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(54) Bi-directional self-inflating tire with pressure regulator

(57) A self-inflating tire (12) is disclosed having a tire cavity (40), first and second sidewalls (15) extending respectively from first and second tire bead regions to a tire tread region and a first and second air passageway (43, 44) each having an inlet end (42, 48) and an outlet end (46, 52), each air passageway outlet end (46, 52) being in fluid communication with the tire cavity (40). The tire (12) further comprises a regulator device (300) having a regulator body (310) having an interior chamber (320) and a pressure membrane (550) mounted on the regulator device (300). The regulator body (310) has a first, second and third, preferably flexible duct (350, 360, 370), wherein the first, second and third ducts (350, 360, 370) each have an internal passageway (352, 362, 372), wherein the third, preferably flexible duct (370) has a first end in fluid communication with the outside air and a second end in fluid communication with the interior chamber (320) of the regulator device (300), wherein the first, preferably flexible duct (350) has a first end (354) in fluid communication with the inlet end (42) of the first air passageway (43), and a second end in fluid communication with the outlet port (330) of the regulator device (300), and wherein the second, preferably flexible duct (370) has a first end in fluid communication with the inlet end (48) of the second air passageway (44) and a second end in fluid communication with the outlet port (330) of the regulator device (300).

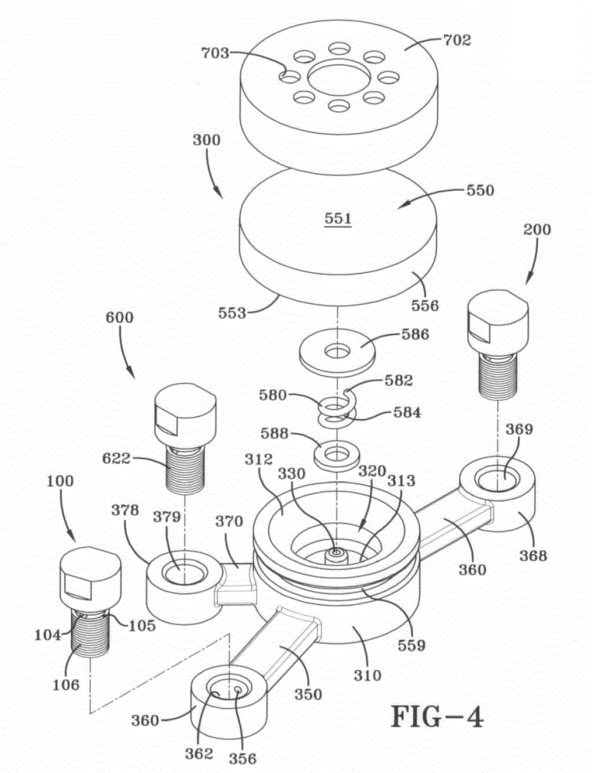


FIG-4

EP 2 886 373 A2

Description

Field of the Invention

[0001] The invention relates generally to self-inflating tires and, more specifically, to a pump mechanism and pressure regulator for such tires.

Background of the Invention

[0002] Normal air diffusion reduces tire pressure over time. The natural state of tires is under inflated. Accordingly, drivers must repeatedly act to maintain tire pressures or they will see reduced fuel economy, tire life and reduced vehicle braking and handling performance. Tire Pressure Monitoring Systems have been proposed to warn drivers when tire pressure is significantly low. Such systems, however, remain dependant upon the driver taking remedial action when warned to re-inflate a tire to recommended pressure. It is desirable, therefore, to incorporate a self-inflating feature within a tire that will self-inflate the tire in order to compensate for any reduction in tire pressure over time without the need for driver intervention.

Summary of the Invention

[0003] The invention relates to a self-inflating tire in accordance with claim 1.

[0004] Dependent claims refer to preferred embodiments of the invention.

[0005] The invention provides in a first preferred aspect a self-inflating tire assembly including a tire mounted to a rim, the tire having a tire cavity, first and second sidewalls extending respectively from first and second tire bead regions to a tire tread region; a first and second air passageway each having an inlet end and an outlet end, each air passageway being composed of a flexible material operative to open and close when the tire rotates, wherein each air passageway outlet end is in fluid communication with the tire cavity; a regulator device having a regulator body having an interior chamber; a pressure membrane being mounted on the regulator device to enclose the interior chamber, wherein the pressure membrane has a lower surface that is positioned to open and close the outlet port mounted in the interior chamber, wherein the pressure membrane is in fluid communication with the tire cavity pressure; wherein the body of the regulator device has a first, second and third flexible duct, wherein said first, second and third flexible ducts each have an internal passageway; wherein the third flexible duct has a first end in fluid communication with the outside air, and a second end in fluid communication with the interior chamber of the regulator device, wherein the first flexible duct has a first end in fluid communication with the inlet end of the first air passageway, and a second end in fluid communication with the outlet port of the regulator device; wherein the second flexible duct has a first end in fluid communication with the inlet end of the second air passageway, and a second end in fluid communication with the outlet port of the regulator device.

Definitions

[0006] "Axial" and "axially" means lines or directions that are parallel to the axis of rotation of the tire.

[0007] "Chafer" is a narrow strip of material placed around the outside of a tire bead to protect the cord plies from wearing and cutting against the rim and distribute the flexing above the rim.

[0008] "Circumferential" means lines or directions extending along the perimeter of a surface, perpendicular to the axial direction.

[0009] "Equatorial Centerplane (CP)" means the plane perpendicular to the tire's axis of rotation and passing through the center of the tread.

[0010] "Footprint" means the contact patch or area of contact of the tire tread with a flat surface at zero speed and under normal load and pressure.

[0011] "Lateral" means an axial direction.

[0012] "Net contact area" means the total area of ground contacting tread elements between the lateral edges around the entire circumference of the tread divided by the gross area of the entire tread between the lateral edges.

[0013] "Peristaltic" means operating by means of wave-like contractions that propel contained matter, such as air, along tubular pathways.

[0014] "Radial" and "radially" means directions radially toward or away from the axis of rotation of the tire.

Brief Description of the Drawings

[0015] The invention will be described by way of example and with reference to the accompanying drawings in which:

FIG. 1 is an isometric view of tire and rim assembly showing a pump and regulator assembly.

Fig. 2A is a schematic of a double pump and regulator assembly.

FIG. 2B is a front view of the tire of Fig. 1 showing the system in operation.

Fig. 3 is a front view of the regulator assembly as shown from inside the tire of Fig. 1.

FIG. 4 is an exploded view of the regulator assembly.

Fig. 5 is a top view of the regulator assembly of Fig. 4.

Fig. 6A is a section view of Figure 5 in the direction 6A-6A showing the regulator in the closed position during operation.

Fig. 6B is a section view of Figure 5 in the direction 6A-6A showing the regulator in the open position during operation.

Fig. 7A is a section view of Figure 5 in the direction 7A-7A showing the regulator in the open position during operation when the tire is rotating in a first direction.

Fig. 7B is a section view of Figure 5 in the direction 7A-7A showing the regulator in the open position during operation when the tire is rotating in a first direction, and flow exiting the outlet valve from the pump air passageway.

Fig. 8A is a section view of Figure 5 in the direction 7A-7A showing the regulator in the open position during operation when the tire is rotating in a second direction opposite the first direction.

