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CA 2795637 C 2016/01/05

(11)(21) **2 795 637**

(12) **BREVET CANADIEN**
CANADIAN PATENT

(13) **C**

(22) **Date de dépôt/Filing Date:** 2012/11/14
(41) **Mise à la disp. pub./Open to Public Insp.:** 2013/08/10
(45) **Date de délivrance/Issue Date:** 2016/01/05
(30) **Priorité/Priority:** 2012/02/10 (US13/370,314)

(51) **Cl.Int./Int.Cl.** ***B64C 3/44*** (2006.01),
B64C 13/24 (2006.01), ***B64C 3/50*** (2006.01),
B64C 9/04 (2006.01)

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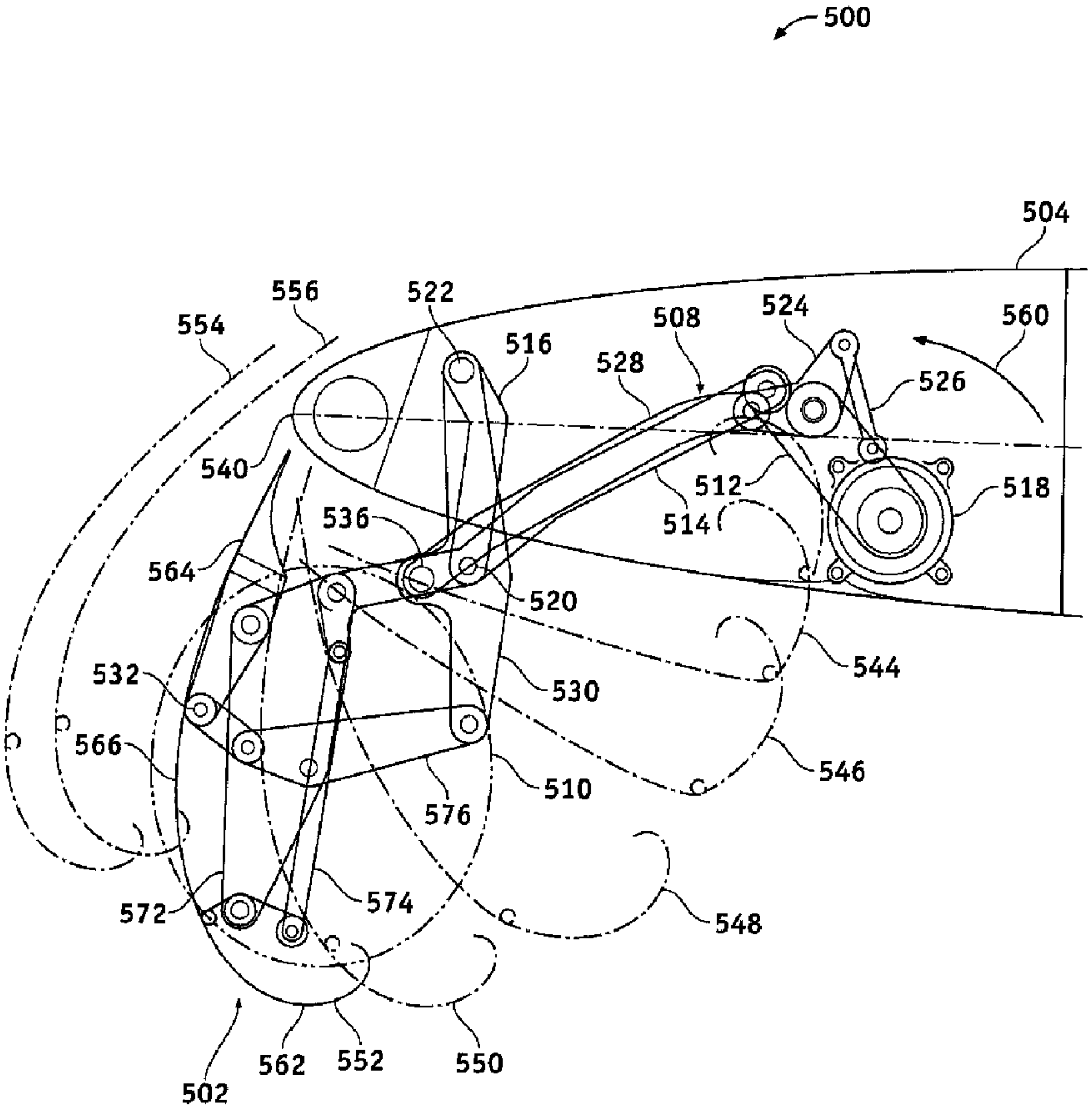
(54) **Titre : VOLET KRUEGER SURELEVE A CAMBRURE VARIABLE A TROIS POSITIONS**
(54) **Title: HIGH-POSITIONED 3-POSITION VARIABLE CAMBER KRUEGER**



(57) **Abrégé/Abstract:**

A fluid-dynamic apparatus includes an airfoil, a flap assembly, and a link assembly including: a first drive arm; an actuator operable to rotate the first drive arm; a first drive link coupled to the first drive arm and to the trailing end portion of the flap assembly; a

(57) **Abrégé(suite)/Abstract(continued):**

second drive arm rotatably coupled to the first drive arm such that the second drive arm rotates relative to the first drive arm in association with the rotation of the first drive arm; a drive transfer arm coupled to the airfoil; and a second drive link rotatably coupled to the second drive arm, to the drive transfer arm, and to the bullnose portion of the flap assembly.

ABSTRACT

A fluid-dynamic apparatus includes an airfoil, a flap assembly, and a link assembly including: a first drive arm; an actuator operable to rotate the first drive arm; a first drive link coupled to the first drive arm and to the trailing end portion of the flap assembly; a second drive arm rotatably coupled to the first drive arm such that the second drive arm rotates relative to the first drive arm in association with the rotation of the first drive arm; a drive transfer arm coupled to the airfoil; and a second drive link rotatably coupled to the second drive arm, to the drive transfer arm, and to the bullnose portion of the flap assembly.

HIGH-POSITIONED 3-POSITION VARIABLE CAMBER KRUEGER

BACKGROUND

Embodiments of the present disclosure relate generally to fluid-dynamic design. More particularly, embodiments of the present disclosure relate to design of fluid-dynamic control surfaces. In aeronautics and aeronautical engineering, a Krueger flap is generally a wing leading edge device that provides high-lift capability. A camber of a Krueger flap may comprise an asymmetry between an upper surface and a lower surface of an airfoil of the Krueger flap. A camber of an airfoil can be defined by a camber line, which is a curve that is halfway between the upper surface and the lower surface of the airfoil. Camber is generally an important contributing factor determining a stall speed of an aircraft. A change in a camber of an airfoil can change a stall speed of an aircraft.

SUMMARY

A system and method to enable natural laminar flow over a fluid-dynamic body using a variable camber Krueger flap is disclosed. A sequence of flap positions is deployed where the variable camber Krueger flap is below and aft of a wing leading edge before reaching a configured takeoff and landing position. The variable camber Krueger flap is positioned in a high position relative to the wing leading edge when the variable camber Krueger flap is fully deployed.

In this manner, embodiments of the discloser provide a high-positioned three-position variable camber Krueger flap that provides high-lift capability and bug shielding to enable natural laminar flow.

In one embodiment, there is provided a flap deployment linkage mechanism comprising a first linkage assembly operable to couple to a flap assembly and an airfoil, the first linkage assembly comprising: a first drive arm coupled to the airfoil, and operable to rotate in a chord-wise plane; a first drive link coupled to the first drive arm and a trailing end of the flap assembly; and a support arm coupled to a middle link portion of the first drive link and rotatably coupled to the airfoil at a common joint. The flap deployment linkage mechanism further comprises a second linkage assembly operable to couple to the flap assembly and the airfoil, the second linkage assembly comprising: a second drive arm rotatably coupled to the first drive arm; a rotation control arm coupled to the second drive arm and the airfoil, and operable to control a rotation of the second drive arm; a drive transfer arm coupled to a middle flap portion of the flap assembly and rotatably coupled to the airfoil at the common joint; and a second drive link rotatably coupled to a middle transfer arm portion of the drive transfer arm and to the second drive arm.

In another embodiment, there is provided a method of controlling a position of a flap assembly relative to an airfoil comprising a leading edge, the method comprising causing an actuator to rotate a first drive arm relative to the airfoil in a chord-wise plane, wherein: causing the actuator to rotate the first drive arm relative to the airfoil in the chord-wise plane comprises causing a first drive link, coupled to the first drive arm and to a trailing end portion of the flap assembly, to move in a direction of movement relative to the airfoil; causing the first drive link to move relative to the airfoil comprises causing the trailing end portion of the flap assembly to move generally in the direction of movement of the first drive link; causing the actuator to rotate the first drive arm relative to the airfoil in the chord-wise plane comprises causing a second drive arm, rotatably coupled to the first drive, to rotate relative to the first drive arm; causing the second drive arm to rotate relative to the first drive arm comprises causing a second drive link, rotatably coupled to the second drive arm, to a drive transfer arm coupled to the airfoil, and to a bullnose portion of the flap assembly, to move generally in a direction of movement relative to the airfoil; and causing the second drive link to move relative to the airfoil comprises causing the bullnose portion of the flap assembly to move generally in the direction of movement of the second drive link.

In another embodiment, there is provided a fluid-dynamic apparatus comprising: an airfoil comprising a leading edge; a flap assembly comprising a trailing end portion and a bullnose portion; and a link assembly. The link assembly comprises: a first drive arm; an actuator operable to rotate the first drive arm relative to the airfoil in a chord-wise plane; a first drive link coupled to the first drive arm and to the trailing end portion of the flap assembly such the first drive link to transfers forces between the first drive arm and the trailing end portion of the flap assembly; a second drive arm rotatably coupled to the first drive arm such that the second drive arm rotates relative to the first drive arm in association with the rotation of the first drive arm in the chord-wise plane; a drive transfer arm coupled to the airfoil; and a second drive link rotatably coupled to the second drive arm, to the drive transfer arm, and to the bullnose portion of the flap assembly such that the second drive link transfers forces between the second drive arm and the bullnose portion of the flap assembly.

