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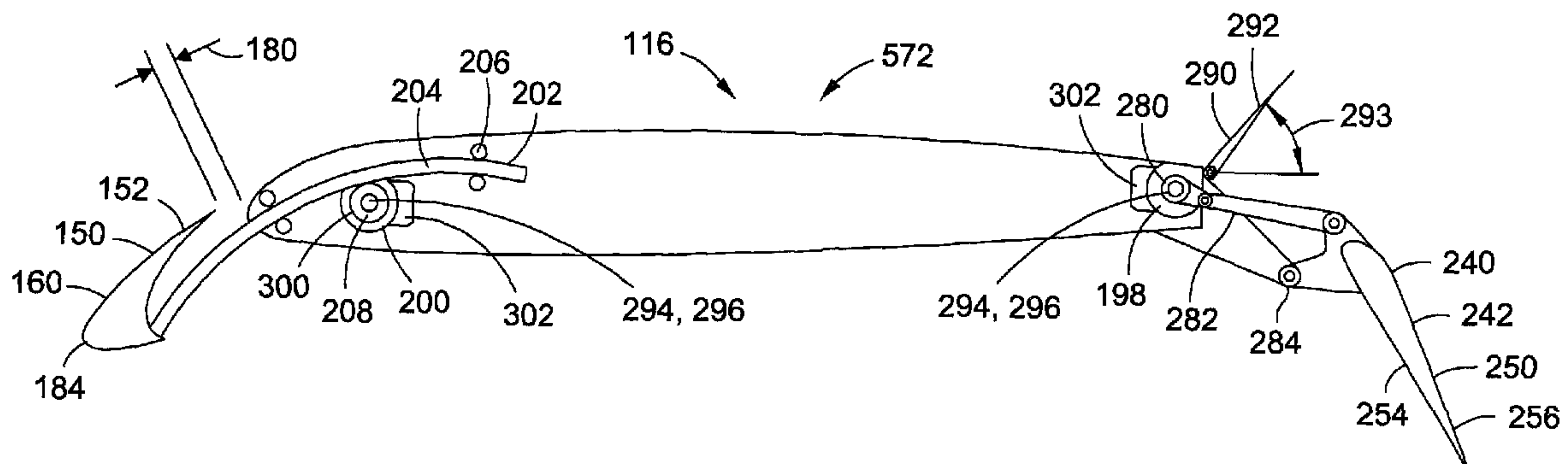
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(54) **Titre : SYSTEME ET PROCEDE POUR REDUIRE LA DISTANCE D'ARRET D'UN AERONEF**

(54) **Title: SYSTEM AND METHOD FOR REDUCING THE STOPPING DISTANCE OF AN AIRCRAFT**



(57) **Abrégé/Abstract:**

A system for reducing a stopping distance of an aircraft may include an edge control system configured to control a leading edge device mounted to a wing of an aircraft. The edge control system may be configured to automatically command extension of the leading edge device from a first position to a second position in response to deployment of a spoiler if a ground speed of the aircraft is greater than a threshold ground speed.

ABSTRACT

A system for reducing a stopping distance of an aircraft may include an edge control system configured to control a leading edge device mounted to a wing of an aircraft. The edge control system may be configured to automatically command extension of the leading edge device from a first position to a second position in response to deployment of a spoiler if a ground speed of the aircraft is greater than a threshold ground speed.

SYSTEM AND METHOD FOR REDUCING THE STOPPING DISTANCE OF AN AIRCRAFT

FIELD

The present disclosure relates generally to control surfaces of an aircraft and, more particularly, to the positioning of control surfaces of a wing during a rejected takeoff or a landing.

BACKGROUND

During takeoff of an aircraft, a pilot may need to perform a rejected takeoff maneuver for any one of a variety of different reasons. For example, as the aircraft accelerates down the runway, the pilot may receive an indication of an engine failure or a blown tire. Alternatively, a takeoff warning horn may be activated on the flight deck or instructions may be received from air traffic control to abort the takeoff.

For aircraft certification, the Federal Aviation Administration (FAA) requires that when a rejected takeoff is initiated below a takeoff decision speed, the aircraft must be capable of safely stopping before the end of the runway. Upon initiation of a rejected takeoff, the pilot and other flight crew members may reconfigure the aircraft from an initial configuration to a stopping configuration. For example, engine thrust may be reduced to idle and speedbrakes (e.g., spoilers) may be deployed to generate aerodynamic drag to reduce the stopping distance.

Certain aircraft may include an autobrake system which may automatically apply maximum braking force to the aircraft wheel brakes upon the initiation of a rejected takeoff. The autobrake system may reduce the number of tasks required by the flight crew to reconfigure the aircraft into the stopping configuration which may further reduce the stopping distance. Although an autobrake system may reduce the stopping distance, aircraft initiating a rejected takeoff near the takeoff decision speed may require increased stopping capability to maximize the performance of the aircraft.

As can be seen, there may be a need in the art for systems and methods, which may improve the stopping performance of an aircraft.

SUMMARY

The present disclosure describes a system for reducing a stopping distance of an aircraft. The system comprises an edge control system configured to control a leading edge device deployable from a leading edge of a wing of an aircraft on the ground and a thrust control system including a thrust lever positionable in at least an idle position corresponding to an idle thrust setting and a non-idle position corresponding to a thrust setting different than the idle thrust setting. The system further includes a speedbrake control system automatically commanding deployment of a spoiler at least partially responsive to movement of the thrust lever from the non-idle position to the idle position when the aircraft is on ground and moving in excess of a threshold ground speed. The edge control system automatically commands extension of the leading edge device from a first position to a second position when the spoiler is automatically deployed by the speedbrake control system. The system further includes a device actuation system deploying a trailing edge device to a maximum deflection angle at least partially responsive to deployment of the spoiler in conjunction with deployment of the leading edge device.

The first position may be a retracted position, a sealed position, or a gapped position. The second position may be the sealed position or the gapped position.

The trailing edge device may comprise at least one of a flap, an aileron, and a flaperon.

The system may further comprise a device actuation system communicatively coupled to the edge control system. The leading edge device may be one of a plurality of leading edge devices coupled to the wing. The plurality of leading edge devices may include an inboard leading edge device and an outboard leading edge device, and the device actuation system may be configured to actuate the inboard leading edge device independently of the outboard leading edge device.

The edge control system may be configured to automatically command the device actuation system to extend the outboard leading edge device prior to extending the inboard leading edge device.

5 The device actuation system may include a variable camber trim unit (VCTU) positioned between the inboard leading edge device and the outboard leading edge device. The VCTU may be configured to actuate the outboard leading edge device independent of the inboard leading edge device.

10 The VCTU may include a speed sum gearbox including an inboard shaft coupled to the inboard leading edge device and an outboard shaft coupled to the outboard leading edge device, and a VCTU electric motor engaged to the speed sum gearbox. The VCTU electric motor may be configured to selectively operate in conjunction with the speed sum gearbox to rotate the outboard shaft independent of the inboard shaft in a manner causing the outboard leading edge device to be actuated independent of the inboard leading edge device.

15 In a further embodiment, there is provided an autoslat system for reducing the stopping distance of an aircraft. The autoslat system comprises an edge control system including a device actuation system configured to position a leading edge device deployable from a leading edge of a wing of an aircraft on the ground and a thrust control system including a forward thrust lever positionable in one of an idle position and a non-idle position. The system further includes a speedbrake control system automatically commanding a spoiler
20 actuation system to deploy a spoiler when the forward thrust lever is moved from the non-idle position to the idle position and the aircraft is on ground and moving in excess of a threshold ground speed. The edge control system automatically commands the device actuation system to extend the leading edge device from a first extended position to a second extended position in response to deployment of the spoiler when the spoiler is automatically deployed by the
25 spoiler actuation system. The device actuation system deploys a trailing device to a maximum deflection angle at least partially responsive to deployment of the spoiler in conjunction with deployment of the leading edge device.

Also disclosed is a method of reducing the stopping distance of an aircraft, the method comprising moving a thrust lever from a non-idle position to an idle position, automatically
30 commanding, using a speedbrake control system, deployment of a spoiler mounted on a wing

of an aircraft at least partially responsive to moving the thrust lever from the non-idle position to the idle position when the aircraft is on ground and moving in excess of a threshold ground speed, automatically commanding, using an edge control system, extension of a leading edge device on the wing from a first position to a second position in response to deployment of the spoiler by the speedbrake control system, and deploying a trailing edge device to a maximum deflection angle responsive, at least in part, to the deployment of the spoiler.

The first position may be a retracted position, a sealed position, or a gapped position, and the second position may be the sealed position or the gapped position.

The trailing edge device may comprise at least one of a flap, an aileron, and a flaperon.

The method may further comprise moving an inboard leading edge device independently of an outboard leading edge device.

The method may further comprise extending the outboard leading edge device prior to extending the inboard leading edge device.

The features, functions and advantages that have been discussed can be achieved independently in various embodiments of the present disclosure or may be combined in yet

other embodiments, further details of which can be seen with reference to the following description and drawings below.

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BRIEF DESCRIPTION OF THE DRAWINGS

These and other features of the present disclosure will become more apparent upon reference to the drawings wherein like numbers refer to like parts throughout and wherein:

Figure 1 is a top view of an aircraft;

Figure 2 is a diagrammatic view of an aircraft during a rejected takeoff or landing;

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Figure 3 is a sectional view of a wing showing a slat in a sealed position;

Figure 4 is a sectional view of a wing showing the slat in a gapped position;

Figure 5 is a diagrammatic view of an embodiment of an autoslat system for automatically extending a leading edge device to a gapped position during a rejected takeoff or landing;

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Figure 6 is a diagrammatic plan view of a leading edge of a wing illustrating a variable camber trim unit (VCTU) positioned between an inboard slat and an outboard slat;

Figure 7 is a diagrammatic plan view of the leading edge of the wing of Figure 6 illustrating the inboard slat and the outboard slat actuated in unison;

Figure 8 is a diagrammatic plan view of the leading edge of the wing of Figure 6 illustrating the inboard slat actuated independently of the outboard slat;

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Figure 9 is a diagrammatic plan view of the leading edge of the wing of Figure 6 illustrating the outboard slat actuated independently of the inboard slat;

Figure 10 is a diagrammatic view of a pair of wings incorporating a VCTU between the inboard and outboard slats and between the inboard and outboard flaps on each wing;

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Figure 11 is a diagrammatic view of a center portion of the wing of Figure 10 and illustrating a leading edge power drive unit (PDU) for driving the inboard slats and a trailing edge PDU for driving the inboard flaps;

Figure 12 is a schematic view of a VCTU including a speed sum gearbox having an outboard brake and a VCTU electric motor;

Figure **13** is a perspective illustration of an embodiment of a VCTU;

Figure **14** is a forward-looking view of an aft side of the VCTU;

Figure **15** is a sectional view of the VCTU taken along line **15** of Figure **14** and illustrating the interconnectivity of an inboard pinion, an inboard gear, and a position sensor gear;

Figure **16** is a sectional view of the VCTU taken along line **16** of Figure **14** and illustrating the interconnectivity of a planetary gear system and the outboard brake; and

Figure **17** is an illustration of a flow chart containing one or more operations that may be included in a method of operating a leading edge device to reduce the stopping distance of an aircraft.

DETAILED DESCRIPTION

Referring now to the drawings wherein the showings are for purposes of illustrating preferred and various embodiments of the disclosure, shown in Figure **1** is a top view of an aircraft **100** having a fuselage **102** and a pair of wings **116**. Each wing **116** may be attached to the fuselage **102** at a wing root **128** and may extend from an inboard portion **130** toward an outboard portion **134** and terminating at a wing tip **132**. The aircraft **100** may include one or more propulsion units **104** which may be mounted to the wings **116**. The aircraft **100** may further include an empennage including a horizontal tail **108** and an elevator **110**, and a vertical tail **112** and a rudder **114**.

As shown in the example in Figure **1**, the aircraft **100** may include one or more leading edge devices **150** and one or more trailing edge devices **240** which may be extended and retracted to alter the lift characteristics of the wings **116**. For example, the aircraft **100** may include leading edge devices **150** configured as slats **152** mounted to the leading edge of the wings **116**. However, the leading edge devices **150** may be provided in alternative configurations such as Krueger flaps or other device configurations, and are not limited to slats **152**. The leading edge devices **150** may include one or more inboard leading edge devices **144** and one or more outboard leading edge devices **146** such as inboard slats **154** and outboard slats **156**.

The aircraft **100** may include an autoslat system **300** for reducing the stopping distance of an aircraft **100**. In an embodiment, the autoslat system **300** may include an edge control system **452** configured to control a leading edge device **150** mounted to a wing of an aircraft. The edge control system **452** may be configured to automatically command extension
 5 of one or more leading edge devices **150** from an initial or first position to a second position in response to deployment of a spoiler **290** if a ground speed of the aircraft **100** is greater than a threshold ground speed **564**. The second position of the leading edge device **150** may be a more deployed position than the first position, which may reduce the stopping distance **586** (see e.g., Figure 2) of the aircraft **100** such as during a rejected takeoff or during a landing, as described in
 10 greater detail below.

The wings **116** may include trailing edge devices **240** such as flaps **242** or other trailing edge device **240** configurations, as shown in the example in Figure 1. Similar to the leading edge devices **150**, the trailing edge devices **240** may include inboard devices and outboard devices. For example, the inboard devices may include one or more inboard flaps **244**,
 15 and an inboard roll-control flap device configured as a flaperon **286** (e.g., a combination flap-aileron). The outboard devices may include one or more outboard flaps **246** and an outboard roll-control flap device such as an aileron **288**. However, the trailing edge devices **240** may be provided in other configurations including, but not limited to, elevons and other trailing edge device configurations. The aircraft **100** may also include one or more spoilers **290** on each wing
 20 **116**, which may be used for generating aerodynamic drag and/or reducing wing lift.

Referring to Figure 2, shown is a diagrammatic view of an aircraft **100** moving down a runway **580** such as during a takeoff roll or after landing. For example, during a takeoff roll, the pilot may abort the takeoff by initiating a rejected takeoff maneuver upon the occurrence of a situation, a condition, or an event as the aircraft **100** accelerates down the runway **580**. For
 25 example, a rejected takeoff maneuver may be initiated in the event of an engine failure, a blown tire, activation of a takeoff warning horn, instructions from air traffic control, or any one of a variety of other events that may occur during a takeoff roll. A rejected takeoff maneuver may be initiated prior to the aircraft **100** reaching a takeoff decision speed V_1 which may be described as a minimum speed, following an engine failure, at which a takeoff may be

performed with only the remaining engines providing thrust. At speeds below the takeoff decision speed V_1 , the takeoff may be aborted by performing a rejected takeoff maneuver.

After initiation of a rejected takeoff, the flight crew may reconfigure the aircraft **100** from an initial configuration **572** (e.g., a takeoff configuration) to a stopping configuration **574** so that the aircraft **100** may stop within a stopping distance **586**. The aircraft **100** may travel a certain distance (e.g., distance **584**) during the time period during which the flight crew is reconfiguring the aircraft **100** from the initial configuration **572** to the stopping configuration **574**. The distance **584** may be described as a transition distance **584**. In some instances, it may be desirable to minimize the transition distance **584**, which may minimize the stopping distance **586**.

Referring to Figure 3, shown is a sectional view of a wing **116** of an aircraft **100** in the initial configuration **572** (e.g., takeoff configuration) during a takeoff roll. In the initial configuration **572**, the leading edge devices **150** may be placed in the initial configuration **572** by moving the leading edge devices **150** from a retracted position **158** (shown in phantom lines) to a deployed position **160** (shown in solid lines). For example, the leading edge devices **150** may comprise slats **152** which may be moved from the retracted position **158** to a partially extended and sealed position **182** during preparation for takeoff. In the sealed position **182**, a portion (e.g., an aft edge) of the slats **152** may remain in contact with the wing upper surface **122**. However, when the aircraft **100** is in the takeoff configuration, one or more of the leading edge devices **150** may be maintained in a retracted position **158** or a partially-deployed position (not shown) which may or may not be sealed with the wing upper surface **122**. In addition, one or more of the leading edge devices **150** may be moved from the retracted position **158** to a partially-gapped position (not shown). In the initial configuration **572** for a takeoff, the spoilers **290** may be maintained in a retracted position **291** relative to a wing upper surface **122**. In addition, the trailing edge devices **240** such as the flaps **242** may also be moved to a takeoff flaps setting **252**.