Fig. 8B is a section view of Figure 5 in the direction 7A-7A showing the regulator in the open position during operation when the tire is rotating in a second direction opposite the first direction, and flow exiting the outlet valve of the pump air passageway.

Detailed Description of Example Embodiments of the Invention

[0016] Referring to FIGS. 1 and 2, a tire assembly 10 is shown. The assembly includes a tire 12 having a first and second pump assembly 14 and a tire rim 16. The tire further comprises a tire cavity 40. The tire cavity 40 is enclosed by the tire 12 and the rim 16 when the tire is mounted to the rim 16. As shown in FIGS. 1 and 3, the pump assembly 14 is preferably mounted into the sidewall area 15 of the tire, preferably near the bead region.

Pump Assembly 14

[0017] The first and second pump assembly 14 include a first and second air passageway 43, 44 which may be molded into the sidewall of the tire during vulcanization or formed post cure. Each passageway 43, 44 acts as a pump or a peristaltic pump. When the first and second air passageways 43, 44 are molded into the tire sidewall as shown in Figure 2B, and each of the air passageway 43, 44 has an arc length L as measured by a respective angle $\psi 1$, $\psi 2$ that is measured from the center of rotation of the tire. In a first embodiment, the angle $\psi 1$, $\psi 2$ may range, and is preferably in the range of at least 150 degrees, and more preferably in the range of from 150 to 190 degrees or 150 to 170 degrees or about 160 degrees as shown. The air passageway 43, 44 comprises a tube body formed of a resilient, flexible material such as plastic, elastomer or rubber compounds, and is capable of withstanding repeated deformation cycles when the tube is deformed into a flattened condition subject to external force and, upon removal of such force, returns to an original condition preferably generally circular or elliptical in cross-section. The tube is of a diameter sufficient to operatively pass a volume of air sufficient for the purposes described herein and allowing a positioning of the tube in an operable location within the tire assembly as will be described. In one embodiment, the tube has a circular cross-sectional shape, although other shapes such as elliptical may also be utilized. The tube may be a discrete tube that is inserted into the tire during tire manufacturing, or the tube may be molded into shape by the presence of a removable strip that forms the passageway when removed.

[0018] As shown in Figure 2A, an inlet filter assembly 600 is connected to a regulator assembly 300 for providing inlet filtered air to the regulator assembly 300. The regulator assembly is connected to the inlet end 42 of the first pump passageway 43 preferably via an inlet banjo fitting 100. The first pump passageway has an outlet end 46 that is connected to an outlet check valve 400. The regulator assembly is connected to the inlet end 48 of a second pump passageway 44 preferably via a banjo fitting 200. The second pump passageway 44 has an outlet end 52 connected to an outlet check valve 500.

Regulator Device

[0019] A regulator device 300 is shown in Figures 3-8. The regulator device 300 functions to regulate the flow of air to the air passageways 43, 44. The regulator device 300 has a central regulator housing or regulator body 310 that houses an interior chamber 320. The interior chamber 320 has a central opening 312. Opposite the central opening 312 is an outlet port 330. The outlet port is preferably raised from the bottom surface 313 and extends into the interior of the chamber 320. The outlet port is positioned to engage a pressure membrane 550.

[0020] The pressure membrane has an upper surface 551 that is preferably substantially planar. Preferably, the pressure membrane has a lower surface 553 wherein a plug 555 extends from the lower surface. The pressure membrane further has a preferably annular sidewall 556 which extends downwardly from the upper surface, forming a lip 557. The lip 557 is preferably annular, and snaps in an annular cutout 559 formed on the outer regulator housing 310. The pressure membrane is preferably a disk shaped member made of a flexible material such as rubber, elastomer, plastic or silicone. A rigid lid 700 is received over the pressure membrane. The lid 700 preferably has a plurality of holes 703 on an upper surface 702 to allow the outer surface 551 of the pressure membrane to be in fluid communication with the pressure of the tire chamber 40. The outer surface 551 of the pressure membrane is in fluid communication with the pressure of the tire chamber 40 and in contact with the rigid lid 600. The lower surface 553 of the pressure membrane is in fluid communication with the interior chamber 320. The plug 555 is positioned to close the outlet port 330 as shown in Fig 6A. A spring 580 is positioned in the interior chamber 320 to bias the pressure membrane 550 in the open position. The spring preferably has a first end 582 that is received about the plug 555. The spring preferably has a second end 584 that is wrapped around the outer surface of the outlet port 330. An optional first washer 586 may be received between the spring first end 582 and the pressure membrane 550. An optional second washer 588 may be received between the spring second end 584 and the bottom of the chamber 313. The lid 700 is preferably made of a rigid material and resists the spring force, thus functioning to preload the spring via the pressure membrane 550. Thus the balance of pressure forces on each side of the pressure membrane actuates the pressure membrane plug 555 to open and close the outlet port 330.

[0021] Extending from the central regulator housing 310 is a first, second and third, preferably flexible duct 350, 360, 370 positioned on either side of the central regulator housing 310. Each flexible duct 350, 360, 370 may be integrally formed with the regulator housing as shown, or be a discrete part connected to the central regulator housing 310. Each duct 350, 360, 370 has an internal passageway 352, 362, 372 for communicating fluid.

[0022] As shown in Figure 7A, the internal passageway 352 of the first flexible duct 350 has a first end 354 that is connected to the outlet port 330. The first flexible duct 350 has a preferably circular flanged distal end 360 having a hole 362 for receiving the body of the inlet banjo fitting 100. The internal passageway 352 has an outlet hole 356 that is in fluid communication with inlet holes 104 of an inlet banjo fitting 100. A circumferential groove 105 surrounds the inlet holes 104 to channel the fluid from the internal passageway 352 to an internal passageway 102. The internal channel 102 is connected to the inlet 48 of the pump passageway 44. The banjo fitting 100 may be replaced with an internally relieved bolt or a hollow screw with an internal passageway. The banjo fitting 100 has an outer threaded surface 106 that is received in the tire sidewall.

[0023] As shown in Fig. 7A, the internal passageway 362 of the second flexible duct 360 is shown connected to the outlet port 330 of the interior chamber 320 and the internal passageway 352 of the first flexible duct 350. The internal passageway 362 has an outlet 364 in fluid communication with a banjo fitting 200. The second flexible duct has a distal end formed in a preferably circular flange 368. The circular flange has a hole 369 for receiving the body of banjo fitting 200. The banjo fitting 200 has an internal passageway 202 with inlet holes 204 that receive flow from the outlet hole 364 of the internal passageway 362 of the second flexible duct 360. The internal passageway 202 communicates flow to the inlet end 42 of the first pump passageway 43. The banjo fitting 200 may comprise a screw with an internal passageway, and has an outer threaded surface 206 that is received in the tire sidewall.

[0024] As shown in Figs. 5 and 6A, the internal passageway 372 of the third flexible duct 370 has a first opening 374 that is connected to the outlet port 642 of the inlet filter assembly 600. The internal passageway 372 of the first flexible duct 370 has a second end 376 that opens to the inlet chamber 320 of the regulator 300. The third flexible duct has a preferably circular flanged distal end 378 that has an interior hole 379 for receiving the inlet filter assembly 600.

