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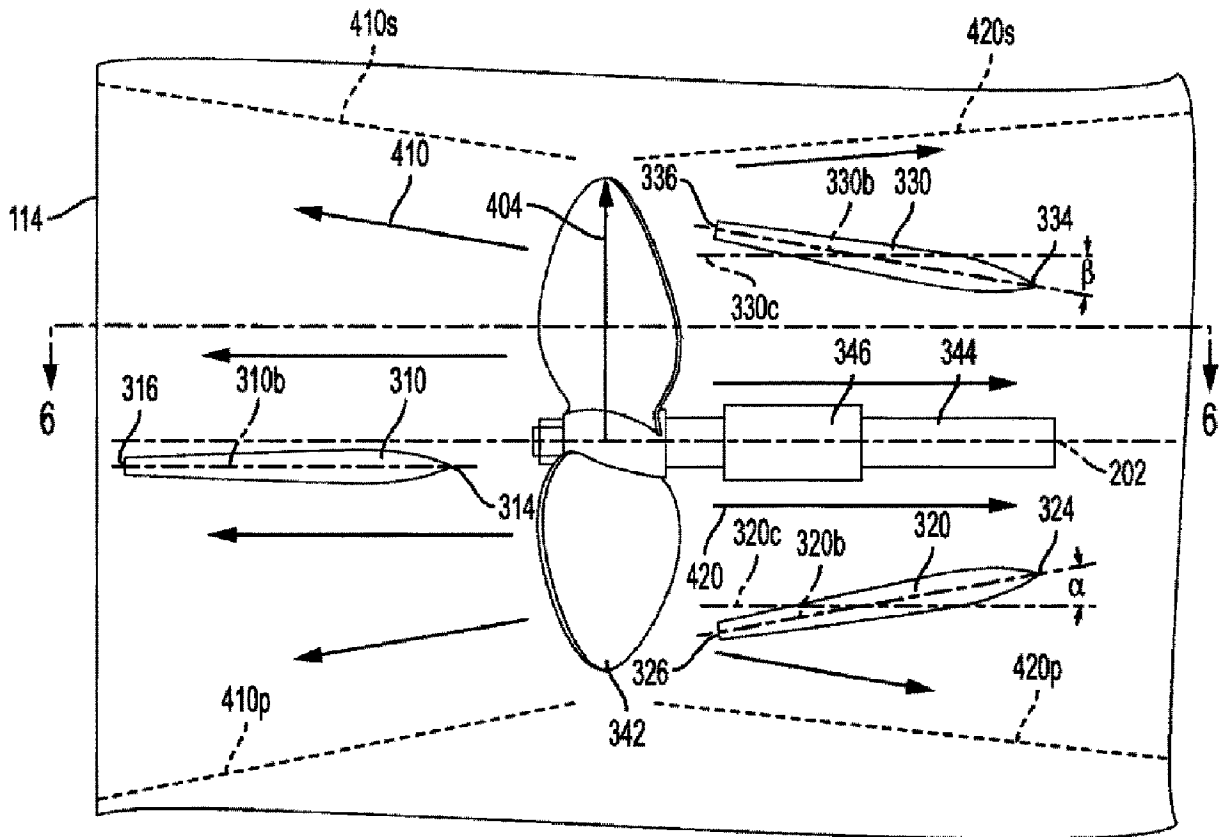
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(54) **Titre : MECANISME DE DIRECTION DESTINE A UN BATEAU A COQUE A FAIBLE DEJAUGEAGE**

(54) **Title: STEERING MECHANISM FOR A BOAT HAVING A PLANING HULL**



(57) **Abrégé/Abstract:**

A boat includes a planing hull, a propeller, a main rudder, and a pair of flanking rudders. The planing hull has port and starboard sides, a transom, a hull bottom, and a centerline running down the middle of the boat, halfway between the port and starboard

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

sides. The propeller is positioned forward of the transom and beneath the hull bottom. The main rudder is positioned aft of the propeller. The main rudder has a rotation axis about which the main rudder rotates. The flanking rudders are positioned forward of the propeller. One of the flanking rudders is positioned on the port side of the centerline, and the other flanking rudder is positioned on the starboard side of the centerline.

Abstract

A boat includes a planing hull, a propeller, a main rudder, and a pair of flanking rudders. The planing hull has port and starboard sides, a transom, a hull bottom, and a centerline running down the middle of the boat, halfway between the port and starboard sides. The propeller is positioned forward of the transom and beneath the hull bottom. The main rudder is positioned aft of the propeller. The main rudder has a rotation axis about which the main rudder rotates. The flanking rudders are positioned forward of the propeller. One of the flanking rudders is positioned on the port side of the centerline, and the other flanking rudder is positioned on the starboard side of the centerline.

STEERING MECHANISM FOR A BOAT HAVING A PLANING HULL

Cross Reference to Related Application

[0001] Intentionally blank.

Field of the Invention

[0002] This invention relates to a steering mechanism for a boat having a planing hull.

Background of the Invention

[0003] Water sports, such as water skiing and wakeboarding, are typically performed at high speeds, and many recreational sport boats used for these sports have planing hulls, which are designed for efficient high-speed operation. In addition, many of these recreational sport boats are also inboards, having a propeller positioned beneath the hull, forward of the transom. This configuration is generally safer for water sports, as compared to outboards or sterndrives, for example, where the propeller extends behind the transom of the boat. But inboards, which typically have a single rudder positioned behind a stationary propeller, may be more difficult to handle, particularly in reverse, than an outboard where the propeller turns along with the motor when the boat turns. In reverse, inboards have a tendency to pull in one direction even if the rudder is turned hard over to turn the boat the other way. There is thus desired a planing hull boat with an inboard motor having improved handling characteristics.

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Summary of the Invention

[0004] In one aspect, the invention relates to a boat including a planing hull, a propeller, a main rudder, and a pair of flanking rudders. The planing hull has port and starboard sides, a transom, a hull bottom, and a centerline running down the middle of the boat, halfway between the port and starboard sides. The propeller is positioned forward of the transom and beneath the hull bottom. The main rudder is positioned aft of the propeller. The main rudder has a rotation axis about which the main rudder rotates. The flanking rudders are positioned forward of the propeller. One of the flanking rudders is positioned on the port side of the centerline, and the other flanking rudder is positioned on the starboard side of the centerline. Each flanking rudder has a rotation axis about which that flanking rudder rotates.

[0005] In another aspect, the invention relates to a boat including a planing hull, a propeller, a main rudder, and a pair of flanking rudders. The planing hull has port and starboard sides, a transom, a hull bottom, and a centerline running down the middle of the boat, halfway between the port and starboard sides. The propeller is positioned forward of the transom and beneath the hull bottom. The main rudder is positioned aft of the propeller. The main rudder has a rotation axis about which the main rudder rotates. The flanking rudders are positioned forward of the propeller. One of the flanking rudders is positioned on the port side of the centerline, and the other flanking rudder is positioned on the starboard side of the centerline. Each flanking rudder has an aft edge and a rotation axis about which that flanking rudder rotates. When the aft edge of each flanking rudder is rotated to port, the starboard flanking rudder is configured to rotate at a rotation rate that is different than a rotation rate at which the port flanking rudder is configured to rotate. When the aft edge of each flanking rudder is rotated to starboard, the port flanking rudder

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is configured to rotate at a rotation rate that is different than a rotation rate at which the starboard flanking rudder is configured to rotate.

[0006] In a further aspect, the invention relates to a boat including a planing hull, a propeller, a main rudder, a pair of flanking rudders, at least one actuator and a controller. The planing hull has port and starboard sides, a transom, a hull bottom, and a centerline running down the middle of the boat, halfway between the port and starboard sides. The propeller is positioned forward of the transom and beneath the hull bottom. The main rudder is positioned aft of the propeller. The main rudder has a rotation axis about which the main rudder rotates. The flanking rudders are positioned forward of the propeller. One of the flanking rudders is positioned on the port side of the centerline, and the other flanking rudder is positioned on the starboard side of the centerline. Each of the flanking rudders has (i) a rotation axis about which that flanking rudder rotates, (ii) a neutral position, and (iii) a forward edge that has an angle of toe in the neutral position. The at least one actuator is configured to rotate each flanking rudder about its rotation axis and change the angle of toe. The controller is configured to actuate the at least one actuator and change the angle of toe.

[0007] In still another aspect, the invention relates to a boat including a planing hull, a propeller, a main rudder, and a flanking rudder. The planing hull has port and starboard sides, a transom, a hull bottom, and a centerline running down the middle of the boat, halfway between the port and starboard sides. The propeller is positioned forward of the transom and beneath the hull bottom. The main rudder is positioned aft of the propeller. The flanking rudder is positioned forward of the propeller and offset from the centerline.

[0008] These and other aspects of the invention will become apparent from the following disclosure.

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Brief Description of the Drawings

- [0009] Figure 1 shows a boat according to a preferred embodiment of the invention.
- [0010] Figure 2 is a bottom view of the boat shown in Figure 1.
- [0011] Figure 3 is a detailed perspective view of a rudder assembly and section of a hull for the boat shown in Figures 1 and 2.
- [0012] Figure 4 is a bottom view of the rudder assembly and section of the hull shown in Figure 3.
- [0013] Figure 5 is a bottom view of an alternate configuration of the rudder assembly and section of the hull shown in Figure 3.
- [0014] Figure 6 is a cross-sectional view of the boat of Figures 1 and 2 taken along section line 6-6 in Figure 4.
- [0015] Figure 7A is a cross-sectional view of the flanking rudders taken along line 7-7 in Figure 5. Figure 7B is a cross-sectional view of an alternate configuration of the flanking rudders taken along line 7-7 in Figure 5.
- [0016] Figure 8A is a top view of a rudder assembly according to a preferred embodiment of the invention. Figure 8B is a top view of the rudder assembly shown in Figure 8A with an alternate steering system.
- [0017] Figure 9 is the top view of the rudder assembly shown in Figure 8A in a position for a turn to port when the boat is moving forward.
- [0018] Figure 10 is the top view of the rudder assembly shown in Figure 8A in a position for a turn to starboard when the boat is moving forward.
- [0019] Figure 11 is a top view of a rudder assembly according to another preferred embodiment of the invention.

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[0020] Figure 12 is a top view of a rudder assembly according to another preferred embodiment of the invention.

[0021] Figure 13 is a detailed perspective view of a rudder assembly according to another preferred embodiment of the invention.

[0022] Figure 14 is a bottom view of the rudder assembly and section of the hull shown in Figure 13.

[0023] Figure 15 is a top view of the rudder assembly shown in Figure 13.

[0024] Figure 16 is a detailed perspective view of a rudder assembly according to a further preferred embodiment of the invention.

[0025] Figure 17 is a bottom view of the rudder assembly and section of the hull shown in Figure 16.

[0026] Figure 18 is a top view of the rudder assembly shown in Figure 16.

Detailed Description of the Preferred Embodiments

[0027] Figures 1 and 2 show a boat 100 in accordance with an exemplary preferred embodiment of the invention. The boat 100 includes a hull 110 with a bow 112, a transom 114, a port side 116, and a starboard side 118. Figure 1 is a perspective view of the boat 100 from above, and Figure 2 is a perspective view of the boat 100 from below showing a bottom 210 of the hull 110. The boat 100 has a centerline 202 running down the middle of the boat 100, halfway between the port and starboard sides 116, 118.

[0028] The hull 110 is a planing hull. When planing hull boats reach a certain speed, the resistance of the hull dramatically drops as the boat is supported by hydrodynamic forces instead of hydrostatic (buoyant) forces. This is referred to as planing. To achieve planing, the boat must

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overcome the drag produced by the hull and any appendages, such as the propeller and rudders. Appendages increase the drag of the hull. In general, the more appendages there are, the greater the drag. Some characteristics of the hull 110 that are typical of planing hull boats include lifting strakes 212, a chine 214 that is a hard chine, and a deadrise from 0° to 30°.

[0029] The boat 100 shown in Figures 1 and 2 is driven through the water by a single inboard motor and turned by a rudder assembly 300. Figure 3 is a detailed perspective view of the rudder assembly 300. Figure 4 is a bottom view of the section of the hull 110 shown in Figure 3.

Figure 5 is a bottom view of the section of the hull 110 shown in Figure 3, showing an alternate configuration of the rudder assembly 300. Figure 6 is a cross-sectional view of the boat 100 taken along section line 5-5 in Figure 4.

[0030] The inboard motor includes an engine 610 (see Figure 6) connected to a propeller 342 by a drive shaft 344. A strut 346 extends from the hull bottom 210 to support the drive shaft 344 and thus the propeller 342. The drive shaft 344 extends through a bushing in the strut 346. The propeller 342 is positioned beneath the hull bottom 210 and forward of the transom 114. In this embodiment, the drive shaft 344, when viewed from below the boat 100 (e.g., Figure 4) or above the boat 100, is aligned with the centerline 202 of the boat 100.

[0031] Also in this embodiment, the propeller 342 is a left-handed propeller, but any suitable propeller, including a right-handed propeller, may be used. The propeller 342 has a propeller radius 404 and a corresponding propeller diameter. Suitable propellers include propellers with a diameter from 12 inches to 18 inches. The propeller 342 accelerates a stream of water both in the forward and reverse directions, depending on its direction of rotation. As the propeller 342 rotates in the counterclockwise direction when viewed from the stern, the boat 100 moves forward, and the propeller 342 generates a forward race 410, which is an accelerated a stream of

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water. The forward race 410 has outer edges, shown generally between line 410p and line 410s in Figure 4 when viewed from above or below the boat 100. Likewise, when the propeller 342 rotates in the clockwise direction, the boat 100 moves in reverse, and the propeller 342 generates a reverse race 420. The reverse race 420 has outer edges, shown generally between line 420p and line 420s in Figure 4 when viewed from above or below the boat 100.

[0032] In this embodiment, the engine 610 and the propeller 342 may be operated by a user at a control console 120 (see Figure 1). The control console 120 may include a control lever 122 (see Figure 1) to operate a throttle 612 of the engine 610 and engage the engine 610 with the drive shaft 344. The control lever 122 has a neutral position, and the user may move the control lever 122 forward from the neutral position to engage a running gear 602 with the drive shaft 344, accelerate the engine 610 using the throttle 612, and rotate the propeller 342 counterclockwise to drive the boat 100 forward. To move the boat 100 in reverse, the user may move the control lever 122 back from the neutral position to engage a reverse gear 604 with the drive shaft 344, accelerate the engine 610 using the throttle 612, and rotate the propeller 342 clockwise. Any suitable means known in the art may be used to operate the engine 610 and engage it with the drive shaft 344.

[0033] The rudder assembly 300 includes three rudders: a main rudder 310 and a pair of flanking rudders 320, 330. The main rudder 310 includes a main rudder post 312 (better seen in Figure 8A) that extends through the hull bottom 210 and is used to rotate the main rudder 310. The main rudder 310 rotates about a rotation axis 310a, which extends through the center of the main rudder post 312. The main rudder 310 has a forward edge 314 and an aft edge 316.

[0034] The main rudder 310 is positioned behind (aft) of the propeller 342 and preferably is positioned laterally within the outer edges 410p, 410s of the forward race 410. The main rudder

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post 312 may be positioned on the centerline 202 of the boat 100, when viewed from above (see Figure 4), but in some instances, it may be preferable to offset the main rudder post 312 to one side of the centerline of the boat 100 (see Figure 5). The main rudder post 312 is preferably offset far enough to facilitate removal of the drive shaft 344 without removing the main rudder 310. In some instances, the main rudder post 312 may be offset from the centerline 202 by up to the diameter of the drive shaft 344. For example, if the drive shaft 334 has a diameter of 1.125 inches, the main rudder post 312 may be offset from the centerline 202 by 1.125 inches, but it may also be offset by a value less than 1.125 inches, such as from 0.75 inch to 0.875 inch.

Preferably, the main rudder post 312 is positioned forward of the transom, but other suitable locations, including on the transom, are contemplated to be within the scope of the invention.

[0035] The neutral position of a rudder 310, 320, 330 is its position when the boat 100 is moving straight and not turning. In this embodiment, when the main rudder 310 is in its neutral position, the chord 310b of the main rudder 310 is parallel to the centerline 202 of the boat 100 when viewed from above or below the boat 100. In embodiments where the main rudder post 312 is positioned on the centerline 202 of the boat 100, the chord 310b is preferably aligned with the centerline 202.

[0036] The flanking rudders 320, 330 are positioned forward of the propeller 342. One of the flanking rudders 320 is positioned on the port side of the centerline 202 of the boat 100, and the other flanking rudder 330 is positioned on the starboard side of the centerline 202 of the boat 100. Each flanking rudder 320, 330 includes a flanking rudder post 322, 332 (better seen in Figures 7A and 7B) that extends through the hull bottom 210 and is used to rotate the respective flanking rudder 320, 330. Each flanking rudder 320, 330 rotates about a rotation axis 320a,

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330a, which extends through the center of the corresponding flanking rudder post 322, 332.

Each flanking rudder 320, 330 includes a forward edge 324, 334 and an aft edge 326, 336.