During preparation for a landing (not shown), the initial configuration **572** of the aircraft **100** may comprise a landing configuration (not shown). In the landing configuration, one or more leading edge devices **150** may be placed in a sealed position **182** (Figure 3), a partially-gapped position (not shown), or a gapped position **184** (Figure 4). However, in the

landing configuration, it is contemplated that one or more leading edge devices **150** may be retained in a retracted position **158** (Figure 3). In addition, in the landing configuration, a portion of the spoilers **290** (e.g., ground spoilers) may be maintained in a retracted position **291** (Figure 3) prior to touchdown of the aircraft **100**, and a portion of the spoilers **290** (e.g., flight
 5 spoilers) may be deployed (Figure 4) to reduce wing lift and increase aerodynamic drag during approach in preparation for landing.

In Figure 3, when the aircraft **100** is configured for takeoff, the trailing edge devices **240** such as the flaps **242** may be moved to a takeoff flaps setting **252**. Trailing edge devices **240** such as ailerons **288** (Figure 1) and/or flaperons **286** (Figure 1) may be maintained in a
 10 retracted position **248** when the aircraft **100** is in the initial configuration **572** (e.g., takeoff configuration). Configuring the aircraft **100** into the takeoff configuration may also include adjustment of the thrust setting of the engine control device **453** (Figure 5) and/or engagement of an autothrottle (not shown). In an embodiment, the takeoff roll may be initiated by moving the forward thrust levers **534** (Figure 5) from the idle position **538** to a takeoff thrust position
 15 (not shown) and by releasing the wheel brakes (not shown). The forward thrust levers **534** may be manually moved to a takeoff thrust position and/or the forward thrust levers **534** may be moved to the takeoff thrust position via the autothrottle such that the propulsion units **104** (Figure 1) generate the required thrust for accelerating the aircraft **100** down the runway **580**. Configuring the aircraft **100** in a landing configuration for landing may include positioning the
 20 flaps **242** in a landing flaps setting **254** (Figure 4) or other shallower flap setting, reducing engine thrust, extending the landing gear **106** (Figure 2), arming the speedbrakes, and arming the autobrake, if included with the aircraft **100**.

In Figure 3, the leading edge devices **150** and trailing edge devices **240** may be actuated using one or more device actuation systems **198**. For example, the slats **152** may be
 25 actuated by a slat actuation system **200**. The slats **152** may be coupled to an inboard torque tube **294** or an outboard torque tube **296** or other mechanical linkage. In an embodiment, the inboard torque tube **294** on the leading edge **118** may be coupled to a centrally-located, leading edge power drive unit (PDU) **402** (Figure 10) as described below. Each slat **152** may be supported by one or more carrier track assemblies **202**. Each carrier track assembly **202** may include one or
 30 more arcuate guide tracks **204** which may be supported by one or more guide rollers **206**

mounted to the wing **116** structure. A pinion gear **208** may be mounted on the torque tube **294**, **296** for engaging gear teeth (not shown) of the guide track **204**.

In Figure 3, extension and retraction of the slats **152** may be effectuated by rotating the torque tubes **294**, **296** and pinion gear **208** using the PDU **402**. In an embodiment, the leading edge devices **150** such as slats **152** may also be actuated by a variable camber trim unit (VCTU) **302** (Figure 10) operating in conjunction with the PDU **402**. As described in greater detail below, a VCTU **302** may be positioned between an inboard slat **154** and an outboard slat **156** on each wing **116**, and may allow for actuation of the inboard and outboard slats **154**, **156** independent of one another which may advantageously reduce actuation power requirements and/or hydraulic demand at the PDU **402** during a rejected takeoff or a landing.

In Figure 3, actuation of the trailing edge devices **240** such as the flaps **242** may be effectuated by a flap actuation system **280** which may be operated in a manner similar to the above described slat actuation system **200**. In this regard, the flap **242** may be actuated using a trailing edge linkage assembly **282** that may be coupled to a torque tube **294**, **296**. The flap **242** actuation system **280** may include a trailing edge PDU **404** (Figure 10) which may operate in conjunction with a VCTU **302** that may be positioned between an inboard flap **244** and an outboard flap **246** on each wing **116**. The deployment and retraction of the flaps **242** may be effected by rotating the torque tubes **294**, **296** using the PDU **404** and/or the VCTUs **302**. Although the trailing edge device **240** in Figure 3 is shown as a simple flap **242** supported on a drop hinge **284**, the flaps **242** may be provided in any one of a variety of different trailing edge device configurations including, but not limited to, a plain flap, a single-slotted flap, a multi-slotted Fowler flap, or any one of a variety of other flap configurations.

In Figure 3, the wing **116** may also include trailing edge devices **240** such as ailerons **288** (Figure 1) and flaperons **286** (Figure 1) that be actuated during a rejected takeoff or a landing. The ailerons **288** (Figure 1) and flaperons **286** may each be actuated by dedicated actuation systems (not shown). The wing **116** may further include spoilers **290** mounted on the wing upper surface **122**. As indicated above, one or more of the spoilers **290** may be operated as speed brakes for generating aerodynamic drag and/or reducing aerodynamic lift of the wings **116** during a rejected takeoff or a landing.

Referring to Figure 4, shown is a cross section of the wing **116** illustrating the slat **152** extended to the gapped position **184**. Although the present disclosure describes the autoslat system **300** in the context of extending a slat **152** from a sealed position **182** to a gapped position **184** during a rejected takeoff or a landing, the autoslat system **300** encompasses the extension of any type of leading edge device **150**, without limitation, from any initial position to a more deployed or further deployed position. In this regard, the autoslat system **300** encompasses the further deployment of one or more leading edge devices **150** from an initial position such as fully-retracted, stowed, partially-deployed, sealed, or partially-gapped position, to a more deployed position such as a further-deployed sealed position or to a gapped position from an initial partially-gapped position to a further deployed partially-gapped position or fully-gapped position. The extension of one or more leading edge devices **150** may be performed as part of the process of reconfiguring an aircraft **100** into a stopping configuration **574** during a rejected takeoff or during a landing, as described below.

In Figure 4, shown is a slat **152** extended to a gapped position **184** where the slat **152** may be positioned further downwardly and forward of the wing leading edge **118** relative to the sealed position **182** (Figure 3). Deployment of the slats **152** to the gapped position **184** results in the formation of a gap **180** between the upper aft edge of the slat **152** and the fixed leading edge of the wing **116**. In the gapped position **184**, the slats **152** generate increased aerodynamic drag due to exposure of a larger amount of frontal area of the slats **152** to the oncoming airflow. In addition, turbulent airflow over the exposed edges of the slats **152** and turbulent airflow through the gap **180** may generate increased aerodynamic drag relative to the amount of drag generated by the slats **152** in the sealed position **182**. Furthermore, in the gapped position **184**, the slats **152** may alter the wing camber which may reduce the amount of aerodynamic lift generated by the wings **116** by altering the sectional lift characteristics of the wing airfoil sections.

In Figure 4, reconfiguring the aircraft **100** into the stopping configuration **574** may also include deployment of one or more of the spoilers **290** to a maximum deflection angle **293** such that increased aerodynamic drag is generated. The stopping configuration **574** may include deployment of all of the spoilers **290** on each wing **116** to the maximum deflection angle **293** including all of the ground spoilers and flight spoilers. Deployment of the spoilers **290** to the

maximum deflection angle **293** may also reduce aerodynamic lift generated by the wings **116** allowing more of the aircraft weight to be transferred from the wings **116** to the landing gear **106** which may improve braking performance and decrease the stopping distance **586** (Figure 2) of the aircraft **100**. During a rejected takeoff or during a landing, the trailing edge devices **240**
 5 such as flaps **242**, ailerons **288**, and/or flaperons **286** may also be fully extended to the maximum deflection angle **256** to generate maximum aerodynamic drag to further reduce the stopping distance **586** (Figure 2).

Referring briefly to Figure 2, the process of reconfiguring the aircraft **100** into the stopping configuration **574** during a rejected takeoff or landing may also include moving the
 10 forward thrust levers **534** (Figure 5) to an idle position **538** (Figure 5) and disengaging an autothrottle (not shown) if included with the aircraft **100**. The aircraft **100** may also include an autobrake system (not shown) which may be automatically engaged when the forward throttle levers are moved to the idle position **538**, for example during a rejected takeoff or landing. An autobrake system may be configured to automatically apply a maximum braking force to the
 15 wheel brakes of the aircraft **100** which may reduce the stopping distance **586** (Figure 2). An autobrake system may eliminate the need for the flight crew to manually apply the wheel brakes which may reduce the number of tasks that must be performed by the flight crew to reconfigure the aircraft **100** from the initial configuration **572** into the stopping configuration **574**. By eliminating the task of manual braking, the transition distance **584** may be shortened which may
 20 further reduce the stopping distance **586** (Figure 2) during a rejected takeoff or landing.

Referring to Figure 5, shown is a diagrammatic view of an embodiment of an autoslat system **300** configured to automatically deploy a leading edge device **150** from an initial or first position, such as a retracted position (e.g., as shown in Figure 3), a sealed position (e.g., as shown in Figure 4), or a partially-gapped position (not shown) or gapped position, to
 25 second position, which may be a further deployed position such as a further-deployed sealed position, a partially-gapped position, or a fully-gapped position **184**. In one example, if the first or initial position is a retracted position, the second position may be virtually any position in which the leading edge device **150** is more deployed than in the initial position. For example, the second position may be any sealed position, any partially-gapped position, or a fully-gapped
 30 position **184**. In some examples, if the first or initial position is a partially deployed position,

for example a sealed position, the second position may be virtually any position in which the leading edge device **150** is more deployed than in the initial position, such as a further deployed sealed position, or a partially or fully-gapped position. The edge control system may be further configured to automatically command deployment of a trailing edge device **240** responsive, at least in part, to deployment of the spoiler **290** in conjunction with deployment of the leading edge device **150**.

As described herein, further deployment of the leading edge devices **150** may generate increased aerodynamic drag and may reduce aerodynamic lift of the wings **116** which may improve the braking performance of the aircraft **100**. In an embodiment, the autoslat system **300** may include an edge control system **452** for controlling the leading edge devices **150** and the trailing edge devices **240** mounted to the wings **116**. The autoslat system **300** may further include a thrust control system **530** for controlling a thrust setting of the one or more propulsion units **104**, and a speedbrake control system **500** for controlling the spoilers **290**. The thrust control system may be operable for selecting an idle thrust setting and a non-idle thrust setting. The speedbrake control system **530** may be configured to automatically command deployment of the spoiler **290** responsive, at least in part, to selection of the idle thrust setting. The thrust control system may include a forward thrust lever **534** positionable in at least an idle position **538** corresponding to the idle thrust setting and a non-idle position **540** corresponding to a thrust setting different than the idle thrust setting. The speedbrake control system **530** may be configured to automatically command deployment of the spoiler **290** responsive, at least in part, to movement of the forward thrust lever **534** from the non-idle position **540** to the idle position **538**.

In Figure 5, the autoslat system **300** may additionally include a flight control computer **450** which may be communicatively coupled to the edge control system **452**, the thrust control system **530**, and the speedbrake control system **500**. Any one of the edge control system **452**, the thrust control system **530**, the speedbrake control system **500**, and/or the flight control computer **450** may be mounted on a control stand (not shown) on a flight deck of the aircraft **100**. In an embodiment, the flight control computer **450** may be integrated into the edge control system **452**, the thrust control system **530**, and/or the speedbrake control system **500**. In a further embodiment, the edge control system **452**, the thrust control system **530**, the

speedbrake control system **500**, and/or the flight control computer **450** may be integrated into a flight control system (not shown) of the aircraft **100**.

The flight control computer **450** may be configured to detect the occurrence of an autoslat condition **570**, for example during a rejected takeoff or during a landing to cause
 5 automatic deployment of the one or more leading edge devices **150** from an initial position to a further deployed position. For example, in an embodiment, the flight control computer **450** may determine that an autoslat condition **570** exists when the flight control computer **450** receives an indication that the aircraft **100** is on the ground (i.e., the runway **580**) and is moving in excess of a predetermined threshold ground speed **564** during a takeoff roll or landing, the forward thrust
 10 levers **534** have been moved from a non-idle position **540** to the idle position **538**, and the spoilers **290** have been deployed (Figure 4). As described in greater detail below, spoiler **290** deployment may occur as a result of manual positioning of a speedbrake control device **502** (e.g., a speedbrake lever **506**) into an UP detent by the pilot or flight crew, or the spoilers **290** may be automatically deployed by a speedbrake control system **500** (e.g., an auto speed brake
 15 system – not shown) in response to the pilot moving the forward thrust levers **534** from a non-idle position **540** to the idle position **538**. Spoilers **290** may also be automatically deployed during a landing when the speedbrake lever **506** is in the armed detent **512** and/or an airplane-on-ground **566** indication is received at the flight control computer **450** indicating that the landing gear **106** is supporting at least a portion of the aircraft **100** weight.

20 In Figure 5, the edge control system **452** may include the edge control device **453** which may be movable into any one of a plurality of control device positions **458** corresponding to leading edge device **150** (e.g., see Figures 3-4) settings and trailing edge device **240** settings (e.g., see Figures 3-4). The edge control system **452** may include a device actuation system **198** which may be configured to position one or more of the leading edge devices **150** and trailing
 25 edge devices **240**. The device actuation system **198** may be configured to extend and retract the leading edge devices **150** and/or trailing edge devices **240** based on commands issued by the edge control system **452**. In an embodiment, the device actuation system may be configured to deploy a trailing edge device **240** to a maximum deflection angle responsive, at least in part, to deployment of the spoiler **290** in conjunction with deployment of a leading edge device **150**.

In Figure 5, the edge control device 453 may be configured as a flap control lever 454 that may be movable along a forward-and-aft direction. The flap control lever 454 may be positionable at one or more control device positions 458 or flap control lever positions, although the edge control device 453 may be provided in alternative embodiments. The edge control device 453 may include one or more mechanical gates 456 to prevent inadvertent retraction of the leading edge devices 150 and/or the trailing edge devices 240 by requiring manual manipulation the edge control device 453 to move the edge control device 453 past the gate 456. In the embodiment shown, the control device positions 458 may include a cruise position 462 designated as UP, a hold position 464 designated as HOLD, a climb position or approach position 466 designated as CLB/APP, a takeoff position 468 or go-around position 470 designated as TOGA, and a landing position 472 designated as LAND. The control device positions 458 may be designated by different nomenclature and are not limited to the designations shown in Figure 6. For example, the control device positions 458 may include UP, F1, F5, F20, and F30, or the control device positions 458 may include 0, 1, 2, 3/OPT, FULL, and which may generally correspond to the above-noted UP, HOLD, CLB/APP, TOGA, and LAND control device positions 458.

In Figure 5, for takeoff, the flap control lever 454 may be moved to the takeoff position prior to the aircraft 100 initiating the takeoff roll down the runway 580. With the flap control lever 454 in the takeoff position, the trailing edge devices 240 such as the flaps 242 may move to a takeoff flaps setting 252 and the leading edge devices 150 such as the slats 152 may move to a takeoff slat setting such as the sealed position 182 (Figure 4) or to a partially-gapped position. Alternatively, the takeoff slat setting for the leading edge devices 150 may comprise a stowed or retracted position 158. For landing, the flap control lever 454 may be moved to the landing position 472 or to a shallower flap position.