In another embodiment, a flap deployment linkage mechanism comprises a first linkage assembly and a second linkage assembly. The first linkage assembly is operable to couple to a flap assembly and an airfoil, and comprises a first drive arm, a first drive link, and a support arm. The first drive arm is coupled to the airfoil, and rotates in a chord-wise plane. The first drive link is coupled to the first drive arm and a trailing end of the flap assembly. The support arm is coupled to a middle link portion of the first drive link and is rotatably coupled to the airfoil at a common joint. The second linkage assembly is operable to couple to the flap assembly and the airfoil, and comprises a second drive arm, a rotation control arm, a drive transfer arm, and a second drive link. The second drive arm is rotatably coupled to the first drive arm. The rotation control arm is coupled to the second drive arm and the airfoil, and operable to control a rotation of the second drive arm. The drive transfer arm is coupled to a middle flap portion of the flap assembly and rotatably coupled to the airfoil at the common joint. The second drive link is rotatably coupled to a middle transfer arm portion of the drive transfer arm and to the second drive arm.

In another embodiment, a method to enable natural laminar flow over a fluid-dynamic body using a variable camber Krueger flap deploys a sequence of flap positions where the variable camber Krueger flap is below and aft of a wing leading edge before reaching a configured takeoff and landing position. The method further positions the variable camber Krueger flap in a high position relative to the wing leading edge when the variable camber Krueger flap is fully deployed.

In a further embodiment, a flap linkage assembly is operable to couple to a flap comprising a bullnose member, a trailing end member, and a flexible surface coupled between the bullnose member and the trailing end member. The flap linkage assembly comprises a flap link, a bullnose link, and a rotation arm link. The flap link coupled to the bullnose member, the trailing end member, and the first drive link. The bullnose link coupled to the bullnose member and the first drive link. The rotation arm link coupled to the rotation arm, the trailing end member.

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

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.

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

Figure **2** is an illustration of an exemplary block diagram of an aircraft.

Figure **3** is an illustration of an exemplary variable camber fluid-dynamic body system according to an embodiment of the disclosure.

Figure **4** is an illustration of an exemplary airfoil with variable camber according to an embodiment of the disclosure.

Figure **5** is an illustration of an exemplary cross-sectional view of a variable camber Krueger flap mechanism according to an embodiment of the disclosure.

Figure **6** is an illustration of an exemplary cross-sectional view of the variable camber Krueger flap mechanism of Figure **5** in a barndoor position according to an embodiment of the disclosure.

Figure **7** is an illustration of an exemplary cross-sectional view of the variable camber Krueger flap mechanism of Figure **5** in a landing position according to an embodiment of the disclosure.

Figure **8** is an illustration of an exemplary cross-sectional view of the variable camber Krueger flap mechanism of Figure **5** in a take-off position according to an embodiment of the disclosure.

Figure **9** is an illustration of an exemplary flowchart showing a process for providing a variable camber fluid-dynamic body system according to an embodiment of the disclosure.

DETAILED DESCRIPTION

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 scope of the disclosure. The present disclosure should not be limited to the examples described and shown herein.

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, 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.

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

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.

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).

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.

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 high-positioned **3**-position variable camber Krueger flap system **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.

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**.

Embodiments of the discloser provide a high-positioned **3**-position variable camber Krueger flap that provides high-lift capability and bug shielding to enable natural laminar flow. The Krueger flap is positioned high, relative to the wing, in the airplane takeoff and landing positions. During deployment, the Krueger flap avoids transition stalls. The linkage arrangement positions the Krueger flap high, relative to the wing, to enable natural laminar flow.

Figure **3** is an illustration of an exemplary variable camber fluid-dynamic body system **300** (system **300**) according to an embodiment of the disclosure. The system **300** may comprise, a fluid-dynamic body **302** (airfoil **302**), a variable camber Krueger mechanism **304**, a Krueger flap **306**, an actuator **314**, and a controller **308**.

The airfoil **302** comprises a variable camber resulting from deployment of the Krueger flap **306** by the variable camber Krueger mechanism **304**. The airfoil **302** may comprise a lifting surface and/or a control surface of a fluid-dynamic body (e.g., an aerodynamic body **504** shown in cross section in Figure **5**). 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 aileron, a tail, a rudder, an elevator, a flap, a spoiler, an elevon, or other control surface.

The Krueger flap **306** changes a camber of the airfoil **302** when the Krueger flap **306** is deployed by the variable camber Krueger mechanism **304**. Furthermore, a camber of the Krueger flap **306** may change during deployment of the Krueger flap **306** by the variable camber Krueger mechanism **304**. Krueger flap **306** and variable camber Krueger flap **306** may be used interchangeably in this document. The variable camber Krueger flap **306** may comprise, for example but without limitation, a flap link **572**, a bullnose link **574**, and a transfer arm link **576** (Figure **5**), or other flap component. The variable camber Krueger flap **306** may be operable to change camber in response to control from the variable camber Krueger mechanism **304**.

The airfoil **302** is operable to configure a shape of a camber **414** (Figure **4**) to a first camber configuration using the variable camber Krueger mechanism **304** to deploy the Krueger flap **306** at a first camber position in response to a first control actuation command. The airfoil **302** is further operable to configure a shape of the camber **414** (Figure **4**) to reshape the first camber configuration to a second camber configuration using the variable camber Krueger mechanism **304** to deploy the Krueger flap **306** at a second camber position in response to a second control actuation command by the actuator **314**. In this manner, a camber profile of the airfoil **302** changes from a fixed camber profile prior to an actuation of the variable camber Krueger mechanism **304** to a variable camber profile after the actuation of the variable camber Krueger mechanism **304**. The camber **414** (Figure **4**) of the airfoil **302** may be defined by a mean camber line **410** (Figure **4**), which is the curve that is halfway between an upper surface **420** (Figure **4**) and a lower surface **422** (Figure **4**) of the airfoil **302** (airfoil **400** in Figure **4**). As mentioned above, a change in the camber **414** of the airfoil **302/400** can change a stall speed of the aircraft **200**.

The variable camber Krueger mechanism **304** is operable to vary a shape (i.e., bend, deflect, change shape) of a camber in response to an actuation command. In this manner, the camber **414** can change shape to alter a flow over the airfoil **302/400**. In one embodiment, the variable camber Krueger mechanism **304** may be made from a shape memory alloy material and be controlled via a passive control mechanism to control the shape of the camber **414** based on an ambient temperature corresponding to an altitude at a flight condition. In another embodiment, the controller **308** may include or be realized as a controller (connected to the aircraft systems), to facilitate controlling a change in the shape of the camber **414**. The variable camber Krueger mechanism **304** according to various embodiments is discussed in more detail below in the context of discussion of Figures **5**-**8**.

The controller **308** may comprise, for example but without limitation, a processor module **310**, a memory module **312**, or other module. The controller **308** 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 software devoted to the variable camber Krueger mechanism **304**, or other processor.

The controller **308** is configured to control the variable camber Krueger mechanism **304** to vary a shape of the camber **414** according to various operation conditions. The operation conditions may comprise, for example but without limitation, flight conditions, ground operations, and the like. The flight conditions may comprise, for example but without limitation, take off, cruise, approach, landing, and the like. The ground operations may comprise, for example but without limitation, air breaking after landing, or other ground operation. The controller **308**, may be located remotely from the variable camber Krueger mechanism **304**, or may be coupled to the variable camber Krueger mechanism **304**.

In operation, the controller **308** may control the variable camber Krueger mechanism **304** by sending actuation commands from the actuator **314** to the variable camber Krueger mechanism **304**, thereby moving the variable camber Krueger flap **306**.

The processor module **310** 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 **310** may direct the variable camber Krueger mechanism **304** to vary a shape of the camber **414** by moving the variable camber Krueger flap **306** based on various flight conditions.

The processor module **310** 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, 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.

The memory module **312** may comprise a data storage area with memory formatted to support the operation of the system **300**. The memory module **312** is configured to store, maintain, and provide data as needed to support the functionality of the system **300**. For example, the memory module **312** may store flight configuration data, control temperature data, or other data.

In practical embodiments, the memory module **312** 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.

The memory module **312** may be coupled to the processor module **310** and configured to store, for example but without limitation, a database, and the like. Additionally, the memory module **312** may represent a dynamically updating database containing a table for updating the database, and the like. The memory module **312** may also store, a computer program that is executed by the processor module **310**, an operating system, an application program, tentative data used in executing a program, or other application.

The memory module **312** may be coupled to the processor module **310** such that the processor module **310** can read information from and write information to the memory module **312**. For example, the processor module **310** may access the memory module **312** to access an aircraft speed, a flight control surface position, an angle of attack, a Mach number, an altitude, or other data.

As an example, the processor module **310** and memory module **312** may reside in respective application specific integrated circuits (ASICs). The memory module **312** may also be integrated into the processor module **310**. In an embodiment, the memory module **312** may comprise a cache memory for storing temporary variables or other intermediate information during execution of instructions to be executed by the processor module **310**.

Figure **4** is an illustration of an exemplary airfoil **400** with variable camber according to an embodiment of the disclosure. The airfoil **400** may comprise a leading edge **402**, a trailing edge **404**, the upper surface **420**, and the lower surface **422**. The airfoil **400** changes the camber **414** in response to control from the variable camber Krueger mechanism **304** (Figure **3**). As explained in more detail below, the variable camber Krueger mechanism **304** may be coupled in various ways to the airfoil **400**. The variable camber Krueger mechanism **304** may configure the airfoil **400** into a first camber configuration **406** and a second camber configuration **408** by deploying the Krueger flap **306** at desired camber positions as explained below. The first camber configuration **406** may comprise, for example but without limitation, a stowed position, a barndoor position, a landing position, a take-off position, or other camber configuration. The second camber configuration **408** may comprise, for example but without limitation, a stowed position, a barndoor position, a landing position, a take-off position, or other camber configuration.

The airfoil **400** may be characterized by the mean camber line **410** (camber line) and a chord line **412**. The camber line **410** may comprise a curve halfway between the upper surface **420** and the lower upper surface **422** of the airfoil **400** characterizing an asymmetry between the upper surface **420** and the lower surface **422**. The camber **414** of the airfoil **400** can be defined by a camber line **410**. The camber **414** may comprise distances between the camber line **410** and the chord line **412** defining a shape of the camber line **410**.

