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TUBULAR SEVERING SYSTEM AND METHOD OF USING SAME**CROSS-REFERENCE TO RELATED APPLICATIONS**

5 This application is a continuation-in-part of US Non-Provisional Application No. 12/883,469 filed on September 16, 2010, which is a continuation of US Patent No. 7,814,979 filed on May 5, 2008, which is a divisional of US Patent No. 7,367,396 filed on April 25, 2006, the entire contents of which are hereby incorporated by reference. This application also claims the benefit of US Provisional
10 Application No. 61/349,660 filed on May 28, 2010, US Provisional Application No. 61/349,604 filed on May 28, 2010, US Provisional Application No. 61/359,746 filed on June 29, 2010, and US Provisional Application No. 61/373,734 filed on August 13, 2010, the entire contents of which are hereby incorporated by reference.

15 BACKGROUND OF THE INVENTION**Field of the Invention**

This present invention relates generally to techniques for performing wellsite operations. More specifically, the present invention relates to techniques for preventing blowouts, for example, involving severing a tubular at the wellsite.

20 Description of Related Art

Oilfield operations are typically performed to locate and gather valuable downhole fluids. Oil rigs are positioned at wellsites, and downhole tools, such as drilling tools, are deployed into the ground to reach subsurface reservoirs. Once the downhole tools form a wellbore to reach a desired reservoir, casings may be
25 cemented into place within the wellbore, and the wellbore completed to initiate production of fluids from the reservoir. Downhole tubular devices, such as pipes, certain downhole tools, casings, drill pipe, liner, coiled tubing, production tubing, wireline, slickline, or other tubular members positioned in the wellbore and associated components, such as drill collars, tool joints, drill bits, logging tools,
30 packers, and the like, (referred to as 'tubulars' or 'tubular strings') may be positioned in the wellbore to enable the passage of subsurface fluids to the surface.

Leakage of subsurface fluids may pose a significant environmental threat if released from the wellbore. Equipment, such as blow out preventers (BOPs), are often positioned about the wellbore to form a seal about a tubular therein to prevent
35 leakage of fluid as it is brought to the surface. Typical BOPs may have selectively

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actuatable rams or ram bonnets, such as pipe rams (to contact, engage, and encompass tubulars and/or tools to seal a wellbore) or shear rams (to contact and physically shear a tubular), that may be activated to sever and/or seal a tubular in a wellbore. Some examples of BOPs and/or ram blocks are provided in U.S. Patent/Application Nos. 4647002, 6173770, 5025708, 5575452, 5655745, 5918851, 4550895, 5575451, 3554278, 5505426, 5013005, 5056418, 7051989, 5575452, 2008/0265188, 5735502, 5897094, 7234530 and 2009/0056132. Additional examples of BOPs, shear rams, and/or blades for cutting tubulars are disclosed in U.S. Pat. Nos. 3946806, 4043389, 4313496, 4132267, 4558842, 4969390, 4492359, 4504037, 2752119, 3272222, 3744749, 4253638, 4523639, 5025708, 5400857, 4313496, 5360061, 4923005, 4537250, 5515916, 6173770, 3863667, 6158505, 4057887, 5178215, and 6016880.

Despite the development of techniques for addressing blowouts, there remains a need to provide advanced techniques for more effectively severing a tubular within a BOP. The invention herein is directed to fulfilling this need in the art.

SUMMARY OF THE INVENTION

In at least one aspect, the invention relates to a blade for severing a tubular of a wellbore, the wellbore penetrating a subterranean formation. The blade is extendable by a ram of a blowout preventer positionable about the tubular. The blade includes a blade body having a front face on a side thereof facing the tubular. At least a portion of the front face has a vertical surface and at least a portion of the front face has an inclined surface. The vertical surface is perpendicular or substantially perpendicular to a bottom surface of the blade body. The blade body has a loading surface on an opposite side of the blade body to the front face (the loading surface receivable by the ram, a cutting surface along at least a portion of the front face for engagement with the tubular, and a piercing point along the front face for piercing the tubular. The piercing point has a tip extending a distance from the cutting surface.

The piercing point may be positioned along a central portion of the front face, or offset from a central portion of the front face. The blade body may further have at least one trough along the front face. The trough may be flat and/or curved. The tip may be pointed, rounded, inverted, and/or flat. The tip may have at least one bevel extending therefrom, or a pair of puncture walls adjacent thereto. At least a portion of the piercing point may have an angled blade step. The piercing point may be

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stepped, serrated, and/or replaceable. A top surface of the blade body may be stepped. The inclined surface may be at an acute angle to the bottom surface of the blade. The blade body may have a geometry to provide at least a portion of the cutting surface and the tip with simultaneous contact with the tubular. The blade body may have a geometry to provide the tip with initial contact with the tubular. The blade body may have a geometry to provide a portion of the cutting surface with initial contact with the tubular. The blade body may also have a pair of shavers along the front face. The pair of shavers may be positioned a distance from the tip on either side thereof for engagement with the tubular. The pair of shavers each may have a projection extending a distance beyond the cutting surface.

In another aspect, the invention relates to a blade for severing a tubular of a wellbore, the wellbore penetrating a subterranean formation. The blade extendable by a ram of a blowout preventer positionable about the tubular. The blade includes a blade body having a front face on a side thereof facing the tubular. The blade body has a loading surface on an opposite side of the blade body to the front face (the loading surface receivable by the ram), a cutting surface along at least a portion of the front face for engagement with the tubular, a piercing point along the front face for piercing the tubular, and a pair of shavers along the front face of the blade body. The piercing point has a tip extending a distance from the cutting surface. Each of the pair of shavers has a projection extending a distance beyond the cutting surface. The pair of shavers are positioned a distance from the tip on either side thereof for engagement with the tubular.

Each projection may have a leading edge for engagement with the tubular. The leading edge may be linear. Each leading edge may have an exit angle. The exit angle may be greater than zero. The leading edge may be stepped or curved. The tip may extend further from the cutting surface than each projection. Each projection may extend further from the cutting surface than the tip. The blade body may also have at least one recess between the tip and each of the projections.

In yet another aspect, the invention relates to a blowout preventer for severing a tubular of a wellbore, the wellbore penetrating a subterranean formation. The blowout preventer has a housing with a channel therethrough for receiving the tubular, a plurality of rams slidably positionable in the housing, and at least one pair of opposing blades supportable by the plurality of rams and selectively extendable thereby. At least one of the pair of opposing blades has a blade body having a front face on a side thereof facing the tubular. At least a portion of the front face has a

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vertical surface and at least a portion of the front face has an inclined surface. The vertical surface is perpendicular or substantially perpendicular to a bottom surface of the blade body. The blade body has a loading surface on an opposite side of the blade body to the front face. The loading surface is receivable by at least one of the plurality of rams. The blade body further having a cutting surface along at least a portion of the front face for engagement with the tubular, and a piercing point along the front face for piercing the tubular. The piercing point has a tip extending a distance from the cutting surface.

The pair of opposing blades may be the same. At least a portion of the blades may be different. At least one of the blades may have a trough for receivingly positioning the tubular for engagement by at least one other blade. The pair of opposing blades may include an upper cutting blade and a lower cutting blade. The upper cutting blade may pass through the tubular at a position above the lower cutting blade.

Finally, in yet another aspect, the invention may relate to a method of severing a tubular of a wellbore. The method involves positioning a blowout preventer about the tubular, the blowout preventer having a plurality of rams slidably positionable therein, and providing each of the rams with a blade. At least one of the blades includes a blade body having a front face on a side thereof facing the tubular. At least a portion of the front face has a vertical surface and at least a portion of the front face has an inclined surface. The vertical surface is perpendicular or substantially perpendicular to a bottom surface of the blade body. The blade body has a loading surface on an opposite side of the blade body to the front face (the loading surface receivable by at least one of the plurality of rams), a cutting surface along at least a portion of the front face for engagement with the tubular, and a piercing point along the front face for piercing the tubular. The piercing point has a tip extending a distance from the cutting surface. The method further involves advancing the plurality of rams such that the piercing point pierces a hole in the tubular, and advancing the rams such that the cutting surface rakes through at least a portion of the tubular.

The blade body may also have a pair of troughs on either side of the blade body. The step of raking may involve advancing the plurality of rams such that the pair of troughs rake through at least a portion of the tubular. The blade body may also have a pair of shavers on either side of the tip. The step of raking may involve advancing the plurality of rams such that the pair of shavers rake through at least a

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portion of the tubular.

The tubular may be pierced before the tubular is raked. The method may further involve continuing to advance the plurality of rams until the tubular is severed.

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BRIEF DESCRIPTION OF THE DRAWINGS

So that the above recited features and advantages of the present invention can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to the embodiments thereof that are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are, therefore, not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments. The Figures are not necessarily to scale and certain features, and certain views of the Figures may be shown exaggerated in scale or in schematic in the interest of clarity and conciseness.

FIG. 1 shows a schematic view of an offshore wellsite having a blowout preventer (BOP) with blades for severing a tubular.

FIGS. 2A-2B show schematic side and top views, respectively, partially in cross-section, of the BOP of Figure 1 prior to initiating a severing operation.

FIG. 2C is a schematic side view, partially in cross-section, of the BOP of Figure 1 during a severing operation.

FIGS. 3A-3G are various schematic views of a blade usable in the BOP of FIG. 2A.

FIGS. 4A-4D are various schematic views of a replaceable blade tip.

FIGS. 5A-5G are various schematic views of an alternate blade having a replaceable blade tip.

FIGS. 6A-6H are various schematic views of another alternate blade.

FIGS. 7A-7G are various schematic views of another alternate blade.

FIGS. 8A-8G are various schematic views of another alternate blade.

FIGS. 9 -15 are schematic views of various other alternate blades.

FIGS. 16A-16J are schematic views of various blade profiles.

FIG. 17 is a schematic top view, partially in cross-section of a blade engaging a tubular.

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FIGS. 18A and 18B are schematic views, partially in cross-section of a pair of blades engaging a tubular.

FIGS. 19A – 19D are schematic, cross-sectional views of a shear area of a tubular.

5 FIGS. 20A-20H are schematic views depicting various portions of a tubular severed by a BOP, and the blade used therewith.

FIGS. 21A-21B are force versus time graphs for a tubular severed by a BOP using various blades.

FIGS. 22A and 22B are flow charts depicting methods of severing a tubular.

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DETAILED DESCRIPTION OF THE INVENTION

The description that follows includes exemplary apparatus, methods, techniques, and/or instruction sequences that embody techniques of the present
15 inventive subject matter. However, it is understood that the described embodiments may be practiced without these specific details.

This application relates to a BOP and at least one blade used to sever a tubular at a wellsite. The tubular may be, for example, a tubular that is run through the BOP during wellsite operations. The severing operation may allow the tubular to be
20 removed from the BOP and/or the wellhead. Severing the tubular may be performed, for example, in order to seal off a borehole in the event the borehole has experienced a leak, and/or a blow out.

The BOP is provided with various blade configurations for facilitating severance of the tubular. These blades may be configured with piercing points, cutting surfaces and/or shavers intended to reduce the force required to sever a
25 tubular. The invention provides techniques for severing a variety of tubulars (or tubular strings), such as those having a diameter of up to about 8.5" (21.59 cm). Preferably, the BOP and blades provide one or more of the following, among others: efficient part (e.g., blade) replacement, reduced wear, less force required to sever
30 tubular, automatic sealing of the BOP, efficient severing, incorporation into (or use with) existing equipment and less maintenance time for part replacement.

Figure 1 depicts an offshore wellsite 100 having a subsea system 106 and a surface system 120. The subsea system 106 has a stripper 102, a BOP 108, a wellhead 110, and a tubing delivery system 112. The stripper 102 and/or the BOP
35 108 may be configured to seal a tubular 118 (and/or conveyance), and run into a

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wellbore 116 in the sea floor 107. The BOP 108 has at least one blade 150 for severing the tubular 118, a downhole tool 114, and/or a tool joint (or other tubular not shown). The BOP 108 may have one or more actuators 28 for moving the blade 150 and severing the tubular 118. One or more controllers 126 and/or 128 may operate, monitor and/or control the BOP 108, the stripper 102, the tubing delivery system 112 and/or other portions of the wellsite 100.

The tubing delivery system 112 may be configured to convey one or more downhole tools 114 into the wellbore 116 on the tubular 118. Although the BOP 108 is described as being used in subsea operations, it will be appreciated that the wellsite 100 may be land or water based and the BOP 108 may be used in any wellsite environment.

The surface system 120 may be used to facilitate the oilfield operations at the offshore wellsite 100. The surface system 120 may comprise a rig 122, a platform 124 (or vessel) and the controller 126. As shown the controller 126 is at a surface location and the subsea controller 128 is in a subsea location, it will be appreciated that the one or more controllers 126/128 may be located at various locations to control the surface 120 and/or the subsea systems 106. Communication links 134 may be provided by the controllers 126/128 for communication with various parts of the wellsite 100.

As shown, the tubing delivery system 112 is located within a conduit 111, although it should be appreciated that it may be located at any suitable location, such as at the sea surface, proximate the subsea equipment 106, without the conduit 111, within the rig 122, and the like. The tubing delivery system 112 may be any tubular delivery system such as a coiled tubing injector, a drilling rig having equipment such as a top drive, a Kelly, a hoist and the like (not shown). Further, the tubular string 118 to be severed may be any suitable tubular and/or tubular string as previously described. The downhole tools 114 may be any suitable downhole tools for drilling, completing, evaluating and/or producing the wellbore 116, such as drill bits, packers, testing equipment, perforating guns, and the like. Other devices may optionally be positioned about the wellsite for performing various functions, such as a packer system 104 hosting the stripper 102 and a sleeve 130.

Figures 2A-2C depict the BOP 108 in greater detail. Figures 2A and 2B show the BOP 108 before actuation. Figure 2C shows the BOP 108 after actuation. The BOP 108 may be similar to, for example, the BOP described in US Non-Provisional Application No. 12/883,469, previously incorporated herein. As shown in FIGS. 2A-

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2C, the BOP 108 may have a body 12 with a bore 14 extending therethrough. The tubular 118 may pass through the bore 14. The body 12 may have a lower flange 16 and an upper flange 18 for connecting the BOP 108 to other equipment in a wellhead stack, for example the stripper 102 (as shown in Figure 1), the wellhead 110 and the like. The BOP 108 may have the one or more actuators 28 for actuating the one or more blades 150, such as a pair of blades 150a,b, in order to sever the tubular 118.

The actuators 28 may move a piston 30 within a cylinder 32 in order to move a rod 34. The rod 34 may couple to a blade holder 24 and 26, or first and second ram 24 and 26. Each of the blade holders 24 and 26 may couple to one of the blades 150a,b. Thus, the actuators 28 may move the blades toward and away from the bore 14 in order to sever the tubular 118 within the bore 14. The actuators 28 may actuate the blades 150a,b in response to direct control from the controllers 126 and/or 128, an operator, and/or a response to a condition in the wellbore 116 (as shown in Figure 1) such as a pressure surge. As shown, the actuators 28 are hydraulically operated and may be driven by a hydraulic system (not shown), although any suitable means for actuating the blades 150a,b may be used such as pneumatic, electric, and the like.

One or more ram guideways 20 and 22, or guides, may guide each of the blades 150a,b within the BOP 108 as the actuator 28 moves the blades 150a,b. The ram guideways 20 and 22 may extend outwardly from opposite sides of the bore 14. Figure 2B shows a top view of the BOP 108. The blade holders 24 and 26 are shown holding the blades 150a,b in an un-actuated position within the ram guideways 20 and 22.

The blades 150a,b of blade holders 24 and 26 may be positioned to pass one another within the bore 14 while severing the tubular 118. As shown, the pair of blades 150a,b includes an upper cutting blade 150a (any blade according to the present invention) on the ram 24 and a lower cutting blade 150b (any blade according to the present invention) on the ram 26. The cutting blades 150a and 150b may be positioned so that a cutting edge of the blade 150b passes some distance below the cutting edge of the blade 150a when severing and/or shearing a section of a tubular 118.

The severing action of cutting blades 150a and 150b may pierce, rake, shear, and/or cut the tubular 118 (see FIG. 2C) into upper portion 118a and lower portion 118b. After the tubular 118 is severed, the lower portion of the tubular 118b may drop into the wellbore 116 (as shown in Figure 1) below the BOP 108. Optionally (as is true for any method according to the present invention) the drill string may be

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hung off a lower set of rams (not shown). The BOP 108 and/or another piece of equipment may then seal the borehole and/or the wellbore 116 in order to prevent an oil leak, and/or explosion.

Figures 3A-8G shows various views of shapes that the blade 150 may take. Figures 3A-3G depict various views of a blade 350 usable, for example, as the blade 150 of Figure 1-2C (and/or the upper blade 150a and/or the lower blade 150b). FIG. 3A is an exploded perspective view of the blade 350. Figure 3B shows a bottom view of the blade 350 and a cross-sectional view of the tubular 118. Figure 3C shows a top view of the blade 350. Figure 3D shows a perspective rear view of the blade 350. Figure 3E shows a side view of the blade 350. Figure 3F shows a front view of the blade 350. Figure 3G shows a cross-sectional view of the blade 350 taken along line 3G-3G of Figure 3F.

The blade 350 is preferably configured to pierce, rake, shear and/or shave the tubular 118 as the blade 350 travels through a tubular, such as the tubular 118 of Figure 1. The blade 350 as shown is provided with a blade body 307, a piercing point (or projection) 300, one or more shave points (or shavers) 302, one or more blade cutting surfaces 306, one or more troughs (or recesses) 304, a loading surface 308, and one or more apertures 310. The piercing point 300 and shavers 302 may extend from a front face 303 of the blade body 307. The front face 303 has a first portion 311 and a second portion 315 having the cutting surface thereon 306. The piercing point 300 is positioned between the first and second portions 311, 315. The blade body 307 may have a base 305 along a bottom thereof.

The apertures 310 may be configured for receipt of one or more connectors 312 for connecting the blade 350 to the blade holders 24 and 26 (as shown in Figure 2A). The one or more connectors 312 may be used to secure the blades 350 to the blade holders 24 and 26. The connectors 312 may be any suitable connector such as a bolt, a pin, a screw, a weld and the like. The blade 350 may also be provided with, for example, shoulders 309 extending laterally for support, for example, in the guideways 20, 22 of the BOP 108 of Figures 2A-2C.

The piercing point 300 may be configured to substantially engage the tubular 118, preferably near the center (or a central portion) thereof. As the piercing point 300 engages the tubular 118, a tip (or apex) 314 of the piercing point 300 pierces and/or punctures the tubular 118. The piercing point 300 terminates at the tip 314, which may have a variety of shapes, such as rounded, pointed, an edge, etc., as described herein. As the piercing point 300 continues to move through the tubular

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118, the blade cutting surfaces 306 on either side of the piercing point 300 may cut through the tubular 118 from the initial puncture point. The blade cutting surfaces 306 may also assist in centering the tubular 118 therebetween. Centering the tubular 118 may facilitate positioning the tubular 118 for optimized piercing and/or cutting.

5 The one or more shavers 302 may be configured to engage the tubular 118 at a location toward an outer portion and/or away from a center (or a central portion) of the tubular 118 as shown in Figure 3B. As shown, the one or more shavers 302 are configured to engage the tubular 118 near an edge (or outer portion) of the tubular 118. The one or more shavers 302 may have projections 351 to puncture the tubular
10 118 in a similar manner as the piercing point 300. A width W (Fig. 3B) between the tip 314 of the piercing point 300 and the projection 351 of the shavers 302 may be configured for contact with a desired portion of the tubular 118.

 As the blade 350 continues to move through the tubular 118, the shavers 302 may pass through the tubular. The blade cutting surface 306 on the shavers 302 may
15 have a cutting (or incline) angle γ for passing through the tubular 118. The cutting angle γ of the blade cutting surface 306 may vary at locations about the blade 350 as needed to facilitate the severing process. The cutting angle γ is shown, for example, in Figure 3E with a complement angle of 90 degrees - γ shown in Figure 3G. The shavers 302 may also have an exit angle θ on an outer surface, as shown in Figure
20 3C, that may continue to cut the walls of the tubular 118. The exit angle θ may be configured to pull apart the wall of the tubular 118 as the blade cutting surface 306 cuts the wall thereby reducing the force required to sever the tubular.

 The one or more shavers 302 may be configured to shave, and/or shear, away a portion of the tubular 118 on both sides of the piercing point 300 thereby
25 decreasing the strength and integrity of the tubular 118. The one or more shavers 302 may centrally align the tubular 118 relative to the blade 350 as the blade 350 engages the tubular 118. As shown in Figures 3A-3C, the one or more shavers 302 may engage the tubular 118 prior to the piercing point 300 engaging the tubular 118. By adjusting the configuration such that the piercing point 300 and/or shaving points 302
30 may be at various lengths relative to each other, the shavers 302 may be configured to engage the tubular 118 substantially simultaneously with the piercing point 300 and/or after the piercing point 300. In this manner, the blade 350 may pierce and/or shave the tubular 118 at one or more locations to facilitate severance thereof.

 The geometry of the blades described herein may be adjusted to provide
35 contact points at various locations along the blade. By manipulating the dimensions

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and position of the piercing point 300, the shavers 302 and the front face 303, the contact of the blade with the tubular may be adjusted and/or optimized. While Figures 3A-3G depict a specific configuration of the shavers 302 for contact with the tubular, the blade dimensions may be selected to permit the tubular to pass between the shavers 302. In such cases, the shaver 302 is pierced by the piercing point 300, and cutting surfaces 306 along the front face 303 of the blade between the shavers 302 may be used to shave and/or shear away portions of the tubular and sever therethrough.

The blades described herein may be constructed of any suitable material for cutting the tubular 118, such as steel. Further, the blade may have portions, such as the points 300, 302, and/or blade cutting surfaces 306 that are hardened and/or coated in order to prevent wear of the blades. The hardening may be achieved by any suitable method such as, hard facing, heat treating, hardening, changing the material, inserting a hardened material 352 (as shown in Figure 3A) such as poly diamond carbonate, INCONEL™ and the like.

Each of the blades herein may have replaceable blade tips 400 as shown in Figures 4A-4D. Figure 4A is an exploded top view of the blade tip 400. Figure 4B is a perspective view of the blade tip 400. Figure 4C is an end view of the blade tip 400. Figure 4D is a cross-sectional view of the blade tip 400 of Figure 4A taken along line 4D-4D.

The replaceable blade tips 400 may be sized to replace part or all of any of the tips and/or points described herein, such as the piercing points 300 and the shavers 302 of blade 350 (as shown in Figures 3A-3G). Further, there may be a replaceable blade cutting surface (not shown) that may replace part or all of the front face of the blade, such as the cutting surfaces 306 of shavers 302 of blade 350 of Figures 3A-3G.

The replaceable blade tips 400 may be used to replace worn and/or damaged parts of existing blades. The replaceable blade tips 400 may have compatible shapes and edges to conform to, for example, the piercing point 300 and related tip 314 and cutting surfaces 306 of the original blade. In some cases, the replaceable blade tips 400 may provide alternate shapes, sizes and/or materials to provide variable configurations for the blade. For example, the replaceable blade tips 400 may be used to provide an extended piercing point 300 to vary the points of contact of the blade.

The replaceable blade tips 400 may be constructed with the same material as the blade 350 and/or any of the hardening materials and/or methods described herein.

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The replaceable blade tips 400, as shown, may have the same shape as any of the piercing points 300 and/or shavers 302 described herein, and may have one or more connector holes 402 for receiving a connector 452 for coupling the replaceable tips 400, for example, to the blades 150 and/or 350 (as shown in Figures 1-3G). The replaceable tips 400 may have a tip angle λ at, for example, an acute angle of about 60 degrees.