During the takeoff roll and during landing, the flight control computer 450 may analyze aircraft state data 560 to determine whether an autoslat condition 570 exists requiring the further deployment of one or more leading edge devices 150. During takeoff, the flight control computer may determine that an autoslat condition exists upon the occurrence of an event such as a blown tire, engine failure, warning horn, air traffic control instructions, or other events 582 triggering a rejected takeoff maneuver. During landing, the flight control computer 450

may determine that an autoslat condition **570** exists when an indication is received by the flight control computer **450** that the landing gear **106** is supporting at least a portion of the aircraft **100** weight, and the spoilers **290** are deployed. In an embodiment, the edge control system **452** may automatically command the device actuation system **198** to further deploy the leading edge devices **150** from their initial position to a further deployed position upon the occurrence of the autoslat condition **570**. Upon deployment of the spoilers **290** during a rejected takeoff or a landing, the edge control system **452** may also command the device actuation system **198** to move the trailing edge devices **240** (e.g., flaps **242**, ailerons **288**, flaperons **286**) to the maximum deflection angle **256** regardless of the position of the flap control lever **454** prior to initiation of the rejected takeoff or prior to the landing. For the flaps **242**, the maximum deflection angle **256** may correspond to the landing flaps setting **254** (Figure 4).

In Figure 5, in an embodiment, the autoslat system **300** may include the thrust control system **530** which may include one or more forward thrust levers **534** and one or more reverse thrust levers **532**. For takeoff, the forward thrust levers **534** may be advanced from an idle position **538** to a non-idle position **538** corresponding to a desired thrust setting of the propulsion units **104** (Figure 1). The reverse thrust levers **532** may be coupled to the forward thrust levers **534** and may allow for controlling engine reverse thrust via thrust reversers (not shown) on the propulsion units **104** and which may be activated when the forward thrust levers **534** are in the idle position **538**. As indicated above, the thrust control system **530** may be communicatively coupled to the flight control computer **450**. The thrust control system **530** may provide an indication to the flight control computer **450** when the forward thrust levers **534** are moved by the pilot or other flight crew from a non-idle position **540** to the idle position **538** during the initiation of a rejected takeoff or during a landing.

In Figure 5, in an embodiment, the autoslat system **300** may further include the above-mentioned speedbrake control system **500** which may be communicatively coupled to the flight control computer **450**. The speedbrake control system **500** may include a speedbrake control device **502** and a spoiler actuation system **504** for deploying the spoilers **290**. The speedbrake control device **502** may be configured as a speedbrake lever **506** and may have a plurality of speedbrake detents **508** which may represent a deflection angle for the spoilers **290** (Figure 4). In the embodiment shown, the speedbrake detents **508** may include a down detent

510 designated as DOWN, an armed detent **512** designated as ARMED, a flight detent **514** designated as FLIGHT DETENT, and an up detent **516** designated as UP. However, the speedbrake control device **502** may include a larger or smaller quantity of speedbrake detents **508**. In addition, the speedbrake detents **508** may be designated by different nomenclature and
 5 are not limited to the illustrated designations in Figure 5.

As indicated above, during the initiation of a rejected takeoff or during a landing, one or more of the spoilers **290** may be deployed to a maximum deflection angle **293** in response to the pilot or other flight crew member manually moving the speedbrake control device **502** to the UP detent to cause the spoiler actuation system **504** to deploy the spoilers **290**. The spoilers **290**
 10 on each wing **116** may be deployed substantially simultaneously to the maximum deflection angle **293**. In a further embodiment, during a rejected takeoff or a landing, the speedbrake control system **500** may automatically command the spoiler actuation system **504** to deploy the spoilers **290** when the flight control computer **450** receives an indication that the forward thrust levers **534** have been moved from a non-idle position **540** (e.g., a takeoff thrust setting) to the
 15 idle position **538** and/or the aircraft **100** is on the ground and is moving in excess of a threshold ground speed **564**.

In Figure 5, the flight control computer **450** may receive aircraft state data **560** regarding the state of the aircraft **100** during the takeoff roll or landing. The aircraft state data **560** may include the above-mentioned airplane-on-ground **566** indication, an indication of the
 20 actual ground speed **562** of the aircraft **100**, an indication of movement of the forward thrust levers **534** to the idle position **538**, and an indication of the speedbrake setting **568** representing deployment of the spoilers **290**. The airplane-on-ground **566** indication may be provided by one or more sensors (not shown) on the landing gear **106** (not shown) which may sense spin-up of the wheels, compression of landing gear struts, tilt of the landing gear trucks, or other
 25 parameters indicating that the landing gear **106** is supporting at least a portion of the aircraft **100** weight. One or more ground speed sensors (not shown) may transmit an indication of the aircraft **100** actual ground speed **562** to the flight control computer **450**. The flight control computer **450** may compare the actual ground speed **562** to a predetermined threshold ground speed **564**, and determine whether the actual ground speed **562** exceeds the threshold ground
 30 speed **564**.

In Figure 5, the thrust control system **530** may transmit to the flight control computer **450** an indication of movement of the forward thrust levers **534** from a non-idle position **540** to the idle position **538**. The speedbrake control system **500** may transmit an indication to the flight control computer **450** regarding the deployment of the spoilers **290** from the retracted position **291** (Figure 3) to the deployed position **160** (Figure 4). The flight control computer **450** may analyze the above-noted aircraft state data **560** to determine whether the autoslat condition **570** exists. Upon determining that the autoslat condition **570** exists, the flight control computer **450** may transmit a signal to the edge control system **452** to cause the edge control system **452** to automatically command the device actuation system **198** to further deploy the leading edge devices **150** from their initial position in preparation for takeoff or their initial position in preparation for landing.

In an embodiment, the edge control system **452** may automatically command the device actuation system **198** to extend the leading edge devices **150** when the spoilers **290** are automatically deployed (i.e., using the auto speed brake) by the spoiler actuation system **504** in response to the forward thrust levers **534** being moved to the idle position **538**. The further deployment of the leading edge devices **150** may advantageously alter the wing camber which may alter (e.g., reduce) the sectional lift characteristics of the wings **116** which may improve the stopping performance of the aircraft **100** and reduce the stopping distance **586** (Figure 2). For example, depending on the aircraft **100**, autogapping of the leading edge devices **150** during a rejected takeoff may provide an estimated **5,000-10,000** pounds of additional weight on the aircraft wheels which may improve braking performance and reduce takeoff field length by up to approximately **50** feet or more. Furthermore, further deployment of the leading edge devices **150** may increase aerodynamic drag. In addition, by automating the deployment of the leading edge devices **150** instead of the pilot manually deploying the leading edge device **150** using the flap control lever **454**, the transition time and transition distance **584** (Figure 2) may be minimized.

In an embodiment, the autoslat system **300** may be configured such that the edge control system **452** automatically deploys the trailing edge devices **240** upon deployment of the spoilers **290** from the retracted position **291** to the deployed position **292**. Alternatively, the autoslat system **300** may be configured such that the edge control system **452** automatically

deploys the trailing edge devices **240** in conjunction with the further deployment of the leading edge devices **150**. Trailing edge devices **240** that may be automatically deployed may include the flaps **242**, the ailerons **288**, and/or the flaperons **286** (Figure 1). For example, the flaps **242**, ailerons **288**, and/or flaperons **286** may be automatically deployed such as from a retracted position **248** to a maximum deflection angle **256** in a deployed position **250** upon deployment of the spoilers **290** from the retracted position **291** to the deployed position **292**. Movement of the trailing edge devices **240** to the maximum deflection angle **256** may increase aerodynamic drag which may shorten the stopping distance **586** (Figure 2) of the aircraft **100** during a rejected takeoff or a landing.

Referring to Figure 6-9, shown are diagrammatic views of an embodiment of the autoslat system **300** allowing for further deployment of the inboard and outboard leading edge devices **144**, **146** independent of one another. In this regard, the device actuation system may be configured to actuate the inboard leading edge device **144** independently of the outboard leading edge device **146**, and vice versa. By initially deploying a subset of the leading edge devices **150** such as from the sealed position **182** to the gapped position **184**, actuation power requirements may be reduced. For example, by initially deploying the outboard leading edge devices **146** followed by deploying the inboard leading edge devices **144** during a rejected takeoff or a landing, the total power requirements and/or hydraulic demand for actuating the leading edge devices **150** may be reduced relative to higher power requirements and greater hydraulic demand for further deploying all of leading edge devices **150** at one time. As indicated above, reduced power requirements and reduced hydraulic demand may be advantageous in the event of an engine-out situation during a rejected takeoff or landing. An engine-out situation may result in reduced availability of power for actuating the spoilers **290**, the leading and trailing edge devices **150**, **240**, and other systems due to the inability of the non-operative engine to generate power and/or hydraulic pressure.

In Figures 6-9, independent actuation of the inboard and outboard leading edge devices **144**, **146** may be facilitated by a variable camber trim unit (VCTU) **302** as part of the device actuation system **198**. As indicated above, a VCTU **302** may be positioned between an inboard and outboard leading edge device **144**, **146** to allow for independent actuation of the inboard and outboard leading edge devices **144**, **146**. A VCTU **302** may also be positioned

between an inboard trailing edge device **240** and outboard trailing edge device **240** to allow for independent actuation of the inboard and outboard trailing edge devices **240**. In this regard, the VCTU **302** may allow for further deployment of a subset of the leading edge devices **150** upon the occurrence of an autoslat condition **570** (Figure 5). For example, upon the occurrence of an autoslat condition **570**, a VCTU **302** positioned between the inboard slats **154** and the outboard slats **156** may allow for automatically moving the outboard slats **156** to a further deployed position while the inboard slats **154** are held stationary. In an embodiment, the outboard slats **156** may be automatically deployed to a gapped position **184** (Figure 4) while the inboard slats **154** are momentarily retained in a sealed position **182** (Figure 3). After the outboard slats **156** reach the further deployed position (e.g., the gapped position **184**), the inboard slats **154** may then be automatically moved to a further deployed position (e.g., the gapped position **184**). However, the VCTUs may operate in conjunction with the PDUs **400** to automatically deploy the inboard and outboard slats **154**, **156** in unison.

Referring more particularly to Figure 6, shown is diagrammatic plan view of a leading edge **118** of a wing **116** schematically illustrating a VCTU **302** positioned between an inboard leading edge device **144** (e.g., an inboard slat **154**) and outboard leading edge devices **146** (e.g., outboard slats **156**). The inboard slats **154** may be coupled to an inboard torque tube **294** and the outboard slats **156** may be coupled to an outboard torque tube **296**. The VCTU **302** may include a dedicated electric motor **304** which may be operated in conjunction with the speed sum gearbox **320** and an outboard brake **354**. The inboard slat **154** may be driven by a central motor **406** (Figure 11) of a leading edge PDU **402** (Figure 11). As described in greater detail below, the VCTU **302** may be included with the device actuation system **198** and may be operated in conjunction with the PDU **402** to automatically deploy the inboard and outboard leading edge devices **144**, **146** independent of one another.

In Figure 7, shown is a diagrammatic view of the wing **116** leading edge **118** of Figure 6 illustrating the operation of the VCTU **302** in conjunction with the leading edge PDU **402** to further deploy the inboard and outboard slats **154**, **156** in unison from their initial position. As described below, the power-off brake **310** of the VCTU **302** may be applied to prevent rotational movement of the electric motor **304**. The central motor **406** (Figure 11) of the leading edge PDU **402** (Figure 11) may be activated for actuating the inboard slat **154**. With the

power-off brake **310** applied, actuation of the inboard slat **154** by the central motor **406** of the leading edge PDU **402** may rotate the inboard torque tube **294**. When the power-off brake **310** of the VCTU **302** is applied, the rotational movement of the inboard torque tube **294** may be transferred through the speed sum gearbox **320** to the outboard torque tube **296** resulting in
 5 actuation of the inboard slat **154** and the outboard slat **156** in unison.

In Figure **8**, shown is a diagrammatic view of the wing **116** leading edge **118** of Figure **6** illustrating the further deployment of the inboard slat **154** independently of the outboard slats **156**. For independent deployment of the inboard slats **154**, the power-off brake **310** of the electric motor **304** may be released. The outboard brake **354** of the VCTU **302** may
 10 be applied to prevent rotation of the outboard slats **156**. The central motor **406** (Figure **11**) of the leading edge PDU **402** (Figure **11**) may be activated resulting in rotation of the inboard torque tube **294**. The speed sum gearbox **320** of the electric motor **304** may be configured such that rotation of the inboard torque tube **294** causes the electric motor **304** to be back-driven while the inboard slat **154** is actuated by the central motor **406** of the leading edge PDU **402**.

In Figure **9**, shown is a diagrammatic view of the wing **116** leading edge **118** of Figure **6** and illustrating the further deployment of the outboard slats **156** independently of the inboard slat **154**. In an embodiment, the autoslat system **300** may be configured such that the edge control system **452** automatically commands the device actuation system **198** to extend one or more outboard leading edge devices **146** (e.g., the outboard slats **156**) such as from the sealed
 20 position **182** (Figure **4**) to a further-deployed sealed position, partially-gapped position, or gapped position **184** (Figure **5**) prior to further deploying one or more inboard leading edge devices **144** (e.g., the inboard slat **154**). As indicated above, by initially moving only the outboard leading edge devices **146**, total power requirements for further deploying the leading edge devices **150** may be reduced as may hydraulic demand at the leading edge PDU **402**.

In Figure **9**, for independent deployment of the outboard slats **156**, the central motor **406** of the leading edge PDU **402** may be prevented from rotating the inboard slat **154** by applying a central brake **414** which may be coupled to the central motor **406**. The outboard brake **354** of the VCTU **302** may be released. Additionally, the power-off brake **310** of the electric motor **304** may be released. The electric motor **304** may then be activated causing
 25 rotation of the outboard torque tube **296** and resulting in deployment of the outboard slats **156**
 30

independently of the inboard slat **154**. In this manner, upon detection by the flight control computer **450** of an autoslat condition **570**, the edge control system **452** may automatically command the VCTU motor controller **303** to activate the electric motor **304** in a manner causing the outboard slats **156** to be further extended.

5 In Figure **9**, after the outboard slats **156** are further extended, the outboard brake **354** of the VCTU **302** may be applied. With the power-off brake **310** of the VCTU electric motor **304** released, the central brake **414** of the leading edge PDU **402** may be released and the central motor **406** of the leading edge PDU **402** may be activated causing the inboard torque tube **294** to rotate. Rotation of the inboard torque tube **294** may cause the inboard slat **154** to be further
10 extended while the outboard slats **156** are stationary. The VCTU electric motor **304** may be back-driven while the inboard slat **154** is further deployed.

In Figure **10**, shown is a diagrammatic view of a device actuation system **198** incorporating VCTUs **302** between the inboard leading edge devices **144** and outboard leading edge devices **146** on the leading edge **118** of each wing **116** of the aircraft **100**. A similar
15 arrangement of VCTUs **302** may be implemented with the trailing edge devices **240**. In the embodiment shown, the device actuation system **198** may include a leading edge PDU **402** coupled to the leading edge devices **150** on opposite sides of the fuselage **102**, and a trailing edge PDU **404** coupled to the trailing edge devices **240** on opposite sides of the fuselage **102**. The device actuation system **198** may be controlled by flight control electronics **422** which may
20 be centrally-located on the aircraft **100** and/or may be positioned adjacent to one or both of the PDUs **400**. The flight control electronics **422** may be configured to generate command signals for actuating the leading edge devices **150** and the trailing edge devices **240**. The command signals may be transmitted via one or more command lines **424** or wirelessly transmitted to the leading edge PDU **402**, the trailing edge PDU **404**, and to the motor controller **303** of each
25 VCTU **302**.

In Figure **10**, each motor controller **303** may control the VCTU electric motor **304**, the outboard brake **354**, and/or the power-off brake **310** of the VCTU **302**. The flight control electronics **422** may transmit command signals to the motor controller **303** of the VCTU electric motor **304** and to the central motor **406** causing actuation (e.g., deployment and retraction) of
30 the inboard leading edge devices **144** and the outboard leading edge devices **146**. The flight

control electronics **422** may receive position signals from one or more position sensors **312** (see e.g., Figure **13**) that may be included with each one of the VCTUs **302**. The position signals may represent the current position or deflection angle of each one of the inboard leading edge devices **144**.

