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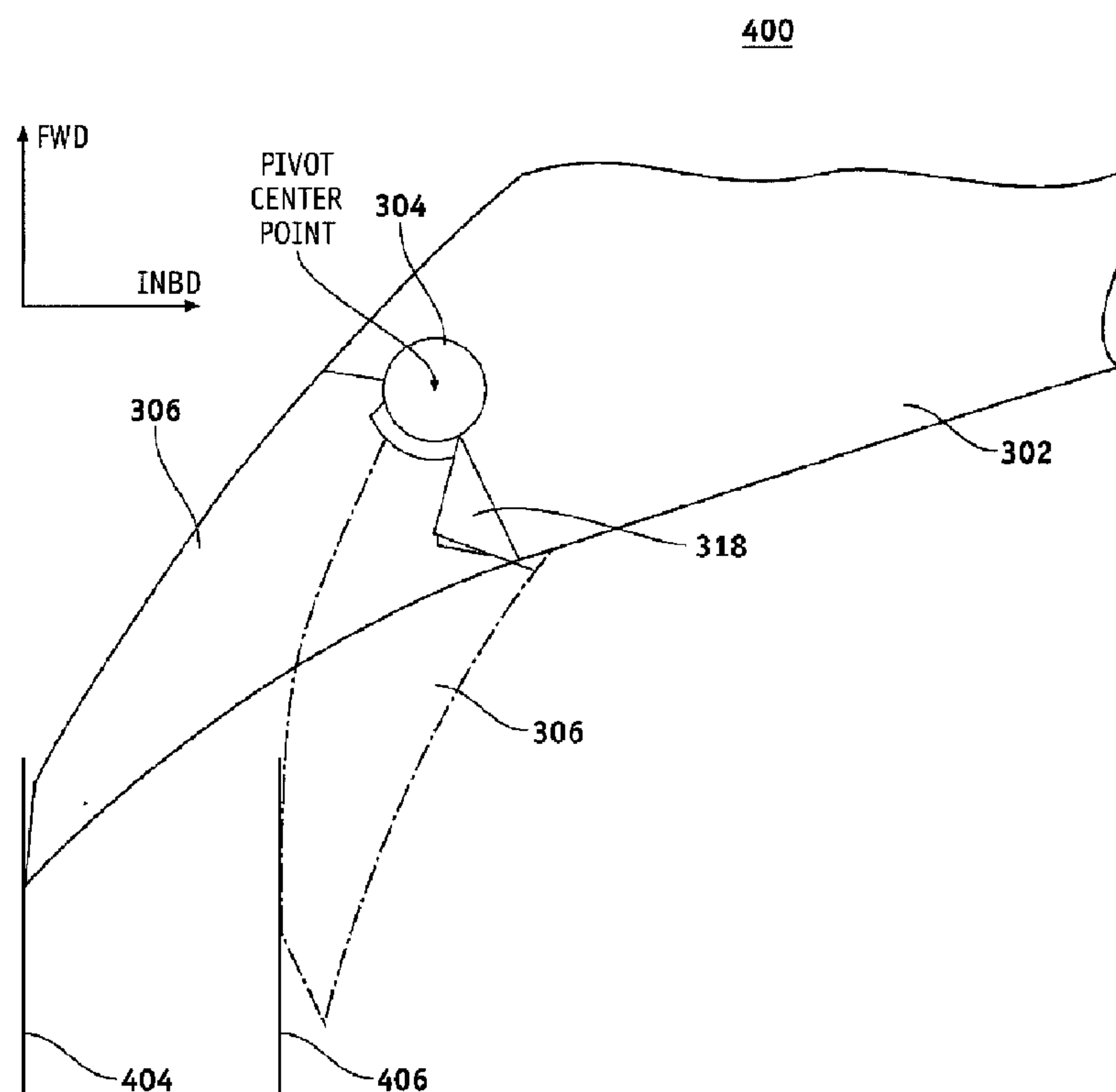
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(54) Title: SWING TIP ASSEMBLY ROTATION JOINT



(57) Abrégé/Abstract:

A rotation joint and methods for rotationally coupling a swing tip assembly to a fluid-dynamic body are presented. A rotation plate configured to couple to the swing tip assembly comprises a slide ring comprising an open center, an upper slide surface, an inner slide surface, and a lower slide surface. An upper joint plate is slidably coupled to the upper slide surface and the inner slide surface is configured to couple the fluid-dynamic body. A lower joint plate is slidably coupled to the lower slide surface and the inner slide surface, and is coupled to the upper joint plate through the open center. The lower joint plate is configured to couple to the fluid-dynamic body.



ABSTRACT

A rotation joint and methods for rotationally coupling a swing tip assembly to a fluid-dynamic body are presented. A rotation plate configured to couple to the swing tip assembly comprises a slide ring comprising an open center, an upper slide surface, an inner slide surface, and a lower slide surface. An upper joint plate is slidably coupled to the upper slide surface and the inner slide surface is configured to couple the fluid-dynamic body. A lower joint plate is slidably coupled to the lower slide surface and the inner slide surface, and is coupled to the upper joint plate through the open center. The lower joint plate is configured to couple to the fluid-dynamic body.

SWING TIP ASSEMBLY ROTATION JOINT

FIELD

[0001] Embodiments of the present disclosure relate generally to fluid-dynamic design. More particularly, embodiments of the present disclosure relate to design of variable-sweep fluid-dynamic bodies.

BACKGROUND

[0002] Wing span limitations of commercial aircraft may be driven by airport gate and taxiway size restrictions. Lengthened wing spans may be used to increase performance of aircraft such as lift-to-drag related efficiency performance. Increasing aircraft wing span to increase aircraft performance may conflict with airport gate and taxiway size restrictions. For example, airport gate and taxiways built for one generation of aircraft may be too small for later generations of aircraft built with longer wing spans. The airport restrictions may prevent aircraft having larger wing spans for flying more efficiently from being utilized at airports with such airport restrictions.

SUMMARY

[0003] A rotation joint and methods for rotationally coupling a swing tip assembly to a fluid-dynamic body are presented. A rotation plate that can be coupled to the swing tip assembly comprises a slide ring comprising an open center, an upper slide

surface, an inner slide surface, and a lower slide surface. An upper joint plate is slidably coupled to the upper slide surface and the inner slide surface and can be coupled to the fluid-dynamic body. A lower joint plate is slidably coupled to the lower slide surface and the inner slide surface, and is coupled to the upper joint plate through the open center. The lower joint plate can also be coupled to the fluid-dynamic body.

[0004] The rotation joint allows a wing tip to rotate aft in order to facilitate a reduced wing span, e.g., during taxi and gate parking, and other applications. The rotation joint comprises a “donut” inner ring attached to the wing tip, clamped in place by upper and lower plates attached to a wing box structure. In addition, the wing tip can be rotated forward for high speed aerodynamic benefit, rotated part way aft for low speed aerodynamic benefit, and rotated further aft for taxi and gate parking.

[0005] In this manner, embodiments of the disclosure provide an ability to change a wing span of an aircraft. Thereby, the aircraft may be more efficient in flight with a larger wing span yet still be accommodated within existing airport restrictions.

[0006] In an embodiment, a rotation joint for rotationally coupling a wing tip assembly to a fluid-dynamic body comprises a rotation plate, an upper joint plate, and a lower joint plate. The rotation plate couples to a wing tip assembly, and comprises a slide ring comprising an open center, an upper slide surface, an inner slide surface, and a lower slide surface. The upper joint plate is slidably coupled to the upper slide surface and the inner slide surface, and is configured to couple to a fluid-dynamic body. The lower joint plate is slidably coupled to the lower slide surface and the inner

slide surface, and is configured to couple to the upper joint plate through the open center, and is configured to couple to the fluid-dynamic body.

[0007] In another embodiment, a method for providing rotation of a swing tip assembly coupled to a fluid-dynamic body provides a rotation plate configured to couple to the swing tip assembly. The rotation plate comprises a slide ring comprising an open center, an upper slide surface, an inner slide surface, and a lower slide surface. The method further slidably couples an upper joint plate to the upper slide surface and the inner slide surface, the upper joint plate is operable to couple to a fluid-dynamic body. The method further slidably couples a lower joint plate to the lower slide surface and the inner slide surface, the lower joint plate is operable to couple to the fluid-dynamic body. The method further couples the lower joint plate to the upper joint plate through the open center.

[0008] In a further embodiment, a method for operating a rotation joint for a swing tip assembly coupled to a fluid-dynamic body slides an upper slide surface of a slide ring of a rotation plate on an upper slidable coupling to an upper joint plate coupled to the fluid-dynamic body. The method further, slides a lower slide surface of the slide ring on a lower slidable coupling to a lower joint plate coupled to the fluid-dynamic body. The method further, slides an inner slide surface of the slide ring on the upper slidable coupling to the upper joint plate and on the lower slidable coupling to the lower joint plate, the lower joint plate is coupled to the upper joint plate through an open center of the slide ring. The method, then configures a position of the swing tip assembly in a plane of the fluid-dynamic body by rotation of the rotation plate

relative to the upper joint plate and the lower joint plate, the rotation plate is coupled to the swing tip assembly.

[0009] This summary is provided to introduce a selection of concepts in a simplified form that are further described below in the detailed description. This summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter.

BRIEF DESCRIPTION OF DRAWINGS

[0010] A more complete understanding of embodiments of the present disclosure may be derived by referring to the detailed description and claims when considered in conjunction with the following figures, wherein like reference numbers refer to similar elements throughout the figures. The figures are provided to facilitate understanding of the disclosure without limiting the breadth, scope, scale, or applicability of the disclosure. The drawings are not necessarily made to scale.

[0011] Figure 1 is an illustration of a flow diagram of an exemplary aircraft production and service methodology.

[0012] Figure 2 is an illustration of an exemplary block diagram of an aircraft.

[0013] Figure 3 is an illustration of an exemplary block diagram of a swing tip assembly system according to an embodiment of the disclosure.

[0014] Figure 4 is an illustration of an exemplary perspective view of a swing tip assembly system showing a rotating wing tip in a high speed extended configuration

and in a rotated stowed configuration (ground position) according to an embodiment of the disclosure.

[0015] Figure 5 is an illustration of an exemplary perspective view of a swing tip assembly system showing a rotating wing tip in a high speed extended configuration, in a low speed rotated swept back configuration, and in a rotated stowed configuration according to an embodiment of the disclosure.

[0016] Figure 6 is an illustration of an exemplary perspective view of a swing tip assembly system showing a rotation joint and a moving panel of a rotating wing in a folding configuration according to an embodiment of the disclosure.

[0017] Figure 7 is an illustration of a swing tip assembly system showing more detail of the swing tip assembly system of the Figure 6.

[0018] Figure 7A is an illustration of an exemplary perspective view of a swing tip assembly system showing a rotation joint and a moving panel of a rotating wing in a sliding configuration according to an embodiment of the disclosure.

[0019] Figure 8 is an illustration of an expanded top view of a portion of the swing tip assembly system of Figure 7.

[0020] Figure 9 is an illustration of a cross sectional view of the swing tip assembly system of Figure 6 taken along a line A-A.

[0021] Figure 10 is an illustration of an exemplary perspective view of mating cylindrical surfaces of a rotation joint of a swing tip assembly according to an embodiment of the disclosure.

[0022] Figure 11 is an illustration of exemplary perspective views of an upper fixed joint plate of the rotation joint of Figure 10.

[0023] Figure 12 is an illustration of exemplary perspective views of an inner mid rotation joint plate of the rotation joint of Figure 10.

[0024] Figure 13 is an illustration of exemplary perspective views of a lower fixed joint plate of the rotation joint of Figure 10.

[0025] Figure 14 is an illustration of an exemplary perspective view of a swing tip assembly system according to an embodiment of the disclosure.

[0026] Figure 15 is an illustration of an exemplary flowchart showing a process for providing rotation of a swing tip assembly coupled to a fluid-dynamic body according to an embodiment of the disclosure.

[0027] Figure 16 is an illustration of an exemplary flowchart showing a process for operating a rotation joint for a swing tip assembly coupled to a fluid-dynamic body, according to an embodiment of the disclosure.

[0028] Figure 17 is an illustration of an exemplary actuation mechanism of a swing tip assembly system according to an embodiment of the disclosure.

DETAILED DESCRIPTION

[0029] The following detailed description is exemplary in nature and is not intended to limit the disclosure or the application and uses of the embodiments of the disclosure. Descriptions of specific devices, techniques, and applications are provided only as examples. Modifications to the examples described herein will be readily apparent to those of ordinary skill in the art, and the general principles defined herein may be applied to other examples and applications without departing from the spirit and scope of the disclosure. The present disclosure should be accorded scope

consistent with the claims, and not limited to the examples described and shown herein.

[0030] Embodiments of the disclosure may be described herein in terms of functional and/or logical block components and various processing steps. It should be appreciated that such block components may be realized by any number of hardware, software, and/or firmware components configured to perform the specified functions. For the sake of brevity, conventional techniques and components related to aerodynamics, actuators, vehicle structures, fluid dynamics, flight control systems, and other functional aspects of systems described herein (and the individual operating components of the systems) may not be described in detail herein. In addition, those skilled in the art will appreciate that embodiments of the present disclosure may be practiced in conjunction with a variety of hardware and software, and that the embodiments described herein are merely example embodiments of the disclosure.

[0031] Embodiments of the disclosure are described herein in the context of a practical non-limiting application, namely, a rotation joint for an aircraft wing tip. Embodiments of the disclosure, however, are not limited to such aircraft wing tip applications, and the techniques described herein may also be utilized in other applications. For example but without limitation, embodiments may be applicable to a rotation joint for swing assemblies of hydrofoils, wind turbines, tidal power turbines, or other fluid-dynamic surface.

[0032] As would be apparent to one of ordinary skill in the art after reading this description, the following are examples and embodiments of the disclosure and are

not limited to operating in accordance with these examples. Other embodiments may be utilized and structural changes may be made without departing from the scope of the exemplary embodiments of the present disclosure.

[0033] Referring more particularly to the drawings, embodiments of the disclosure may be described in the context of an exemplary aircraft manufacturing and service method **100** (method **100**) as shown in Figure **1** and an aircraft **200** as shown in Figure **2**. During pre-production, the method **100** may comprise specification and design **104** of the aircraft **200**, and material procurement **106**. During production, component and subassembly manufacturing **108** (process **108**) and system integration **110** of the aircraft **200** takes place. Thereafter, the aircraft **200** may go through certification and delivery **112** in order to be placed in service **114**. While in service by a customer, the aircraft **200** is scheduled for routine maintenance and service **116** (which may also comprise modification, reconfiguration, refurbishment, and so on).

[0034] Each of the processes of method **100** may be performed or carried out by a system integrator, a third party, and/or an operator (e.g., a customer). For the purposes of this description, a system integrator may comprise, for example but without limitation, any number of aircraft manufacturers and major-system subcontractors; a third party may comprise, for example but without limitation, any number of vendors, subcontractors, and suppliers; and an operator may comprise, for example but without limitation, an airline, leasing company, military entity, service organization; and the like.

[0035] As shown in Figure 1, the aircraft **200** produced by the method **100** may comprise an airframe **218** with a plurality of systems **220** and an interior **222**. Examples of high-level systems of the systems **220** comprise one or more of a propulsion system **224**, an electrical system **226**, a hydraulic system **228**, an environmental system **230**, and a swing tip assembly rotation joint **232**. Any number of other systems may also be included. Although an aerospace example is shown, the embodiments of the disclosure may be applied to other industries.

