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(54) **Pneumatic tire**

(57) A pneumatic tire comprising a tire cavity (40), first and second sidewalls extending respectively from first and second tire bead regions to a tire tread region, and an air passageway is disclosed. The air passageway is designed and located such that it is operative to allow a portion of the air passageway near a tire footprint to at least substantially close the air passageway. An inlet regulator device (44) is connected to an inlet end of the air passageway and includes an insert (60) mounted in the tire. The insert (60) has a hole or bore extending therethrough having a first end located in or close to the tire cavity (40) and a second end which extends through the tire. The tire further either includes a pressure membrane (74) which is received within the first end of the insert (60) and a regulator body (68) which is received within the second end of the insert.

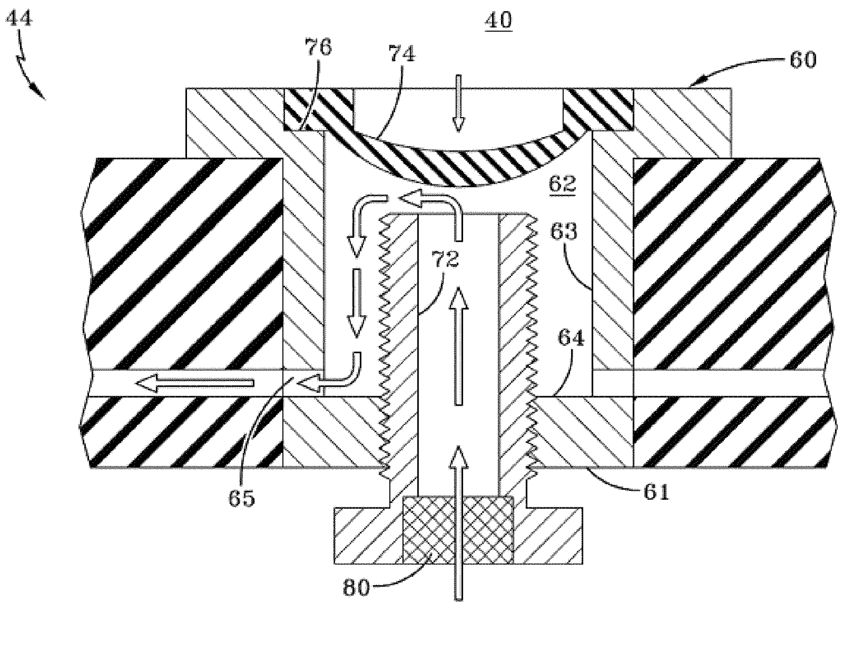


FIG-9

EP 2 565 059 A2

Description

Field of the Invention

[0001] The invention relates generally to self-inflating tires and, more specifically, to a pump mechanism 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 a 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. EP-A- 2 338 703 and EP-A- 2 343 200 describe prior art self-inflating tire assemblies.

Summary of the Invention

[0003] The invention relates to a tire in accordance with claim 1 and to a tire and rim assembly in accordance with claim 15.

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

[0005] The invention provides in a first preferred aspect a self-inflating tire assembly comprising a tire mounted to a rim, the tire having a tire cavity, and first and second sidewalls extending respectively from first and second tire bead regions to a tire tread region. The assembly preferably further includes an air tube connected to the tire and defining an air passageway, the air tube being composed of a flexible material operative to allow a portion of the air tube segment near a tire footprint to substantially close the annular passageway. The assembly further includes an inlet regulator device connected to an inlet end of the air tube, the inlet regulator device includes an insert mounted in the tire, wherein the insert has a bore therethrough having a first end located in the tire cavity, and a second end which extends through the tire, wherein a pressure membrane is received within the first end of the insert, and a regulator body is received within the second end of the insert, wherein the regulator body has a interior passageway which extends from a first end to a distal end, wherein the distal end extends into a cavity of the insert, wherein the pressure membrane is responsive to the cavity tire pressure and the outside air pressure, wherein the pressure membrane is positioned for engagement with the distal end of the regulator body when the tire pressure reaches a set value.

[0006] The invention provides in a second preferred aspect a self-inflating tire assembly comprising a tire mounted to a rim, the tire having a tire cavity, and first and second sidewalls extending respectively from first and second tire bead regions to a tire tread region. The invention preferably further includes an air tube connected to the tire and defining an air passageway, the air tube being composed of a flexible material operative to allow a portion of the air tube segment near a tire footprint to substantially close the annular passageway. The assembly also has an inlet regulator device connected to an inlet end of the air tube, the inlet regulator device includes an insert mounted in the tire, wherein the insert has a bore therethrough having a first end located in the tire cavity, a middle portion forming a chamber, and a second end which extends through the tire and which is in fluid communication with the outside air and the chamber, wherein a piston is slidably mounted within the first end of the insert, and a regulator body is received within the chamber and positioned to engage a stop, the chamber having a hole for fluid communication with a pump inlet air tube, a spring mounted within the chamber and having a first end for engagement with the piston and a second end for engagement with a bottom wall of the chamber wherein the regulator body has a interior passageway which extends from a first end to a distal end, wherein the distal end extends into a cavity of the insert.

Definitions

[0007] "Axial" and "axially" means lines or directions that are parallel to the axis of rotation of the tire.

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

[0009] "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.

[0010] "Peristaltic" means operating by means of wave-like contractions that propel contained matter, such as air, along tubular pathways.

[0011] "Radial" and "radially" means directions radially toward or away from the axis of rotation of the tire.

Brief Description of the Drawings

[0012] 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 two peristaltic pump assemblies.
FIG. 2 is a side view of the tire of Fig. 1.
FIG. 3A is an enlarged perspective view of the pump outlet mechanism.
FIG. 3B is a cross-sectional view of the pump outlet mechanism of Fig. 3A.
FIGS. 4A and 4B illustrate side views of the tire, rim,

tubing, and valves showing operation of the pump to the tire cavity when the tire rotates.

FIG. 5A is a partial section view through the tire.

FIG. 5B is an enlarged view of pump tube location next to rim.

FIG. 6A is a partial section view through the tire under load at road surface.

FIG. 6B is an enlarged view of Fig. 6A illustrating the tube being compressed in the tire bead area.

FIG. 7 is an enlarged cross sectional view of the tire and rim assembly with the pressure regulator shown mounted in the tire.