<u>Inlet Filter Assembly</u>

[0025] The inlet filter assembly 600 is shown in Figures 6A, 6B. The inlet filter assembly 600 includes an insert sleeve 612 that is hollow and has an internal threaded bore 614. The first end of the insert sleeve 612 is inserted into the tire, typically in the outer surface of the sidewall 15. The insert sleeve 612 may be inserted into the tire post cure or may be molded into the tire. An air passage screw 620 has an outer threaded body 622 that is screwed into the second end 624 of the insert sleeve. The air passage screw 620 may be a banjo screw or an internally relieved bolt. The air passage screw 620 has an internal passageway 630 in fluid communication with the bore 614 of the insert sleeve 612. A filter 640 is received within the bore 614 of the insert sleeve 612, and may also be located in the internal passageway 630. The internal passageway 630 has outlet ports 642 that communicates filtered air from the internal passageway 630 to the inlet 374 of the internal passageway 372 of the third flexible duct 370. The internal passageway 372 communicates filtered air to the inlet chamber 320.

<u>Pump outlet check valve</u>

[0026] The outlet end 46 of the pump passageway 43 is connected to a pump outlet valve 400. The pump outlet valve is shown in Figures 7A-B. The pump outlet valve 400 includes a valve body 410 having an outer threaded surface 412 that is mounted within the sidewall of the tire. The valve body 410 has a central passage 415 that has a first opening 418 that is in fluid communication with the first pump passageway 43 outlet end 46. The central passage 415 has an outlet end 417 that communicates flow to the tire cavity 40. The outlet end 417 is covered by a flexible sleeve 419. The flexible member 419 opens to allow airflow to exit the pump and into the tire cavity 40 as shown in Figure 7b. The flexible member is shown closed in Figure 7A, and prevents flow of air from the tire cavity into the pump passageway 43.

[0027] The outlet end 52 of second pump passageway 44 is also connected to a pump outlet valve 500, as shown in Figures 8A, 8B. The pump outlet valve 500 includes a valve body 510 having an outer threaded surface 512 that is received within the sidewall of the tire. The valve body 510 has a central passage 515 that has a first opening 518 that is in fluid communication with the pump passageway 44 outlet end 52. The central passage 515 has an outlet end 517 that is covered by a flexible member 519. The flexible sleeve 519 opens to allow airflow to exit the pump and into the tire cavity 40 as shown in Figure 8b. The flexible member is shown closed in Figure 8A, and prevents back flow of air from the tire cavity into the pump passageway 44.

<u>System Operation</u>

[0028] Figures 1-2 illustrate the first and second pump assemblies 43, 44. The system is bidirectional, so that only one pump assembly will pump for a given tire direction. Thus, if the tire rotates clockwise as viewed from Fig. 2B, pump air passageway 44 will pump air into the tire. When the tire rotates counterclockwise, pump air passageway 43 will pump air into the tire. As shown in FIGS. 2A and 2B, the regulator device 300 is in fluid communication with each inlet end 42, 48 of each pump passageway 43, 44. As the tire 12 rotates, a footprint is formed against the ground surface. A compressive force F is directed into the tire from the footprint and acts to flatten the pump passageway 43, 44. Flattening of the pump passageway 43, 44 forces the compressed air towards the respective pump outlet device 400, 500. Due to the increase in pressure at the pump outlet 46, 52, the pressure opens the sleeve 419, 519 from the opening 417, 517 of the pump outlet valve, which allows the pumped air to exit into the tire cavity 40.

[0029] The regulator device 300 controls the inflow of outside air into the pump. If the tire pressure is above the preset threshold value, the plug 555 of the pressure membrane seals the central outlet port 330 and no air enters the pump passageway, as shown in Figure 6A. The pressure preset threshold value can be predetermined based upon the tire size, and the material properties of the pressure membrane, spring preloading, and spring constant can be selected to determine the pressure at the preset threshold value. If the tire pressure falls below the preset threshold value, the plug 555 of the membrane 550 will unseat from the central outlet port 330, opening the outlet port 330 as shown in Fig 6B. As the chamber pressure 320 falls due to the opening of the central outlet port 330, outside air will be sucked through the filter assembly 600 to the interior chamber 320. If the tire rotates in a clockwise direction as shown in Figs 8A and 8B, the filtered air exits the interior chamber through the outlet port 330, and enters the first flexible duct 360. Then the filtered air passes through the banjo fitting 100 into the pump inlet 48, as shown in Fig 8A. The flow is then compressed through the pump passageway 44 and then exits the pump outlet valve 400 into the tire cavity 40 as shown in fig 8B. The pump will pump air with each tire rotation. The pump passageway 44 fills with air when the pump system is not in the footprint.

[0030] If the tire rotates in a counterclockwise direction as shown in Figs 7A and 7B, the filtered air exits the interior chamber 320 through the outlet port 330, and enters the second flexible duct 360 then through the banjo fitting 200 and then into the pump inlet 42. The flow is then compressed through the pump passageway 43 and then exits the pump outlet valve 400 into the tire cavity 40. The pump will pump air with each tire rotation. The pump passageway 43 fills with air when the pump system is not in the footprint.

[0031] The location of the pump assembly in the tire will be understood from FIGS. 1, 2A and 3. In one embodiment, the pump assembly 14 is positioned in the tire sidewall, radially outward of the rim flange surface. So positioned, the air passageway 43, 44 is radially inward from the tire footprint and is thus positioned to be flattened by forces directed from the tire footprint as described above. Although the positioning of the air passageway 43, 44 is specifically shown in a region of the tire near the bead region, it is not limited to same, and may be located at any region of the tire that undergoes cyclical compression. The cross-sectional shape of the air passageway 43, 44 may be elliptical or round or any desired shape.

[0032] The length as represented by the angle Ψ of each pump passageway is illustrated at about 160 degrees, the invention is not limited to same, and may be shorter or longer as desired.

[0033] The pump assembly 14 may also be used with a secondary tire pressure monitoring system (TPMS) (not shown) of conventional configuration that serves as a system fault detector. The TPMS may be used to detect any fault in the self-inflation system of the tire assembly and alert the user of such a condition.

Claims

1. A self-inflating tire having
a tire cavity (40) and first and second sidewalls (15) extending respectively from first and second tire bead regions to a tire tread region;
a first and second air passageway (43, 44) each having an inlet end (42, 48) and an outlet end (46, 52), wherein each air passageway is composed of or established by a flexible material and is operative to open and close when the tire (12) rotates in contact with a contact area under its standard load and normal pressure, and wherein each air passageway outlet end (46, 52) is in fluid communication with the tire cavity (40); and
a regulator device (300) having a regulator body (310) having an interior chamber (320) and a pressure membrane (550) mounted on the regulator device (300) to at least partially enclose the interior chamber (320), wherein the pressure membrane (550) has a lower surface (553) that is positioned to open and close an outlet port (330) mounted in the interior chamber (320), and wherein the pressure membrane (550) is in fluid communication with tire cavity pressure;
wherein the regulator body (310) of the regulator device (300) has a first, second and third, preferably flexible duct (350, 360, 370), wherein the first, second and third ducts (350, 360, 370) each have an internal passageway (352, 362, 372), wherein the third, preferably flexible duct (370) has a first end in fluid communication with the outside air and a second end in fluid communication with the interior chamber (320) of the regulator device (300), wherein the first, preferably flexible duct (350) has a first end (354) in fluid communication with the inlet end (42)

of the first air passageway (43), and a second end in fluid communication with the outlet port (330) of the regulator device (300), and wherein the second, preferably flexible duct (370) has a first end in fluid communication with the inlet end (48) of the second air passageway (44) and a second end in fluid communication with the outlet port (330) of the regulator device (300).

