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(54) **Self-inflating tire with inlet control valve**

(57) A self-inflating tire (12) comprising a tire cavity (40), first and second sidewalls (15) extending respectively from first and second tire bead regions to a tire tread region, and an air passageway (43) having an inlet end (42) and an outlet end (44) is disclosed. The air passageway (43) 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. The tire (12) further comprises a regulator device or inlet control valve assembly (300). The regulator device or inlet control valve assembly (300) includes a housing (310) or regulator body. The

housing (310) or regulator body has an interior chamber (320). A pressure membrane (550) is mounted in the interior chamber (320) and positioned to open and close an outlet port (330) provided in the interior chamber (320). The pressure membrane (550) is in fluid communication with the tire cavity pressure. The outlet port (330) of the regulator device or inlet control valve assembly (300) is in fluid communication with the inlet end (42) of the air passageway (43). The interior chamber (320) is in fluid communication with an outside air supply. The outlet end (44) of the air passageway (43) is in fluid communication with the tire cavity (40).

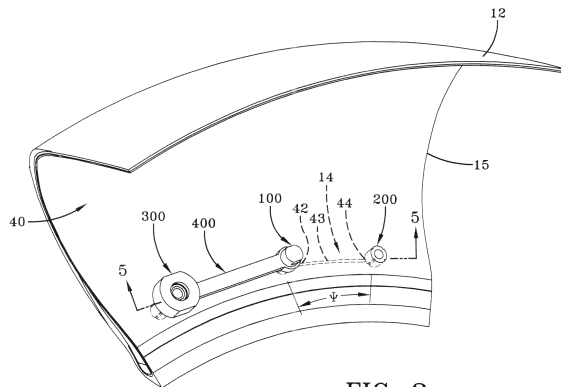


FIG-2

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## 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. It is also desired to provide a valve system in order to regulate the tire pressure.

### 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 which may be 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, an air passageway having an inlet end and an outlet end, the air passageway being composed of a flexible material operative to open and close when the tire rotates, a regulator device, the regulator device including a regulator body, wherein the regulator body has an interior chamber; a pressure membrane being mounted in the interior chamber and positioned to open and close an outlet port mounted in the chamber, wherein the pressure membrane is in fluid communication with the tire cavity pressure, wherein the outlet port of the regulator device is in fluid communication with the inlet end of the air passageway, said interior chamber being in fluid communication with an outside air supply, wherein the air passageway outlet end is in fluid communication with the tire cavity.

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

**[0013]** "Radial" and "radially" means directions radially toward or away from the axis of rotation of the tire.

### Brief Description of the Drawings

**[0014]** 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 a tire and rim assembly showing a pump and an inlet regulator valve assembly.

FIG. 2 is a front view of the pump and inlet regulator valve assembly as shown from inside the tire of Fig. 1.

FIG. 3 is an exploded view of the inlet regulator valve assembly of Fig. 2.

FIG. 4 is an exploded view of the inlet regulator valve assembly of Fig. 3, as viewed from below.

Fig. 5 is a section view of Figure 2 in the direction 5-5 showing the inlet regulator valve assembly in operation during pumping.

Fig. 6 illustrates the system of Figure 5 shown when the inlet regulator valve is closed.

Fig. 7 illustrates the system of Figure 5 shown when the inlet check valve is closed.

Fig. 8 is a section view showing an alternate embodiment of an inlet regulator valve assembly in operation during pumping.

Fig. 9 illustrates the system of Figure 8 shown when the inlet regulator valve is closed.

Fig. 10 illustrates the system of Figure 8 shown when the inlet check valve is closed.

Fig. 11 illustrates the system during tire rotation.

Fig. 12 is an exploded view of the outlet valve.

Fig. 13A, B, C illustrate the outlet valve closed, during cracking and open, respectively.

### Detailed Description of Example Embodiments of the Invention

**[0015]** Referring to FIGS. 1 and 2, a tire assembly 10 is shown. The assembly includes a tire 12 having a pump

assembly 14 or peristaltic pump assembly 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. 1-3, the pump assembly 14 is preferably mounted into the sidewall area 15 of the tire, preferably near the bead region.

#### Pump Assembly 14

**[0016]** The pump assembly 14 includes an air passageway 43 which may be molded into the sidewall of the tire during vulcanization or molded or formed post cure. The air passageway has an arc length L, wherein the arc length is measured by angle  $\psi$  that is measured from the center of rotation of the tire. In a first embodiment, the angle  $\psi$  may range, and is preferably in the range of from 15-50 degrees, and/or optionally has an angular length sufficient to extend the length of the tire footprint Z, as shown in Fig 11. The pump air passageway 43 comprises of an inserted tube body or a passageway formed in the tire wall. For example, the tube may be molded in the tire into a desired shape by the presence of a removable strip that forms the passageway when removed. If the passageway 43 is a inserted tube body, it should be formed of a resilient, flexible material such as plastic, elastomer or rubber compounds, and be capable of withstanding repeated deformation cycles when the tube is deformed into a partially flattened condition or a completely flattened condition subject to external force and, upon removal of such force, returns to an original condition. 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 or air passageway has a circular cross-sectional shape, although other shapes such as elliptical may be utilized. Preferably, the air passageway is located inside the tire sidewall.

**[0017]** The pump passageway 43 has an inlet end 42 connected to an optional inlet check valve 100, and an outlet end 44 that is connected to an optional outlet check valve 200. The inlet check valve 100 is in fluid communication with an inlet control valve 300 or a regulator device.

#### Inlet Control Valve 300 or Regulator Device

**[0018]** The inlet control valve 300 or regulator device is shown in Figures 3-7. It functions to regulate the flow of air to the pump 14. If the tire is determined by the inlet control valve to need additional air, the inlet control valve will allow air to enter the system. The inlet control valve 300 has a preferably T-shaped housing 310 (or a valve housing or regulator body). At the upper end 312 of the T-shaped housing there is an interior chamber 320. The interior chamber 320 preferably has a central opening 314. Opposite the central opening 314 is an outlet port

330. The outlet port is raised from the bottom surface 313 and extends into the interior of the chamber 320. The outlet port 330 is positioned to engage a pressure membrane 550. The pressure membrane 550 is preferably positioned within a recessed slot 340 formed in the sidewall 315 of the interior chamber 320. The pressure membrane is preferably a disk shaped member made of a flexible material such as rubber, elastomer, plastic or silicone. The pressure membrane is operable to open and close the outlet port 330. The outer surface 551 of the pressure membrane is in fluid communication with the pressure of the tire chamber 40 via central opening 314 and via the cap hole 370. The lower surface 553 of the pressure membrane is in fluid communication with the inlet air supplied from the distal end 380 of the inlet control valve, as described in more detail, below. Thus, the balance of pressure forces on each side of the pressure membrane actuates the pressure membrane to open and close the outlet port 330. A cap 360 is received over the upper end 312 of the valve housing 310. The cap has an interior, preferably threaded surface 362 that is secured to the outer, preferably threaded surface 311 of the upper end of the valve housing 310. The cap 360 has an opening 370 that is preferably aligned with central opening 312 so that pressure membrane is in fluid communication with the tire cavity 40. An optional washer 361 is received between the pressure membrane and the cap.

**[0019]** The distal end 380 of the inlet control valve housing preferably has an outer threaded surface 382 that is received in insert sleeve 384. The insert sleeve is preferably inserted into the tire post cure or may be molded into the tire as shown in Figure 5. Preferably, the insert sleeve 384 is permanently affixed in the tire sidewall 15. A first opening 386 of the insert sleeve 384 is preferably flush with the tire outer sidewall 15.

**[0020]** The distal end 380 of the inlet control valve housing has an internal cavity 390 for receiving a filter 392. A filter cap 394 has preferably a threaded end 395 that is received in the opening 391 of the internal cavity 390. The filter cap 394 is positioned on the outside surface of the tire, typically on the tire sidewall as shown in Figure 1. The filter cap is received in the opening 391 and preferably has a plurality of holes 396 for allowing the flow of air into the filter 392. Outside air enters hole 396 and then proceeds through the filter 392. As shown in Fig. 5, the filtered air exits the filter 392 into an internal passageway 393 that extends from the internal cavity 390 to the internal chamber 320.

**[0021]** If the tire pressure is lower than the target pressure, the pressure membrane 550 will not block the central opening 330 of the internal chamber 320. Filtered air from the first internal passageway 393 may flow through central opening 330 and then into an exit channel 397 having an exit 399 that is in fluid communication with the interior channel 406 of the flexible duct.

