 5**



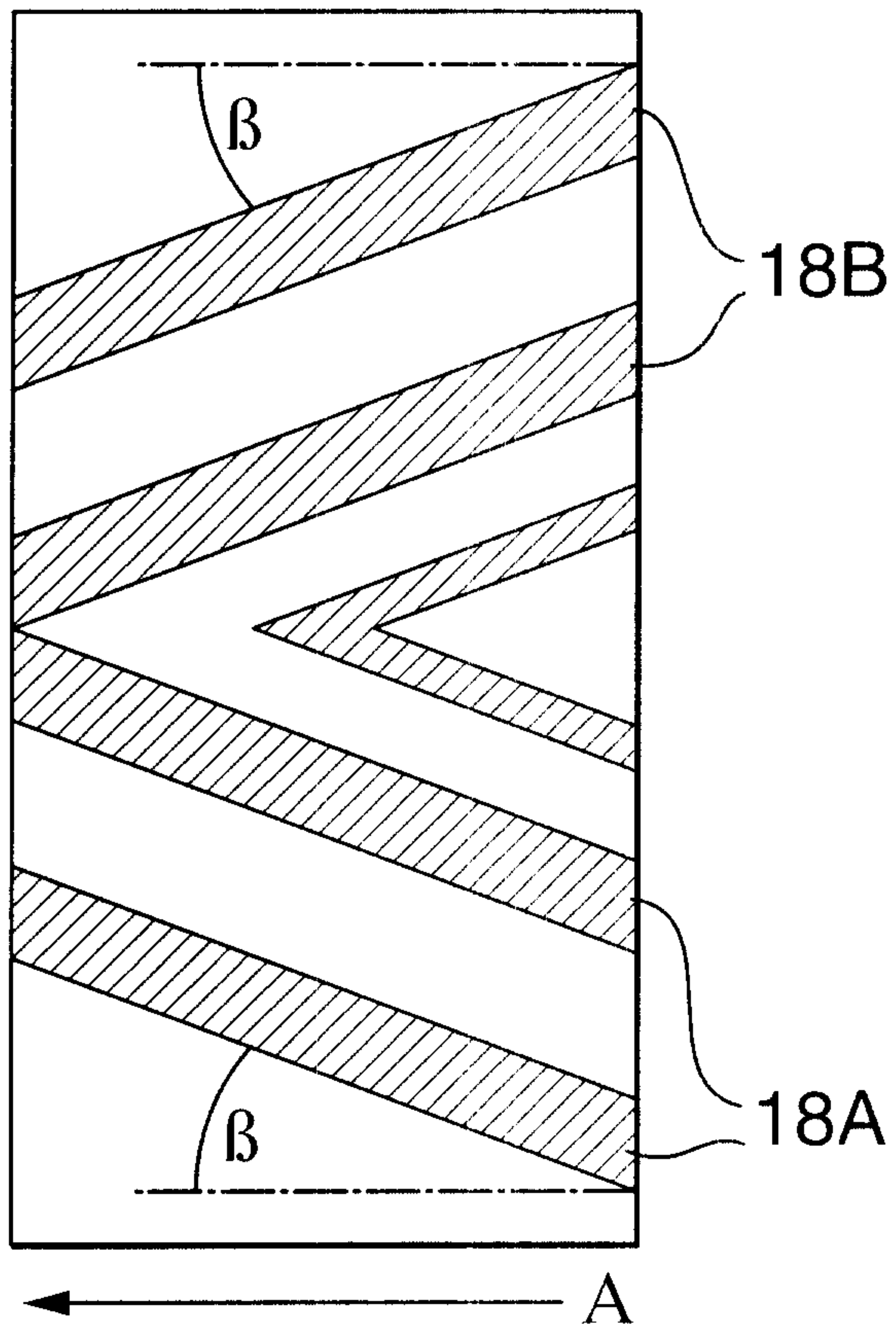
**FIG. 6**