Figure **5** is an illustration of an exemplary cross-sectional view of a variable camber Krueger flap mechanism **500** (**304** in Figure **3**) (flap deployment linkage mechanism **500**) according to an embodiment of the disclosure. The flap deployment linkage mechanism **500** is coupled to a flap assembly **502** and an aerodynamic body **504** (airfoil **302/400**). The variable camber Krueger flap mechanism **500** comprises a combined single joint such as a common joint **522** for deploying the variable camber Krueger flap **306** (flap assembly **502**). In this manner, two joints in the variable camber Krueger flap mechanism **500** may be combined into a single location to form the common joint **522**.

The flap assembly **502** (variable camber Krueger flap **306** in Figure **3**) may comprise a bullnose member **562**, a trailing end member **564**, and a flexible surface **566** coupled between the bullnose member **562** and the trailing end member **564**. In some embodiments, a camber (curvature) of the flap assembly **502** may be changed in response to a change in position of the bullnose member **562**, the trailing end member **564**, and the flexible surface **566**.

The flap assembly **502** may be deployed by the flap deployment linkage mechanism **500** from the aerodynamic body **504** through a plurality of positions **542**-**556**. The positions **542**-**556** may begin deployment at a stowed position **542**, and move through intermediate positions **544**-**550** to a deployed position. The deployed position may comprise, for example but without limitation, a barndoor position **552** (also shown in Figure **6**), a landing position **554** (also shown in Figure **7**), a take-off position **556** (also shown in Figure **8**), or other deployed position. The flap deployment linkage mechanism **500** may comprise a first linkage assembly **506**, a second linkage assembly **508**, and a flap linkage assembly **510**.

The first linkage assembly **506** is operable to couple to the flap assembly **502** (e.g., through the flap linkage assembly **510**) and the aerodynamic body **504**. The first linkage assembly **506** comprises a first drive arm **512**, a first drive link **514**, and a support arm **516**. The first drive arm **512** is coupled to the aerodynamic body **504**, and operable to rotate in a chord-wise rotational plane **560** when driven by the actuator **518**. The first drive link **514** is coupled to the first drive arm **512** and the trailing end member **564** (e.g., via the flap link **572**) of the flap assembly **502**. The support arm **516** is coupled to a middle link portion **520** of the first drive link **514** and rotatably coupled to the aerodynamic body **504** at the common joint **522**. In this manner, two joints in the variable camber Krueger flap mechanism **500** may be combined into a single location as explained above.

The second linkage assembly **508** is operable to couple to the flap assembly **502** (e.g., through the flap linkage assembly **510**) and the aerodynamic body **504**. The second linkage assembly **508** comprises a second drive arm **524**, a rotation control arm **526**, a second drive link **528**, and a drive transfer arm **530**. The second drive arm **524** rotatably is coupled to the first drive arm **512**. The rotation control arm **526** is coupled to the second drive arm **524** and the aerodynamic body **504**, and is operable to control a rotation of the second drive arm **524**. The drive transfer arm **530** is coupled to a middle flap portion **532** of the flap assembly **502** and is rotatably coupled to the aerodynamic body **504** at the common joint **522**. The second drive link **528** is rotatably coupled to a middle transfer arm portion **536** of the drive transfer arm **530** and to the second drive arm **524**.

The flap linkage assembly **510** is operable to couple to the flap assembly **502**. The flap linkage assembly **510** comprises the flap link **572**, the bullnose link **574**, and the transfer arm link **576**. The flap link **572** is coupled to the bullnose member **562**, the trailing end member **564**, and the first drive link **514**. The bullnose link **574** is coupled to the bullnose member **562** and the first drive link **514**. The transfer arm link **576** is coupled to the drive transfer arm **530**, and the trailing end member **564**.

Figure **6** is an illustration of an exemplary cross-sectional view **600** of a variable camber Krueger flap mechanism **500** of Figure **5** in a barndoor position **602** according to an embodiment of the disclosure. The barndoor position **602** is an in-transit position, as the variable camber Krueger flap **306** is being deployed to landing/takeoff detents. The barndoor position is an aerodynamically favorable position. In this position, and in other deployed positions, the variable camber Krueger flap mechanism **500** can be subject to high loads generated by aerodynamic forces acting on the flap assembly **502**. The variable camber Krueger flap mechanism **500** can be configured to efficiently transmit aerodynamic loads to the aerodynamic body **504**. The variable camber Krueger flap mechanism **500** can transmit loads generally in compression or tension, without incurring significant bending loads. However, some joints such the first drive link **514** and the drive transfer arm **530** may have bending loads.

Figure **7** is an illustration of an exemplary cross-sectional view **700** of a variable camber Krueger flap mechanism **500** of Figure **5** in a landing position

702 according to an embodiment of the disclosure. The flap assembly **502** Krueger flap **306**) is positioned in an elevated position relative to the aerodynamic body **504** (airfoil **302** in Figure **3**) sufficient to provide foreign object deflection protection for the airfoil **302**.

Figure **8** is an illustration of an exemplary cross-sectional view **800** of a variable camber Krueger flap mechanism **500** of Figure **5** in a take-off position **802** according to an embodiment of the disclosure. The flap assembly **502** is positioned in an elevated position relative to the aerodynamic body **504** (airfoil **302** in Figure **3**) sufficient to provide foreign object deflection protection for the airfoil **302**.

Figure **9** is an illustration of an exemplary flowchart showing a process **900** (process **900**) for providing a variable camber Krueger flap system according to an embodiment of the disclosure. The various tasks performed in connection with process **900** 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 **900** may include any number of additional or alternative tasks, the tasks shown in Figure **9** need not be performed in the illustrated order, and the process **900** may be incorporated into a more comprehensive procedure or process having additional functionality not described in detail herein.

For illustrative purposes, the following description of process **900** may refer to elements mentioned above in connection with Figures **1**-**8**. In practical embodiments, portions of the process **900** may be performed by different elements of the system **300** such as: the fluid-dynamic body **302**, the variable camber Krueger mechanism **304**, the controller **308**, etc. It should be appreciated that process **900** may include any number of additional or alternative tasks, the tasks shown in Figure **9** need not be performed in the illustrated order, and the process **900** may be incorporated into a more comprehensive procedure or process having additional functionality not described in detail herein.

Process **900** may begin by the variable camber Krueger flap mechanism **500** deploying a sequence of flap positions where a variable camber Krueger flap such as the variable camber Krueger flap **306** (flap assembly **502**) is below and aft of a wing leading edge such as the wing leading edge **540** before reaching a configured takeoff and landing position (task **902**).

Process **900** may continue by the variable camber Krueger flap mechanism **500** positioning the variable camber Krueger flap **306** in a high position relative to the wing leading edge **540** when the variable camber Krueger flap **306** is fully deployed (task **904**). The fully deployed position may be at the position **556** in Figure **5**.

Process **900** may continue by the variable camber Krueger flap mechanism **500** positioning the variable camber Krueger flap **306/502** in a barndoor position such as the barndoor position **602** providing an aerodynamically favorable position (task **906**). As mentioned above the barndoor position **602** is an in-transit position, as the variable camber Krueger flap **306** is being deployed to the landing/takeoff detents. The barndoor position is an aerodynamically favorable position.

Process **900** may continue by the variable camber Krueger flap mechanism **500** positioning the variable camber Krueger flap **306/502** in a landing position such as the landing position **702** (task **908**).

Process **900** may continue by the variable camber Krueger flap mechanism **500** positioning the variable camber Krueger flap **306/502** in a take-off position such as the take-off position **802** (task **910**).

In the figures and the text, a flap deployment linkage mechanism is disclosed including: a first linkage assembly **506** operable to couple to a flap assembly **502** and an airfoil **302**, **400**, the first linkage assembly **506** including: a first drive arm **512** coupled to the airfoil **302**, **400**, and operable to rotate in a chord-wise plane **560**; a first drive link **514** coupled to the first drive arm **512** and a trailing end of the flap assembly **502**; and a support arm **516** coupled to a middle link portion **520** of the first drive link **514** and rotatably coupled to the airfoil **302**, **400** at a common joint **522**; and a second linkage assembly **508** operable to couple to the flap assembly **502** and the airfoil **302**, **400**, the second linkage assembly **508** including: a second drive arm **524** rotatably coupled to the first drive arm **512**; a rotation control arm **526** coupled to the second drive arm **524** and the airfoil **302**, **400**, and operable to control a rotation of the second drive arm **524**; a drive transfer arm **530** coupled to a middle flap portion **532** of the flap assembly **502** and rotatably coupled to the airfoil **302**, **400** at the common joint **522**; and a second drive link rotatably coupled to a middle transfer arm portion **536** of the drive transfer arm **530** and to the second drive arm **524**.

In one variant, the flap deployment linkage mechanism includes wherein the flap assembly **502** is positioned in an elevated position relative to the airfoil **302**, **400** to provide foreign object deflection protection for the airfoil **302**, **400**. In another variant, the flap deployment linkage mechanism includes wherein the flap assembly **502** includes a bullnose member **562**, a trailing end member **564**, and a flexible surface **566** coupled between the bullnose member **562** and the trailing end member **564**. In still another variant, the flap deployment linkage mechanism further includes a flap linkage assembly **510** operable to couple to the flap assembly **502**, wherein the flap linkage assembly **510** includes: a flap link **572** coupled to the bullnose member **562**, the trailing end member **564**, and the first drive link **514**; a bullnose link **574** coupled to the bullnose member **562** and the first drive link **514**; and a transfer arm link **576** coupled to the drive transfer arm **530**, and the trailing end member **564**. In still another variant, the flap deployment linkage mechanism includes wherein the transfer arm link **576** is further coupled to the flap link **572**.

In one aspect, a method is disclosed to enable natural laminar flow over a fluid-dynamic body using a variable camber Krueger flap mechanism **500**, the method including: deploying a sequence of flap positions where a variable camber Krueger flap **306** is below and aft of a wing leading edge **402**, **540** before reaching a configured takeoff and landing position **554**, **702**; and positioning the variable camber Krueger flap **306** in a high position relative to the wing leading edge **402**, **540** when the variable camber Krueger flap **306** is fully deployed. In one variant, the method includes wherein the variable camber Krueger flap mechanism **500** includes a combined single joint deploying the variable camber Krueger flap **306**. In yet another variant, the method further includes positioning the variable camber Krueger flap **306** in a barndoor position **552**, **602** providing an aerodynamically favorable position. In still another variant, the method further includes positioning the variable camber Krueger flap **306** in a landing position **554**, **702**. In one example, the method further includes positioning the variable camber Krueger flap **306** in a take-off position (**556**, **802**).