2. The self-inflating tire of claim 1, wherein a spring (580) is positioned in the interior chamber (320) and wherein the spring (580) is configured to bias the pressure membrane (550) into an open position.

3. The self-inflating tire of claim 1 or 2, wherein the first air passageway (43) and/or the second air passageway (44) is located in the sidewall (15) of the tire (12).

4. The self-inflating tire assembly of at least one of the previous claims, wherein the outlet port (330) of the regulator device (300) is connected to the second end of the first duct (350).

5. The self-inflating tire assembly of at least one of the previous claims, wherein the outlet port (330) of the regulator device (300) is connected to the second end of the second duct (360).

6. The self-inflating tire assembly of at least one of the previous claims, wherein the regulator body (310) is not directly mounted in the tire (12).

7. The self-inflating tire assembly of at least one of the previous claims, wherein the regulator device (300) further comprises an inlet filter assembly (600).

8. The self-inflating tire assembly of claim 7, wherein the inlet filter assembly (600) is in fluid communication with the first end of the third duct (370).

9. The self-inflating tire of at least one of the previous claims, wherein the first air passageway (43) and/or the second air passageway (44) is substantially circular or elliptical in cross-section.

10. The self-inflating tire of at least one of the previous claims, wherein the first air passageway (43) and/or the second air passageway (44) is positioned between a tire bead region and the rim tire mounting surface radially inward of the tire tread region.

11. The self-inflating tire at least one of the previous claims, wherein a check valve is located between the outlet end of the first air passageway (43) and the tire cavity (40) and/or wherein a check valve is located between the outlet end of the second air passageway (44) and the tire cavity (40).

12. The self-inflating tire at least one of the previous claims, wherein the regulator device (300) is mounted to the inside of the tire (12) by a first and second banjo fitting (100, 200) which is affixed to the inside surface of the tire (12).

13. The self-inflating tire of claim 11 or 12 wherein at least one or both of the check valves has a flexible sleeve positioned for covering an outlet port of the respective check valve.

14. The self-inflating tire of claim 11, 12 or 13 wherein at least one or both of the check valves has a flexible sleeve positioned for covering an outlet port of the respective check valve.

15. A self-inflating tire assembly including a tire (12) in accordance with at least one of the previous claims mounted to a rim (16).

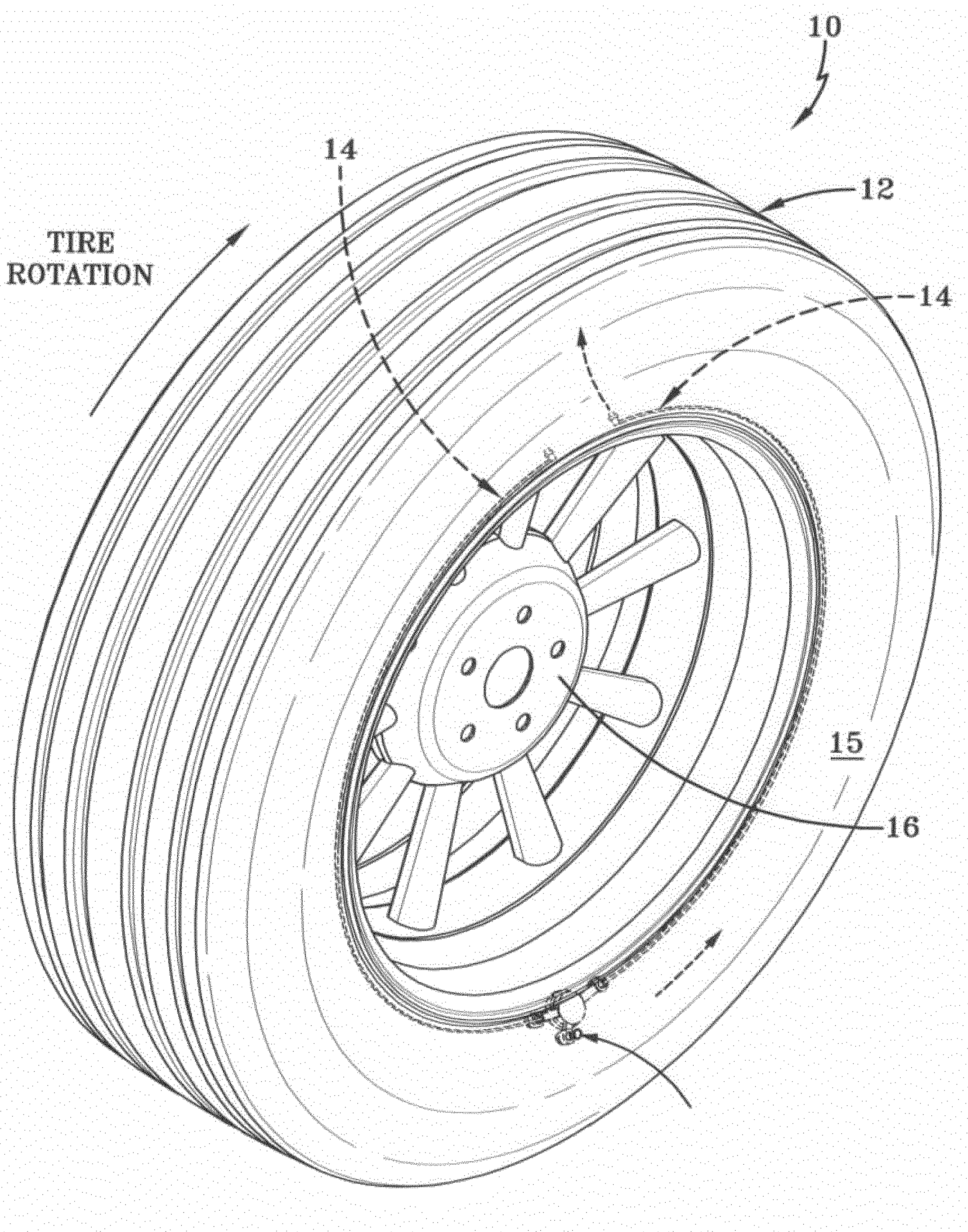
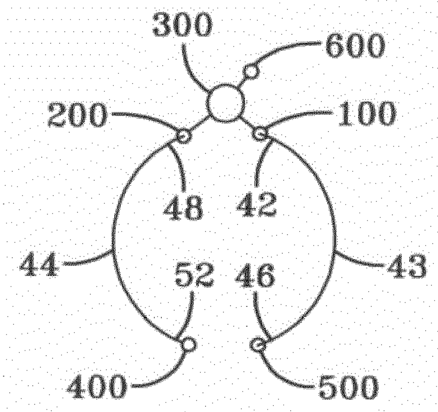


FIG-1


300
600
200
100
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42
44
43
52
46
400
500