[0037] Preferably, the flanking rudders 320, 330 are positioned to intersect the reverse race 420 when rotated from their neutral positions. More preferably, the flanking rudder posts 322, 332 are laterally positioned within the outer edges 420p, 420s of the reverse race 420, and even more preferably, within the radius 404 of the propeller 342. Preferably, both flanking rudders 320, 330 are symmetrical to each other. The posts 322, 332 of each flanking rudder 320, 330 are thus preferably located the same distance from the centerline 202 of the boat 100 and preferably positioned the same distance forward of the propeller 342. The flanking rudders 320, 330 are also preferably located close to the propeller 342 because the speed of the water and the lifting force of the reverse race dissipates the farther forward from the propeller 342 the flanking rudders 320, 330 are positioned. The flanking rudders 320, 330 are preferably positioned a distance forward of the propeller 342 that is equal to or less than three times the diameter of the propeller 342, more preferably a distance equal to or less than two times the diameter of the propeller 342, and even more preferably a distance equal to or less than the diameter of the propeller 342.

[0038] The neutral position of the flanking rudders 320, 330 is preferably set to balance the rudder load and drag to create a neutral feel in steering at all speeds. For some boats 100, the chord 320b, 330b of each flanking rudder 320, 330 is parallel to the centerline 202 in the neutral position. In other boats 100, the inventors have surprisingly found that the neutral position of the flanking rudders 320, 330 should be either toed-in or toed-out, relative to the forward direction of the boat 100. In a toed-in configuration (shown in Figure 4) the forward edge 324, 334 of each flanking rudder 320, 330 is angled inboard with an angle of toe α , β measured from a line

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320c, 330c that intersects the rotation axis 320a, 330a and is parallel to the centerline 202 of the boat 100, instead of being parallel to the centerline 202 of the boat 100. In a toed-out configuration (shown in Figure 5) the forward edge 324, 334 of each flanking rudder 320, 330 is angled outboard with the angle of toe α , β . In this embodiment, the chord 320b, 330b of each flanking rudder 320, 330 is toed-in or out at the same angle of toe α , β from line 320c, 330c.

[0039] The inventors have found that the angles of toe α , β are preferably greater than 0° and less than 10° , and more preferably greater than 0° and less than 5° . As discussed above, the flanking rudders 320, 330 are preferably symmetrical about the centerline 202 and thus the angle of toe α of the port flanking rudder 320 is preferably the same as the angle of toe β of the starboard flanking rudder 330. One way of finding the neutral position for each flanking rudder 320, 330 is to disconnect the flanking rudders 320, 330 from their respective turning mechanisms and allow the flanking rudders 320, 330 to align naturally with the flow of water when the boat 100 is operated forward through the water at speed, for example from 5 mph to 50 mph.

[0040] Figure 7A is a cross-section taken along line 7-7 in Figure 5 (the drive shaft 344, engine 610 and associated components, and first linkage 830 (discussed further below) have been omitted from this view for clarity). Note, Figure 7A is applicable to any of the angles of toe α , β discussed herein (e.g., Figure 4). In the preferred embodiment, shown in Figure 7A the flanking rudders 320, 330 and corresponding flanking rudder posts 322, 332 are oriented vertically. To assist in achieving this orientation, a structural supports 702, 704 are positioned along the hull bottom 210. These structural supports 702, 704 have the shape of a wedge to assist in orienting the flanking rudders 320, 330 vertically. Although shown as pieces separate from the hull bottom 210, those skilled in the art will recognize that the structural supports 702, 704 may be formed integrally with the hull bottom. Alternatively, the flanking rudders 320, 330 and

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corresponding flanking rudder posts 322, 332 may be oriented perpendicular to the hull bottom 210 (i.e., orientated perpendicular to the dead rise), as shown in Figure 7B. In the alternative orientation shown in Figure 7B, the linkages (e.g., 850) and/or tiller arms (e.g., 842, 844, 862), discussed further below with reference to Figures 8, 9, and 10, may include features such as joints 710 to account for the angled flanking rudder posts 322, 332. A suitable joint 710 may include, for example, heim joints.

[0041] In the preferred embodiment, all three rudders 310, 320, 330 are rotated in concert and about their respective rotation axes 310a, 320a, 330a to maneuver the boat 100. The rudder assembly 300 may be operated as follows to turn the boat 100 as it moves forward. To turn to port, the forward edge 314, 324, 334 of each rudder 310, 320, 330 is rotated to starboard from the neutral position, and correspondingly, the aft edge 316, 326, 336 of each rudder 310, 320, 330 is rotated to port from the neutral position. When the flanking rudders 320, 330 are toed-in, the starboard flanking rudder 330 is preferably rotated through line 330c to generate a force that assists in turning the boat 100 and not one that resists, and when the flanking rudders 320, 330 are toed-out, the port flanking rudder 320 is preferably rotated through line 320c. Conversely, to turn to starboard, the forward edge 314, 324, 334 of each rudder 310, 320, 330 is rotated to port from the neutral position, and correspondingly, the aft edge 316, 326, 336 of each rudder 310, 320, 330 is rotated to starboard from the neutral position. When the flanking rudders 320, 330 are toed-in, the port flanking rudder 320 is preferably rotated through line 320c to likewise generate a force to assist in turning the boat 100 and not one that resists, and when the flanking rudders 320, 330 are toed-out the starboard flanking rudder 330 is preferably rotated through line 330c. Figure 9 is a top view of the rudder assembly 300 turned hard over to port, and Figure 10 is a top view of the rudder assembly 300 turned hard over to starboard. The inventors have

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found that a boat having the two flanking rudders 320, 330 in addition to the main rudder 310 has a smaller minimum turning radius than a boat having only a main rudder.

[0042] When the boat 100 is moving in reverse, the rudders 310, 320, 330 are rotated in a manner similar to the way the rudders 310, 320, 330 are rotated when the boat 100 is moving forward. To turn to port, the aft edge 316, 326, 336 of each rudder 310, 320, 330 is rotated to port from the neutral position, and correspondingly, the forward edge 314, 324, 334 of each rudder 310, 320, 330 is rotated to starboard from the neutral position. Conversely, to turn to starboard, the aft edge 316, 326, 336 of each rudder 310, 320, 330 is rotated to starboard from the neutral position, and correspondingly, the forward edge 314, 324, 334 of each rudder 310, 320, 330 is rotated to port from the neutral position. As in the forward direction when the flanking rudders 320, 330 are toed-in, the starboard flanking rudder 330 is preferably rotated through line 330c when turning to port and the port flanking rudder 320 is preferably rotated through line 320c when turning to starboard. Likewise, when the flanking rudders 320, 330 are toed-out, the port flanking rudder 320 is preferably rotated through line 330c when turning to port and the starboard flanking rudder 330 is preferably rotated through line 323c when turning to starboard.

[0043] Rudders work best when there is high-velocity flow over the surfaces of the rudder. As a result, a boat having only a main rudder 310 positioned aft of the propeller 342 may not generate enough lift in reverse to overcome lateral forces generated by the propeller 342 rotation because the main rudder 310 is outside of the reverse race 420 and the boat is typically operating at low speed. Thus, the rear of the boat may pull to starboard, even if the main rudder 310, in a main rudder-only configuration, is rotated hard over to turn the boat to port. The inventors have

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found that using the flanking rudders 320, 330 may counteract this adverse effect, especially if the flanking rudders 320, 330 are positioned as discussed above.

[0044] Each of the rudders 310, 320, 330 may have a rotation angle γ , δ , ϵ . In this embodiment, the rotation angle γ of the main rudder 310 may be measured from the neutral position of the main rudder 310. Thus the rotation angle γ of the main rudder 310 is relative to the centerline 202 of the boat 100 when the main rudder post 312 is aligned with the centerline 202 of the boat 100 as shown in Figure 5. Also in this embodiment, the rotation angle δ of the port flanking rudder 320 may be measured from line 320c, and the rotation angle ϵ of the starboard flanking rudder 330 may be measured from line 330c.

[0045] During a turn, the rotation angles γ , δ , ϵ may be the same, but in some instances, it may be advantageous for each rudder 310, 320, 330 to be rotated to different angles. The inventors have also found that it may be beneficial for the rotation angles δ , ϵ of the flanking rudders 320, 330 to be greater than the rotation angle γ of the main rudder 310 during a turn. Although it may also be beneficial in other situations for the rotation angle γ of the main rudder 310 to be greater than the rotation angles δ , ϵ of the flanking rudders 320, 330. In addition, it may also be beneficial for the rotation angles δ , ϵ of the flanking rudders 320, 330 to be different. In particular, it may be beneficial for the rotation angle δ , ϵ of the flanking rudder 320, 330 on the outside of the turn (for example, rotation angle ϵ of the starboard flanking rudder 330 during a turn to port) to be less than the rotation angle δ , ϵ of the flanking rudder 320, 330 on the inside of the turn (for example, rotation angle δ of the port flanking rudder 320 during a turn to port). Although, again, in other instances it may be beneficial for the rotation angle δ , ϵ of the flanking rudder 320, 330 on the inside of the turn to be less than or equal to the rotation angle δ , ϵ of the flanking rudder 320, 330 on the inside of the turn.

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[0046] In this embodiment, the flanking rudders 320, 330 are linked to the main rudder 310 such that they all rotate together. Figure 8A is a top view of the rudder assembly 300 showing the main rudder 310, flanking rudders 320, 330, and the linkages between them (the engine 610 and associated drive components (e.g., propeller 342 and drive shaft 344) and hull bottom 210 are omitted for clarity). Hydraulic steering is used in this embodiment, although any suitable steering mechanism may be used, including rack-and-pinion cable steering or electric steering for example. The rudders 310, 320, 330 may be turned using a steering wheel 124 located at the control console 120 (see Figure 1). A user may turn the boat 100 by rotating the steering wheel 124, which in turn, rotates a steering column 812. A hydraulic pump 814 is located is located on the steering column 812 and pumps hydraulic fluid into or out of a hydraulic cylinder 816 to extend or retract the ram 818 of the hydraulic cylinder 816.

[0047] The hydraulic cylinder 816 is connected to a first tiller arm 822 of the main rudder 310. In the configuration shown in Figure 8A, the first tiller arm 822 is connected to the main rudder post 312 at a 90° angle to the chord 310b of the main rudder 310. With the main rudder 310 in its neutral position, extending the ram 818 pushes the first tiller arm 822 aft, rotates the post 312, and turns the aft edge 316 of the main rudder 310 to port, as shown in Figure 9. Conversely, retracting the ram 818 with the main rudder 310 in its the neutral position pulls the first tiller arm 822 forward, rotates the post 312, and turns the aft edge 316 of the main rudder 310 to starboard, as shown in Figure 10.

[0048] A first linkage 830 is used to couple the flanking rudders 320, 330 to the main rudder 310. In the configuration shown in Figure 8A, a single first linkage 830 is used to connect the port flanking rudder 320 to the main rudder 310. Skilled artisans will recognize, based on the following disclosure, how the first linkage 830 could be used to connect the main rudder 310

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with the starboard flanking rudder 330, instead of the port flanking rudder 320. The first linkage 830 is located on the opposite side of the main rudder 310 from the hydraulic cylinder 816 and connected to a second tiller arm 824 of the main rudder 310 at a connection point 832. The second tiller arm 824 is connected to the post 312 at a 90° angle to the chord 310b. Although referenced as separate tiller arms, skilled artisans will recognize that the first and second tiller arms 822, 824 of the main rudder 310 may also be a single tiller arm. For example, the tiller arm for the main rudder 310 may be a single cast piece having a keyway used to connect to the main rudder shaft 312 and first and second portions, corresponding to the first and second tiller arms 822, 824, respectively. In this embodiment, the first linkage 830 is a rod with adjustable length that can transmit force to turn the port flanking rudder 320 either by pushing or pulling, although any suitable linkage may be used.

[0049] The port flanking rudder 320 has a first tiller arm 842 that is connected to the post 322 and extends outboard from the post 322. The first linkage 830 is connected the first tiller arm 842 of the port flanking rudder 320 at a connection point 834. Each connection point 832, 834 of the first linkage 830 is located on the same side relative to the rudder post 312, 322 to which it corresponds. In this embodiment, both connection points 832, 834 are located on the port side of their corresponding rudder posts 312, 322. When the main rudder 310 is turned to port, the second tiller arm 824 of the main rudder 310 moves forward, pushing the first linkage 830 forward. When the first linkage 830 moves forward, it pushes the first tiller arm 842 of the port flanking rudder 320 forward and rotates the aft edge 326 of the port flanking rudder 320 to port. Conversely, when the first linkage 830 moves aft, it pulls the first tiller arm 842 of the port flanking rudder 320 aft and rotates the aft edge 326 of the port flanking rudder 320 to starboard.

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[0050] A second linkage 850 is used to couple the flanking rudders 320, 330 to each other. In the configuration shown in Figure 8A, a single second linkage 850 is used to connect the starboard flanking rudder 330 to the port flanking rudder 320. The port flanking rudder 320 has a second tiller arm 844 that is connected to the post 322 and extends forward from the post 322. The second linkage 850 is connected the second tiller arm 844 of the port flanking rudder 320 at a connection point 852. Although referenced as separate tiller arms, skilled artisans will recognize that the first and second tiller arms 842, 844 of the port flanking rudder 320 may also be a single tiller arm. For example, the tiller arm for the port flanking rudder 320 may be a single cast piece having a keyway used to connect to the main rudder shaft 312 and first and second portions, corresponding to the first and second tiller arms 842, 844, respectively.

[0051] The starboard flanking rudder 330 has a tiller arm 862 that is connected to the post 332 and also extends forward from the post 332. The second linkage 850 is connected the tiller arm 862 of the starboard flanking rudder 330 at a connection point 854. Each connection point 852, 854 of the second linkage 850 is located on the same side relative to the rudder post 322, 332 to which it corresponds. In this embodiment, both connection points 852, 854 are located forward of their corresponding rudder post 322, 332. As with the first linkage 830, the second linkage 850 of this embodiment is a rod with adjustable length that can transmit force to turn the starboard flanking rudder 330 either by pushing or pulling, although any suitable linkage may be used.

[0052] As the aft edge 326 of the port flanking rudder 320 rotates to port (i.e., when the first linkage 830 moves forward), the second tiller arm 844 rotates to starboard pushing the second linkage 850 to starboard. As the second linkage 850 moves to starboard, it pushes the tiller arm 862 of the starboard flanking rudder 330 to starboard and rotates the aft edge 336 of the

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starboard flanking rudder 330 to port. Conversely, as the aft edge 326 of the port flanking rudder 320 rotates to starboard (i.e., when the first linkage 830 moves aft), the second tiller arm 844 rotates to port pulling the second linkage 850 to port. As the second linkage 850 moves to port, it pulls the tiller arm 862 of the starboard flanking rudder 330 to port and rotates the aft edge 336 of the starboard flanking rudder 330 to starboard.

[0053] As discussed above, the flanking rudders 320, 330 may be rotated to a different rotation angle δ , ϵ than the main rudder 310 during a turn. The different rotation angles may be achieved by having a different relative rate of rotation between a drive rudder and a rudder being driven. For example, in the configuration shown in Figure 8A, the main rudder 310 is the drive rudder, and the port flanking rudder 320 is the rudder being driven (driven rudder) by the main rudder 310. Each connection point 832, 834, 852, 854 is located on a tiller arm 824, 842, 844, 862, which in turn is associated with the rotation axis 310a, 320a, 330a for each rudder 310, 320, 330. If the distance between the connection point and corresponding rotation axis for the driven rudder is less than the distance between the connection point and corresponding rotation axis for the drive rudder, the driven rudder will rotate faster than the drive rudder. In the configuration shown in Figure 8A, for example, the connection point 834 of the first linkage 830 on the first tiller arm 842 of the port flanking rudder 320 is closer to its corresponding rotation axis 320a than the connection point 832 of the first linkage 830 on the second tiller arm 824 of the main rudder 310 is to its corresponding rotation axis 310a. Thus, in this configuration, the rate of rotation for the port flanking rudder 320 is faster than the rate of rotation for the main rudder 310. Conversely, the driven rudder will rotate slower than the drive rudder if the distance between the connection point and corresponding rotation axis for the driven rudder is greater

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than the distance between the connection point and corresponding rotation axis for the drive rudder.

[0054] Angling the two tiller arms, which are connected by a linkage 830, 850, relative to each other also adjusts the relative rotation rates between the two rudders. Each connection point 832, 834, 852, 854 may be associated with a vector that originates at the corresponding rotation axis 310a, 320a, 330a and is perpendicular to that rotation axis 310a, 320a, 330a when the rudder 310, 320, 330 is in its neutral position. In the embodiment shown in Figure 8A, a first vector 826 originates at the rotation axis 310a for the main rudder 310 and extends to the connection point 832 on the second tiller arm 824 of the main rudder 310. A second vector 846 originates at the rotation axis 320a for the port flanking rudder 320 and extends to the connection point 834 on the first tiller arm 842 of the port flanking rudder 320. A third vector 848 also originates at the rotation axis 320a for the port flanking rudder 320 but extends to the connection point 852 on the second tiller arm 844 of the port flanking rudder 320. Likewise, a fourth vector 864 originates at the rotation axis 330a for the starboard flanking rudder 330 and extends to the connection point 854 on the tiller arm 862 of the starboard flanking rudder 330.