**[0022]** A second embodiment 700 of the inlet control valve is shown in Figures 8-10. The main difference be-

tween the second embodiment 700 and the first embodiment 300 is the channel which is plugged by the membrane. In the first embodiment, the channel plugged by the membrane is in fluid communication with the pump. In the second embodiment, the channel plugged by the membrane is coming from the filter. The inlet control valve 700 is the same as the inlet control valve 300 described above, except for the following differences. Internal passageway 393 and exit channel 397 have been eliminated. The T-shaped regulator housing 310 has a central channel 710 that has a first end 712 that opens to the interior chamber 720. The pressure membrane positioned in the interior chamber 720 is positionable over the opening 712. A filter 392 is positioned in the channel 710 and is secured within the channel 710 with a filter cap 394. The inlet control valve 700 further includes an exit passageway 730 that has a first end 732 that opens to the interior chamber 720, and a second end 734 that is in fluid communication with the first end 420 of a flexible duct 400. The passageway 730 may be annular in shape. An preferably annular notch 736 surrounds the second end 734 of the exit passageway 734.

#### Flexible Duct 400

**[0023]** A preferably flexible duct 400 has an interior channel 406 that extends to two opposed flanged ends 410, 412. The interior channel 406 is useful for communicating fluid from the inlet pressure regulator to the inlet check valve 100, or between two or more devices. Each flanged end 410, 412 is circular for reception about the body of the inlet control valve 300 and the body of the inlet check valve, respectively. Each flanged end 410, 412 has a hole therethrough 414, 416 respectively. The interior channel 406 has a first end 420 that terminates in the first flanged end 410, and a second end 422 that terminates in the second flanged end 412. The first flanged end 410 is received about the preferably T-shaped housing 310 of the inlet control valve 300. The second flanged end 412 is received about the housing of the inlet check valve 100. The flexible duct 400 may be integrally formed with the inlet control valve housing, or be a discrete part connected to the central housing 310.

#### Inlet check valve 100

**[0024]** An inlet check valve 100 that communicates with the inlet control valve 300 is shown in Figures 3-7. The inlet check valve 100 includes an insert sleeve 102 that is inserted into the tire on an interior surface, typically the inner sidewall as shown in Figure 5. The insert sleeve 102 preferably has an internal threaded bore 104. The insert sleeve 102 may be molded into the tire 12 or inserted post cure. The insert is installed in the tire area so that the internal bore 104 is in fluid communication with an inlet end 42 of the pump passageway 43. A valve body 110 has an outer threaded surface 112 that is received within insert 102. The valve body 110 has a pref-

erably central passage 115 that has a first opening 118 that is in fluid communication with the insert sleeve bore 104 and the pump passageway 43 inlet end 42 when inserted into the tire. The central passage 115 has preferably two opposed holes 120 near the head 122 of the valve body 110. The head 122 has a preferably hex head bore 124 (or any screwdriver slot shape) for receiving for instance an alien wrench useful for tightening the valve body 110 inside the sleeve 102. The central passage 115 further includes a retainer slot 130 or opening for receiving a preferably flexible stopper 140. The flexible stopper 140 is preferably made of a resilient material such as rubber, silicone, or an elastomer. The flexible stopper 140 has a preferably disk shaped lower end 142, and preferably two opposed legs 144 which extend from the lower end 142. Each leg 144 has a shoe 150 which preferably has a curved enlarged shape and is made of a resilient material. As shown, the shoe is a semi-circle, although other shapes would work for the invention. Although the flexible stopper 140 is shown with two legs 144, the stopper could have a single leg 144 with a shoe thereon, and the shoe could be annular with holes that allow passage of air therethrough.

**[0025]** The disk shaped lower end 142 of the flexible stopper is seated on the valve body distal end and the legs 144 extend into the passage 115. Each shoe 150 is received in the annular retainer slot 130. The disk lower end 142 is positioned to seal the opening 118 of the central passage 115 as shown in figure 7.

**[0026]** Figures 7-8 illustrate the regulator check valve 100 installed and operational. Figure 8 illustrates flow from the inlet control valve 300, through the check valve 100 and to the pump inlet 42. The disk lower end 142 of the flexible stopper 140 does not seal the central passage 115 when the flow direction is towards the pump 43. Figure 7 illustrates the disk lower end 142 of the flexible stopper 140 sealing the passageway 115 so that no flow travels in the reverse direction from the pump to the inlet control valve 300.

#### Pump outlet check valve

**[0027]** As described above, a first end 42 of the pump is in fluid communication with an inlet control valve 300 and a check valve 100. The second end 44 of the pump is connected to a pump outlet valve 200. The pump outlet valve is shown in Figures 12, 13A-C. The pump outlet valve 200 includes an insert sleeve 202 that is inserted into the tire on an interior surface, typically the inner sidewall. The insert sleeve 202 preferably has an internal threaded bore 204. The insert sleeve 202 may be molded into the tire 12 or inserted post cure. The insert is installed in the tire area so that the internal bore 204 is in fluid communication with the pump outlet end 44. A valve body 210 has an outer, preferably threaded surface 212 that is received within insert 202. The valve body 210 has a preferably central passage 215 that has a first opening 218 that is in fluid communication with the insert sleeve

bore 204 and the pump passageway 43 outlet end 44 when inserted into the tire. The central passage 215 has an outlet end 217 that is in fluid communication with the tire cavity. The valve body has a head 222 having a preferably hex head bore 224 (or any screwdriver slot shape) for receiving an alien wrench useful for tightening the valve body 210 inside the sleeve 202. The central passage 215 further includes a retainer slot 230 or opening for receiving the preferably flexible stopper 240. The flexible stopper 240 is preferably made of a resilient material such as rubber, silicone, or an elastomer. The flexible stopper 240 has a preferably disk shaped lower end 242, and preferably two opposed legs 244 which extend from the lower end 242. Each leg 244 has a shoe 250 which has a preferably curved enlarged shape and is made of a resilient material. As shown, the shoe is a semi-circle, although other shapes would work for the invention. Although the flexible stopper 240 is shown with two legs 244, the stopper could have a single leg 244 with a shoe thereon, and the shoe could be annular with holes that allow passage of air therethrough.

**[0028]** The flexible stopper is mounted inside the central passage so that each shoe 250 of the flexible stopper is received in the annular retainer slot 230, and the disk lower end 242 is positioned to open and close the pump end 44.

**[0029]** Figures 13A-C illustrate the pump outlet valve 200 installed and operational. Figure 13C illustrates the pump outlet valve 200 in the open position. The disk lower end 242 of the flexible stopper 240 does not seal the pump outlet 44 when the flow direction is towards the pump outlet valve 200. The flow travels through the central passage 215, around and through the legs 244 and exits the passage outlet 217 to the tire cavity. Figure 13A illustrates the disk lower end 142 of the flexible stopper 140 sealing the pump end 44 so that flow is blocked from flowing to the cavity. This occurs when the pump is not pumping. Figure 13B illustrates the disk lower end 142 of the flexible stopper 140 being cracked open by the pressure force when the pump starts pumping.

#### System Operation

**[0030]** As will be appreciated from FIG. 5, the inlet control valve 300 is in fluid communication with the inlet end 42 of the pump passageway 43. As the tire 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. Flattening of the pump passageway 43 forces the pumped air towards the pump outlet device 200. Any back flow that is directed towards the inlet control valve 300 is blocked from entering the regulator by the regulator check valve 100 as shown in Fig 10. Due to the increase in pressure at the pump outlet 44, the pressure unseats the disk 242 from the opening of the pump outlet 44, which allows the pumped air to exit the pump outlet device through passage 215 into the tire cavity 40 as shown in Fig 13C.

**[0031]** The inlet control valve 300 controls the inflow of outside air into the pump. If the tire pressure is low, the membrane 550 in the inlet control valve 300 is responsive to the tire pressure in the tire cavity 40. If the cavity pressure falls below a preset threshold value, the membrane will unseat from the central outlet port 330, allowing outside filtered air to enter the central chamber 320 from passageway 393. Outside air will then enter the first flexible duct 400. The flow then exits the first flexible duct and enters in inlet check valve 100, and then into the pump inlet 42. As the tire rotates, the air flow in the pump is then compressed through the pump and then exits the pump outlet valve 200 into the tire cavity. 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.

**[0032]** If the tire pressure is sufficient, the regulator device will block flow from entering the pump inlet. The pressure membrane is responsive to the cavity tire pressure and engages the central port 330 forming a seal which prevents air flow from passing through the regulator device. The pressure membrane material properties are adjusted to have the desired tire pressure settings.