FIG. 8 is a cross-sectional view of a pressure regulator;

FIG. 9 is a cross-sectional view of the pressure regulator of FIG. 8 shown in operation;

FIG. 10 is a cross-sectional view of the pressure regulator of FIG. 8 shown in the closed position;

FIG. 11A is a cross-sectional view of a second embodiment of a pressure regulator;

FIG. 11B is a cross-sectional view of the pressure regulator of Fig. 11 A showing the adjustability feature;

FIG. 12 is a cross-sectional view of the pressure regulator of FIG. 11 shown in operation in the closed position;

FIG. 13 is a cross-sectional view of the pressure regulator of FIG. 11 shown in operation in the open position; and

FIG. 14 is an enlarged cross sectional view of the tire and rim assembly with the pressure regulator of Fig. 11 shown mounted in the tire.

Detailed Description of the Invention

[0013] Referring to FIGS. 1 and 5A, a tire assembly 10 includes a tire 12, a peristaltic pump assembly 14, and a tire rim 16. The tire mounts in a conventional fashion to a pair of rim mounting surfaces 18, 20 located adjacent outer rim flanges 22, 24. The outer rim flanges 22, 24 have an outer rim surface 26. An annular rim body 28 joins the rim flanges 22, 24 and supports the tire assembly as shown. The tire is of conventional construction, having a pair of sidewalls 30, 32 extending from opposite bead areas 34, 36 to a crown or tire tread region 38. The tire and rim enclose a tire cavity 40.

[0014] As shown in FIGS. 1, 2 and 4, the peristaltic pump assembly 14 includes a first and second pump 41, 42 that are mounted in a passageway 43 located in the sidewall area of the tire, preferably near the bead region. The air passageway is preferably molded into the sidewall of the tire during vulcanization and is preferably annular in shape. Each pump 41, 42 has a first end 41 a, 42a joined together by an inlet device 44 and a second end 41 b, 42b joined together by an outlet device 46. Each pump 41, 42 comprises a tube 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 generally circular 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. Preferably, the tube has a circular cross-sectional shape, although other shapes such as elliptical may be utilized.

[0015] As shown, the inlet device 44 and the outlet device 46 are spaced apart approximately 180 degrees at respective locations forming two 180 degree pumps 41, 42. The inlet and outlet device may be located adjacent each other, thus forming a single 360 degree pump. Other variations may be utilized, such as 270 degrees, etc. As shown in Figures 3A and 3B, the outlet device 46 is a connector having a body 47 having a first port 48 that connects to pump 41 outlet end 41 b. The first port 48 is in fluid communication with outlet port 52. Outlet port 52 extends into the tire cavity so that the pump end 41 b is in fluid communication with the tire cavity. The outlet device further includes a second port 50 that connects to pump 42 outlet end 42b. The second port 50 is connected to an outlet port 54 that is located in the tire cavity so that the pump end 42 is in fluid communication with the tire cavity. Fig 3B further illustrates that each outlet end 52, 54 may further comprise a check valve 56, 58 to prevent backflow of air into the pump. The outlet ends 52, 54 of the outlet device 46 extend into the tire cavity so that the outlet ends are in fluid communication with the internal tire cavity 40.

[0016] A first embodiment of an inlet device 44 is shown in Figures 8-10. The inlet device functions to regulate the inlet flow of both pumps 41, 42. The inlet device 44 includes an outer T-shaped insert 60 that may be molded into a green tire and then cured. Figures 8-10 illustrate the inlet device installed in the sidewall 32 of a tire, wherein the T shaped portion of the insert is located on the interior portion of the tire sidewall, facing the tire cavity 40. An outer face 61 of the insert is preferably flush with the tire sidewall 32. The insert 60 has an inner chamber 62 formed by sidewalls 63 and bottom wall 64. Two holes 65, 66 are located in the inner chamber sidewall 63 for fluid communication with inlet tube ends 41 a, 42a of the pumps 41, 42.

[0017] A regulator body 68 is received within the inner chamber 62 of the insert through threaded hole 69 of the outer face 61. Preferably, the outer surface of the regulator body is threaded, so that the regulator body can be screwed in or out of the threaded hole 69, thereby adjusting the length of the distal end 70 of the regulator body located within the chamber. The regulator body 68 has an interior channel 72 that extends throughout the regulator body and is in fluid communication with the outside air of the tire and the inner cavity 62 of the insert.

[0018] A pressure membrane 74 is received within a hole 75 of the T-shaped insert chamber wherein the outer circumference of the pressure membrane is supported by a rim 76 about the inner chamber wall 63. The pressure membrane is preferably disk shaped and formed of a flexible material such as, but not limited to, rubber, elastomer, plastic or silicone. The pressure membrane 74 is responsive to the pressure in the interior of the tire cavity 40 on one side of the membrane, and is responsive to the pressure in inlet chamber 63 on the other side of the membrane. As shown in Figure 8, if the tire pressure is sufficiently high, the membrane flexes and engages the distal end 70 of the regulator body 68, wherein the pressure membrane seals off flow from the channel 72 so that no airflow may enter the pump inlet ends 41 a, 42a. As the tire loses air pressure, the pressure membrane 74 retracts from the distal end 70 of the regulator body, opening up the regulator channel 72. Outside air may then enter the channel 72 of the regulator body, then through the chamber 63 and out the holes 65, 66 into the pump inlet ends 41 a, 42a.

[0019] The operation of the inlet regulator device 44 may now be described. The pressure membrane is responsive to the pressure in the tire cavity and the pressure in the regulator body chamber 63. The pressure in the chamber is similar to the pressure in the outside air. When the tire pressure is sufficiently high, the pressure membrane is responsive to the tire pressure, and if the pressure is sufficiently higher than the chamber pressure, the pressure membrane is forced into engagement with the distal end 70 of the regulator body, thus sealing off flow to the inlet ends of the pump, as shown in Figure 10. As the tire pressure decreases, the pressure membrane unseats from the distal end of the regulator body as shown in Figure 9, allowing air to enter the chamber 63 and into the inlet ends of the pumps 41, 42 via side holes 65, 66 in the chamber walls. As shown in Fig 8, the inlet regulator device 44 may be adjusted by screwing (rotating) the regulator body 68 in either direction in order to increase or decrease the distance from the distal end of the regulator body to the pressure membrane, thus altering the pressure at which flow will be shut off to the pumps.

[0020] A second embodiment of an inlet device 200 is shown in Figures 11-14. The inlet device functions to regulate the inlet flow of both pumps 41, 42. The inlet device 200 includes an outer T shaped insert 210 that may be molded into a green tire and then cured. Figure 14 illustrates the inlet device installed in the sidewall 32 of a tire, wherein the T shaped portion of the insert is located on the interior portion of the tire sidewall, facing the tire cavity 40. An outer face 212 of the insert is preferably flush with the tire sidewall 32. The insert has an inner chamber 220 formed by sidewalls 222 and bottom wall 224. Two holes 226, 228 are located in the inner chamber sidewall 222 for fluid communication with inlet tube ends 41,42a of the pumps 41, 42.