[0055] In an embodiment where the tiller arms 824, 842, 844, 862 are straight, such as Figure 8A, the tiller arms 824, 842, 844, 862 can be said to have the direction of the respective vectors 826, 846, 848, 864. For example, two linked tiller arms may be considered to point toward each other if the vectors corresponding to these tiller arms intersect when viewed from above. In Figure 8A, the second tiller arm 824 of the main rudder 310 and the first tiller arm 842 of the port flanking rudder 320 are pointed toward each other. Conversely, two linked tiller arms may be considered to point away from each other if the vectors corresponding to these tiller arms diverge when viewed from above. In Figure 8A, the second tiller arm 844 of port flanking

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rudder 320 and the tiller arm 862 of the starboard flanking rudder 330 are pointed away from each other.

[0056] When two linked tiller arms, such as the second tiller arm 824 of the main rudder 310 and the first tiller arm 842 of the port flanking rudder 320 shown in Figure 8A, are angled toward each other, the driven rudder (port flanking rudder 320 in Figure 8A) rotates slower than the drive rudder (main rudder 310 in Figure 8A) if the drive rudder is rotated in a clockwise direction as viewed from above, but the driven rudder (port flanking rudder 320 in Figure 8A) rotates faster than the drive rudder (main rudder 310 in Figure 8A) if the drive rudder is rotated in a counterclockwise direction as viewed from above. In the configuration shown in Figure 8A, however, the overall relative rate of rotation of the port flanking rudder 320 is increased relative to the main rudder 310 even when rotating in a counterclockwise direction because, as discussed above, the connection point 834 for the port flanking rudder 320 is closer to its corresponding rotation axis 320a than the connection point 832 for the main rudder 310 is to its corresponding rotation axis 310a, which overcomes the slowing effect of the tiller arms 824,842 being pointed toward each other. The flanking rudders 320, 330 are thus configured to rotate faster than the main rudder 310.

[0057] As also discussed above, it is beneficial for the flanking rudder 320, 330 on the outside of the turn (for example, the starboard flanking rudder 330 during a turn to port) to pass through line 320c or line 330c. In the configuration shown in Figure 8A, this is accomplished by angling the second tiller arm 844 of the port flanking rudder 320 and the tiller arm 862 of the starboard flanking rudder 330 shown in Figure 8A away from each other. When two linked tiller arms are angled away from each other, the driven rudder (starboard flanking rudder 330 in Figure 8A) rotates faster than the drive rudder (port flanking rudder 320 in Figure 8A) if the drive rudder is

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rotated in a clockwise direction as viewed from above, but the driven rudder (starboard flanking rudder 330 in Figure 8A) rotates slower than the drive rudder (port flanking rudder 320 in Figure 8A) if the drive rudder is rotated in a counterclockwise direction as viewed from above.

[0058] In the embodiment shown in Figure 8A, the second tiller arm 844 of the port flanking rudder 320 is offset from line 320c by an offset angle ζ . Likewise, the tiller arm 862 of the starboard flanking rudder 330 is offset from line 330c by an offset angle η . Preferably, the third vector 848 and fourth vector 864 are symmetrical about the centerline 202 of the boat 100 and the offset angles ζ , η are equal. Also, the offset angles are preferably the same as the angles of toe α , β .

[0059] Figure 8B shows an embodiment having an alternate steering control arrangement using rack and pinion cable steering. A user may turn the boat 100 by rotating the steering wheel 124, which in turn, rotates a steering column 812. A rack and pinion assembly 872 is located on the end of the steering column 812. Rotating the steering column 812 turns a pinion gear, which in turn translates a rack. Connected to the end of the rack are two steering cables, a main steering cable 874, and a flanking rudder steering cable 876. As the rack translates to starboard, it pulls the steering cables 874, 876, and moves the first tiller arm 822 of the main rudder 310 (only tiller arm in the configuration shown in Figure 8B) and the first tiller arm 842 of the port flanking rudder 320 to turn the rudders 310, 320, 330, just as extending the ram 818 does in the configuration shown in Figure 8A. Likewise, as the rack translates to port, it pushes the steering cables 874, 876, and moves the first tiller arm 822 of the main rudder 310 and the first tiller arm 842 of the port flanking rudder 320 to turn the rudders 310, 320, 330, just as retracting the ram 818 does in the configuration shown in Figure 8A.

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[0060] In the configuration shown in Figure 8B, the flanking rudders 320, 330 are turned in concert with the main rudder 310 through the use of a common rack, and thus the first linkage 830 is not necessary. As with the first linkage 830 discussed above, the relative rates of rotation between the main rudder 310 and the flanking rudders 320, 330 may be adjusted by the relative distances between the connection point of the steering cable 874, 876 to the tiller arm 822, 842 and corresponding rotation axis 310a, 320a. As shown in Figure 8B for example, the flanking rudders 320, 330 rotate faster than the main rudder 310 because the distance between the rotation axis 320a of the port flanking rudder 320 and the point where the flanking rudder steering cable 376 attaches to the tiller arm 842 is shorter than the distance between the rotation axis 310a of the main rudder 310 and the point where the main rudder steering cable 374 attaches to the tiller arm 822.

[0061] In the configuration shown in Figure 8A, the first and second linkages 830, 840 are manually adjustable rods, and the toed-in or toed-out orientation of the flanking rudders 320, 330 is set during boat construction or a maintenance operation. In other words, the toed-in or toed-out orientation is not readily adjustable, and the orientation of the flanking rudders 320, 330 is generally set to maximize the neutral feel of the flanking rudders 320, 330 over the widest range of operating conditions. There may, however, be some operating conditions where another orientation of the flanking rudders 320, 330 would be beneficial. For example, using toe-out when the boat 100 is in reverse, but toe-in when the boat 100 is moving forward. Instead of using manually adjustable linkages 830, 840, an actuator may be used to change the orientation of the flanking rudders 320, 330 on the fly. Any suitable actuator may be used including, for example, motors or linear actuators, which may be used as remotely adjustable linkages 1110, 1120 as discussed in the preferred embodiment below.

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[0062] As shown in Figure 11, first and second remotely adjustable linkages 1110, 1120 are used instead of the first and second linkages 830, 850 discussed above. The remotely adjustable linkages 1110, 1120 may be electrical linear actuators, although any suitable remotely adjustable linkage may be used including, for example, hydraulic and pneumatic actuators. The first and second remotely adjustable linkages 1110, 1120 are each connected to a power distribution module (“PDM”) 1132, which in turn, is connected to a power source 1134 and a controller 1140. Any suitable power distribution module may be used, and any suitable power source may be used, including, for example, the boat’s onboard battery.

[0063] The controller 1140 provides an input control signal to the power distribution module 1132, which then provides power to the first and second remotely adjustable linkages 1110, 1120 to drive them in the appropriate direction. In Figure 11, the flanking rudders 320, 330 are shown toed-in. When the input control signal is received by the power distribution module 1132 from the controller 1140 to change the orientation from toed-in to toed-out, the power distribution module 1132 provides power from the power source 1134 to the first remotely adjustable linkage 1110 to retract the ram 1112 and provides power from the power source 1134 to the second remotely adjustable linkage 1120 to extend the ram 1122. Conversely, to move the flanking rudders 320, 330 from a toed-out orientation to a toed-in orientation the power distribution module 1132 provides power to the first remotely adjustable linkage 1110 to extend the ram 1112 and provides power to the second remotely adjustable linkage 1120 to retract the ram 1122. In addition to moving between toed-in and toed-out configurations, the flanking rudders 320, 330 may be moved to and from an orientation where the chord 320b, 330b of each flanking rudder is parallel to the centerline 202 of the boat 100.

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[0064] The controller 1140 may be any suitable controller including a microprocessor based controller that has a processor and a memory. The controller 1140 may be responsive to an input device 126. The input device 126 may be preferably located at the control console 120 (see Figure 1) in order to receive inputs from the operator; such an input device 126 may include a switch or a touch screen, for example. The operator may adjust the angle of toe α , β by selecting the appropriate direction on the input device 126 and the controller generates a control signal to the power distribution module 1132 for the length of time the direction on the input device 126 is selected. There may be a stop to limit the range of travel of the first and second remotely adjustable linkages 1110, 1120. The stop may be, for example, a mechanical stop associated with the rams 1112, 1122 of the first and second remotely adjustable linkages 1110, 1120, an electrical stop associated with the motor of the adjustable linkage 1110, 1120, or even a limit programmed into the control software stored in the memory of the controller 1140.

[0065] The controller 1140 may also have a plurality of programmed angles of toe α , β stored in its memory. For example, no toe (an angle α , β of zero), toed-in 5° , toed-in 10° , toed-out 5° , toed-out 10° . A user may then select one of these programmed positions through the input device 126, and in response to the user's selection, the controller 1140 sends the appropriate control signal to power distribution module 1132 to drive the first and second remotely adjustable linkages 1110, 1120 to the programmed positions.

[0066] The controller 1140 does not need to be responsive to an input device 126 operated by the user. Instead, the controller 1140 may be responsive to various other switches and sensors that monitor or are activated by various operating conditions of the boat. For example, one angle of toe α , β may be preferred when the boat is operating in the forward direction (e.g., toed-in at 5°), and another angle of toe α , β may be preferred when the boat is operating in the reverse

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direction (e.g., toed-out at 5°). Thus, the controller 1140 may be responsive to the control lever 122, such that controller 1140 sets the angle of toe α , β from one of the plurality of programmed angles of toe α , β based on the direction the boat 100 is being driven. Other operational conditions that the controller 1140 may be programmed to adjust the angle of toe α , β include, for example, a speed range, an engine RPM range, gear positions, or steering compensation.

[0067] The rams 1112, 1122 of the first and second remotely adjustable linkages 1110, 1120 are preferably moved both concurrently and the same distance. As discussed above, the port and starboard flanking rudders 320, 330 are preferably symmetrical about the centerline 202, and moving the rams 1112, 1122 concurrently the same distance may be desirable to maintain this symmetry. However, those skilled in the art will recognize that the controller 1140 and associated input device 126, such as touch screen 126, may be configured to operate each of the first and second remotely adjustable linkages 1110, 1120 independently and to extend and retract the rams 1112, 1122 different distances.

[0068] In the embodiments discussed above, the flanking rudders 320, 330 are turned in concert with the main rudder 310. Under some operational conditions, it may be preferable to decouple the flanking rudders 320, 330 from the main rudder 310. For example, it may be beneficial for the flanking rudders 320, 330 to turn in concert with the main rudder 310 during reverse operation, but remain fixed during high speed forward operation. A suitable configuration for decoupling the flanking rudders 320, 330 from the main rudder 310 is shown in Figure 12. In this configuration, the main rudder 310 and port flanking rudder 320 are not linked by the first linkage 830. Instead, the flanking rudders are turned by a second hydraulic cylinder 1212 and ram 1214. The second hydraulic cylinder 1212 may also be operated by the hydraulic pump 814. A valve 1216 may be placed between the pump 814 and the second hydraulic

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cylinder 1212. The valve 1216 may be closed to decouple the flanking rudders 320, 330 from the main rudder. In addition to being operated by the user, the valve 1216 may be operated the controller 1140 and responsive to the operational conditions of the boat 100 as discussed above.

[0069] The embodiments discussed above include a pair of flanking rudders 320, 330.

Having a pair of flanking rudders 320, 330 is desirable for a number of reasons, including for example, maintaining a balanced load on either side of the boat's centerline 202 when the flanking rudders are angled relative to the forward and aft direction of the boat 100. However, a single flanking rudder 320, 330 positioned forward of the propeller 342, may also be suitable.

[0070] The single flanking rudder 320, 330 is positioned to intersect the reverse race 420 when rotated from its neutral position and sized to generate sufficient lift to counteract any yaw moment generated by the propeller 342 in when the boat 100 is operated in reverse. As a result, the single flanking rudder 320, 330 is preferably offset from the centerline 202 of the boat 100.

An embodiment having a single flanking rudder 320 positioned on the port side of the boat is shown in Figures 13, 14, and 15, and an embodiment having a single flanking rudder 330 positioned on the starboard side of the boat is shown in Figures 16, 17, and 18. The embodiment with a single flanking rudder 320, 330 operates similarly to the embodiment discussed above having a pair of flanking rudders 320, 330, and the same reference numerals are used to denote the same or similar features in Figures 13-18 as in Figures 1-12. Although, the single flanking rudder 320, 330 may be either toed-in or toed-out, under most circumstances, the chord 320b, 330b of the single flanking rudder 320, 330 is preferably parallel to the centerline 202 when the rudder 320, 330 is in its neutral position.

[0071] The embodiments discussed herein are examples of preferred embodiments of the present invention and are provided for illustrative purposes only. They are not intended to limit

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the scope of the invention. Although specific configurations, structures, etc. have been shown and described, such are not limiting. Modifications and variations are contemplated within the scope of the invention, which is to be limited only by the scope of the issued claims.

Claims

What is claimed is:

1. A boat comprising:
 - a planing hull including a port and starboard sides, a transom, a hull bottom, and a centerline running down the middle of the boat, halfway between the port and starboard sides;
 - a propeller positioned forward of the transom and beneath the hull bottom;
 - a main rudder positioned aft of the propeller, the main rudder having a rotation axis about which the main rudder rotates; and
 - a pair of flanking rudders positioned forward of the propeller, one of the flanking rudders being positioned on the port side of the centerline, and the other flanking rudder being positioned on the starboard side of the centerline, each flanking rudder having a rotation axis about which that flanking rudder rotates.
2. The boat of claim 1, wherein the planing hull includes at least one of lifting strakes, a hard chine, and a deadrise from 0° to 30°.
3. The boat of claim 1, further comprising a drive shaft for rotating the propeller, the drive shaft being aligned with the centerline when viewed from above.
4. The boat of claim 1, the boat further comprising a main rudder post passing through the hull bottom, one end of the main rudder post connected to the main rudder and configured to rotate the main rudder about the rotation axis of the main rudder,
 - wherein, when the propeller is rotated in a direction to move the boat forward, the propeller accelerates a stream of water as a forward race, and the main rudder post is located within outer edges of the forward race when viewed from above.
5. The boat of claim 1, further comprising a main rudder post passing through the hull bottom, one end of the main rudder post connected to the main rudder and configured to

rotate the main rudder about the rotation axis of the main rudder, the main rudder post being positioned on the centerline when viewed from above.

6. The boat of claim 1, wherein, when the propeller is rotated in a direction to move the boat in reverse, the propeller accelerates a stream of water as a reverse race, and the flanking rudders are positioned to intersect the reverse race when the flanking rudders are rotated from a neutral position.

7. The boat of claim 1, further comprising:

a port flanking rudder post passing through the hull bottom, one end of the port flanking rudder post connected to the port flanking rudder and configured to rotate the port flanking rudder about the rotation axis of the port flanking rudder; and

a starboard flanking rudder post passing through the hull bottom, one end of the starboard flanking rudder post connected to the starboard flanking rudder and configured to rotate the starboard flanking rudder about the rotation axis of the starboard flanking rudder,

wherein the propeller has a diameter, and the port flanking rudder post and the starboard flanking rudder post are positioned forward of the propeller a distance that is less than or equal to three times the propeller diameter.

8. The boat of claim 7, wherein the port flanking rudder post and the starboard flanking rudder post are located the same distance forward of the propeller.

9. The boat of claim 7, wherein, when the propeller is rotated in a direction to move the boat in reverse, the propeller accelerates a stream of water as a reverse race, and each of the port and starboard flanking rudder posts is positioned within outer edges of the reverse race when viewed from above.

10. The boat of claim 1, wherein each of the flanking rudders further has a neutral position and a forward edge that is angled toward the centerline as viewed from above when the flanking rudder is in the neutral position.

11. The boat of claim 10, wherein each of the flanking rudders further has an aft edge that is angled away from the centerline as viewed from above when the flanking rudder is in the neutral position.

12. The boat of claim 10, wherein, when viewed from above, the forward edge of the port flanking rudder is angled toward the centerline at a toed-in angle relative to a line that extends parallel to the centerline and intersects the rotation axis of the port flanking rudder, the toed-in angle of the port flanking rudder being from 0° to 10°, and

wherein, when viewed from above, the forward edge of the starboard flanking rudder angled is toward the centerline at a toed-in angle relative to a line that extends parallel to the centerline and intersects the rotation axis of the starboard flanking rudder, the toed-in angle of the starboard flanking rudder being from 0° to 10°.

13. The boat of claim 1, wherein each of the flanking rudders further has a neutral position and a forward edge that is angled away from the centerline as viewed from above when the flanking rudder is in the neutral position.

14. The boat of claim 13, wherein each of the flanking rudders further has an aft edge that is angled toward the centerline as viewed from above when the flanking rudder is in the neutral position.

15. The boat of claim 13, wherein, when viewed from above, the forward edge of the port flanking rudder is angled away from the centerline at a toed-out angle relative to a line that extends parallel to the centerline and intersects the rotation axis of the port flanking rudder, the toed-out angle of the port flanking rudder being from 0° to 10°, and

wherein, when viewed from above, the forward edge of the starboard flanking rudder angled is away from the centerline at a toed-out angle relative to a line that extends parallel to the centerline and intersects the rotation axis of the starboard flanking rudder, the toed-out angle of the starboard flanking rudder being from 0° to 10°.

16. The boat of claim 1, wherein the port flanking rudder and the starboard flanking rudder are each configured to rotate at rotation rates faster than a rotation rate at which the main rudder is configured to rotate.