**[0033]** The location of the pump assembly in the tire will be understood from FIGS. 1 and 2. In one embodiment, the pump air passageway 43 is positioned inside the tire sidewall, 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 is specifically shown inside the sidewall area 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 may be elliptical or round.

**[0034]** As described above, the length  $L$  of the pump passageway may be about the size of the tire's footprint length  $Z$ . However, the invention is not limited to same, and may be shorter or longer as desired. For example, the pump length may be any desired length, such as 10 degrees or more. As the length of the pump increases, the pump passageway will need to substantially open and close like a peristaltic pump.

**[0035]** 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 comprising a tire cavity (40), first and second sidewalls (15) extending respectively from first and second tire bead regions to a tire tread region, and an air passageway (43) having an inlet end (42) and an outlet end (44), wherein the air pas-

- sageway (43) 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, wherein the tire (12) further comprises a regulator device or inlet control valve assembly (300), the regulator device or inlet control valve assembly (300) including a housing (310) or regulator body, wherein the housing (310) or regulator body has an interior chamber (320), wherein a pressure membrane (550) is mounted in the interior chamber (320) and positioned to open and close an outlet port (330) provided in the interior chamber (320), wherein the pressure membrane (550) is in fluid communication with the tire cavity pressure, wherein the outlet port (330) of the regulator device or inlet control valve assembly (300) is in fluid communication with the inlet end (42) of the air passageway (43), wherein the interior chamber (320) is in fluid communication with an outside air supply, and wherein the outlet end (44) of the air passageway (43) is in fluid communication with the tire cavity (40).
2. The self-inflating tire of claim 1, wherein the housing (310) or regulator body has a distal end (380) and an internal passageway (393) that is in fluid communication with the outside air.
  3. The self-inflating tire of claim 2, wherein the internal passageway (393) is in fluid communication with the interior chamber (320).
  4. The self-inflating tire of claim 2 or 3, wherein a filter (392) is received in the internal passageway (393).
  5. The self-inflating tire of at least one of the previous claims wherein a preferably flexible duct (400) having an internal passageway and having a first end (410) in fluid communication with the outlet port (330) of the regulator device or inlet control valve assembly (300) and a second end (412) in fluid communication with the inlet end (42) of the air passageway (43)
  6. The self-inflating tire of claim 5, wherein the second end (412) of the duct (400) is connected to an inlet check valve (100).
  7. The self-inflating tire of at least one of the previous claims, wherein the regulator device or inlet control valve assembly (300) comprises has a filter (392).
  8. The self-inflating tire of at least one of the previous claims, wherein the length of the air passageway (43) is about the same as the length of the tire footprint or is in a range of from 50% to 150 %, alternatively 80 to 120%, of the length of the tire footprint.
  9. The self-inflating tire of at least one of the previous claims, wherein the air passageway (43) has an arc length in a range of from 10 to 50 degrees or 10 to 30 degrees as measured by an angle ( $\psi$ ) that is measured from the center of rotation of the tire (12).
  10. The self-inflating tire of at least one of the previous claims, wherein the air passageway (43) has a length in a range of from 10 to 50 cm, alternatively 25 to 38 cm.
  11. The self-inflating tire of at least one of the previous claims, wherein the air passageway (43) is substantially circular or elliptical in cross-section.
  12. The self-inflating tire of at least one of the previous claims, wherein the air passageway (43) is positioned in the sidewall (15) or the tire (12).
  13. The self-inflating tire of at least one of the previous claims, wherein the air passageway (43) is positioned between a tire bead region and a rim tire mounting surface of the tire (12) radially inward of the tire tread region.
  14. The self-inflating tire of at least one of the previous claims, wherein an outlet check valve (200) is located between the outlet end (44) of the air passageway (43) and the tire cavity (40).
  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).