In one aspect, a flap linkage assembly **510** is disclosed operable to couple to a flap comprising a bullnose member **562**, a trailing end member **564**, and a flexible surface coupled between the bullnose member **562** and the trailing end member **564**, the flap linkage assembly **510** including: a flap link **572** coupled to the bullnose member **562**, the trailing end member **564**, and a first drive link **514**;

a bullnose link **574** coupled to the bullnose member **562** and the first drive link **514**; and a transfer arm link **576** coupled to a drive transfer arm **530**, the trailing end member **564**. In one variant, the flap linkage assembly **510** includes wherein the transfer arm link **576** is further coupled to the flap link **572**. In another variant, the flap linkage assembly **510** includes wherein the flap assembly **502** is further coupled to an airfoil **302**, **400**. In another variant, the flap linkage assembly **510** includes wherein the flap assembly **502** is positioned in an elevated position relative to the airfoil **302**, **400** to provide foreign object deflection protection for the airfoil **302**, **400**. In yet another variant, the flap linkage assembly **510** further includes: a first drive arm **512** coupled to the airfoil **302**, **400**, and operable to rotate in a chord-wise plane **560**, wherein the first drive link **514** is coupled to the first drive arm **512** and a trailing end of the flap assembly **502**; and a support arm **516** coupled to a middle link portion **520** of the first drive link **514** and rotatably coupled to the airfoil **302**, **400** at a common joint **522**.

In one instance, the flap linkage assembly **510** further includes: a second linkage assembly **508** operable to couple to the flap assembly **502** and the airfoil

302, **400**, the second linkage assembly **508** including: a second drive arm **524** rotatably coupled to the first drive arm; a rotation control arm **526** coupled to the second drive arm **524** and the airfoil **302**, **400**, and operable to control a rotation of the second drive arm **524**; a drive transfer arm **530** coupled to a middle flap portion **532** of the flap assembly **502** and rotatably coupled to the airfoil **302**, **400** at the common joint **522**; and a second drive link **528** rotatably coupled to a middle transfer arm portion **536** of the drive transfer arm **530** and to the second drive arm **524**.

In one example, the flap linkage assembly **510** includes wherein the airfoil **302**, **400** comprises a wing and the flap assembly **502** comprises a variable camber Krueger flap **306**. In another example, the flap linkage assembly **510** includes wherein a sequence of flap positions are deployed where the variable camber Krueger flap **306** is below and aft of the wing leading edge **402**, **540** before reaching a configured takeoff and landing position **554**, **702**. In still another example, the flap linkage assembly **510** includes wherein the variable camber Krueger flap **306** is positioned in a high position relative to the wing leading edge **402**, **540** when the variable camber Krueger flap **306** is fully deployed. In one instance, the flap linkage assembly **510** includes wherein the variable camber Krueger flap **306** enables natural laminar flow over the wing.

In this manner, the embodiments of the disclosure provide various means for configuring a camber of a fluid-dynamic body.

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.

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.

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.

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, or storage unit. These and other forms of computer-readable media may be involved in storing one or more instructions for use by the processor module **310** to cause the processor module **310** 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 variable camber Krueger flap mechanism **500** of the system **300**.

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 flap deployment linkage mechanism comprising:

a first linkage assembly operable to couple to a flap assembly and an airfoil, the first linkage assembly comprising:

a first drive arm coupled to the airfoil, and operable to rotate in a chord-wise plane;

a first drive link coupled to the first drive arm and a trailing end of the flap assembly; and

a support arm coupled to a middle link portion of the first drive link and rotatably coupled to the airfoil at a common joint; and

a second linkage assembly operable to couple to the flap assembly and the airfoil, the second linkage assembly comprising:

a second drive arm rotatably coupled to the first drive arm;

a rotation control arm coupled to the second drive arm and the airfoil, and operable to control a rotation of the second drive arm;

a drive transfer arm coupled to a middle flap portion of the flap assembly and rotatably coupled to the airfoil at the common joint; and

a second drive link rotatably coupled to a middle transfer arm portion of the drive transfer arm and to the second drive arm.

2. The flap deployment linkage mechanism of claim **1**, wherein when the flap deployment linkage mechanism deploys the flap assembly, the trailing end of the flap assembly is positioned in front of a leading edge of the airfoil to provide foreign object deflection protection for the airfoil.

3. The flap deployment linkage mechanism of claim **1** or **2**, wherein the flap assembly comprises a bullnose member, a trailing end member, and a flexible surface coupled between the bullnose member and the trailing end member.

4. The flap deployment linkage mechanism of claim **3**, further comprising a flap linkage assembly operable to couple to the flap assembly, wherein the flap linkage assembly comprises:

a flap link coupled to the bullnose member, the trailing end member, and the first drive link;

a bullnose link coupled to the bullnose member and the first drive link; and

a transfer arm link coupled to the drive transfer arm, and the trailing end member.

5. The flap deployment linkage mechanism of claim **4**, wherein the transfer arm link is further coupled to the flap link.

6. A method of controlling a position of a flap assembly relative to an airfoil comprising a leading edge, the method comprising:

causing an actuator to rotate a first drive arm relative to the airfoil in a chord-wise plane, wherein:

causing the actuator to rotate the first drive arm relative to the airfoil in the chord-wise plane comprises causing a first drive link, coupled to the first drive arm and to a trailing end portion of the flap assembly, to move in a direction of movement relative to the airfoil;

causing the first drive link to move relative to the airfoil comprises causing the trailing end portion of the flap assembly to move generally in the direction of movement of the first drive link;

causing the actuator to rotate the first drive arm relative to the airfoil in the chord-wise plane comprises causing a second drive arm, rotatably coupled to the first drive, to rotate relative to the first drive arm;

causing the second drive arm to rotate relative to the first drive arm comprises causing a second drive link, rotatably coupled to the second drive arm, to a drive transfer arm coupled to the airfoil, and to a bullnose portion of the flap assembly, to move generally in a direction of movement relative to the airfoil; and

causing the second drive link to move relative to the airfoil comprises causing the bullnose portion of the flap assembly to move generally in the direction of movement of the second drive link.

7. The method of claim **6**, wherein the first drive link is coupled to a support arm rotatably coupled to the airfoil.

8. The method of claim **7**, wherein the drive transfer arm and the support arm are rotatably coupled to the airfoil at a combined single joint.

9. The method of claim **6**, **7**, or **8**, wherein causing the actuator to rotate the first drive arm relative to the airfoil in the chord-wise plane comprises positioning the flap assembly in a barndoor position, in which the flap assembly is below the leading edge of the airfoil.

10. The method of claim **6**, **7**, **8**, or **9**, wherein causing the actuator to rotate the first drive arm relative to the airfoil in the chord-wise plane comprises positioning the flap assembly in a landing position, in which the flap assembly is in front of the leading edge of the airfoil.

11. The method of claim **6**, **7**, **8**, **9**, or **10**, wherein causing the actuator to rotate the first drive arm relative to the airfoil in the chord-wise plane comprises positioning the flap assembly in a take-off position, in which the flap assembly is in front of the leading edge of the airfoil.

12. The method of claim **10**, wherein causing the actuator to rotate the first drive arm relative to the airfoil in the chord-wise plane further comprises causing the flap assembly to transition from the landing position to a take-off position, in which the flap assembly is in front of the leading edge of the airfoil.

13. The method of claim **12** wherein causing the flap assembly to transition from the landing position to the take-off position comprises lowering the trailing end portion of the flap assembly to move a trailing end of the flap assembly closer to the leading edge of the airfoil.

14. The method of any one of claims **6** to **13**, wherein the airfoil comprises a wing.

15. The method of any one of claims **6** to **14**, wherein the flap assembly comprises a variable camber Krueger flap assembly.

16. A fluid-dynamic apparatus comprising:

an airfoil comprising a leading edge;

a flap assembly comprising a trailing end portion and a bullnose portion; and a link assembly comprising:

a first drive arm;

an actuator operable to rotate the first drive arm relative to the airfoil in a chord-wise plane;

a first drive link coupled to the first drive arm and to the trailing end portion of the flap assembly such the first drive link to transfers forces between the first drive arm and the trailing end portion of the flap assembly;

a second drive arm rotatably coupled to the first drive arm such that the second drive arm rotates relative to the first drive arm in association with the rotation of the first drive arm in the chord-wise plane;

a drive transfer arm coupled to the airfoil; and

a second drive link rotatably coupled to the second drive arm, to the drive transfer arm, and to the bullnose portion of the flap assembly such that the second drive link transfers forces between the second drive arm and the bullnose portion of the flap assembly.

17. The apparatus of claim **16**, wherein the link assembly is operable to position the flap assembly in a barndoor position, in which the flap assembly is below the leading edge of the airfoil.

18. The apparatus of claim **16** or **17**, wherein the link assembly is operable to position the flap assembly in a landing position, in which the flap assembly is in front of the leading edge of the airfoil.

19. The apparatus of claim **16**, **17**, or **18**, wherein the link assembly is operable to position the flap assembly in a take-off position, in which the flap assembly is in front of the leading edge of the airfoil.

20. The apparatus of claim **18**, wherein the link assembly is operable to transition the flap assembly from the landing position to a take-off position, in which the flap assembly is in front of the leading edge of the airfoil.

21. The apparatus of claim **20** wherein the link assembly is operable to transition the flap assembly from the landing position to the take-off position by lowering the trailing end portion of the flap assembly to move a trailing end of the flap assembly closer to the leading edge of the airfoil.

22. The apparatus of any one of claims **16** to **21**, wherein the link assembly further comprises a flap link coupled to the bullnose member, the trailing end member, and the first drive link.

23. The apparatus of any one of claims **16** to **22**, wherein the link assembly further comprises a bullnose link coupled to the bullnose member and the first drive link.

24. The apparatus of any one of claims **16** to **23**, wherein the link assembly further comprises a transfer arm link coupled to the drive transfer arm and to the trailing end member.

25. The apparatus of claim **24** when ultimately dependent on claim **22**, wherein the transfer arm link is further coupled to the flap link.