[0021] A regulator piston 230 is slidably received within the inner chamber 220 of the insert. The regulator piston 230 has an outer flanged surface 232 which is slidably received within a slot 234 or cylinder of the chamber sidewall. An outer stop 236 located on the upper chamber wall of the T shaped insert retains the piston 230 within the chamber. An optional outer membrane 221 is received over the top of the piston 230 to make the system airtight and to prevent leakage of air between the piston and the cylinder 234. The regulator piston has an interior threaded bore 240 in which an adjustable member 242 is received. The adjustable member 242 is positioned to engage an inner stop 250 located on an interior annular wall 252 of the T shaped insert 210. The interior annular wall 252 surrounds a channel 266 that extends from the outer face 212 to the inner chamber220 so that the outside air is in fluid communication with the chamber. A spring 260 is positioned in the insert chamber 220 with a first end 261 engaging the piston end wall 262 and a second end 263 engaging the bottom wall of the chamber 224. The spring biases the piston and the adjustable member away from the inner stop 250.

[0022] The operation of the inlet regulator device 200 may now be described. The regulator piston 230 is responsive to the pressure in the tire cavity, the pressure in the insert chamber 220 and the spring 260. The pressure in the chamber is similar to the pressure in the outside air. When the tire pressure is sufficiently high, the regulator piston overcomes the spring force and is forced into engagement with the stop 250 of the insert, thus sealing off flow to the inlet ends of the pump, as shown in Figure 12. As the tire pressure decreases, the spring force overcomes the force from the tire pressure, pushing the piston 230 away from the stop 250 as shown in Figure 13, allowing outside air to enter the chamber 220 and into the inlet ends of the pumps 41,42 via side holes 226, 228 in the chamber walls. The inlet regulator device 200 may be adjusted by screwing (rotating) the adjustable member 242 in either direction in order to increase or decrease the distance from the distal end of the adjustable member to the stop 250, thus altering the pressure at which flow will be shut off to the pumps.

[0023] As will be appreciated from FIG. 4A, the inlet device 44 and the outlet device 46 are in fluid communication with the circular air tube 42 and positioned generally 180 degrees apart. As the tire rotates in a direction of rotation 88, a footprint 100 is formed against the ground surface 98. A compressive force 104 is directed into the tire from the footprint 100 and acts to flatten a segment 110 of the pump 42 a as shown at numeral 106. Flattening of the segment 110 of the pump 42 forces a portion of air located between the flattened segment 110 and the outlet device 46, in the direction shown by arrow 84 towards the outlet device 46.

[0024] As the tire continues to rotate in direction 88 along the ground surface 98, the pump tube 42 will be sequentially flattened or squeezed segment by segment in a direction 90 which is opposite to the direction of tire rotation 88. The sequential flattening of the pump tube 42 segment by segment causes the column of air located between the flattened segments to and the outlet device

46 be pumped in the direction 84 within pump 42 to the outlet device 46.

[0025] With the tire rotating in direction 88, flattened tube segments are sequentially refilled by air 92 flowing into the inlet device 44 along the pump tube 42 in the direction 90 as shown by FIG. 4A. The inflow of air from the inlet device 44 in direction 90 continues until the outlet device 46, rotating counterclockwise as shown with the tire rotation 88, passes the tire footprint. 100.

[0026] FIG. 4B shows the orientation of the peristaltic pump assembly 14 in such a position. In the position shown, the tube 42 continues to be sequentially flattened segment by segment 102, 102', 102", opposite the tire footprint by compressive force 104 as shown at numeral 106. Air is pumped in the clockwise direction 94 to the inlet device 44 where it is evacuated or exhausted from the passageway 43. Passage of exhaust air 96 from the inlet device 44 is through the filter 80 which acts to self-clean the filter of accumulated debris or particles within the porous medium. With the evacuation of pumped air out of the inlet device 44, the outlet device is in the closed position and air does not flow therefrom to the tire cavity. When the tire rotates further in counterclockwise direction 88 until the inlet device 44 passes the tire footprint 100 (as shown in FIG. 4A), the airflow resumes to the outlet device 46 causing the pumped air to flow out (86) to the tire cavity 40.

[0027] The above-described cycle is then repeated for each tire revolution, half of each rotation resulting in pumped air going to the tire cavity and half of the rotation the pumped air is directed back out the inlet device filter 80 to self-clean the filter. It will be appreciated that while the direction of rotation 88 of the tire 12 is shown in FIGS. 4A and 4B to be counterclockwise, the subject tire assembly and its peristaltic pump assembly 14 will function in like manner in a (clockwise) reverse direction of rotation to that shown at numeral 88. The peristaltic pump is accordingly bidirectional and equally functional with the tire assembly moving in a forward or a reverse direction of rotation.

[0028] The location of the peristaltic pump assembly will be understood from FIGS. 5-6. In one embodiment, the peristaltic pump assembly 14 is positioned in the tire sidewall, radially outward of the rim flange surface 26 in the chafer 120. So positioned, the air tube 42 is radially inward from the tire footprint 100 and is thus positioned to be flattened by forces directed from the tire footprint as described above. The segment that is opposite the footprint 100 will flatten from the compressive force 114 from the footprint 100 pressing the tube segment against the rim flange surface 26. Although the positioning of the tube 42 is specifically shown as between a chafer 120 of the tire at the bead region 34 and the rim surface 26, it is not limited to same, and may be located at any region of the tire such as anywhere in the sidewall or tread. The diametric sizing of the peristaltic pump air tube 42 is selected to span the circumference of the rim flange surface 26, although it is not limited to same.