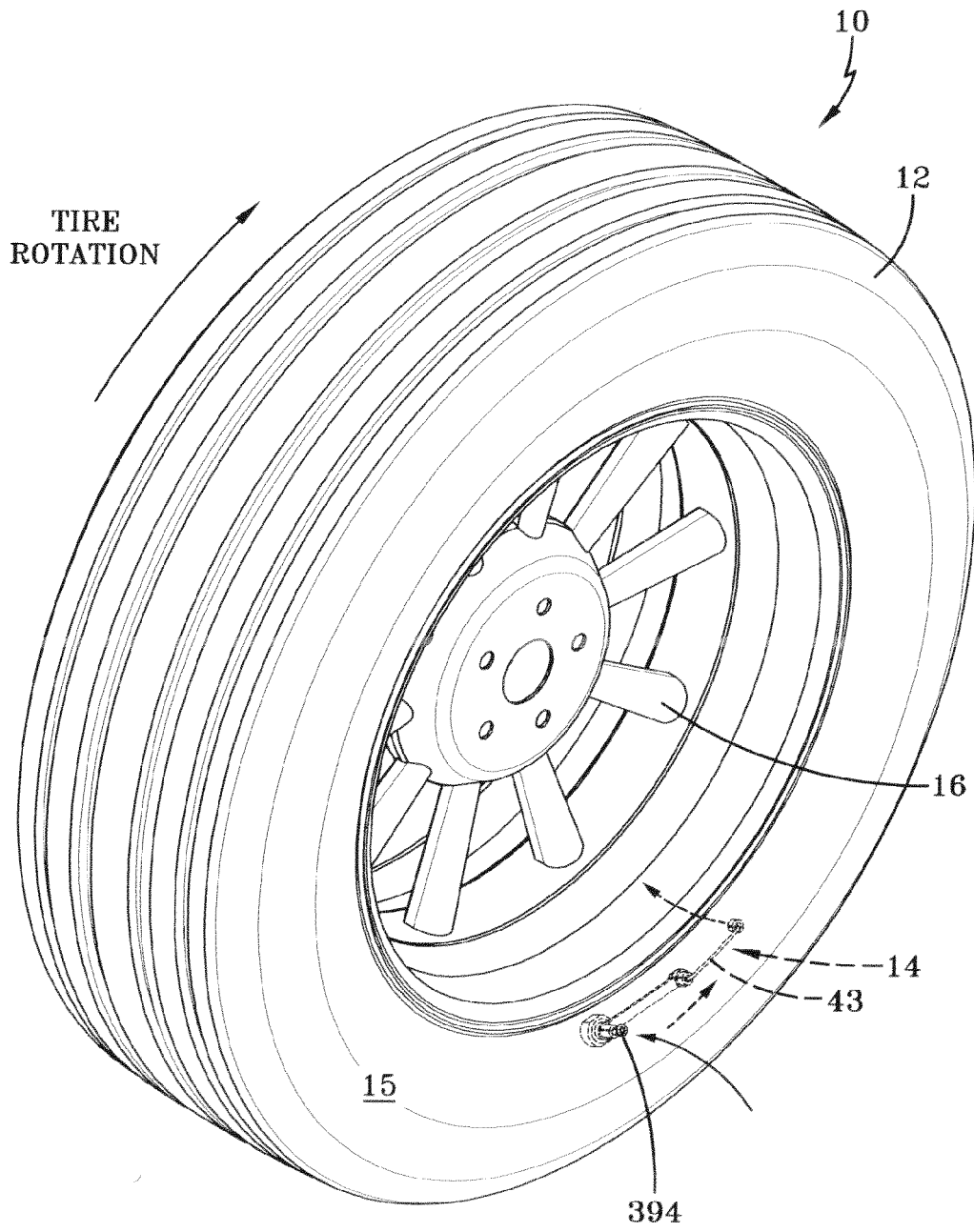


FIG-1

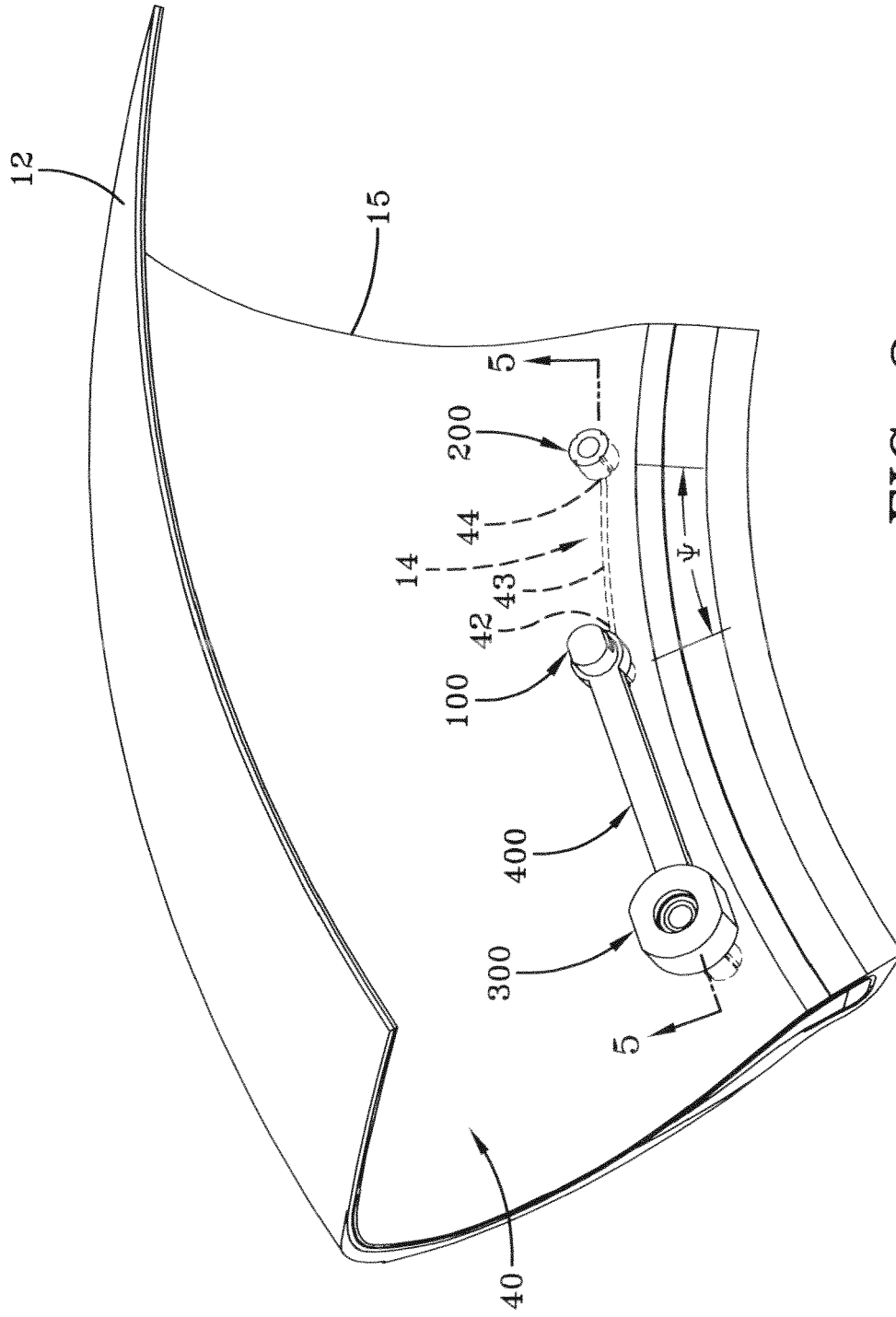


FIG-2



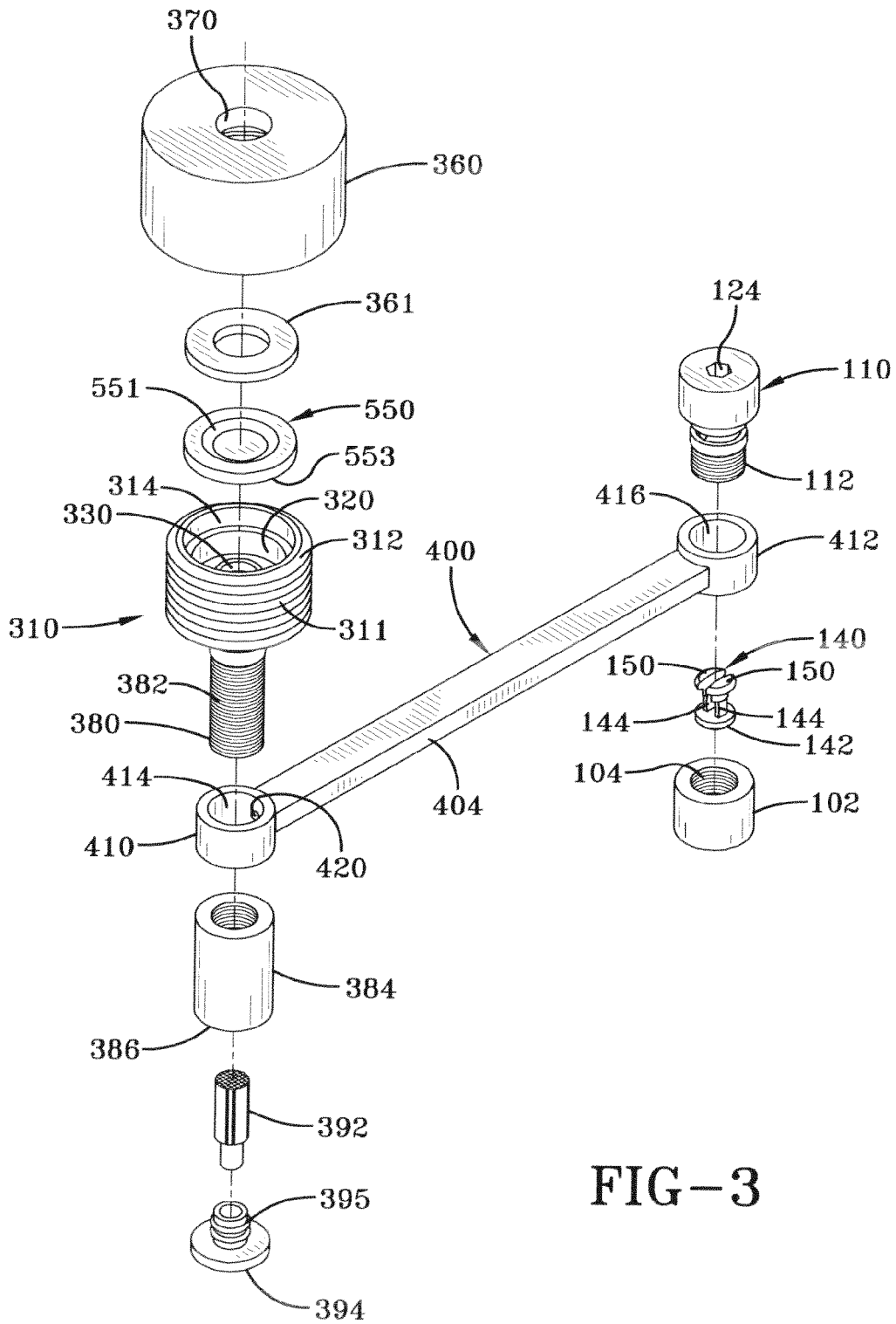