17. The boat of claim 16, further comprising:

- a main rudder post passing through the hull bottom, one end of the main rudder post connected to the main rudder and configured to rotate the main rudder about the rotation axis of the main rudder;

- a main tiller arm connected to the other end of the main rudder post and configured to rotate with the main rudder post;

- a flanking rudder post passing through the hull bottom, one end of the flanking rudder post connected to one of the flanking rudders and configured to rotate the flanking rudder to which it is connected about the rotation axis of that flanking rudder;

- a flanking rudder tiller arm connected to the other end of the of the flanking rudder post and configured to rotate with the flanking rudder post; and

- a linkage connecting the main tiller arm and the flanking rudder tiller arm, the linkage being connected to the main tiller arm at a first connection point and connected to the flanking rudder tiller arm at a second connection point, wherein the distance between the first connection point and the main rudder post is greater than the distance between the second connection point and the flanking rudder post.

18. A boat comprising:

- a planing hull including port and starboard sides, a transom, a hull bottom, and a centerline running down the middle of the boat, halfway between the port and starboard sides;

- a propeller positioned forward of the transom and beneath the hull bottom;

- a main rudder positioned aft of the propeller, the main rudder having a rotation axis about which the main rudder rotates; and

- a pair of flanking rudders positioned forward of the propeller, one of the flanking rudders being positioned on the port side of the centerline, and the other flanking rudder being positioned on the starboard side of the centerline, each flanking rudder having an aft edge and a rotation axis about which that flanking rudder rotates,

wherein, when the aft edge of each flanking rudder is rotated to port, the starboard flanking rudder is configured to rotate at a rotation rate that is different than a rotation rate at which the port flanking rudder is configured to rotate, and

wherein, when the aft edge of each flanking rudder is rotated to starboard, the port flanking rudder is configured to rotate at a rotation rate that is different than a rotation rate at which the starboard flanking rudder is configured to rotate.

19. The boat of claim 18, wherein, when the aft edge of each flanking rudder is rotated to port, the starboard flanking rudder is configured to rotate at a rotation rate that is faster than a rotation rate at which the port flanking rudder is configured to rotate, and

wherein, when the aft edge of each flanking rudder is rotated to starboard, the port flanking rudder is configured to rotate at a rotation rate that is faster than a rotation rate at which the starboard flanking rudder is configured to rotate.

20. The boat of claim 19, further comprising:

a port flanking rudder post passing through the hull bottom, one end of the port flanking rudder post connected to the port flanking rudder and configured to rotate the port flanking rudder about the rotation axis of the port flanking rudder;

a port tiller arm connected to the other end of the port flanking rudder post and configured to rotate with the port flanking rudder post, the port tiller arm being angled in a direction from the port flanking rudder post away from the centerline when viewed from above;

a starboard flanking rudder post passing through the hull bottom, one end of the starboard flanking rudder post connected to the starboard flanking rudder and configured to rotate the starboard flanking rudder about the rotation axis of the starboard flanking rudder;

a starboard tiller arm connected to the other end of the starboard flanking rudder post and configured to rotate with the starboard flanking rudder post, the starboard tiller arm being angled in a direction from the starboard flanking rudder post away from the centerline when viewed from above; and

a linkage connecting the port tiller arm and the starboard tiller arm.

21. The boat of claim 20, wherein the linkage is connected to the port tiller arm at a first connection point and is connected to the starboard tiller arm at a second connection point, and

wherein, the distance between the first connection point and the port flanking rudder post is the same as the distance between the second connection point and the starboard flanking rudder post.

22. The boat of claim 18, wherein when the aft edge of each flanking rudder is rotated to port, the starboard flanking rudder is configured to rotate at a rotation rate that is less than a rotation rate at which the port flanking rudder is configured to rotate, and

wherein, when the aft edge of each flanking rudder is rotated to starboard, the port flanking rudder is configured to rotate at a rotation rate that is less than a rotation rate at which the starboard flanking rudder is configured to rotate.

23. A boat comprising:

a planing hull including a port and starboard sides, a transom, a hull bottom, and a centerline running down the middle of the boat, halfway between the port and starboard sides;

a propeller positioned forward of the transom and beneath the hull bottom;

a main rudder positioned aft of the propeller, the main rudder having a rotation axis about which the main rudder rotates;

a pair of flanking rudders positioned forward of the propeller, one of the flanking rudders being positioned on the port side of the centerline, and the other flanking rudder being positioned on the starboard side of the centerline, each of the flanking rudders having (i) a rotation axis about which that flanking rudder rotates, (ii) a neutral position, and (iii) a forward edge having an angle of toe in its neutral position;

at least one actuator configured to rotate each flanking rudder about its rotation axis and change the angle of toe; and

a controller configured to actuate the at least one actuator and change the angle of toe.

24. The boat of claim 23, wherein the controller includes a memory and a processor coupled to the memory, the memory storing a plurality of angles of toe for each flanking rudder.
25. The boat of claim 24, wherein the controller is configured to:
receive an operational condition of the boat;
select one of the stored angles of toe based on the operational condition of the boat;
and
activate the at least one actuator to change the angle of toe based on the selected angle of toe.
26. The boat of claim 23, further comprising:
a port flanking rudder post passing through the hull bottom, one end of the port flanking rudder post connected to the port flanking rudder and configured to rotate the port flanking rudder about the rotation axis of the port flanking rudder;
a port tiller arm connected to the other end of the port flanking rudder post and configured to rotate with the port flanking rudder post, the port tiller arm being angled in a direction from the port flanking rudder post away from the centerline when viewed from above;
a starboard flanking rudder post passing through the hull bottom, one end of the starboard flanking rudder post connected to the starboard flanking rudder and configured to rotate the starboard flanking rudder about the rotation axis of the starboard flanking rudder;
and
a starboard tiller arm connected to the other end of the starboard flanking rudder post and configured to rotate with the starboard flanking rudder post, the starboard tiller arm being angled in a direction from the starboard flanking rudder post away from the centerline when viewed from above,
wherein the at least one actuator is a remotely adjustable linkage connecting the port tiller arm and the starboard tiller arm.
27. The boat of claim 26, wherein the remotely adjustable linkage is a linear actuator.

28. A boat comprising:

- a planing hull including a port and starboard sides, a transom, a hull bottom, and a centerline running down the middle of the boat, halfway between the port and starboard sides;

- a propeller positioned forward of the transom and beneath the hull bottom;

- a main rudder positioned aft of the propeller; and

- a flanking rudder positioned forward of the propeller and offset from the centerline.

29. The boat of claim 28, wherein the flanking rudder is positioned on the port side of the centerline.

30. The boat of claim 28, wherein the flanking rudder is positioned on the starboard side of the centerline.

31. A boat comprising:

- a planing hull including a port and starboard sides, a transom, a hull bottom, and a centerline running down the middle of the boat, halfway between the port and starboard sides;

- a propeller positioned forward of the transom and beneath the hull bottom, the propeller being configured to accelerate a stream of water as a reverse race when the propeller is rotated in a direction to move the boat in reverse;

- a main rudder positioned aft of the propeller, the main rudder having a rotation axis about which the main rudder rotates; and

- a pair of flanking rudders, one of the flanking rudders being positioned on the port side of the centerline, and the other flanking rudder being positioned on the starboard side of the centerline, each flanking rudder having (i) a neutral position and (ii) a rotation axis about which that flanking rudder rotates, the rotation axis of each flanking rudder being positioned forward of the propeller and positioned such that each flanking rudder is configured to intersect the reverse race when rotated from its neutral position.

32. The boat of claim 31, wherein the planing hull includes at least one of lifting strakes, a hard chine, and a deadrise from 0° to 30°.

33. The boat of claim 31, further comprising a drive shaft for rotating the propeller, the drive shaft being aligned with the centerline when viewed from above.

34. The boat of claim 31, the boat further comprising a main rudder post passing through the hull bottom, one end of the main rudder post connected to the main rudder and configured to rotate the main rudder about the rotation axis of the main rudder, wherein, when the propeller is rotated in a direction to move the boat forward, the propeller accelerates a stream of water as a forward race, and the main rudder post is located within outer edges of the forward race when viewed from above.

35. The boat of claim 31, further comprising a main rudder post passing through the hull bottom, one end of the main rudder post connected to the main rudder and configured to rotate the main rudder about the rotation axis of the main rudder, the main rudder post being positioned on the centerline when viewed from above.

36. The boat of claim 31, further comprising:
a port flanking rudder post passing through the hull bottom, one end of the port flanking rudder post connected to the port flanking rudder and configured to rotate the port flanking rudder about the rotation axis of the port flanking rudder; and
a starboard flanking rudder post passing through the hull bottom, one end of the starboard flanking rudder post connected to the starboard flanking rudder and configured to rotate the starboard flanking rudder about the rotation axis of the starboard flanking rudder, wherein the propeller has a diameter, and the port flanking rudder post and the starboard flanking rudder post are positioned forward of the propeller a distance that is less than or equal to three times the propeller diameter.

37. The boat of claim 36, wherein the port flanking rudder post and the starboard flanking rudder post are located the same distance forward of the propeller.

38. The boat of claim 31, further comprising:

a port flanking rudder post passing through the hull bottom, one end of the port flanking rudder post being connected to the port flanking rudder and being configured to rotate the port flanking rudder about the rotation axis of the port flanking rudder; and a starboard flanking rudder post passing through the hull bottom, one end of the starboard flanking rudder post being connected to the starboard flanking rudder and being configured to rotate the starboard flanking rudder about the rotation axis of the starboard flanking rudder,

wherein each of the port and starboard flanking rudder posts is positioned within outer edges of the reverse race when viewed from above.

39. The boat of claim 31, wherein each of the flanking rudders further has a neutral position and a forward edge that is angled toward the centerline as viewed from above when the flanking rudder is in the neutral position.

40. The boat of claim 39, wherein each of the flanking rudders further has an aft edge that is angled away from the centerline as viewed from above when the flanking rudder is in the neutral position.

41. The boat of claim 39, wherein, when viewed from above, the forward edge of the port flanking rudder is angled toward the centerline at a toed-in angle relative to a line that extends parallel to the centerline and intersects the rotation axis of the port flanking rudder, the toed-in angle of the port flanking rudder being from 0° to 10°, and

wherein, when viewed from above, the forward edge of the starboard flanking rudder angled is toward the centerline at a toed-in angle relative to a line that extends parallel to the centerline and intersects the rotation axis of the starboard flanking rudder, the toed-in angle of the starboard flanking rudder being from 0° to 10°.

42. The boat of claim 31, wherein each of the flanking rudders further has a neutral position and a forward edge that is angled away from the centerline as viewed from above when the flanking rudder is in the neutral position.

43. The boat of claim 42, wherein each of the flanking rudders further has an aft edge that is angled toward the centerline as viewed from above when the flanking rudder is in the neutral position.

44. The boat of claim 42, wherein, when viewed from above, the forward edge of the port flanking rudder is angled away from the centerline at a toed-out angle relative to a line that extends parallel to the centerline and intersects the rotation axis of the port flanking rudder, the toed-out angle of the port flanking rudder being from 0° to 10°, and

wherein, when viewed from above, the forward edge of the starboard flanking rudder angled is away from the centerline at a toed-out angle relative to a line that extends parallel to the centerline and intersects the rotation axis of the starboard flanking rudder, the toed-out angle of the starboard flanking rudder being from 0° to 10°.

45. The boat of claim 31, wherein the port flanking rudder and the starboard flanking rudder are each configured to rotate at rotation rates faster than a rotation rate at which the main rudder is configured to rotate.

46. The boat of claim 45, further comprising:

a main rudder post passing through the hull bottom, one end of the main rudder post connected to the main rudder and configured to rotate the main rudder about the rotation axis of the main rudder;

a main tiller arm connected to the other end of the main rudder post and configured to rotate with the main rudder post;

a flanking rudder post passing through the hull bottom, one end of the flanking rudder post connected to one of the flanking rudders and configured to rotate the flanking rudder to which it is connected about the rotation axis of that flanking rudder;

a flanking rudder tiller arm connected to the other end of the of the flanking rudder post and configured to rotate with the flanking rudder post; and

a linkage connecting the main tiller arm and the flanking rudder tiller arm, the linkage being connected to the main tiller arm at a first connection point and connected to the flanking rudder tiller arm at a second connection point, wherein the distance between the first

connection point and the main rudder post is greater than the distance between the second connection point and the flanking rudder post.

47. The boat of claim 31, wherein each flanking rudder further has an aft edge, wherein, when the aft edge of each flanking rudder is rotated to port, the starboard flanking rudder is configured to rotate at a rotation rate that is different than a rotation rate at which the port flanking rudder is configured to rotate, and

wherein, when the aft edge of each flanking rudder is rotated to starboard, the port flanking rudder is configured to rotate at a rotation rate that is different than a rotation rate at which the starboard flanking rudder is configured to rotate.

48. The boat of claim 47, wherein, when the aft edge of each flanking rudder is rotated to port, the starboard flanking rudder is configured to rotate at a rotation rate that is faster than a rotation rate at which the port flanking rudder is configured to rotate, and

wherein, when the aft edge of each flanking rudder is rotated to starboard, the port flanking rudder is configured to rotate at a rotation rate that is faster than a rotation rate at which the starboard flanking rudder is configured to rotate.

49. The boat of claim 48, further comprising:

a port flanking rudder post passing through the hull bottom, one end of the port flanking rudder post connected to the port flanking rudder and configured to rotate the port flanking rudder about the rotation axis of the port flanking rudder;

a port tiller arm connected to the other end of the port flanking rudder post and configured to rotate with the port flanking rudder post, the port tiller arm being angled in a direction from the port flanking rudder post away from the centerline when viewed from above;

a starboard flanking rudder post passing through the hull bottom, one end of the starboard flanking rudder post connected to the starboard flanking rudder and configured to rotate the starboard flanking rudder about the rotation axis of the starboard flanking rudder; a starboard tiller arm connected to the other end of the starboard flanking rudder post and configured to rotate with the starboard flanking rudder post, the starboard tiller arm being

angled in a direction from the starboard flanking rudder post away from the centerline when viewed from above; and

a linkage connecting the port tiller arm and the starboard tiller arm.

50. The boat of claim 49, wherein the linkage is connected to the port tiller arm at a first connection point and is connected to the starboard tiller arm at a second connection point, and

wherein, the distance between the first connection point and the port flanking rudder post is the same as the distance between the second connection point and the starboard flanking rudder post.

51. The boat of claim 47, wherein when the aft edge of each flanking rudder is rotated to port, the starboard flanking rudder is configured to rotate at a rotation rate that is less than a rotation rate at which the port flanking rudder is configured to rotate, and

wherein, when the aft edge of each flanking rudder is rotated to starboard, the port flanking rudder is configured to rotate at a rotation rate that is less than a rotation rate at which the starboard flanking rudder is configured to rotate.

52. The boat of claim 31, wherein each of the flanking rudders further has a forward edge having an angle of toe in its neutral position, and the boat further comprises:

at least one actuator configured to rotate each flanking rudder about its rotation axis and change the angle of toe; and

a controller configured to actuate the at least one actuator and change the angle of toe.

53. The boat of claim 52, wherein the controller includes a memory and a processor coupled to the memory, the memory storing a plurality of angles of toe for each flanking rudder.

54. The boat of claim 53, wherein the controller is configured to:
receive an operational condition of the boat;

select one of the stored angles of toe based on the operational condition of the boat;
and

activate the at least one actuator to change the angle of toe based on the selected angle of toe.

55. The boat of claim 52, further comprising:

a port flanking rudder post passing through the hull bottom, one end of the port flanking rudder post connected to the port flanking rudder and configured to rotate the port flanking rudder about the rotation axis of the port flanking rudder;

a port tiller arm connected to the other end of the port flanking rudder post and configured to rotate with the port flanking rudder post, the port tiller arm being angled in a direction from the port flanking rudder post away from the centerline when viewed from above;

a starboard flanking rudder post passing through the hull bottom, one end of the starboard flanking rudder post connected to the starboard flanking rudder and configured to rotate the starboard flanking rudder about the rotation axis of the starboard flanking rudder;
and

a starboard tiller arm connected to the other end of the starboard flanking rudder post and configured to rotate with the starboard flanking rudder post, the starboard tiller arm being angled in a direction from the starboard flanking rudder post away from the centerline when viewed from above,

wherein the at least one actuator is a remotely adjustable linkage connecting the port tiller arm and the starboard tiller arm.

56. The boat of claim 55, wherein the remotely adjustable linkage is a linear actuator.

57. A boat comprising:

a planing hull including a port and starboard sides, transom, a hull bottom, and a centerline running down the middle of the boat, halfway between the port and starboard sides;

a propeller positioned forward of the transom and beneath the hull bottom, the propeller being configured to accelerate a stream of water as a reverse race when the propeller is rotated in a direction to move the boat in reverse;
a main rudder positioned aft of the propeller; and

a flanking rudder positioned forward of the propeller and offset from the centerline the flanking rudder having a rotation axis about which the flanking rudder rotates, the rotation axis being positioned forward of the propeller and being positioned such that the flanking rudder is configured to intersect the reverse race when rotated from its neutral position.