[0029] From the forgoing, it will be appreciated that the subject invention provides a bi-directionally peristaltic pump for a self-inflating tire in which a circular air tube 42 flattens segment by segment and closes in the tire footprint 100. The air inlet T-device 44 may include a filter 80 and be self-cleaning. The peristaltic pump assembly 14 pumps air under rotation of the tire in either direction, one half of a revolution pumping air to the tire cavity 40 and the other half of a revolution pumping air back out of the inlet device 44 (filter 80). The peristaltic pump assembly 14 may 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 pneumatic tire comprising a tire cavity (40); first and second sidewalls (30, 32) extending respectively from first and second tire bead regions to a tire tread region; an air passageway (43), wherein the air passageway (43) is designed and located such that it is operative to allow a portion of the air passageway (43) near a tire footprint to at least substantially close the air passageway (43); an inlet regulator device (44) connected to an inlet end of the air passageway (43), the inlet regulator device (44) including an insert (60, 210) mounted in the tire (12), wherein the insert (60, 210) has a hole or bore extending therethrough having a first end located in or close to the tire cavity (40), and a second end which extends through the tire (12), wherein

   (i) a pressure membrane (74) is received within the first end of the insert (60), and a regulator body (68) is received within the second end of the insert (60), wherein the regulator body (68) has a interior passageway (72) which extends from a first end to a distal end, wherein the distal end extends into a cavity (62) or a chamber (63) of the insert (60), wherein the pressure membrane (74) is responsive to a tire cavity pressure and an outside air pressure, and wherein the pressure membrane (74) is positioned for engagement with the distal end of the regulator body (68) when the tire pressure reaches a set value; or wherein

   (ii) the insert (210) comprises a middle portion forming a chamber (220), and a second end which extends through the tire (12) and which is in fluid communication with an outside air and the chamber (220), wherein a piston (230) is slidably mounted within the first end of the insert (210), wherein a regulator body is received within the chamber (220) and positioned to engage a stop (250), the chamber (220) having a hole (226, 228) for fluid communication with an air inlet, wherein a spring (260) is mounted within the chamber (220) having a first end for engagement with the piston (230) and a second end for engagement with a bottom wall of the chamber (220), and wherein the regulator body has a interior passageway which extends from a first end to a distal end, the distal end extending into a cavity of the insert (210).

2. The tire of claim 1 comprising an air tube (41), preferably an annular air tube (41), defining the air passageway (43), the air tube (41) being composed of a flexible material operative to allow a portion of the air tube (41) near a tire footprint to at least substantially close the air passageway (43).

3. The tire of claim 1 or 2 wherein the air passageway (43) or the air tube (41) is integrated into the tire (12) or connected to the tire (12).

4. The tire of claim 2 or 3 wherein the inlet regulator device (44) is connected to an inlet end of the air tube (41).

5. The tire of at least one of the previous claims wherein the second end of the insert (60) extends through the tire (12) to an outside of the tire (12).

6. The tire of at least one of the previous claims wherein the second end of the insert (60) forms an outer face flush with an outer surface of the tire (12).

7. The tire of at least one of the previous claims wherein insert (60) is mounted in a sidewall (30, 32) of the tire (12).

8. The tire of at least one of the previous claims 1 to 6 wherein insert (60) is mounted in the tread of the tire (12).

9. The tire of at least one of the previous claims wherein the regulator body (68) has a threaded outer surface and the second end of the insert (60) has a threaded hole for receiving the threaded outer surface of the regulator body (68).

10. The tire of at least one of the previous claims wherein the air tube (41) and/or the air passageway (43) is sequentially flattened by the tire footprint to pump air along the air passageway (43) in either a forward tire direction of rotation or a reverse tire direction of rotation when the tire is mounted to a rim, inflated and operated on a running vehicle.

11. The tire of at least one of the previous claims wherein the tire (12) further comprises an outlet device (46) and wherein and the outlet device (46) and the inlet regulator device (44) are preferably mounted to the annular air tube (41) or the annular air passageway (43) substantially 180 degrees apart.

12. The tire of at least one of the previous claims wherein the air inlet is a pump inlet air tube.

13. The tire of at least one of the previous claims wherein an outer membrane (221) is received over a top of the piston (230).

14. The tire of at least one of the previous claims wherein the tire (12) is a self-inflating tire (12) when the tire (12) is to a rim (16), inflated and operated on a running vehicle.

15. A tire and rim assembly comprising a tire (12) in accordance with at least one of the previous claims mounted to a rim (16).