5 In Figure **10**, the device actuation system **198** may further include a central power supply **426** for powering the VCTU electric motor **304** of each one of the VCTUs **302**. The power supply **426** may be centrally-located such as adjacent to the PDUs **400**. In an embodiment, each VCTU electric motor **304** may include the above-mentioned motor controller **303** which may be powered by the central power supply **426** with a substantially continuous
10 supply of relatively low-voltage power. Such low-voltage power may be removed from the motor controller **303** for certain types of faults. Relatively high-voltage power may be provided to the VCTU electric motors **304** from the central power supply **426** via an electric supply line **428** to cause the VCTU electric motor **304** to rotate such as in response to a command signal transmitted along a command line **424** from the flight control electronics **422** to the motor
15 controller **303**.

As shown in Figure **10**, each one of the VCTUs **302** may include a VCTU electric motor **304** and a speed sum gearbox **320**. An outboard brake **354** may be included with each VCTU **302** to prevent rotation of the outboard device **146** as indicated above. The VCTU **302** may include the above-mentioned power-off brake **310** which may be coupled to the VCTU
20 electric motor **304** and which may be applied by one or more coils **318**. The coils **318** may receive power from the centrally-located central power supply **426** via an electric supply line **428** for activating the power-off brake **310** such as in response to a command signal received from the flight control electronics **422** via a command line **424**. One or more resolvers **316** may be included at different locations on the leading edge devices **150** and/or trailing edge devices
25 **240** for indicating the positions of such devices **150**, **240** and which may be provided to the flight control electronics **422**.

Figure **11** is a diagrammatic view of a center portion of the variable camber actuation system showing the leading edge PDU **402** and the trailing edge PDU **404**. As indicated earlier, the leading edge PDU **402** and the trailing edge PDU **404** may be coupled to the inboard torque
30 tubes **294** on the respective leading edge **118** and trailing edge **120** of each wing **116**. In an

embodiment, each one of the PDUs **400** may include at least one central motor **406**. For example, in Figure **12**, each one of the PDUs **400** may include an active motor **408** and a backup motor **410**. Each one of the central motors **406** may be coupled to or may include a central brake **414** configured as a power-off brake for preventing rotation of the central motor **406** and thereby preventing actuation of the inboard device **144** to which the central motor **406** is coupled.

In Figure **11**, in an embodiment, the active motor **408** and/or the backup motor **410** may be configured as a hydraulic motor or an electrohydraulic actuator which may be coupled to a central hydraulic system **418** via one or more hydraulic lines **420**. In an embodiment, the active motor **408** and/or the backup motor **410** may optionally be configured as an electromechanical actuator or an electric motor for controlling the actuation of the inboard devices. The central motors **406** of the leading edge PDU **402** may be coupled to the inboard torque tubes **294** for driving the inboard leading edge devices **144**. The trailing edge PDU **404** may be coupled to the inboard devices on the trailing edge **120** in a manner similar to the leading edge PDU **402**. Each one of the PDUs **400** may include a central gearbox **412** and one or more central brakes **414**. Each one of the central motors **406** may be coupled to the central brake **414** (e.g., a power-off brake) which may be configured to prevent movement of the inboard devices when both central brakes **414** are applied.

Figure **12** is a schematic diagram of an embodiment of a VCTU **302** illustrating the interconnection of the speed sum gearbox **320** with the outboard brake **354**, the VCTU electric motor **304** and power-off brake **310**, and the position sensor **312**. The arrangement of the VCTU **302** is described below in the context of the inboard and outboard leading edge devices **144**, **146**, and may be implemented in a similar manner for the trailing edge devices **240**. The speed sum gearbox **320** includes an inboard shaft **351** that may be coupled to an inboard leading edge device **144** via an inboard torque tube **294**, and an outboard shaft **352** that may be coupled to an outboard leading edge device **146** via an outboard torque tube **296**. The VCTU electric motor **304** may include a motor shaft **306** having a motor pinion **308** that may be engaged to a ring gear **338** of the speed sum gearbox **320**.

The speed sum gearbox **320** may be configured such that if one of the three shafts (i.e., the inboard shaft **351**, the outboard shaft **352**, the motor shaft **306**) is held stationary and

prevented from rotating, the remaining pair of shafts will rotate under the driving force of one of the remaining shafts of the pair. For example, if the inboard shaft **351** is prevented from rotating due to application of the central brake **414** of the PDU, then rotation of the motor shaft **306** will cause rotation of the outboard shaft **352** resulting in actuation of the outboard leading edge device **146** independent of the inboard leading edge device **144**. If the motor shaft **306** is prevented from being rotated due to application of the power-off brake **310**, then rotation of the inboard shaft **351** will cause rotation of the outboard shaft **352** resulting in actuation of the inboard and outboard leading edge devices **144**, **146** in unison with one another. If the outboard shaft **352** is prevented from rotating due to application of the outboard brake **354**, then rotation of the inboard shaft **351** by the central motor **406** will cause the VCTU electric motor **304** to be back-driven while the inboard leading edge device **144** is actuated and the outboard leading edge device **146** is stationary.

In Figure **12**, the inboard shaft **351** may be fixedly (e.g., non-rotatably) coupled to the inboard device **144** via the inboard torque tube **294**. The outboard shaft **352** may be fixedly (e.g., non-rotatably) coupled to the outboard device **146** via the outboard torque tube **296**. The inboard shaft **351** may include an inboard pinion **334** that may be coupled to an inboard gear **332** of the speed sum gearbox **320**. The inboard gear **332** may be mounted on or fixedly (i.e., non-rotatably) coupled to a sun gear shaft **350** of a sun gear **346** of the speed sum gearbox **320**. The position sensor **312** may include a position sensor gear **314** that may be engaged to the inboard gear **332** for sensing a position of the inboard leading edge device **144** and transmitting a position signal to the flight control electronics **422**. The speed sum gearbox **320** may include a plurality of planet gears **344** that may be supported on a carrier **348**. The carrier **348** may be fixedly (i.e., non-rotatably) coupled to or mounted on the outboard shaft **352**. The planet gears **344** may encircle and may be engaged to the sun gear **346**. The plurality of planet gears **344** may be circumscribed by a ring gear **338**. The motor pinion **308** may be engaged to an external side **342** of the ring gear **338**.

Figure **13** is a perspective illustration of an embodiment of the VCTU **302** and showing the inboard torque tube **294** coupled to the inboard shaft **351** and the outboard torque tube **296** coupled to the outboard shaft **352** of the speed sum gearbox **320**. The VCTU **302** may comprise an integrated unit including the VCTU electric motor **304** and associated power-off

brake **310**, outboard brake **354**, and position sensor **312**, all of which may be supported by or enclosed, at least partially, within the VCTU housing **322**. The VCTU housing **322** may include one or more mounting tabs **324** for mounting the VCTU **302** to the wing **116** structure of an aircraft **100**.

5 Figure **14** is a forward-looking view of the VCTU **302** illustrating the VCTU housing **322**. In an embodiment, the VCTU housing **322** may be made up of an inner housing **326** on the inboard side of the VCTU **302**, an outer housing **330** on an outboard side of the VCTU **302**, and a mid housing **328** sandwiched between the inner housing **326** and the outer housing **330**. Although not shown, the inner housing **326**, the mid housing **328**, and the outer housing **330**
10 may be mechanically coupled together such as with mechanical fasteners. The three-piece arrangement of the VCTU housing **322** may facilitate assembly and disassembly of the VCTU **302** such as for maintenance and inspection. Although not shown, the VCTU housing **322** may be sealed from the elements by a seal extending around a perimeter at the interface of the housings. The VCTU housing **322** may be configured to provide a relatively rigid load path for
15 operational loads.

 Figure **15** is a sectional view of the VCTU **302** showing the inboard pinion **334** and the position sensor gear **314** operatively engaged to one another by the inboard gear **332**. In an embodiment, the inboard gear **332** may be omitted, and the inboard shaft **351** may be directly coupled to the sun gear **346**. In such an arrangement, the position sensor gear **314** may be
20 engaged to another gear (not shown) that may be mounted on or integrally formed with the inboard shaft **351** to allow the position sensor **312** to sense the position of the inboard device **144** for transmitting a representative position signal to the flight control electronics **422**.

 Figure **16** is a sectional view of the VCTU **302** showing the speed sum gearbox **320** configured as a planetary gear system **336**. As indicated above, the speed sum gearbox **320**
25 includes a central sun gear **346** having gear teeth and which is surrounded by a plurality of planet gears **344**. The planet gears **344** are supported on the carrier **348** which may be fixedly mounted to the outboard shaft **352**. The gear teeth of the planet gears **344** are engaged to the gear teeth on the internal side **340** of the ring gear **338** which circumscribes the planet gears **344**. The motor pinion **308** of the VCTU electric motor **304** are engaged to the external side **342** of
30 the ring gear **338**.

In Figure 17, shown is a flow chart containing one or more operations that may be included in a method 600 of reducing the stopping distance 586 (Figure 2) of an aircraft 100 during a rejected takeoff or a landing. Step 602 of the method may include positioning a leading edge device 150 of an aircraft wing 116 in an initial position such as a partially extended and sealed position 182 during preparation for takeoff or landing. In the partially extended or sealed position 182, a portion of the slats 152 (e.g., the aft edge of the slats) may remain in contact with the wing upper surface 122. However, in an embodiment, the leading edge devices 150 may be maintained in a retracted position 158 (Figure 3) or a gapped position. The process of configuring the aircraft 100 in the initial configuration 572 (e.g., the takeoff configuration or the landing configuration) prior to takeoff or landing may also include moving the flaps 242 to a desired flap setting such as the takeoff flaps setting 252 shown in Figure 4 or the landing flaps setting shown in Figure 5. The spoilers 290 may be maintained in the retracted position 291 as may the trailing edge devices such as the ailerons 288 and flaperons 286.

Step 604 of the method 600 of Figure 17 may include advancing the forward thrust levers 534 (Figure 5) from an idle position 538 to a non-idle position 540 such as to a takeoff thrust position (not shown) for takeoff, and to a reduced thrust setting non-idle position 540 for landing. For takeoff, the wheel brakes may be released allowing the thrust from the propulsion units 104 to accelerate the aircraft 100 down the runway 580. The method may include moving the aircraft 100 at an actual ground speed 562 during the takeoff roll or upon touchdown during a landing. As indicated above, an indication of the actual ground speed 562 may be continuously provided to the flight control computer 450 during the takeoff roll.

Step 606 of the method 600 of Figure 17 may include moving one or more of the forward thrust levers 534 of the thrust control system 530 from the non-idle position 540 to the idle position 538 to initiate a rejected takeoff. The initiation of the rejected takeoff may include disengaging an autothrottle (not shown) which may result in activation of an autobrake system (not shown) to automatically apply maximum braking force to the wheels. As indicated above, the pilot or other flight crew member may initiate a rejected takeoff upon the occurrence of an event such as an engine failure, a blown tire, activation of a takeoff warning horn, instructions from air traffic control, or other events that may occur during the takeoff roll. Touchdown of the main landing gear 106 during a landing may also activate the autobrake system to

automatically apply braking force to the wheels. . During landing, moving one or more of the forward thrust levers to the idle position **538** after the main landing gear **106** touches down may also activate the autobrake system.

Step **608** of the method **600** of Figure **17** may include deploying the spoilers **290** responsive, at least in part, to moving the forward thrust levers **534** from the non-idle position **540** to the idle position **538**. In an embodiment, the method may include automatically commanding, using the speedbrake control system **500**, the spoiler actuation system **504** to deploy the spoilers **290** when the forward thrust lever **534** is moved from the non-idle position **540** to the idle position **538**. The spoilers **290** may be deployed at the maximum deflection angle **293** to maximize aerodynamic drag and minimize aerodynamic lift of the wings **116**. The automatic deployment of the spoilers **290** may be included as part of an auto speed brake capability of the aircraft **100**, and may be triggered when it is determined by the flight control computer **450** that the aircraft **100** is on the ground and the actual ground speed **562** exceeds the threshold ground speed **564** which may be preprogrammed into the flight control computer **450**.

For example, a selected threshold ground speed **564** (e.g., **85** knots) may be preprogrammed into the flight control computer **450**. During a takeoff roll or during a landing, the flight control computer **450** may receive an indication of the actual ground speed **562** of the aircraft **100** for comparison to the threshold ground speed **564**. When flight control computer **450** determines that the actual ground speed **562** exceeds the threshold ground speed **564** and that the aircraft **100** is on the ground during a takeoff roll or a landing, the flight control computer may send a signal to the speedbrake control system **500** causing the speedbrake control system **500** to automatically command the speed actuation system to deploy the spoilers **290**.

Step **610** of the method **600** of Figure **17** may include automatically commanding, using the edge control system **452**, the device actuation system **198** to further deploy the leading edge devices **150**. If the actual ground speed **562** of the aircraft **100** exceeds the threshold ground speed **564**, the method may include automatically commanding the leading edge devices **150** from a first position to a second position in response to deployment of the spoilers **290**. The first position of the leading edge devices **150** may be a retracted position **158**, a sealed position **182**, or a partially-gapped or gapped position **184**. The second position of the leading edge

devices **150** may be a sealed position **182** or a gapped position **184**. The autoslat system **300** may be configured to automatically move the leading edge devices **150** from any initial position (e.g., stowed, sealed, gapped) to a further deployed position (e.g., sealed, gapped) when the spoilers **290** are manually or automatically commanded to the deployed position **292**. The
 5 spoilers **290** may also be manually deployed by the pilot manually moving the speedbrake lever **506** to the UP detent (Figure 5).

The spoilers **290** may also be automatically commanded to the deployed position **292** in response to the forward thrust levers **534** being moved to the idle position **538** as part of an auto speed brake capability of the aircraft **100** during a rejected takeoff or a landing, and/or in
 10 response to an airplane-on-ground **566** indication during a landing. In an embodiment, during a rejected takeoff or a landing, the edge control system **452** may automatically command the device actuation system **198** to further extend an inboard leading edge device **144** and an outboard leading edge device **146** independent of one another. For example, the method may include moving an inboard leading edge device **144** independently of an outboard leading edge
 15 device **146**. In some examples, the method may include extending the outboard leading edge device **146** prior to extending the inboard leading edge device **144** by operating the VCTUs **302** in conjunction with the leading edge PDUs **402**. Independent actuation of the inboard and outboard leading edge devices **144**, **146** may reduce actuation power requirements and/or hydraulic demand for the device actuation systems **198**.

Step **612** of the method **600** of Figure 17 may include deploying a trailing edge device **240** responsive, at least in part, to the deployment of the spoiler **290**. In an embodiment, the method may include automatically commanding, using the edge control system **452**, the device actuation system **198** to deploy one or more trailing edge devices **240** when the spoilers **290** are deployed. For example, upon deployment of the spoilers **290** during a rejected takeoff
 25 or a landing, the device actuation system **198** for the trailing edge devices **240** may automatically command the flaps **242** to the maximum deflection angle **256** which may correspond to the landing flaps setting **254** shown in Figure 4. In an embodiment, the flaps **242** may also be differentially actuated to the maximum deflection angle **256** using VCTUs **302** operating in conjunction with the trailing edge PDU **404** in a manner similar to the above-
 30 described system for independently actuating the leading edge devices **150**. The deployment of

the spoilers **290** may also initiate the automatic deflection of the ailerons **288**, flaperons **286**, and other trailing edge devices **240** to the maximum deflection angle **256**.

Step **614** of the method **600** of Figure **17** may include reducing aerodynamic lift of the wings **116** and/or increasing aerodynamic drag in response to further extending the
5 leading edge devices **150** and deploying the spoilers **290** and the trailing edge devices **240** to the maximum deflection angle **256**, **293**. As indicated above, further deployment of the leading edge devices **150** may alter the wing camber resulting in a reduction in aerodynamic lift of the wings **116**. In addition, further deployment of the leading edge devices **150** may increase aerodynamic drag due to a larger frontal area of the leading edge devices **150**, and
10 due to turbulent airflow over the edges of the leading edge devices **150** and through the gap **180** (Figure **2**).