Figures 5A-5G show various views of a blade 550 usable, for example, as the blade 150 of Figures 1-2C. Figure 5A shows a front perspective view of the blade 550. Figure 5B shows a back perspective view of the blade 150. Figure 5C shows a bottom view of the blade 550. Figure 5D shows a top view of the blade 550. Figure 5E shows a front view of the blade 550. Figure 5F shows a side cross-sectional view of the blade 550 of Figure 5E along line 5F-5F. Figure 5G shows a side view of the blade 550.

The blade 550 may be similar to the blade 350 of Figures 3A-3G, except that, in this configuration, the blade 550 defines a different blade shape. The blade 550 as shown is provided with the piercing point (or projection) 300 with an angled piercing tip 500, the one or more shavers (or shavers) 302, the one or more blade cutting surfaces 306, the one or more troughs (or recesses) 304, the loading surface 308, and the one or more apertures 310. In this version, the piercing point 300 extends beyond the shavers 302, and the shavers have an exit angle θ facing toward the piercing point 300. Additionally, the blade 550 may be configured to incorporate, for example, the replaceable blade tip 400 (as shown in Figure 4A-4D).

As shown, the piercing point 300 is a replaceable blade tip 400 that has been removed for replacement. The blade 550 may have a blade connector hole 501 configured to align with one or more connector holes 402 on the replaceable blade tip 400. A connector 452, such as a bolt and the like, may be used to couple the replaceable blade tip 400 with the blade 550. While these figures show the piercing point 300 as a replaceable tip 400, it will be appreciated that the shavers 302 may also be replaceable. Also, while Figures 5A-5G show a specific blade configuration, any blade configuration may be provided with one or more replaceable tips 400. The replaceable blade tip 400 may take the shape of, for example, any of the piercing points 300 and/or shavers 302 provided herein.

Figures 6A-6H depict various views of a blade 650 usable as the upper blade 150a and/or the lower blade 150b of Figures 2A-2C. Figure 6A shows a top view of the blade 650. Figure 6B depicts a bottom view of the blade 650. Figure 6C depicts a

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front view of the blade 650. Figure 6D depicts a cross-sectional view of the blade 650 of Figure 6C taken along line 6D-6D. Figure 6E depicts a cross-sectional view of the blade 650 of Figure 6C taken along line 6E-6E. Figure 6F depicts a side view of the blade 650. Figure 6G depicts another perspective view of the blade 650. Figure 6H depicts a perspective view of the blade 650 taken from line 6H-6H of Figure 6G.

The blade 650 is preferably configured to pierce, rake, shear and/or shave as the blade 650 travels through a tubular, such as the tubular 118 of Figure 1. The blade 650 may be similar to the blade 350 of Figures 3A-3G, except that, in this configuration, the blade 650 defines a different blade shape. The blade 650 as shown is provided with the piercing point (or projection) 300 with an angled piercing tip 600, the one or more shavers (or shavers) 302, the one or more blade cutting surfaces 306, the one or more troughs (or recesses) 304, the loading surface 308, and the one or more apertures 310.

The shavers 302 of blade 650 terminate at the projection 351. The shavers 302 may have a pointed configuration that may be used for piercing the tubular when in contact therewith. In this version, the angled piercing tip 600 extends beyond the shavers 302, and the shavers have an exit angle θ facing toward the piercing point 600. The piercing point 300 for the blade 650 shown in Figures 6A-H terminates at the angled puncture tip 600.

The angled puncture tip 600 may be configured to have two puncture walls 601 extending from a leading edge 602. The leading edge 602, as shown in Figure 6H, may extend from a top 604 to a bottom 606 of the blade 650 in a direction substantially parallel to a longitudinal axis of the tubular 118 (as shown in Figure 1). The two puncture walls 601 may extend from the leading edge 602 toward the troughs 304 at an angle ϕ . The two puncture walls 601 may extend from the top 604 to the bottom 606 as they extend toward the troughs 304 until the two puncture walls 601 reach parallel walls 608, as shown in Figure 6G.

The parallel wall 608 may be walls, or a portion of the walls, that extend substantially parallel to the cutting direction of the blade 650. As shown in Figure 6H, the parallel walls 608 extend linearly toward the troughs 304 on the upper portion of the blade, while a lower portion 610 of the angled puncture tip 600 continues to extend at the angle ϕ until the lower portion 610 meets the trough 304 as shown in Figure 6B. Above the lower portion and around the trough 304 the blade cutting surface 306 is formed. The blade cutting surface 306 above the lower portion 610 may be configured to substantially align with the one or more shavers 302, or

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may be offset therefrom.

The angled puncture tip 600 may be configured to have the leading edge 602 engage the tubular 118 first as the blade 650 engages the tubular (as shown in Figure 1). The leading edge 602 may enter a portion of the tubular 118 while the puncture walls 601 separate the wall of the tubular 118, similar to a chisel. The angled puncture tip 600 may separate and/or remove a portion of the wall of the tubular 118 until the cutting surface 306 of the blade 650 engages the tubular 118.

As shown in Figures 6A-6H, a portion of the blade 650 along puncture tip 600 has a vertical surface and a remainder of the blade 650 has an inclined surface. As demonstrated in these figures, portions of the blade 650 may have vertical and/or inclined surfaces.

Figures 7A-7G depict various views of a blade 750 usable as the upper blade 150a and/or the lower blade 150b of Figures 2A-2C. Figure 7A shows a top view of the blade 750. Figure 7B depicts a bottom view of the blade 750. Figure 7C depicts a front view of the blade 750. Figure 7D depicts a cross-sectional view of the blade 750 of Figure 7C taken along line 7D-7D. Figure 7E depicts a cross-sectional view of the blade 750 of Figure 7C taken along line 7E-7E. Figure 7F depicts a side view of the blade 750. Figure 7G depicts a perspective view of the blade 750 of Figure 7F from the view 7G-7G.

The blade 750 is preferably configured to pierce, rake, shear and/or shave as the blade travels through a tubular, such as the tubular 118 of Figure 1. The blade 650 may be similar to the blade 350 of Figures 3A-3G, except that, in this configuration, the blade 650 defines a different blade shape. The blade 750 as shown is provided with the piercing point (or projection) 300, the one or more shavers (or shavers) 302, the one or more blade cutting surfaces 306, the one or more troughs (or recesses) 304, the loading surface 308, and the one or more apertures 310. The blade 650 may be similar to the blade 350 of Figures 3A-3G, except that the shavers 302 and the piercing point 300 have alternate shapes. The blade 750 may have a square puncture tip 700. The flat puncture face 702 of the shavers 302 may have flat walls 704 extending therefrom. The sloped cutting surfaces 306 may wedge into the tubular during engagement.

The piercing point 300 for the blade 750 shown in Figures 7A-H is a square puncture tip 700. The square puncture tip 700 may have a flat puncture face 702. The flat puncture face 702 as shown is a rectangular surface, although it may have any shape. The flat puncture face 702 may extend from the top 604 to the bottom 606

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of the blade 750 in a direction substantially parallel to a longitudinal axis of the tubular 118 (as shown in Figure 1). Two parallel puncture walls 704 may extend from the flat puncture face 702 toward the troughs 304 in a direction that is substantially parallel to the cutting direction of the blade 750. The two parallel puncture walls 704 may extend from the top 604 to the bottom 606 of the blade 750 as they extend toward the troughs 304. A parallel puncture step 706 may be configured to transition the square puncture tip 700 into the cutting surfaces 306 proximate the troughs 304.

The square puncture tip 700 may be configured to have the flat puncture face 702 engage the tubular 118 first as the blade 750 engages the tubular (as shown in Figure 1). The flat puncture face 702 may puncture, dent and/or enter a portion of the tubular 118. The square puncture tip 700 may separate and/or remove a portion of the wall of the tubular 118. With the puncture tip 700 extending beyond the shavers 302, the puncture tip 700 may engage the tubular before the shavers 302 of the blade 750 engage the tubular 118.

Figures 8A-8G depict various views of a blade 850 usable as the upper blade 150a and/or the lower blade 150a of Figures 2A-2C. Figure 8A shows a top view of the blade 850. Figure 8B depicts a bottom view of the blade 850. Figure 8C depicts a front view of the blade 850. Figure 8D depicts a cross-sectional view of the blade 850 of Figure 8C taken along line 8D-8D. Figure 8E depicts a cross-sectional view of the blade 850 of Figure 8C taken along line 8E-8E. Figure 8F depicts a side view of the blade 850. Figure 8G depicts a perspective view of the blade 850 of Figure 8F from the view 8G-8G.

The blade 850 is preferably configured to pierce, rake, shear and/or shave the tubular 118 as the blade 850 travels through a tubular, such as the tubular 118 of Figure 1. The blade 850 may be similar to the blade 350 of Figures 3A-3G, except that, in this configuration, the blade 850 defines a different blade shape. The blade 850 as shown is provided with an inverted point 800 located between two piercing points (or projections) 803. The blade 850 is further provided with the one or more shavers (or shavers) 302, the one or more blade cutting surfaces 306, the one or more troughs (or recesses) 304, the loading surface 308, and the one or more apertures 310. The blade 850 may be similar to the blade 350 of Figures 3A-3G, except that the shavers 302 and the piercing point 300 have alternate shapes. The blade 850 may have a flat shave front 807. The flat shave front 807 of the shavers 302 may have a sloped cutting surface 306 extending therefrom. The sloped cutting surfaces 306 may

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wedge into the tubular during engagement.

The piercing point 300 has been reconfigured as an inverted puncture tip 802. An inverted point 800 is positioned between two piercing points 300 for the blade 850 shown in Figures 8A-H to form an inverted puncture tip 802. The inverted puncture tip 802 may have two inverted surfaces 804 extending from the inverted point 800 at an angle α toward the piercing points 300. The angle α may be any suitable angle that allows the piercing points 300 to engage the tubular prior to, or simultaneously with, the inverted point 800 engaging the tubular. The two inverted surfaces 804 may be rectangular shaped surfaces, or any other suitable shape.

The inverted puncture tip 802 may only extend a portion of the depth of the blade 850 between the top 604 and the bottom 606, as shown, or may extend the entire depth in a direction substantially in line with a longitudinal axis of the tubular 118 (as shown in Figure 1). A stepped blade surface 808 may extend from a parallel top 810 and/or a parallel bottom 812 of the inverted puncture tip 802. The parallel top 810 may be a distance below the top surface 604. The parallel bottom 812 may be a distance above the bottom surface 606.

Two parallel puncture walls 806 may extend from the piercing points 300 toward the troughs 304 in a direction that is substantially parallel to the cutting direction of the blade 850. The parallel top 810 and the parallel bottom 812 may extend from the top 604 and bottom 606 (respectively) of the inverted surfaces 804 toward the stepped blade surface 808.

The inverted puncture tip 802 may be configured to have the piercing points 803 engage the tubular 118 first as the blade 850 engages the tubular (as shown in Figure 1). The piercing points 300 may puncture, dent, and/or enter a portion of the tubular 118 prior to or at substantially the same time as the inverted piercing point 800. The inverted puncture tip 802 may separate and/or remove a portion of the wall of the tubular 118 until the cutting surface 306, the stepped blade surfaces 808 and/or the shavers 302 of the blade 850 engage the tubular 118.

Figures 9-15 shows perspective views of other shapes that the blade 150 may take. Each of the blades of Figures 9-15 may be similar to the blade 350 of Figures 3A-3G, except having different blade shapes. Figures 9 and 10 depict blades with 'shave and puncture' profiles. Figure 9 shows a blade 950 having flat shavers 302 and a piercing point 300. The shavers 302 have sloped cutting surfaces 306. The shavers 302 have projections 351 at a point thereon. The cutting surfaces 306 may be formed with, for example, a shallow exit angle θ along the face of the shavers 302

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(and/or other portions of the blade 950). The shallow exit angle θ may be a small angle of, for example, less than about 30 degrees. The cutting surfaces 306 may also have a slope (or blade) angle γ . The piercing point 300 defines a piercing point (or puncture tip) 314 at a tip angle Φ . The blade 950 has a blade body with a base 350
5 along a bottom side thereof.

Figure 10 is similar to Figure 9, except that the exit angle θ has increased and the piercing point 300 is further recessed. In Figure 10, a blade 1050 having the piercing point 300 with the troughs 304, and the shavers 302 is provided. The shavers 302 have cutting surfaces 306 at a sharp exit angle θ . The sharp exit angle θ
10 may be a large angle, for example, more than about 30 degrees and less than about 90 degrees.

Figure 11 depicts a blade 1150 with a serrated puncture profile. In Figure 11, the blade 1150 has the piercing point 300 with the troughs 304, the shavers 302, and a serrated edge 1100. The serrated edge 1100 is shown on the blade 1150 along cutting
15 surface 306 on either side of the piercing point 300. However, the serrated edge 1100 may be on any of the cutting surfaces 306. The serrated edge 1100 may have a plurality of serration tips (or serrations) 1102 for engaging and cutting the tubular 118. As also shown in Figure 11, the shavers 302 may have an exit angle θ facing the piercing point 300. The exit angle θ may be, for example, about 45 degrees. As also
20 shown in this Figure, the cutting surface 306 may extend along the entire front face of the blade 1150, and have a cutting angle γ along the entire front face.

Figure 12 depicts a blade 1250 having a flat tip and a flat puncture profile. The blade 1250 has an extended piercing point 300 and flush shavers 302. In Figure 12, the piercing point 300 of the blade 150 has a flat puncture tip 1200, blade cutting
25 surfaces 306 proximate the flat puncture tip 1200, tip engagement portions 1202, a tip cutting angle ψ and a flat front 1206. The flat puncture tip 1200 as shown has a rectangular profile configured to engage the tubular 118 (as shown in Figure 1), although it may have any shape such as square, circular, polygonal and the like. The flat puncture tip 1200 may be on a portion of the blade 1250 extending from the flat
30 front 1206 toward a back of the loading surface 308 of the blade 1250.

As shown, the tip engagement portions 1202 extend substantially parallel to one another along a length of the flat puncture tip 1200, however, they may form an angle (not shown). The tip engagement portion 1202 may be at a side cutting angle Δ to the flat front 1206 and may have the blade cutting surfaces 306 thereon. The side
35 cutting angle Δ may have any suitable angle for cutting the tubular 118 (as shown in

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Figure 1). A series of cutting surfaces 306 are depicted as extending from the flat puncture tip 1200 at various angles therefrom.

The shavers 302 are depicted as being flat surfaces having an exit angle θ of zero degrees parallel to the loading surface 308. The shavers 302 have the cutting surfaces 306 thereon extending at a blade cutting angle γ . The blade cutting angle γ of the cutting surfaces 306 may be constant along the shaver 302 and/or the blade 1250. The flat front 1206 may also have the same cutting angle γ .

Figure 13 depicts a blade 1350 having a broach tip profile. The blade 1350 has an extended piercing point 300 and flush shavers 302. In Figure 13, the blade 1350 also has the blade cutting surface 306 along the entire front fact of the blade 1350, a broach trough 1300, a broach shoulder 1302, a broach portion 1304, an exit trough 1306, and a flat front 1316. The shavers 302 are depicted as being flat surfaces having an exit angle θ of zero degrees parallel to the loading surface 308 and defining the flat front 1316. The flat front 1316 may be similar to the flat fronts described herein. The shavers 302 have the cutting surfaces 306 thereon extending at a blade angle γ . The blade angle γ of the cutting surfaces 306 may be constant along the shaver 302 and/or the blade 1350.

The piercing tip 300 has the blade cutting surfaces 306 on either side that extends a distance from a tip 314 of the piercing tip 300 to the broach trough 1300 at a tip angle Φ . At the broach trough 1300 the tip angle Φ of the blade cutting surface 306 changes to tip angle Φ' to form an angled blade step 1308. The angled blade step 1308 ends at the broach portion 1304 wherein the angle of the blade cutting surface 306 changes again to tip angle Φ'' to form the blade cutting surface 306 at the broach portion 1304. The blade cutting surface 306 may extend from the broach shoulder 1302 along the broach portion 1304 to the exit trough 1306. The exit trough 1306 may be a continuous curve from of the blade cutting surface 306 from the broach portion 1304 to the flat front 1316.

The blade 1350 of Figure 13 may further have a stepped blade front 1310. The stepped blade front 1310 may divide a depth D of the blade 1350, thereby forming a lower plateau 1311 and an upper plateau 1317. The lower plateau 1311 is positioned between a top edge 1319 of the blade cutting surface 306 and a bottom edge 1315 of a second blade cutting surface 1312. The second blade cutting surface 1312 may have a similar pitch as the blade cutting surface 306, or have a different pitch. Further, the second blade cutting surface 1312 may be perpendicular or substantially perpendicular to the direction of blade cutting travel. The upper plateau

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1317 extends from the cutting surface 1312 to the loading surface 308. One or more plateaus and/or shoulders at various angles may be provided.

Figure 14 provides a blade 1450 with a balanced tip and rake on trough profile. The blade 1450 has a piercing point 300 and shavers 302 with sloped troughs 304 therebetween. In Figure 14, the blade 1450 has a balanced tip 1400 having a rounded point 1402 and an equal bevel 1404 on each side of the rounded tip 1402. The rounded point 1402 may be a semi-cylindrical nose that is formed at the front of the piercing point 300 of blade 1450. The semi-cylindrical nose may be raised or extend in a perpendicular or substantially perpendicular direction relative to the blade cutting direction. The bevels 1404 may extend equally from a nose end 1406 to a blade top 1408 and/or a blade bottom 1410 to provide a balance at the rounded tip 1402. The rounded point 1402 may extend along a bevel edge 1412 until the blade cutting surface 306 is reached at the trough 304.

The blade 1450 further has the blade cutting surface 306 that may be located at the troughs 304. The trough 304 may extend back toward the cutting direction to form the shavers 302 at either end of the blade 1450. The shavers 302 have projections 351 at a point thereof. Each of the cutting surfaces 306 extends from the projection 351 along an inner surface of the shaver 302 at an exit angle θ . The cutting surface 306 along the troughs 304 may be at a blade angle γ to define a rake along a portion of the blade 1450. In this rake configuration, the sloped cutting surfaces 306 at the trough may be used to rake through the tubular 118.

Figure 15 provides a blade 1550 having a balanced tip and no rake profile. The blade 1550 is provided with a projection 300 and shavers 302 with perpendicular troughs 304 therebetween. In Figure 15, the blade 1550 has the balanced tip 1400 having a sharp point 1500 and the equal bevels 1404 on top and bottom sides of the sharp tip 1500. The blade 1550 further has the troughs 304 with perpendicular surfaces 1502, along the blade cutting surfaces 306. The sharp point 1500 may be an angled nose that is formed at the front of the blade 1550. The angled nose may extend in a perpendicular or substantially perpendicular direction relative to the blade cutting direction. The equal bevels 1404 may extend from a sharp point 1500 to a blade top 1408 and/or a blade bottom 1410. The sharp point 1500 may extend along the bevel edge 1412 until the blade cutting surface 306 is reached at the trough 304.

The trough 304 may extend back toward the cutting direction to form the shavers 302 at either end of the blade 1550. The shavers 302 have projections 351 at a point thereof. Each of the cutting surfaces 306 extends from the projection 351

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along an inner surface of the shaver 302 at an exit angle θ . The perpendicular surfaces 1502 along the troughs 304 may be perpendicular or substantially perpendicular to a top surface 1504 of the blade 1550. Unlike the sloped cutting surfaces 306 of the blade 1450 of Figure 14, the perpendicular surfaces 1502 of the blade 1550 define a no-rake configuration where the perpendicular cutting surfaces 1502 at the trough may be used to push against the tubular 118.

Figures 16A-16J show various views of shapes that the blade 150 (or any other blades herein, such as blades of Figures 1-15) may take. Each of these figures depicts various blade profiles 1650a-j that may be provided for the blades. The blade profiles 1650a-j each have a front face 1615a-j defined by the piercing point 300, the shavers 302, the recesses 304 and the blade cutting surfaces 306 of the given blade. The shavers 302 each have a shave front 1604a-j for engagement with a tubular (e.g., 118 of Figures 1-2C). The dashed line 1600 on each of the blade profiles 1615a-j in Figures 16A-16J depicts where the blade cutting surfaces 306 may be located. The cutting surfaces 306 may be on part or all of the front face of the blade.

The shavers 302 of the blades may be configured with various shapes. Figure 16A shows the blade profile 1650a having the shavers 302, the piercing point 300 and the exit angle θ . With this blade profile 1650a, the shavers 302 contact the pipe before the piercing point 300. The exit angle θ of the shavers 302 provides the shavers 302 with the pointed shave front 1604a defining a projection 351 with piercing capabilities similar to that of the piercing point 300. Figure 16B shows the blade profile 1650b having the piercing point 300, the shavers 302, and a U-shaped shave front 1604b. The U-shaped shave front 1604b may be along the shaver 302 between the projection 351 and a shave front end point 1605. Figure 16C shows the blade profile 1650c having the piercing point 300, and a flat shave front 1604c. Figure 16D shows the blade profile 1650d having the piercing point 300, and a continuously curved front face 1615d from the shave front 1604d to the piercing point 300. In this configuration, the shavers 302 have a curved shape for contact with the tubular 118.

The projections 300 and shavers 302 may be also configured to provide recesses 304 with various shapes. Figure 16E shows the blade profile 1650e having the piercing point 300 with flat troughs 304 extending between the piercing point 300 and the shavers 302, and with a flat shave front 1604e. Figure 16F shows the blade profile 1650f having the piercing point 300, and a continuously curved blade edge 1615f from the flat shave front 1604f to the piercing point 300. As shown in this

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configuration, inner walls 1608 of the shavers 302 may slant together.

Figures 16G – 16I show stepped configurations. Figure 16G shows the blade profile 1650g having the piercing point 300, a flat shave front 1604g, and a flat stepped front 1606. The flat stepped front 1606 may provide the shave front 302 with an additional contact surface for engaging the pipe. Figure 16H shows the blade profile 1650h having the piercing point 300, the flat shave front 1604h, and the flat stepped front 1606, with an inner wall 1608 between the flat shave front 1604h and the flat stepped front 1606. The inner wall 1608 may create points 1610 similar to the projection 351 of Figure 16A. Figure 16I shows the blade profile 1650i having the piercing point 300, the flat shave front 1604i, and multiple flat step fronts 1606. As shown in these figures, one or more flat or angled steps may be provided on the inner surfaces (or walls) 1608 of the shavers 302.

The piercing point 300 may also be configured with various shapes, such as serrations or steps. Figure 16J shows the blade profile 1650j having the piercing point 300, the flat shave front 1604j, and multiple stepped, or serrated cutting edges 1612 between the piercing point 300 and the trough 304. The serrated cutting edges may be rounded or pointed as shown. As also demonstrated by this figure, the piercing point 300 may optionally extend further than the shavers 302.

Figures 17, 18A-18C, and 19A-D are schematic top views, partially in cross-section of various blades 150, 150a, 150b engaging a tubular 118. For descriptive purposes, the blades may be schematically depicted as being on opposite sides of the tubular, but may be positioned at different heights along the tubular 118 such that an upper blade 150a passes above a lower blade 150b as shown in Figures 2A and 2B.