58. The boat of claim 57, wherein the flanking rudder is positioned on the port side of the centerline.

59. The boat of claim 57, wherein the flanking rudder is positioned on the starboard side of the centerline.

60. A boat comprising:

a planing hull including a port and starboard sides, a transom, a hull bottom, and a centerline running down the middle of the boat, halfway between the port and starboard sides;

a propeller positioned forward of the transom and beneath the hull bottom, the propeller having a diameter;

a main rudder positioned aft of the propeller, the main rudder having a rotation axis about which the main rudder rotates;

a port flanking rudder positioned on the port side of the centerline, the port flanking rudder having a rotation axis about which the port flanking rudder rotates;

a port flanking rudder post passing through the hull bottom, one end of the port flanking rudder post connected to the port flanking rudder and configured to rotate the port flanking rudder about the rotation axis of the port flanking rudder, the port flanking rudder post being positioned forward of the propeller and laterally within the diameter of the propeller;

a starboard flanking rudder positioned on the starboard side of the centerline, the starboard flanking rudder having a rotation axis about which the starboard flanking rudder rotates; and

a starboard flanking rudder post passing through the hull bottom, one end of the starboard flanking rudder post connected to the starboard flanking rudder and configured to rotate the starboard flanking rudder about the rotation axis of the starboard flanking rudder, the starboard flanking rudder post being positioned forward of the propeller and laterally within the diameter of the propeller.

61. The boat of claim 60, wherein the planing hull includes at least one of lifting strakes, a hard chine, and a deadrise from 0° to 30°.

62. The boat of claim 60, further comprising a drive shaft for rotating the propeller, the drive shaft being aligned with the centerline when viewed from above.

63. The boat of claim 60, the boat further comprising a main rudder post passing through the hull bottom, one end of the main rudder post connected to the main rudder and configured to rotate the main rudder about the rotation axis of the main rudder, the main rudder post being located aft of the propeller and laterally within the diameter of the propeller.

64. The boat of claim 63, wherein the main rudder post is positioned on the centerline when viewed from above.

65. The boat of claim 60, wherein the port flanking rudder post is positioned on the port side of the centerline and the starboard flanking rudder post is positioned on the starboard side of the centerline.

66. The boat of claim 60, wherein each of the port flanking rudder post and the starboard flanking rudder post are positioned forward of the propeller a distance that is less than or equal to three times the propeller diameter.

67. The boat of claim 66, wherein the port flanking rudder post and the starboard flanking rudder post are located the same distance forward of the propeller.

68. The boat of claim 60, wherein each of the flanking rudders further has a neutral position and a forward edge that is angled toward the centerline as viewed from above when the flanking rudder is in the neutral position.

69. The boat of claim 68, wherein, when viewed from above, the forward edge of the port flanking rudder is angled toward the centerline at a toed-in angle relative to a line that extends parallel to the centerline and intersects the rotation axis of the port flanking rudder, the toed-in angle of the port flanking rudder being from 0° to 10°, and

wherein, when viewed from above, the forward edge of the starboard flanking rudder angled is toward the centerline at a toed-in angle relative to a line that extends parallel to the centerline and intersects the rotation axis of the starboard flanking rudder, the toed-in angle of the starboard flanking rudder being from 0° to 10°.

70. The boat of claim 60, wherein each of the flanking rudders further has a neutral position and a forward edge that is angled away from the centerline as viewed from above when the flanking rudder is in the neutral position.

71. The boat of claim 70, wherein, when viewed from above, the forward edge of the port flanking rudder is angled away from the centerline at a toed-out angle relative to a line that extends parallel to the centerline and intersects the rotation axis of the port flanking rudder, the toed-out angle of the port flanking rudder being from 0° to 10°, and

wherein, when viewed from above, the forward edge of the starboard flanking rudder angled is away from the centerline at a toed-out angle relative to a line that extends parallel to the centerline and intersects the rotation axis of the starboard flanking rudder, the toed-out angle of the starboard flanking rudder being from 0° to 10°.

72. The boat of claim 60, further comprising:

a main rudder post passing through the hull bottom, one end of the main rudder post connected to the main rudder and configured to rotate the main rudder about the rotation axis of the main rudder;

a main tiller arm connected to the other end of the main rudder post and configured to rotate with the main rudder post;

a flanking rudder tiller arm connected to an end of one of the port flanking rudder post and the starboard flanking rudder post, the flanking rudder tiller arm configured to rotate with the one of the port flanking rudder post and the starboard flanking rudder post; and

a linkage connecting the main tiller arm and the flanking rudder tiller arm, the linkage being connected to the main tiller arm at a first connection point and connected to the flanking rudder tiller arm at a second connection point, wherein the distance between the first connection point and the main rudder post is greater than the distance between the second connection point and the flanking rudder post.

73. The boat of claim 60, further comprising:

a port tiller arm connected to an end of the port flanking rudder post and configured to rotate with the port flanking rudder post, the port tiller arm being angled in a direction from the port flanking rudder post away from the centerline when viewed from above;

a starboard tiller arm connected to an end of the starboard flanking rudder post and configured to rotate with the starboard flanking rudder post, the starboard tiller arm being angled in a direction from the starboard flanking rudder post away from the centerline when viewed from above; and

a linkage connecting the port tiller arm and the starboard tiller arm.

74. The boat of claim 73, wherein the linkage is connected to the port tiller arm at a first connection point and is connected to the starboard tiller arm at a second connection point, and

wherein, the distance between the first connection point and the port flanking rudder post is the same as the distance between the second connection point and the starboard flanking rudder post.

75. The boat of claim 73, wherein the linkage is adjustable.

76. A boat comprising:

a planing hull including a port and starboard sides, a transom, a hull bottom, and a centerline running down the middle of the boat, halfway between the port and starboard sides;

a propeller positioned forward of the transom and beneath the hull bottom, the propeller having a diameter;

a main rudder positioned aft of the propeller, the main rudder having a rotation axis about which the main rudder rotates;

a flanking rudder positioned forward of the propeller and offset from the centerline, the port rudder having a rotation axis about which the flanking rudder rotates; and

a flanking rudder post passing through the hull bottom, one end of the port flanking rudder post connected to the flanking rudder and configured to rotate the flanking rudder about the rotation axis of the flanking rudder, the flanking rudder post being positioned forward of the propeller and laterally within the diameter of the propeller.

77. The boat of claim 76, wherein each of the flanking rudder and the flanking rudder post is positioned on the port side of the centerline.

78. The boat of claim 76, wherein each of the flanking rudder and the flanking rudder post is positioned on the starboard side of the centerline.

79. The boat of claim 76, wherein the flanking rudder post is positioned forward of the propeller a distance that is less than or equal to three times the propeller diameter.

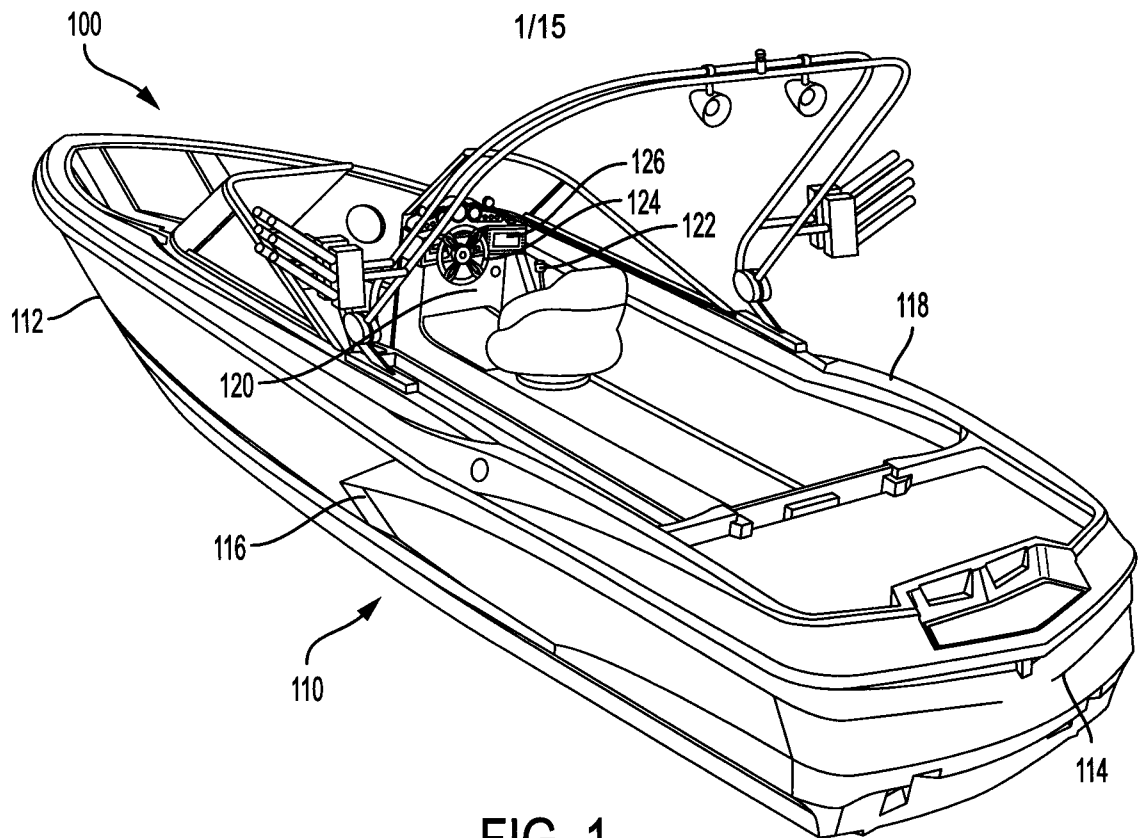


FIG. 1

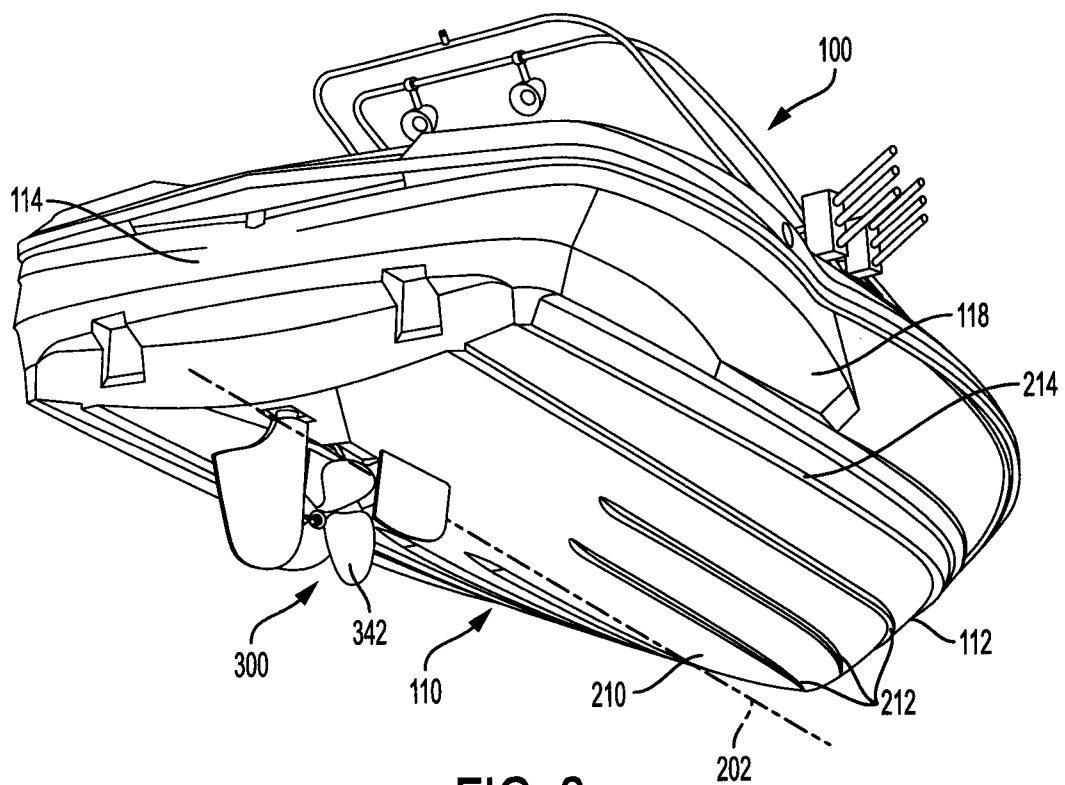
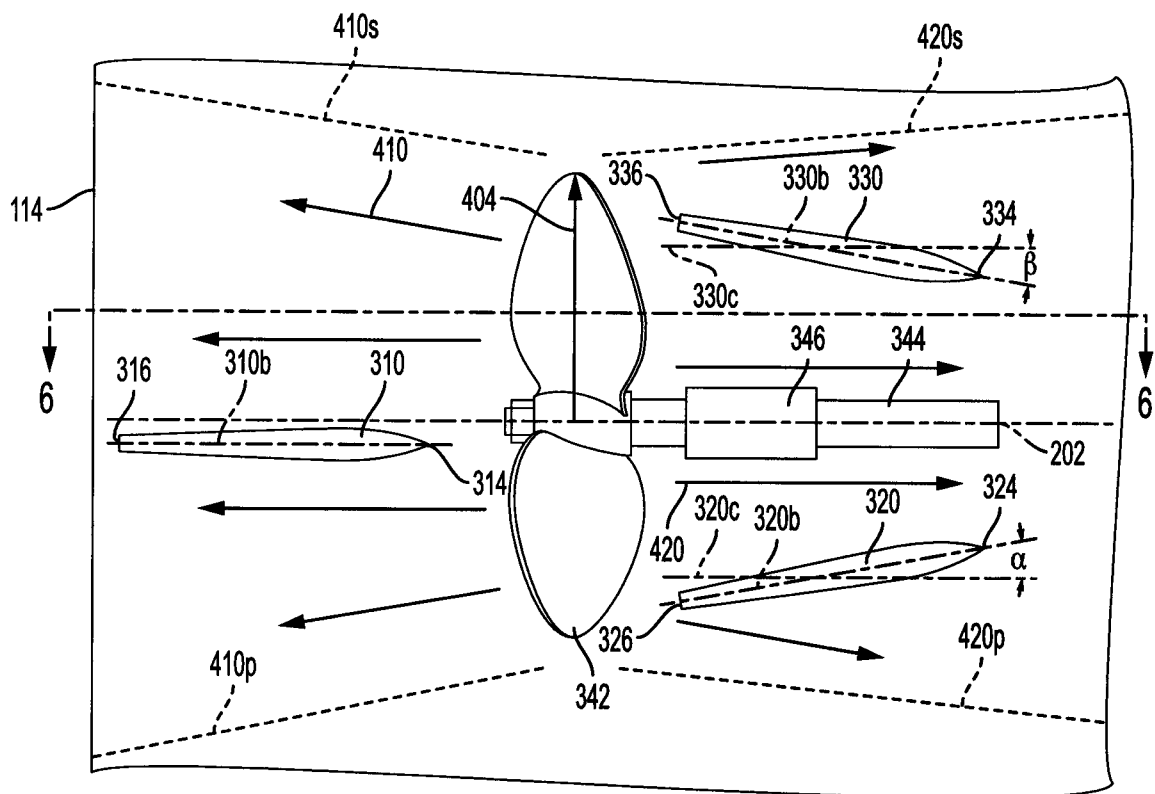
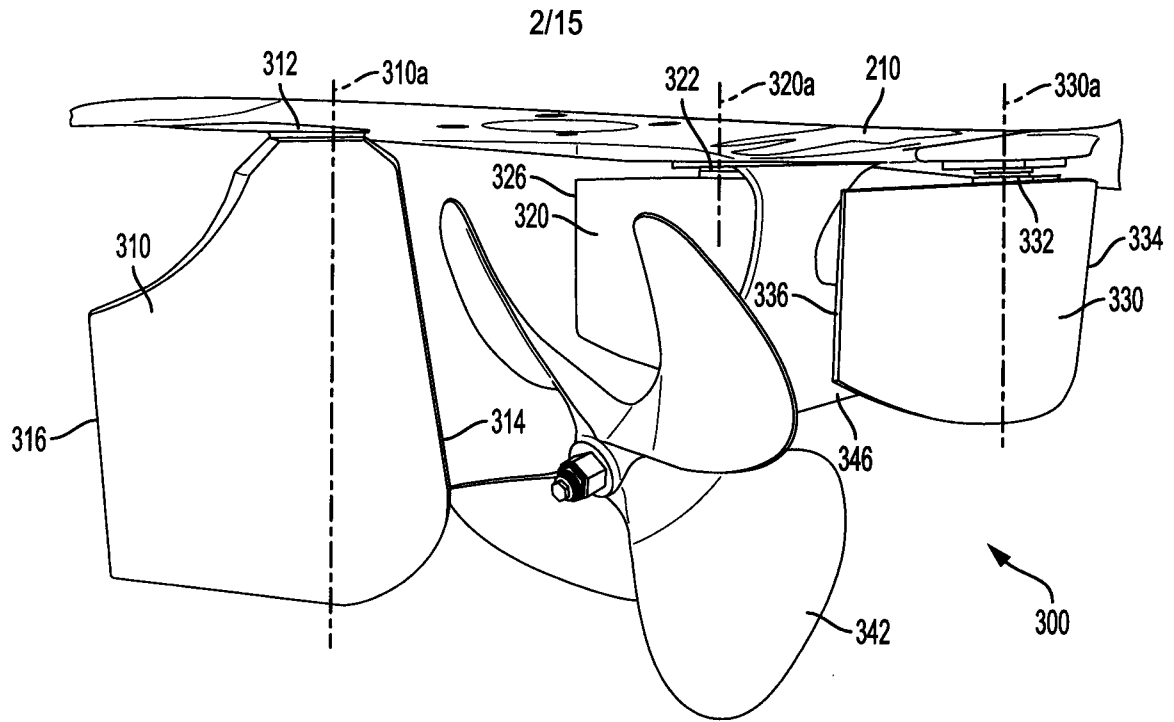