Step **616** of the method **600** of Figure **17** may include reducing the stopping distance **586** (Figure **2**) of the aircraft **100** in response to reducing the aerodynamic lift of the wings **116** and increasing the aerodynamic drag of the aircraft **100**. The lift generated by the
15 wings **116** may be reduced by the further-deployed leading edge devices **150** which may alter the sectional lift characteristics of the wings resulting in a transfer of a portion of the aircraft **100** weight from the wings **116** to the landing gear **106** which may improve braking performance during a rejected takeoff or a landing.

Additional modifications and improvements of the present disclosure may be
20 apparent to those of ordinary skill in the art. Thus, the particular combination of parts described and illustrated herein is intended to represent only certain embodiments of the present disclosure and is not intended to serve as limitations of alternative embodiments or devices within the scope of the disclosure.

According to an aspect of the present disclosure there is provided a system for
25 reducing a stopping distance of an aircraft, comprising an edge control system configured to control a leading edge device mounted to a wing of an aircraft; the edge control system configured to automatically command extension of the leading edge device from a first position to a second position in response to deployment of a spoiler if a ground speed of the aircraft is greater than a threshold ground speed.

The system disclosed wherein the first position is a retracted position, a sealed position, or a gapped position, and wherein the second position is a sealed position or a gapped position.

5 The system disclosed further comprising a thrust control system operable for selecting an idle thrust setting and a non-idle thrust setting; and a speedbrake control system configured to automatically command deployment of the spoiler responsive, at least in part, to selection of the idle thrust setting.

10 The system disclosed wherein the thrust control system includes a thrust lever positionable in at least an idle position corresponding to the idle thrust setting and a non-idle position corresponding to a thrust setting different than the idle thrust setting; and wherein the speedbrake control system is configured to automatically command deployment of the spoiler responsive, at least in part, to movement of the thrust lever from the non-idle position to the idle position.

15 The system disclosed wherein the edge control system is further configured to automatically command deployment of a trailing edge device responsive, at least in part, to deployment of the spoiler in conjunction with deployment of the leading edge device.

20 The system disclosed further comprising a device actuation system communicatively coupled to the edge control system and configured to actuate the leading edge device and/or the trailing edge device; and the device actuation system is configured to deploy the trailing edge device to a maximum deflection angle responsive, at least in part, to deployment of the spoiler in conjunction with deployment of the leading edge device.

The system disclosed wherein the trailing edge device comprises at least one of a flap, an aileron, and a flaperon.

25 The system disclosed further comprising a device actuation system communicatively coupled to the edge control system; wherein the leading edge device is one of a plurality of leading edge devices coupled to the wing, the plurality of leading edge devices including an inboard leading edge device and an outboard leading edge device; and the device actuation system is configured to actuate the inboard leading edge device independently of the outboard leading edge device.

The system disclosed wherein the edge control system is configured to automatically command the device actuation system to extend the outboard leading edge device prior to extending the inboard leading edge device.

5 The system disclosed wherein the device actuation system includes a variable camber trim unit (VCTU) positioned between the inboard leading edge device and the outboard leading edge device; and the VCTU actuating the outboard leading edge device independent of the inboard leading edge device.

10 The system disclosed wherein the VCTU includes a speed sum gearbox including an inboard shaft coupled to the inboard leading edge device and an outboard shaft coupled to the outboard leading edge device; a VCTU electric motor engaged to the speed sum gearbox; and wherein the VCTU electric motor selectively operating in conjunction with the speed sum gearbox to rotate the outboard shaft independent of the inboard shaft in a manner causing the outboard leading edge device to be actuated independent of the inboard leading edge device.

15 According to a further aspect of the present disclosure there is provided an autoslat system for reducing a stopping distance of an aircraft, comprising an edge control system including a device actuation system configured to position a leading edge device mounted to a wing of an aircraft; a thrust control system including a forward thrust lever positionable in one of an idle position and a non-idle position; a speedbrake control system automatically commanding a spoiler actuation system to deploy a spoiler when the forward thrust lever is
20 moved from the non-idle position to the idle position and the aircraft is on ground and moving in excess of a threshold ground speed; and the edge control system automatically commanding the device actuation system to extend the leading edge device when the spoiler is deployed automatically by the spoiler actuation system in response to the forward thrust lever being moved to the idle position.

25 According to another aspect of the present disclosure there is provided a method of reducing a stopping distance of an aircraft, comprising deploying a spoiler mounted on a wing of an aircraft; and if a ground speed of the aircraft exceeds a threshold ground speed, automatically commanding a leading edge device on the wing of the aircraft from a first position to a second position in response to deployment of the spoiler.

The method disclosed wherein the first position is a retracted position, a sealed position, or a gapped position and the second position is a sealed position or a gapped position.

The method disclosed wherein the step of deploying the spoiler includes moving a thrust lever from a non-idle position to an idle position; and deploying the spoiler responsive, at least
5 in part, to moving the thrust lever from the non-idle position to the idle position.

The method disclosed further comprising deploying a trailing edge device responsive, at least in part, to the deployment of the spoiler.

The method disclosed wherein the step of deploying the trailing edge device includes deploying the trailing edge device to a maximum deflection angle.

10 The method disclosed wherein the trailing edge device comprises at least one of a flap, an aileron, and a flaperon.

The method disclosed further comprising moving an inboard leading edge device independently of an outboard leading edge device.

15 The method disclosed further comprising extending the outboard leading edge device prior to extending the inboard leading edge device.

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

1. A system for reducing a stopping distance of an aircraft, comprising:

an edge control system configured to control a leading edge device deployable
5 from a leading edge of a wing of an aircraft on the ground;

a thrust control system including a thrust lever positionable in at least an idle
position corresponding to an idle thrust setting and a non-idle position
corresponding to a thrust setting different than the idle thrust setting;

a speedbrake control system automatically commanding deployment of a
10 spoiler at least partially responsive to movement of the thrust lever from the
non-idle position to the idle position when the aircraft is on ground and
moving in excess of a threshold ground speed;

the edge control system automatically commanding extension of the leading
edge device from a first position to a second position when the spoiler is
15 automatically deployed by the speedbrake control system; and

a device actuation system deploying a trailing edge device to a maximum
deflection angle at least partially responsive to deployment of the spoiler in
conjunction with deployment of the leading edge device.

2. The system of Claim 1, wherein:

20 the first position is a retracted position, a sealed position, or a gapped position;
and

the second position is the sealed position or the gapped position.

3. The system of Claim 1 or Claim 2, wherein:

the trailing edge device comprises at least one of a flap, an aileron, and a flaperon.

4. The system of any one of Claims 1 to 3, further comprising:

5 a device actuation system communicatively coupled to the edge control system;

wherein the leading edge device is one of a plurality of leading edge devices coupled to the wing, the plurality of leading edge devices including an inboard leading edge device and an outboard leading edge device; and

10 the device actuation system is configured to actuate the inboard leading edge device independently of the outboard leading edge device.

5. The system of Claim 4, wherein:

the edge control system is configured to automatically command the device actuation system to extend the outboard leading edge device prior to extending the inboard leading edge device.

15 6. The system of Claim 4, wherein:

the device actuation system includes a variable camber trim unit (VCTU) positioned between the inboard leading edge device and the outboard leading edge device; and

20 the VCTU is configured to actuate the outboard leading edge device independent of the inboard leading edge device.

7. The system of Claim 6, wherein the VCTU includes:

a speed sum gearbox including an inboard shaft coupled to the inboard leading edge device and an outboard shaft coupled to the outboard leading edge device; and

a VCTU electric motor engaged to the speed sum gearbox;

wherein the VCTU electric motor is configured to selectively operate in conjunction with the speed sum gearbox to rotate the outboard shaft independent of the inboard shaft in a manner causing the outboard leading edge device to be actuated independent of the inboard leading edge device.

8. An autoslat system for reducing a stopping distance of an aircraft, the system comprising:

an edge control system including a device actuation system configured to position a leading edge device deployable from a leading edge of a wing of an aircraft on the ground;

a thrust control system including a forward thrust lever positionable in one of an idle position and a non-idle position;

a speedbrake control system automatically commanding a spoiler actuation system to deploy a spoiler when the forward thrust lever is moved from the non-idle position to the idle position and the aircraft is on ground and moving in excess of a threshold ground speed;

the edge control system automatically commanding the device actuation system to extend the leading edge device from a first extended position to a second extended position in response to deployment of the spoiler when the spoiler is automatically deployed by the spoiler actuation system; and

the device actuation system deploying a trailing device to a maximum deflection angle at least partially responsive to deployment of the spoiler in conjunction with deployment of the leading edge device.

9. A method of reducing a stopping distance of an aircraft, comprising:

moving a thrust lever from a non-idle position to an idle position;

automatically commanding, using a speedbrake control system, deployment of a spoiler mounted on a wing of an aircraft at least partially responsive to moving the thrust lever from the non-idle position to the idle position when the aircraft is on ground and moving in excess of a threshold ground speed;

5 automatically commanding, using an edge control system, extension of a leading edge device on the wing from a first position to a second position in response to deployment of the spoiler by the speedbrake control system; and

deploying a trailing edge device to a maximum deflection angle responsive, at least in part, to the deployment of the spoiler.

10 **10.** The method of Claim **9**, wherein:

the first position is a retracted position, a sealed position, or a gapped position; and

the second position is the sealed position or the gapped position.

11. The method of Claim **9** or Claim **10**, wherein:

15 the trailing edge device comprises at least one of a flap, an aileron, and a flaperon.

12. The method of any one of Claims **9** to **11**, further comprising:

moving an inboard leading edge device independently of an outboard leading edge device.

20 **13.** The method of Claim **12**, further comprising:

extending the outboard leading edge device prior to extending the inboard leading edge device.

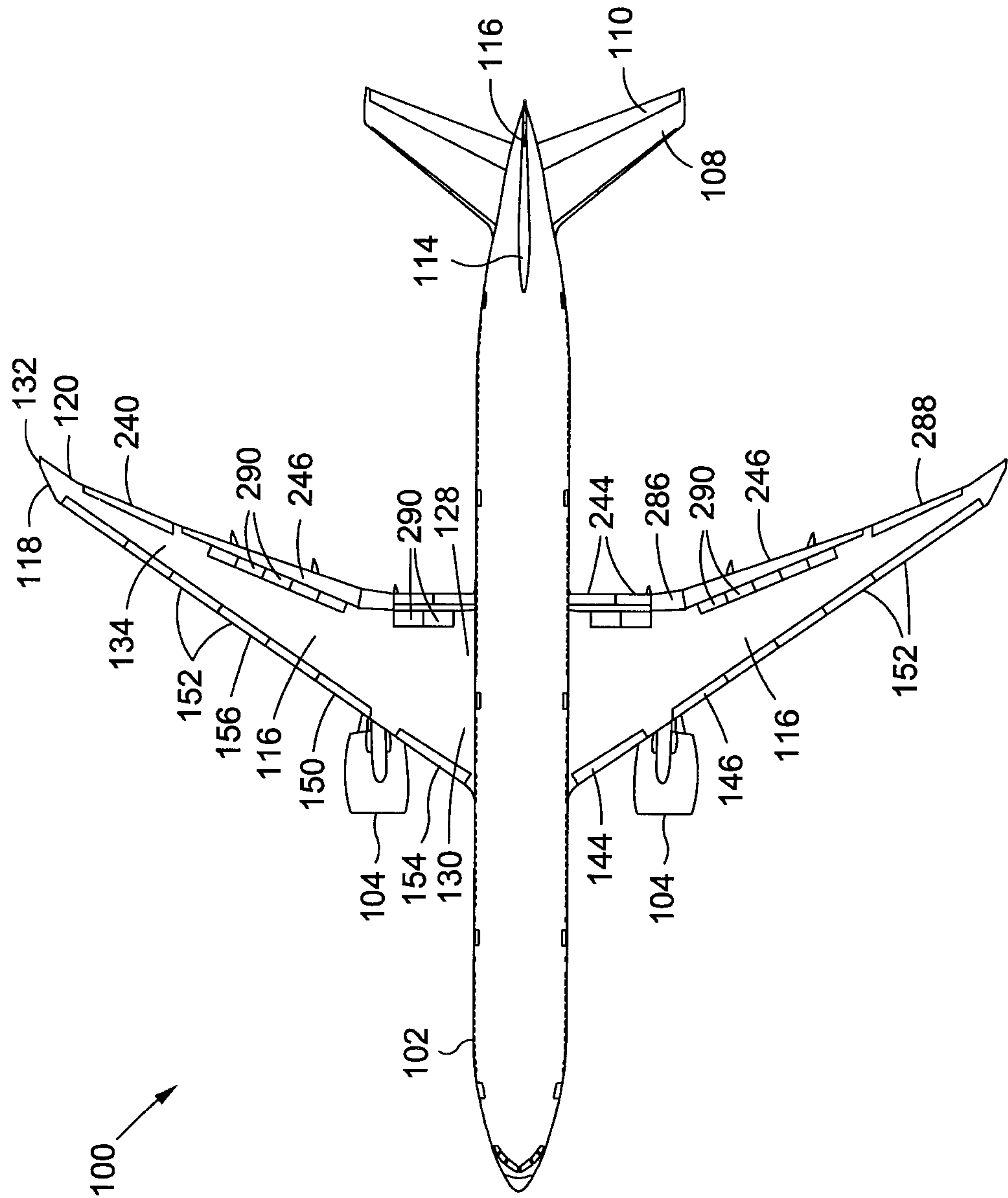
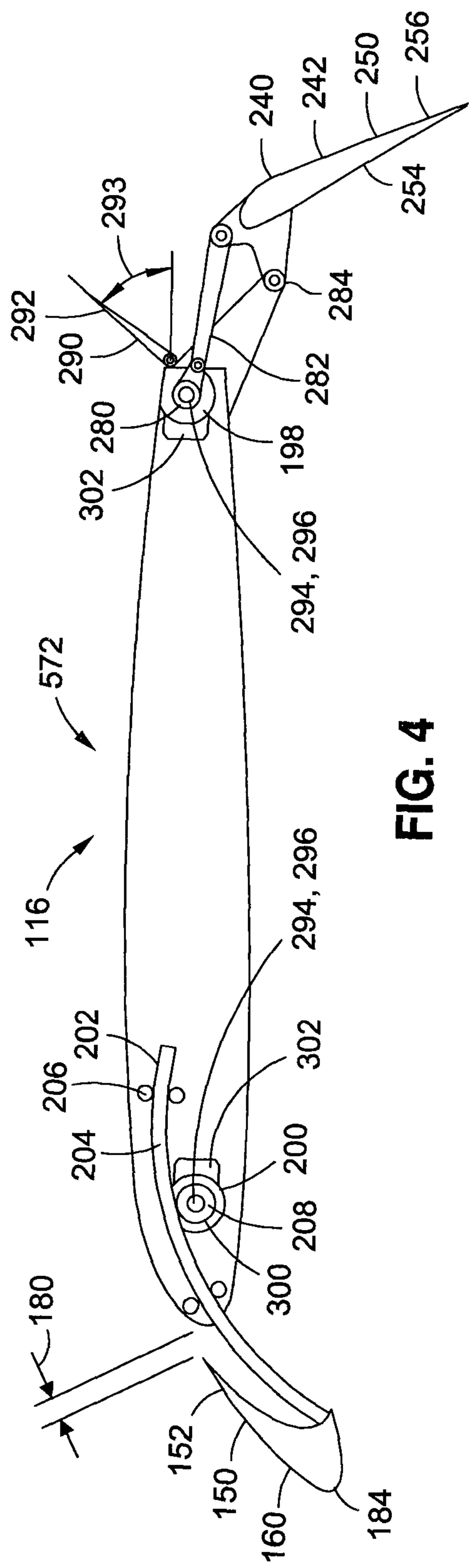
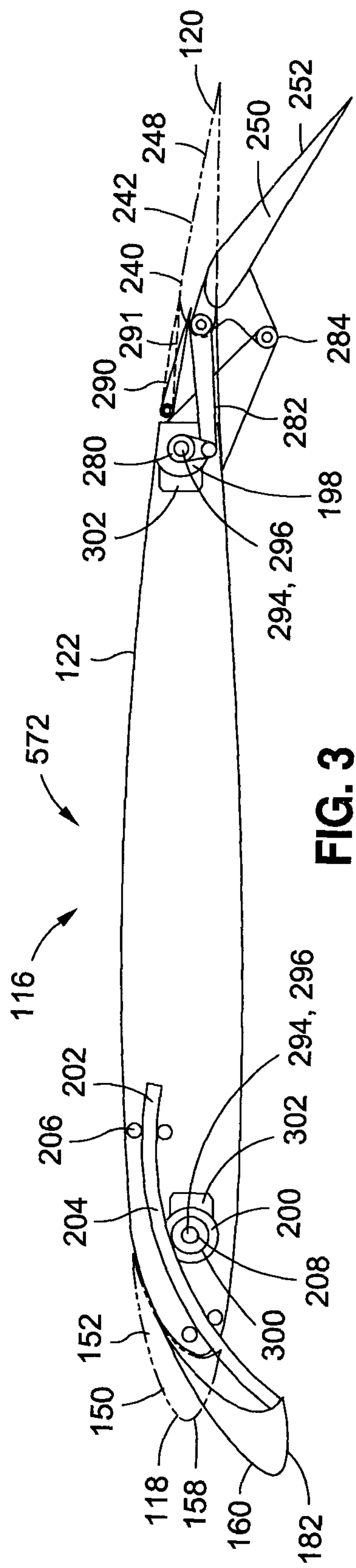
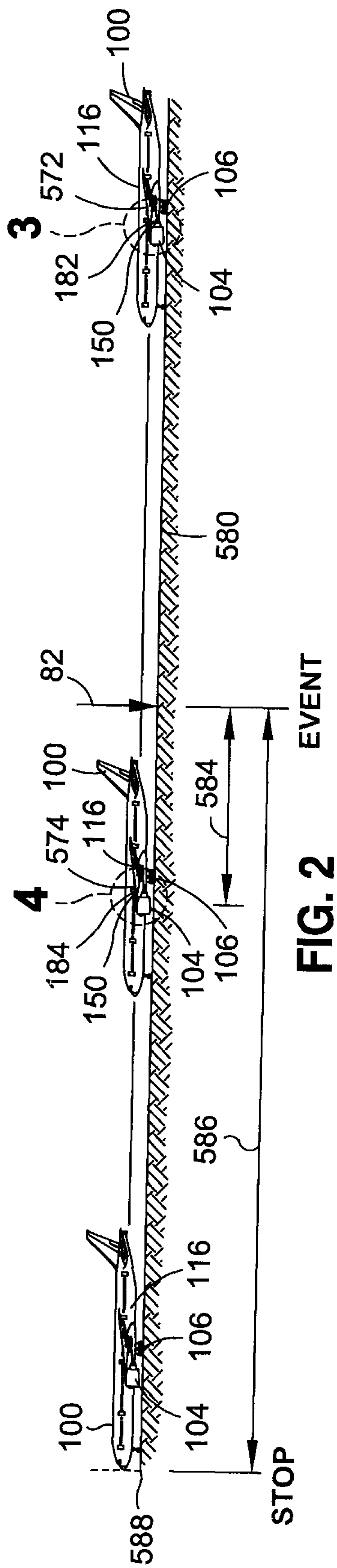