Figure 17 is a schematic diagram depicting the position of a blade 150 about a tubular 118 prior to engagement. The blade 150 may be used in combination with another blade (or blades), but is depicted alone for descriptive purposes. As shown in Figure 17, the shavers 302 may engage an outer portion 1725 of the tubular 118, and the piercing point 300 may engage a central portion 1723 of the tubular 118. The projections 351 engage the tubular 118 as indicated by the dashed lines a distance W from the piercing point. In some cases, the blades 150 may be configured such that the shavers 302 do not pass through the tubular 118. For example, the width W may be greater than a radius of the tubular 118 such that the tubular 118 passes between the shavers 302.

Figures 18A-18B show a pair of different blades 150a,b engaging the tubular 118 from opposite sides thereof. As shown by these figures, the projections 300 may

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contact the tubular 118 at various times relative to the shavers 302. As shown in Figure 18A, the shavers 302 of blade 150a contact the tubular 118 before the piercing point 300. The shavers 302 of blade 150b contact the tubular 118 simultaneously with the piercing point 300. These figures further depict the piercing action of the
5 piercing point 300 and the shavers 302 as they pierce the tubular. One or more piercing points, projections and/or points may be provided to selectively pierce various parts of the tubular at a desired time. The piercing action of a first blade 150a may be selected for cooperation with a piercing action of a second blade 150b.

Figure 18B shows another pair of different blades 150a,b engaging the tubular
10 118. As shown by these figures, a blade 150b may be paired with a blade 150a having no piercing points, projections and/or points. The blade 150b is depicted as the same blade 150b of Figure 17B, but may be any blade. The blade 150a has shavers 302 with a single recess 304 therebetween to support the tubular 118 during the severing operation. The recess 304 of blade 150a may be configured to align the
15 tubular 118 into a desired position for optimum contact with the blade 150b. As also shown in Figure 18B, the shavers 302 may be positioned for engagement with the tubular 118, or not.

While specific blades are depicted in specific positions about the tubular 118 of Figures 17-18B, it will be appreciated that any combination of blades herein may
20 be used and positioned as the upper and/or lower blade 150a,b. Additionally, the selected blades may be sized for severing a desired portion of a given tubular.

The upper and lower blades 150 a,b may employ the same blades. Alternatively, the blades 150a,b may be different. For example, the upper blade 150a may have a shape as shown in Figure 16A and the lower blade 150b may have a
25 shape as shown in Figure 16G, as shown in Figure 17. In some cases, it may be advantageous to have one blade 150 with a piercing point 300 and the other blade 150b to have a recess 304 positioned opposite thereto during operation, as shown in Figure 18B.

Figures 19A-19D depict cross-sectional views of shear areas of the tubular
30 118 severable by blades 150a,b. In a conventional BOP, the shear blades may shear the entire cross section of the tubular 118 at once. The blades 150a and 150b of Figures 19A-D are configured to remove material from the tubular 118 in a multi-phase process. The multi-phase process occurs as the blades 150a and 150b remove and/or displace sections of the tubular 118 until the tubular 118 is severed. Removing
35 and/or displacing the sections of the tubular 118 at different times and/or using

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different portions of the blades 150a and 150b may be used to reduce the force required by the BOP 108 to sever the tubular 118.

Figures 19A-19D depict the tubular 118 broken into sections for descriptive purposes. A central (or initial) engagement section 1900 may be a section of the tubular 118 proximate the piercing point 300 of the blades 150a and/or 150b. For descriptive purposes, blade 150b is depicted in hidden line to show operation of the blade 150a as it pierces and rakes through tubular 118. The central engagement section (or central portion) 1900 may be the section of the tubular 118 wherein the piercing point 300 engages the tubular 118. A mid engagement section 1902 may be located on either side of the central engagement section 1900. The mid engagement section 1902 may be engaged by the troughs 304. An outer engagement section 1904 (or outer portion) may be located on both sides of the tubular 118 offset from the central engagement section 1900. The outer engagement sections 1904 may be engaged by the troughs 304 and/or shavers 302.

The contact surfaces of the blades 150a,b can be defined by the geometry. The blades 150a,b may be configured to selectively pass through the tubular 118 to reduce shear forces during the severing process. As shown in Figures 19A, 19C and 19D, the troughs 304 may contact the mid and outer engagement sections 1902 and 1904. Additionally, the piercing point 300 may be positioned to engage the central engagement section 1900 before, during or after the troughs 304 and/or shavers 302 contact the tubular 118. The piercing point 300 may be positioned relative to the shavers 302 and the trough 304, such that the outer engagement section 1904 may be engaged before, during or after the mid engagement sections 1902, 1904 are engaged by the troughs 304.

As shown by Figures 19A and 19B, the blades 150a,b may be located at a position for contacting various portions of the tubular 118. The blade 150a of Figure 19A is positioned to engage central engagement section 1900. As shown in Figure 19B, the piercing point 300 may be shifted or offset from the central portion of the tubular (or the central engagement section 1900). The piercing point 300, shavers 302 and recesses 304 may be configured to contact desired portions of the tubular to achieve the desired contact locations and sever the tubular 118.

Figure 19C and 19D shows the blade 150a engaging the tubular 118 and dislodging a portion (or slug) of the tubular at central engagement section 1900. As shown in Figures 19A and 19B, blade 150a has a piercing point 300. However, it will be appreciated that blade 150b may engage the tubular and perform the same

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piercing, raking and severing function from an opposite side to the blade 150a to provide severing from both sides of the tubular 118.

The piercing point 300 of blade 150a may be used to pierce the central engagement section 1900. As shown, a chunk of material in section 1900 may be dislodged from the tubing. The blade 150 advances through the tubular 118 and engages the mid engagement sections 1902 along the recesses 304. As the recesses 304 contact the tubular 118, they rake through the tubular 118 and remove material therefrom. The blade 150a may continue to advance into the tubular 118 and wedge along the mid and outer engagement sections 1902, 1904 to sever the tubular 118, or until the tubular 118 breaks apart.

Similar or different blades 150a and 150b may be used to engage the tubular 118 on opposite sides. The opposing blades 150a,b may completely sever through the tubular 118 during the operation. The opposing blades 150a,b may optionally pierce, rake and/or cut through a portion of the tubular 118 and the remainder may fail and break apart on its own. The tubular 118 may optionally be placed under tension and/or torque during the process to facilitate severing.

Although only certain sections are shown, it should be appreciated that each of the sections may be broken up into smaller sections. Further, any portion of the blades 150a and/or 150b may be configured to engage the sections 1900, 1902 and/or 1904 as desired. In some cases, as the blades 150a and/or 150b may engage the tubular 118, the piercing point may pierce and/or remove a portion of the tubular 118 and the shavers 304 may rake through the tubular 118 until the tubular shears either by passing the blades 150a,b completely through the tubular 118 or until the tubular fails and separates.

In operation, the piercing point 300 of the blades 150a and/or 150b may engage the initial engagement section 1900. The troughs 204 of blades 150a and/or 150b then remove and/or displace remaining portions of the initial engagement section 1900. The troughs 304 of the blades 150a and/or 150b may then engage the secondary engagement sections 1902. The troughs 304 may then remove and/or displace the mid engagement sections 1902, or portions thereof. As the blades 150a and/or 150b continue in the cutting direction, the blades 150a and/or 150b may sever the outer engagement section 1904 of the tubular 118 thereby severing the tubular 118. The blades 150a and/or 150b may be configured to engage any of the sections herein at different times. For example, the blades 150a and/or 150b may engage the secondary engagement section 1902 first followed by the initial engagement section

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1900 and/or the final engagement section 1904.

Figures 20A – 20D depict portions of the tubular 118 of Figure 19 having a tool joint 2000 that has been engaged and severed by the blades 150a and/or 150b of, for example, Figures 20G and 20H. These figures depict various views of the tubular 118 severed into upper portions 118a and lower portions 118b as shown in Figure 2C. For descriptive purposes, Figures 20A and 20B show the upper and lower portions 118a,b stacked together. Figures 20A and 20B separately show the upper and lower portions 118a,b, respectively. Figures 20E and 20F depict the removed sections and/or portions (or slugs) of the initial engagement sections 1900 after being removed from the tool joint 2000 of Figures 20A-20D. Although, the removed initial engagement section 1900 is shown as one removed piece, or slug, it may take any suitable form. For example, the initial engagement section 1900 may be in several pieces, may not detach from the tool joint, may split into two pieces, may be displaced, and the like. Figures 20G and 20H depict an example of the blade 150a and/or 150b used to sever the tool joint 2000. Any of the blades 150 described herein may have been used to sever the tool joint 2000.

In cases where a tubular 118 is particularly thick, for example, having a thickness of 8.5" (21.59 cm) or more or more with a thick wall of greater than about 1" (2.54 cm), such as a tool joint, the shear forces used by the blades may be extremely high. By distributing the forces along the blades using the configurations provided herein, the piercing point 300 may be used to pierce the tubular 118 and remove a slug, such as initial engagement section 1900 as depicted in Figures 20E-20F. The cutting surfaces 306 may rake through the tubular 118 to remove pieces of the tubular dislodged by the blade and pass through the remainder of the tubular 118, such as middle engagement section 1902 and/or final engagement section 1904. In cases where the shavers 302 contact the tubular 118, the shavers 302 may also be used to pierce and/or rake through final engagement section 1904 of the tubular 118 as shown in Figures 20A-20D. Depending on the geometry selected (see for example the blade profiles of Figures 16A-J), the initial points of contact and/or piercing may be varied.

In Figures 20A-20D, the tool joint 2000 is shown with its severed tool joint sections 2001 to illustrate the cutting mechanics of the blade 150a and/or 150b used to sever the tool joint 2000. The initial engagement portion 1900 has been engaged by the piercing point 300 and removed from the tool joint 2000 by the blades 150a and/or 150b, as shown by an aperture 2002 in the tool joint 2000 of Figures 20A-

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20B. The secondary engagement section 1902 has been partially displaced and/or removed by the recesses 304 of the blades 150a and/or 150b, as can be seen by a semi-circular wedge 2003 removed from the tool joint 2000. The final engagement section 1904 is engaged by the recesses 304 and/or shavers 302 and may have
5 substantially less material removed from it, and may be a cut line 2005 by severing or by failure of the tubular 118.

Figure 21A depicts a force (F) versus time (t) graph 2100 for tubular 118 severed by, for example, the blades 150a and/or 150b (as shown in Figure 1). A force (F) applied to the blades 150a and/or 150b may be shown on the Y-axis of the graph,
10 and a time (t) for severing using the blades 150a and/or 150b may be shown on the X-axis of the graph.

The graph 2100 shows that the force F in the blades 150a and/or 150b increases as time t progresses until the initial piercing (or removal and/or deformation) of the initial engagement section 1900 by blade 150a as shown by
15 initial puncture point 2106. After the initial puncture point 2106 is breached (e.g., when initial engagement section 1900 is dislodged as shown in Figure 19B), the force F in the blades 150a and/or 150b may drop dramatically with time, until an opposing blade 150b engages an opposite initial engagement section 1900. Once the opposing blade 150b has dislodged initial engagement section 1900 as shown at point 2106,
20 second engagement section 1902 is engaged by each of the blades 150a,b as shown as shown by secondary engagement points 2108. The force F then increases with time t as the blades 150a and/or 150b may begin to rake through (and/or cut, puncture, and/or shear) the secondary engagement section 1902 (e.g., as shown in Figure 19C). The force F may then rise and drop as time t progresses as sections of the tubular 118
25 are removed and/or displaced by the blades 150a and/or 150b, until the tubular 118 is severed, as shown by sever points 2110.

Figure 21B depicts a force versus time graph 2120 for several thin walled tubulars severed by a conventional shear blade (not shown) compared to the several thin wall tubulars severed by the blades 150a and 150b of Figure 2. The conventional
30 shear blades are represented by three conventional shear blade plots 2111a-c, respectively, on the force versus time graph 2120. The blades 150a and/or 150b are represented by three blade plots 2113d-f, respectively, on the force versus time graph 2120.

The conventional shear blade as depicted severs the whole shear area of the
35 tubular at once. As can be seen the force F required to sever the thin wall tubular

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using the conventional shear blades, the force applied to the blades may continually increase with time as the conventional shear blade shears the thin walled tubulars. The force in the conventional shear blades may rise until a peak conventional blade force 2112a-c, respectively, is reached and the thin walled tubulars are cut.

5 The blades 150a and/or 150b may pierce, rake, cut, shear, displace, and/or remove sections of the tubular independent of one another. As can be seen the force required to sever the thin walled tubulars by the blades 150a and/or 150b, the force of the blades 150a and/or 150b may rise and fall until a peak blade force 2114d-f is reached and the thin walled tubular is severed. Therefore, the force required to sever
10 the tubular 118 with the conventional shear blade may be much greater than the force F required to sever the tubular 118 with the blades 150a and/or 150b. Further, the conventional shear blades may be unable to shear large thick walled tubular and/or tool joints 2000.

 Figures 22A and 22B depict methods 2200a and 2200b of severing a tubular.
15 The method 2200a involves positioning (2280) a BOP about the tubular of the wellbore (the BOP having a plurality of rams slidably positionable therein), providing (2282) each of the rams with a blade, piercing (2284) a hole in the tubular with a tip of the piercing point of the blade, and raking (2286) through the pierced tubular with the cutting surface of the blade.

20 The method 2200b involves positioning (2281) a BOP about the tubular of the wellbore, the BOP having a plurality of rams slidably positionable therein (the blowout preventer having a plurality of opposing rams slidably positionable therein and a plurality of blades carried by the plurality of opposing rams for engaging the tubular), piercing (2283) the tubular with a piercing point of at least one of the blades
25 such that a portion of the tubular is dislodged therefrom, and raking (2285) through the tubular with a cutting surface of at least one of the blades to displace material of the tubular.

 The raking of either method may be performed using the cutting surfaces and/or shavers. The cutting surfaces may also be used to pierce a hole in the tubular.
30 Steps of either method may be used together, repeated and/or performed in any order.

 It will be appreciated by those skilled in the art that the techniques disclosed herein can be implemented for automated/autonomous applications via software configured with algorithms to perform the desired functions. These aspects can be implemented by programming one or more suitable general-purpose computers
35 having appropriate hardware. The programming may be accomplished through the

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use of one or more program storage devices readable by the processor(s) and encoding one or more programs of instructions executable by the computer for performing the operations described herein. The program storage device may take the form of, e.g., one or more floppy disks; a CD ROM or other optical disk; a read-only memory chip (ROM); and other forms of the kind well known in the art or
5 subsequently developed. The program of instructions may be "object code," i.e., in binary form that is executable more-or-less directly by the computer; in "source code" that requires compilation or interpretation before execution; or in some intermediate form such as partially compiled code. The precise forms of the program
10 storage device and of the encoding of instructions are immaterial here. Aspects of the invention may also be configured to perform the described functions (via appropriate hardware/software) solely on site and/or remotely controlled via an extended communication (e.g., wireless, internet, satellite, etc.) network.

While the embodiments are described with reference to various
15 implementations and exploitations, it will be understood that these embodiments are illustrative and that the scope of the inventive subject matter is not limited to them. Many variations, modifications, additions and improvements are possible. For example, any of the blades shown herein, may be used in combination with other shaped blades herein, and/or conventional blades. Further, any of the blades may
20 have the replaceable tips 400. The piercing point 300 may extend beyond the blade cutting surfaces, or be recessed therebehind. The piercing points 300 may be rounded or pointed. The recesses may be rounded, squared or other geometries.

Plural instances may be provided for components, operations or structures described herein as a single instance. In general, structures and functionality
25 presented as separate components in the exemplary configurations may be implemented as a combined structure or component. Similarly, structures and functionality presented as a single component may be implemented as separate components. These and other variations, modifications, additions, and improvements may fall within the scope of the inventive subject matter.

30

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CLAIMS

1. A blade for severing a tubular of a wellbore, the wellbore penetrating a subterranean formation, the blade extendable by a ram of a blowout preventer
5 positionable about the tubular, the blade comprising:
 - a blade body having a front face on a side thereof facing the tubular, at least a portion of the front face having a vertical surface and at least a portion of the front face having an inclined surface, the vertical surface perpendicular to a bottom surface of the blade body, the blade body
10 comprising:
 - a loading surface on an opposite side of the blade body to the front face, the loading surface receivable by the ram;
 - a cutting surface along at least a portion of the front face for engagement with the tubular; and
 - 15 a piercing point along the front face for piercing the tubular, the piercing point having a tip extending a distance from the cutting surface.
2. The blade of Claim 1, wherein the piercing point is positioned along a central portion of the front face.
- 20 3. The blade of Claim 1, wherein the piercing point is offset from a central portion of the front face.
4. The blade of Claim 1, 2 or 3, wherein the blade body further comprises at least one trough along the front face.
5. The blade of Claim 4, wherein the trough is flat.
- 25 6. The blade of Claim 4, wherein the trough is curved.
7. The blade of any preceding Claim, wherein the tip is pointed.
8. The blade of any of Claims 1 to 6, wherein the tip is rounded.
9. The blade of any of Claims 1 to 6, wherein the tip is inverted.
10. The blade of any of Claims 1 to 6, wherein the tip is flat.
- 30 11. The blade of any preceding Claim, wherein the tip has at least one bevel extending therefrom.
12. The blade of any preceding Claim, wherein the tip has a pair of puncture walls adjacent thereto.
13. The blade of any preceding Claim, wherein at least a portion of the piercing
35 point has an angled blade step.

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14. The blade of any preceding Claim, wherein at least a portion of the piercing point is stepped.

15. The blade of any of Claims 1 to 13, wherein at least a portion of the piercing point is serrated.

5 16. The blade of any of Claims 1 to 15, wherein at least a portion of the piercing point is replaceable.

17. The blade of any preceding Claim, wherein a top surface of the blade body is stepped.

10 18. The blade of any preceding Claim, wherein the inclined surface is at an acute angle to the bottom surface of the blade.

19. The blade of any preceding Claim, wherein the blade body has a geometry to provide at least a portion of the cutting surface and the tip with simultaneous contact with the tubular.

15 20. The blade of any of Claims 1 to 18, wherein the blade body has a geometry to provide the tip with initial contact with the tubular.

21. The blade of any of Claims 1 to 18, wherein the blade body has a geometry to provide a portion of the cutting surface with initial contact with the tubular.

20 22. The blade of any preceding Claim, wherein the blade body further comprises a pair of shavers along the front face, the pair of shavers positioned a distance from the tip on either side thereof for engagement with the tubular.

23. The blade of Claim 22, wherein the pair of shavers each has a projection extending a distance beyond the cutting surface.

25 24. A blade for severing a tubular of a wellbore, the wellbore penetrating a subterranean formation, the blade extendable by a ram of a blowout preventer positionable about the tubular, the blade comprising:

a blade body having a front face on a side thereof facing the tubular, the blade body comprising:

a loading surface on an opposite side of the blade body to the front face, the loading surface receivable by the ram;

30 a cutting surface along at least a portion of the front face for engagement with the tubular;

a piercing point along the front face for piercing the tubular, the piercing point having a tip extending a distance from the cutting surface; and

35 a pair of shavers along the front face of the blade body, each of the pair

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of shavers having a projection extending a distance beyond the cutting surface, the pair of shavers positioned a distance from the tip on either side thereof for engagement with the tubular.

25. The blade of Claim 24, wherein each projection has a leading edge for
5 engagement with the tubular.
26. The blade of Claim 25, wherein the leading edge is linear.
27. The blade of Claim 25 or 26, wherein the leading edge has an exit angle.
28. The blade of Claim 27, wherein the exit angle is greater than zero.
29. The blade of any of Claims 25 to 28, wherein the leading edge is stepped.
- 10 30. The blade of any of Claims 25 to 29, wherein the leading edge is curved.
31. The blade of any of Claims 24 to 30, wherein the tip extends further from the cutting surface than each of the projections.
32. The blade of any of Claims 24 to 30, wherein each of the projections extends further from the cutting surface than the tip.
- 15 33. The blade of any of Claims 24 to 32, wherein the blade body further comprises at least one recess between the tip and each of the projections.
34. A blowout preventer for severing a tubular of a wellbore, the wellbore penetrating a subterranean formation, the blowout preventer comprising:
a housing having a channel therethrough for receiving the tubular;
20 a plurality of rams slidably positionable in the housing;
at least one pair of opposing blades supportable by the plurality of rams and selectively extendable thereby, at least one of the pair of opposing blades comprising a blade as claimed in any of Claims 1 to 33.
35. The blowout preventer of Claim 34, wherein the pair of opposing blades are
25 the same.
36. The blowout preventer of Claim 34, wherein at least a portion of the pair of opposing blades are different.
37. The blowout preventer of Claim 34, 35 or 36, wherein at least one of the pair of opposing blades comprises a trough for receivingly positioning the tubular for
30 engagement by at least one other of the pair of opposing blades.
38. The blowout preventer of Claim 34, 35, 36 or 37, wherein the pair of opposing blades comprises an upper cutting blade and a lower cutting blade, the upper cutting blade passing through the tubular at a position above the lower cutting blade.
- 35 39. A method of severing a tubular of a wellbore, the wellbore penetrating a

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subterranean formation, the method comprising:

positioning a blowout preventer about the tubular, the blowout preventer

having a plurality of rams slidably positionable therein;

providing each of the rams with a blade, at least one of the blades comprising

5 a blade as claimed in any of Claims 1 to 33.

40. The method of Claim 39, wherein the blade body further comprises a pair of troughs, each of the pair of troughs on either side of the blade body, the step of raking comprising advancing the plurality of rams such that the pair of troughs rake through at least a portion of the tubular.

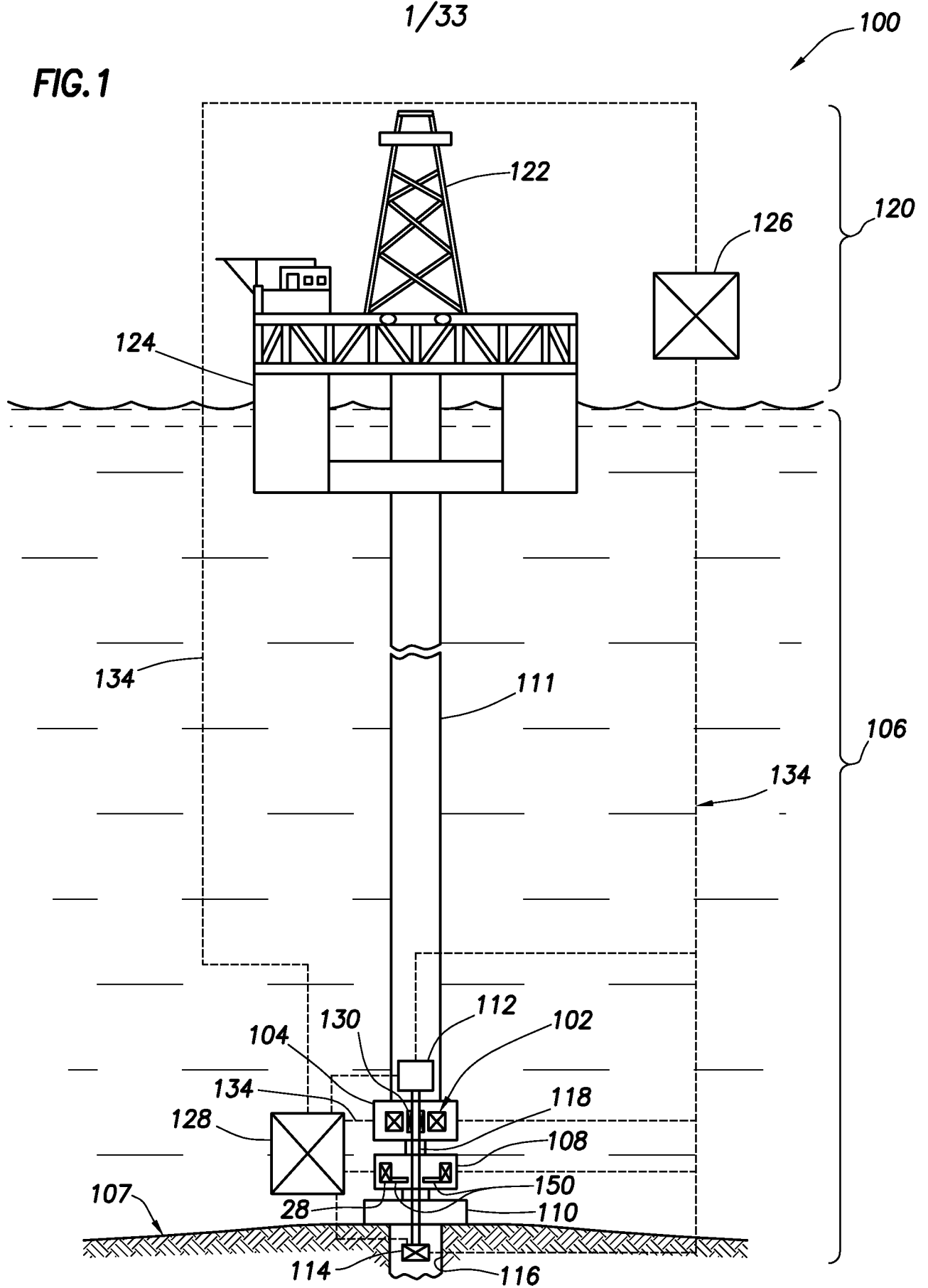
10 41. The method of Claim 39 or 40, wherein the blade body further comprises a pair of shavers, each of the pair of shavers on either side of the tip, the step of raking comprising advancing the plurality of rams such that the pair of shavers rake through at least a portion of the tubular.