FIG. 2



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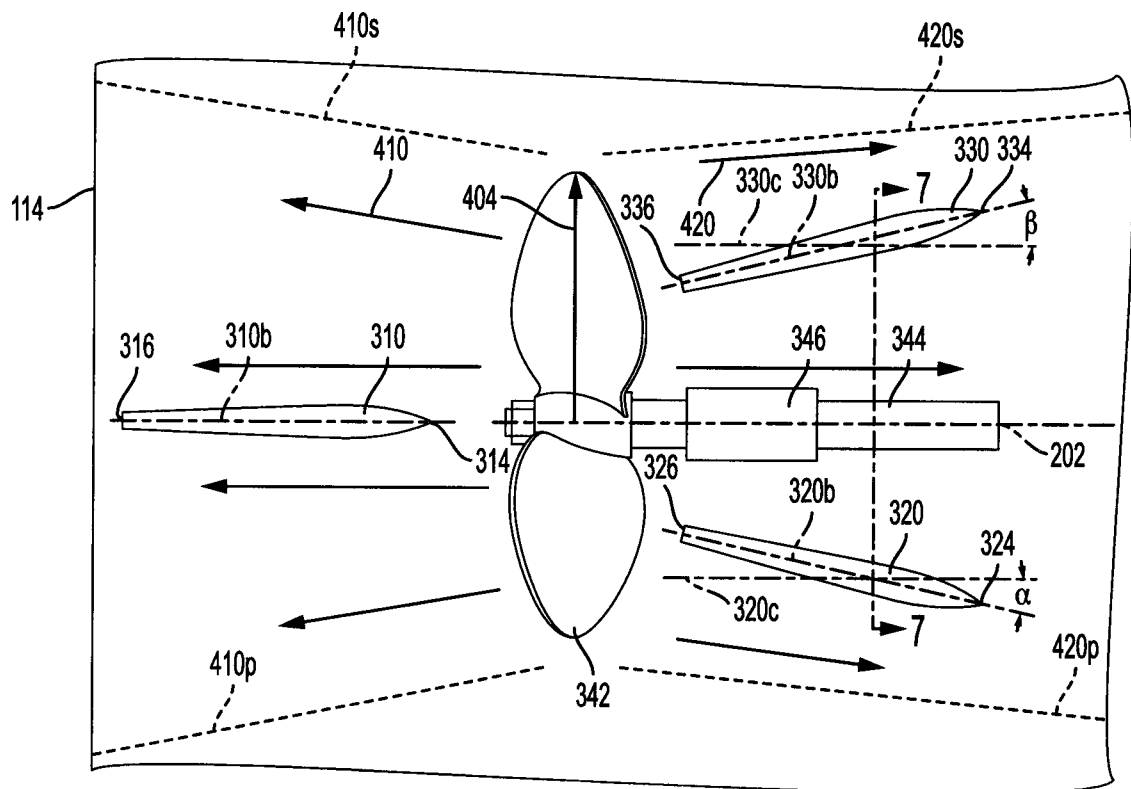


FIG. 5

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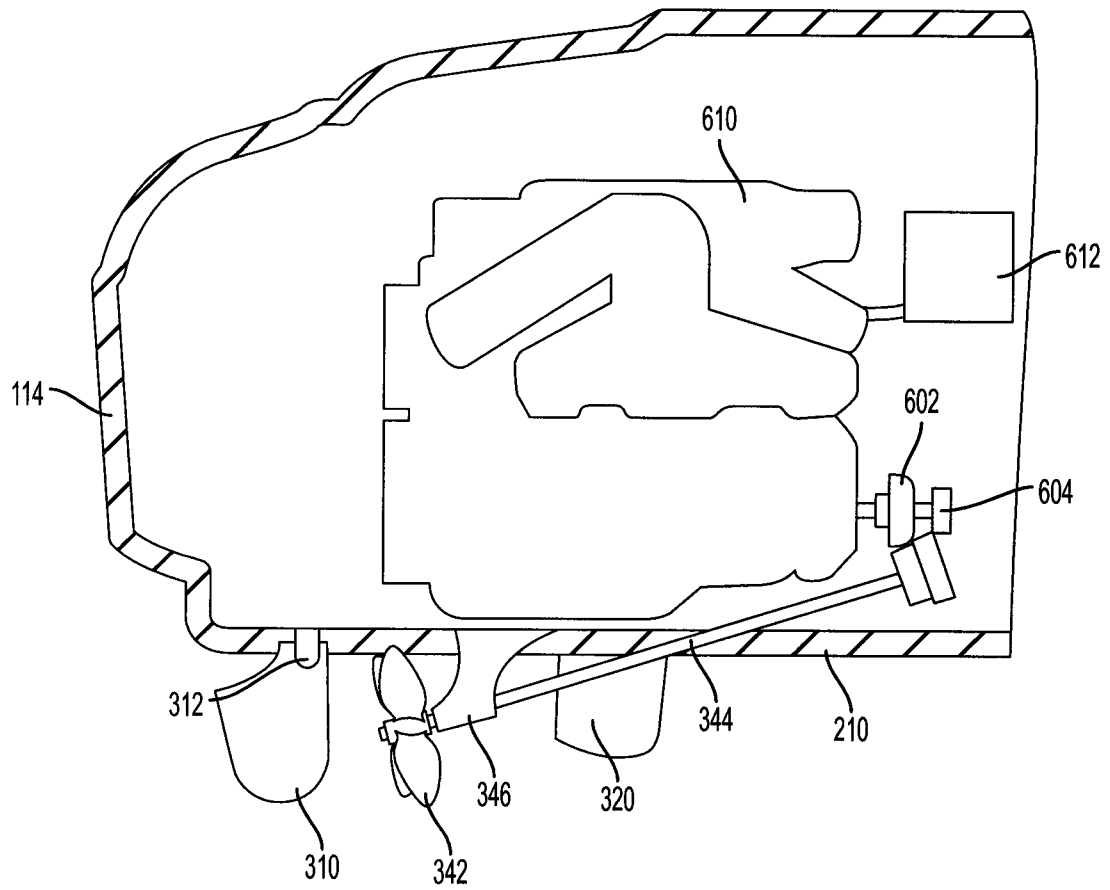


FIG. 6

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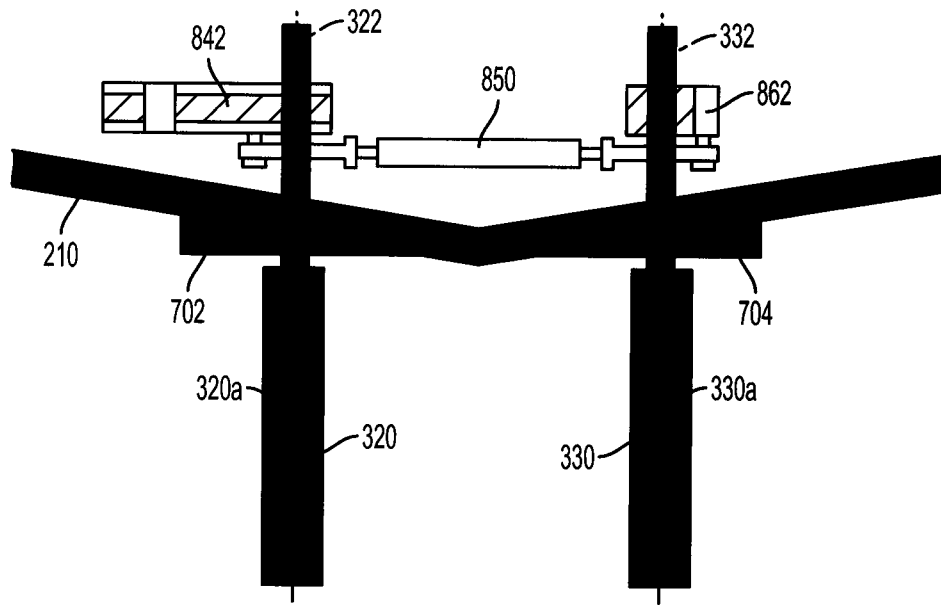


FIG. 7A

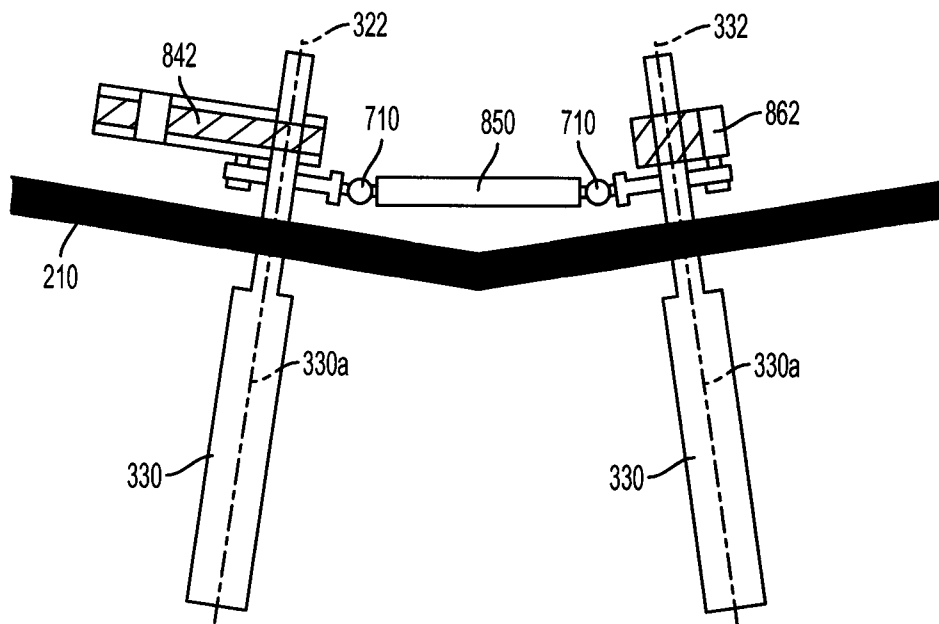


FIG. 7B

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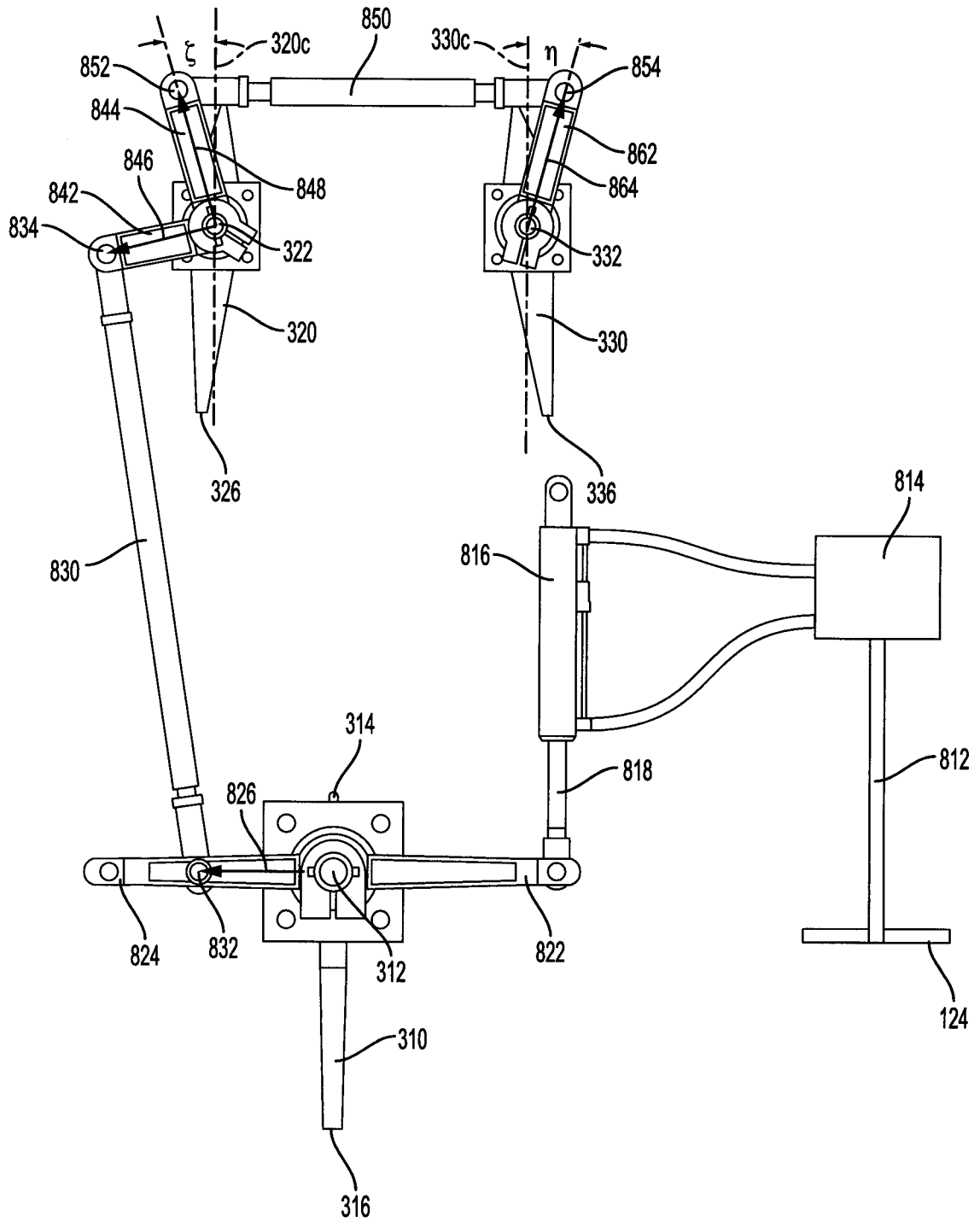


FIG. 8A

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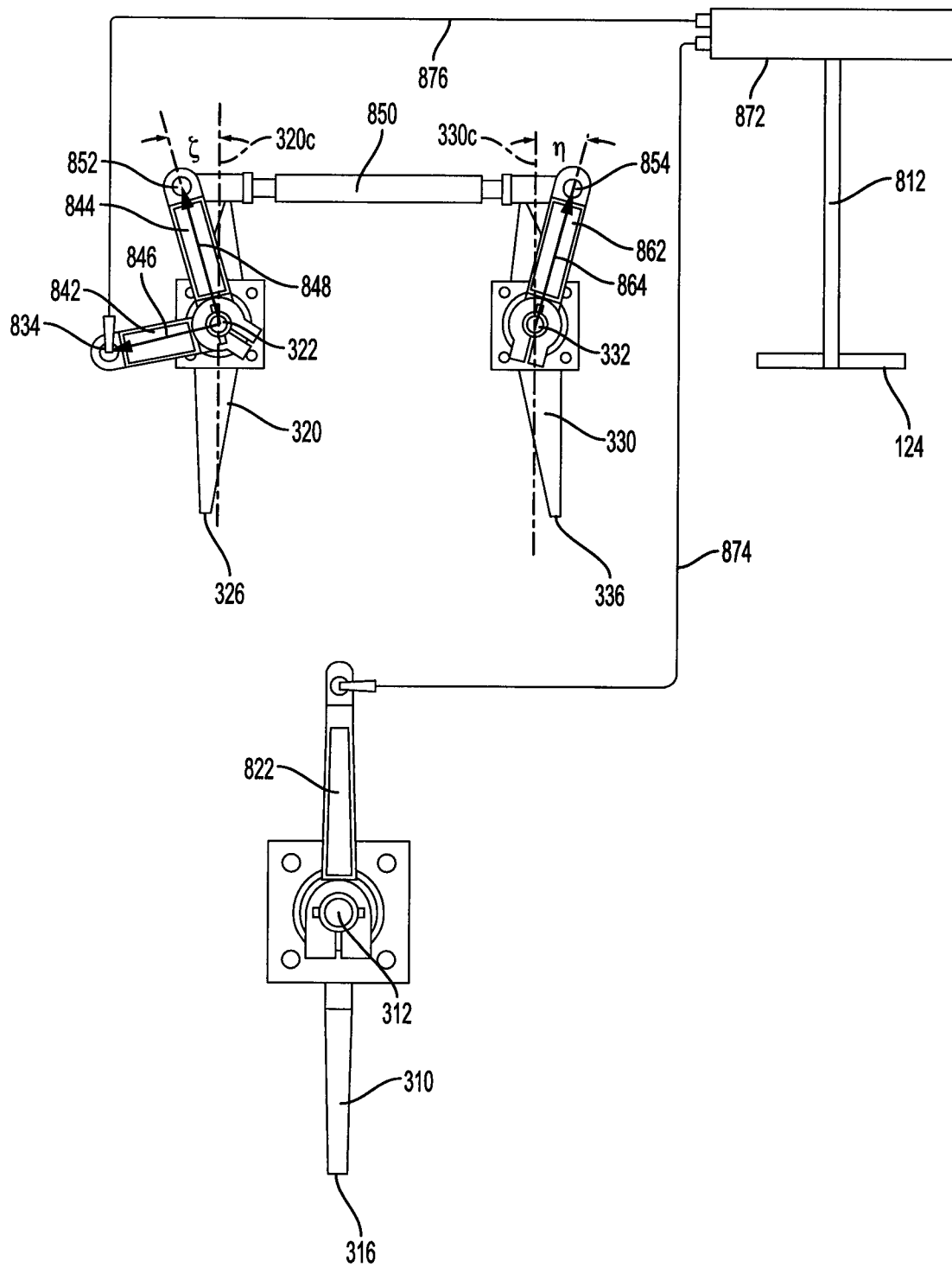