FIG-2A

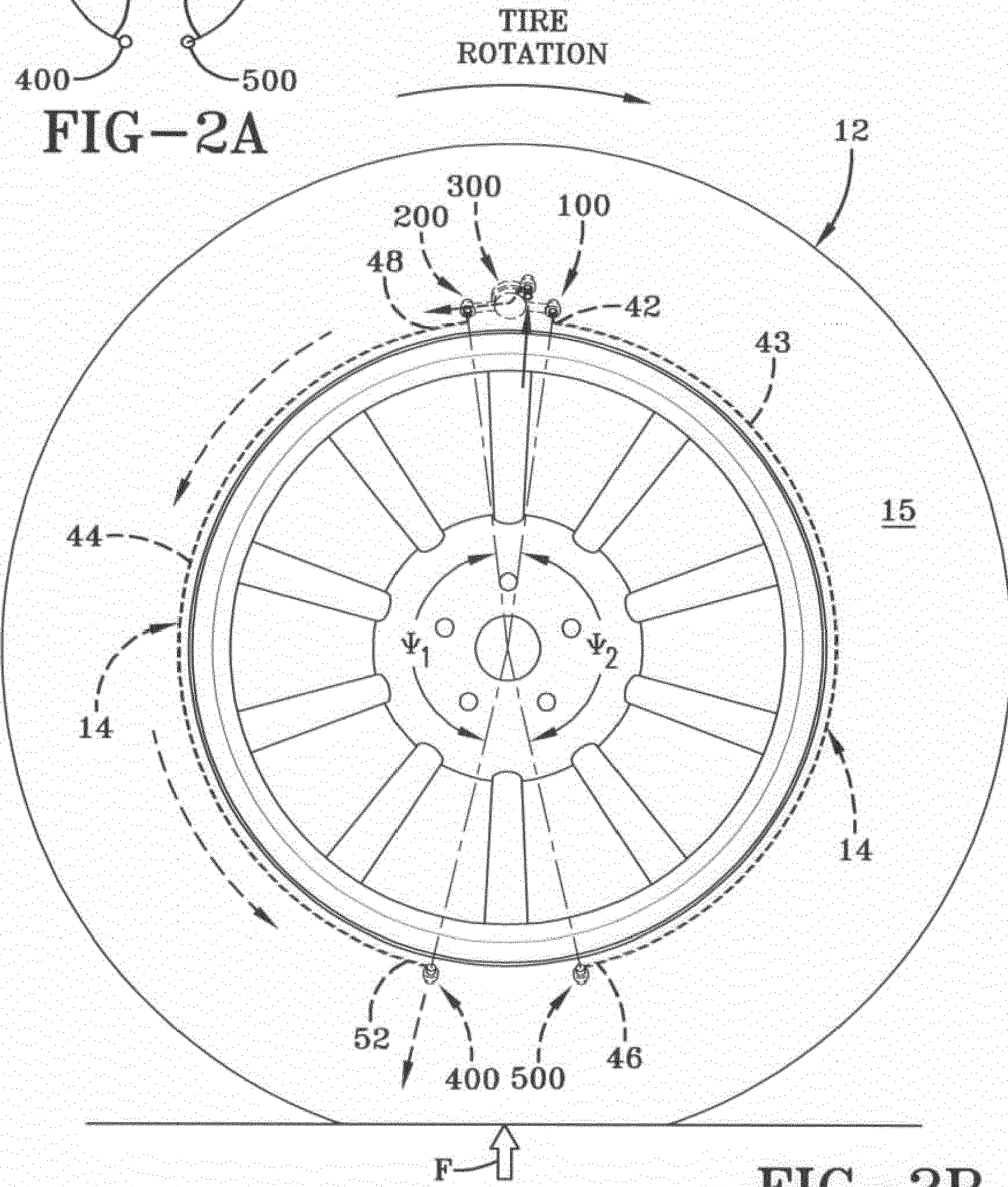

TIRE
ROTATION
12
300
200
100
48
42
43
15
44
14
Ψ1
Ψ2
14
52
400
500
46
F

FIG-2B

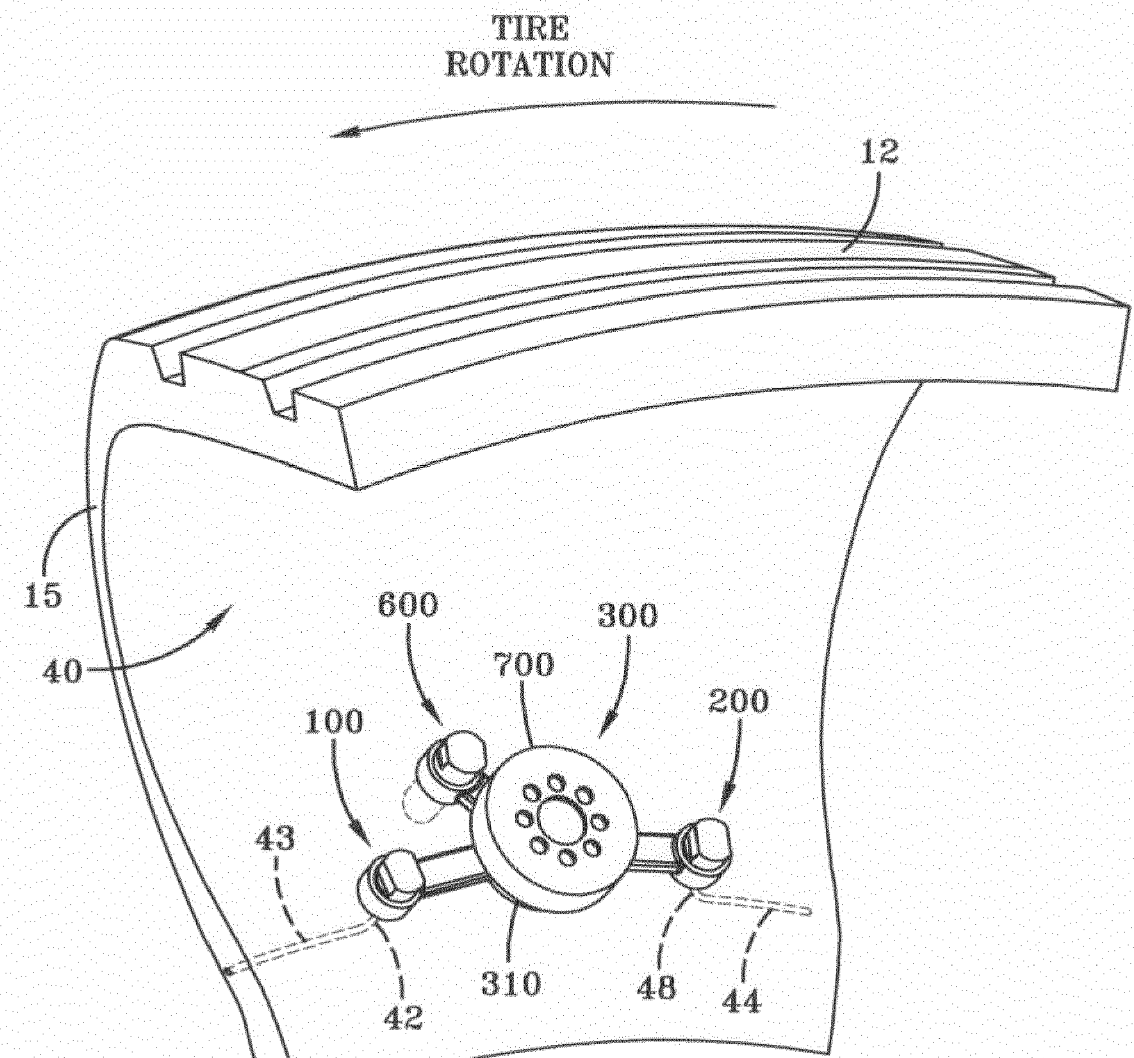