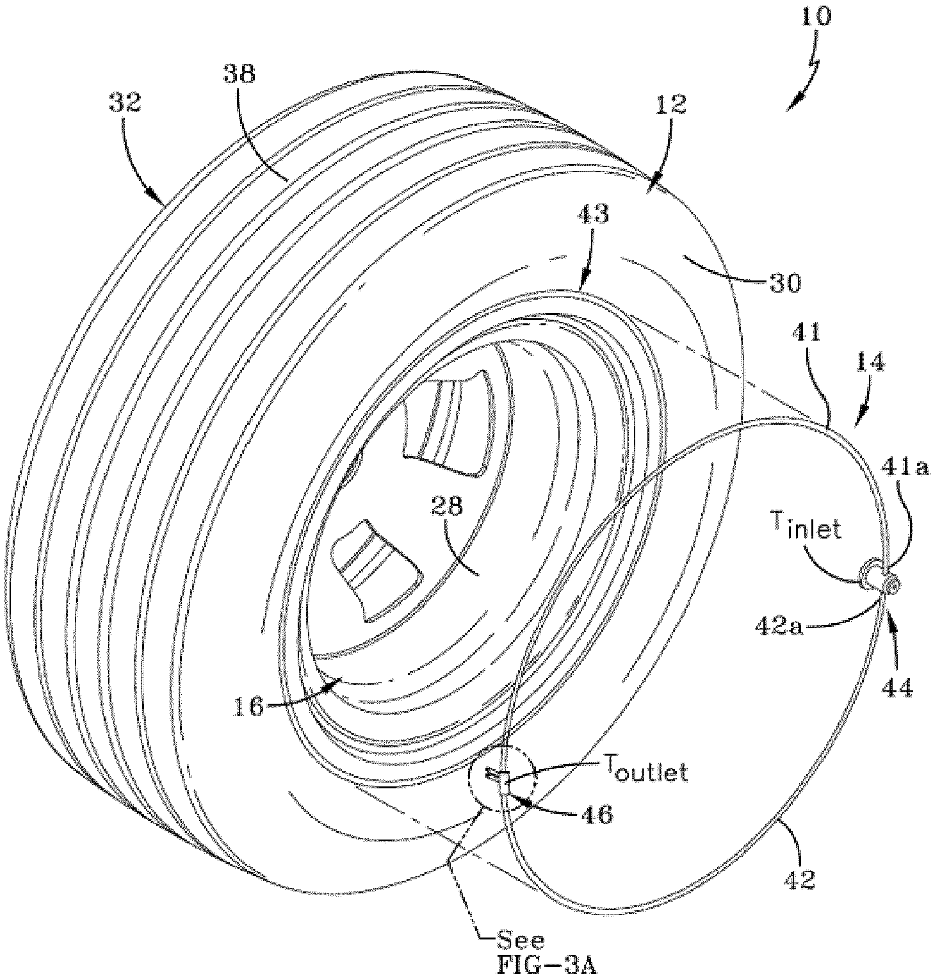

10
32
38
12
43
30
41
14
41a
28
T_{inlet}
42a
44
16
T_{outlet}
46
42
See
FIG-3A

FIG-1

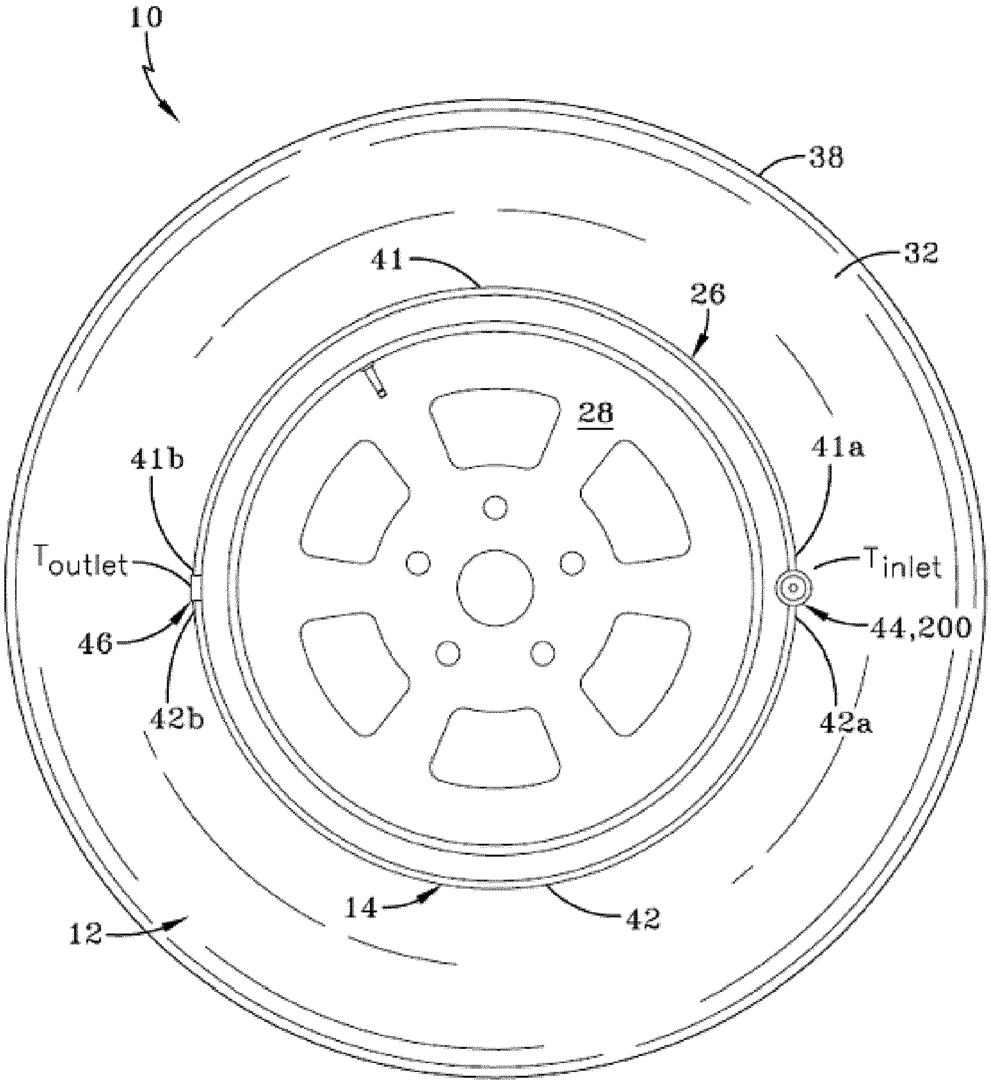
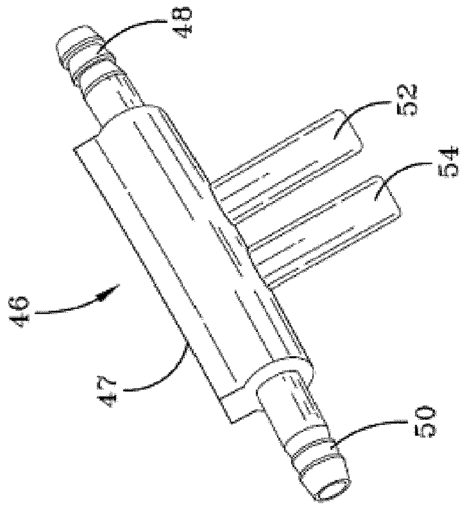
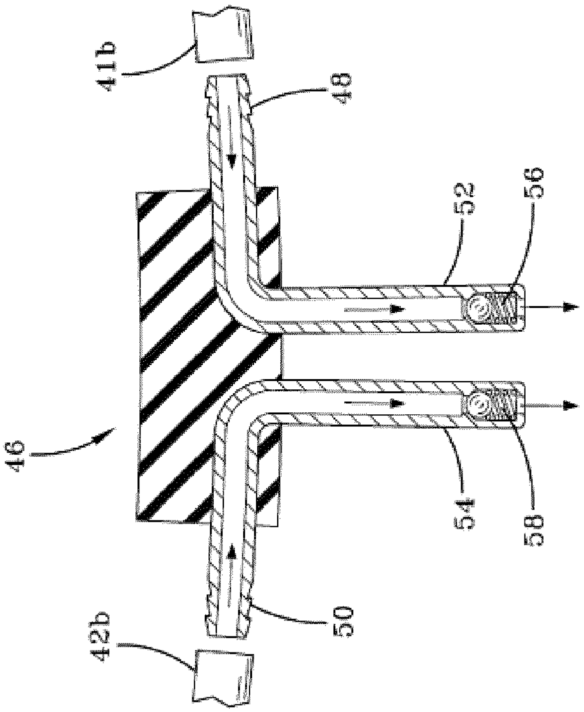