FIG. 8B

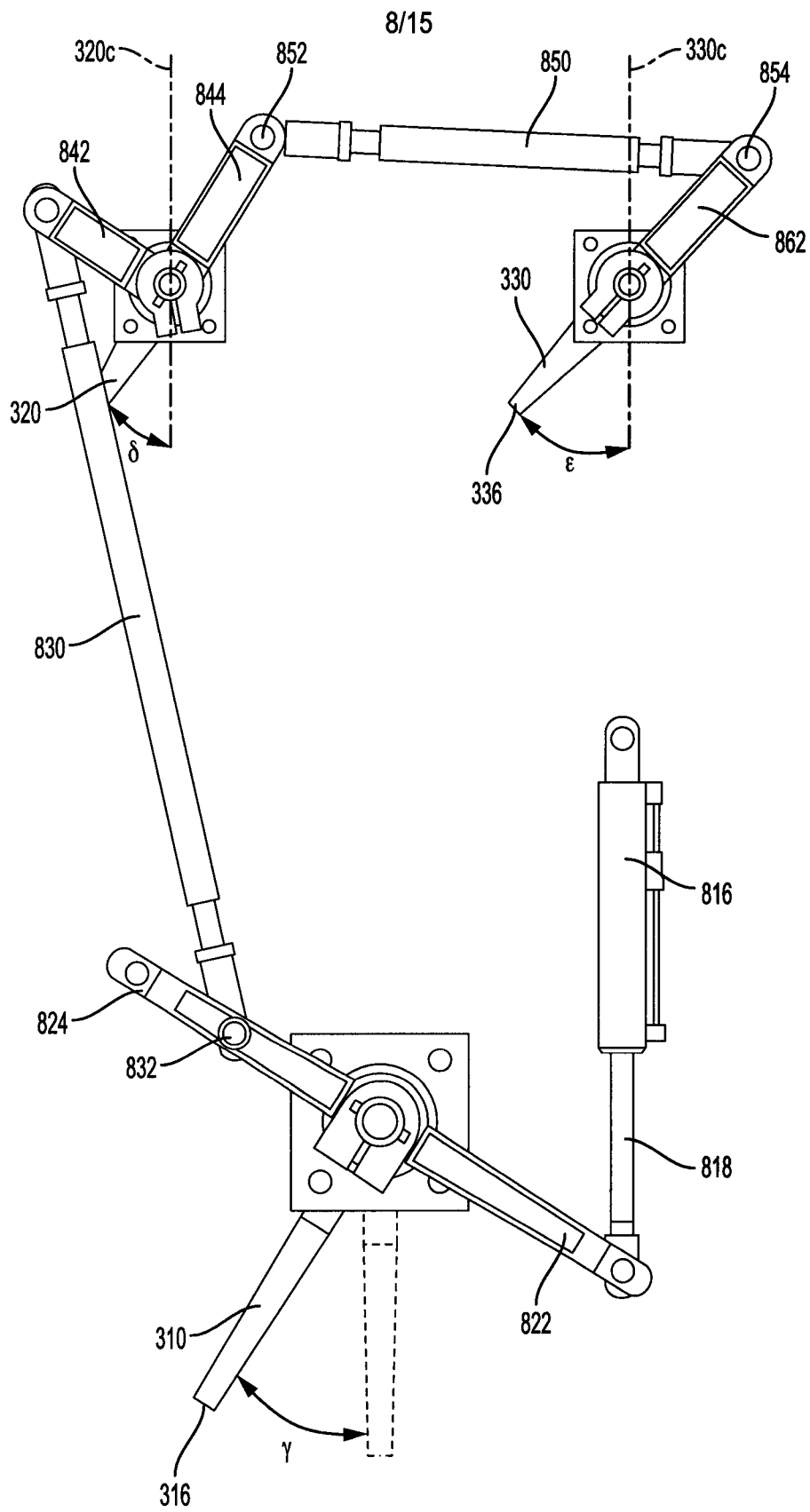


FIG. 9

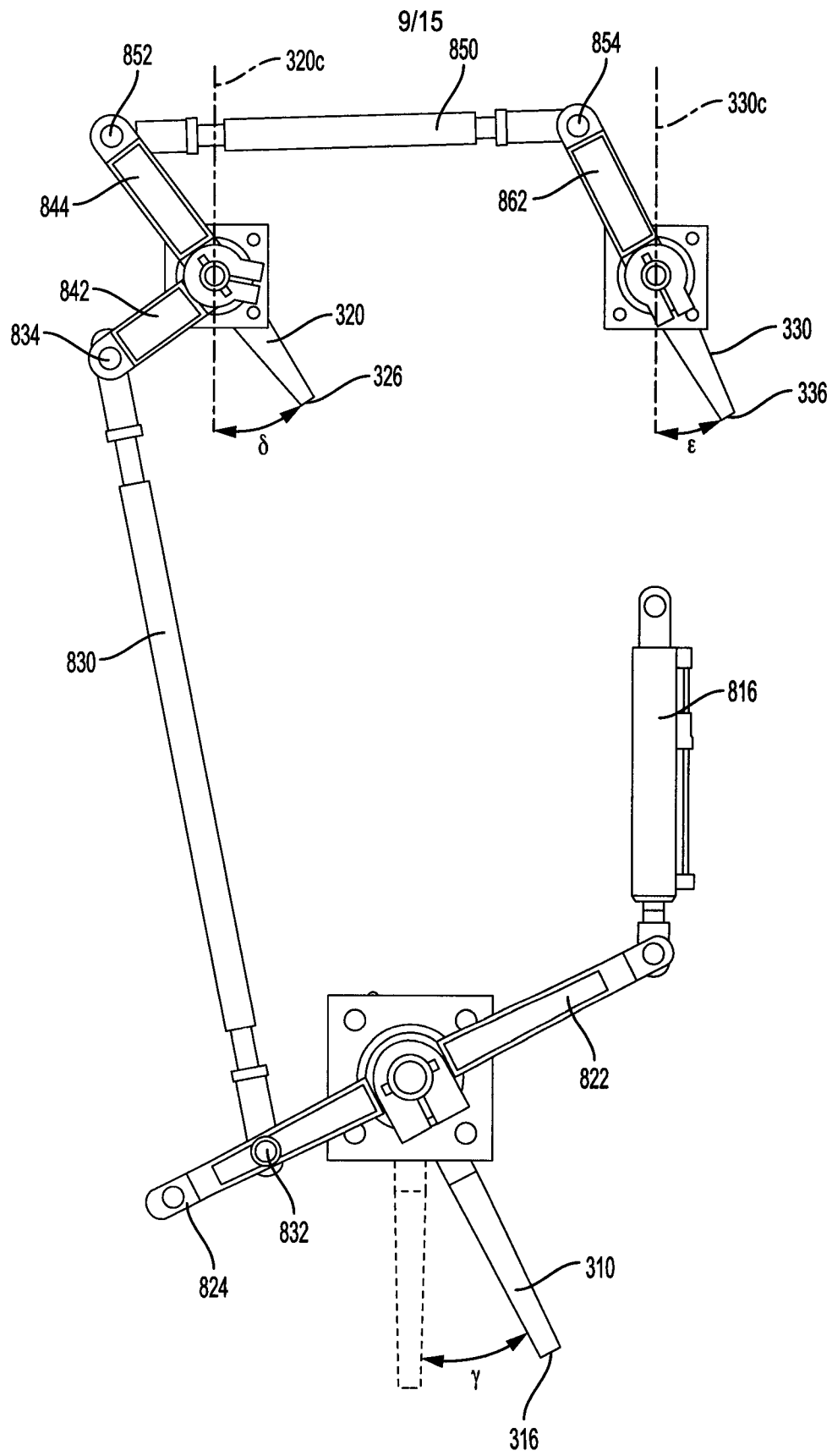


FIG. 10

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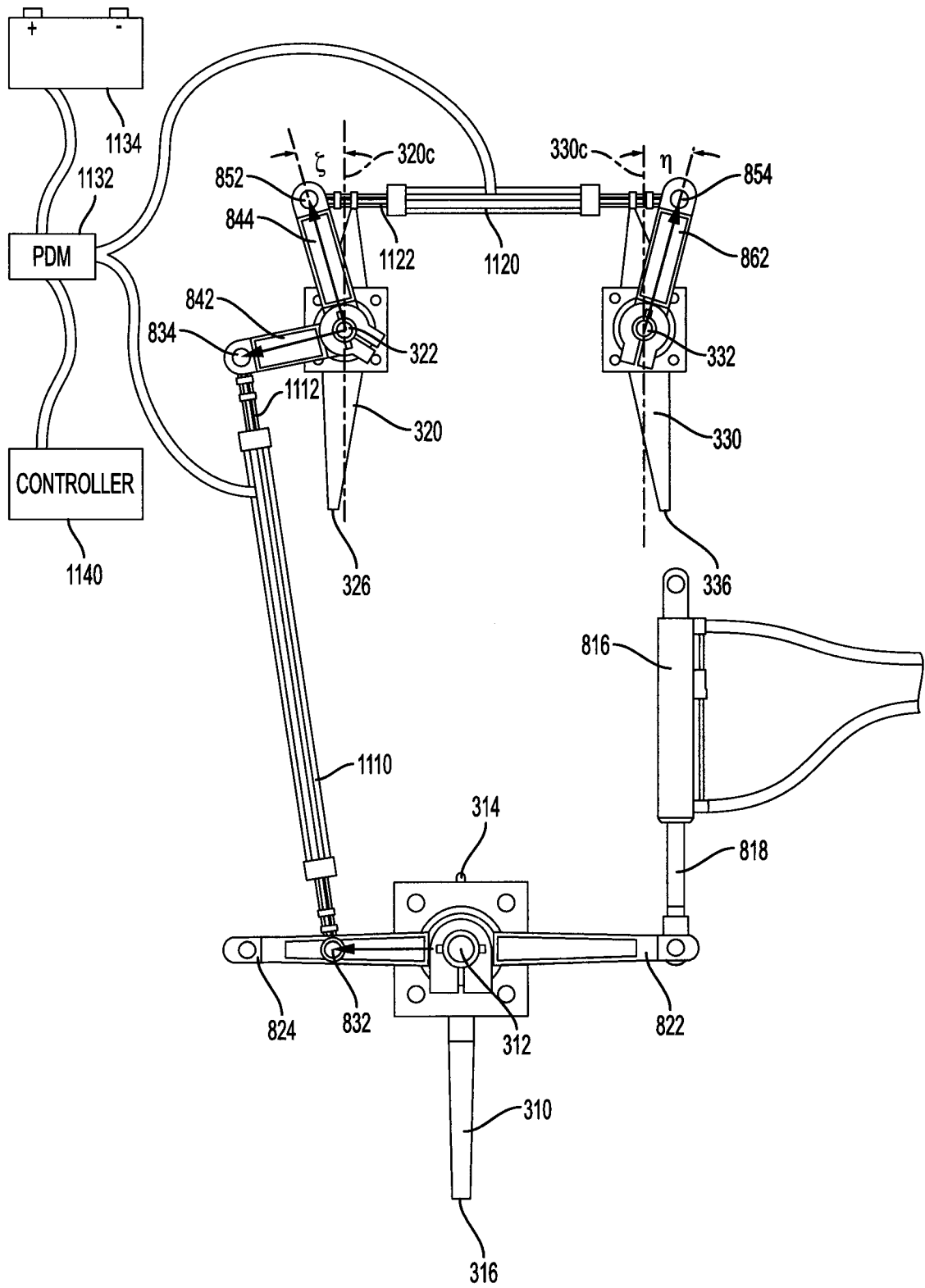


FIG. 11

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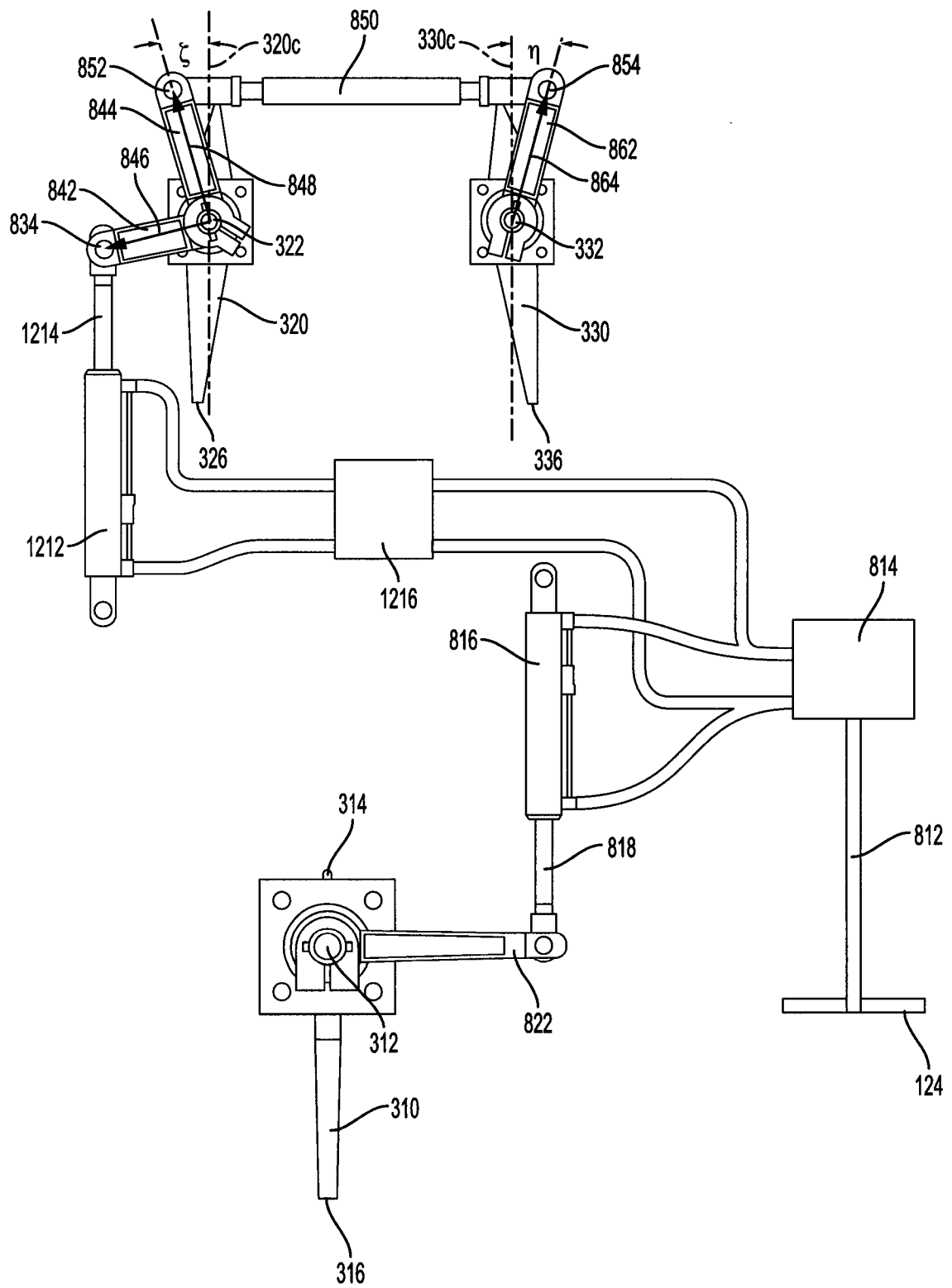