FIG-3

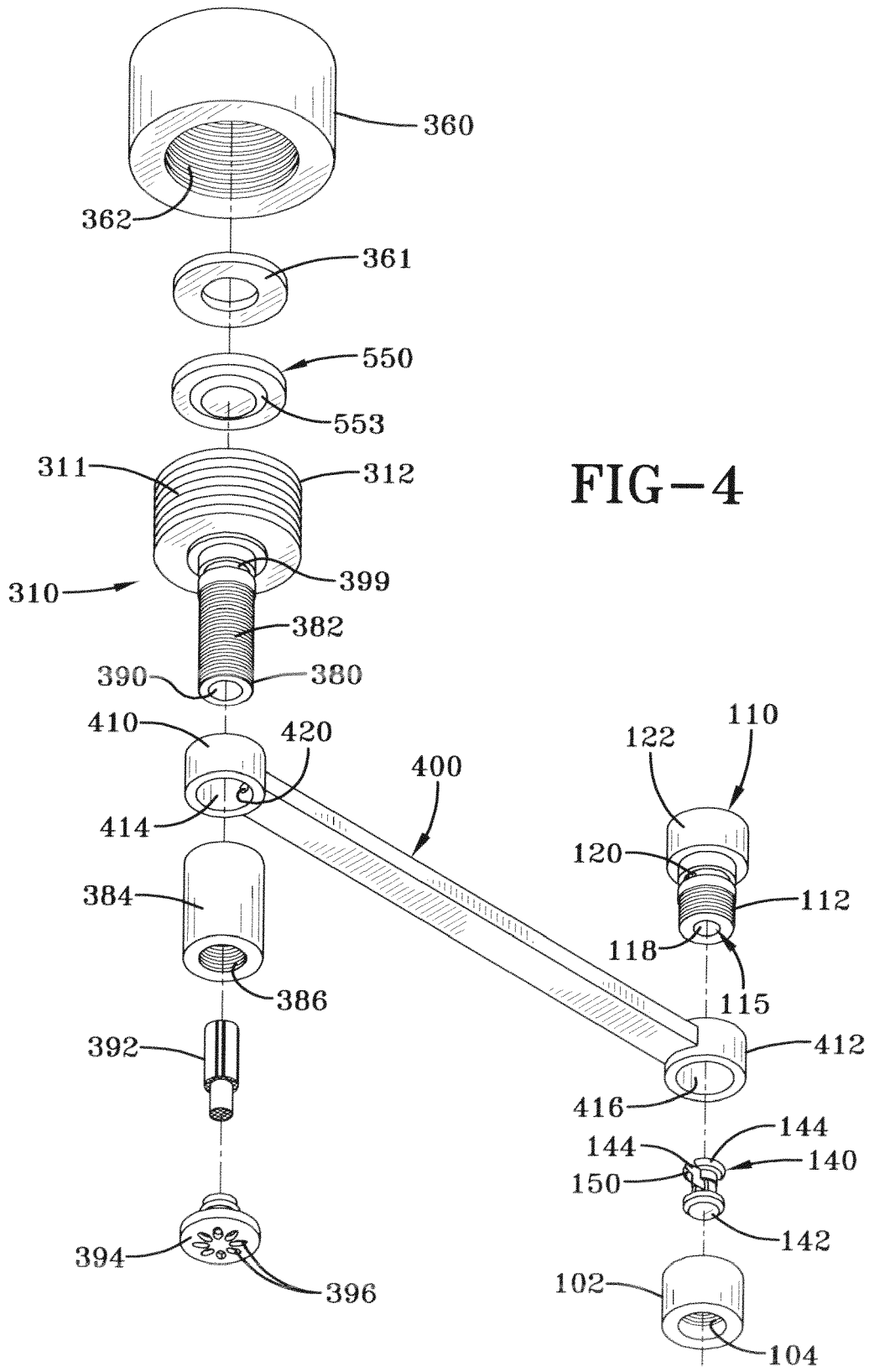
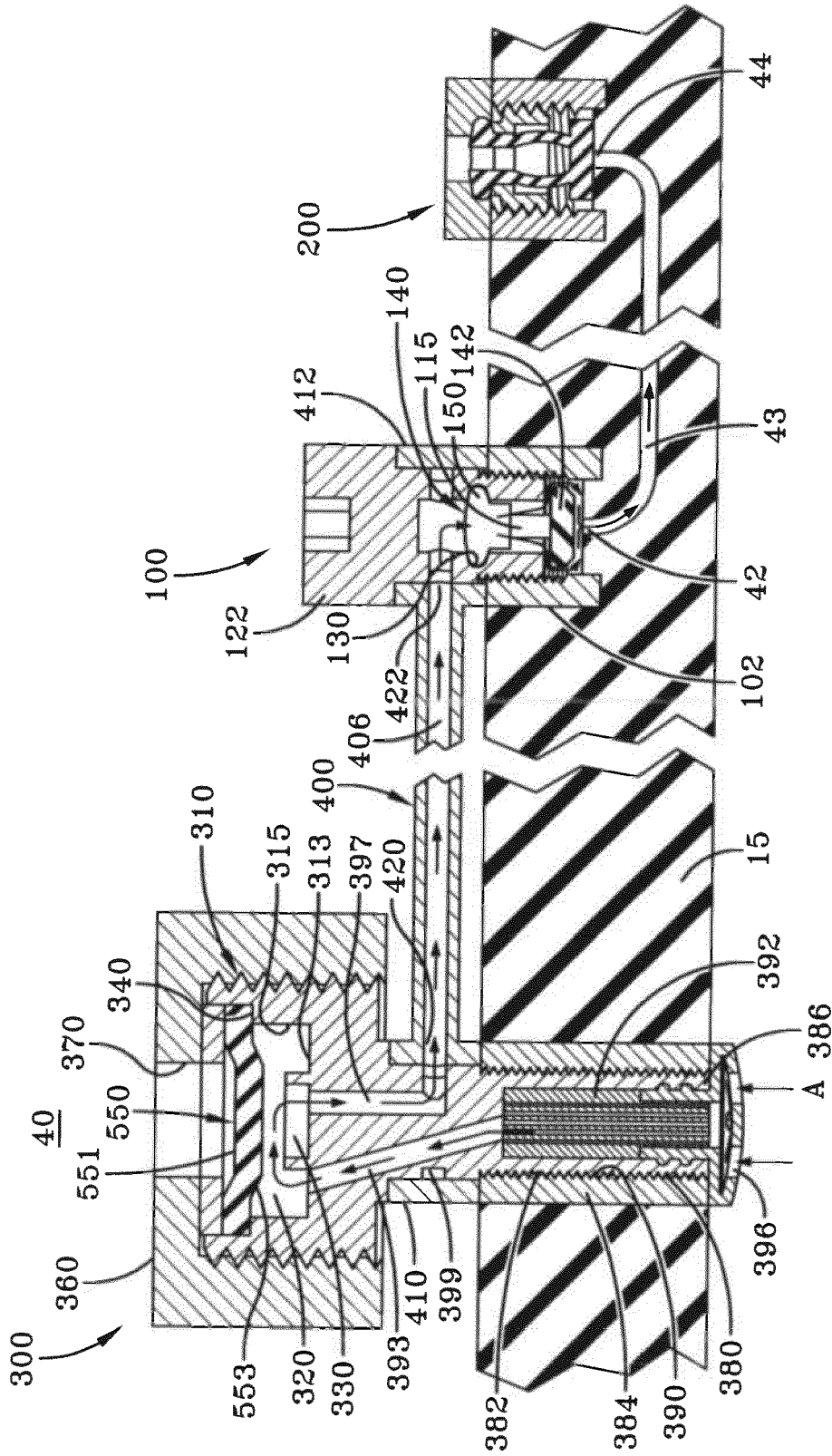
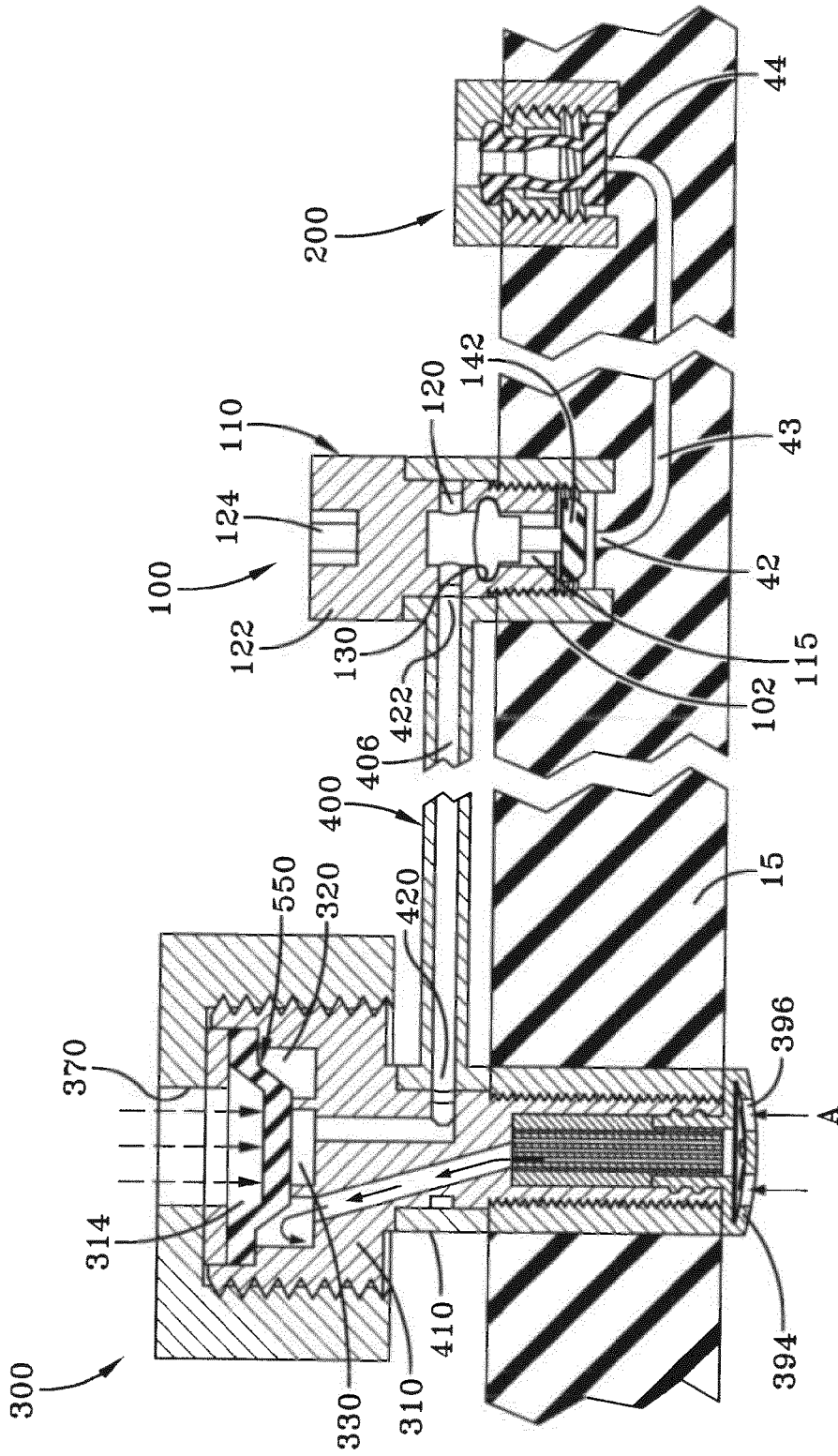