26. The apparatus of any one of claims **16** to **25**, wherein the link assembly is operable to position a trailing end of the flap assembly in front of the leading edge of the airfoil to provide foreign object deflection protection for the airfoil.

27. The apparatus of any one of claims **16** to **26**, wherein the link assembly further comprises a support arm coupled to the first drive link and rotatably coupled to the airfoil.

28. The apparatus of claim **27**, wherein the drive transfer arm and the support arm are rotatably coupled to the airfoil at a combined single joint.

29. The apparatus of claim **27** or **28**, wherein the a support arm is coupled to a middle link portion of the first drive link.

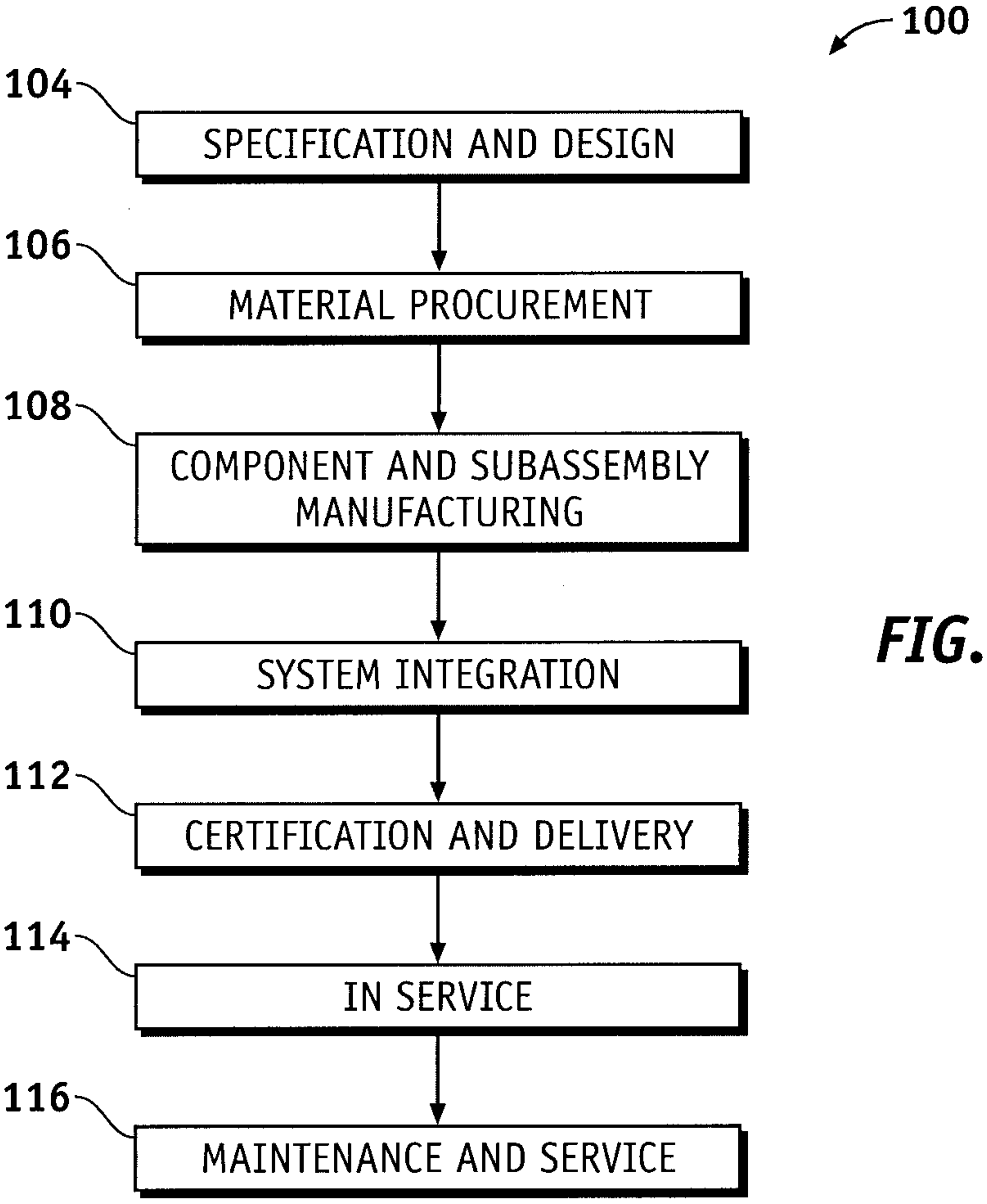
30. The apparatus of any one of claims **16** to **29**, further comprising a rotation control arm coupled to the second drive arm and the airfoil, and operable to control the rotation of the second drive arm relative to the first drive arm in association with the rotation of the first drive arm in the chord-wise plane.

31. The apparatus of any one of claims **16** to **30**, wherein the second drive link is rotatably coupled to a middle transfer arm portion of the drive transfer arm.

32. The apparatus of any one of claims **16** to **31**, wherein the airfoil comprises a wing.

33. The apparatus of any one of claims **16** to **32**, wherein the flap assembly comprises a variable camber Krueger flap.

34. The apparatus of claim **33**, wherein the link assembly is operable to position the variable camber Krueger flap below and aft of the leading edge of the airfoil.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104
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MATERIAL PROCUREMENT
108
COMPONENT AND SUBASSEMBLY MANUFACTURING
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SYSTEM INTEGRATION
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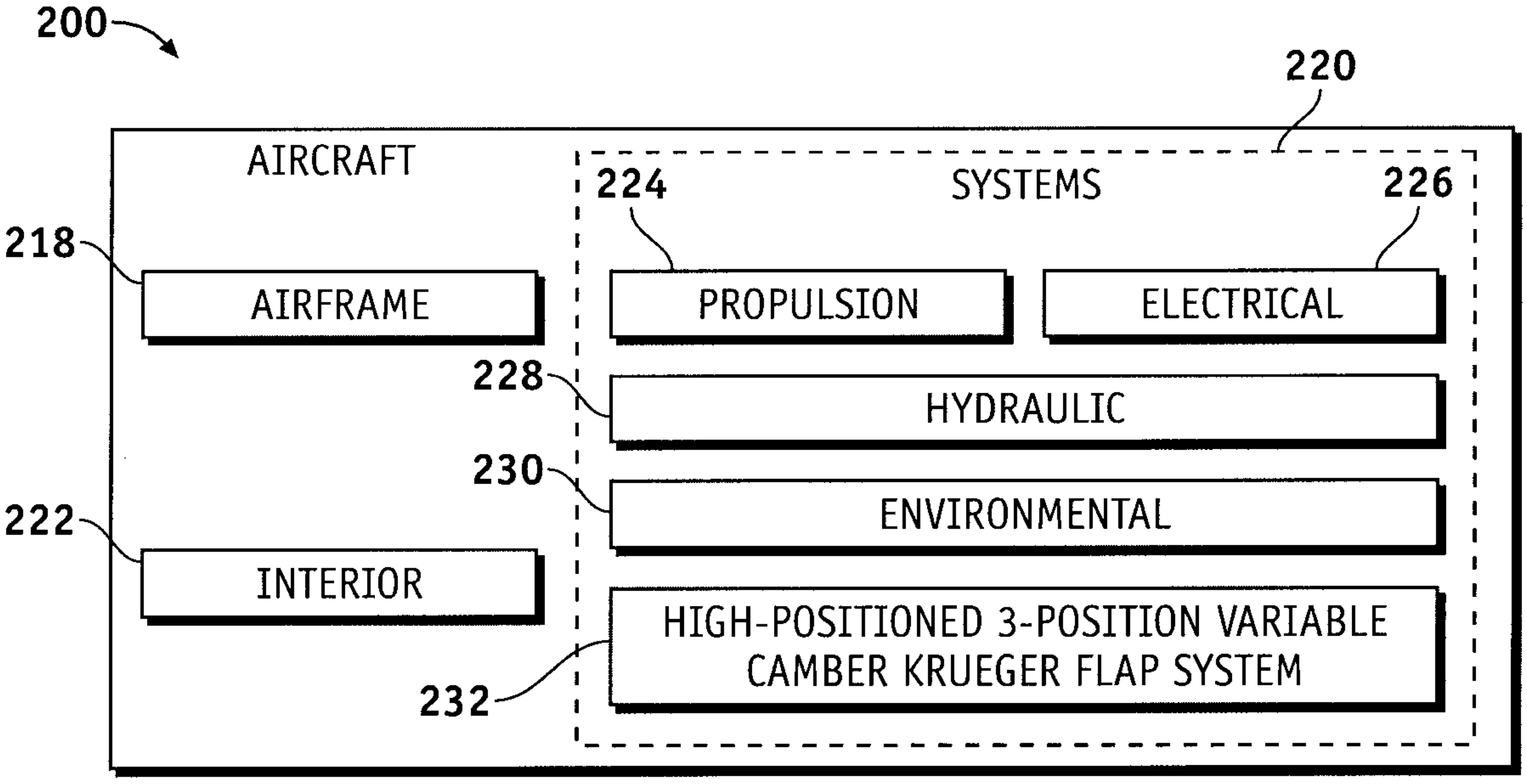
CERTIFICATION AND DELIVERY
114
IN SERVICE
116
MAINTENANCE AND SERVICE

FIG. 1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ENVIRONMENTAL
222
INTERIOR
HIGH-POSITIONED 3-POSITION VARIABLE CAMBER KRUEGER FLAP SYSTEM
232