42. The method of Claim 39, 40 or 41, wherein the tubular is pierced before the
15 tubular is raked.

43. The method of any of Claims 39 to 42, further comprising continuing to advance the plurality of rams until the tubular is severed.

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FIG. 1



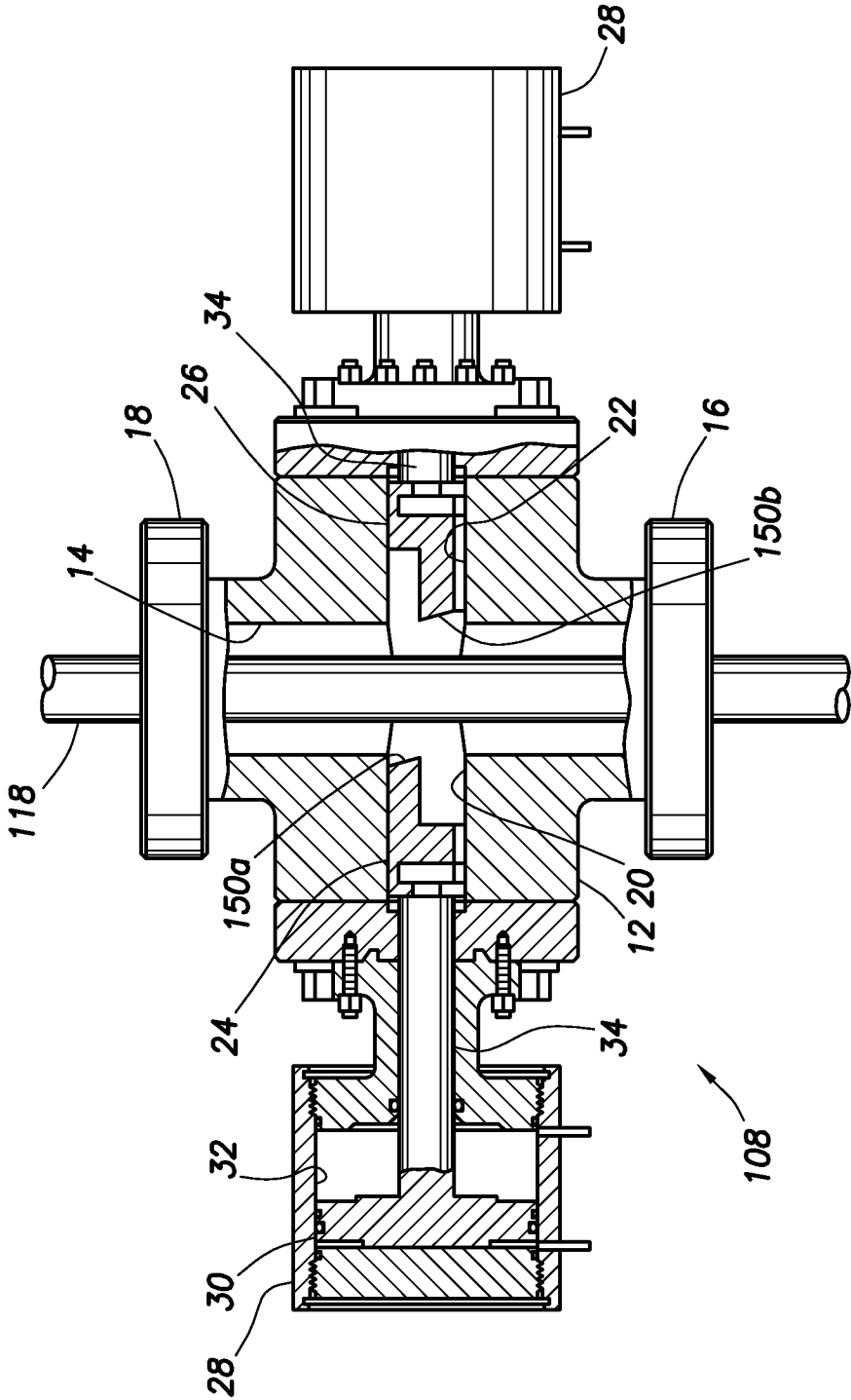


FIG.2A

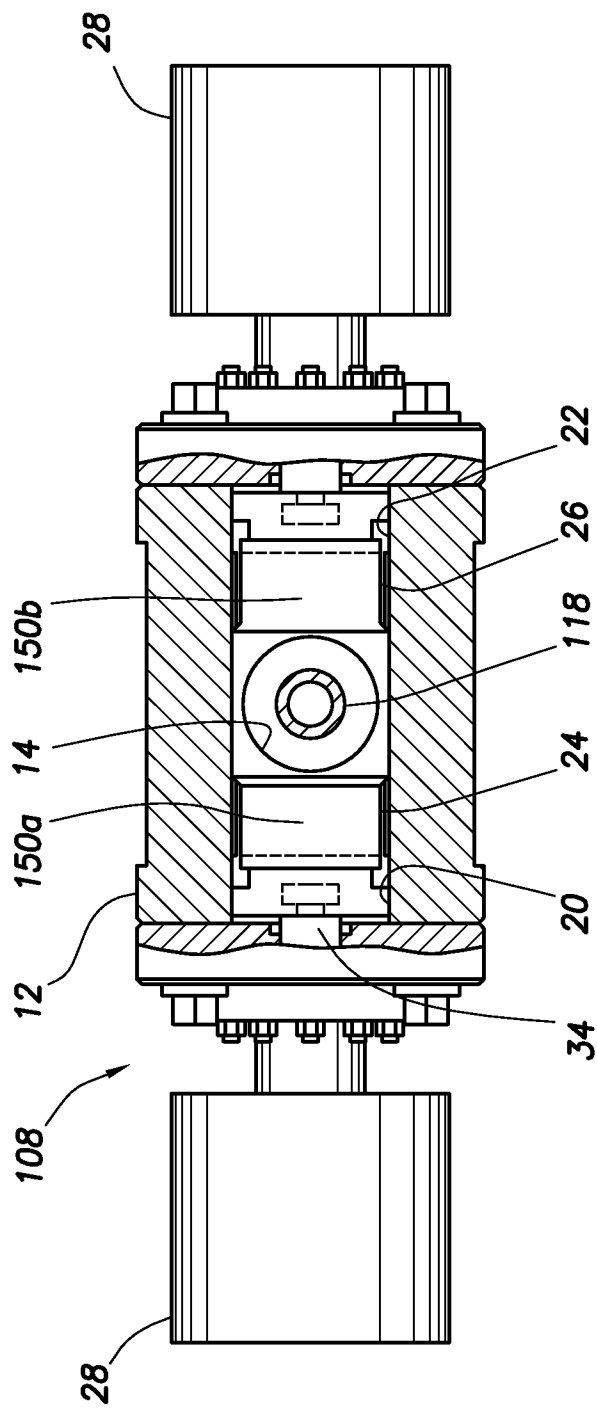


FIG.2B

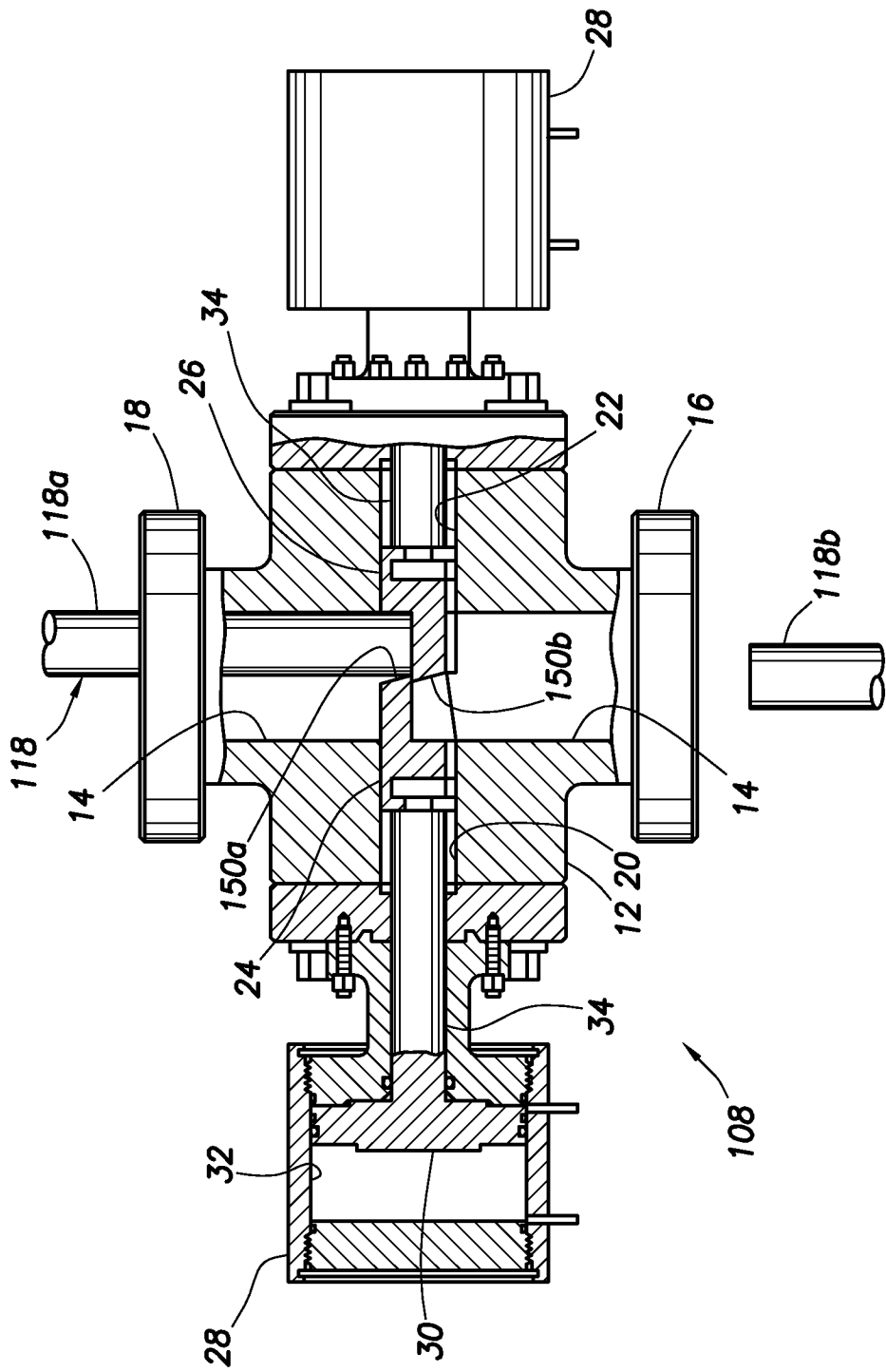
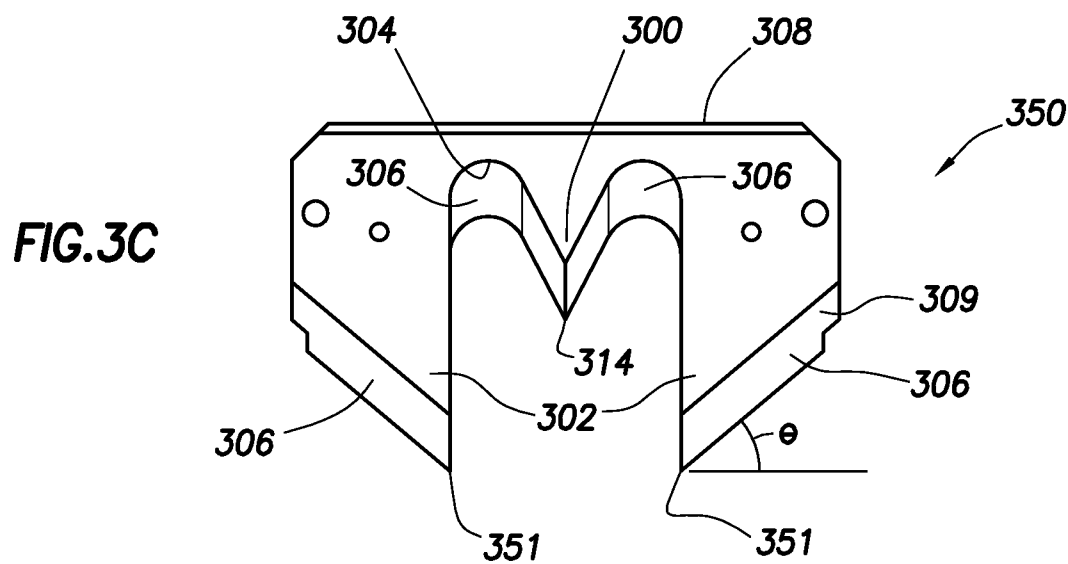
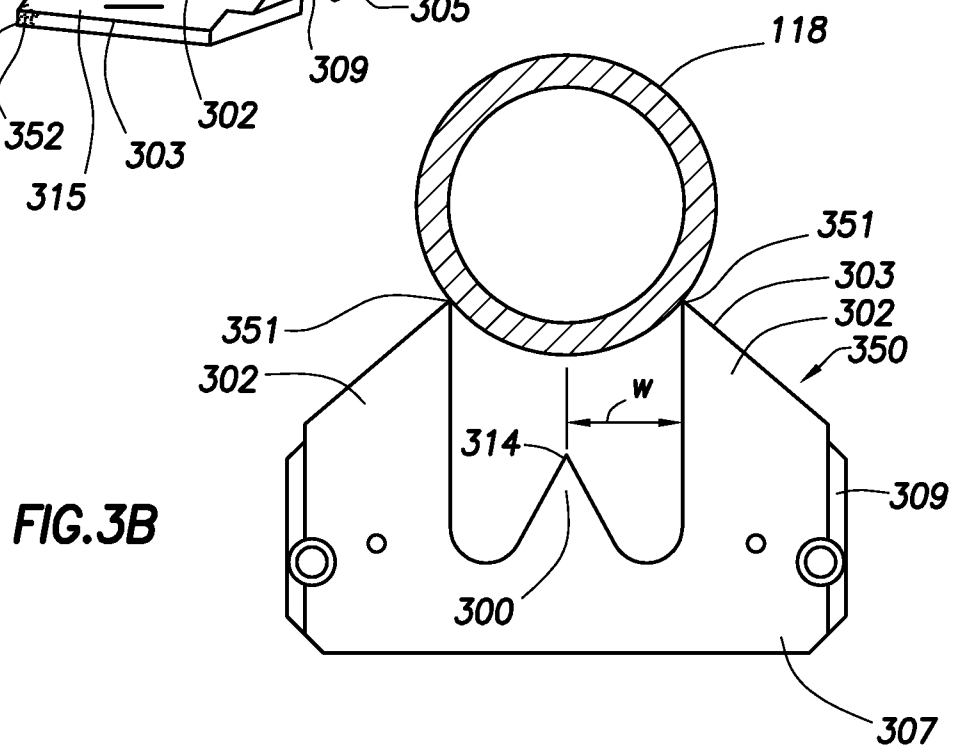
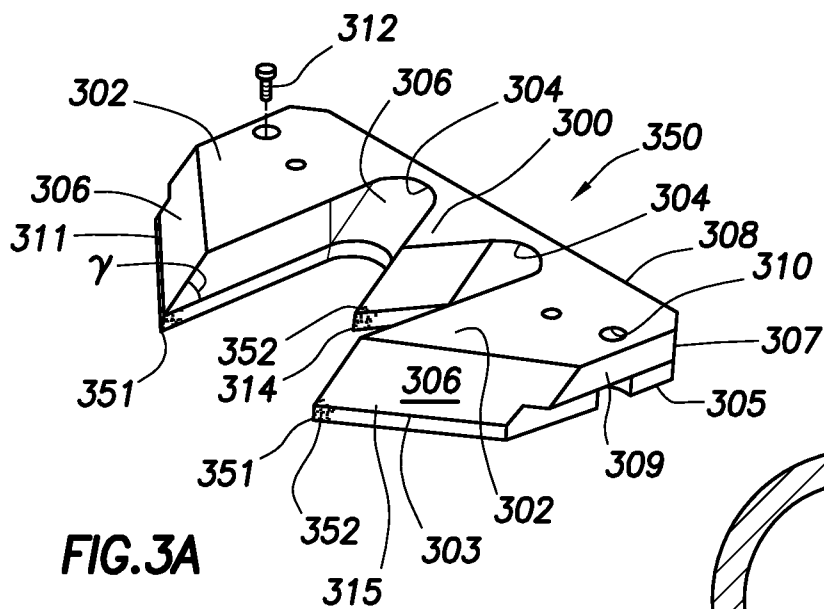


FIG.2C

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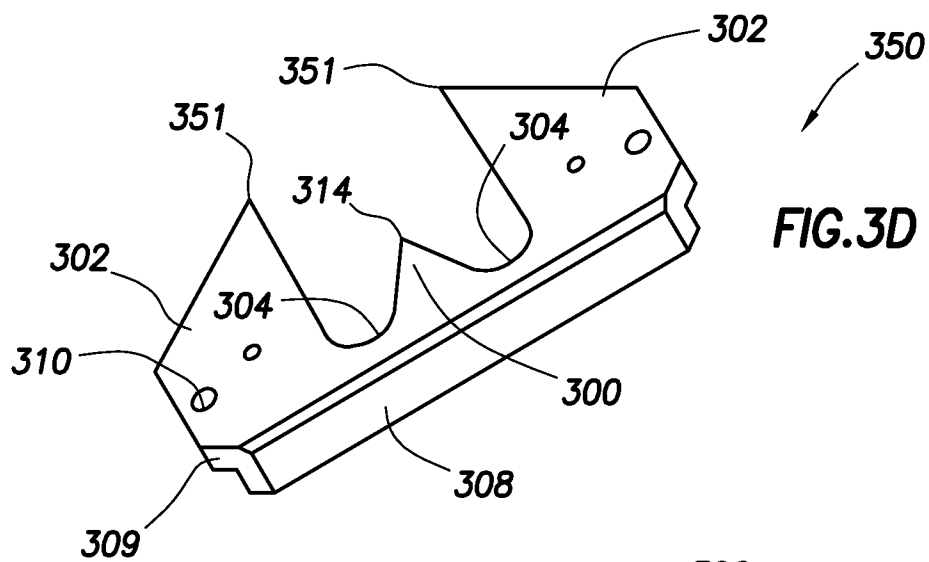


FIG. 3D

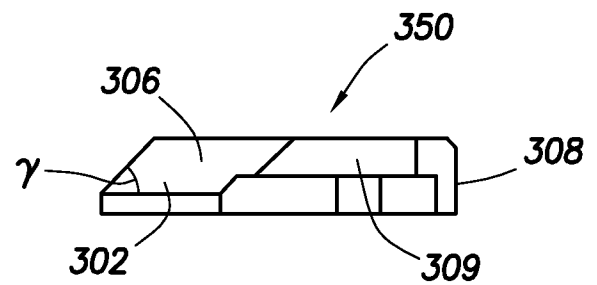


FIG. 3E

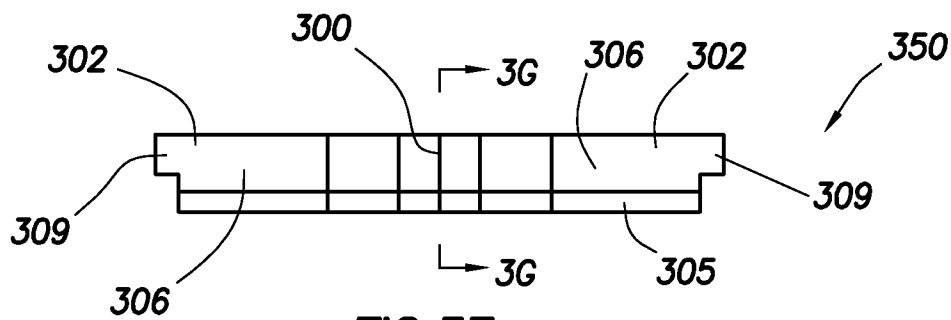


FIG. 3F

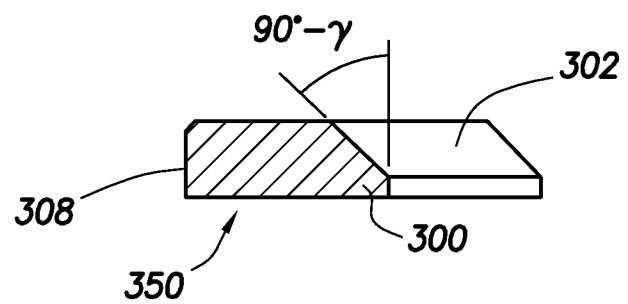


FIG. 3G

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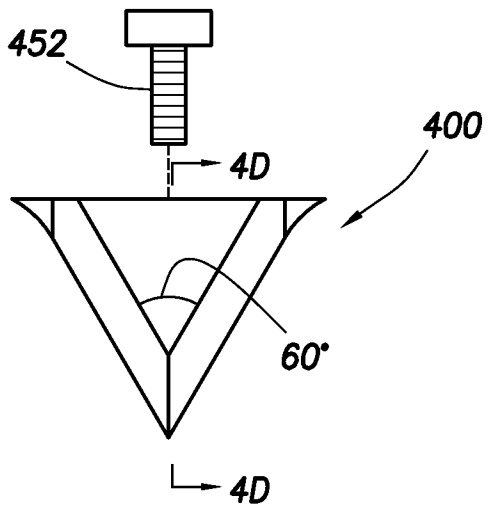