FIG. 12

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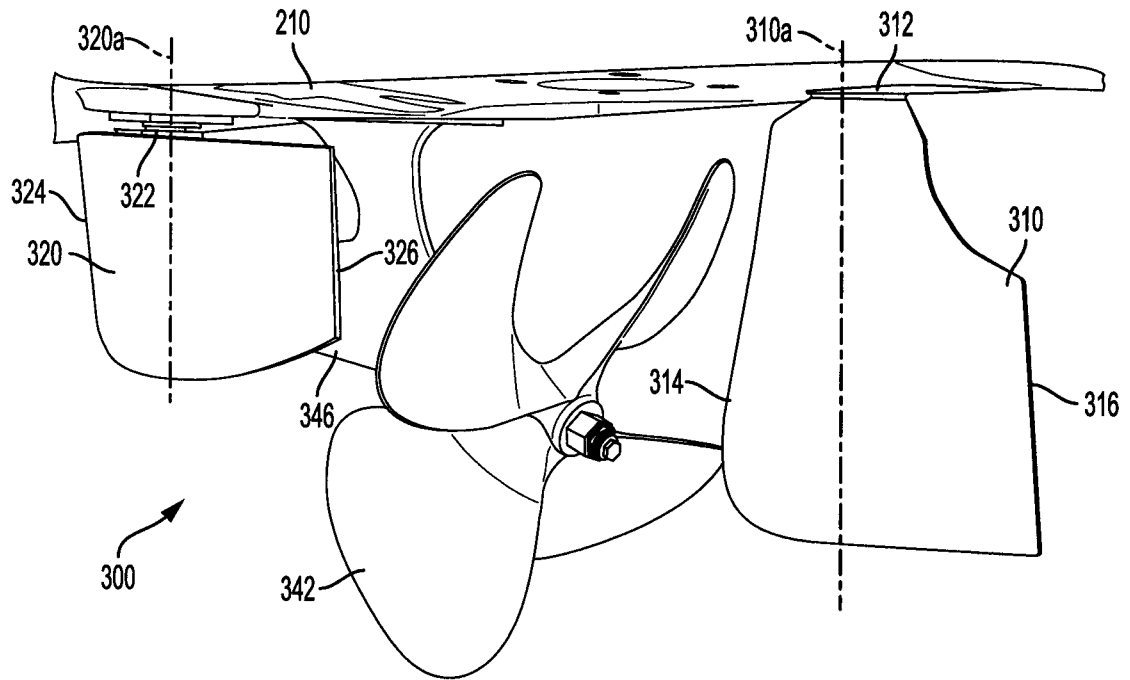


FIG. 13

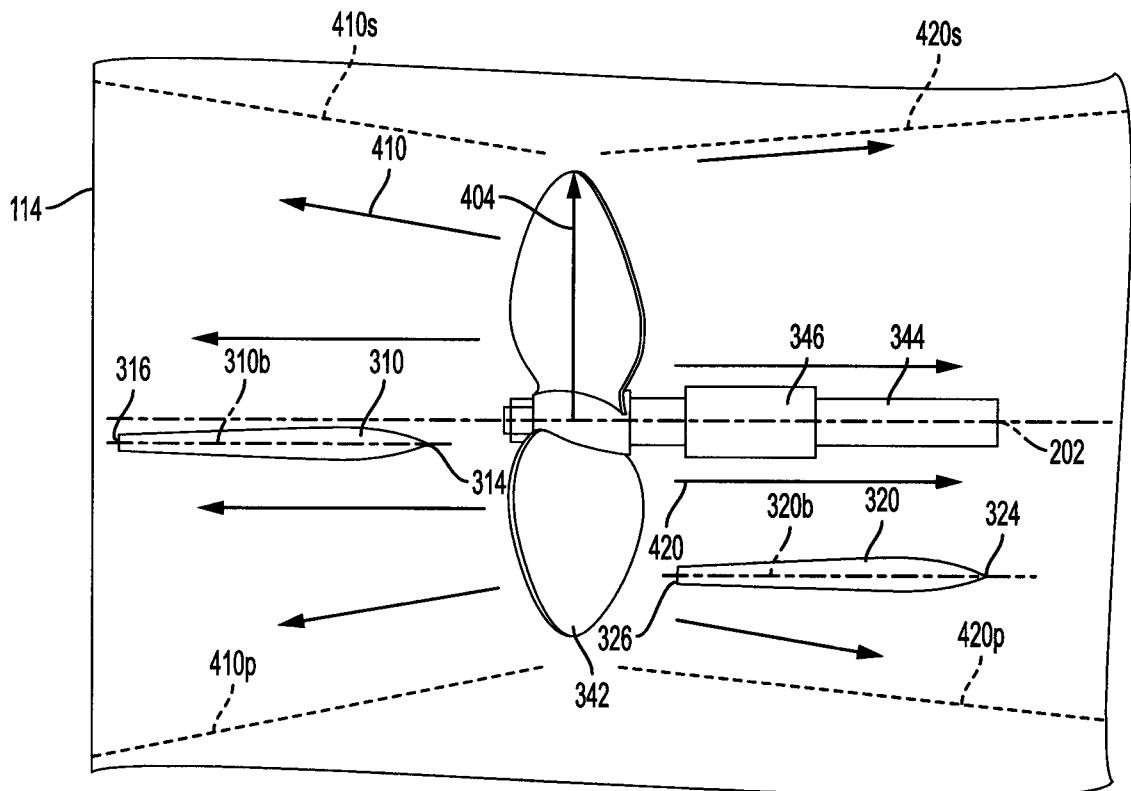


FIG. 14

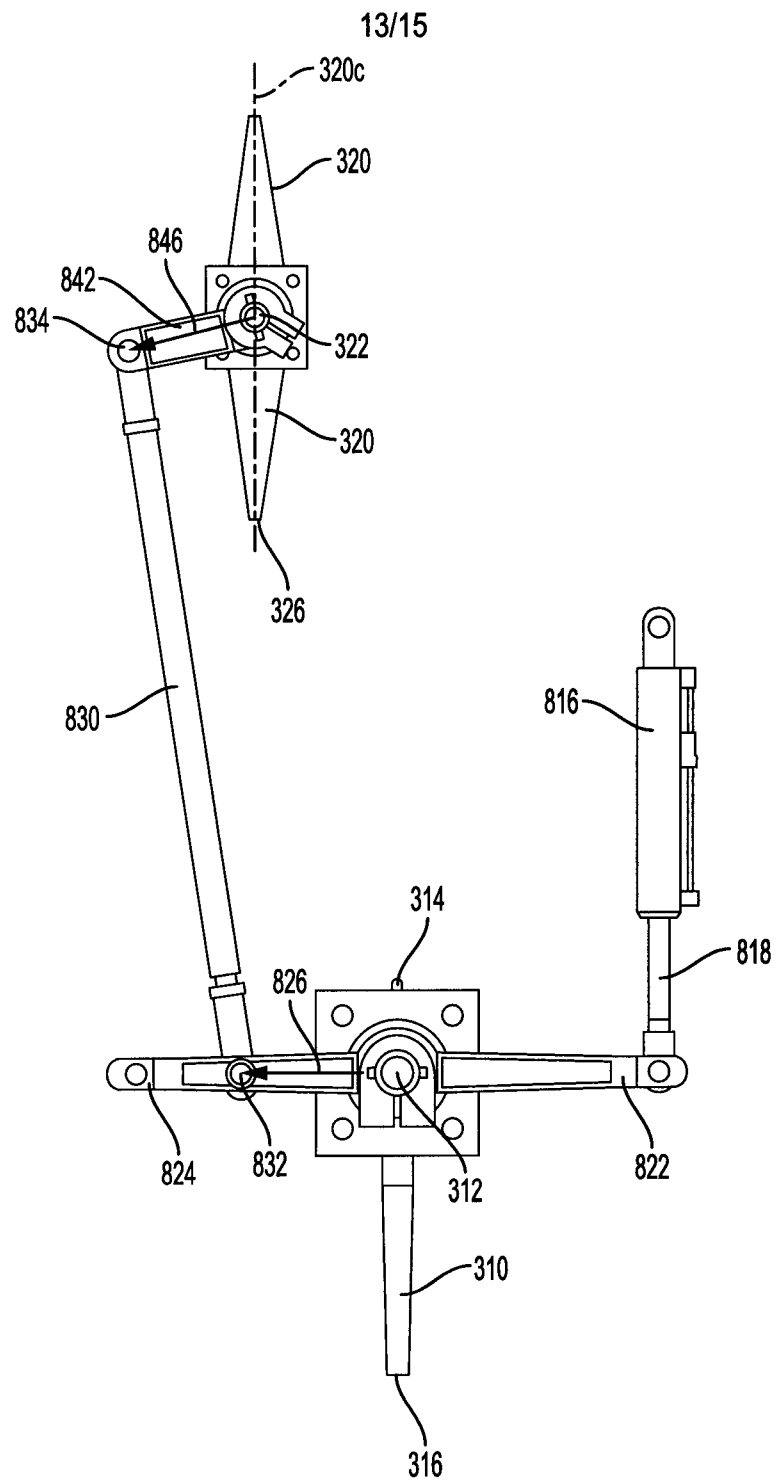


FIG. 15

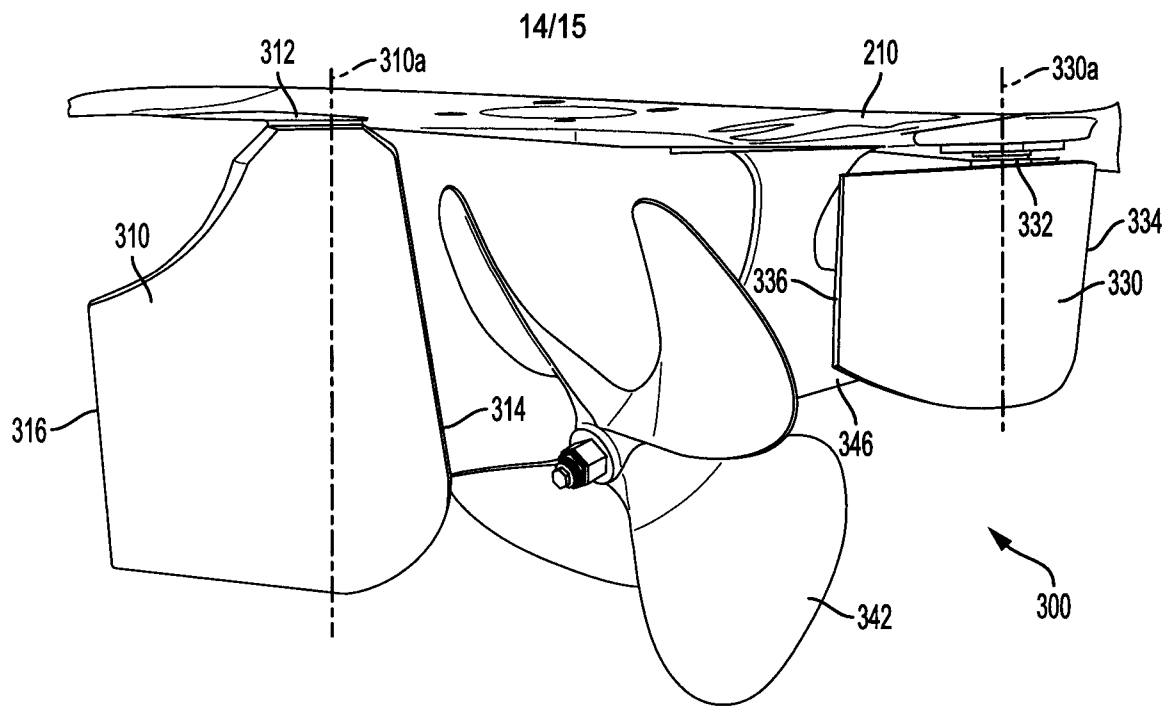


FIG. 16

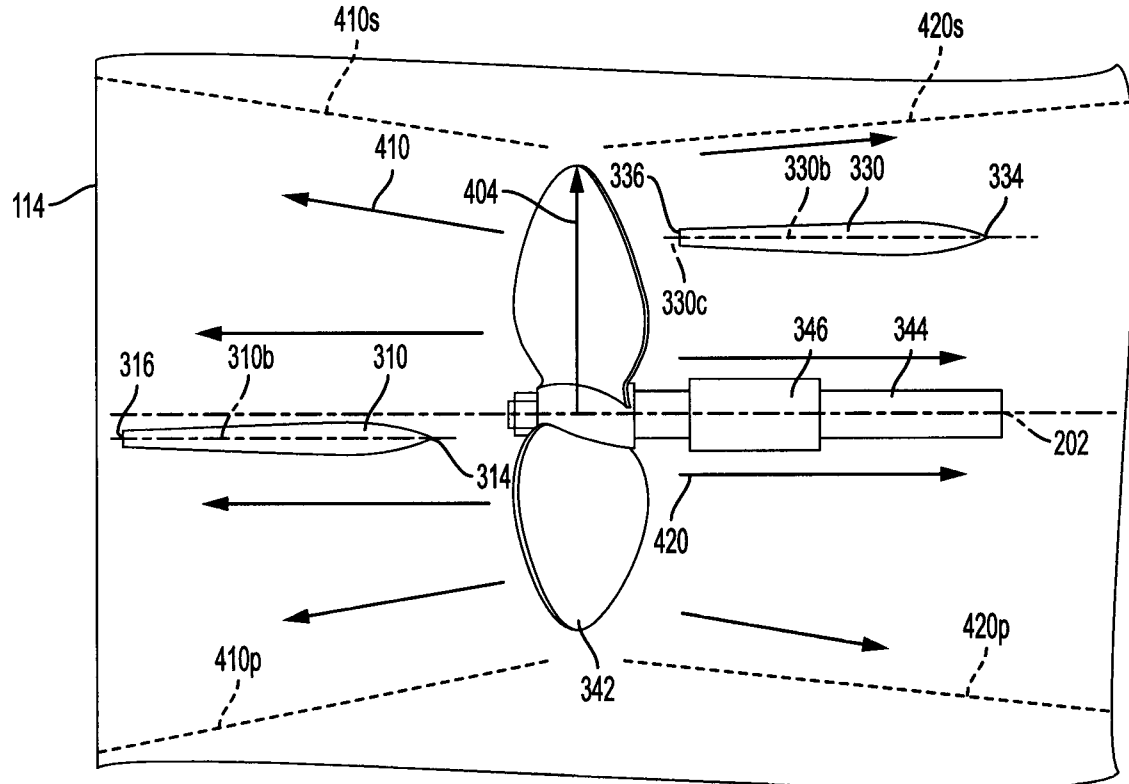


FIG. 17

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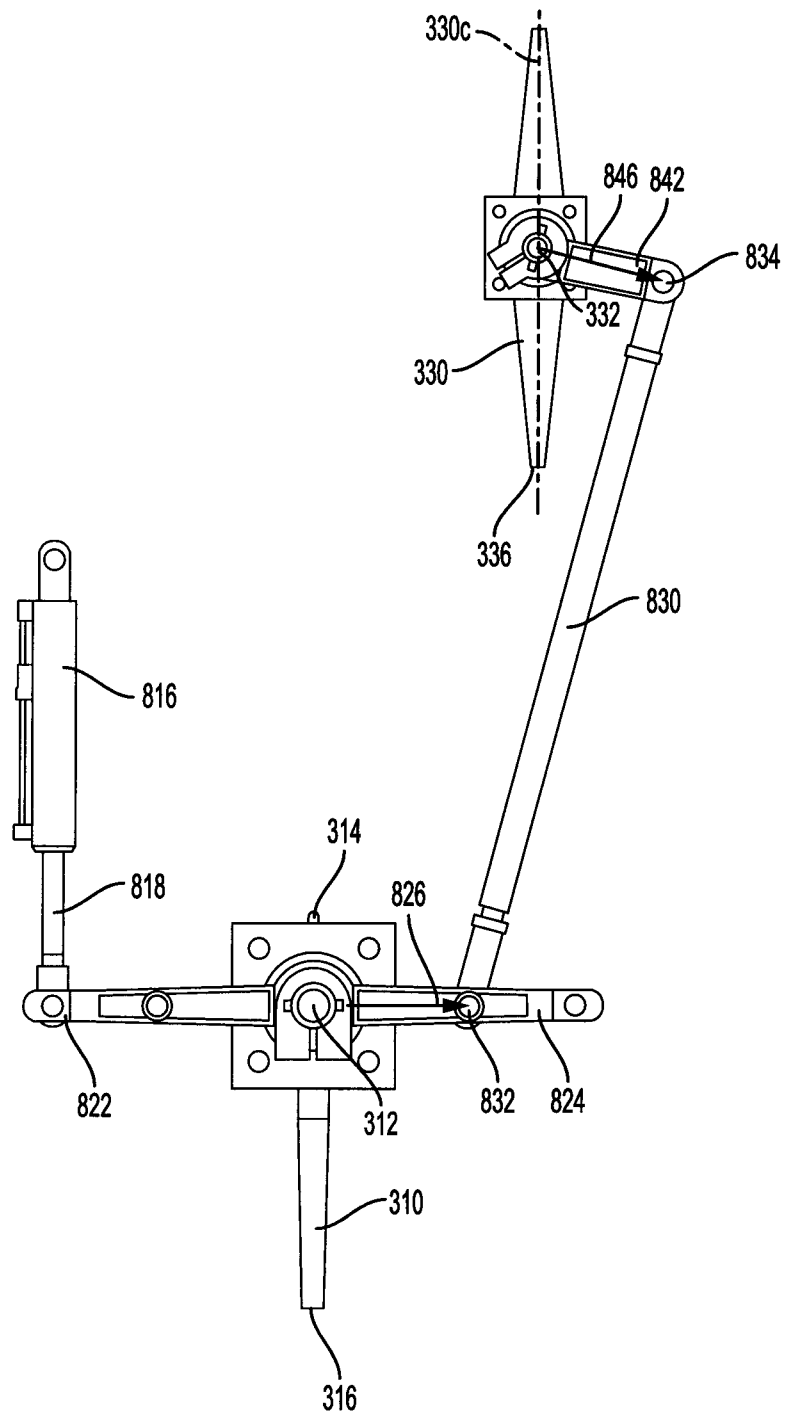


FIG. 18