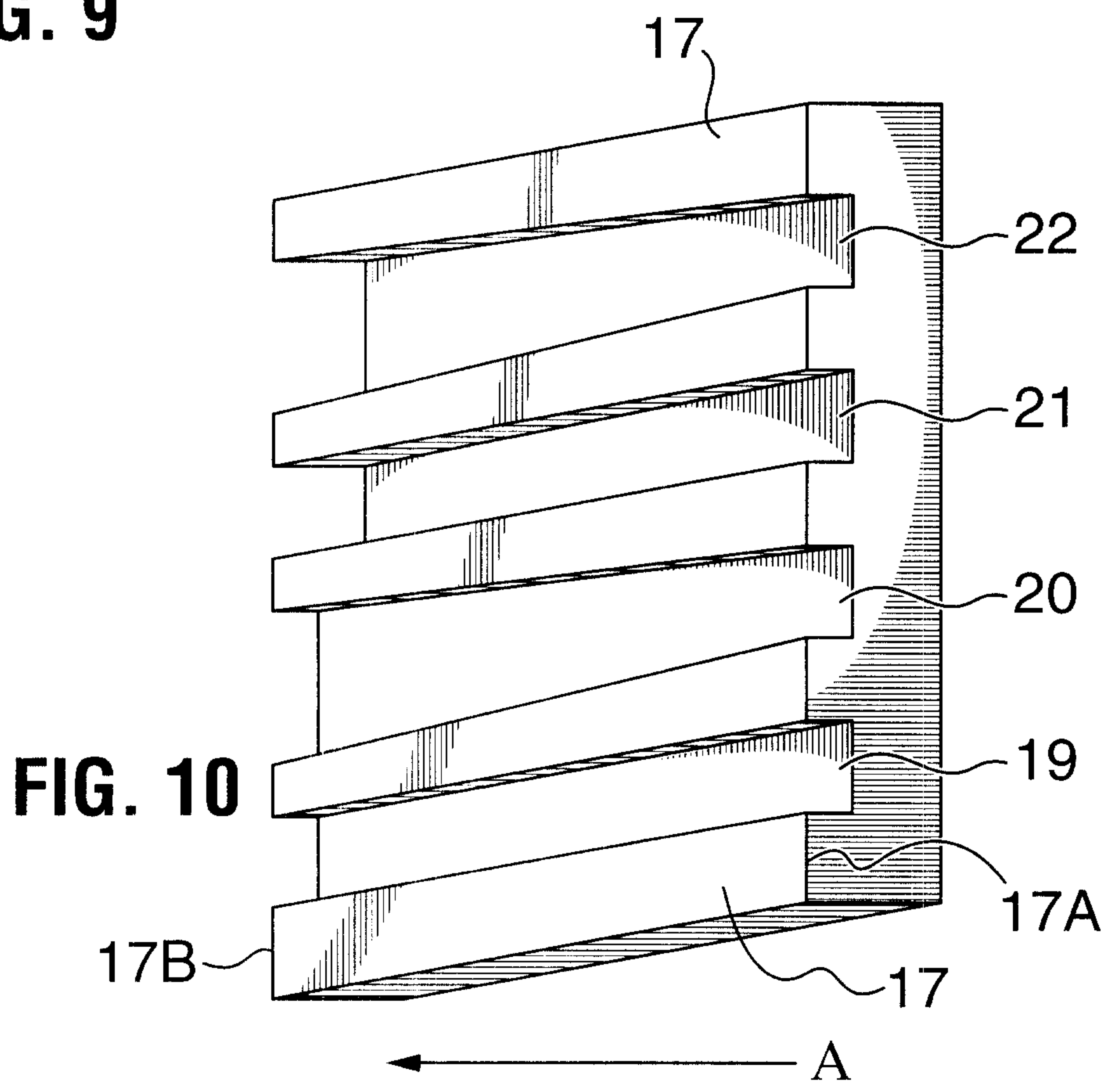
**FIG. 7**



**FIG. 8**



**FIG. 9**



**FIG. 10**