[0036] Apparatus and methods embodied herein may be employed during any one or more of the stages of the method **100**. For example, components or subassemblies corresponding to production of the process **108** may be fabricated or manufactured in a manner similar to components or subassemblies produced while the aircraft **200** is in service. In addition, one or more apparatus embodiments, method embodiments, or a combination thereof may be utilized during production stages of the process **108** and the system integration **110**, for example, by substantially expediting assembly of or reducing the cost of an aircraft **200**. Similarly, one or more of apparatus embodiments, method embodiments, or a combination thereof may be utilized while the aircraft **200** is in service, for example and without limitation, to maintenance and service **116**.

[0037] Figure 3 is an illustration of an exemplary block diagram of a swing tip assembly system **300** (system **300**) according to an embodiment of the disclosure. The system **300** may comprise a fluid-dynamic body **302**, a rotation joint **304**, a swing tip assembly **306**, an actuator **308** (swing tip actuator **308**), and a controller **310**.

[0038] The fluid-dynamic body **302** may be coupled to the rotation joint **304**, and may comprise a lifting surface and/or a control surface. The lifting surface may comprise, for example but without limitation, a wing, a canard, a horizontal stabilizer, or other lifting surface. The control surface may comprise, for example but without limitation, a slat, an elevator, a flap, a spoiler, an elevon, or other control surface. As mentioned above, embodiments may be applicable to hydrofoils, wind turbines, tidal power turbines, or other fluid-dynamic surface. Thus, an aerodynamic body and a fluid-dynamic body may be used interchangeably in this document.

[0039] The rotation joint **304** is configured to rotationally couple the swing tip assembly **306** to the fluid-dynamic body **302** to rotate the swing tip assembly **306** in a plane **504** (Figure 5) of the fluid-dynamic body **302**. The rotation joint **304** comprises a “pinless” joint that relies on mating cylindrical surfaces **316** for transferring torsional, shear and bending loadings while maintaining a required stiffness. This allows for a lighter weight solution because design limits used for flight are generally sufficient to cover ground loading conditions. Surfaces of the mating cylindrical surfaces **316** are lined using low friction material. The rotation joint **304** is discussed in more detail below in the context of discussion of Figures 9-14.

[0040] The swing tip assembly **306** is configured to swing or rotate in the plane **504** of the fluid-dynamic body **320** in response to an actuation of the rotation joint **304** by the actuator **308**. The swing tip assembly **306** may comprise a tip of the fluid-dynamic body **302**. In one embodiment, the swing tip assembly **306** comprises a rotating wing tip **306** of a wing **302** (Figure 4) of the aircraft **200** (Figure 2). In other embodiments, the swing tip assembly **306** may comprise, for example but without

limitation, a tip of a control surface, a tip of a lifting surface, or other portion of a structure that can swing/rotate in a plane of the structure.

[0041] The swing tip assembly **306** may comprise a moving panel **318** located near a stationary part **610** (Figure 6) of the fluid-dynamic body **302** and configured to move before the swing tip assembly **306** is rotated. The moving panel **318** allows for a space envelope for a remainder of the swing tip assembly **306** to occupy while in a rotated state. The moving panel **318** may comprise, for example but without limitation, a folding panel in a folding configuration **612** (Figure 6), a sliding panel in a sliding configuration **726** (Figure 7A), or other movable surface configuration. The moving panel **318** is discussed in more detail in the context of discussion of Figures 6 and 7A below.

[0042] The actuator **308** is configured to produce a rotating motion in response to an actuation command to actuate the rotation joint **304** for rotating the swing tip assembly **306**. The actuator **308** may comprise, for example but without limitation, a linear hydraulic actuator, a ball screw actuator, or other actuator that is capable of actuating the rotation joint **304** for rotating the swing tip assembly **306**.

[0043] The controller **310** may comprise, for example but without limitation, a processor module **312**, a memory module **314**, or other module. The controller **310** may be implemented as, for example but without limitation, a part of an aircraft system, a centralized aircraft processor, a subsystem computing module comprising hardware and/or software devoted to the system **300**, or other processor.

[0044] The controller **310** is configured to control the rotation joint **304** to swing/rotate the swing tip assembly **306** according to various operation conditions.

The operation conditions may comprise, for example but without limitation, flight conditions, ground operations, or other condition. The flight conditions may comprise, for example but without limitation, take off, cruise, approach, landing, or other flight condition. The ground operations may comprise, for example but without limitation, air breaking after landing, taxiing, parking, or other ground operation. The controller **310** may be located remotely from the rotation joint **304**, or may be coupled to the rotation joint **304**.

[0045] In operation, the controller **310** may control the rotation joint **304** by sending an actuation command from the actuator **308** to the rotation joint **304**, thereby swinging/rotating the swing tip assembly **306** in response to the actuation command as explained in more detail below in the context of discussion of Figures 4-5. An actuation mechanism **1700** of the swing tip assembly system **300** that can be controlled by the controller **310** is explained in more detail in the context of discussion of Figure 17 below.

[0046] The processor module **312** comprises processing logic that is configured to carry out the functions, techniques, and processing tasks associated with the operation of the system **300**. In particular, the processing logic is configured to support the system **300** described herein. For example, the processor module **312** may direct the rotation joint **304** to swing/rotate the swing tip assembly **306** based on various operation conditions.

[0047] The processor module **312** may be implemented, or realized, with a general purpose processor, a content addressable memory, a digital signal processor, an application specific integrated circuit, a field programmable gate array,

any suitable programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof, designed to perform the functions described herein. In this manner, a processor may be realized as a microprocessor, a controller, a microcontroller, a state machine, or the like. A processor may also be implemented as a combination of computing devices comprising hardware and/or software, e.g., a combination of a digital signal processor and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a digital signal processor core, or any other such configuration.

[0048] The memory module **314** may comprise a data storage area with memory formatted to support the operation of the system **300**. The memory module **314** is configured to store, maintain, and provide data as needed to support the functionality of the system **300**. For example, the memory module **314** may store flight configuration data, rotation positions of the swing tip assembly **306**, or other data.

[0049] In practical embodiments, the memory module **314** may comprise, for example but without limitation, a non-volatile storage device (non-volatile semiconductor memory, hard disk device, optical disk device, and the like), a random access storage device (for example, SRAM, DRAM), or any other form of storage medium known in the art.

[0050] The memory module **314** may be coupled to the processor module **312** and configured to store, for example but without limitation, a database, and the like. Additionally, the memory module **314** may represent a dynamically updating database containing a table for updating the database, or other application. The memory module **314** may also store, a computer program that is executed by the

processor module **312**, an operating system, an application program, tentative data used in executing a program, or other application.

[0051] The memory module **314** may be coupled to the processor module **312** such that the processor module **312** can read information from and write information to the memory module **314**. For example, the processor module **312** may access the memory module **314** to access an aircraft speed, a swing position of the swing tip assembly **306**, an angle of attack, a Mach number, an altitude, or other data.

[0052] As an example, the processor module **312** and memory module **314** may reside in respective application specific integrated circuits (ASICs). The memory module **314** may also be integrated into the processor module **312**. In an embodiment, the memory module **314** may comprise a cache memory for storing temporary variables or other intermediate information during execution of instructions to be executed by the processor module **312**.

[0053] Figure **4** is an illustration of an exemplary perspective view of a swing tip assembly system **400** (system **400**) showing the rotating wing tip **306** in a high speed extended configuration **404** and in a rotated stowed configuration **406** during taxi or gate parking maneuvers according to an embodiment of the disclosure.

[0054] The system **400** comprises the wing **302** as an example of the fluid-dynamic body **302**, the rotating wing tip **306** as an example of the swing tip assembly **306**, and the rotation joint **304**. Thus, the wing **302** and the fluid-dynamic body **302** may be used interchangeably in this document. Similarly, the rotating wing tip **306** and the swing tip assembly **306** may be used interchangeably in this document. Figure **4** may have functions, material, and structures that are similar to the

embodiments shown in Figure 3. Therefore, common features, functions, and elements may not be redundantly described here.

[0055] Increasing wing span using the rotation joint **304** ensures constant structural integrity whether the rotating wing tip **306** is in a locked out high speed extended configuration **404** in flight or the rotated stowed configuration **406** during taxi or gate parking maneuvers. The rotating wing tip **306** can also rotate in flight during different modes of flight such as low speed flight.

[0056] Figure 5 is an illustration of an exemplary perspective view of a swing tip assembly system **500** (system **500**) showing the rotating wing tip **306** in the high speed extended configuration **404**, in a low speed rotated swept back configuration **502**, and in a rotated stowed position **406** during taxi or gate parking maneuvers according to an embodiment of the disclosure.

[0057] The rotating wing tip **306** may be deployed by the rotation joint **304** from the aerodynamic body **302** through a plurality of positions. The positions may begin by positioning the rotating wing tip **306** forward at the high speed extended configuration **404** and move through intermediate positions to the deployed position. The deployed position may comprise positioning the rotating wing tip **306** at, for example but without limitation, the low speed rotated swept back configuration **502**, the rotated stowed position **406** during taxiing and gate parking maneuvers, or other deployed position.

[0058] The rotating wing tip **306** may be maintained in line with the wing **302** in the high speed extended configuration **404** without rotation during a high speed flight

condition. The rotating wing tip **306** may also rotate forward to provide a high speed fluid-dynamic efficiency.

[0059] The rotating wing tip **306** rotates partially aft in the low speed rotated swept back configuration **502** to provide a low speed fluid-dynamic efficiency. The rotating wing tip **306** rotates aft in full rotation in the rotated stowed position **406** when the aircraft is on ground.

[0060] Figure **6** is an illustration of an exemplary perspective view of a swing tip assembly system **600** showing the rotation joint **304** and the moving panel **318** of the rotating wing tip **306** in a folding configuration **612** according to an embodiment of the disclosure. The rotation joint **304** is coupled to a wing spar **602** of the wing **302** and to the rotating wing tip **306**. In the embodiment shown in Figure **6**, the moving panel **318** is located near a stationary part **610** (fixed part **610**) of the wing **302** and is configured to fold before the rotating wing tip **306** is rotated. The moving panel **318** folds or rotates around a hinge ling **606** and drops below a trailing edge **608** of the rotating wing tip **306** before the rotating wing tip **306** is rotated.

[0061] Figure **7** is an illustration of a swing tip assembly system **700** (system **700**) showing more detail of the system **600** of Figure **6**. The system **700** may comprise the wing **302**, the rotation joint **304**, and the rotating wing tip **306**. The rotation joint **304** is configured to rotate the rotating wing tip **306** around the pivot center **604** from the high speed extended configuration **404**, to a rotated stowed position **406** during taxi and gate operation in response an actuation command from the actuator **308**.

[0062] When the rotating wing tip **306** is not rotated, the moving panel **318** is in an up position **710**.

[0063] Before the rotating wing tip **306** is rotated, the moving panel **318** folds down in a folded down position **712**, and drops below the trailing edge **608** in response to a panel moving actuator **702**. The panel moving actuator **702** may comprise, for example but without limitation, a linear hydraulic actuator, a ball screw actuator, an electric actuator, or other actuation mechanism.

[0064] In a rotated position such as the low speed rotated swept back configuration **502** and the rotated stowed position **406**, a lock mechanism **704** may be coupled to the mating cylindrical surfaces **316** of the rotation joint **304** to secure the rotating wing tip **306**. In this manner, the lock mechanism **704** locks a position of the rotating wing tip **306** by locking a rotation position of a rotation plate **940** relative to an upper joint plate **920** and a lower joint plate **960** (Figure 9). The lock mechanism **704** (lock actuator **704**) may comprise, for example but without limitation, a linear hydraulic actuator, a ball screw actuator, an electric actuator, or other actuation mechanism.

[0065] A navigation light **706** may be located near a separation section between the stationary part **610** of the wing **302** and the rotating wing tip **306**, and is configured to be exposed and activated upon rotation of the rotating wing tip **306**.

[0066] Figure 7A is an illustration of an exemplary perspective view of a swing tip assembly system **700A** (system **700A**) showing a rotation joint **304** and the moving panel **318** in a sliding configuration **726** according to an embodiment of the disclosure. System **700A** may have functions, material, and structures that are

similar to the system **700**. Therefore common features, functions, and elements may not be redundantly described here.

[0067] When the rotating wing tip **306** is not rotated such as in the high speed extended configuration **404**, the moving panel **318** is at a closed position **720**.

[0068] Before the rotating wing tip **306** is rotated, the moving panel **318** in the sliding configuration **726** slides on a roller **716** supported by tacks **718** to a slided position **722** in a low speed rotated swept back configuration **502**, or in a slided position **724** in a rotated stowed position **406** during taxi or gate parking maneuvers.

[0069] Figure **8** is an illustration of an expanded top view **800** of a portion of the swing tip assembly system **700** of Figure **7**.

[0070] Figure **9** is an illustration of a cross sectional view **900** of the swing tip assembly system **700** of Figure **7** taken along a line A-A **708**. The rotation joint **304** comprises mating cylindrical surfaces **920**, **940** and **960** (**316** in Figure **3**), and is coupled to the rotating wing tip **306**. The rotation joint **304** rotates the rotating wing tip **306** in the plane **504** (Figure **5**) of the wing **302**.

[0071] The mating cylindrical surfaces **920**, **940** and **960** comprise an upper fixed joint plate **920**, an inner mid rotation joint plate **940**, and a lower fixed joint plate **960**. The inner mid rotation joint plate **940** is coupled to the rotating wing tip **306** and is configured to rotate the rotating wing tip **306** in the plane **504** of the wing **302** in response to an actuation command. The upper fixed joint plate **920** is clamped to the inner mid rotation joint plate **940** and is coupled to the wing **302** and secures the inner mid rotation joint plate **940** in place. The lower fixed joint plate **960** is also

clamped to the inner mid rotation joint plate **940** and is coupled to wing **302** and secures the inner mid rotation joint plate **940** in place.

[0072] Figure **10** is an illustration of an exemplary perspective view of mating cylindrical surfaces **920/940/960** of the rotation joint **304** of the swing tip assembly **306** according to an embodiment of the disclosure. The mating cylindrical surfaces **920/940/960** comprise the upper fixed joint plate **920** (upper joint plate **920**), the inner mid rotation joint plate **940** (rotation plate **940**), and the lower fixed joint plate **960** (lower joint plate **960**). The rotation plate **940** is coupled to the swing tip assembly **306** at the swing tip assembly side **1004** (tip side) and to the fluid-dynamic body **302** at the fluid-dynamic body side **1006** (wing box side). A lower access cover plate **1002** is coupled to the lower joint plate **960** to allow access to the rotation joint **304**.

[0073] The rotation plate **940** couples to the swing tip assembly **306**, and comprises a slide ring **1008** comprising an open center **1010**, an upper slide surface **1012**, an inner slide surface **1014**, and a lower slide surface **1016**.

[0074] The upper joint plate **920** is slidably coupled to the upper slide surface **1012** and the inner slide surface **1014**, and couples to the fluid-dynamic body **302**.

[0075] The lower joint plate **960** is slidably coupled to the lower slide surface **1016** and the inner slide surface **1014**, and is coupled to the upper joint plate **920** through the open center **1010**, and couples to the fluid-dynamic body **302**.