FIG. 4A

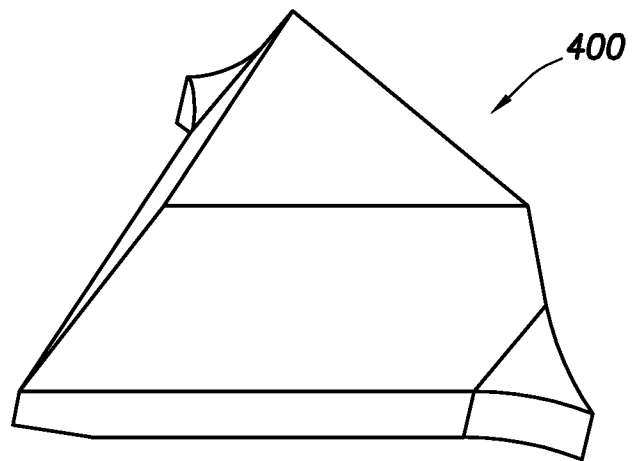


FIG. 4B

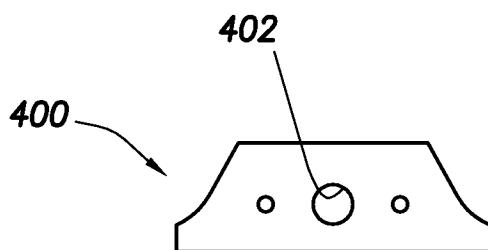


FIG. 4C

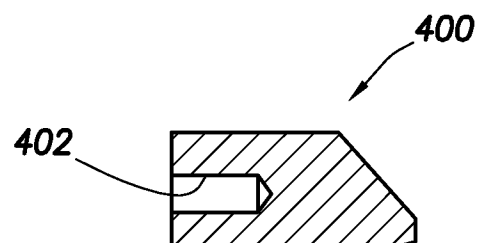
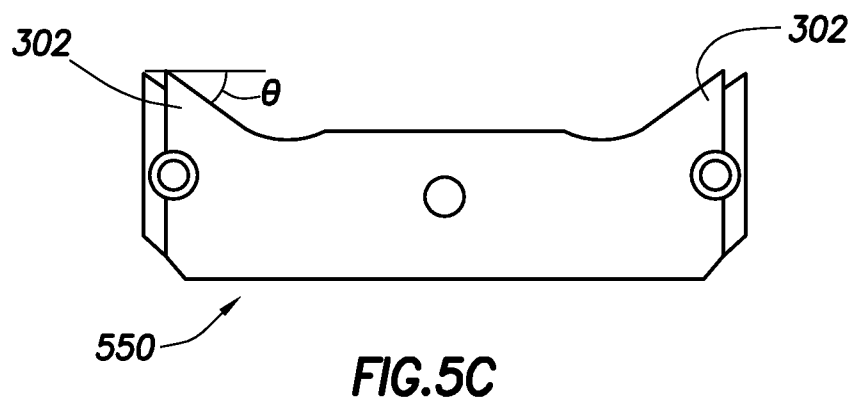
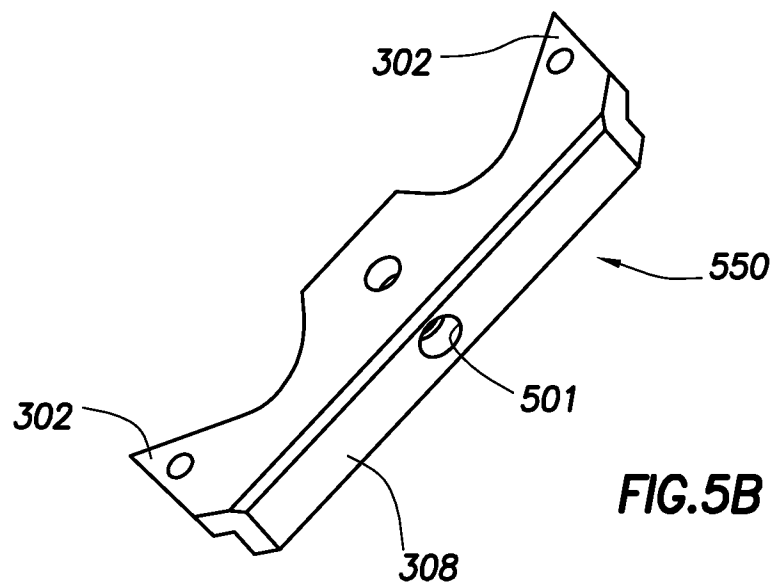
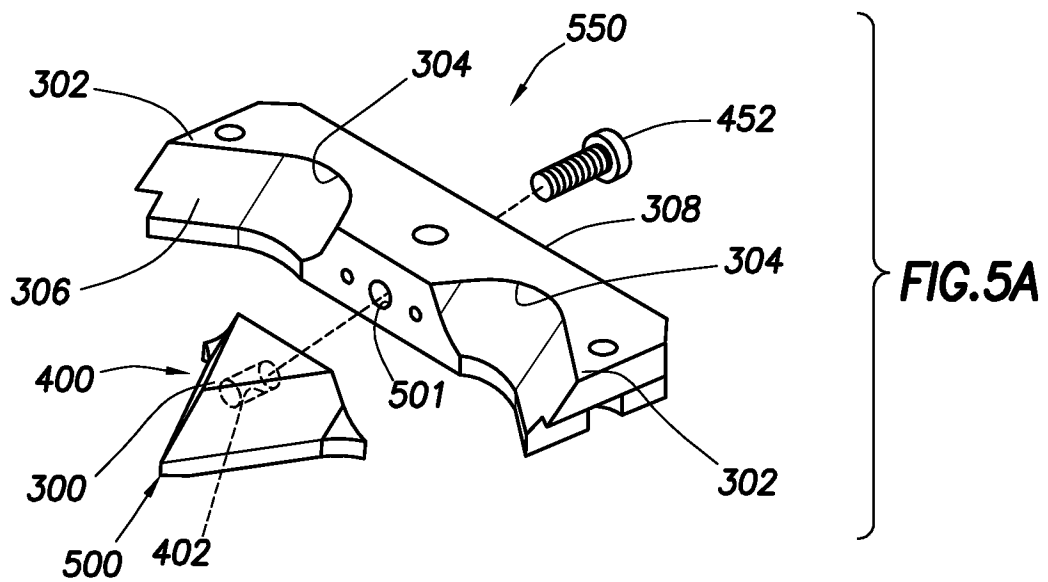


FIG. 4D

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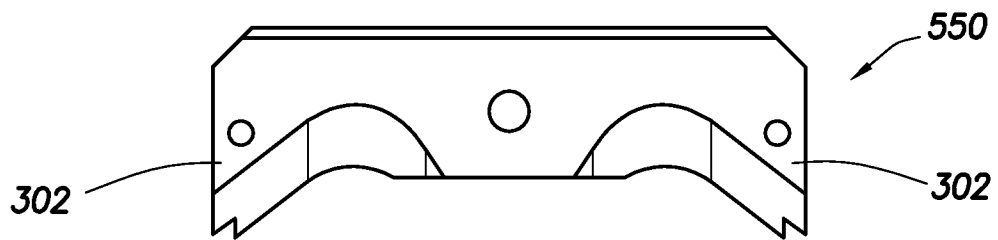


FIG. 5D

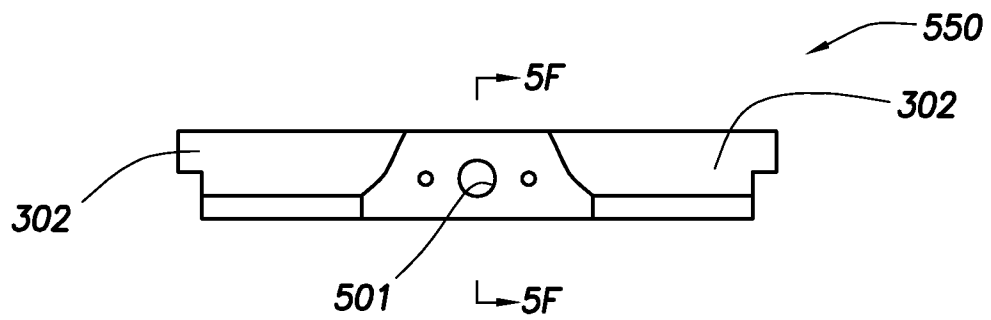


FIG. 5E

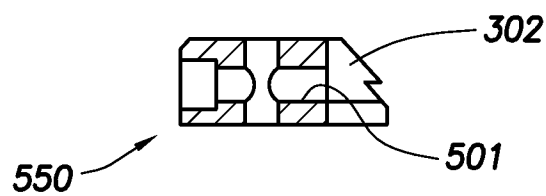


FIG. 5F

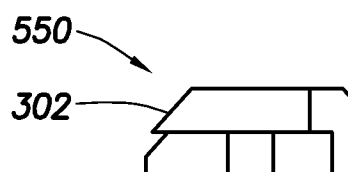
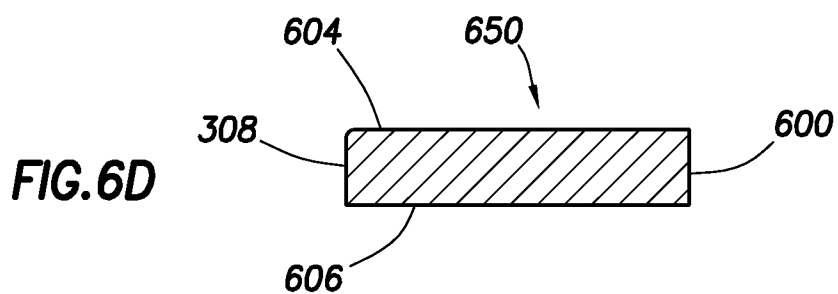
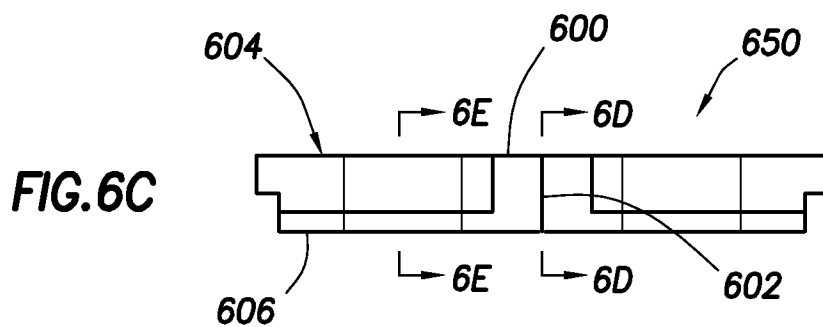
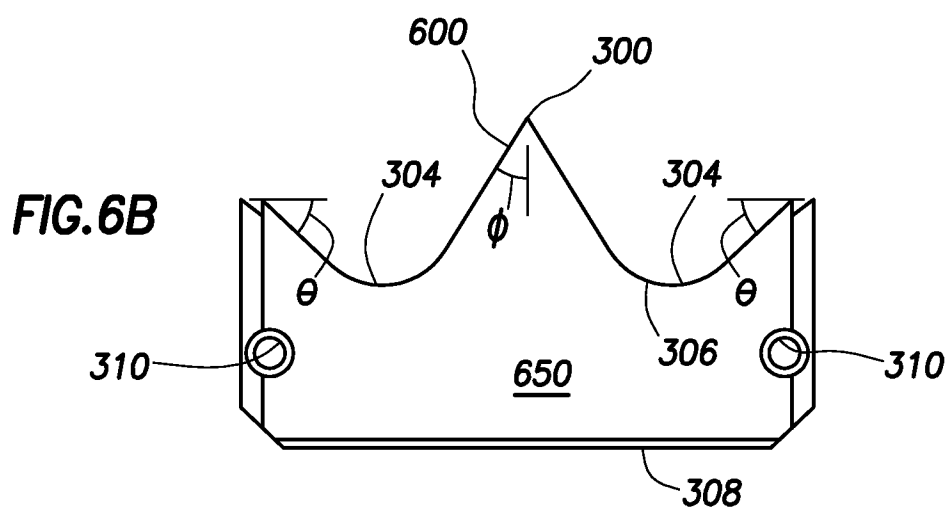
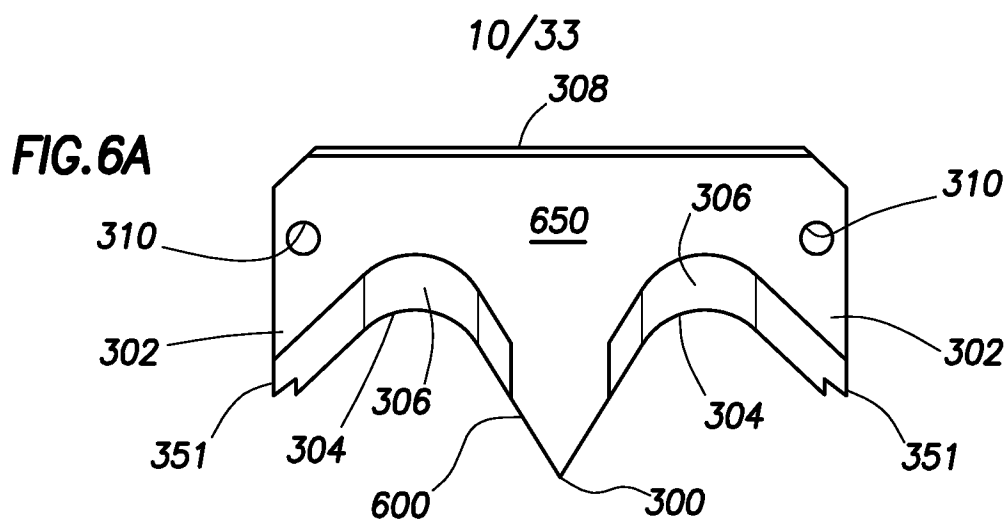


FIG. 5G



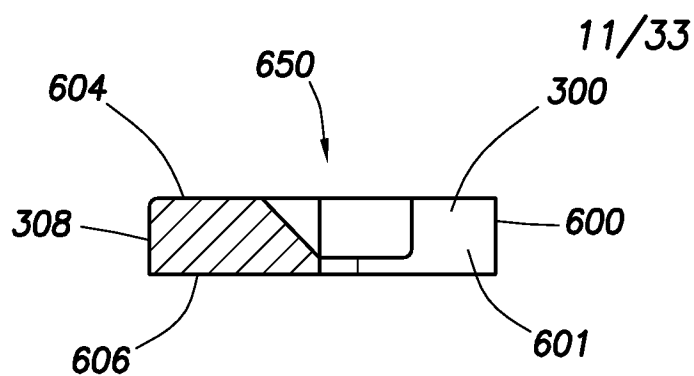


FIG. 6E

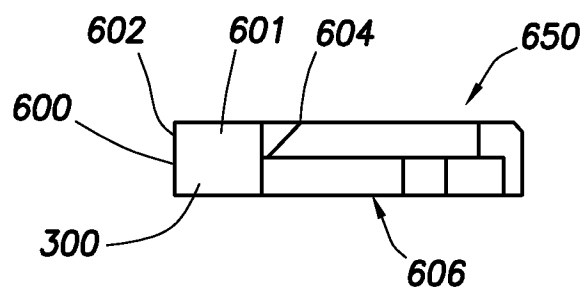


FIG. 6F

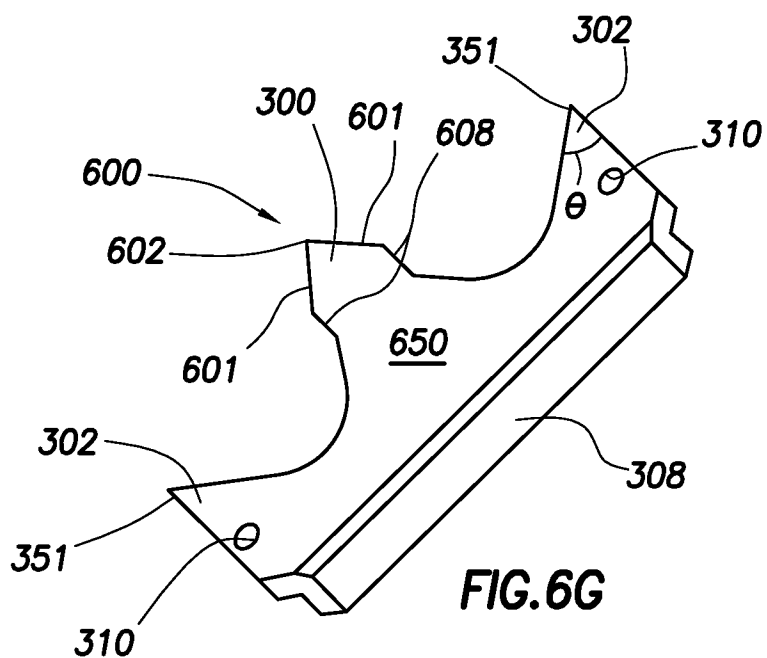


FIG. 6G

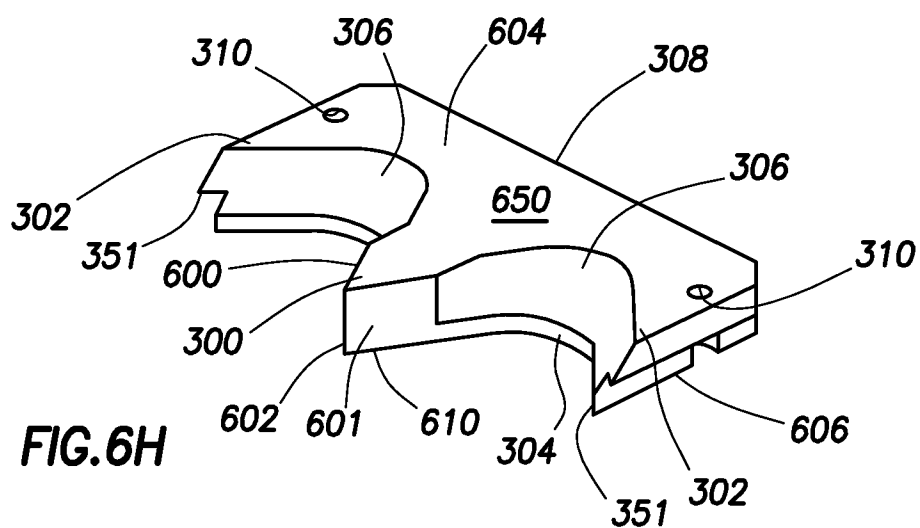
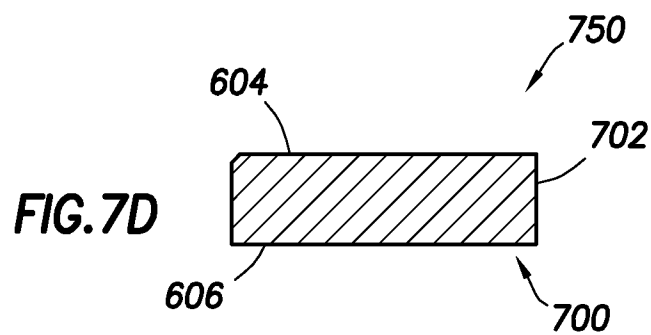
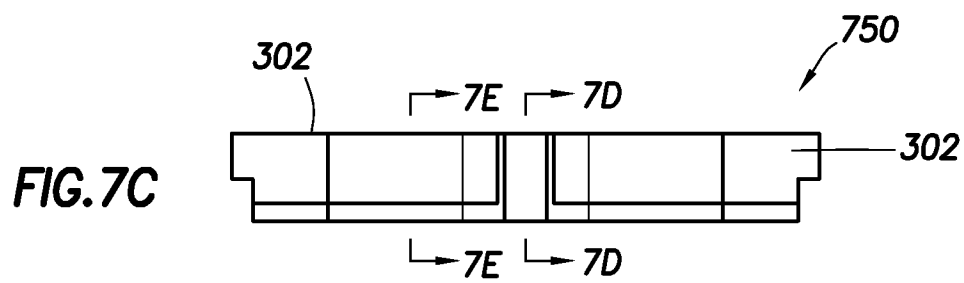
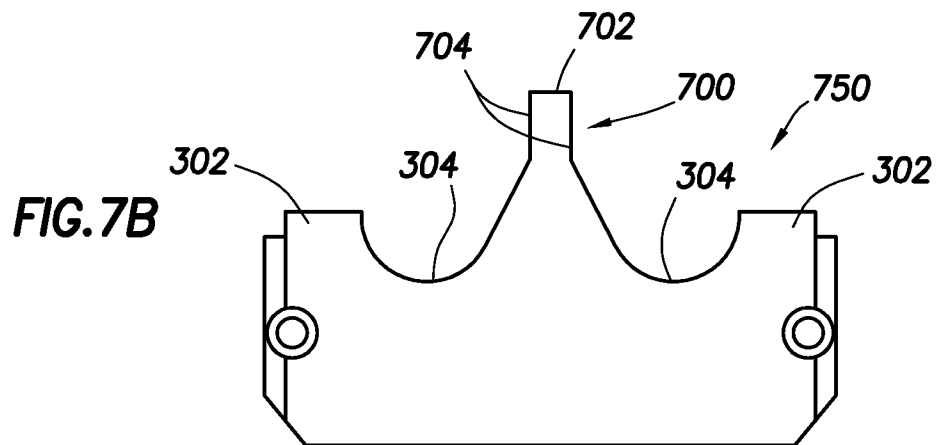
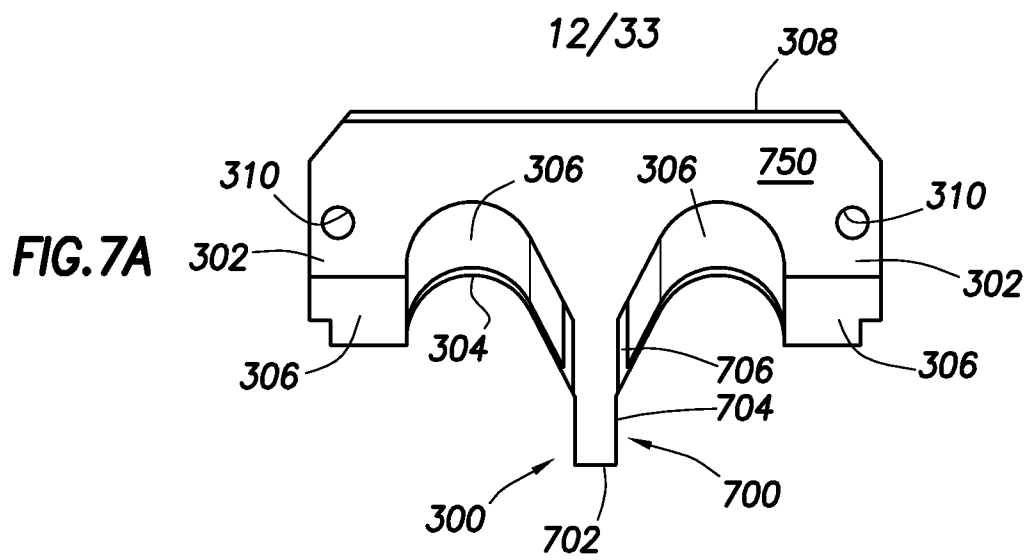


FIG. 6H



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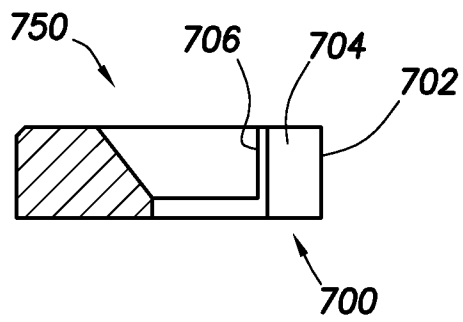