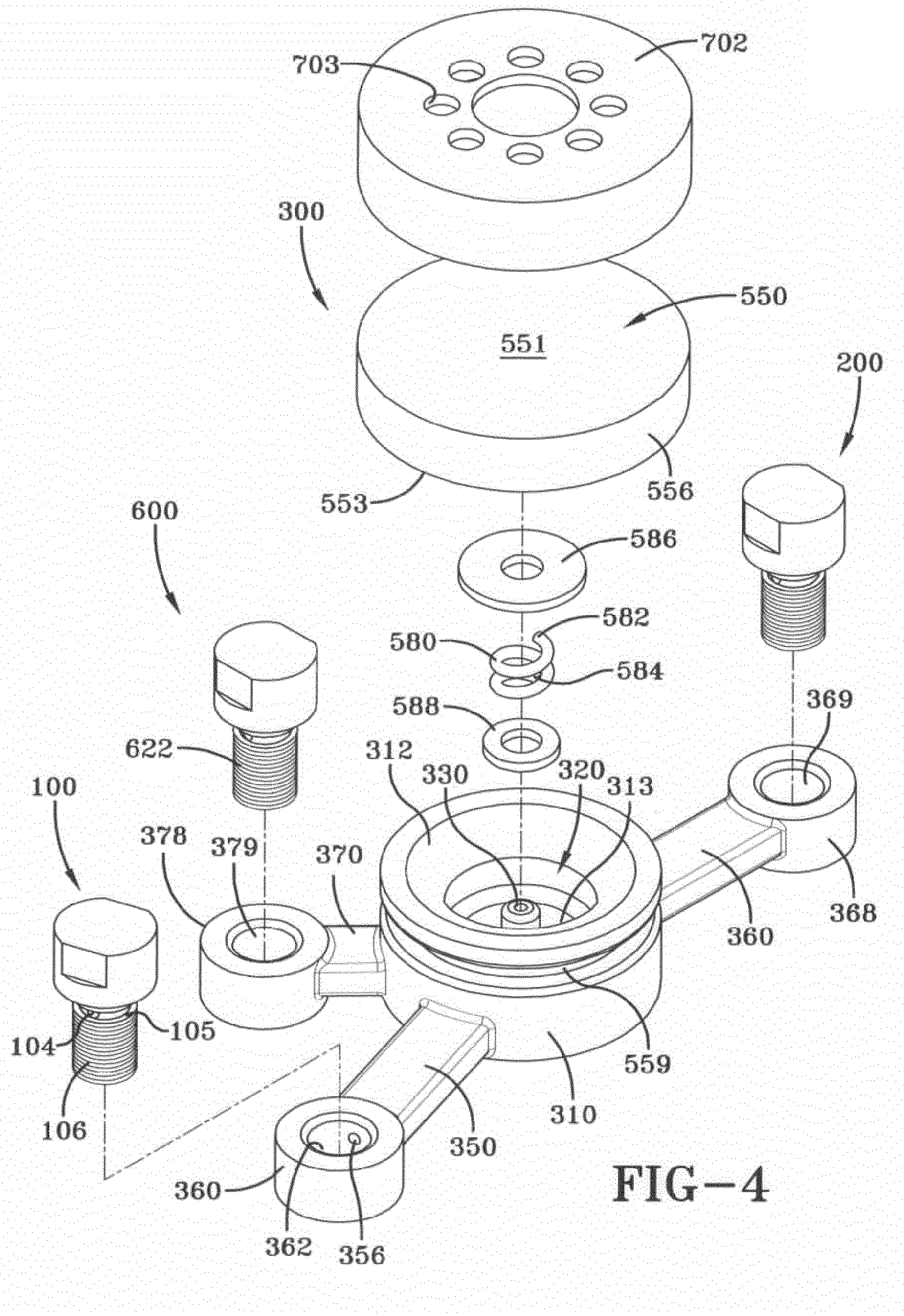


FIG-3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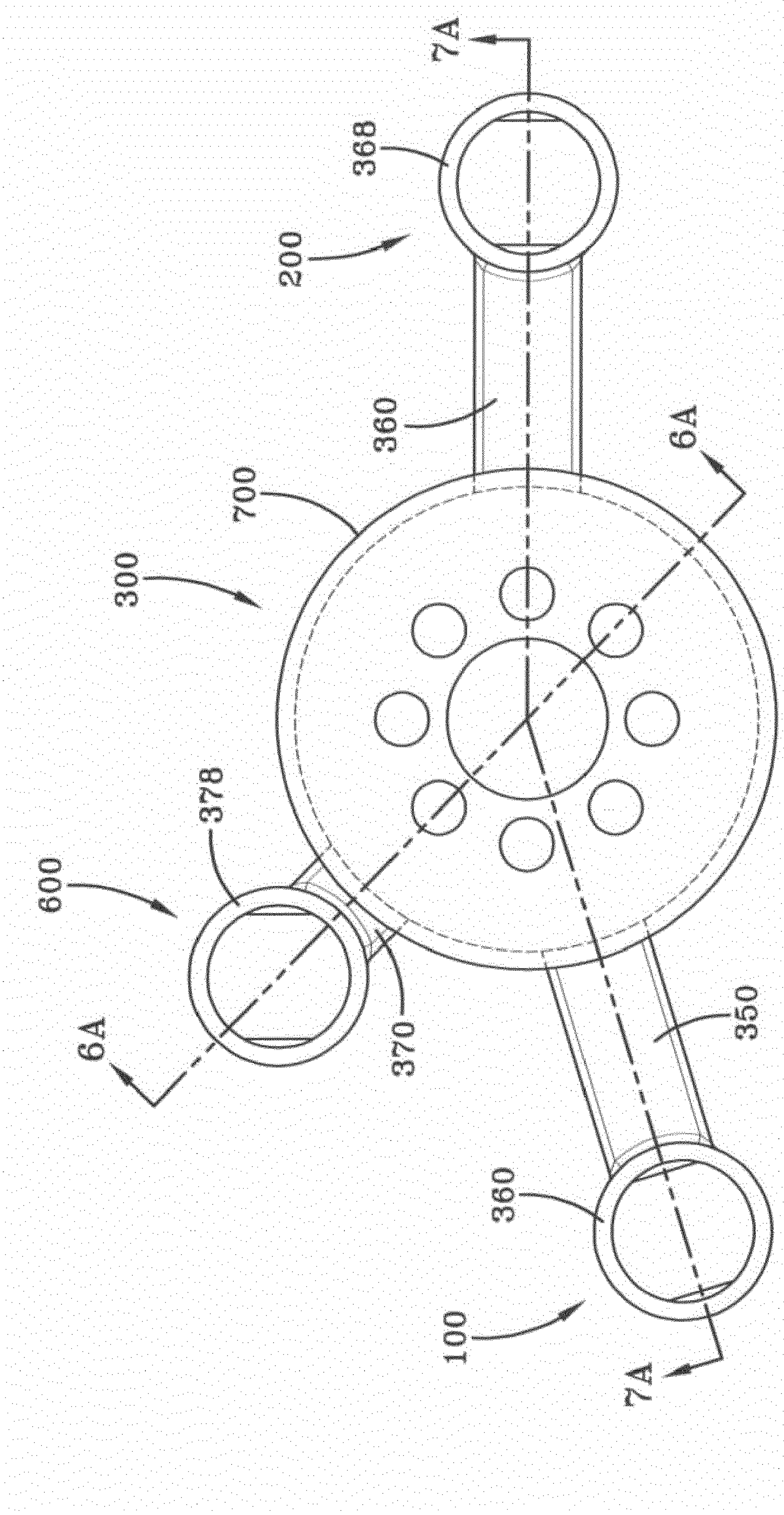
362
356