[0076] The rotation joint **304** is configured to rotationally couple the swing tip assembly **306** to the fluid-dynamic body **302**.

[0077] In operation, a position of the swing tip assembly **306** is configured in the plane **504** (Figure **5**) of the fluid-dynamic body **302** by rotation of the rotation plate

940 relative to the upper joint plate **920** and the lower joint plate **960**. In this manner, the upper slide surface **1012** of the slide ring **1008** of the rotation plate **940** slides on an upper slidable coupling **1018** to the upper joint plate **920** coupled to the fluid-dynamic body **302**. The lower slide surface **1016** of the slide ring **1008** slides on a lower slidable coupling **1020** to the lower joint plate **960** coupled to the fluid-dynamic body **302**. The inner slide surface **1014** of the slide ring **1008** slides on the upper slidable coupling **1018** to the upper joint plate **920** and on the lower slidable coupling **1020** to the lower joint plate **960**.

[0078] Figure **11** is an illustration of exemplary perspective views of the upper joint plate **920** of the rotation joint **304** of Figure **10**. The upper joint plate **920** comprises a contoured upper face **928**, a mating face **930** for coupling to the lower joint plate **960**, low friction wear faces **922**, and lightening pockets **932**. The lightening pockets **932** are placed on the upper joint plate **920** where the upper joint plate **920** mates with the lower joint plate **960**. The low friction wear faces **922** are placed between the rotation plate **940**, the upper joint plate **920**, and the lower joint plate **960**. The low friction wear faces **922** may comprise, for example but without limitation, Karon lining, or other low friction wear strip material.

[0079] Figure **12** is an illustration of exemplary perspective views of the rotation plate **940** of the rotation joint **304** of Figure **10**. The rotation plate **940** comprises the lightening pockets **932**, actuation mount lug **944**, locking pin locations **946**, and the low friction wear faces **922**.

[0080] Figure **13** is an illustration of exemplary perspective views of the lower joint plate **960** of the mating cylindrical surfaces **316** of the rotation joint **304** of Figure

10. The lower fixed joint plate **960** comprises, the lightening pockets **932**, a mating face **964** for coupling to the upper joint plate **920**, the low friction wear faces **922**, a leading edge support tab **968**, and a lower closure panel rebate **970**.

[0081] Figure **14** is an illustration of an exemplary perspective view of a swing tip assembly system **1400** (system **1400**) according to an embodiment of the disclosure. The system **1400** comprises the rotation joint **304** coupled to the fluid-dynamic body **302** by a structure such as the wing spar **602**, and coupled to the swing tip assembly **306** by a structure such as a wing tip spar **1402**. The rotation joint **304** comprises the upper joint plate **920**, the rotation plate **940**, and the lower joint plate **960** as the mating cylindrical surfaces **316** and a lower access cover plate **1002** coupled to the lower joint plate **960** as explained above.

[0082] The swing tip assembly **306** can be rotated from an extended position such as the high speed extended configuration **404** (Figure **4**) to a deployed position by the rotation plate **940** in response to an actuation of the actuator **308** as explained above. For example but without limitation, the deployed position may comprise, the low speed rotated swept back configuration **502**, the rotated stowed configuration **406**, or other deployed position suitable for operation of the system **1400**.

[0083] Figure **15** is an illustration of an exemplary flowchart showing a process **1500** for providing rotation of the swing tip assembly **306** coupled to the fluid-dynamic body **302** according to an embodiment of the disclosure. The various tasks performed in connection with process **1500** may be performed mechanically, by software, hardware, firmware, computer-readable software, computer readable storage medium, or any combination thereof. It should be appreciated that process

1500 may include any number of additional or alternative tasks, the tasks shown in Figure **15** need not be performed in the illustrated order, and the process **1500** may be incorporated into a more comprehensive procedure or process having additional functionality not described in detail herein.

[0084] For illustrative purposes, the following description of process **1500** may refer to elements mentioned above in connection with Figures **1-14**. In practical embodiments, portions of the process **1500** may be performed by different elements of the system **300** such as: the fluid-dynamic body **302**, the rotation joint **304**, the swing tip assembly **306**, the actuator **308**, the controller **310**, the moving panel **318**, the lock actuator **704**, etc. It should be appreciated that process **1500** may include any number of additional or alternative tasks, the tasks shown in Figure **15** need not be performed in the illustrated order, and the process **1500** may be incorporated into a more comprehensive procedure or process having additional functionality not described in detail herein.

[0085] Process **1500** may begin by providing a rotation plate such as a rotation plate **940** operable to couple to a swing tip assembly such as the swing tip assembly **306**, and comprising a slide ring such as the slide ring **1008** comprising an open center such as the open center **1010**, an upper slide surface such as the upper slide surface **1012**, an inner slide surface such as the inner slide surface **1014**, and a lower slide surface such as the lower slide surface **1016** (task **1502**).

[0086] Process **1500** may continue by slidably coupling an upper joint plate such as the upper joint plate **920** to the upper slide surface **1012** and the inner slide

surface **1014**, the upper joint plate **920** operable to couple to a fluid-dynamic body such as the fluid-dynamic body **302** (task **1504**).

[0087] Process **1500** may continue by slidably coupling a lower joint plate such as the lower joint plate **960** to the lower slide surface **1016** and the inner slide surface **1014**, the lower joint plate **960** operable to couple to the fluid-dynamic body **302** (task **1506**).

[0088] Process **1500** may continue by coupling the lower joint plate **960** to the upper joint plate **920** through the open center **1010** (task **1508**).

[0089] Process **1500** may continue by coupling the lower joint plate **960** and the upper joint plate **920** to the fluid dynamic-body **302** (task **1510**).

[0090] Process **1500** may continue by coupling the rotation plate **940** to the swing tip assembly **306** (task **1512**).

[0091] Process **1500** may continue by configuring the rotation plate **940** to rotate the swing tip assembly **306** in a plane such as the plane **504** of the fluid-dynamic body **302** (task **1514**).

[0092] Figure **16** is an illustration of an exemplary flowchart showing a process **1600** for operating the rotation joint **304** for the swing tip assembly **306** coupled to the fluid-dynamic body **302**, according to an embodiment of the disclosure. The various tasks performed in connection with process **1600** may be performed mechanically, by software, hardware, firmware, computer-readable software, computer readable storage medium, or any combination thereof. It should be appreciated that process **1600** may include any number of additional or alternative tasks, the tasks shown in Figure **16** need not be performed in the illustrated order, and the process **1600** may

be incorporated into a more comprehensive procedure or process having additional functionality not described in detail herein.

[0093] For illustrative purposes, the following description of process **1600** may refer to elements mentioned above in connection with Figures **1-14**. In practical embodiments, portions of the process **1600** may be performed by different elements of the system **300** such as: the fluid-dynamic body **302**, the rotation joint **304**, the swing tip assembly **306**, the actuator **308**, the controller **310**, the moving panel **318**, the lock actuator **704**, etc. It should be appreciated that process **1600** may include any number of additional or alternative tasks, the tasks shown in Figure **16** need not be performed in the illustrated order, and the process **1600** may be incorporated into a more comprehensive procedure or process having additional functionality not described in detail herein.

[0094] Process **1600** may begin by sliding an upper slide surface such as the upper slide surface **1012** of a slide ring such as the slide ring **1008** of a rotation plate such as the rotation plate **940** on an upper slidable coupling such as the upper slidable coupling **1018** to an upper joint plate such as the upper joint plate **920** coupled to the fluid-dynamic body **302** (task **1602**).

[0095] Process **1600** may continue by sliding a lower slide surface such as the lower slide surface **1016** of the slide ring **1008** on a lower slidable coupling such as the lower slidable coupling **1020** to a lower joint plate such as the lower joint plate **960** coupled to the fluid-dynamic body **302** (task **1604**).

[0096] Process **1600** may continue by sliding an inner slide surface such as the inner slide surface **1014** of the slide ring **1008** on the upper slidable coupling **1018** to

the upper joint plate **920** and on the lower slidable coupling **1020** to the lower joint plate **960**, the lower joint plate **960** coupled to the upper joint plate **920** through an open center such as the open center **1010** of the slide ring **1008** (task **1606**).

[0097] Process **1600** may continue by moving a moving panel such as the moving panel **318** located near a fixed part such as the fixed part **610** of the fluid-dynamic body **302** before the swing tip assembly **306** is rotated (task **1608**). The moving panel **318** may comprise a folding panel configured to fold in the folding configuration **612**, a sliding panel configured to slide in the sliding configuration **726**, or other movable surface configuration configured to move.

[0098] Process **1600** may continue by configuring a position of the swing tip assembly **306** in a plane such as the plane **504** of the fluid-dynamic body **302** by rotation of the rotation plate **940** relative to the upper joint plate **920** and the lower joint plate **960**, the rotation plate **940** coupled to the swing tip assembly **306** (task **1610**).

[0099] Process **1600** may continue by maintaining the swing tip assembly **306** in line with the fluid-dynamic body **302** in a high speed extended configuration such as the high speed extended configuration **404** without rotation during a high speed flight condition (task **1612**).

[00100] Process **1600** may continue by rotating the swing tip assembly **306** forward to provide a high speed fluid-dynamic efficiency (task **1614**).

[00101] Process **1600** may continue by rotating the swing tip assembly **306** partially aft in a low speed rotated swept back configuration such as the low speed

rotated swept back configuration **502** to provide a low speed fluid-dynamic efficiency (task **1616**).

[00102] Process **1600** may continue by rotating the swing tip assembly **306** aft in full rotation to provide a rotated stowed configuration such as the rotated stowed configuration **406** when an aircraft such as the aircraft **200** is on ground (task **1618**).

[00103] Process **1600** may continue by locking the position (of the swing tip assembly **306**) by locking a rotation position of the rotation plate **940** relative to the upper joint plate **920** and the lower joint plate **960** (task **1620**).

[00104] Figure **17** is an illustration of an exemplary actuation mechanism **1700** of a swing tip assembly system **300** according to an embodiment of the disclosure. The actuation mechanism **1700** comprises the rotation joint **304**, the swing tip actuator **308**, the lock actuator **704**, a swing selector valve **1702**, a motor operation isolation valve **1704**, a manual release **1706**, a latch selector valve **1708**, a swing sensor **1712**, and a moving plate sensor **1714**.

[00105] In operation, the actuation mechanism **1700** can be controlled by the controller **310** to rotate the swing tip assembly **306**. An actuation command from the actuator **308** is sent to the rotation joint **304**, thereby swinging/rotating the swing tip assembly **306** in response to the actuation command. The lock actuator **704** locks the rotation plate **940** in a rotation position relative to the upper joint plate **920** and the lower joint plate **960** when actuated. The manual release **1706** is configured to manually unlock the lock actuator **704** (latches) that lock the rotation plate **940**, followed by driving fluid into a retract side of the lock actuator **704** (latches) with, e.g.,

a hand pump (not shown). When the lock actuator **704** (latches) are retracted, the swing tip assembly **306** may be moved, e.g., by hand.

[00106] In this way, embodiments of the discloser provide a rotating joint that allows the wing tip to rotate aft in order to facilitate a reduced wing span during taxi and gate parking. In addition, the wing tip can be rotated forward for high speed aerodynamic benefit, rotated part way aft for low speed aerodynamic benefit, and rotated further aft for taxi and gate parking. Thus, embodiments provide an ability to change the aircraft wing span allowing the aircraft be more efficient in flight with larger wing span yet still be accommodated within existing airport restrictions.

[00107] Terms and phrases used in this document, and variations thereof, unless otherwise expressly stated, should be construed as open ended as opposed to limiting. As examples of the foregoing: the term “including” should be read as meaning “including, without limitation” or the like; the term “example” is used to provide exemplary instances of the item in discussion, not an exhaustive or limiting list thereof; and adjectives such as “conventional,” “traditional,” “normal,” “standard,” “known” and terms of similar meaning should not be construed as limiting the item described to a given time period or to an item available as of a given time, but instead should be read to encompass conventional, traditional, normal, or standard technologies that may be available or known now or at any time in the future.

[00108] Likewise, a group of items linked with the conjunction “and” should not be read as requiring that each and every one of those items be present in the grouping, but rather should be read as “and/or” unless expressly stated otherwise. Similarly, a group of items linked with the conjunction “or” should not be read as requiring mutual

exclusivity among that group, but rather should also be read as “and/or” unless expressly stated otherwise. Furthermore, although items, elements or components of the disclosure may be described or claimed in the singular, the plural is contemplated to be within the scope thereof unless limitation to the singular is explicitly stated. The presence of broadening words and phrases such as “one or more,” “at least,” “but not limited to” or other like phrases in some instances shall not be read to mean that the narrower case is intended or required in instances where such broadening phrases may be absent.

[00109] The above description refers to elements or nodes or features being “connected” or “coupled” together. As used herein, unless expressly stated otherwise, “connected” means that one element/node/feature is directly joined to (or directly communicates with) another element/node/feature, and not necessarily mechanically. Likewise, unless expressly stated otherwise, “coupled” means that one element/node/feature is directly or indirectly joined to (or directly or indirectly communicates with) another element/node/feature, and not necessarily mechanically. Thus, although Figures 1-8 depict example arrangements of elements, additional intervening elements, devices, features, or components may be present in an embodiment of the disclosure.

[00110] In this document, the terms “computer program product”, “computer-readable medium”, “computer readable storage medium”, and the like may be used generally to refer to media such as, for example, memory, storage devices, storage unit, or other non-transitory media. These and other forms of computer-readable media may be involved in storing one or more instructions for use by the processor

module **312** to cause the processor module **312** to perform specified operations. Such instructions, generally referred to as "computer program code" or "program code" (which may be grouped in the form of computer programs or other groupings), when executed, enable the system **300**.

[00111] As used herein, unless expressly stated otherwise, "operable" means able to be used, fit or ready for use or service, usable for a specific purpose, and capable of performing a recited or desired function described herein. In relation to systems and devices, the term "operable" means the system and/or the device is fully functional and calibrated, comprises elements for, and meets applicable operability requirements to perform a recited function when activated. In relation to systems and circuits, the term "operable" means the system and/or the circuit is fully functional and calibrated, comprises logic for, and meets applicable operability requirements to perform a recited function when activated.

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

1. A rotation joint for rotationally coupling a swing tip assembly to a fluid-dynamic body, the rotation joint comprising:
 - a rotation plate operable to couple to a swing tip assembly, and comprising a slide ring comprising an open center, an upper slide surface, an inner slide surface, and a lower slide surface;
 - an upper joint plate slidably coupled to the upper slide surface and the inner slide surface, and operable to couple to a fluid-dynamic body; and
 - a lower joint plate slidably coupled to the lower slide surface and the inner slide surface, and operable to couple to the fluid-dynamic body, and coupled to the upper joint plate through the open center.
2. The rotation joint of claim 1, further comprising a lower access cover plate coupled to the lower joint plate and operable to allow access to the open center.
3. The rotation joint of claim 1, further comprising a swing tip actuator coupled to the rotation joint and the fluid-dynamic body, and operable to rotate the swing tip assembly in a plane of the fluid-dynamic body in response to an actuation.
4. The rotation joint of claim 3, wherein the swing tip actuator comprises one of: a linear hydraulic actuator, and a ball screw actuator.