FIG. 2

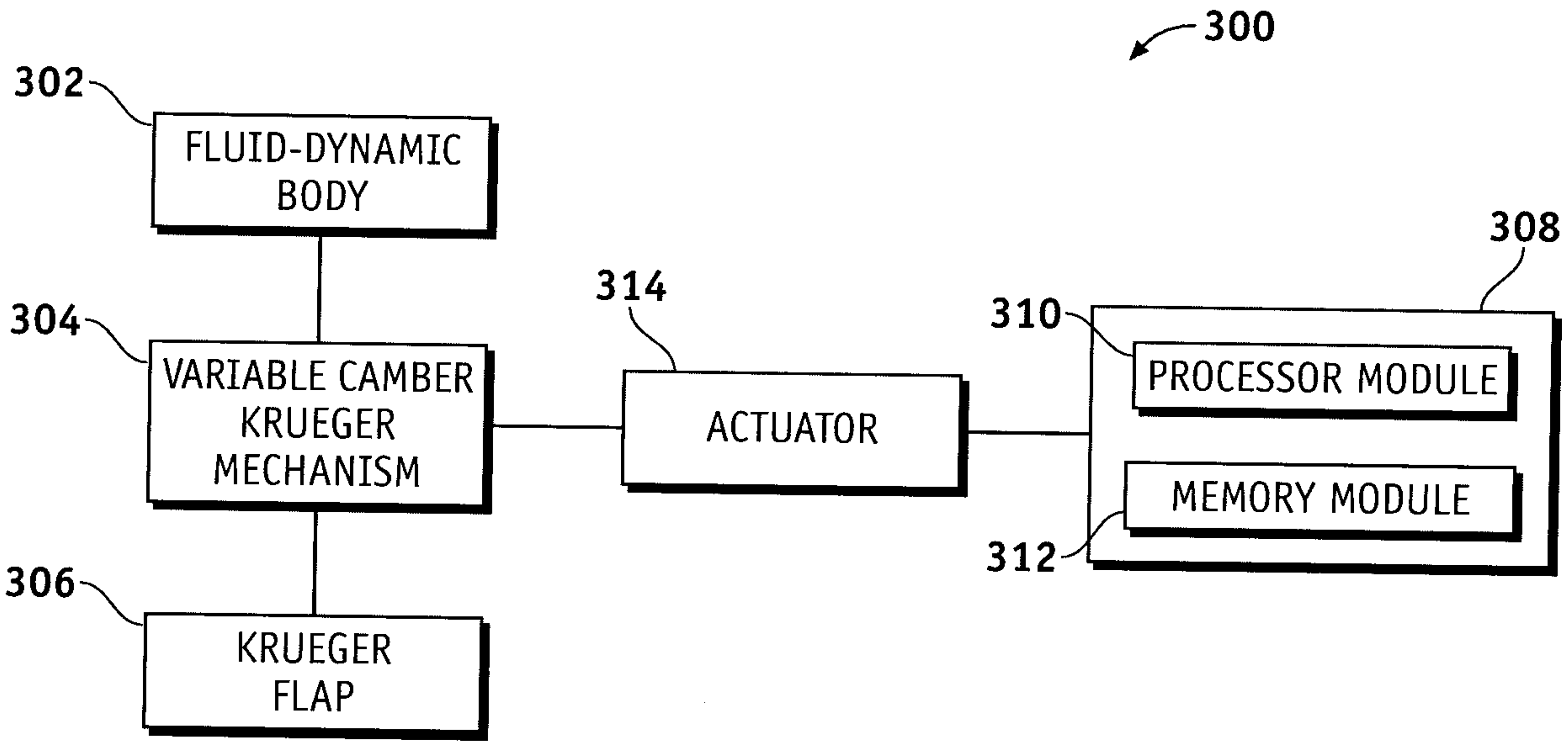
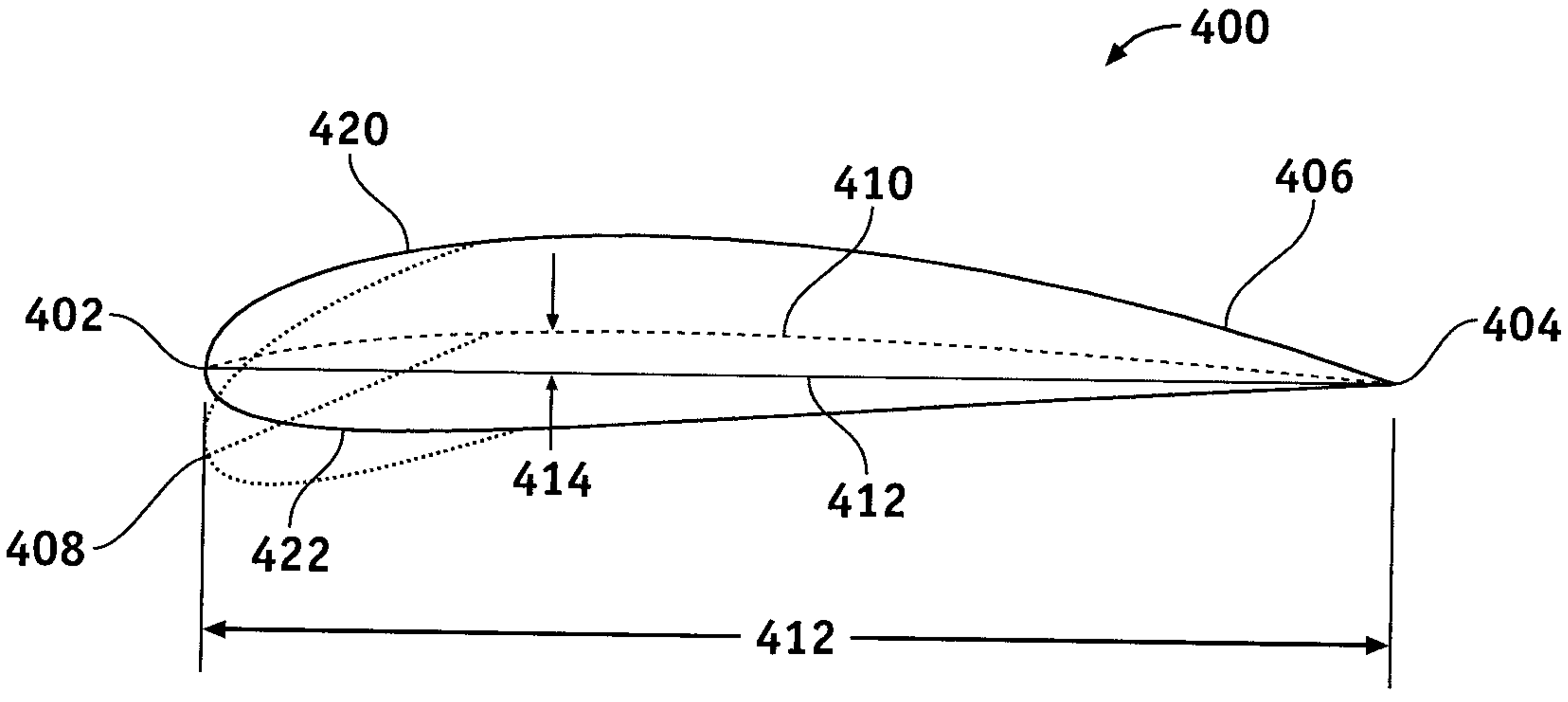

300
302
FLUID-DYNAMIC BODY
304
VARIABLE CAMBER KRUEGER MECHANISM
306
KRUEGER FLAP
314
ACTUATOR
308
310
PROCESSOR MODULE
MEMORY MODULE
312

FIG. 3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412

FIG. 4

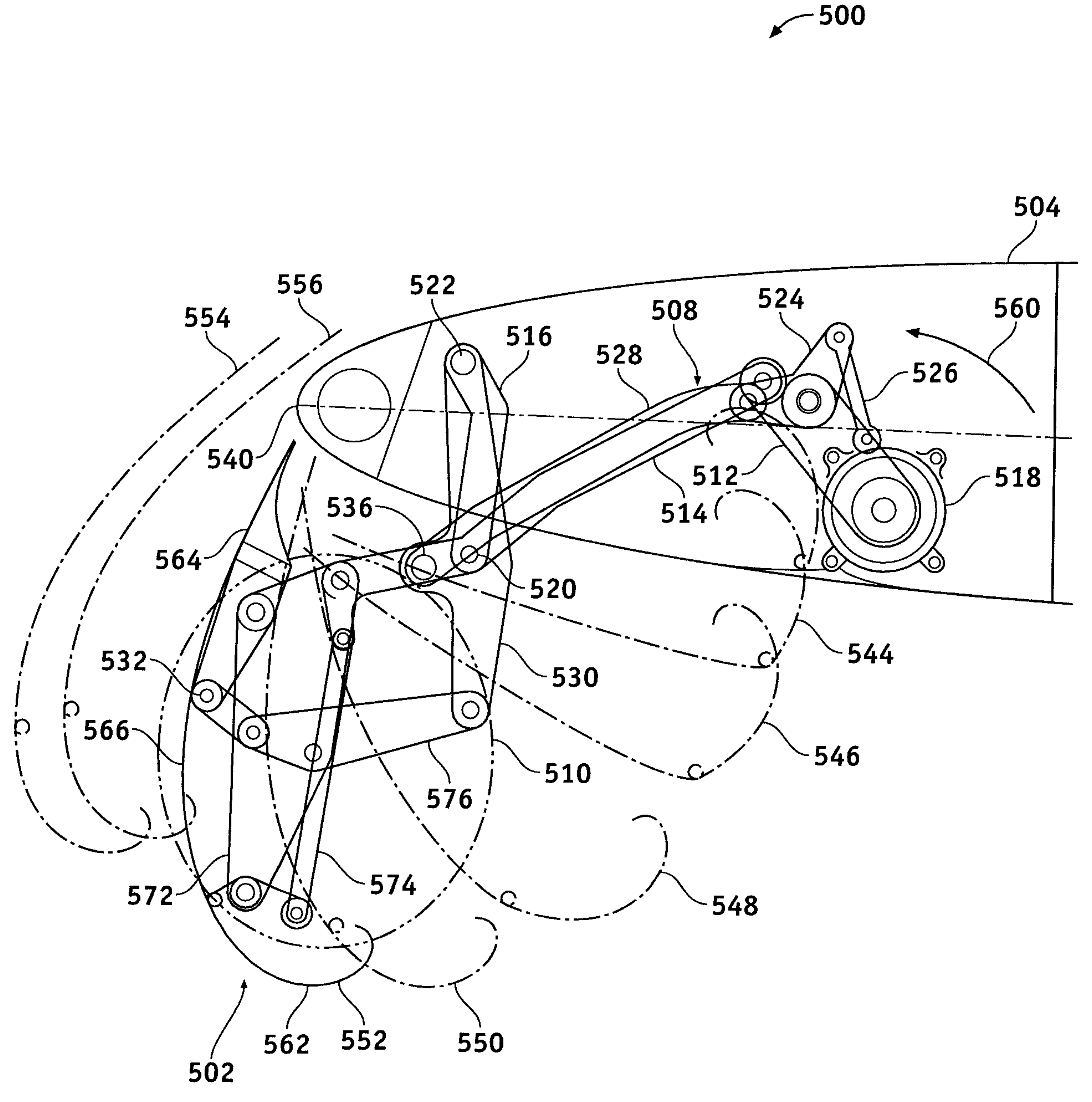
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FIG. 5