FIG. 1



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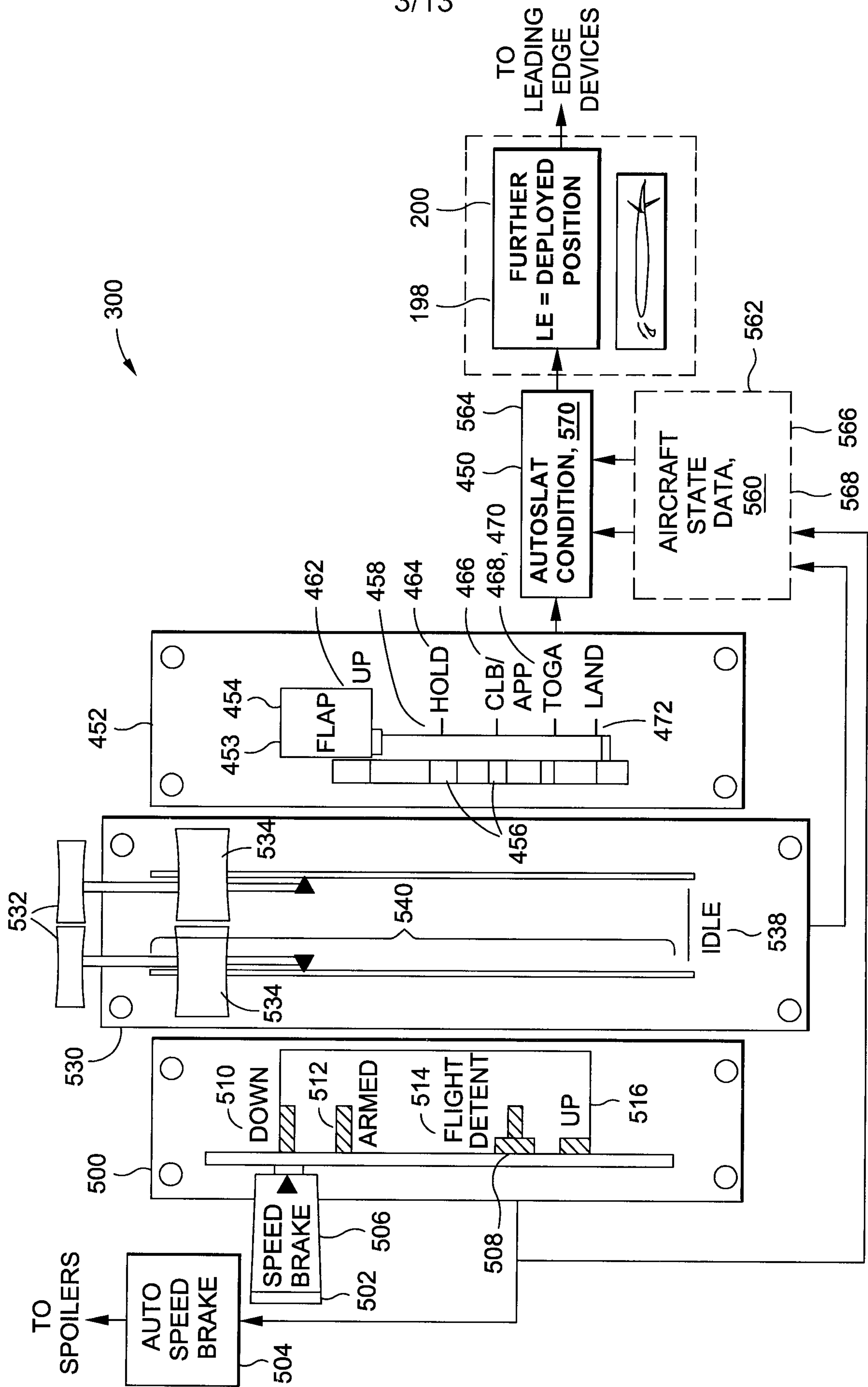