5. The rotation joint of claim 1, further comprising a lock mechanism operable to lock the rotation plate in a rotation position relative to the upper joint plate and the lower joint plate when actuated.
6. The rotation joint of claim 1, wherein:
 - a plurality of lightening pockets are placed on the upper joint plate where the upper joint plate mates with the lower joint plate, and
 - a low friction wear strip material is placed between the rotation joint and the upper joint plate and the rotation joint and the lower joint plate.
7. The rotation joint of claim 1, further comprising:
 - the fluid dynamic-body comprising a wing of an aircraft; and
 - the swing tip assembly comprising a wing tip.
8. The rotation joint of claim 7, further comprising a navigation light located near a separation section between the fluid-dynamic body and the swing tip assembly and operable to be exposed and activated in response to rotation of the swing tip assembly.
9. The rotation joint of claim 7, wherein the swing tip assembly further comprises a moving panel located near a fixed part of the fluid-dynamic body and operable to move before the swing tip assembly is rotated.

- 10.** A method for providing rotation of a swing tip assembly coupled to a fluid-dynamic body, the method comprising:

providing a rotation plate operable to couple to a swing tip assembly, and comprising a slide ring comprising an open center, an upper slide surface, an inner slide surface, and a lower slide surface;

slidably coupling an upper joint plate to the upper slide surface and the inner slide surface, the upper joint plate operable to couple to a fluid-dynamic body;

slidably coupling a lower joint plate to the lower slide surface and the inner slide surface, the lower joint plate operable to couple to the fluid-dynamic body; and

coupling the lower joint plate to the upper joint plate through the open center.

- 11.** The method of claim **10**, further comprising:

coupling the lower joint plate and the upper joint plate to the fluid-dynamic-body; and

coupling the rotation plate to the swing tip assembly.

- 12.** The method of claim **11**, further comprising configuring the rotation plate to rotate the swing tip assembly in a plane of the fluid-dynamic body.

13. The method of claim **11**, wherein:

the fluid-dynamic body comprises a wing of an aircraft; and

the swing tip assembly comprises a wing tip.

14. A method for operating a rotation joint for a swing tip assembly coupled to a fluid-dynamic body, the method comprising:

sliding an upper slide surface of a slide ring of a rotation plate on an upper slidable coupling to an upper joint plate coupled to the fluid-dynamic body;

sliding a lower slide surface of the slide ring on a lower slidable coupling to a lower joint plate coupled to the fluid-dynamic body;

sliding an inner slide surface of the slide ring on the upper slidable coupling to the upper joint plate and on the lower slidable coupling to the lower joint plate, the lower joint plate coupled to the upper joint plate through an open center of the slide ring; and

configuring a position of the swing tip assembly in a plane of the fluid-dynamic body by rotation of the rotation plate relative to the upper joint plate and the lower joint plate, the rotation plate coupled to the swing tip assembly.

15. The method of claim 14, further comprising moving a moving panel located near a fixed part of the fluid-dynamic body before the swing tip assembly is rotated.
16. The method of claim 14, further comprising maintaining the swing tip assembly in line with the fluid-dynamic body in a high speed extended configuration without rotation during a high speed flight condition.
17. The method of claim 14, further comprising rotating the swing tip assembly forward to provide a high speed fluid-dynamic efficiency.
18. The method of claim 14, further comprising rotating the swing tip assembly partially aft in a low speed rotated swept back configuration to provide a low speed fluid-dynamic efficiency.
19. The method of claim 14, further comprising rotating the swing tip assembly aft in full rotation to provide a rotated stowed position when an aircraft is on ground.
20. The method of claim 14, further comprising locking the position by locking a rotation position of the rotation plate relative to the upper joint plate and the lower joint plate.

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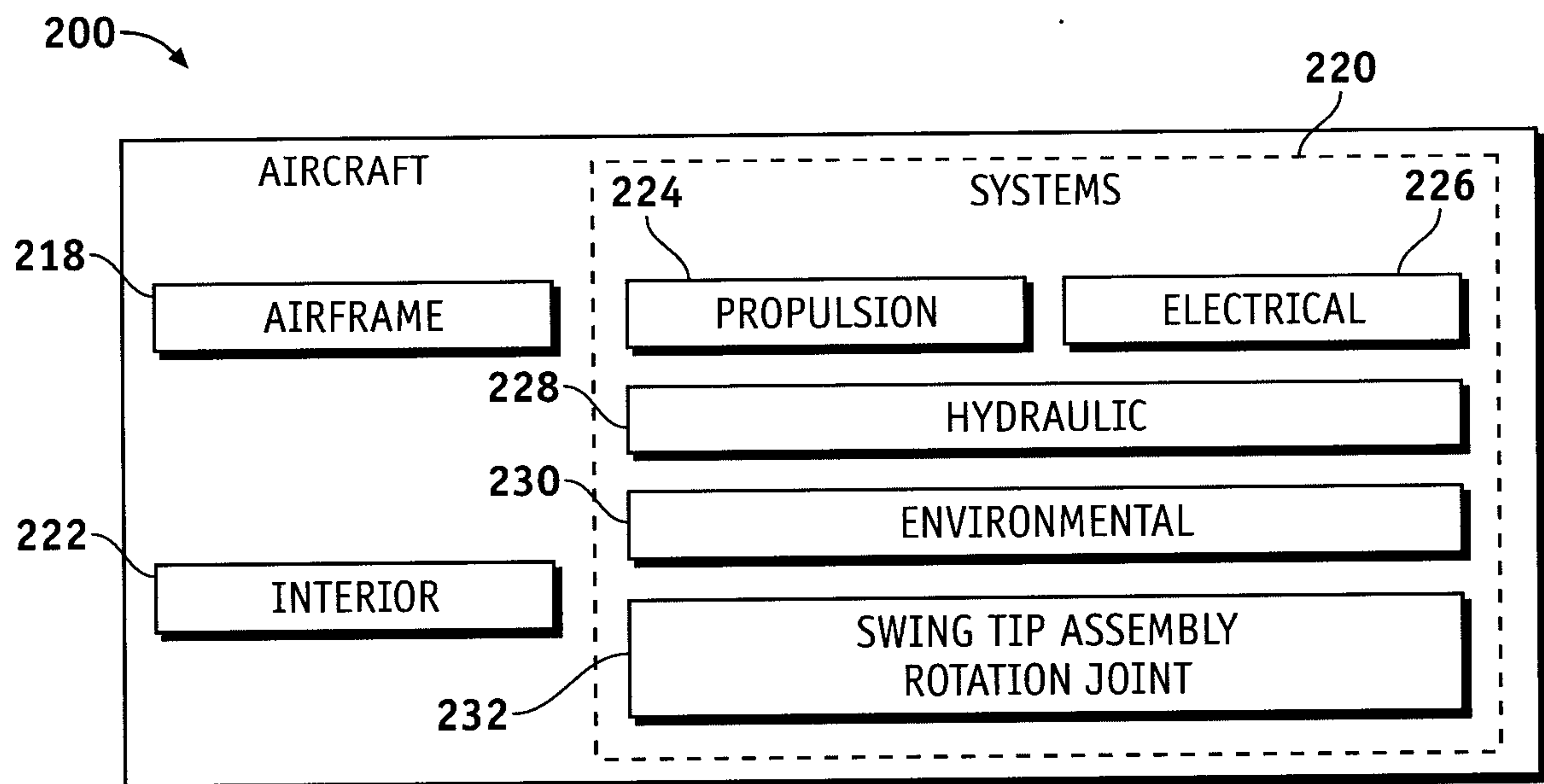
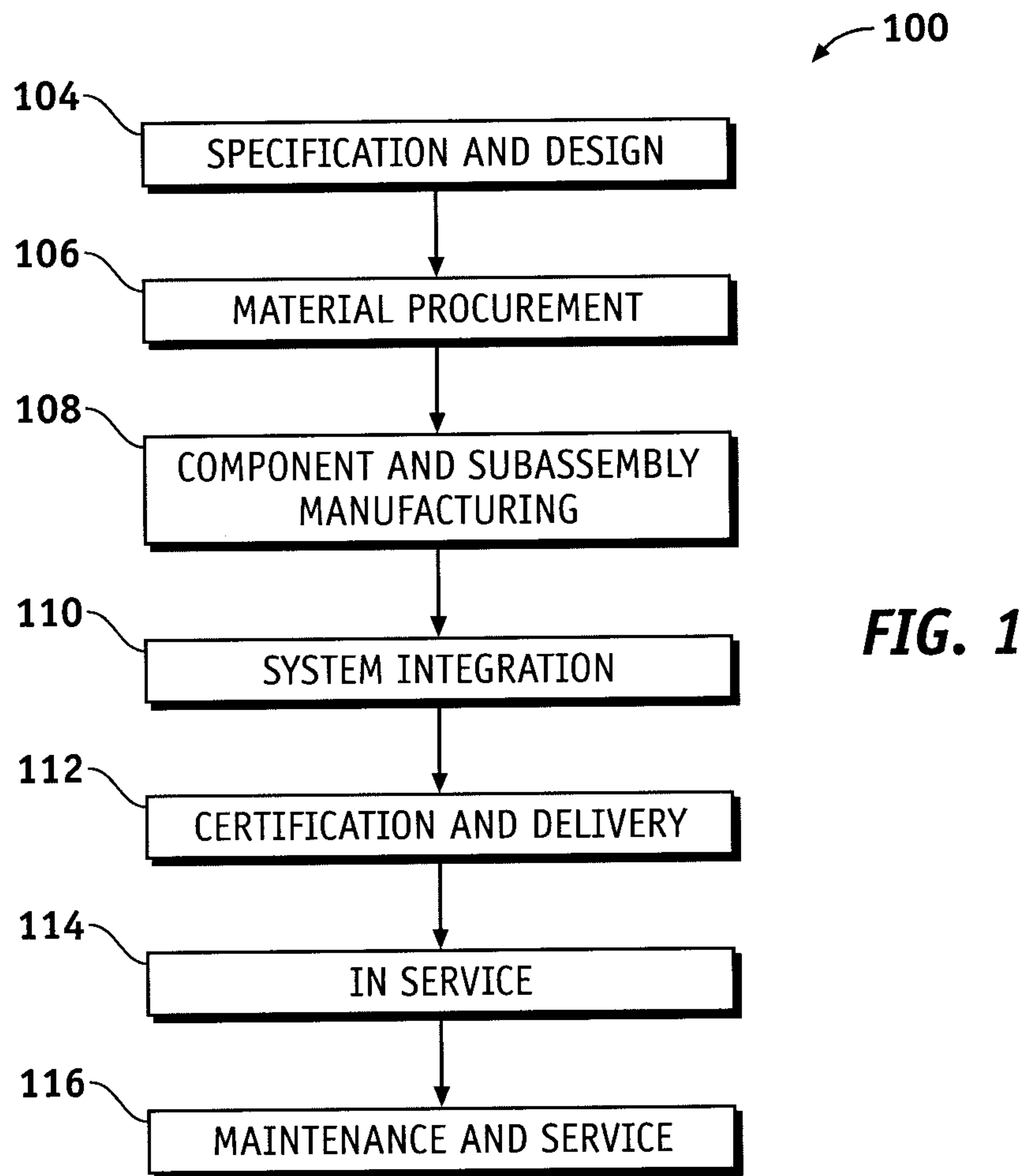
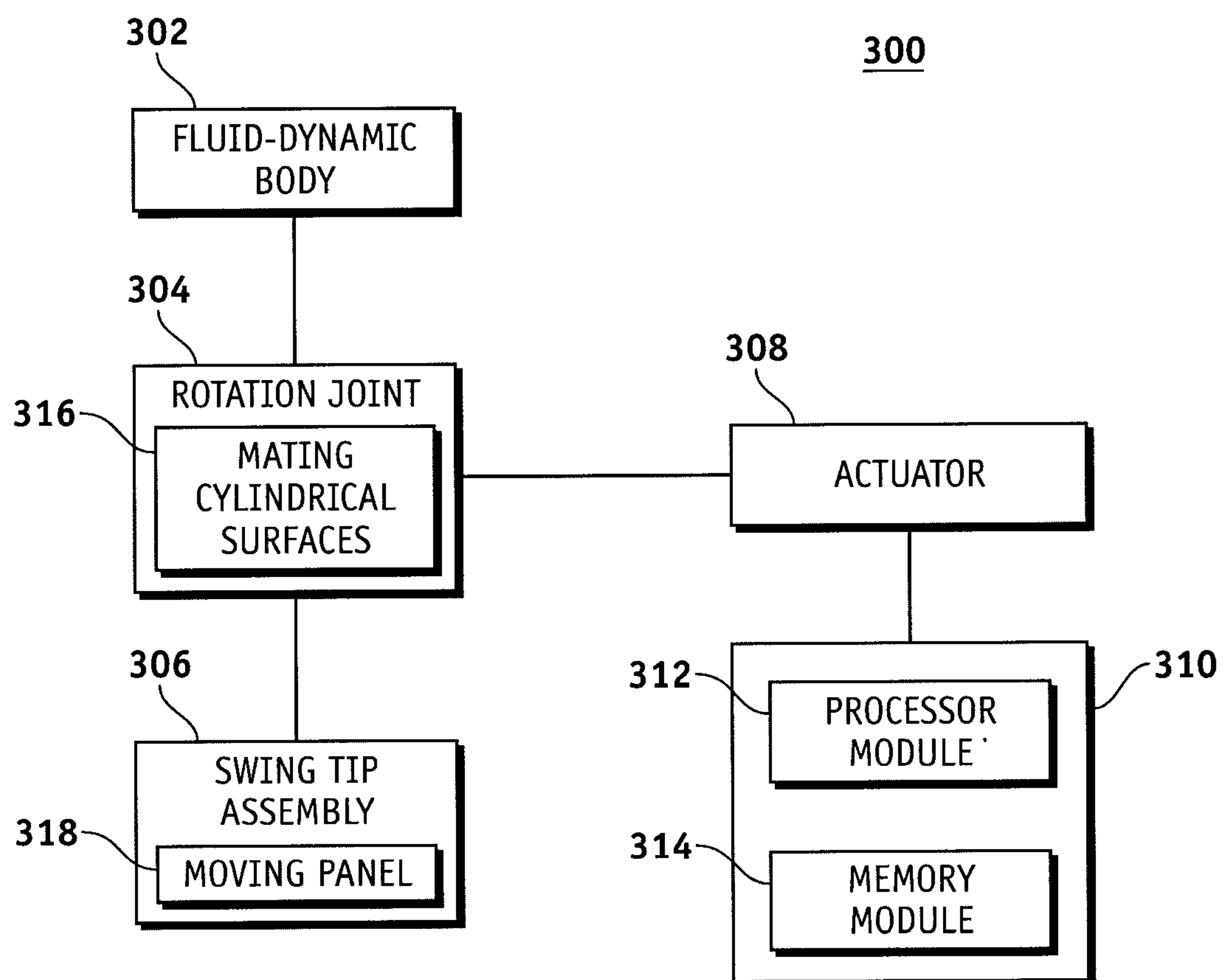
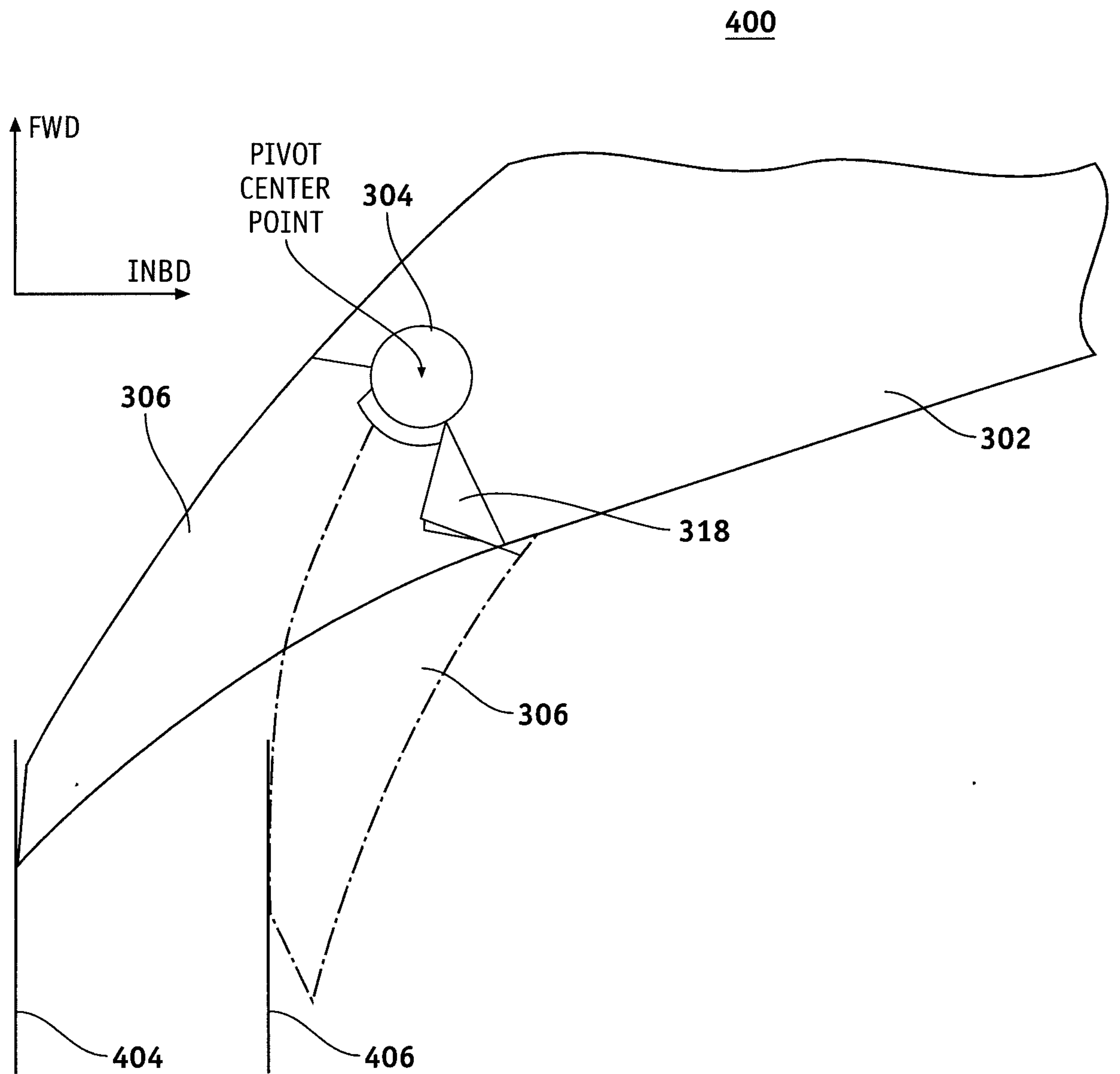