FIG-4





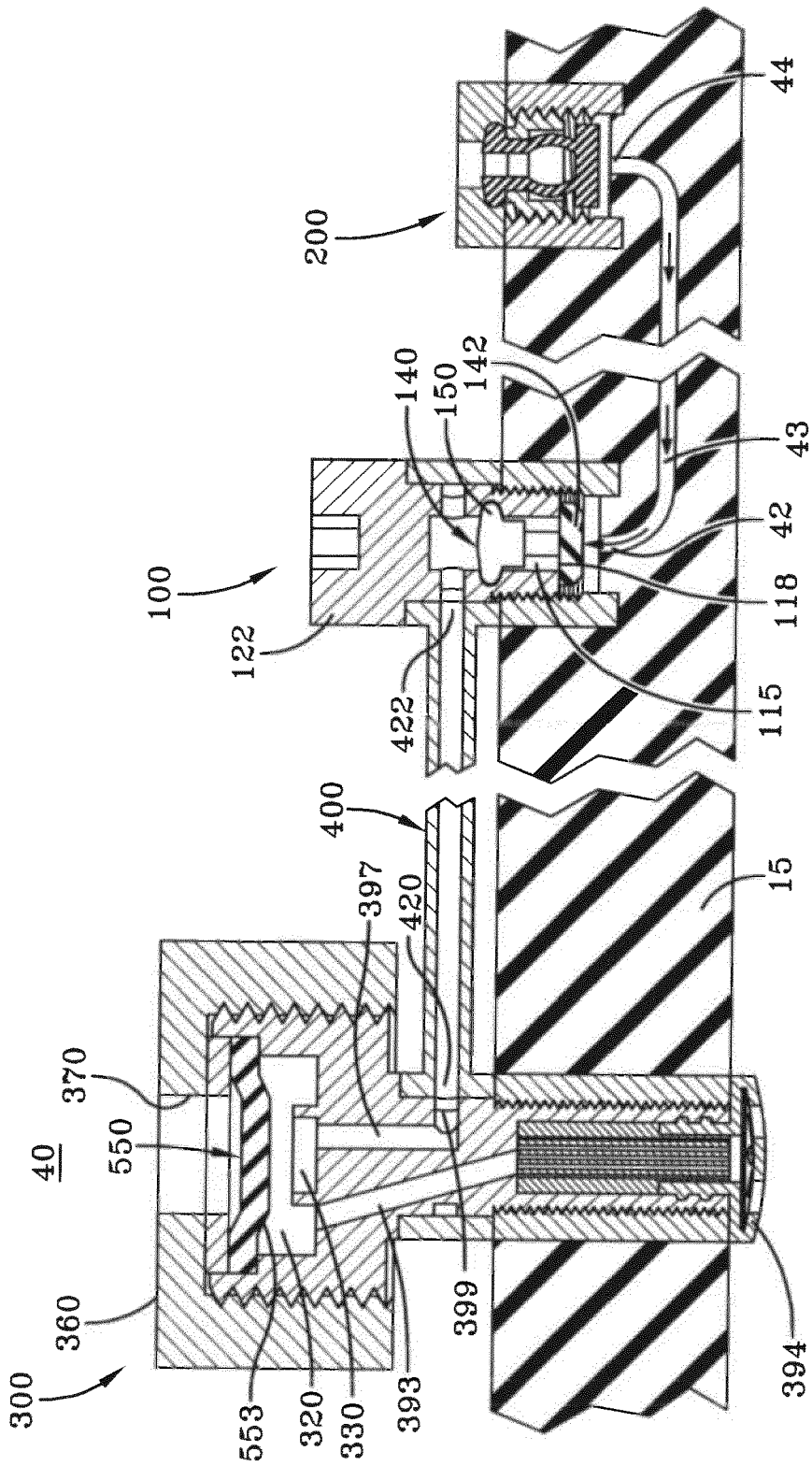


FIG-7

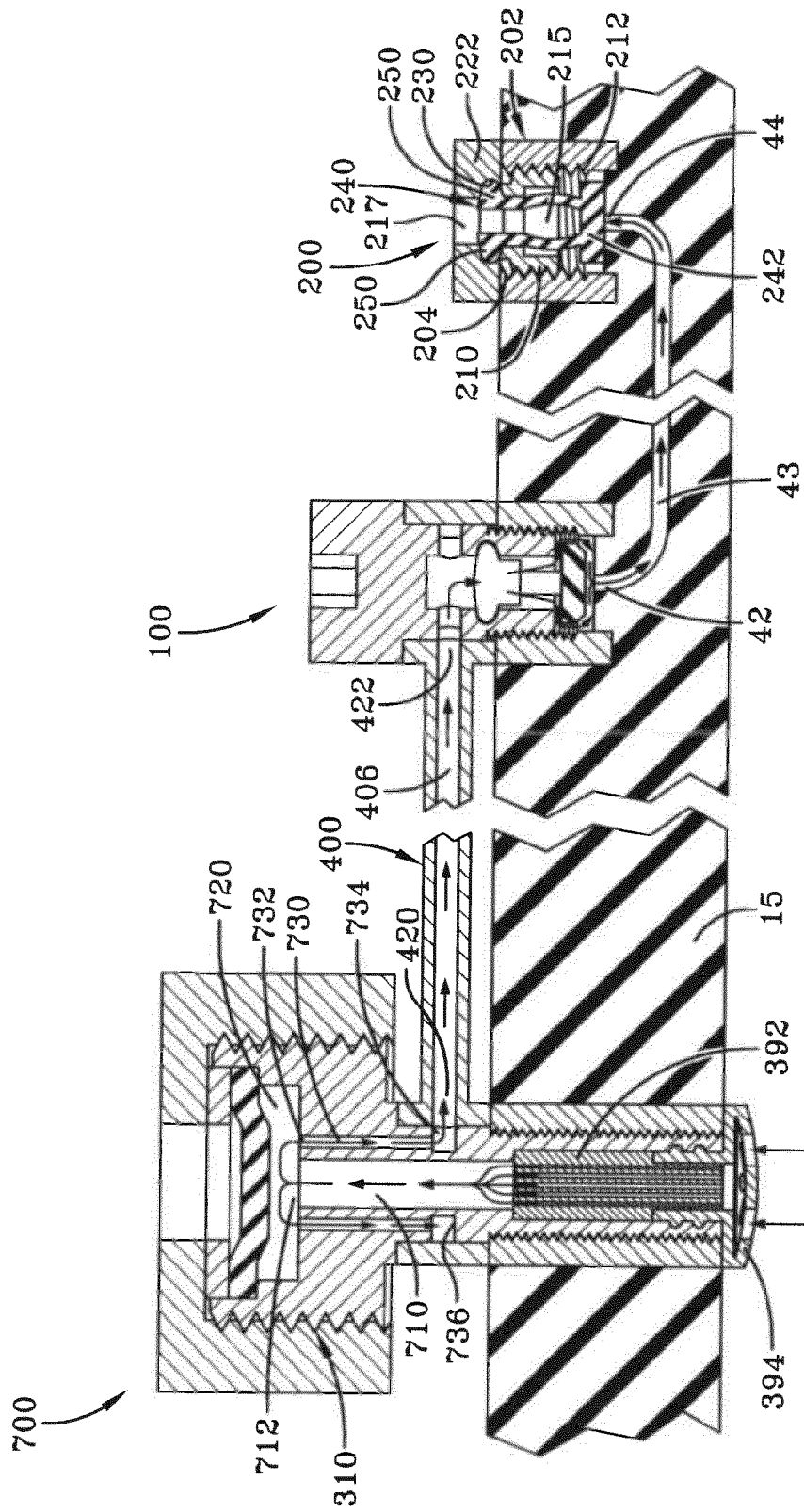


FIG-8

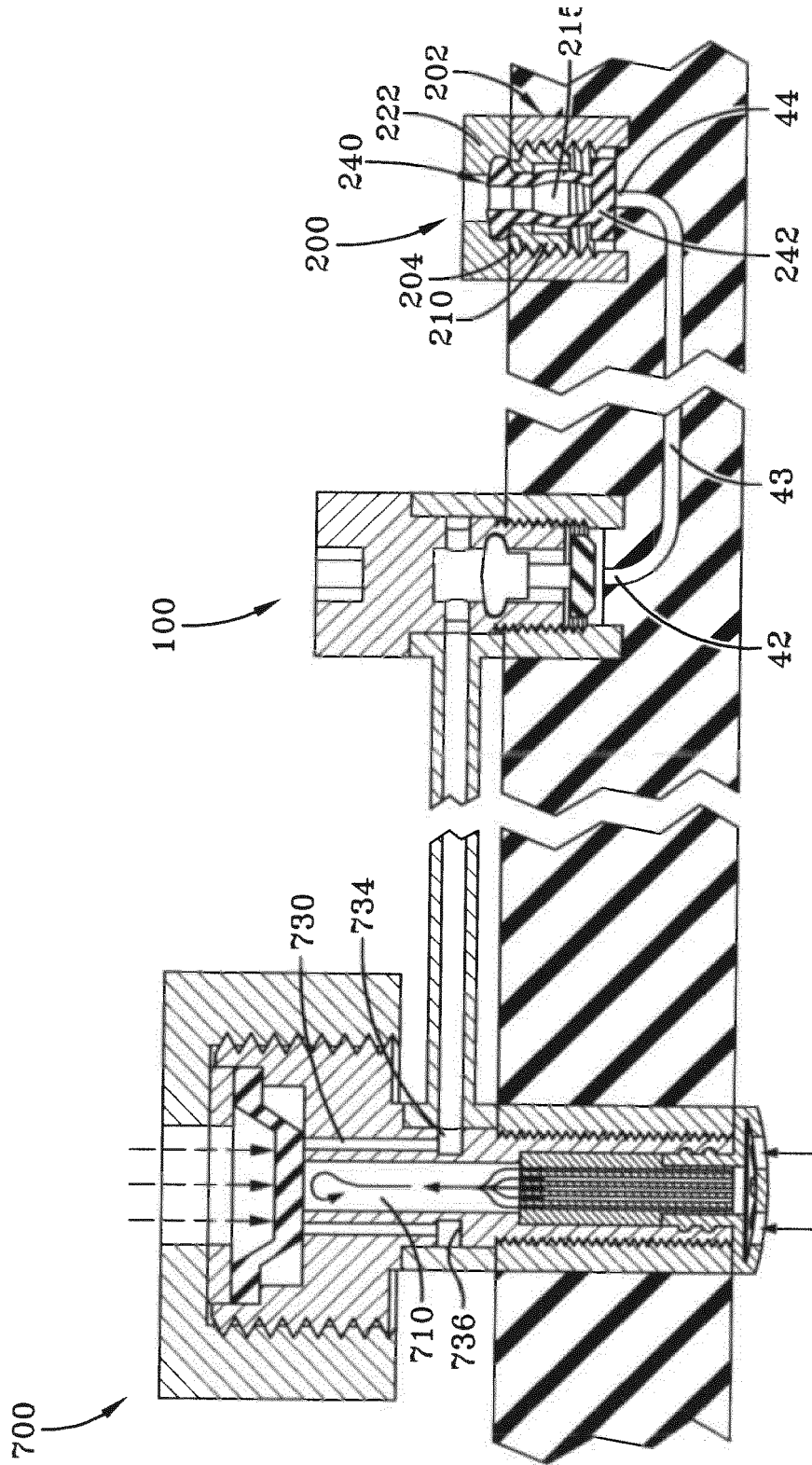