FIG. 5

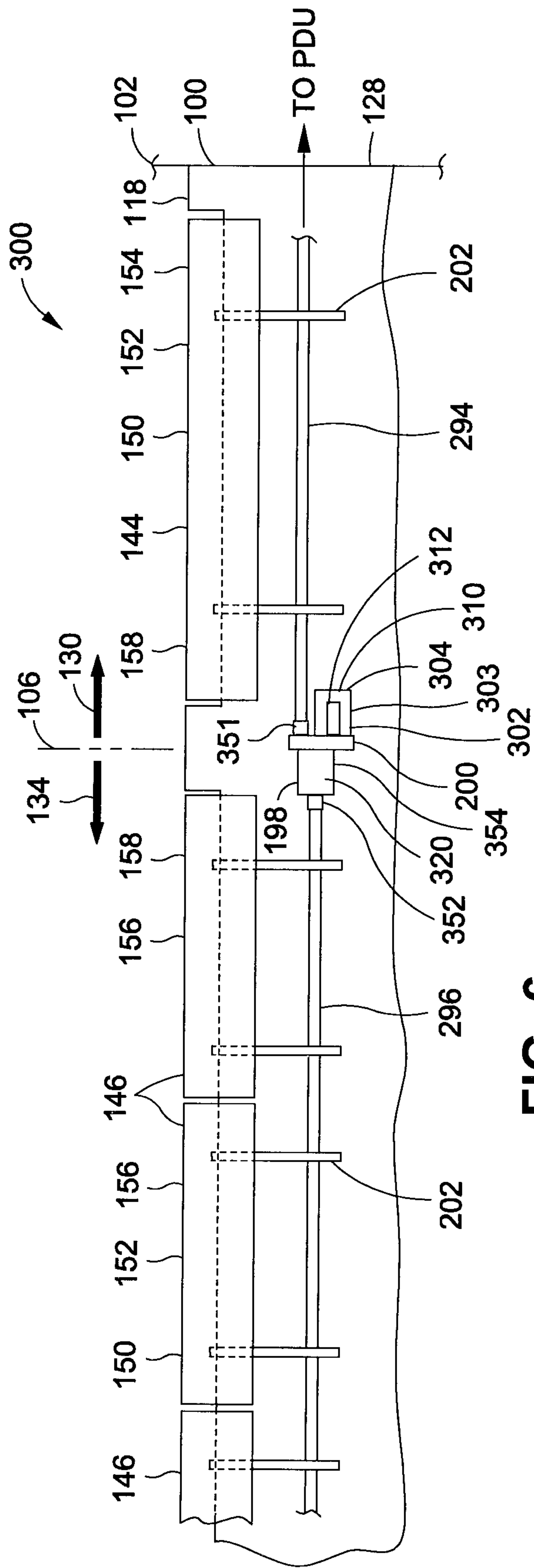


FIG. 6

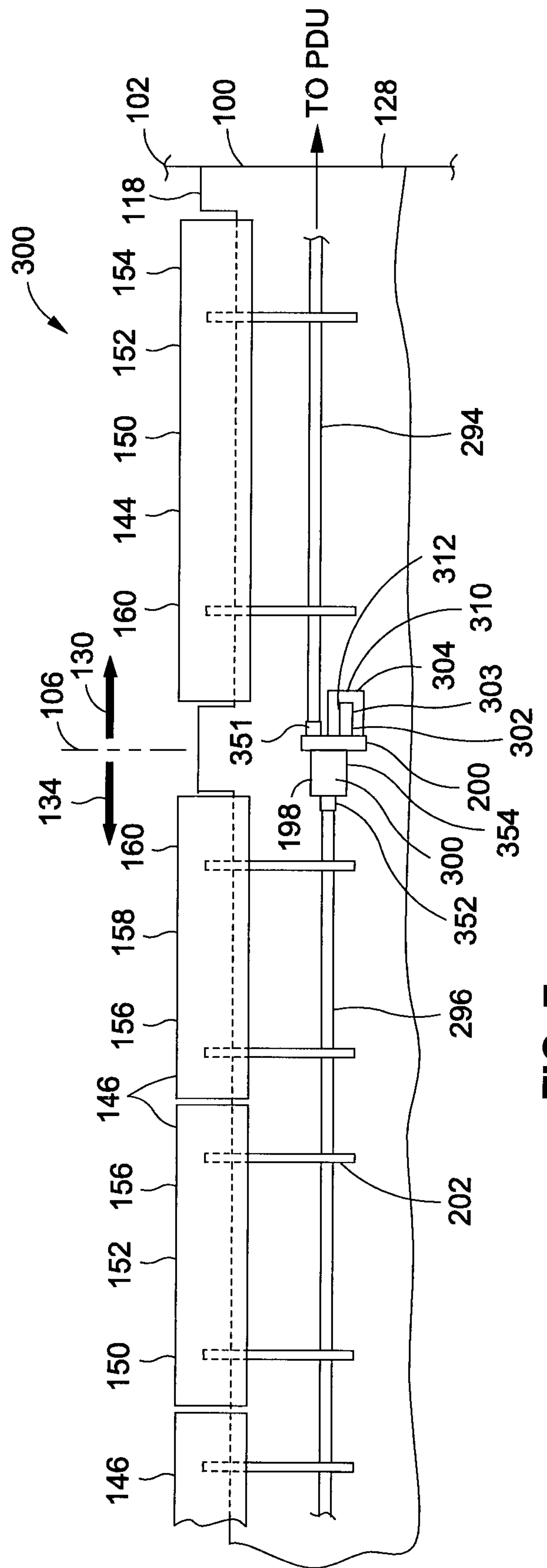


FIG. 7

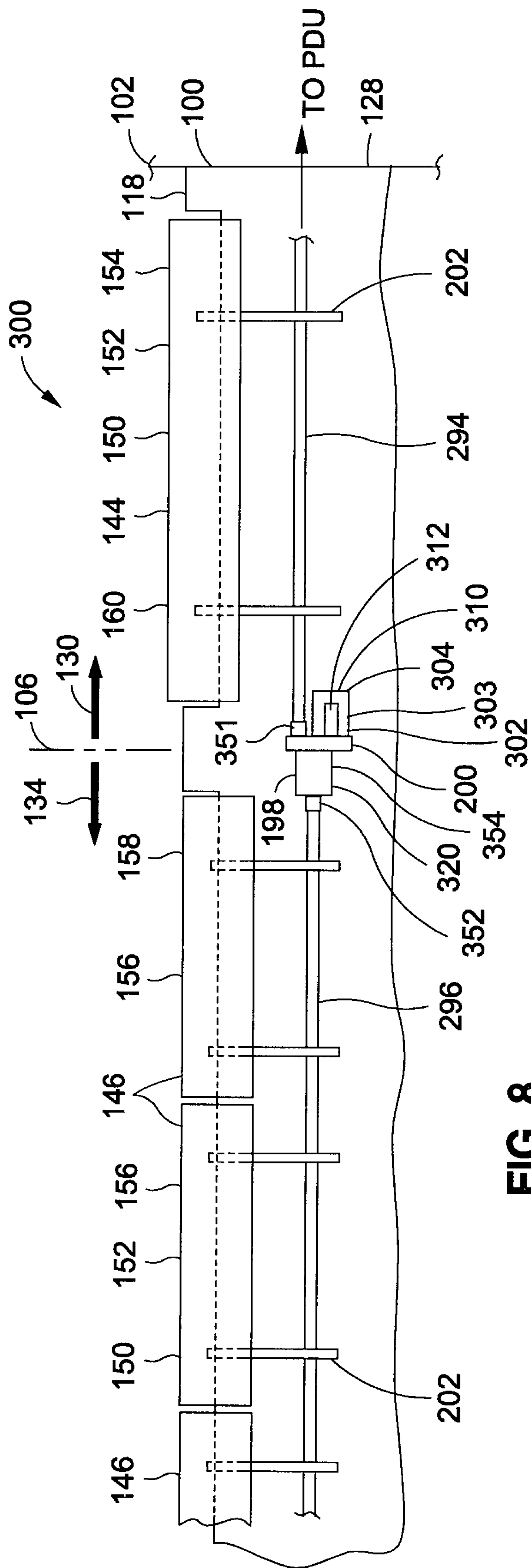


Fig. 8

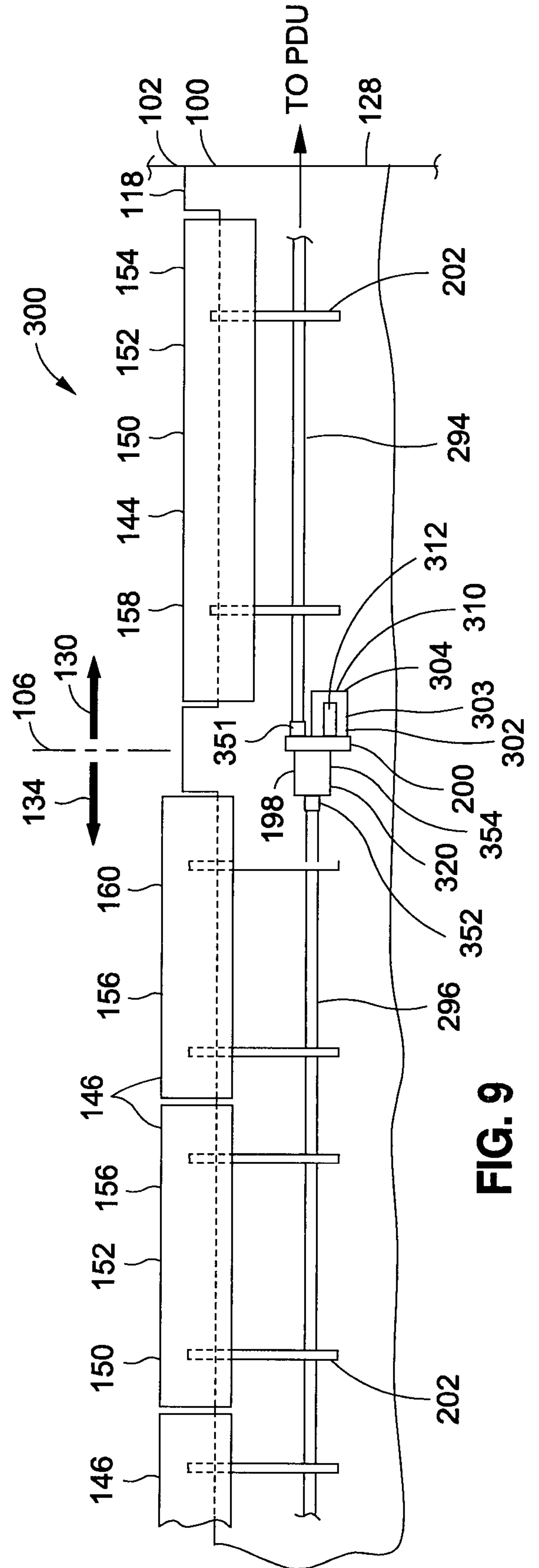


Fig. 9

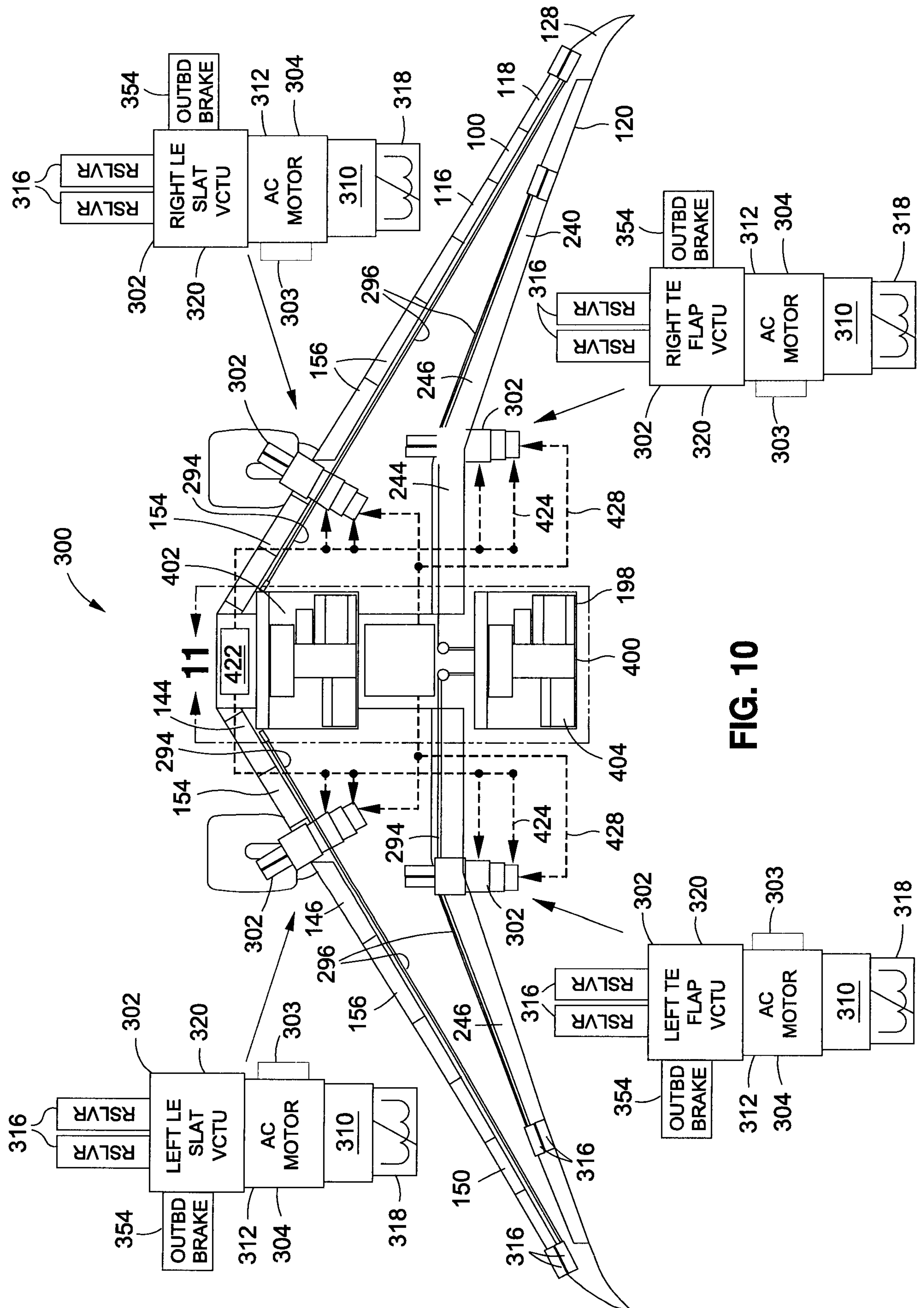


FIG. 10

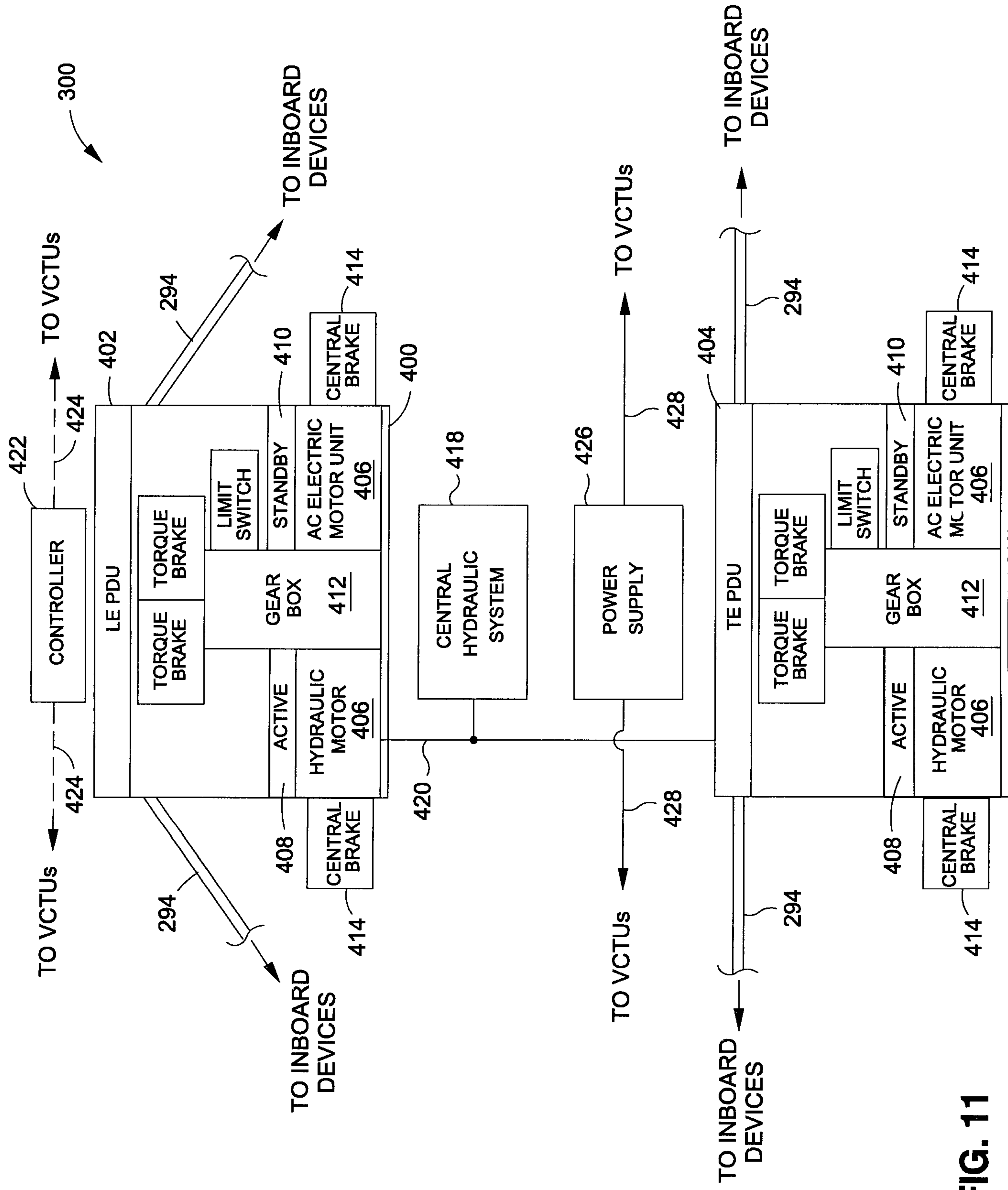


FIG. 11

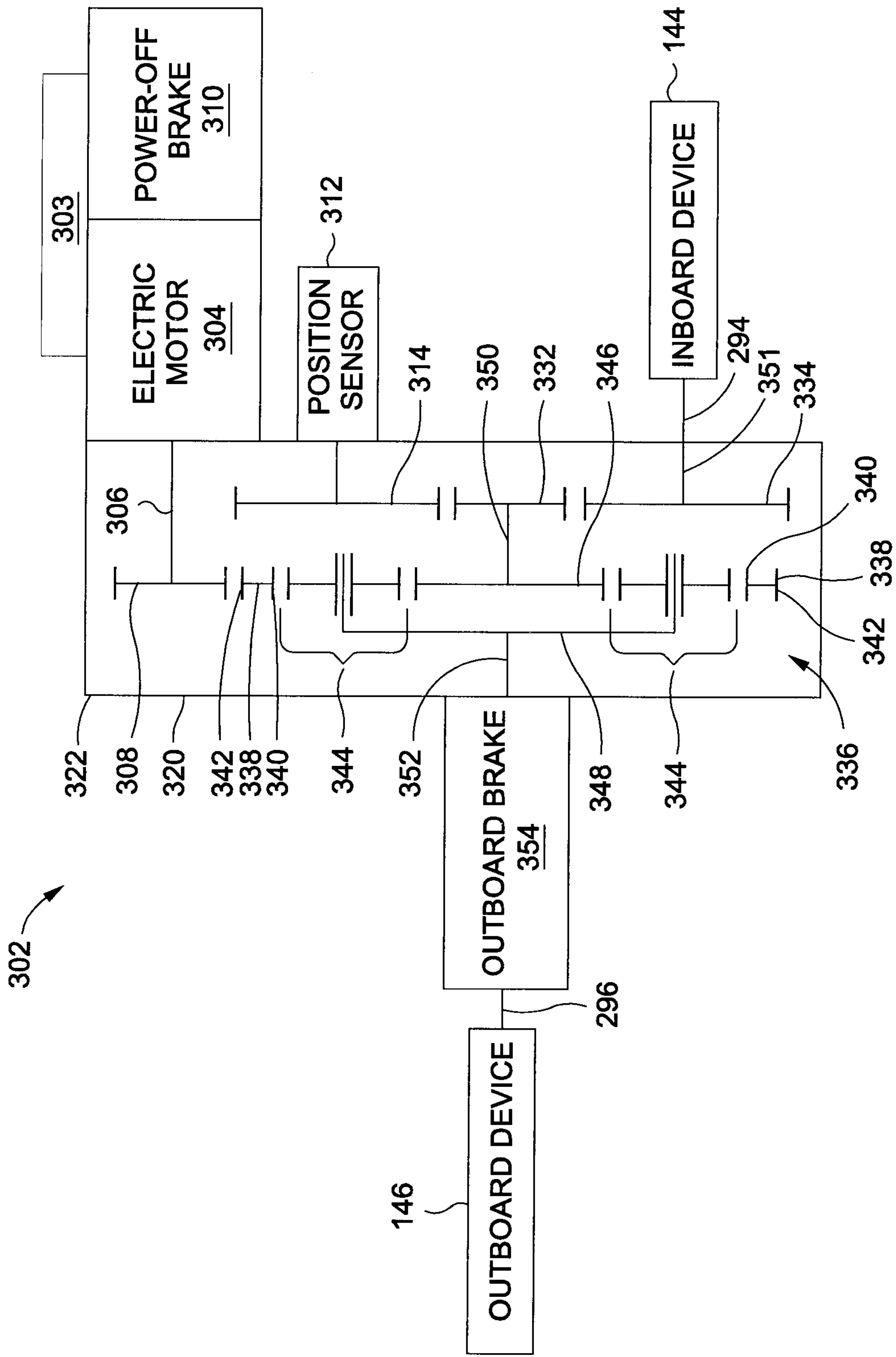