FIG. 7E

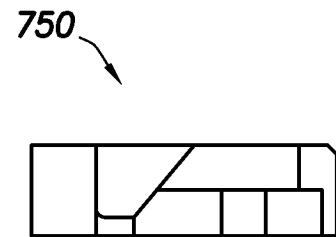


FIG. 7F

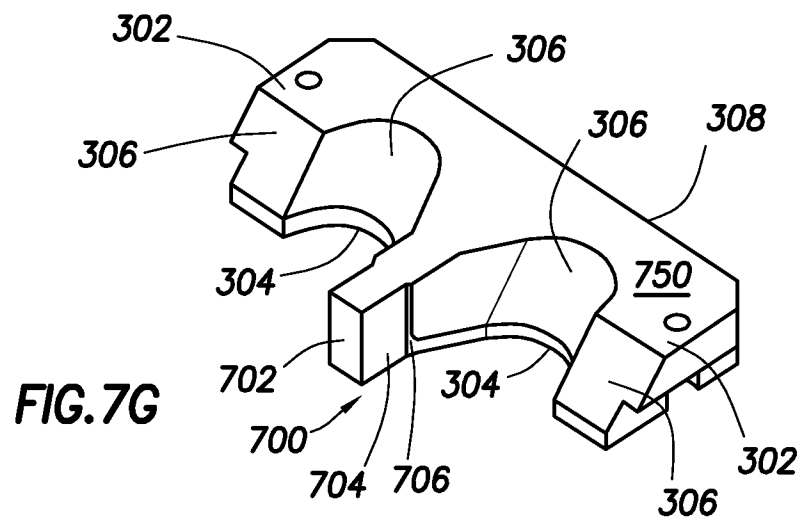
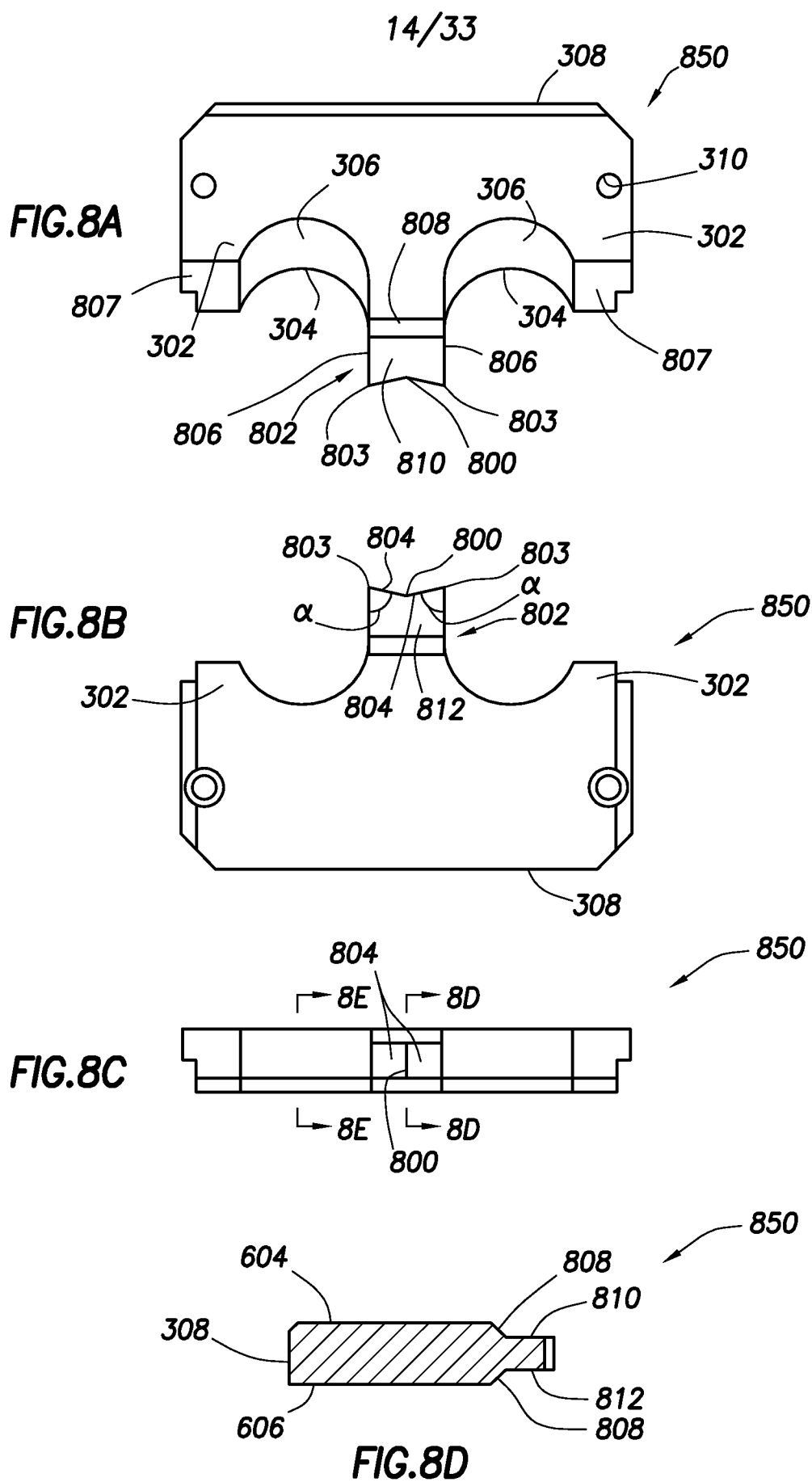


FIG. 7G



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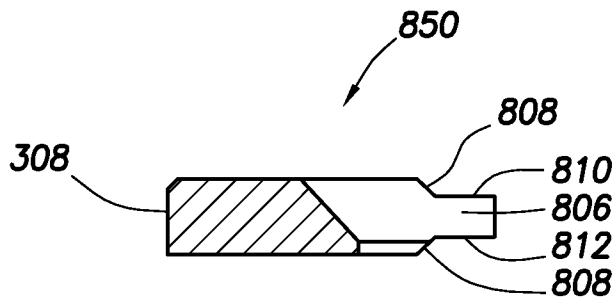


FIG. 8E

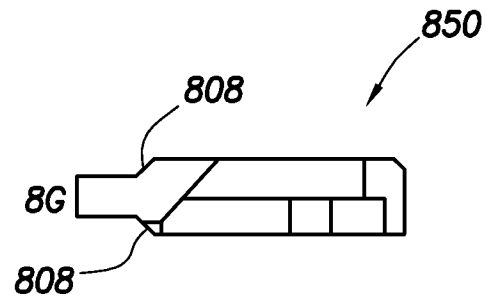


FIG. 8F

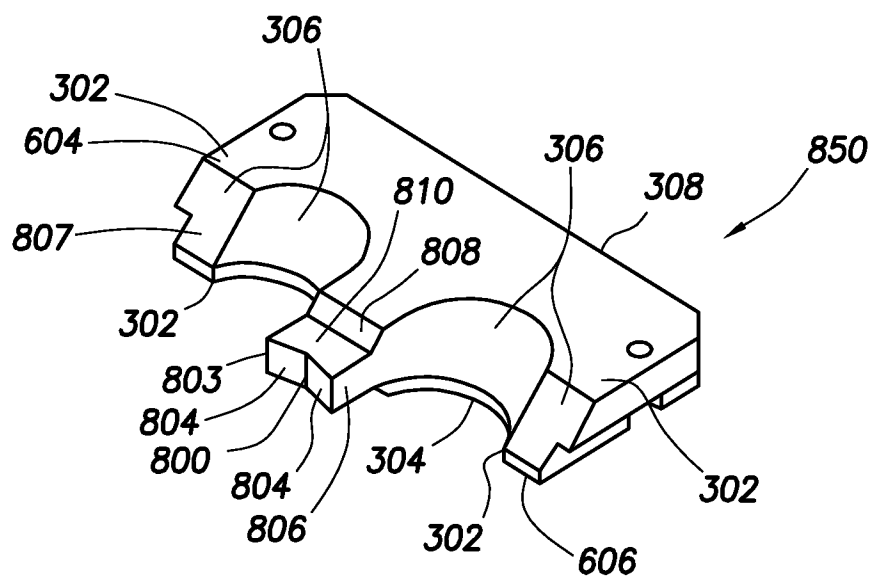


FIG. 8G

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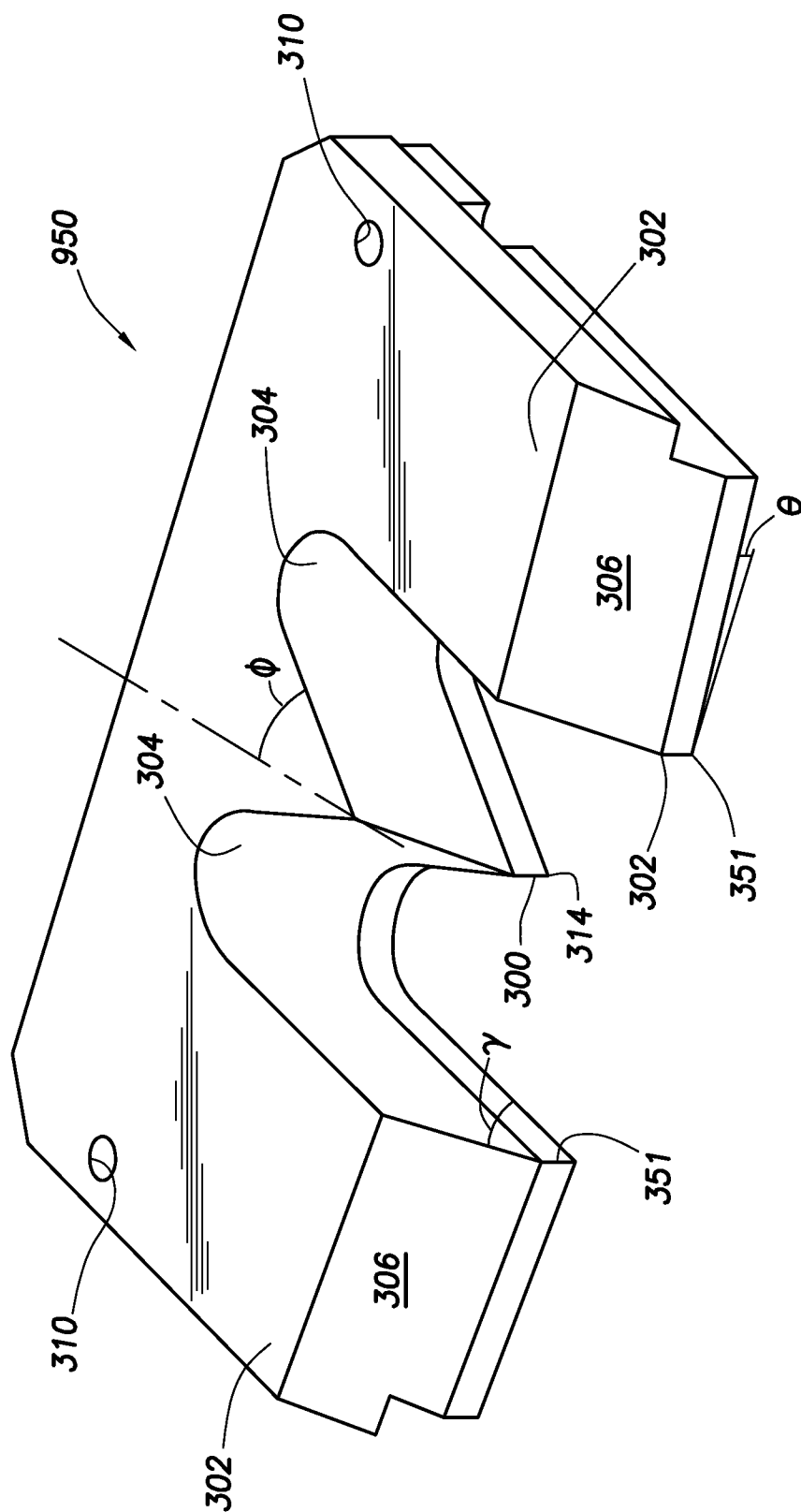


FIG. 9

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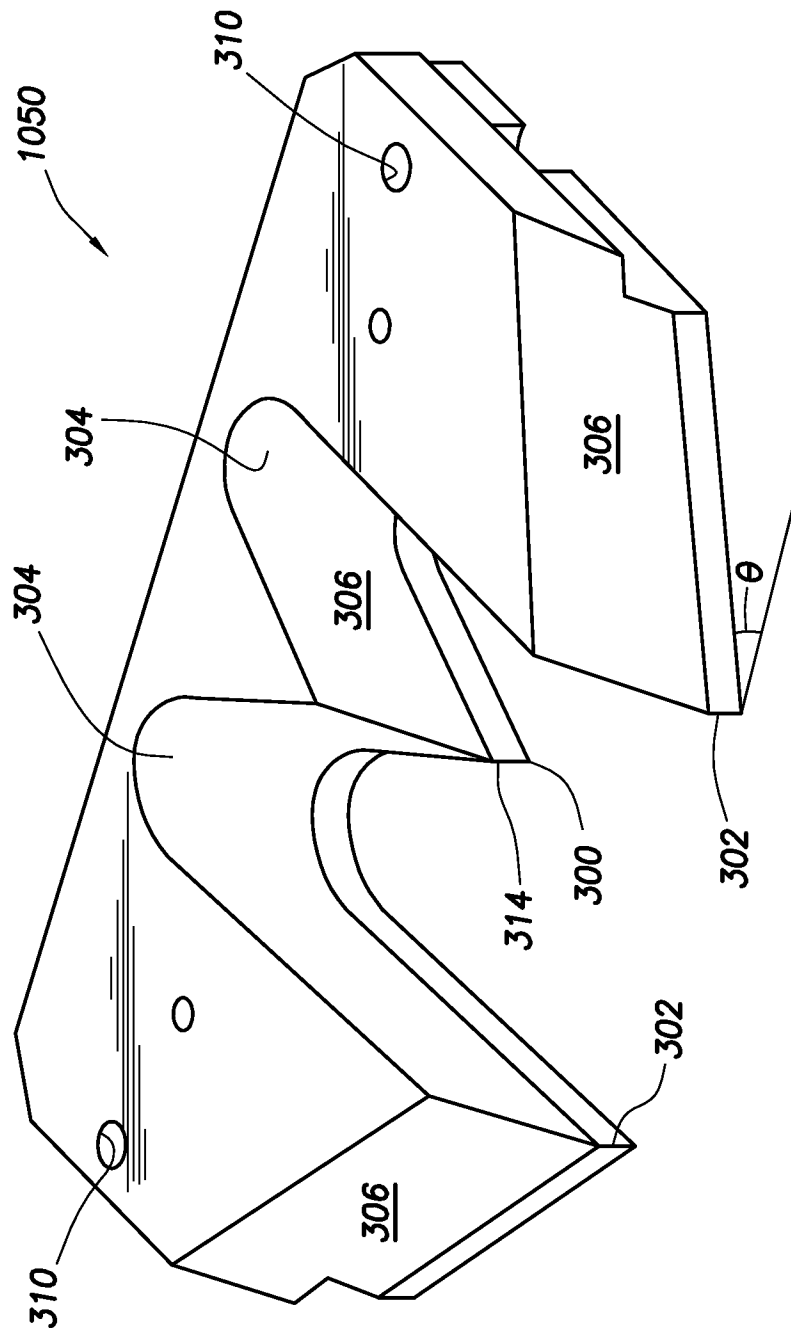
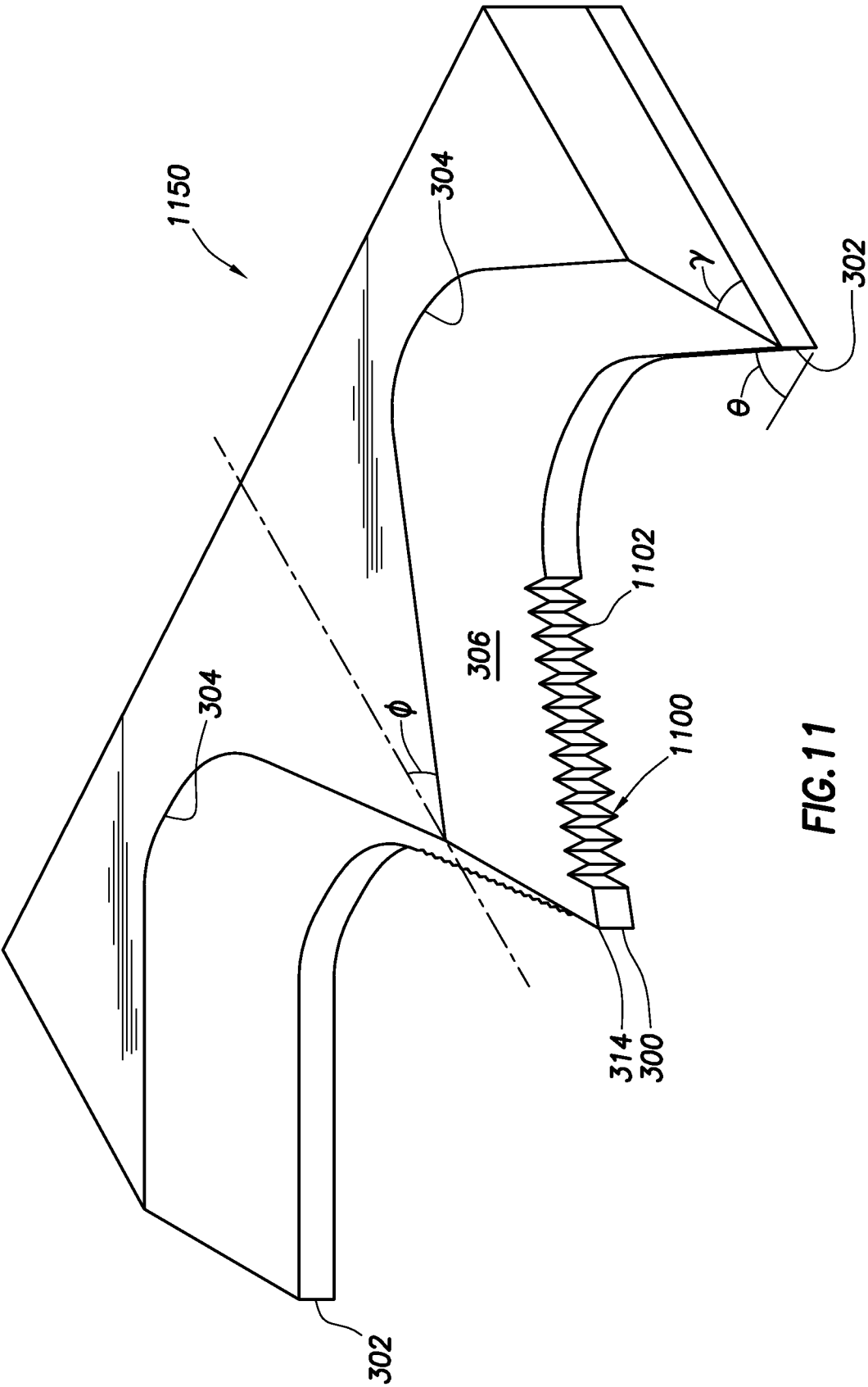


FIG.10



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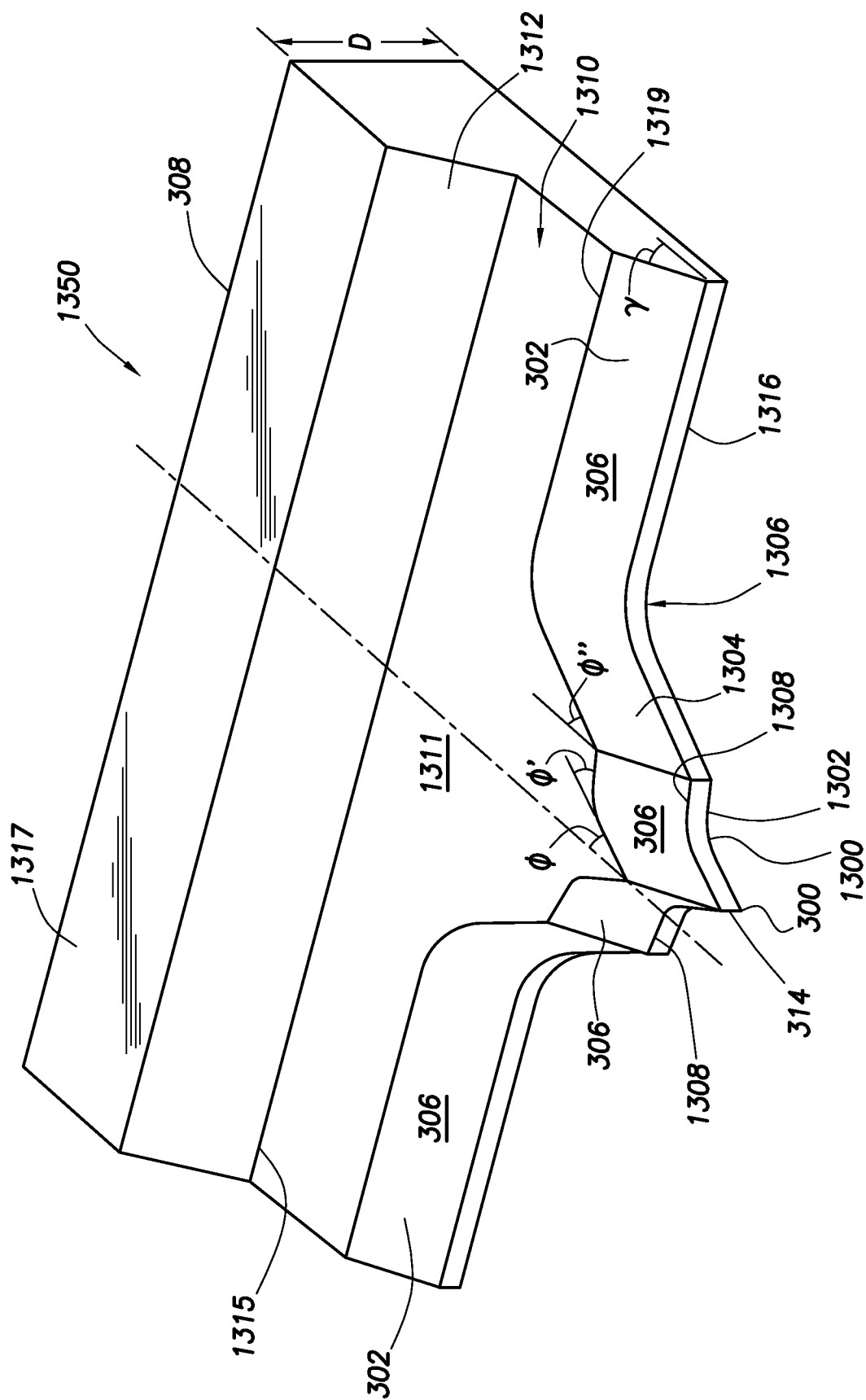