FIG. 2

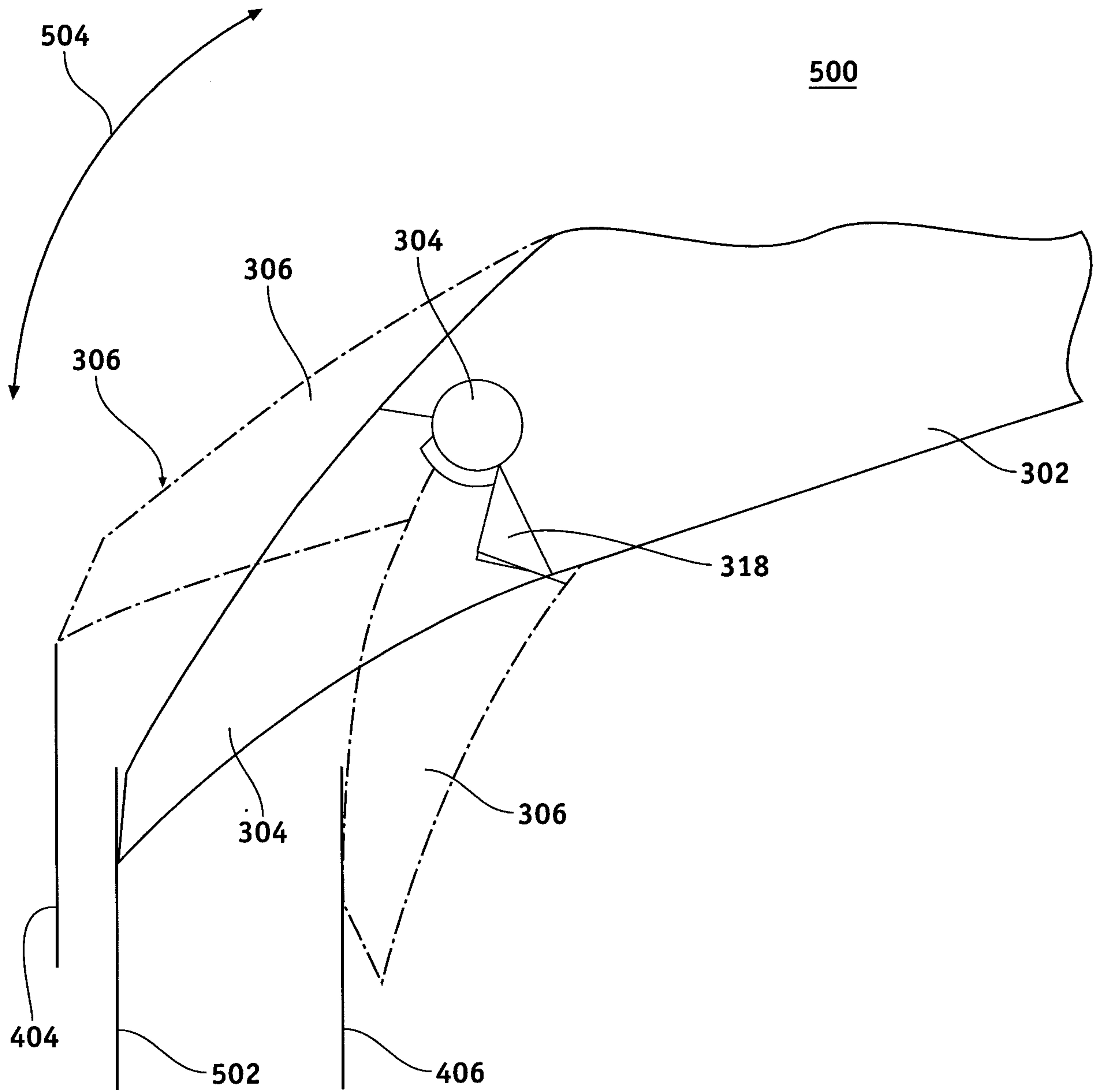
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**FIG. 3**

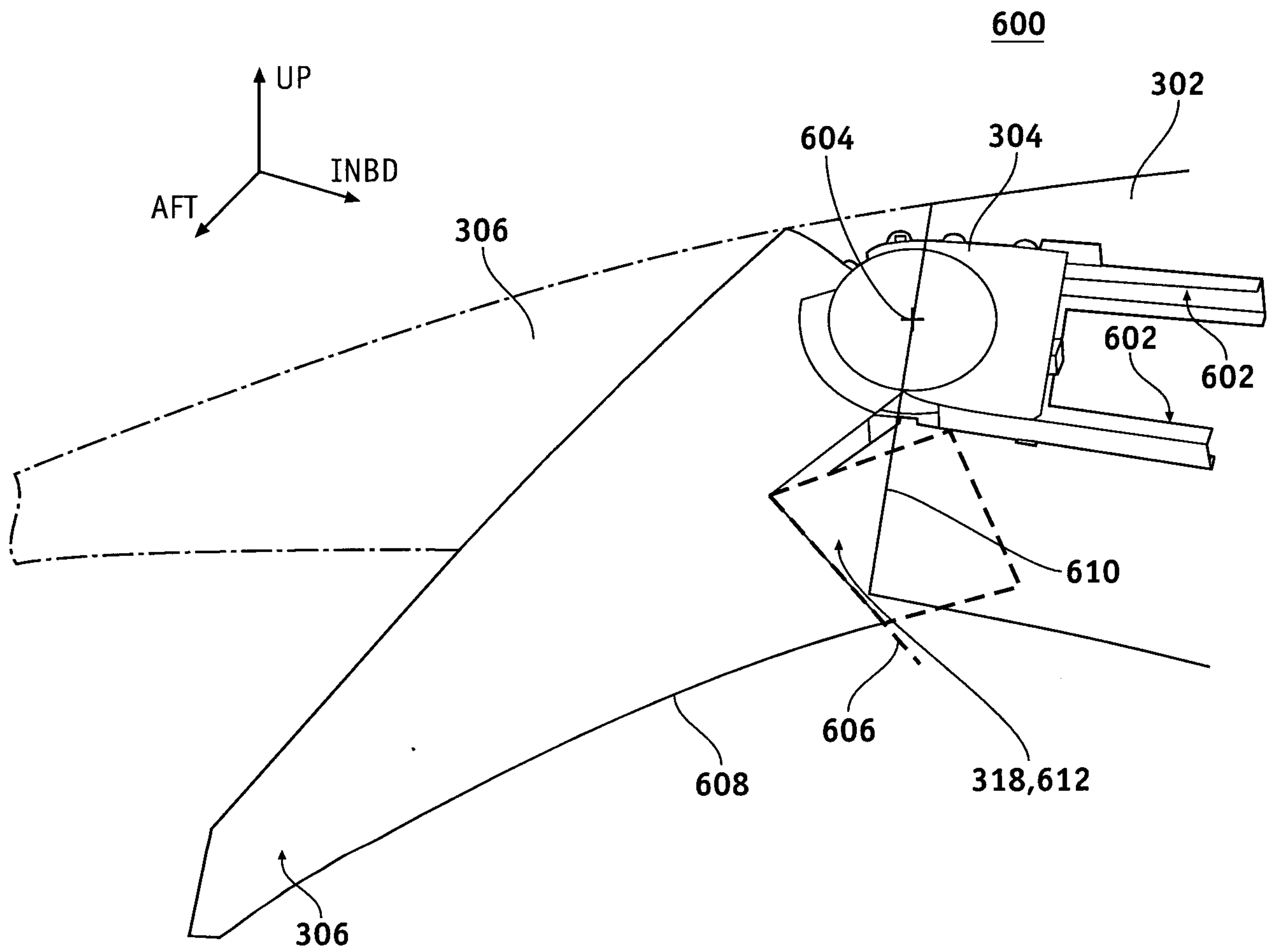
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**FIG. 4**