FIG-4



FIG—5

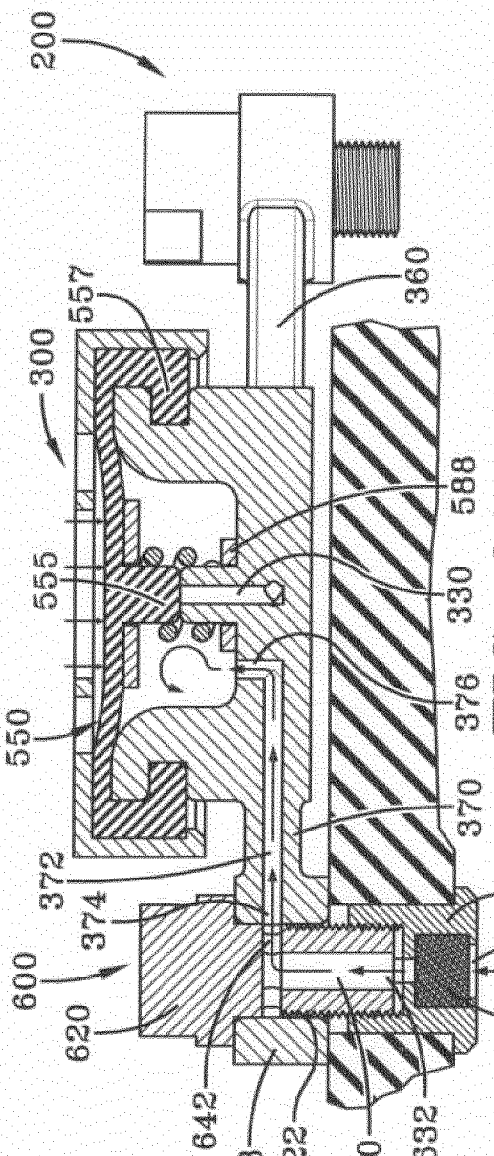

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FIG-6A

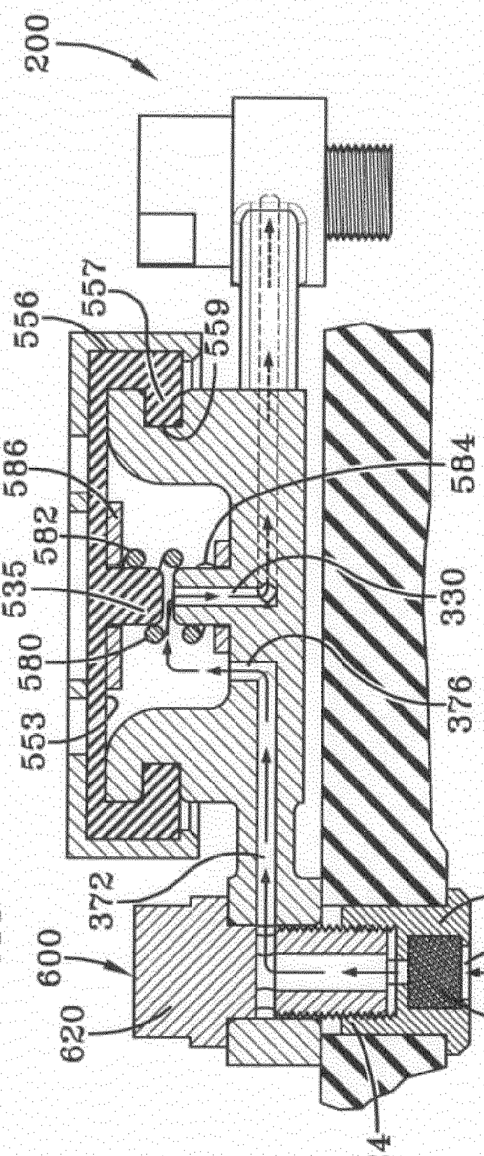
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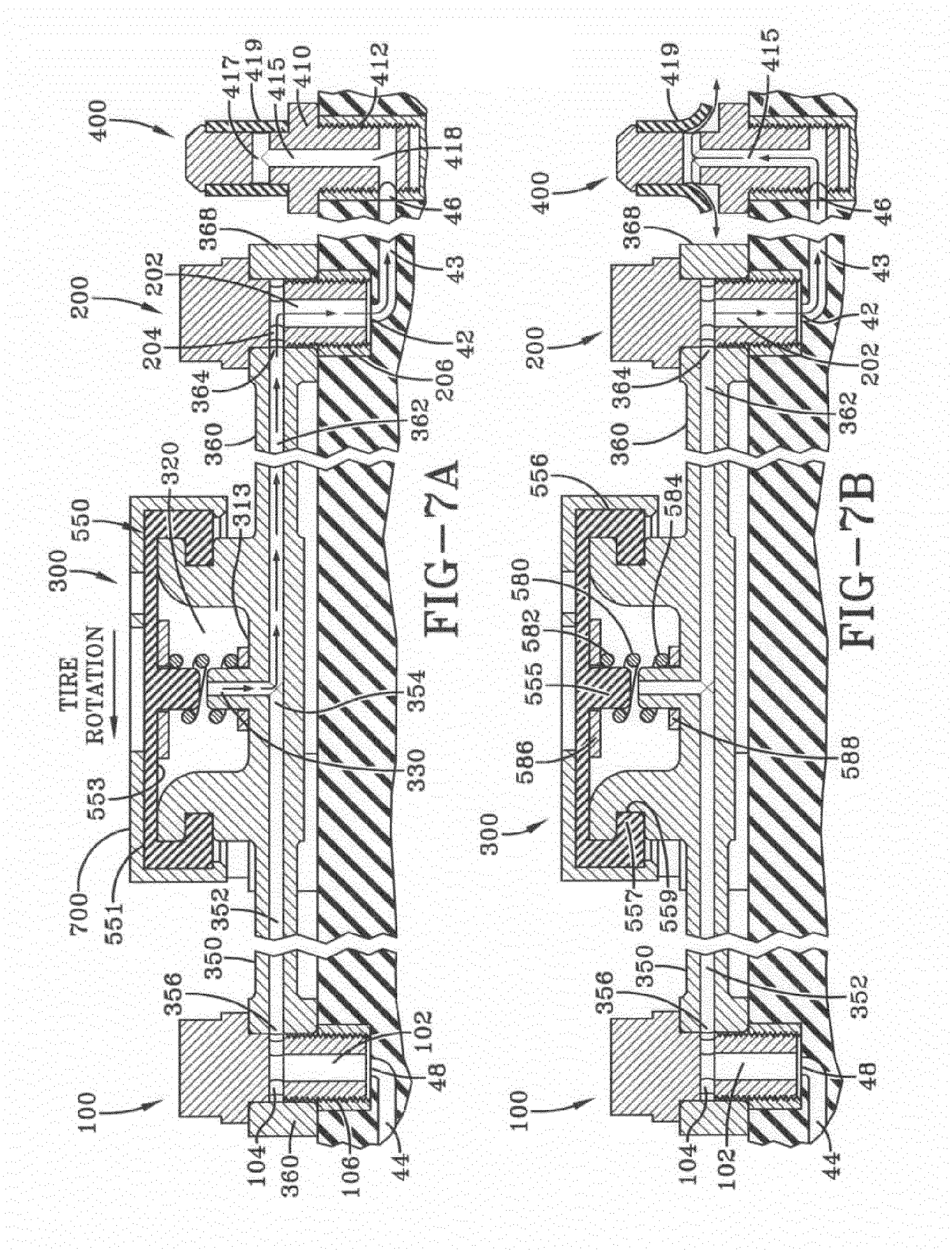
FIG-6B