10
38
32
41
26
28
41b
41a
Toutlet
Tinlet
46
44,200
42b
42a
14
42
12

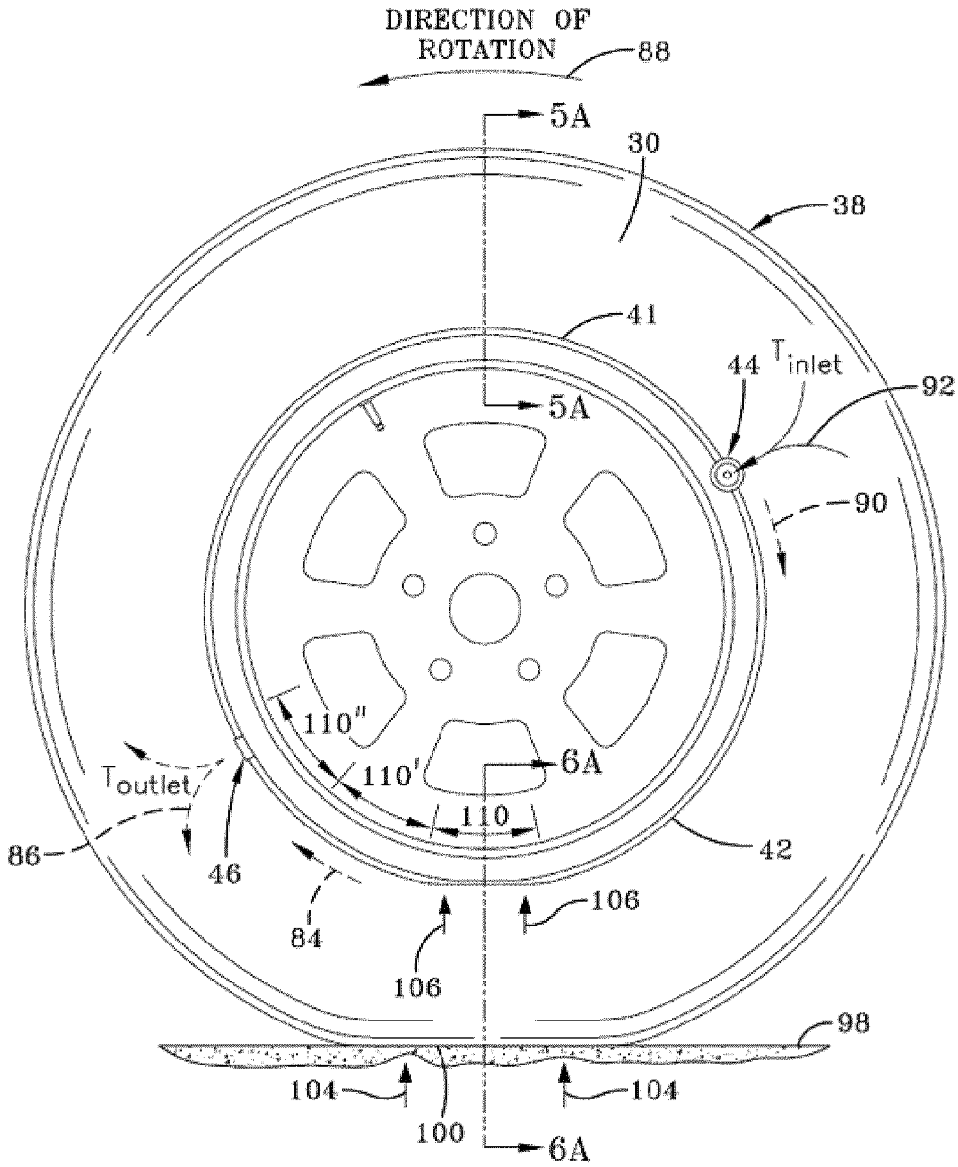
FIG-2



FIG—3A

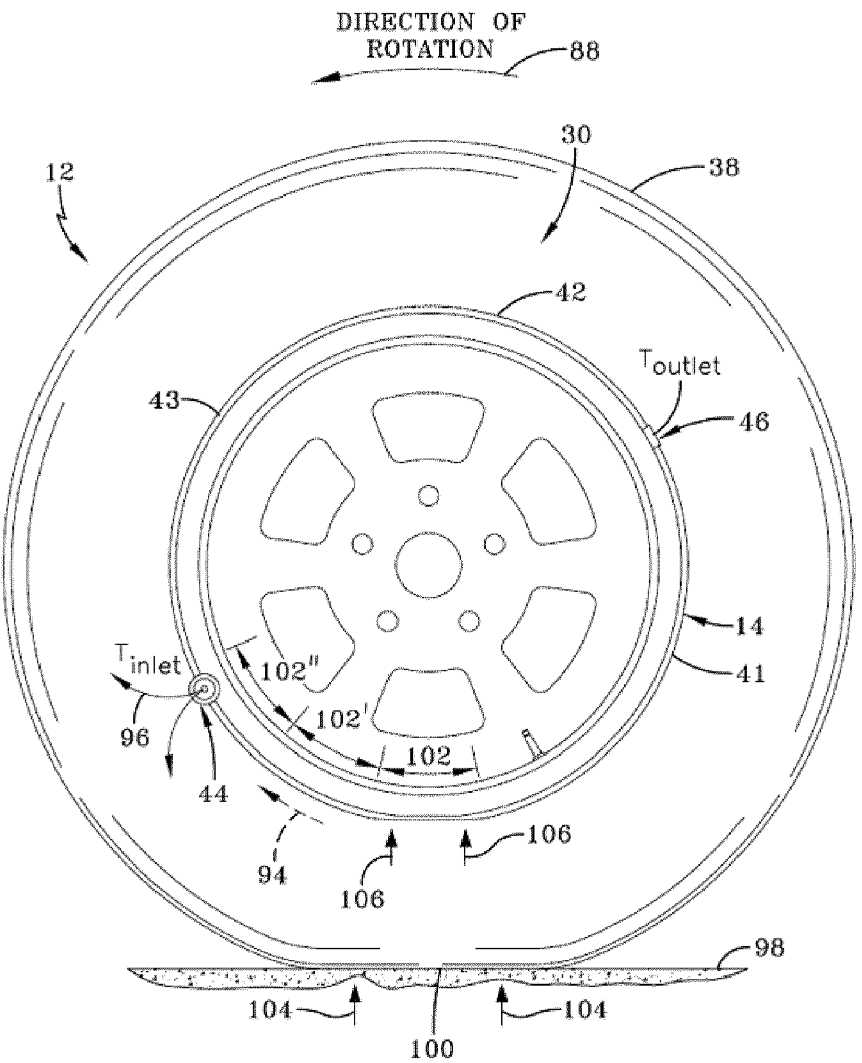


FIG—3B



DIRECTION OF
ROTATION
88
5A
30
38
41
44
T_{inlet}
92
5A
90
110″
110′
6A
110
T_{outlet}
86
46
42
84
106
106
98
104
104
100
6A

FIG-4A


DIRECTION OF
ROTATION
88
30
12
38
42
Toutlet
43
46
14
Tinlet
102''
41
96
102'
102
44
106
94
106
98
104
104
100