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**FIG. 5**

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**FIG. 6**

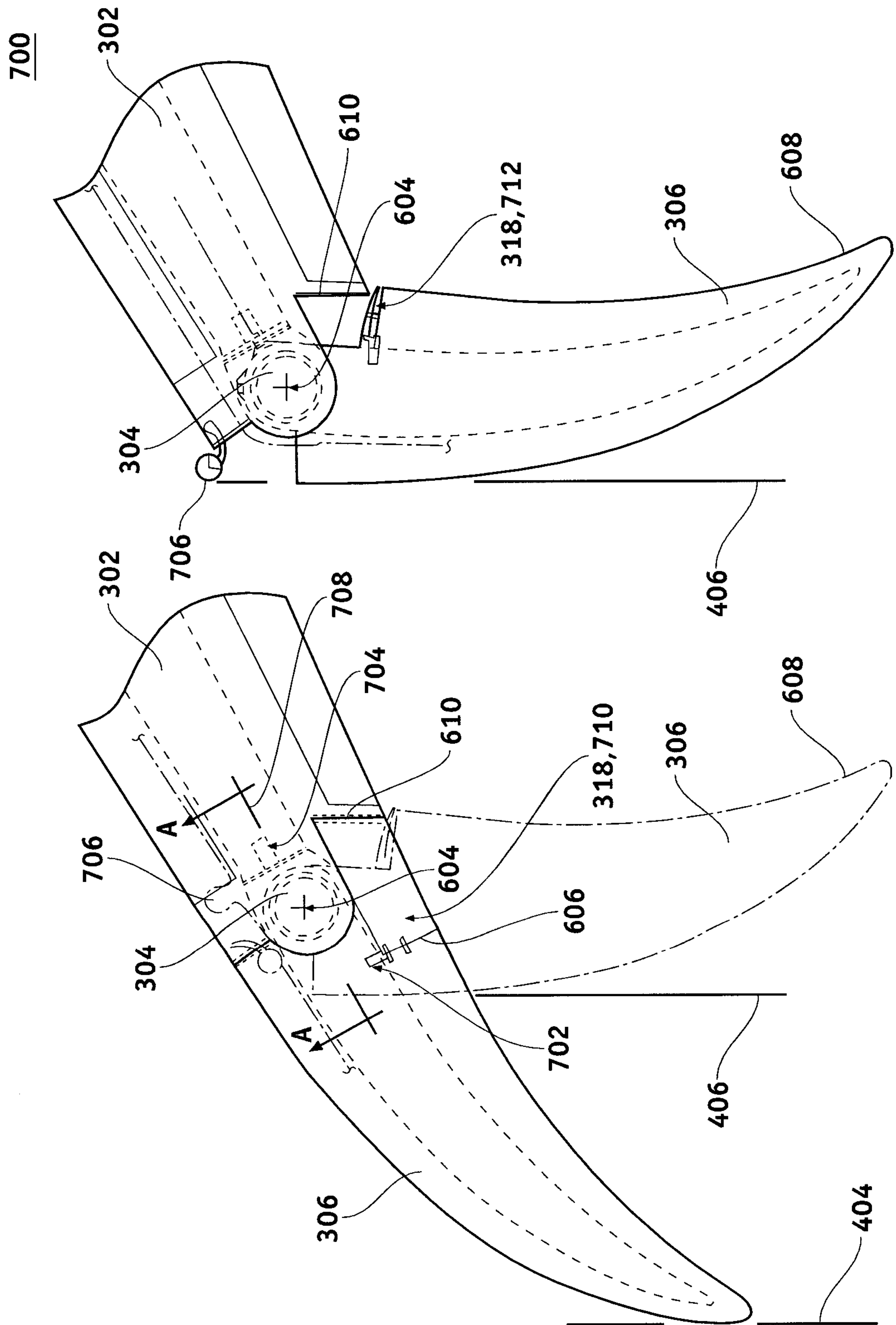


FIG. 7



FIG. 7A

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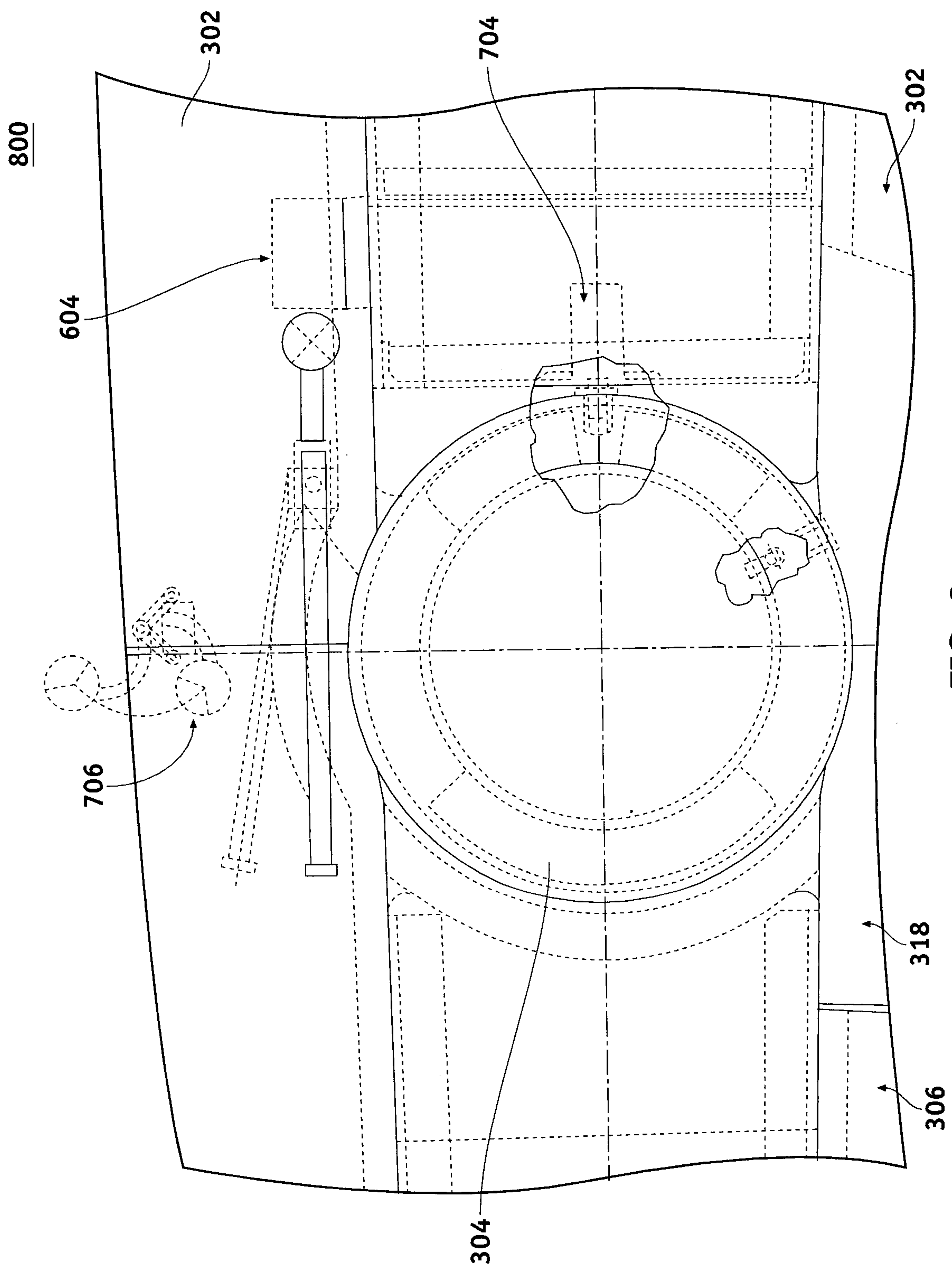
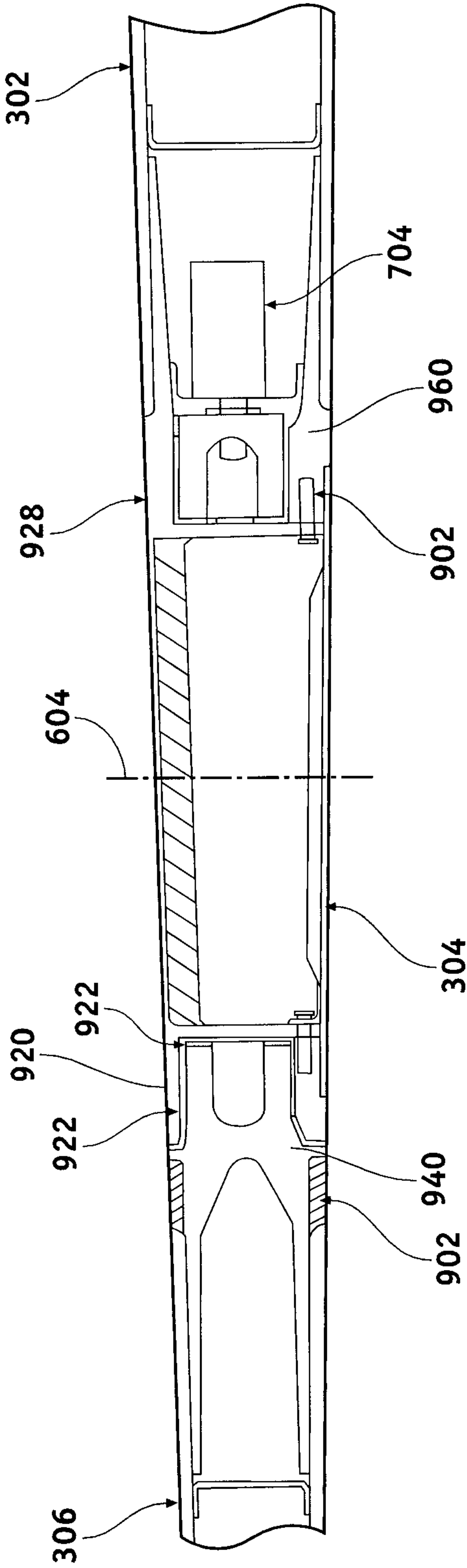


FIG. 8

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900

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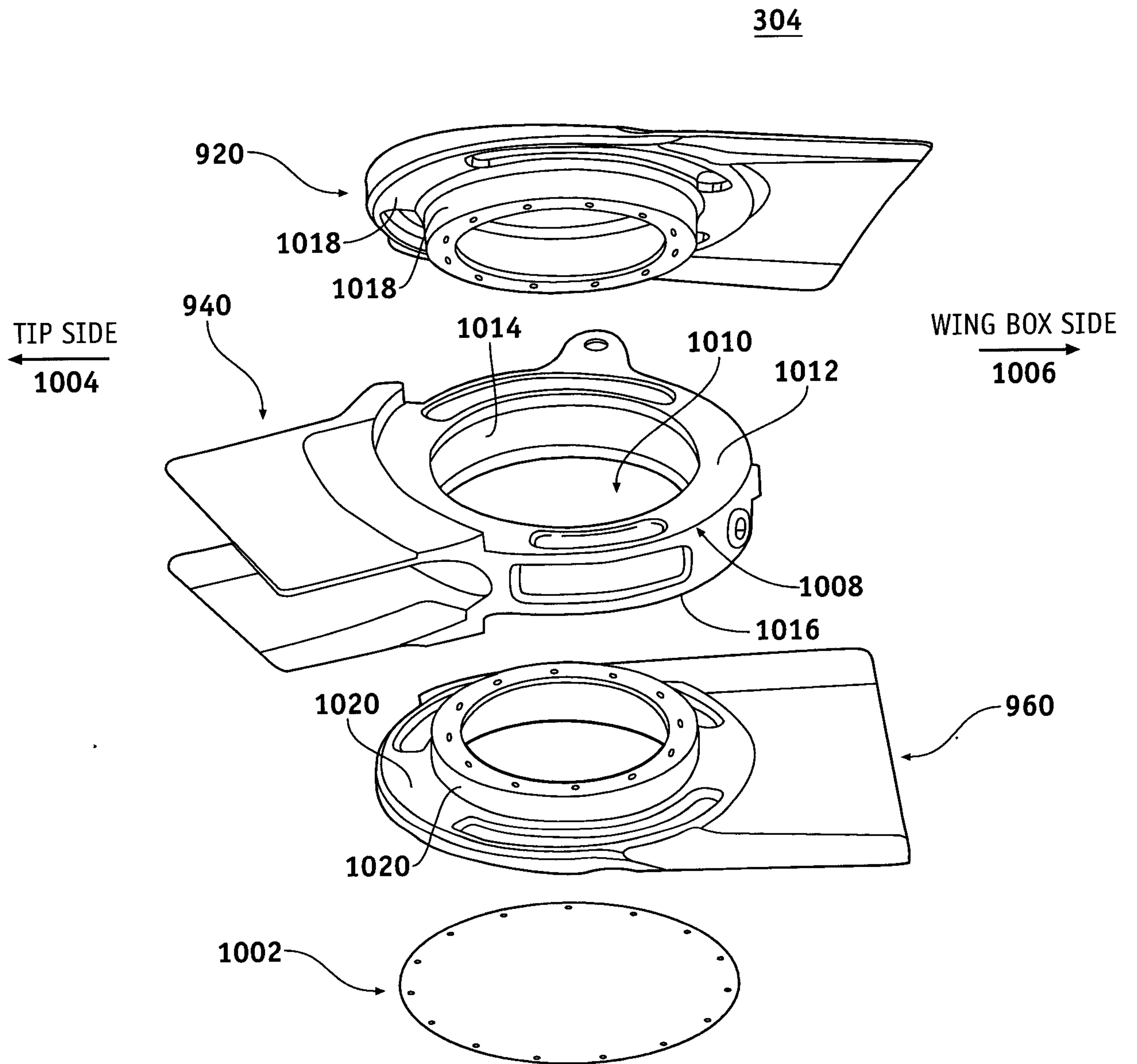


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FIG. 9

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920

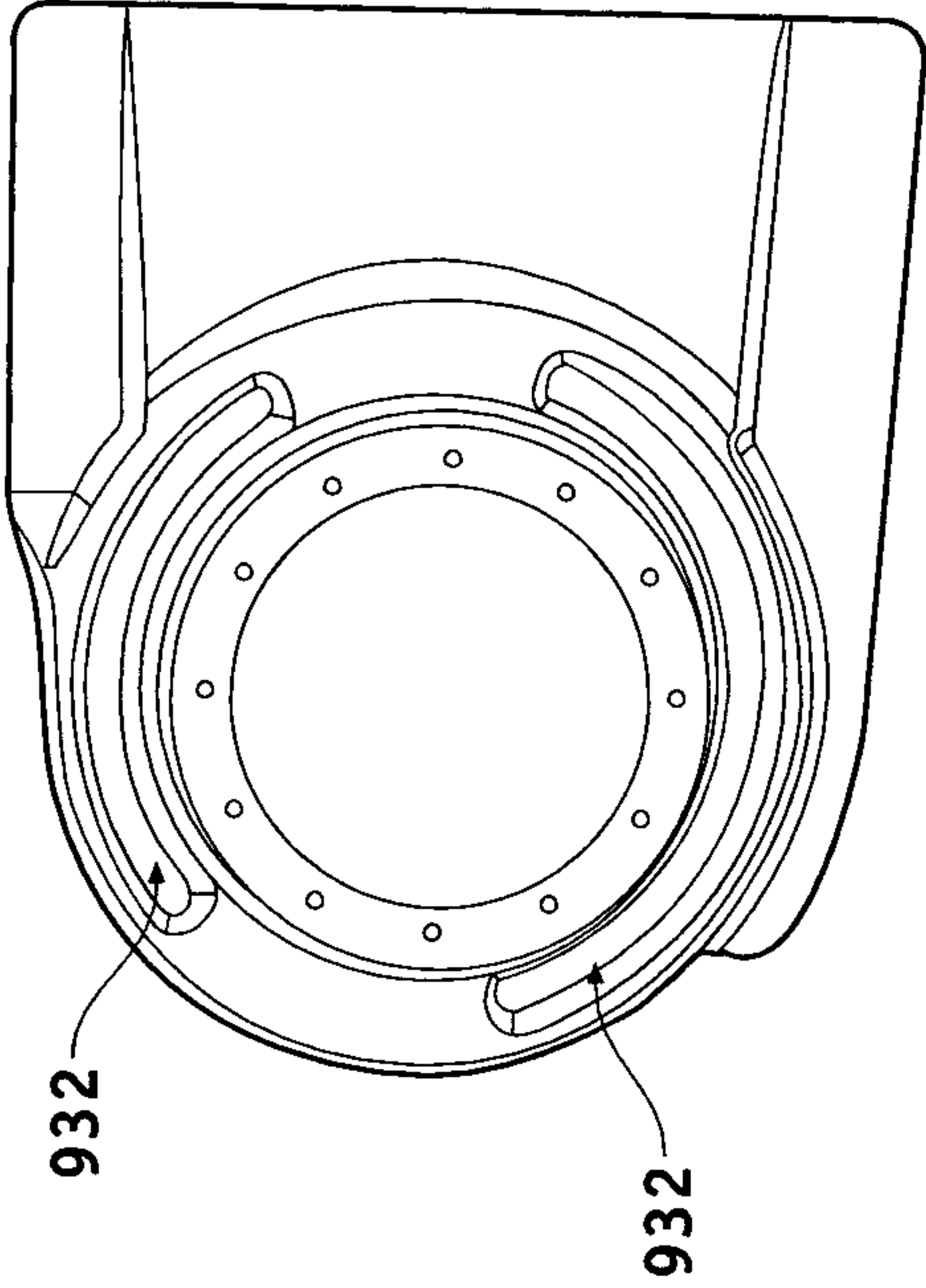
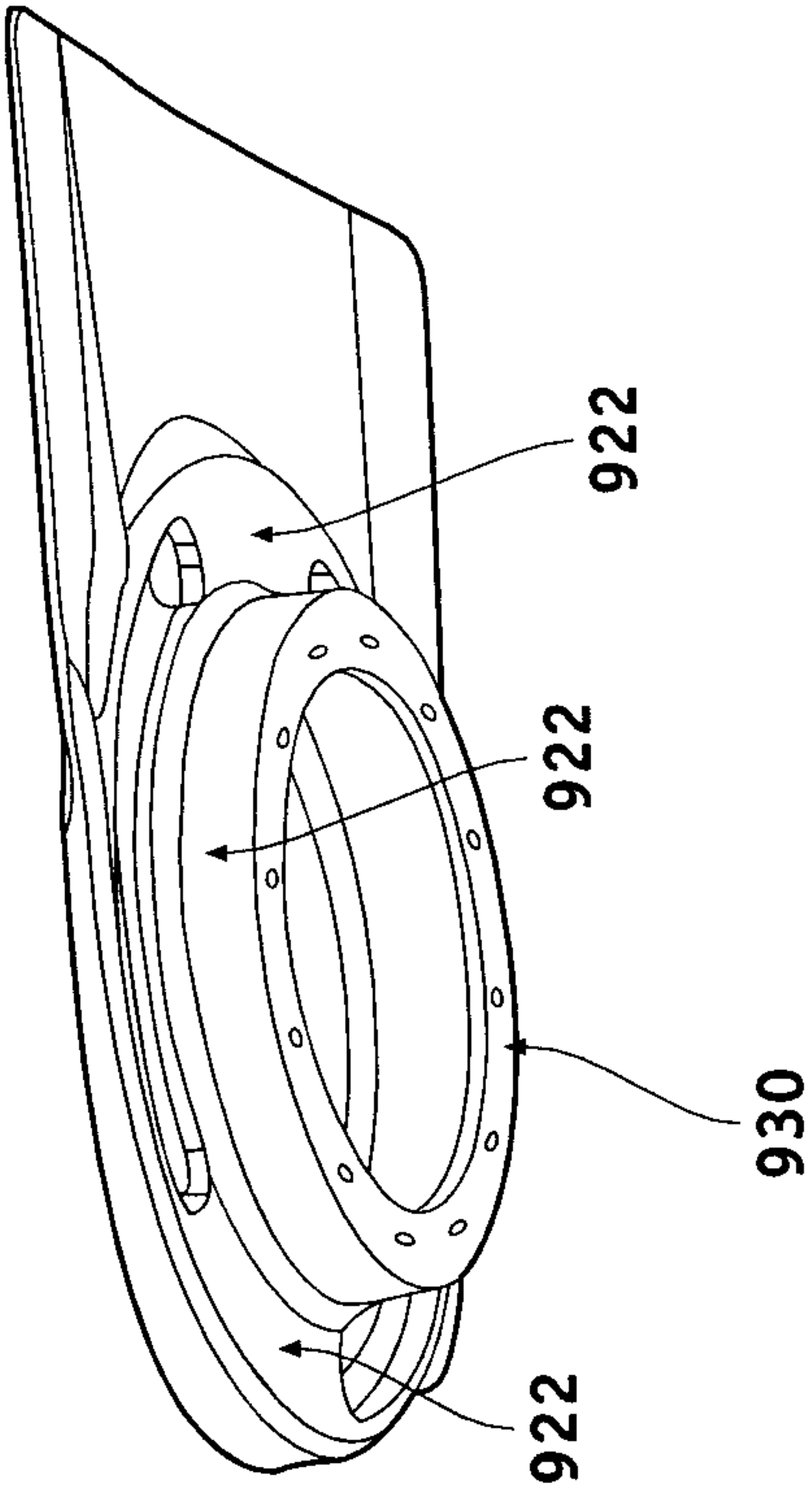
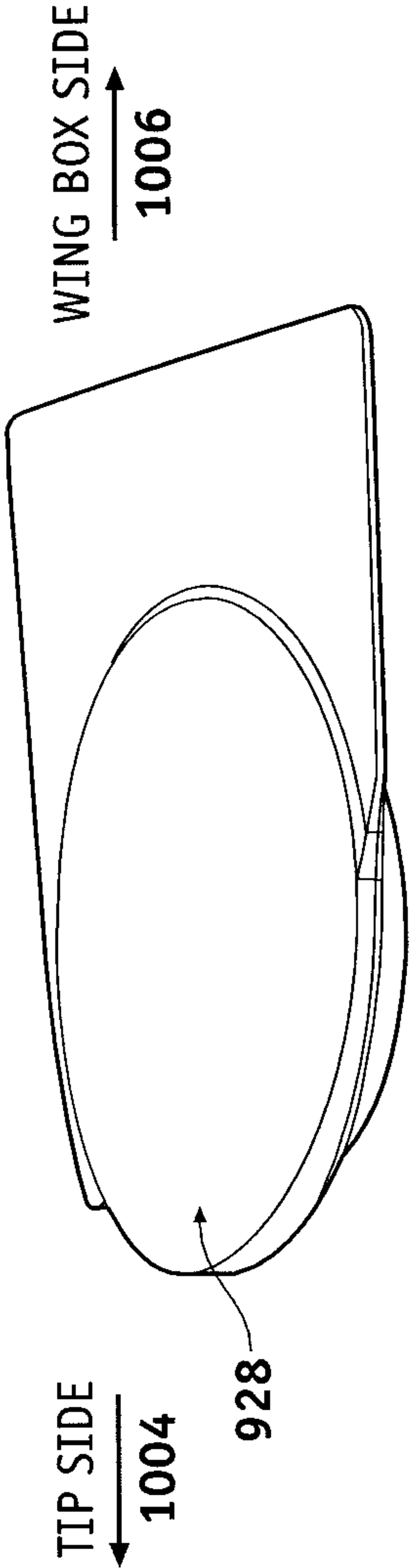