FIG. 12

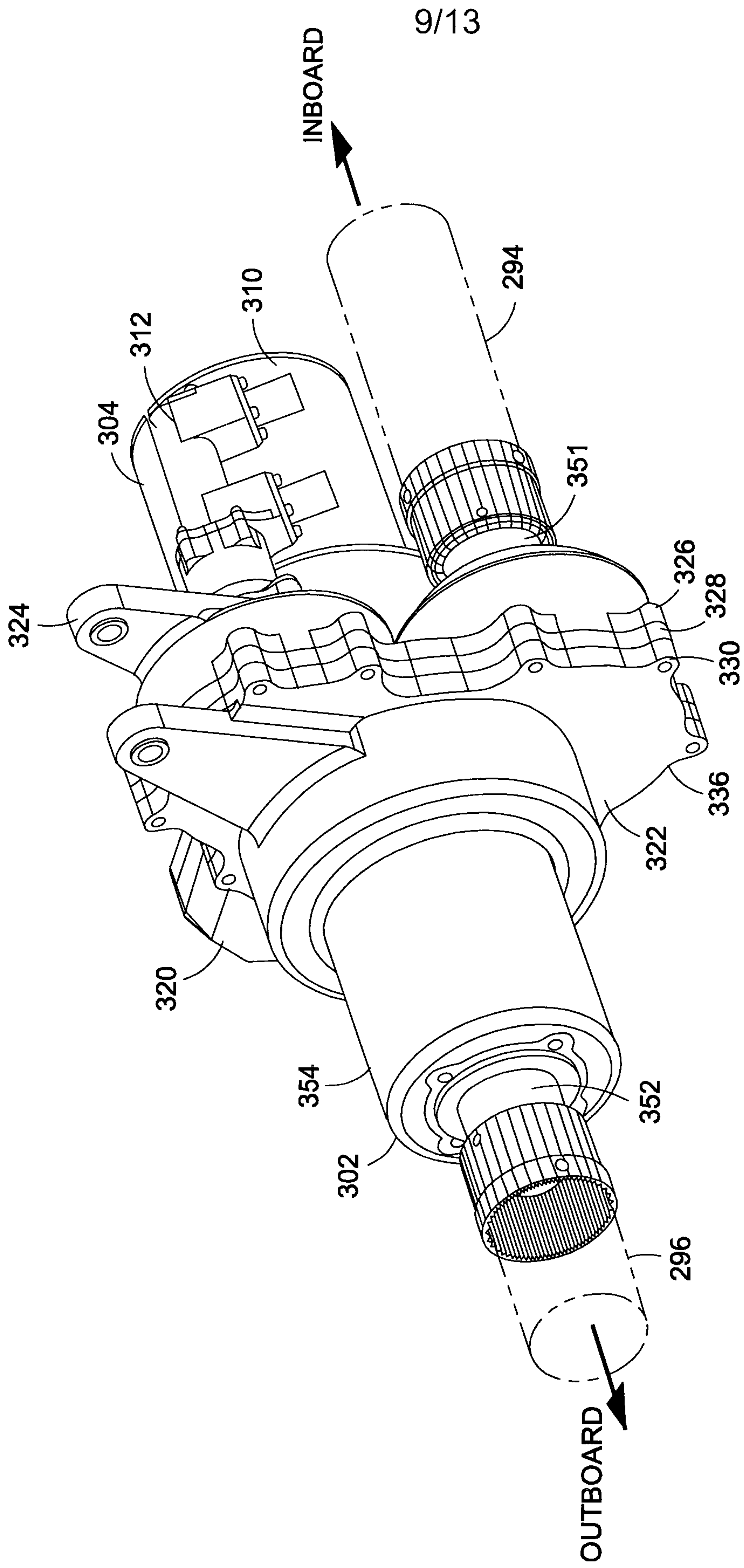


FIG. 13

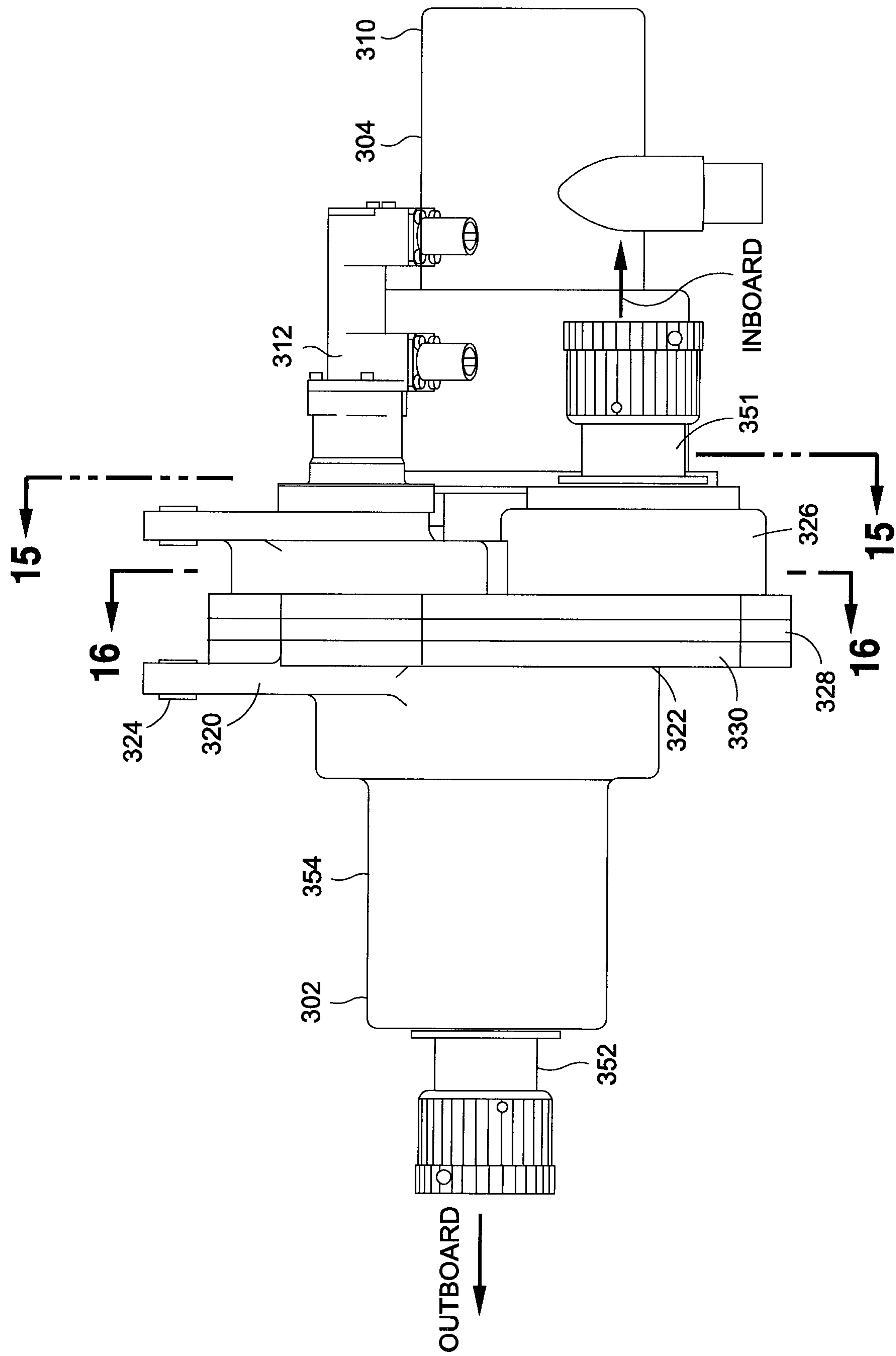


FIG. 14

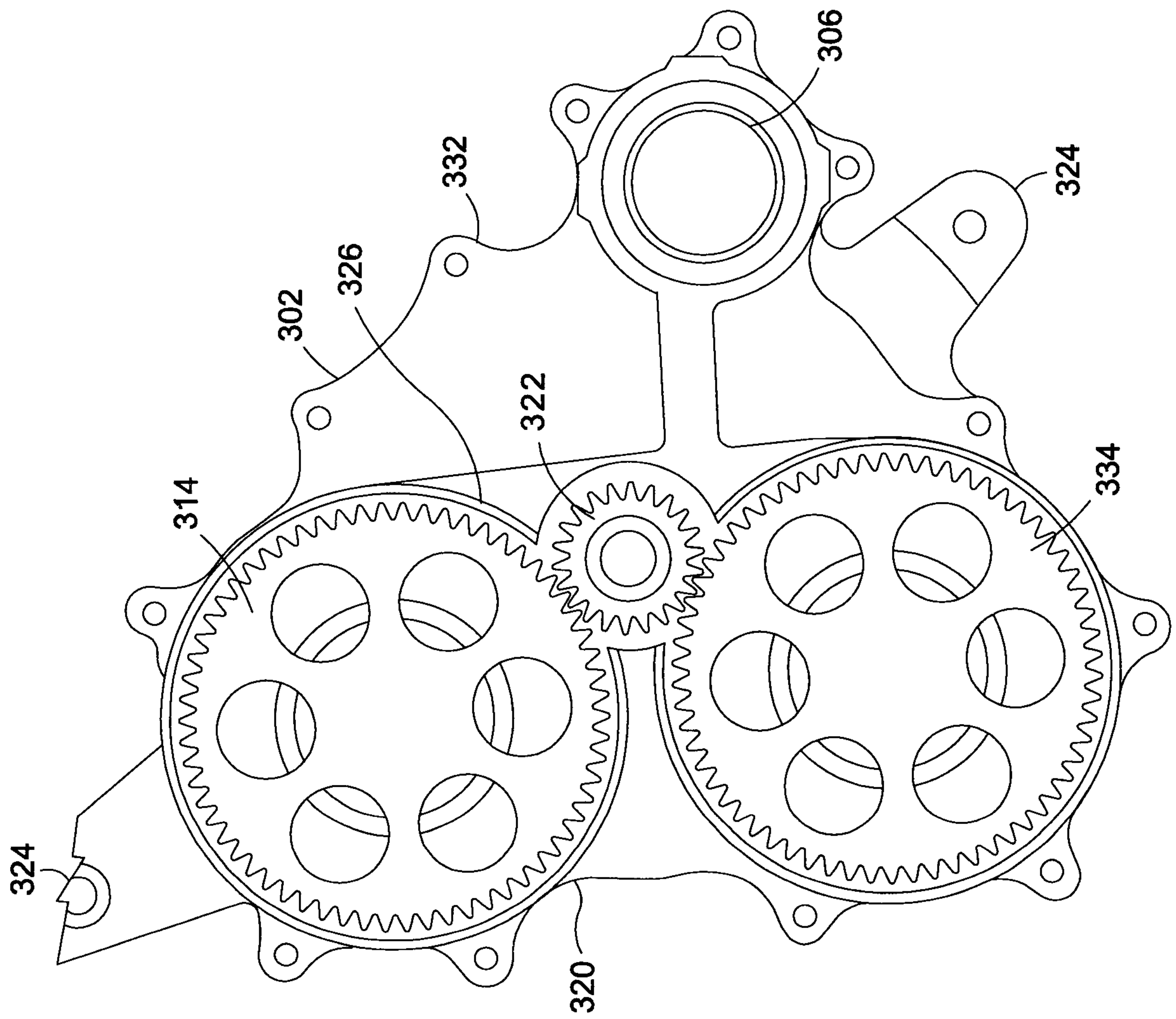


FIG. 15

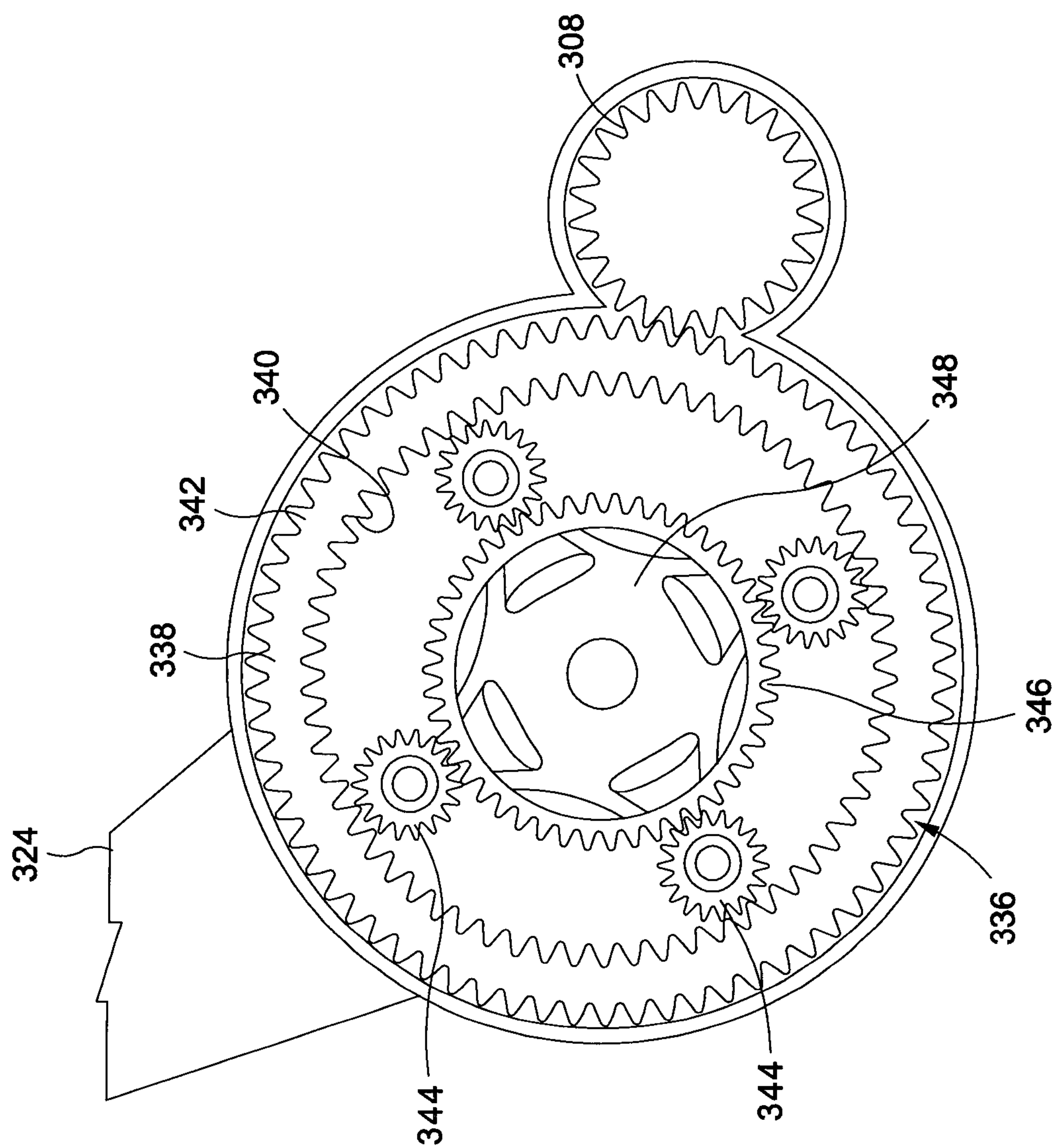


FIG. 16

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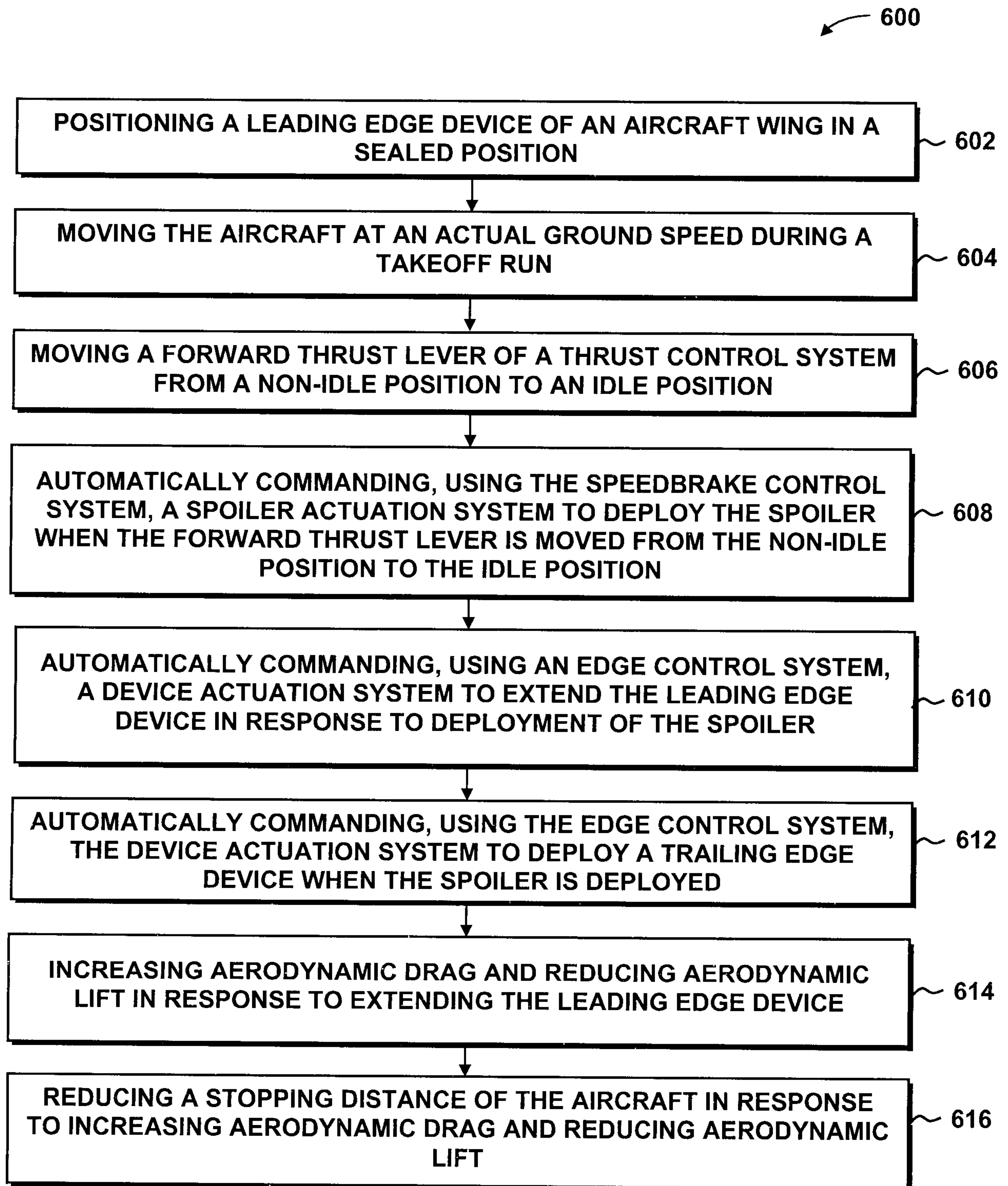


FIG. 17