FIG–4B

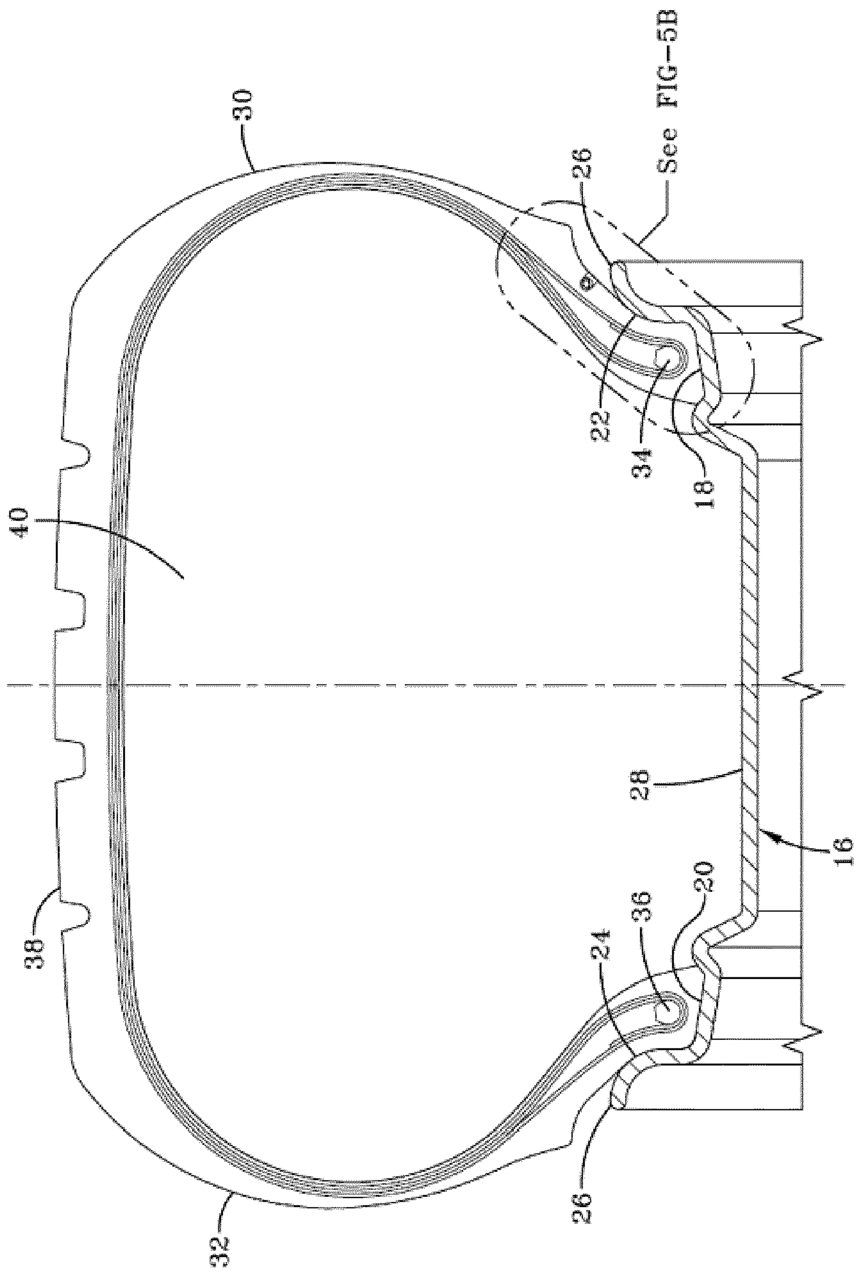


FIG-5A

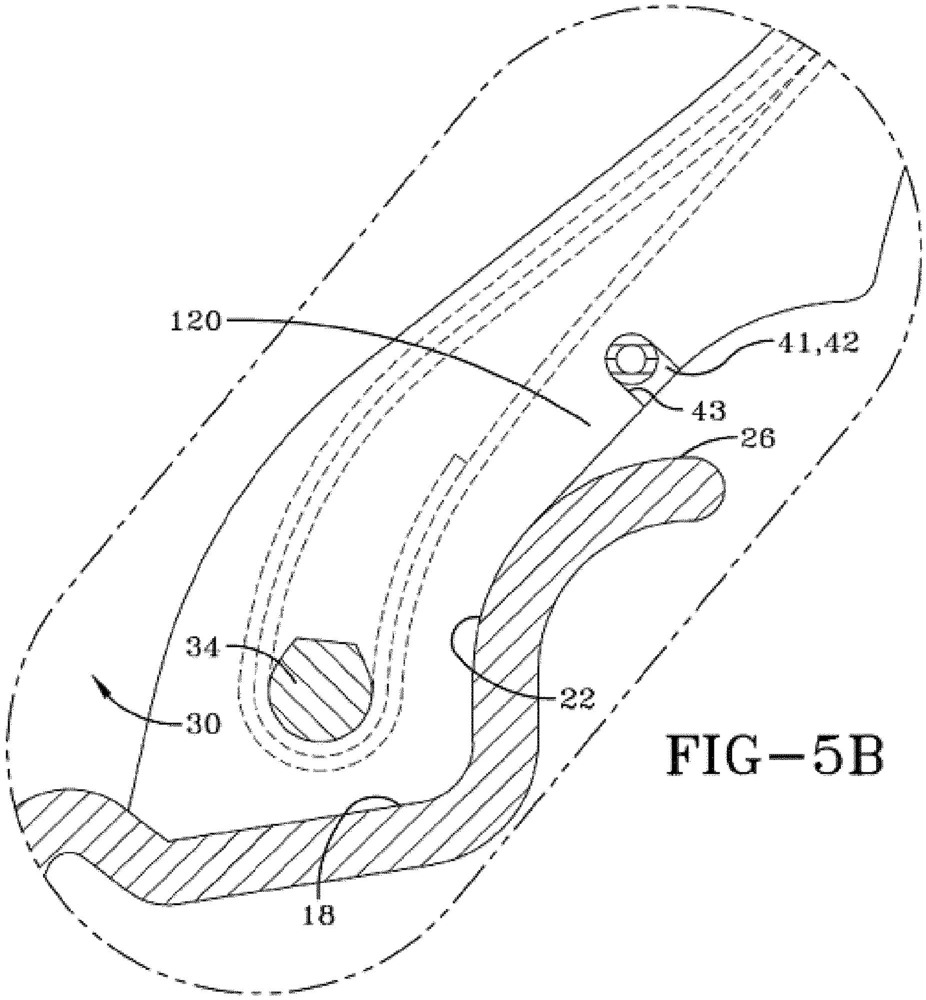