FIG.13

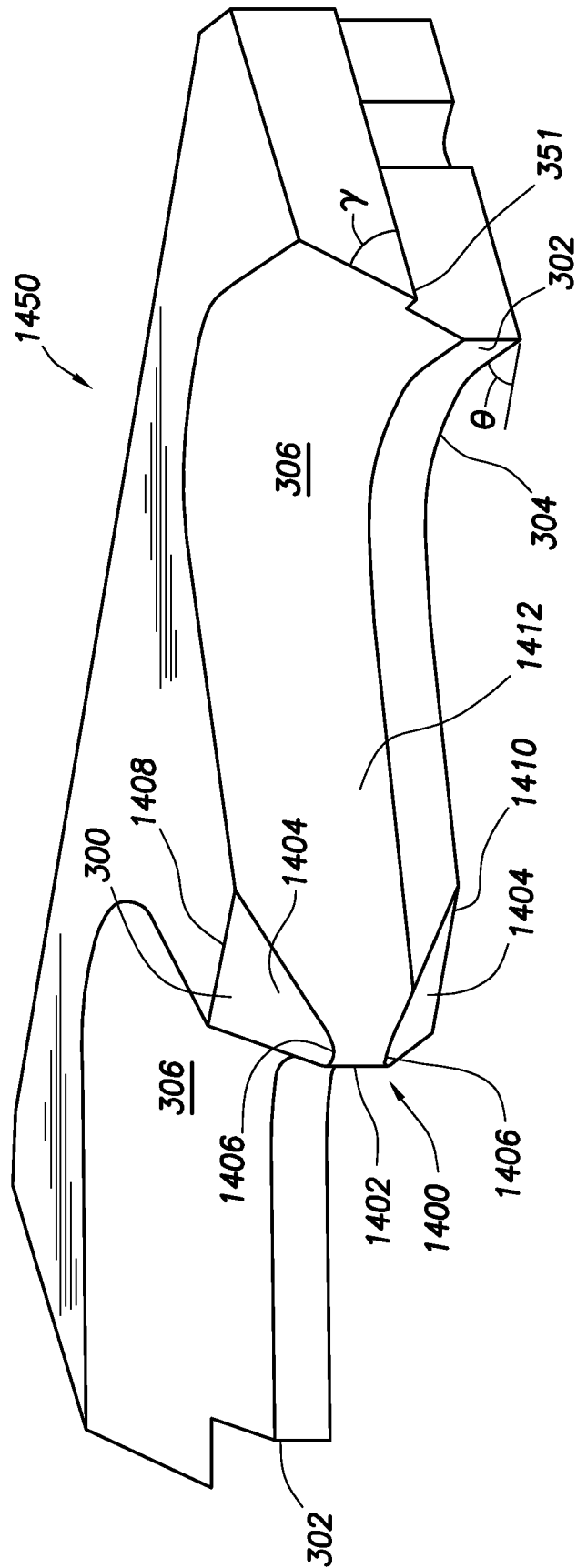


FIG. 14

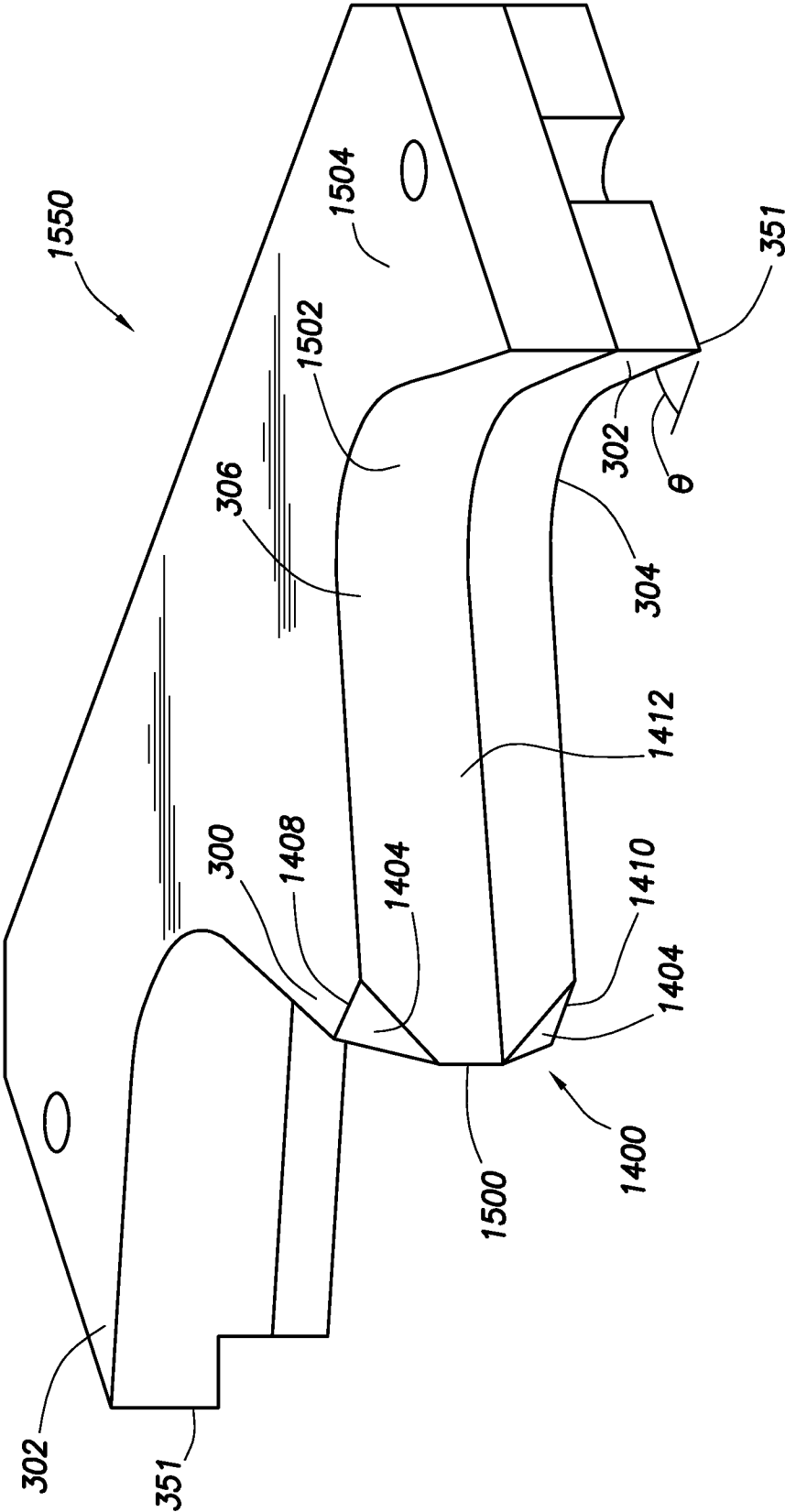


FIG. 15

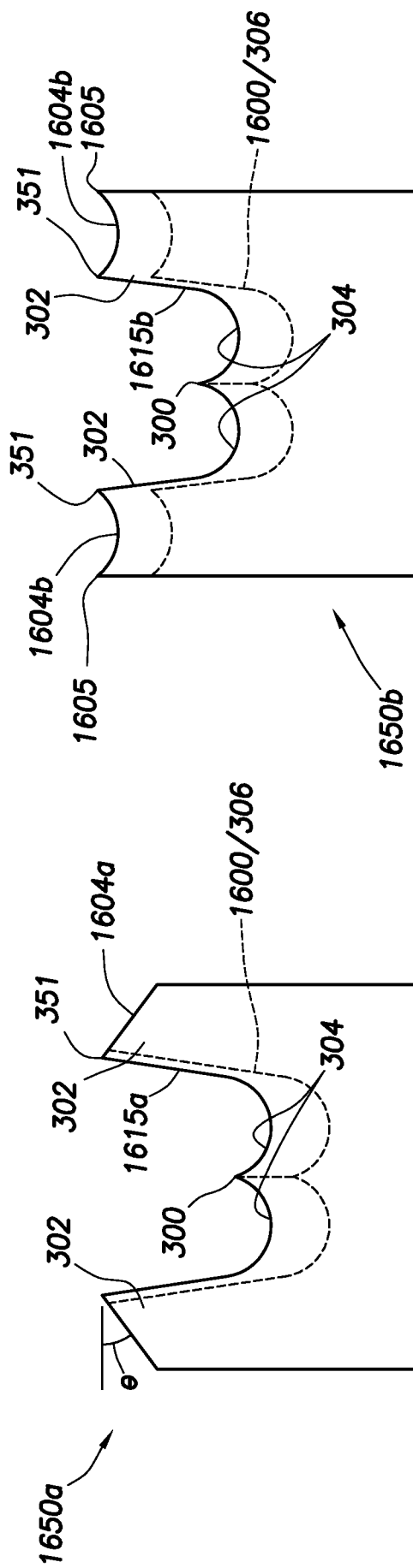


FIG. 16A

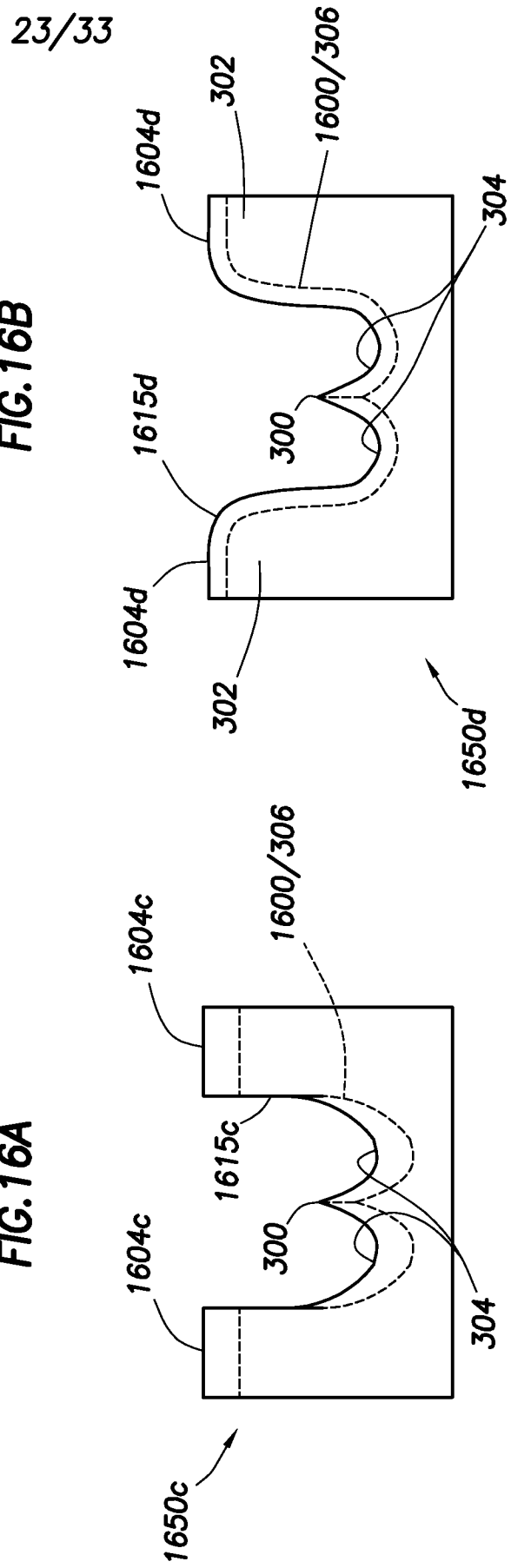


FIG. 16B

FIG. 16C

FIG. 16D

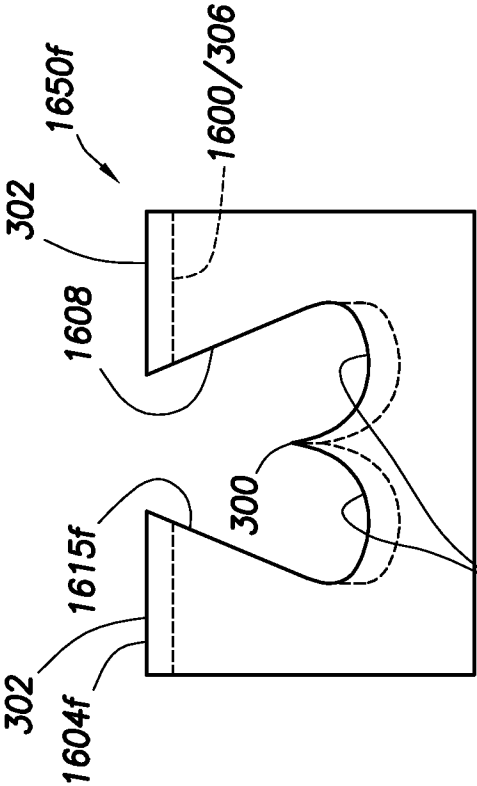


FIG. 16F

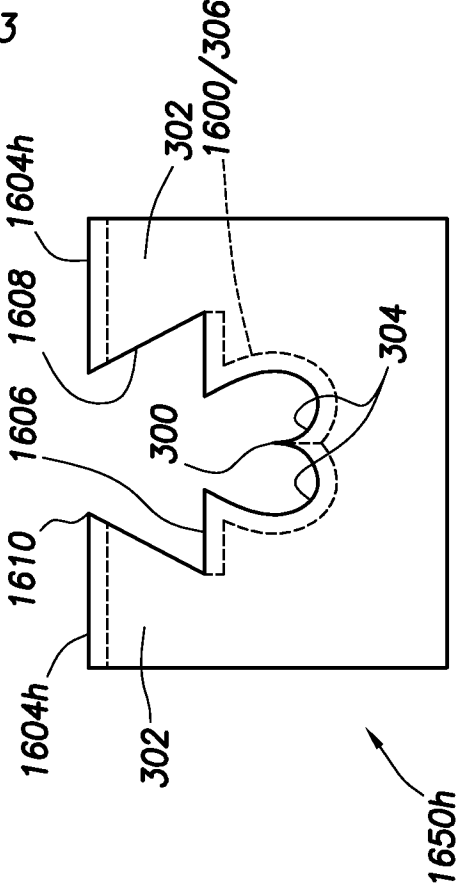


FIG. 16H

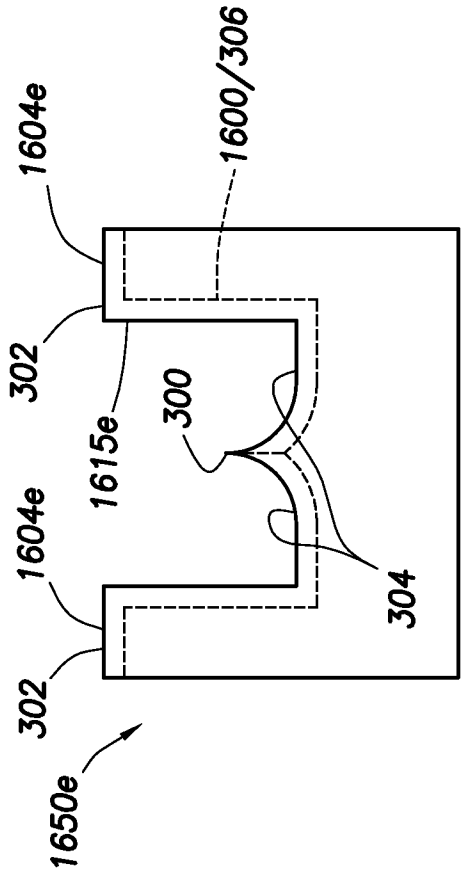


FIG. 16E

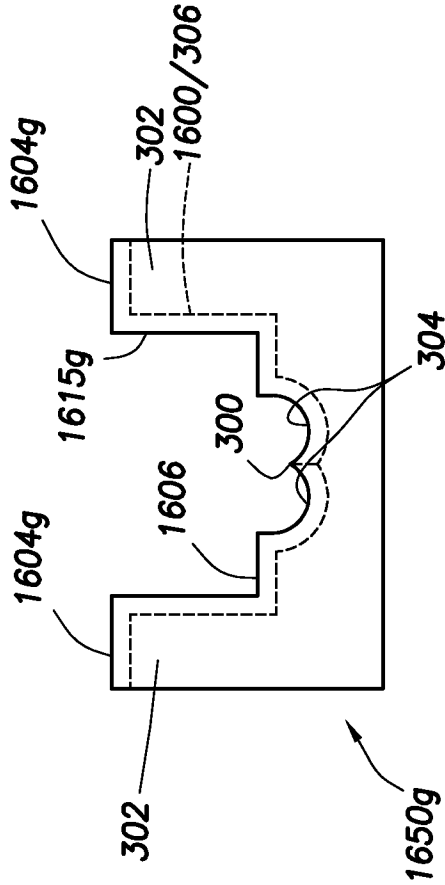
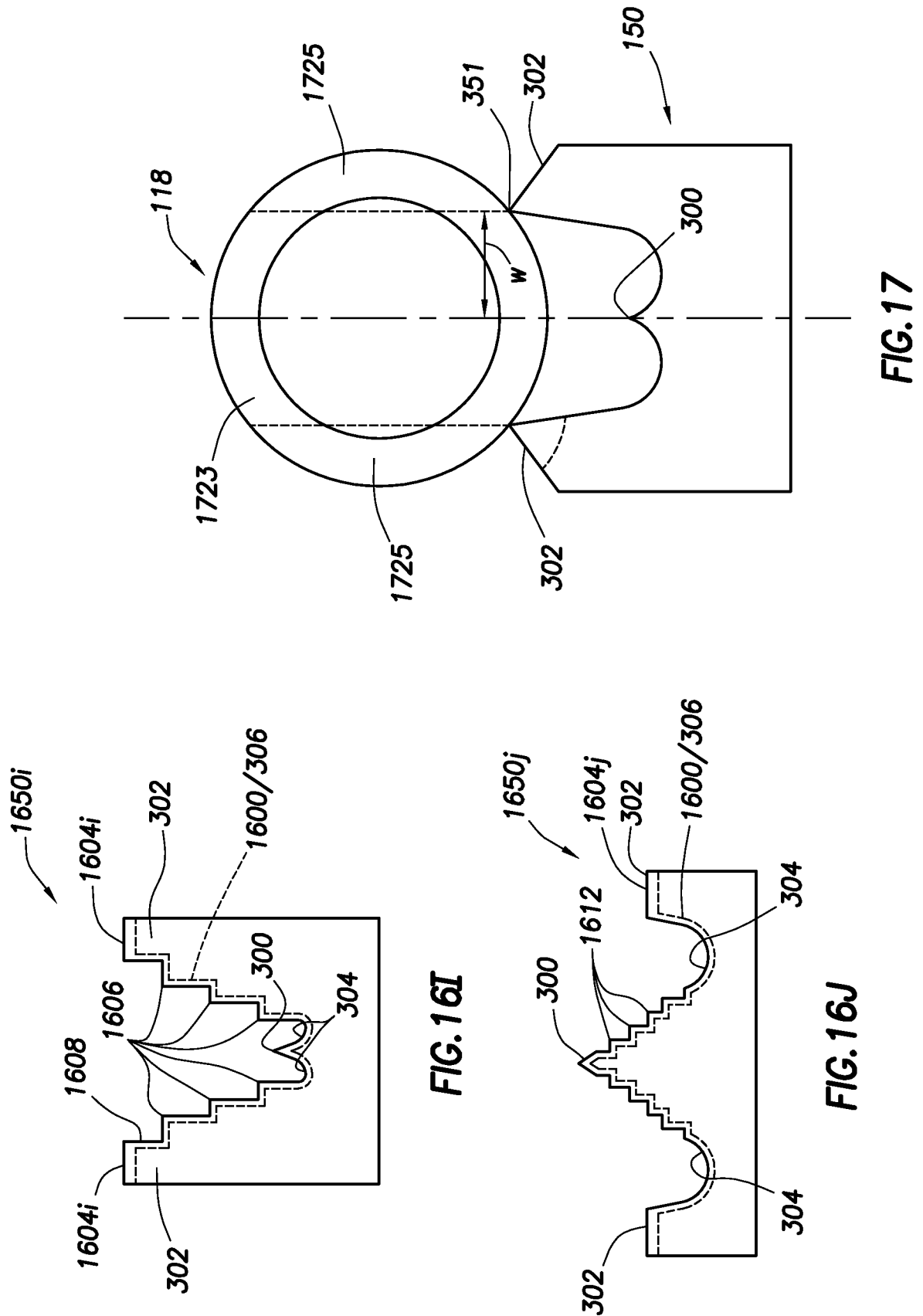