FIG-9

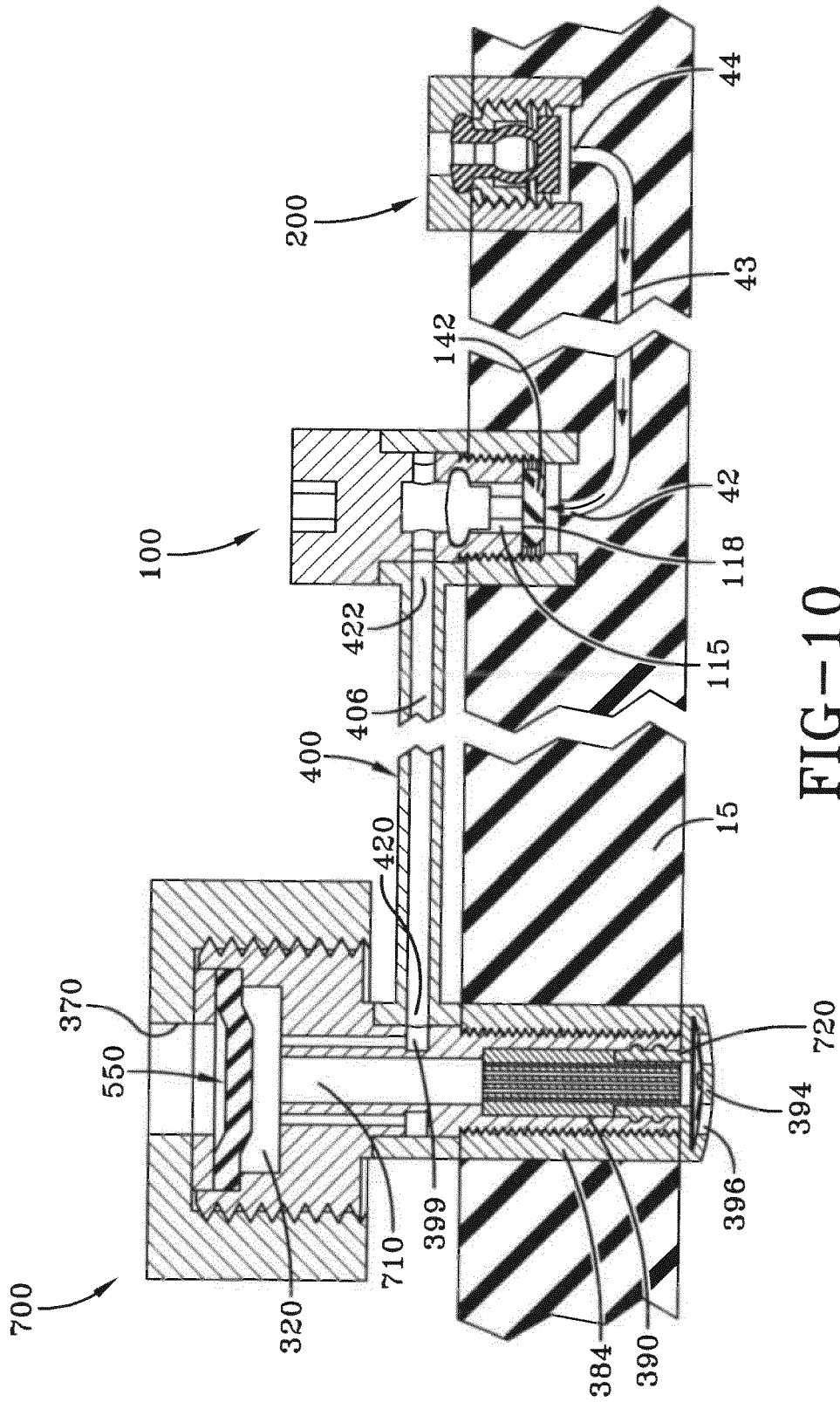


FIG-10



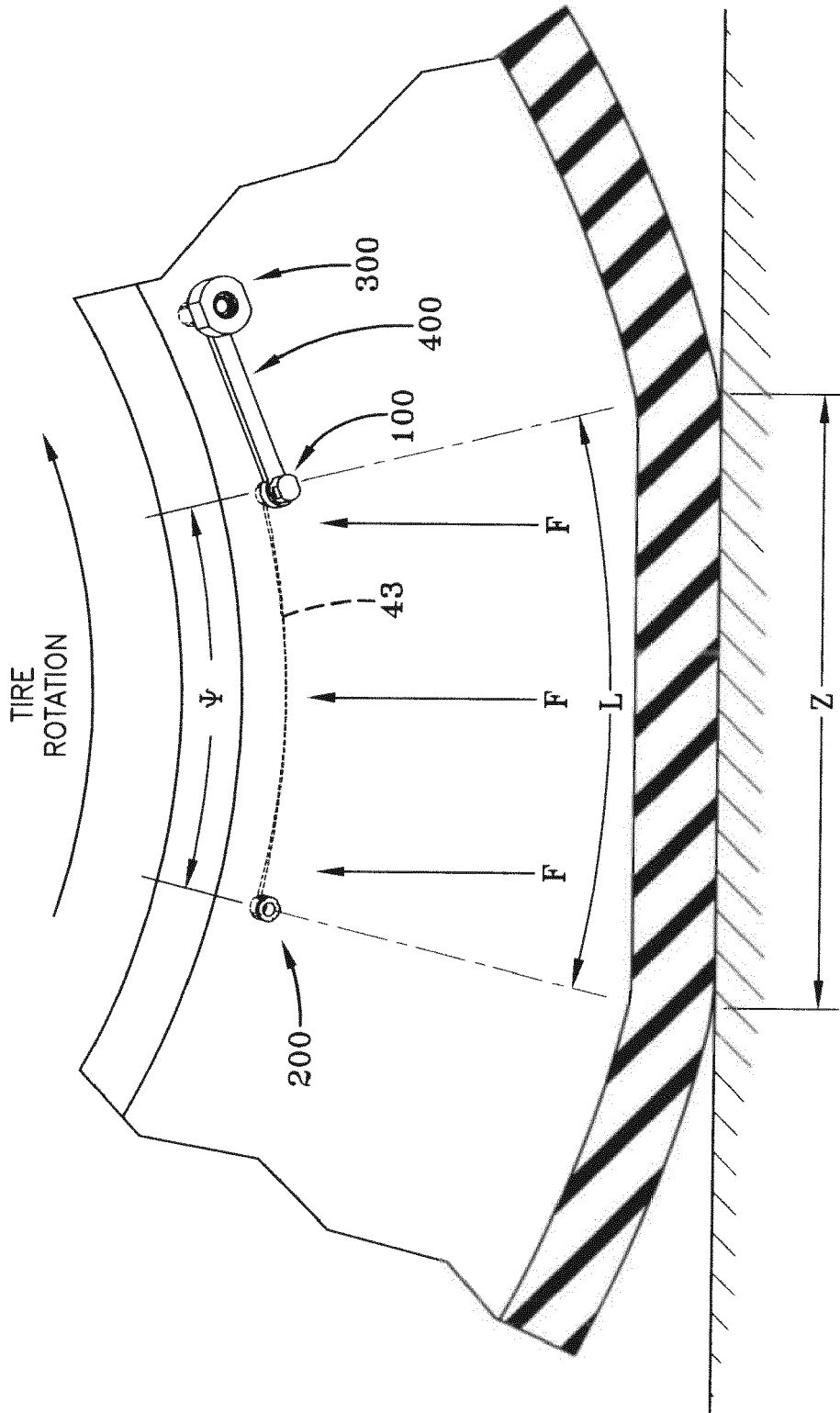


FIG-11