TIRE ROTATION
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550
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356
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360
106
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313
320
360
364
204
202
362
206
42
368
43
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417
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582
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586
588
557
559

FIG-7A

FIG-7B

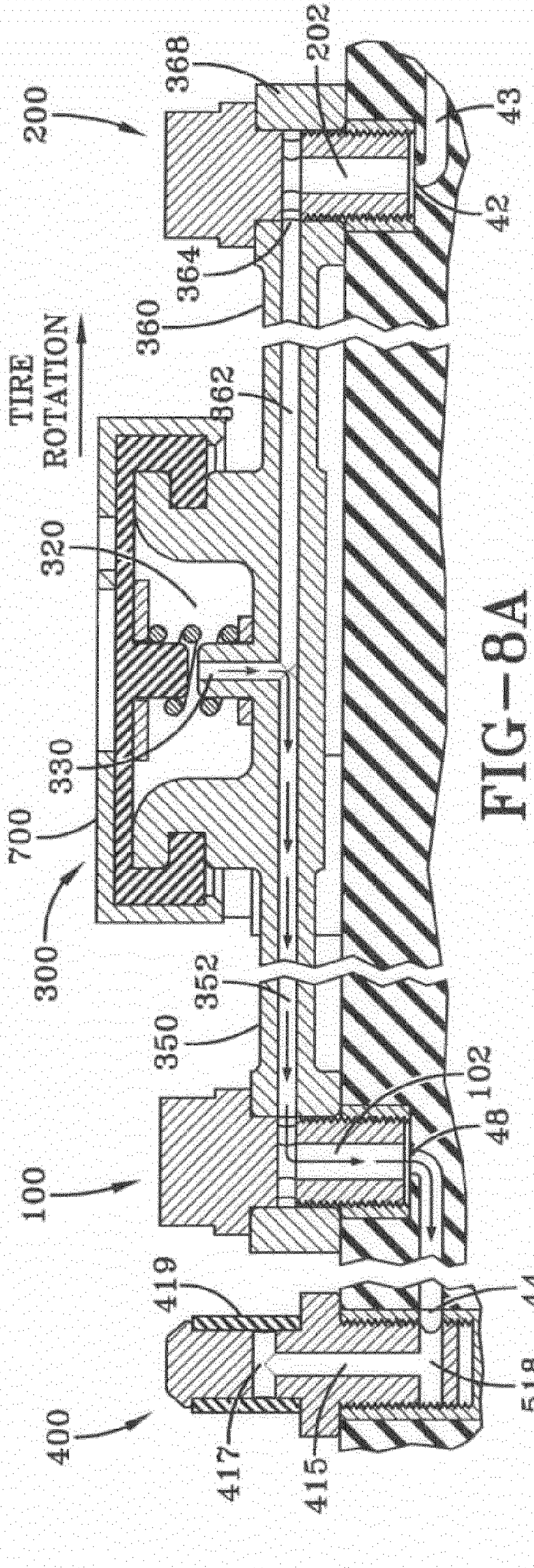
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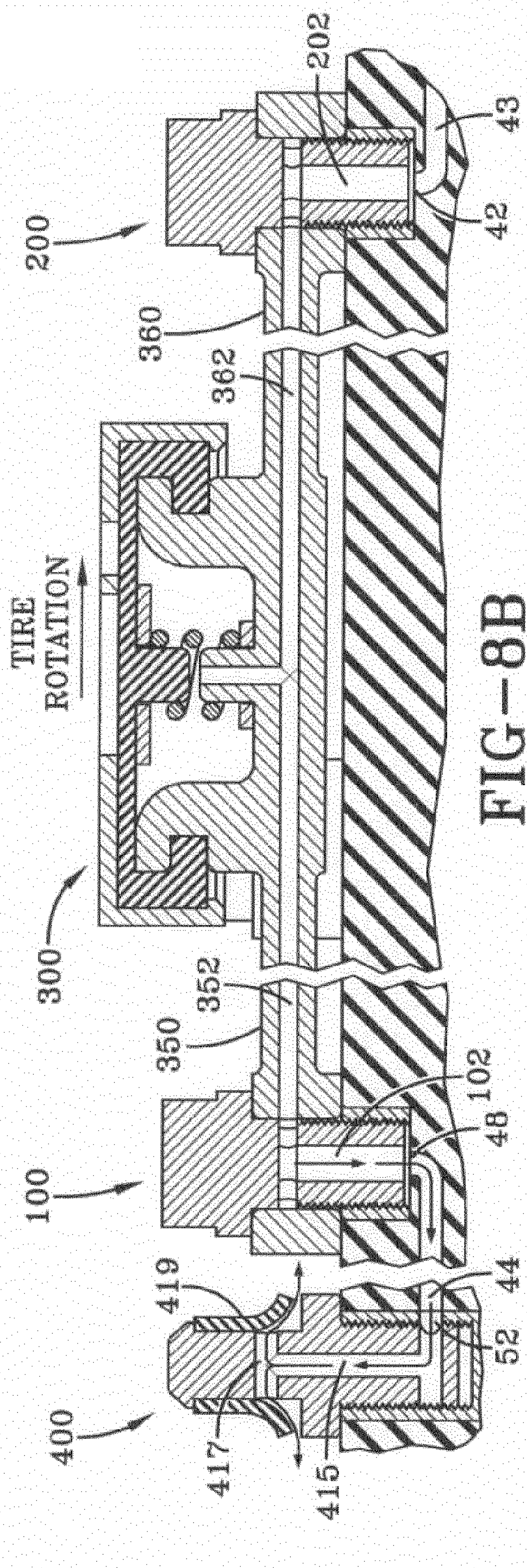
FIG-8A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360
362
TIRE ROTATION
300
352
350
100
102
48
419
44
52
400
417
415

FIG-8B