FIG. 16G



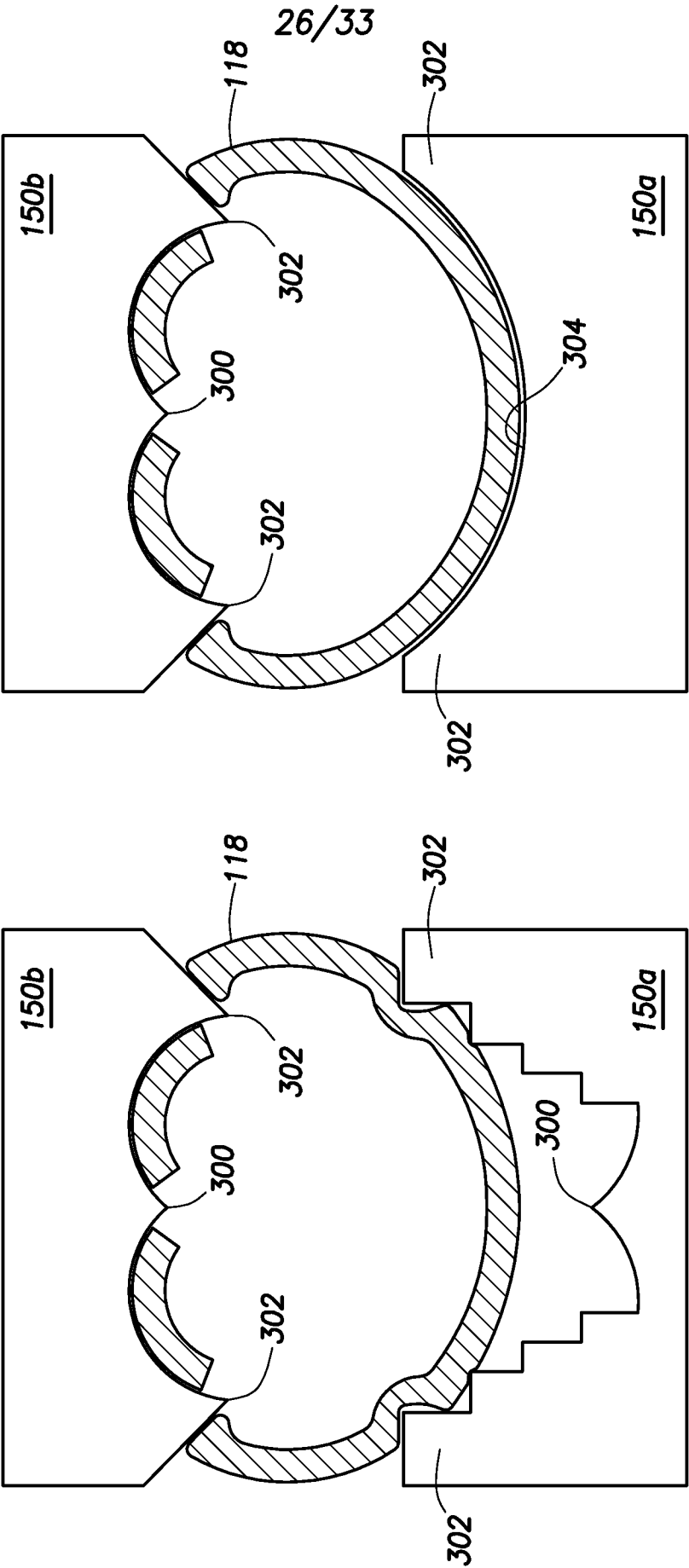


FIG. 18B

FIG. 18A

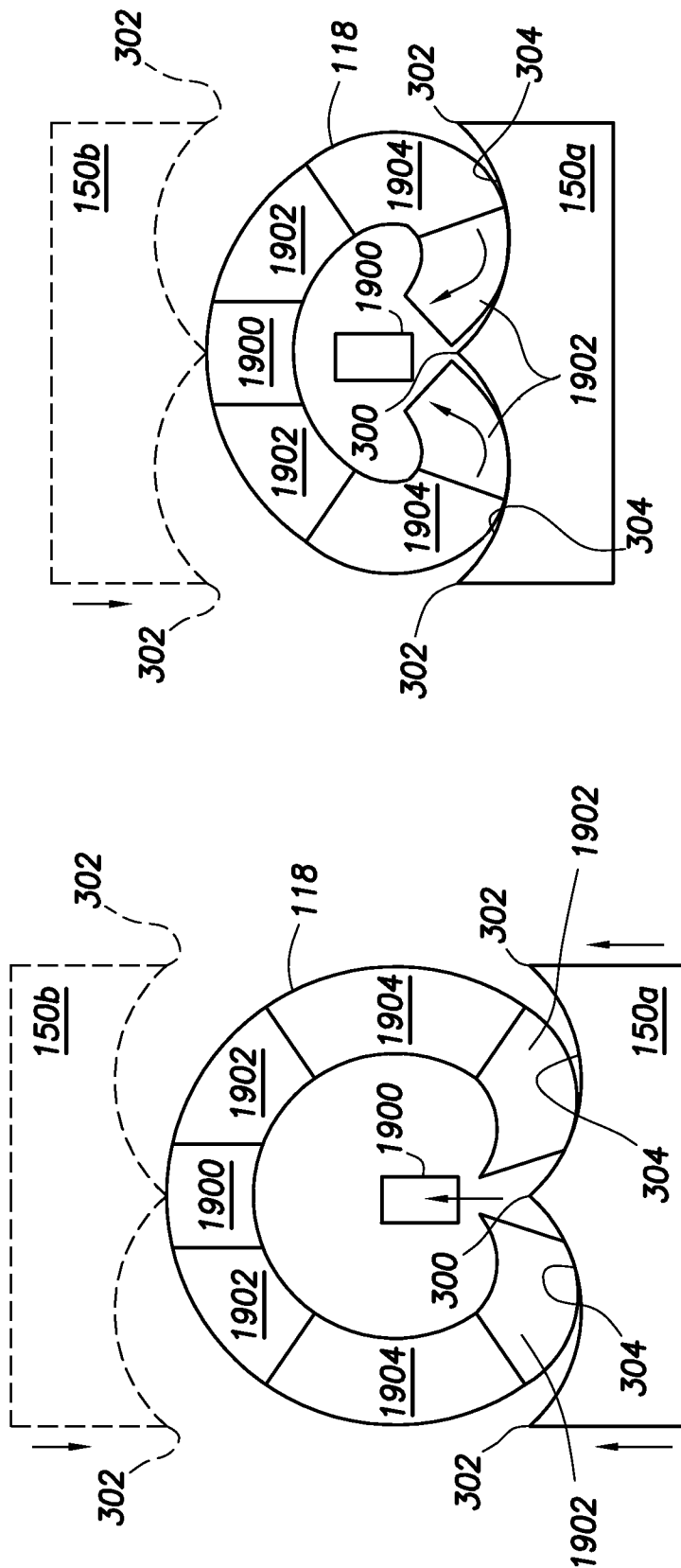


FIG. 19D

FIG. 19C

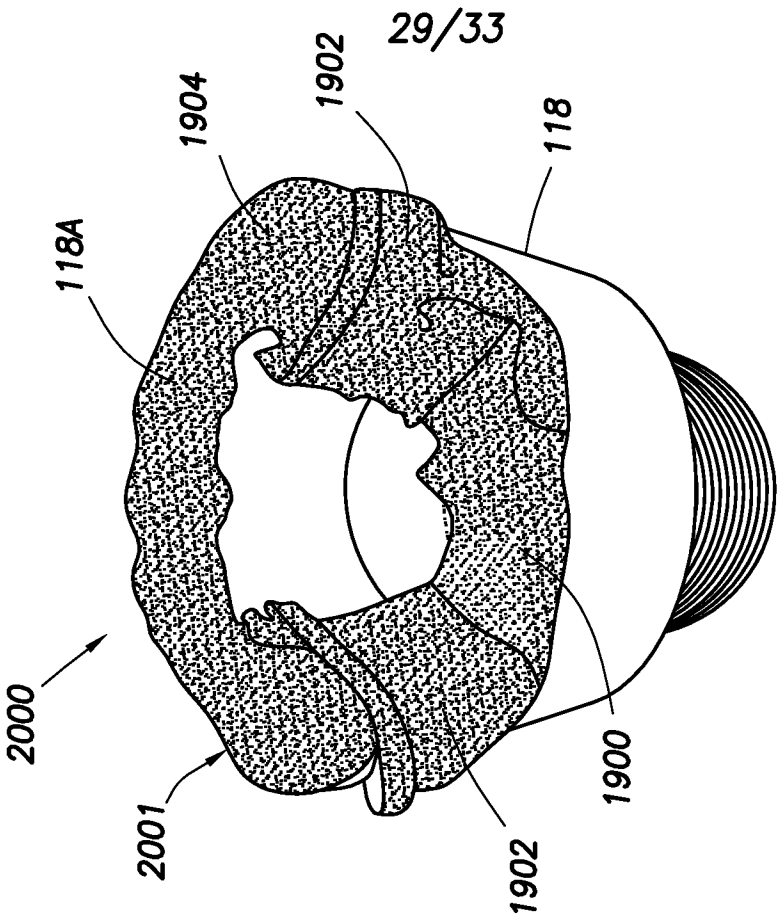


FIG. 20D

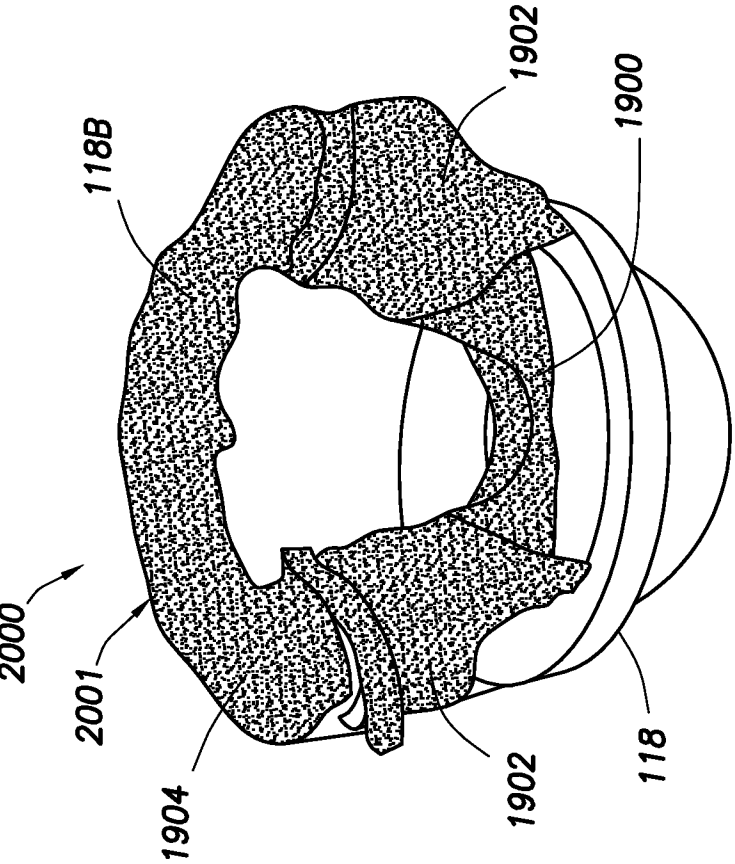


FIG. 20C

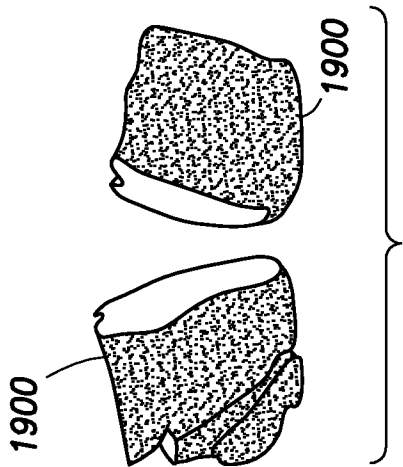


FIG. 20F

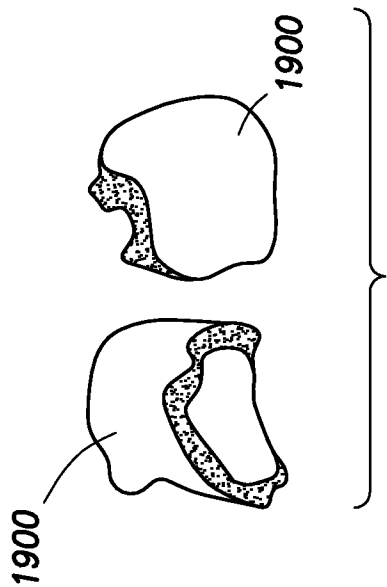


FIG. 20E

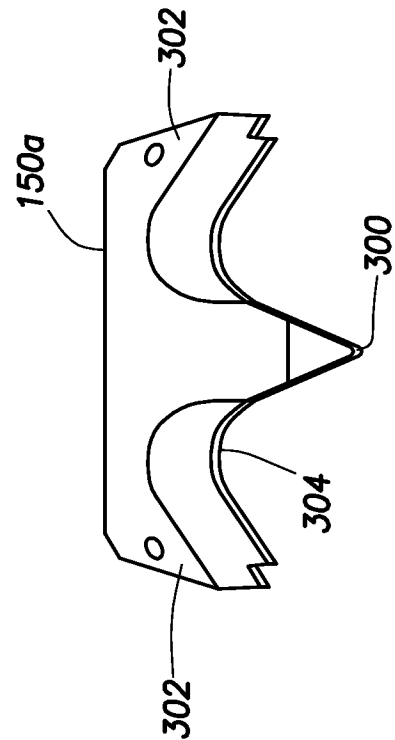


FIG. 20H

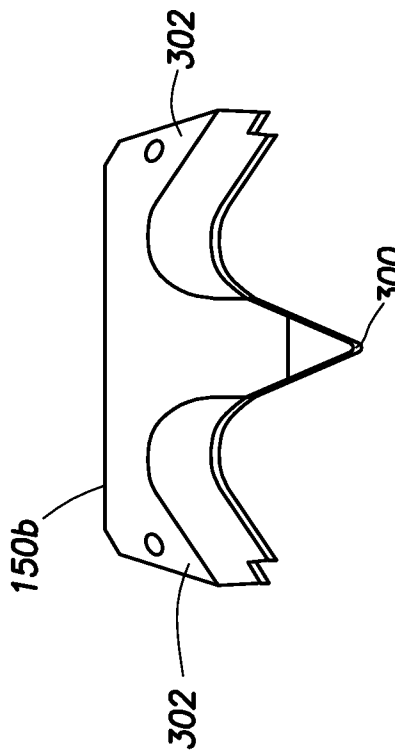


FIG. 20G

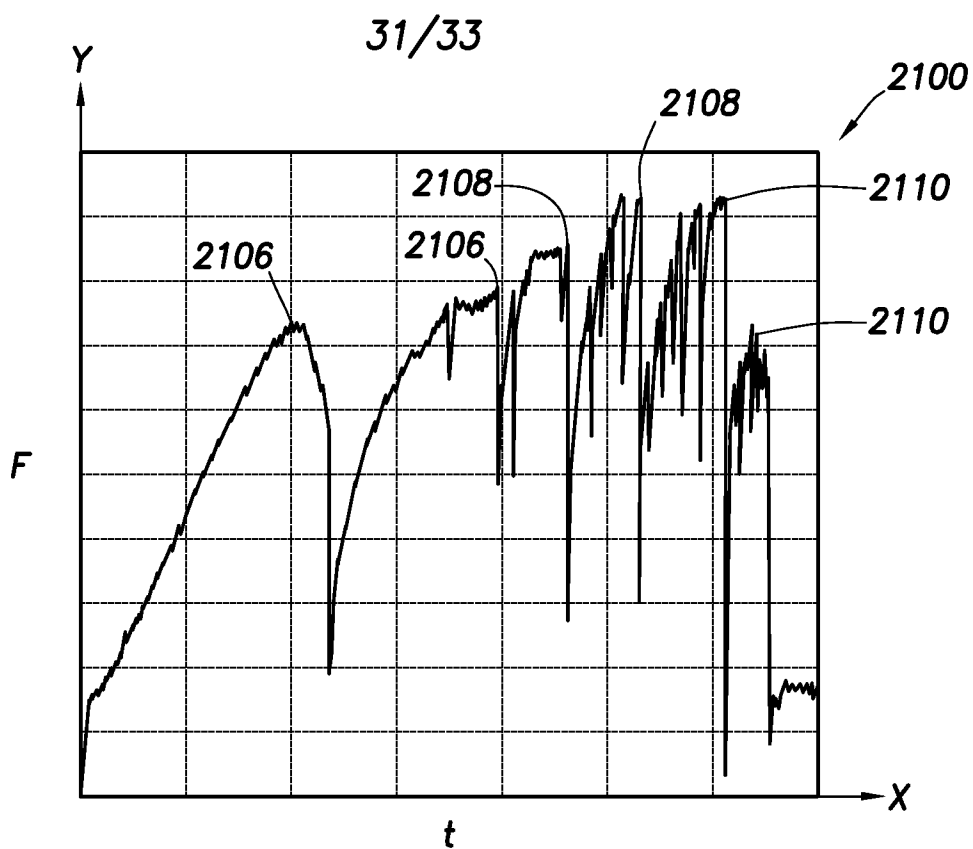


FIG. 21A

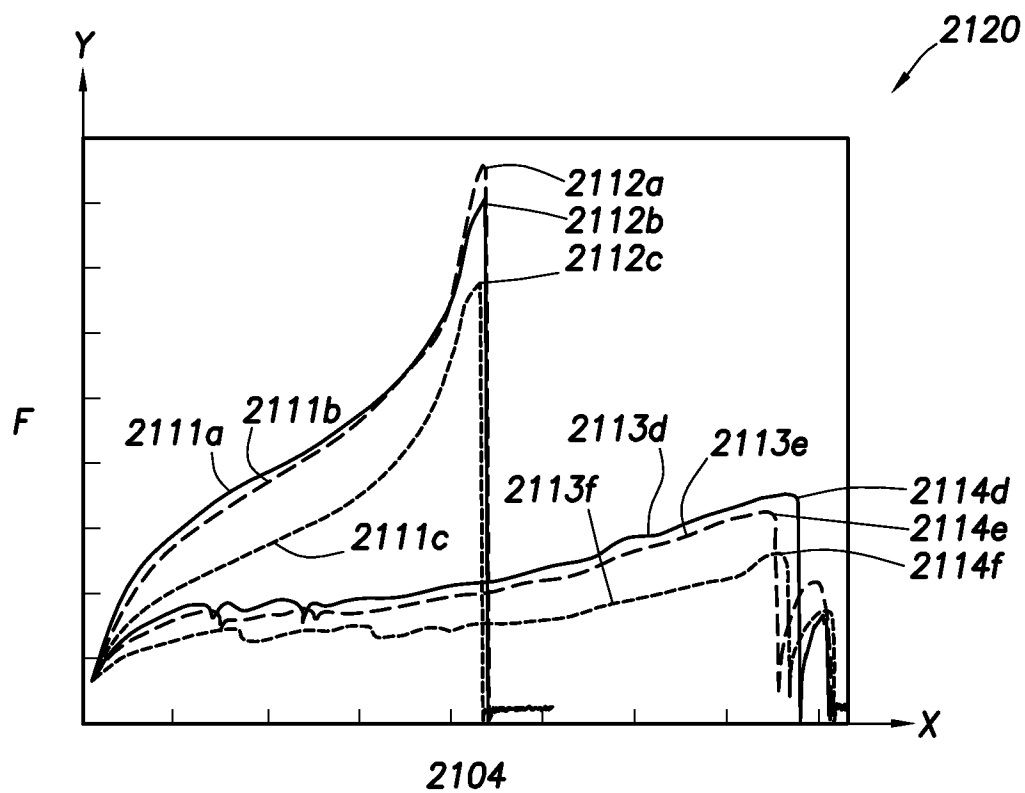


FIG. 21B

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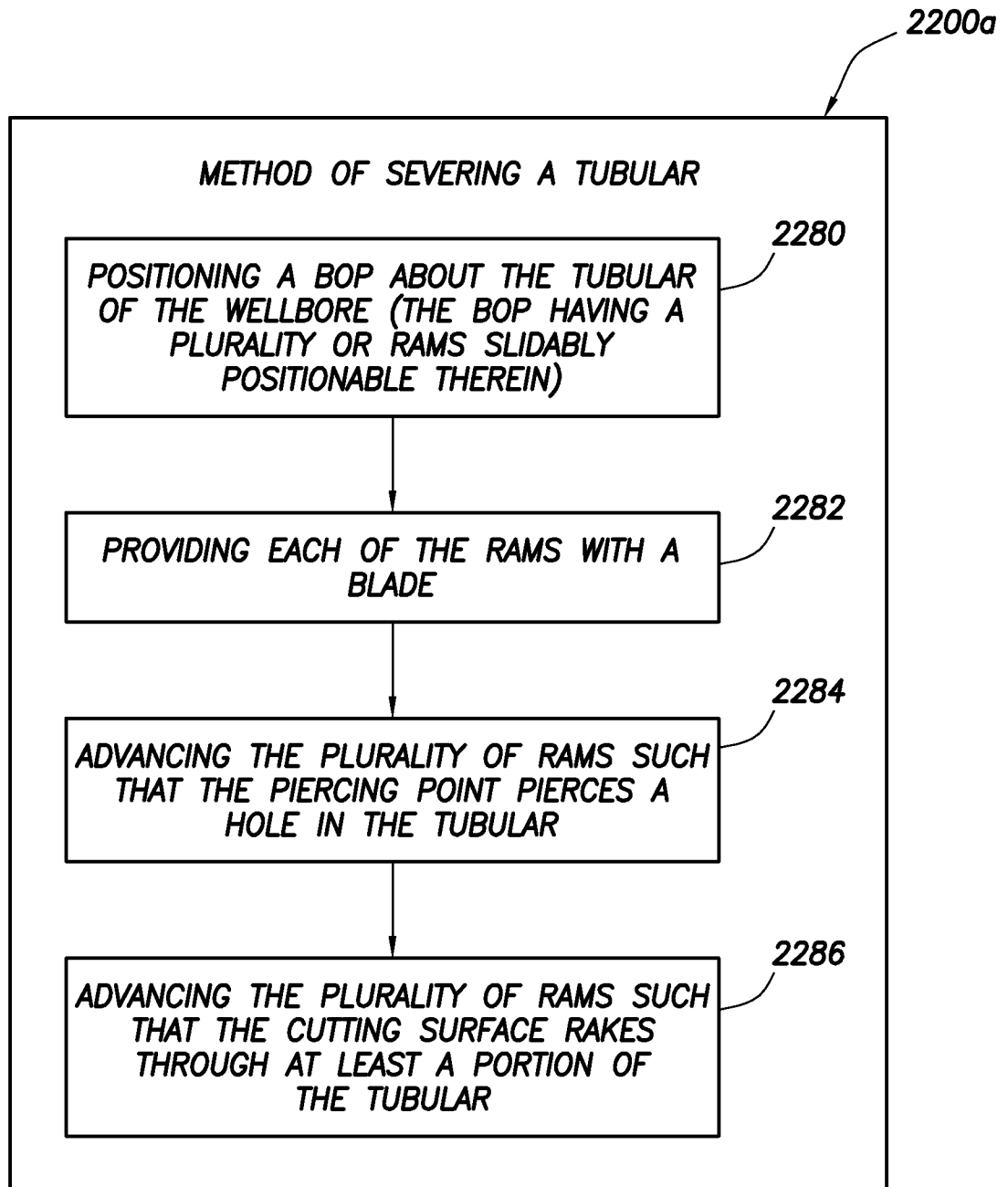


FIG.22A

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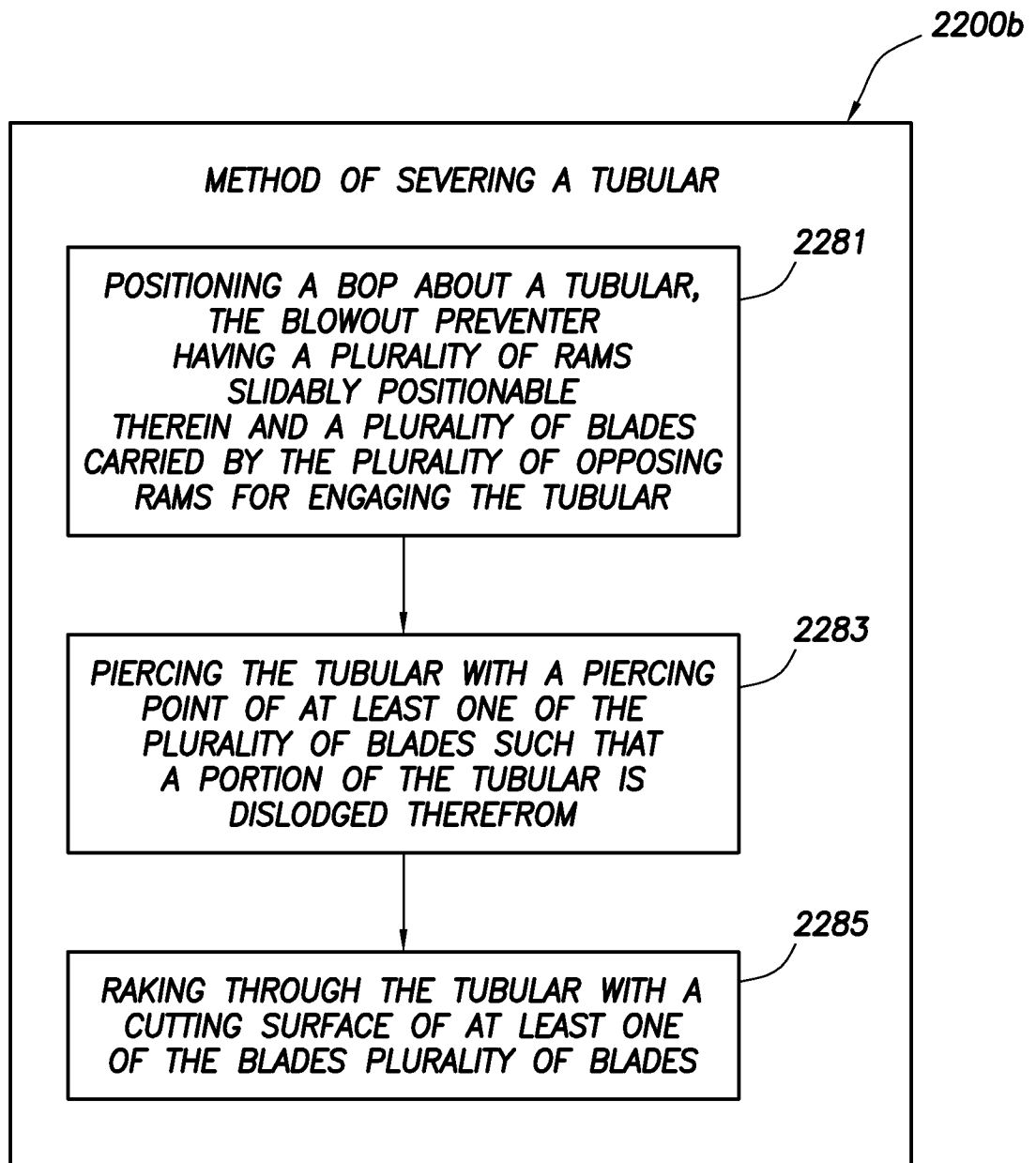


FIG.22B