FIG. 11

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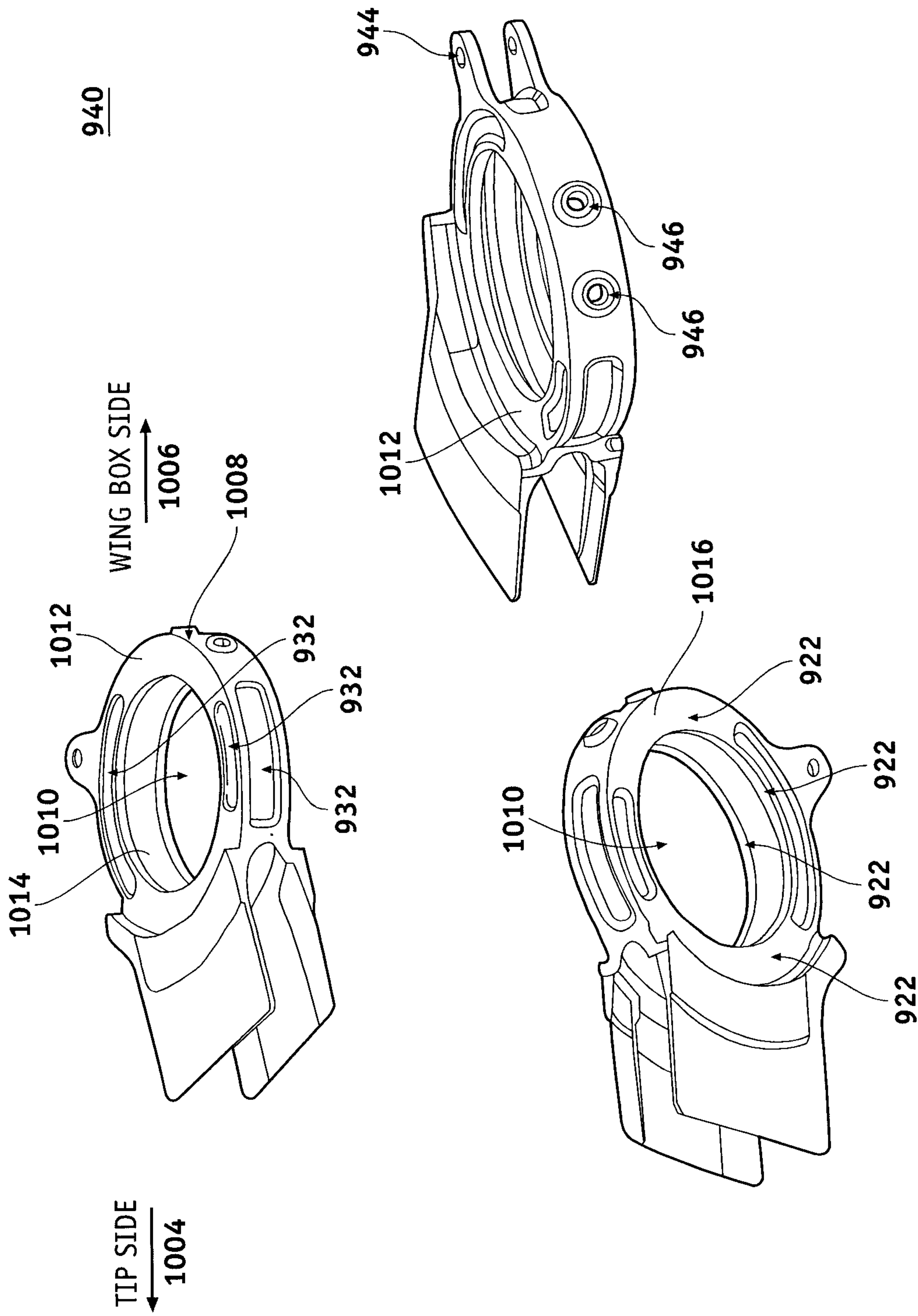
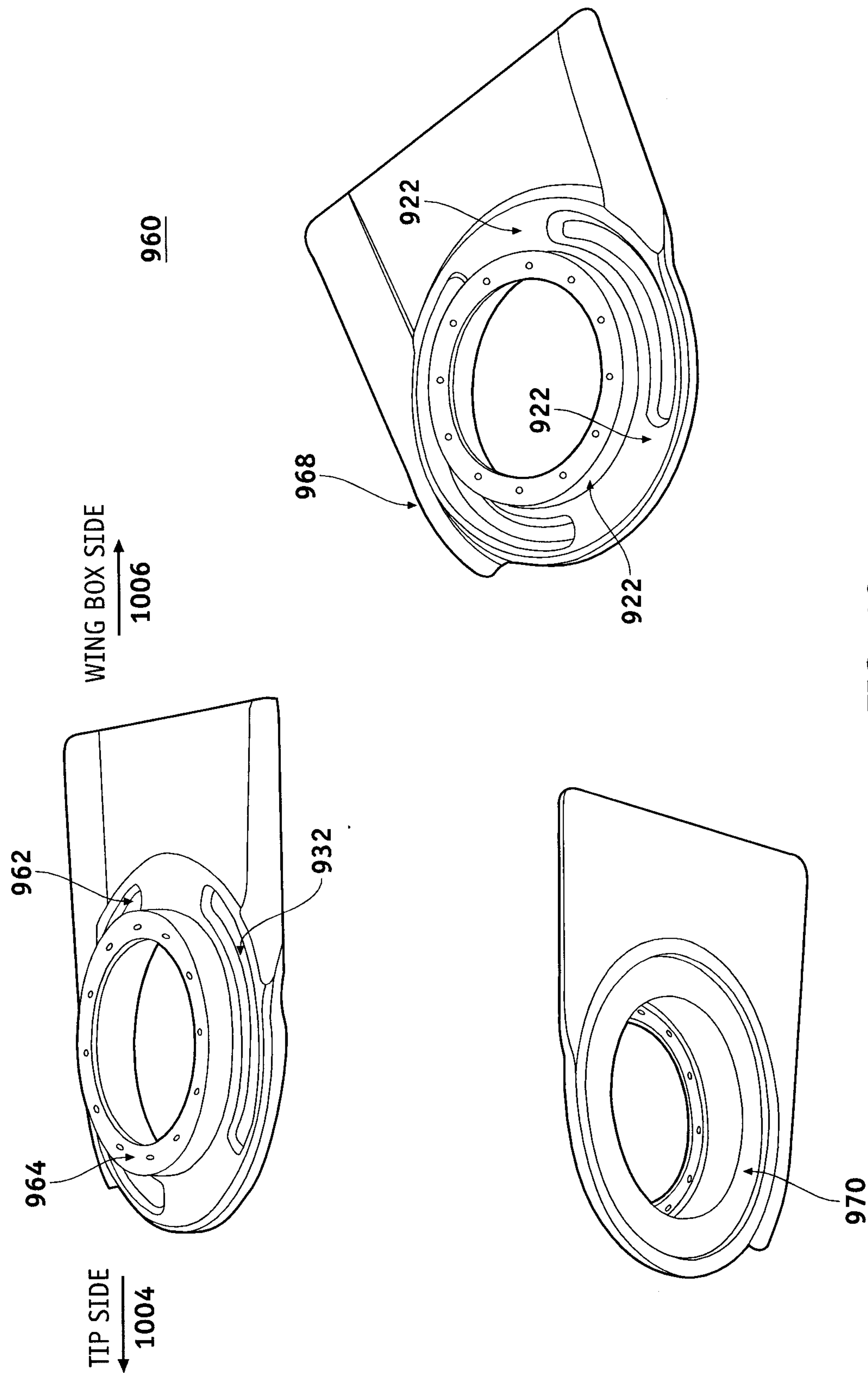