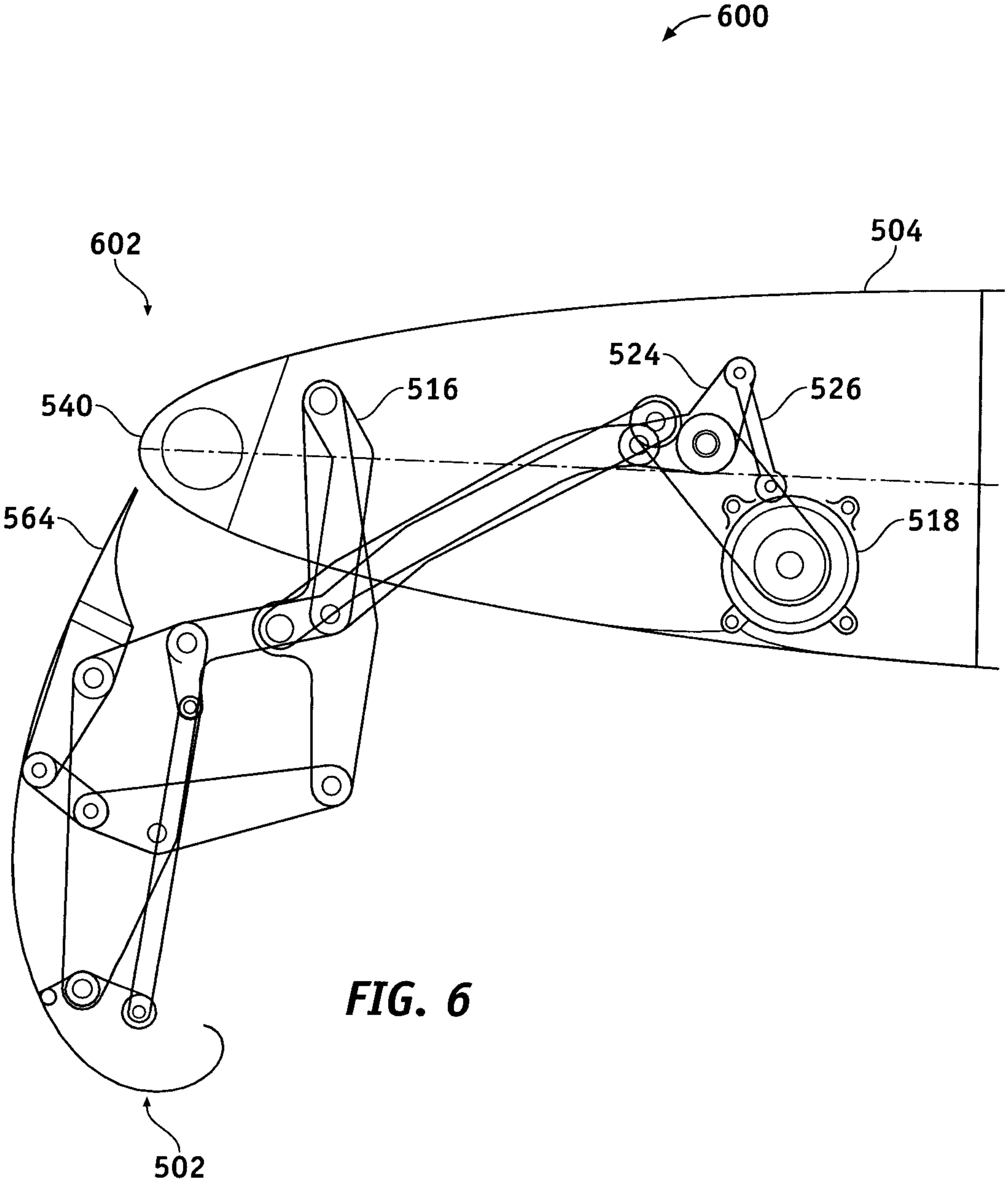


FIG. 6

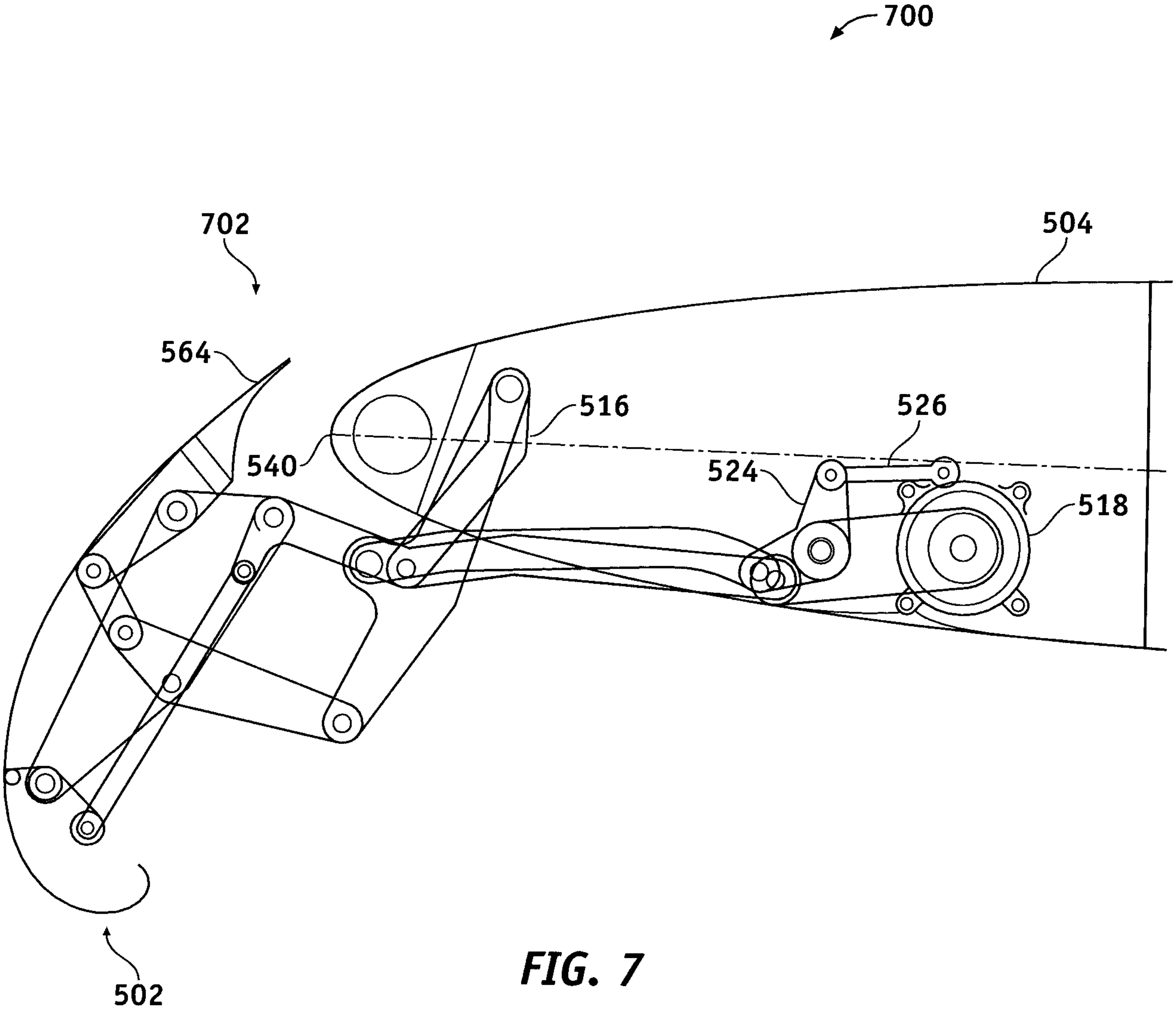


FIG. 7

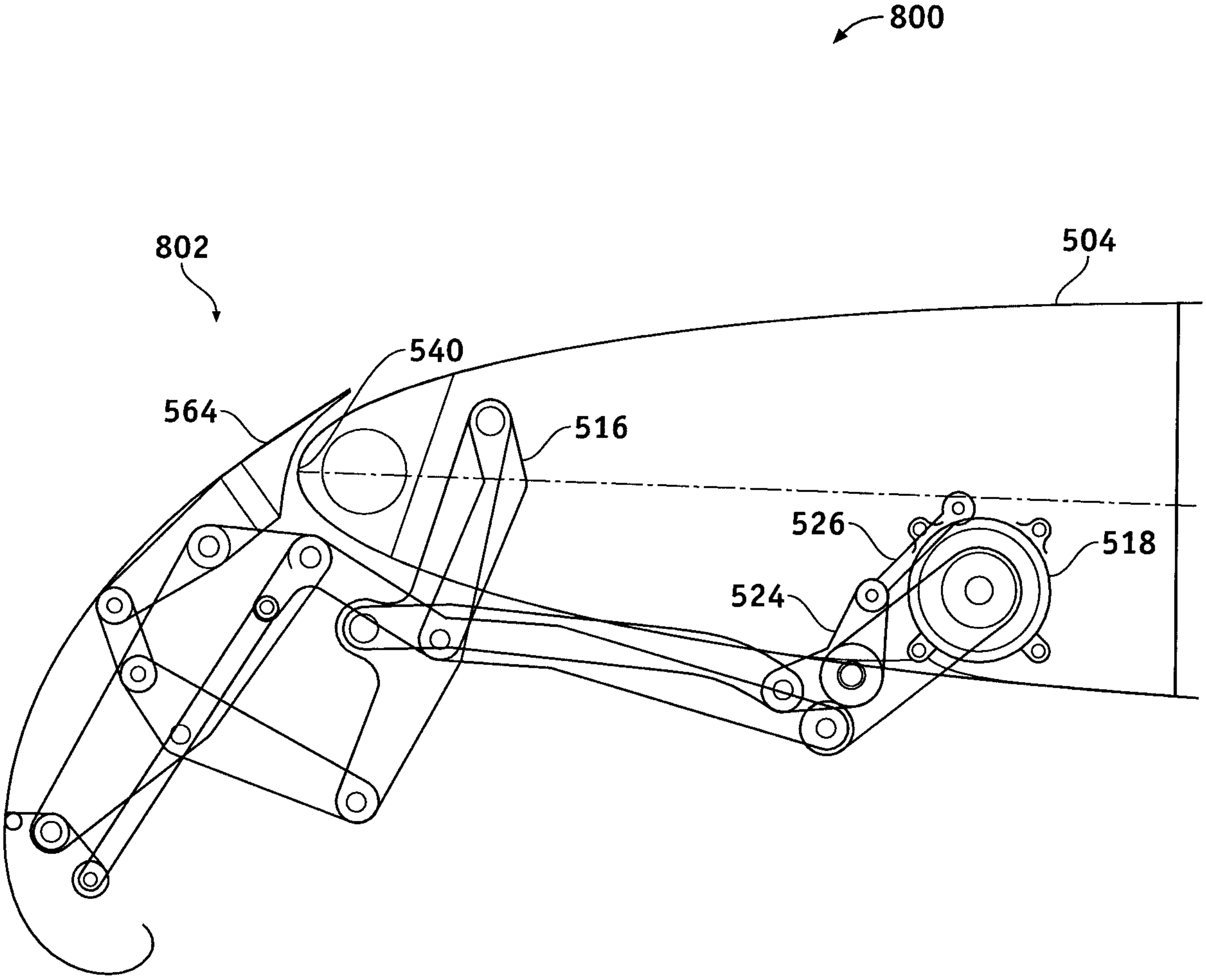


FIG. 8

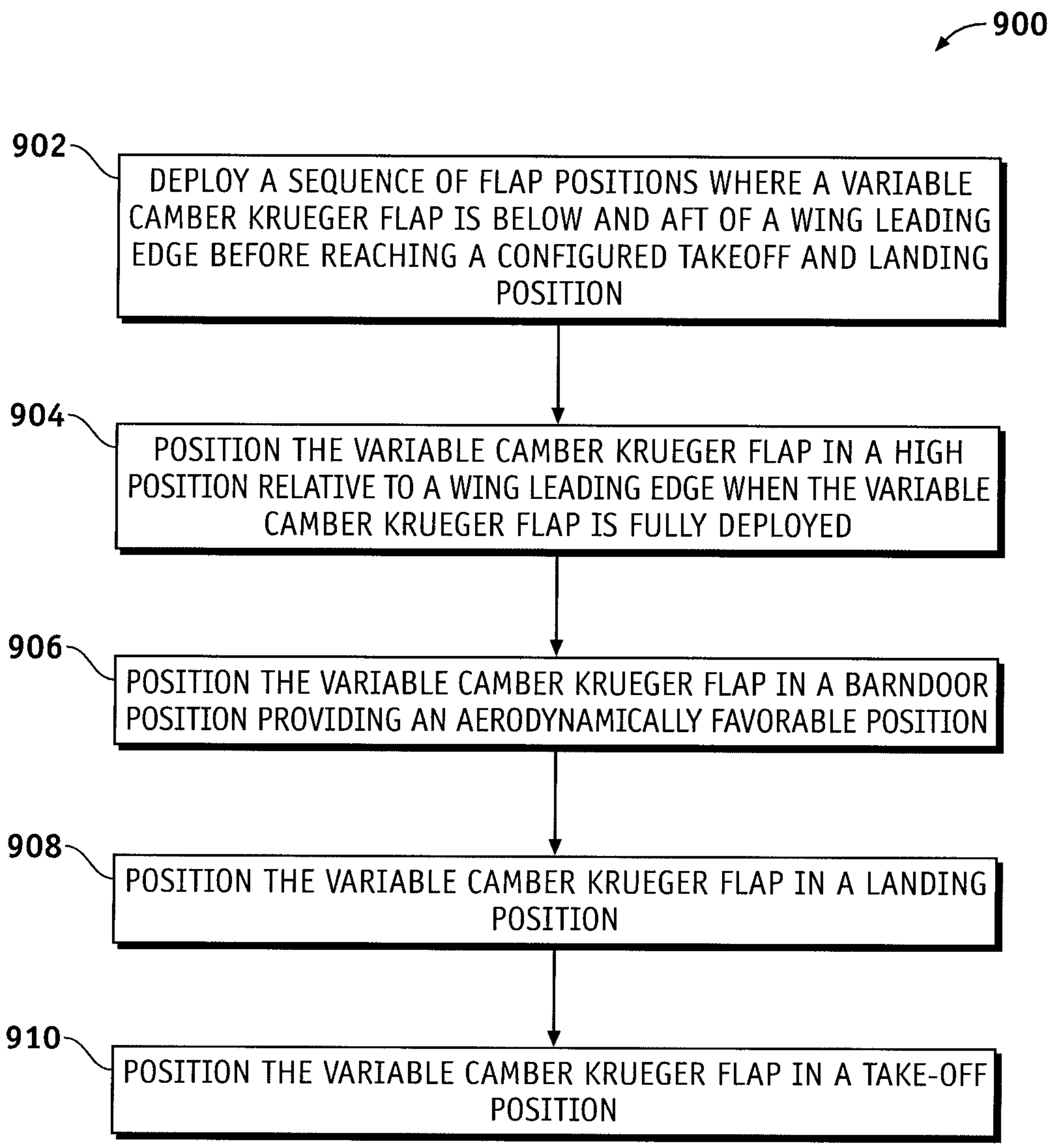
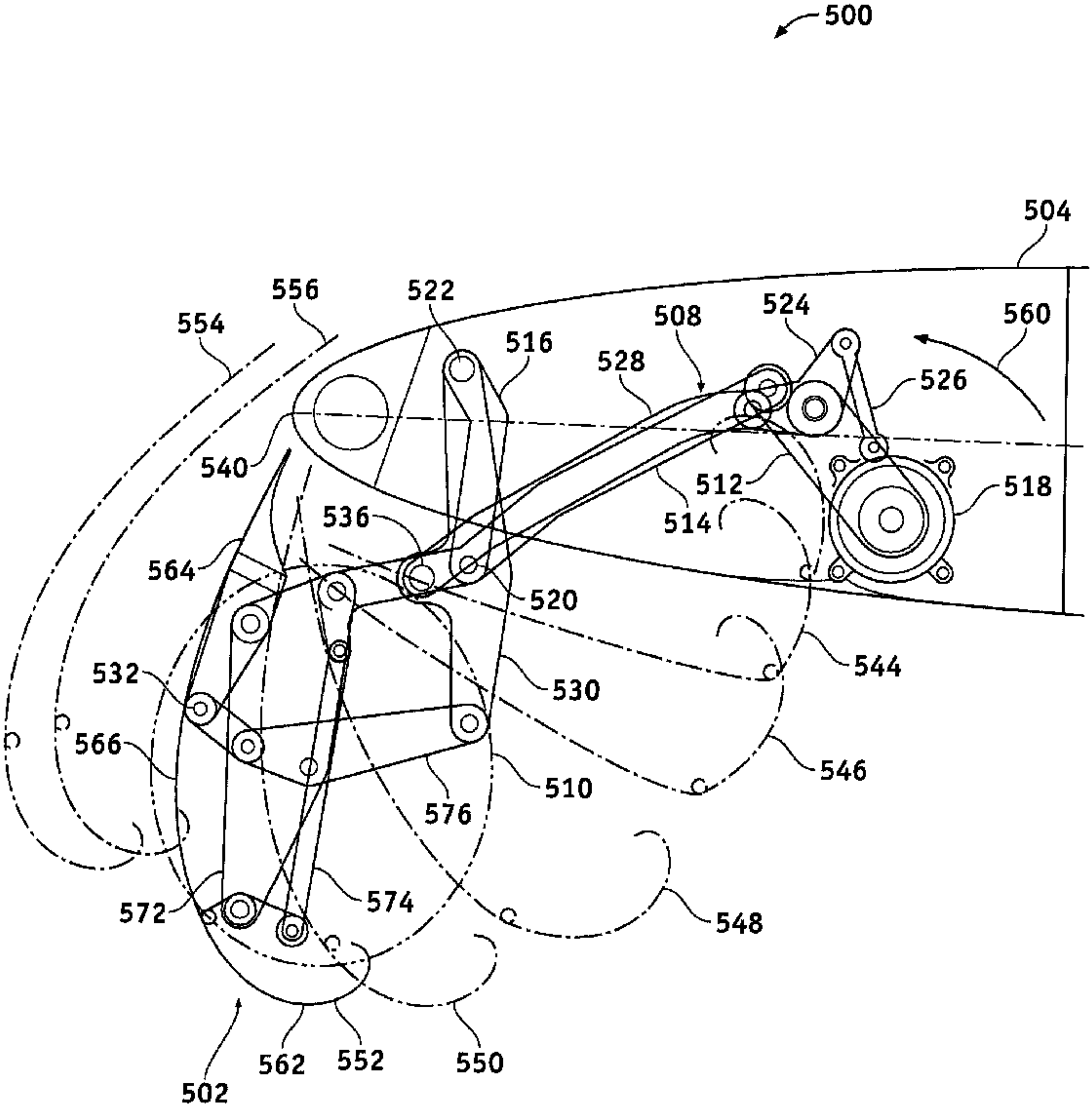

900
902
DEPLOY A SEQUENCE OF FLAP POSITIONS WHERE A VARIABLE CAMBER KRUEGER FLAP IS BELOW AND AFT OF A WING LEADING EDGE BEFORE REACHING A CONFIGURED TAKEOFF AND LANDING POSITION
904
POSITION THE VARIABLE CAMBER KRUEGER FLAP IN A HIGH POSITION RELATIVE TO A WING LEADING EDGE WHEN THE VARIABLE CAMBER KRUEGER FLAP IS FULLY DEPLOYED
906
POSITION THE VARIABLE CAMBER KRUEGER FLAP IN A BARNDOOR POSITION PROVIDING AN AERODYNAMICALLY FAVORABLE POSITION
908
POSITION THE VARIABLE CAMBER KRUEGER FLAP IN A LANDING POSITION
910
POSITION THE VARIABLE CAMBER KRUEGER FLAP IN A TAKE-OFF POSITION

FIG. 9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