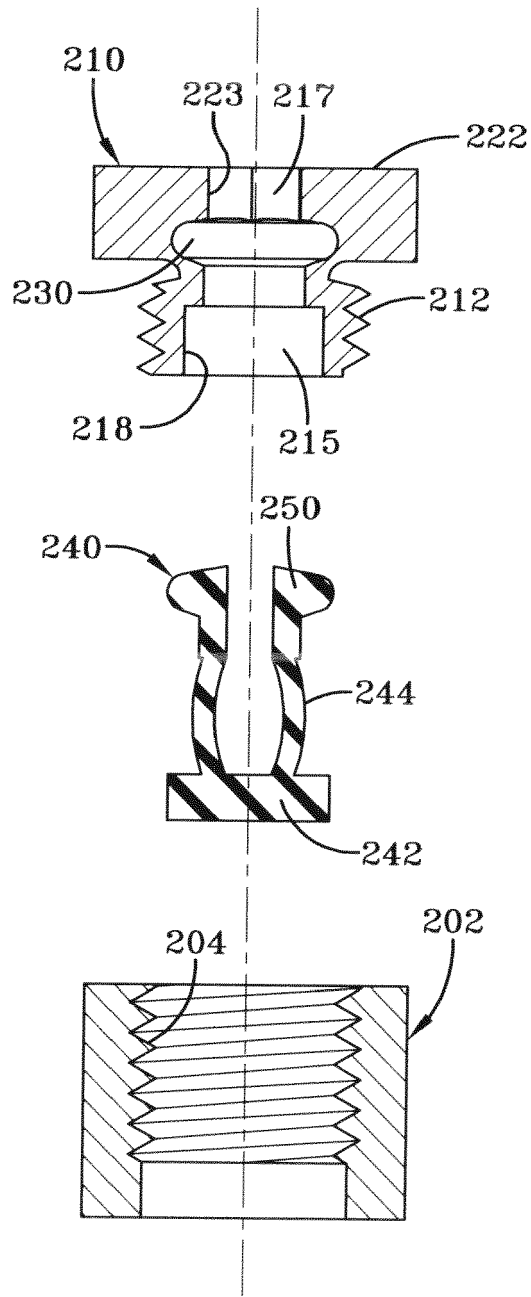


FIG-12

FIG-13A

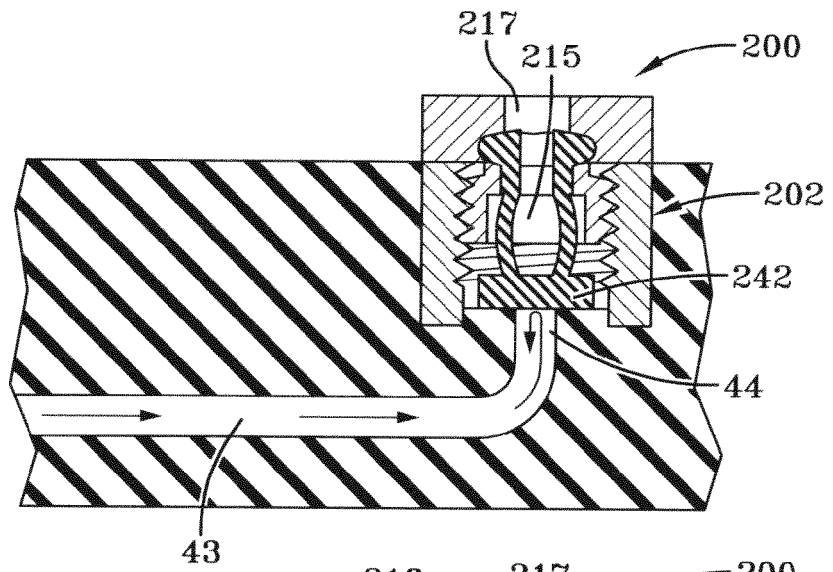


FIG-13B

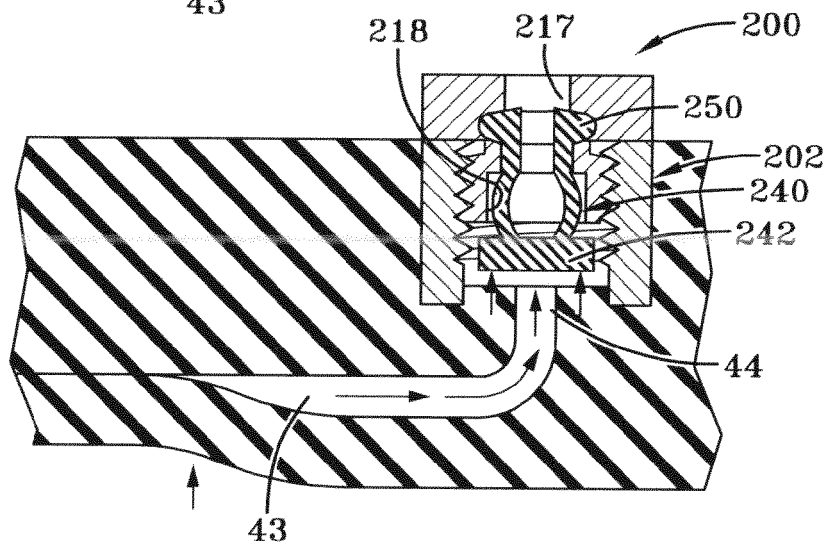


FIG-13C