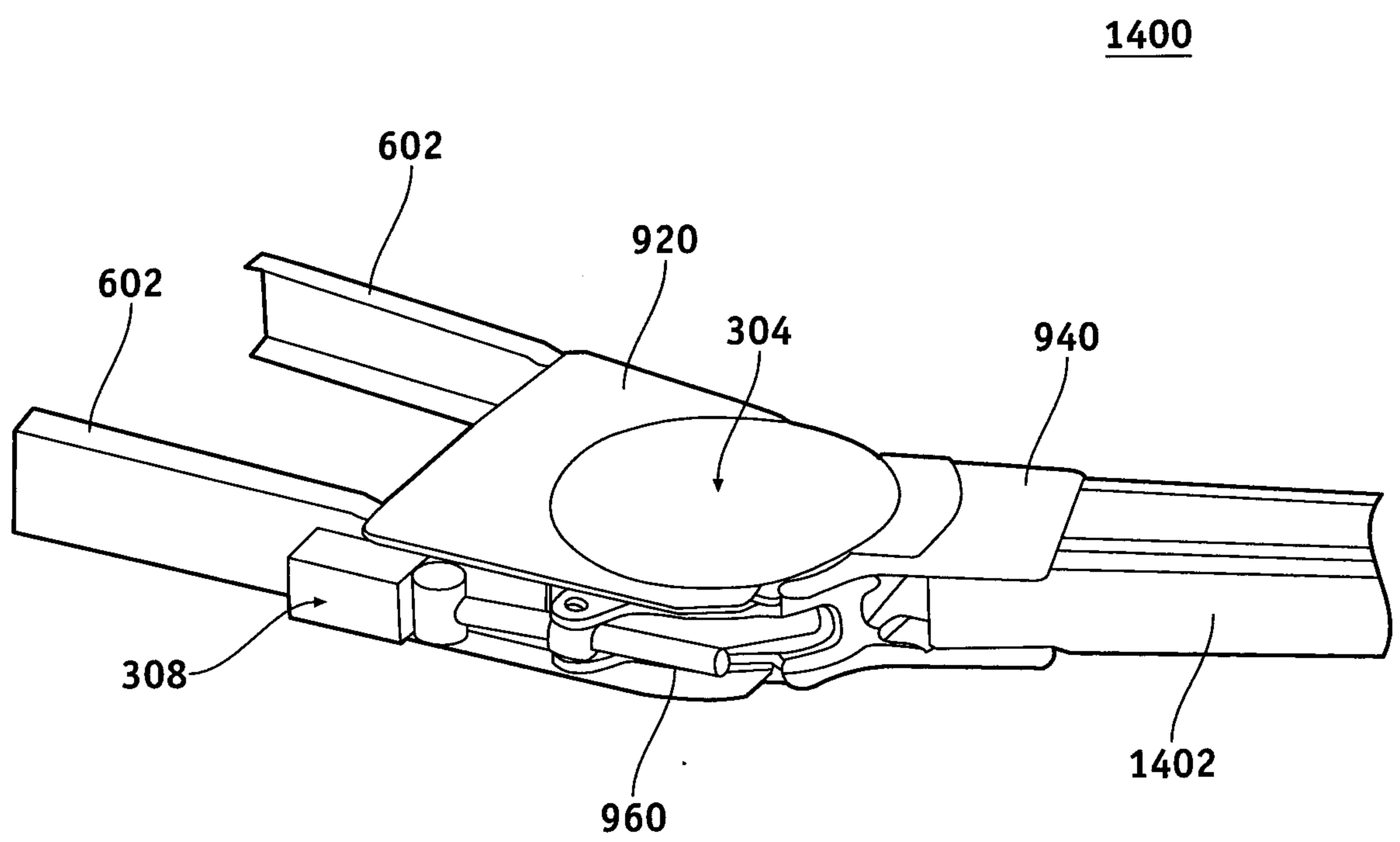
FIG. 12

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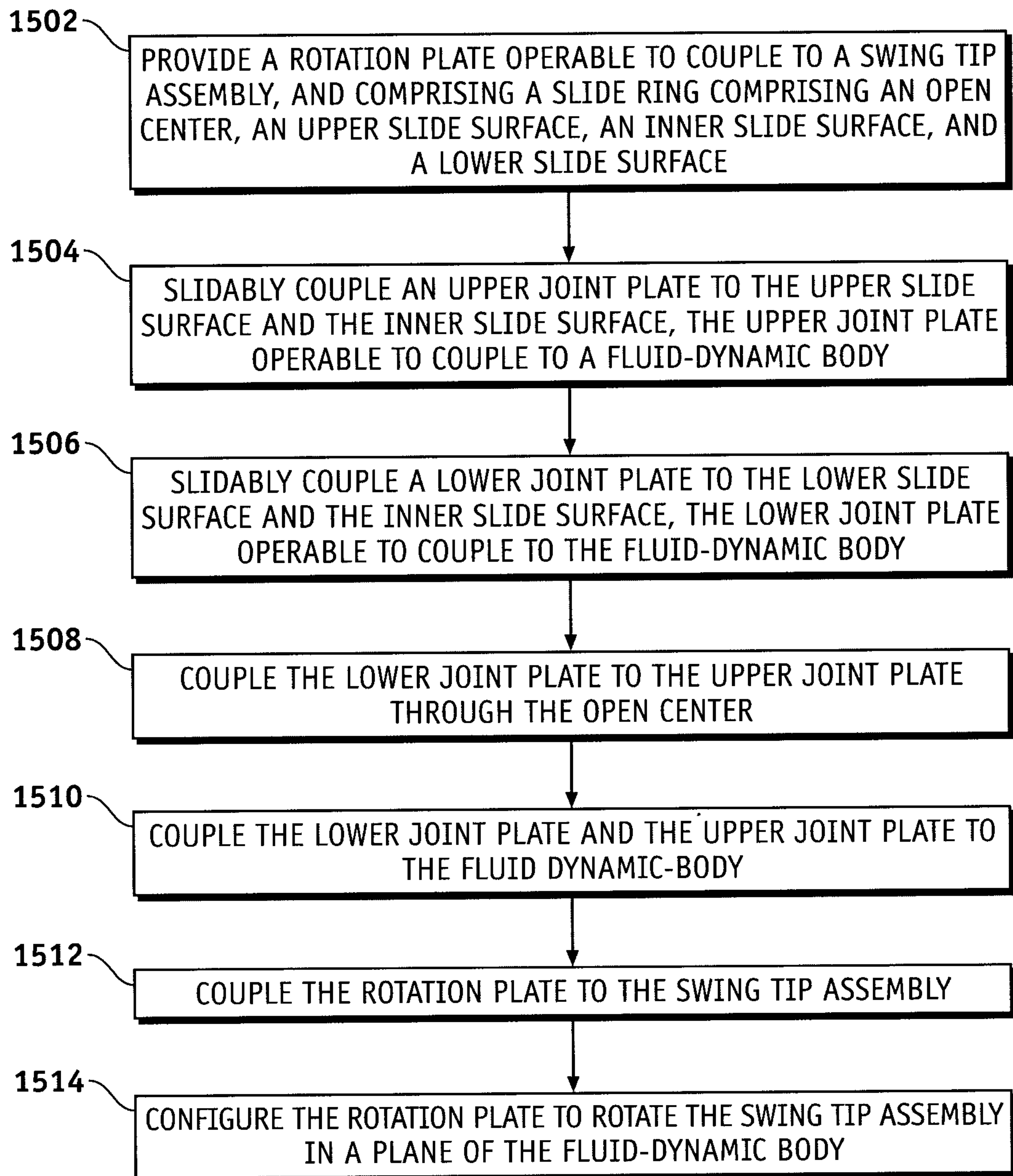


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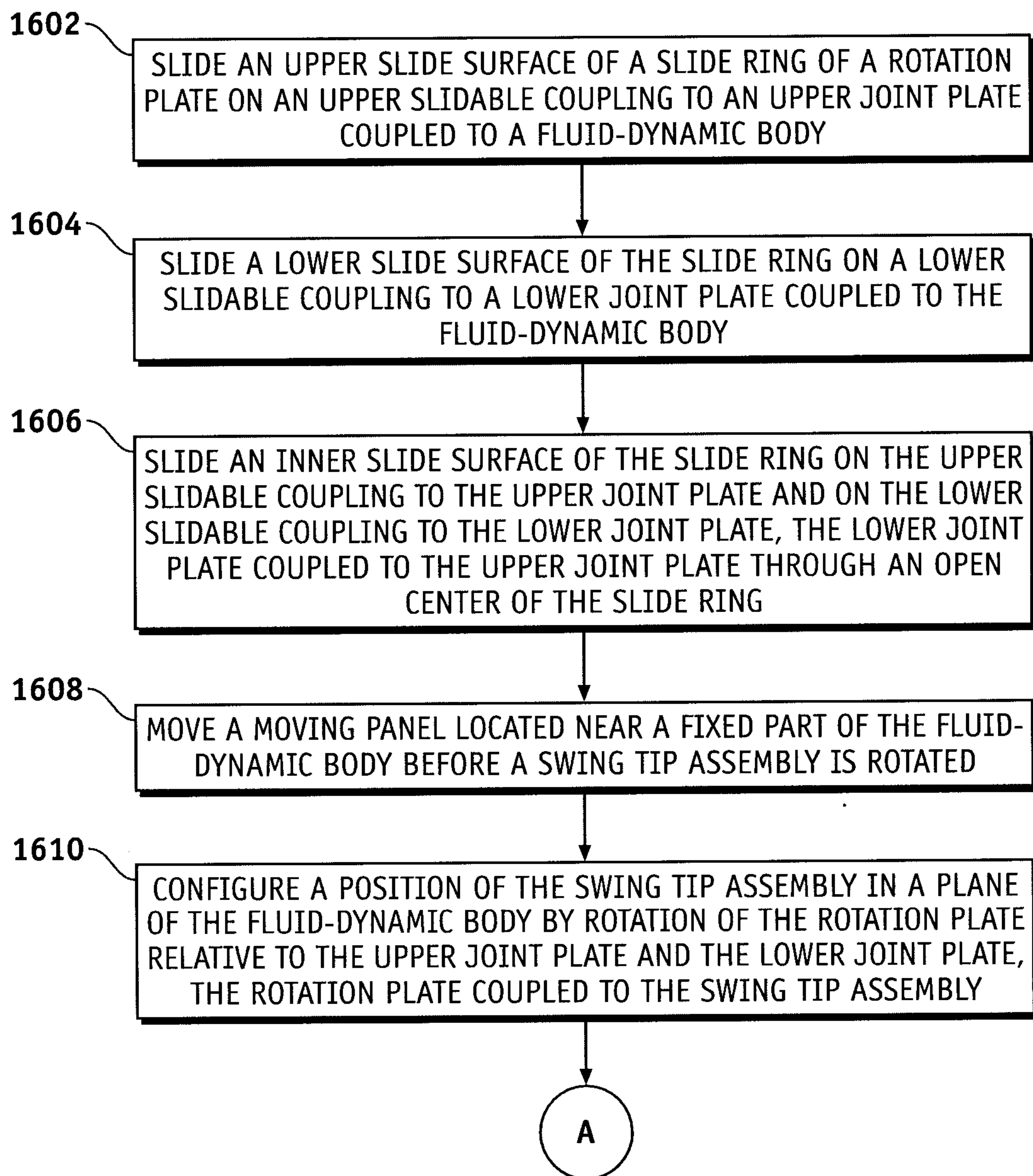
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**FIG. 14**

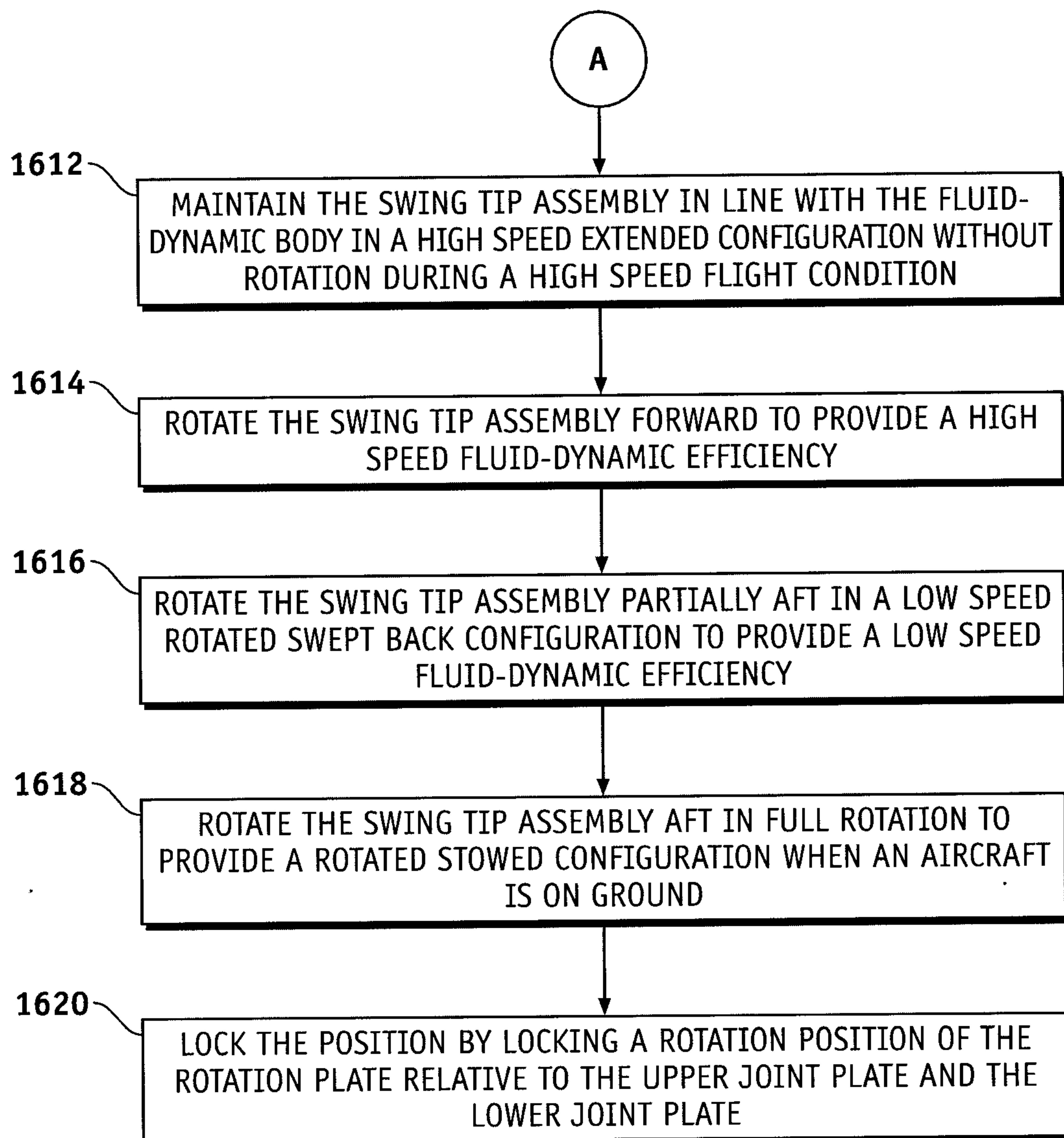
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1500**FIG. 15**

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1600**FIG. 16**

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**FIG. 16 cont.**

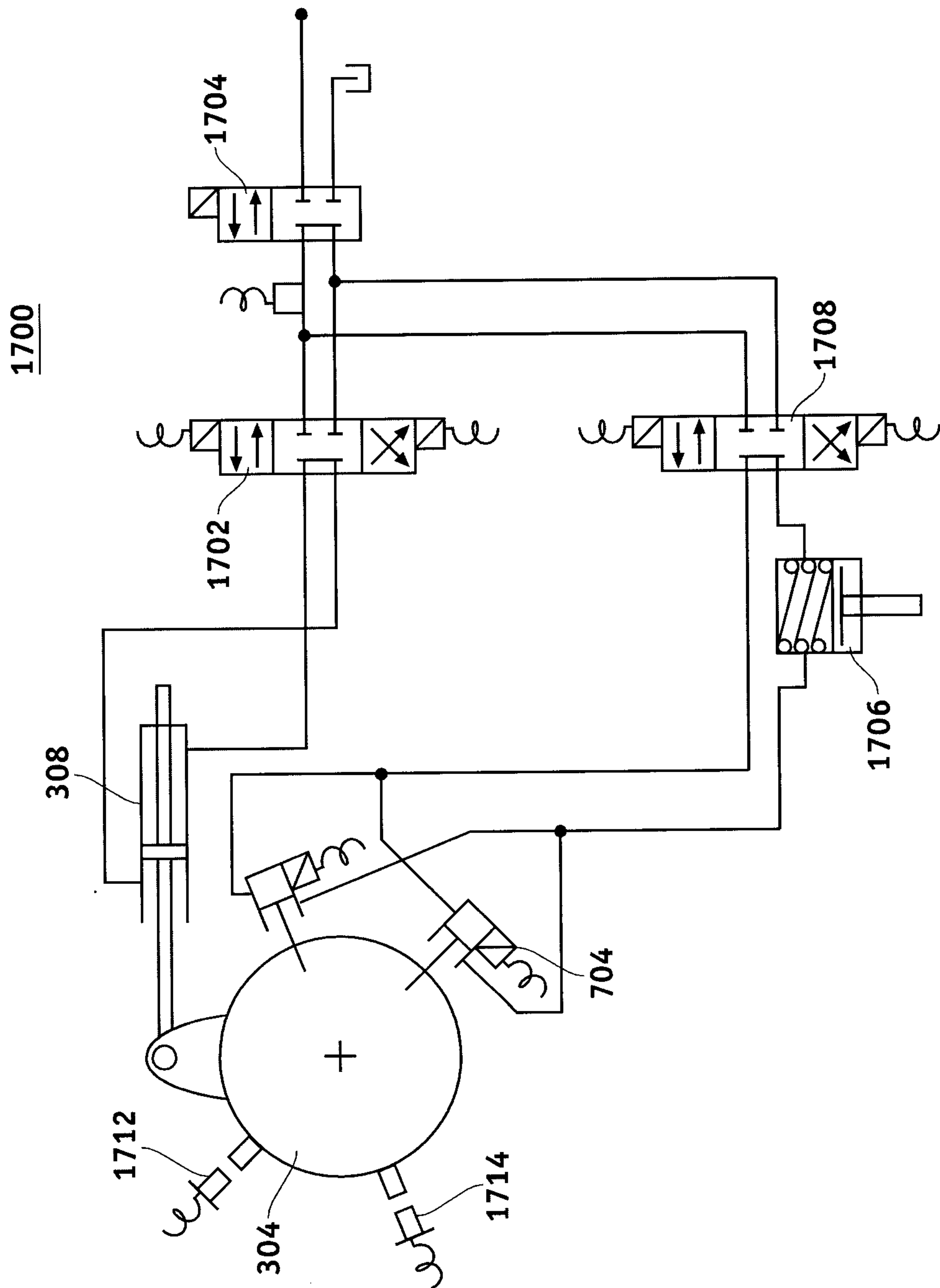


FIG. 17

400