FIG-5B

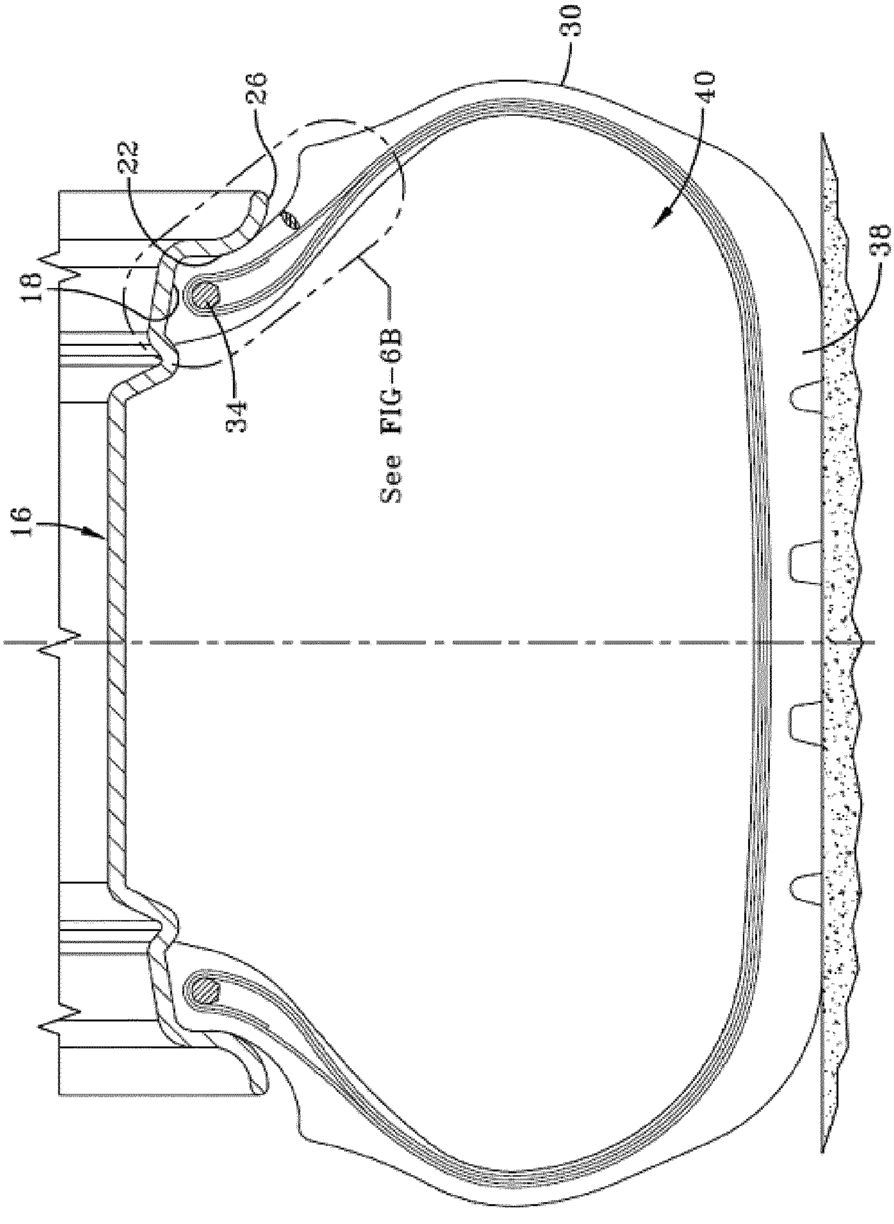


FIG-6A

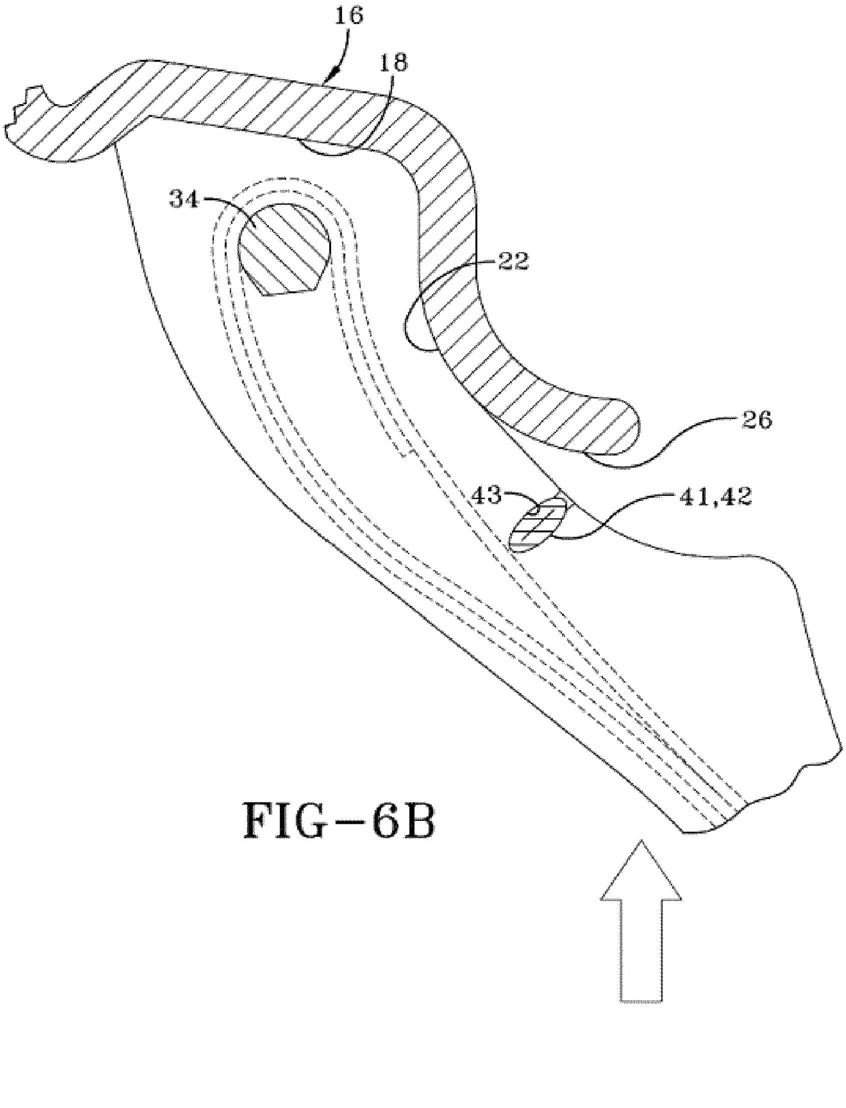


FIG-6B

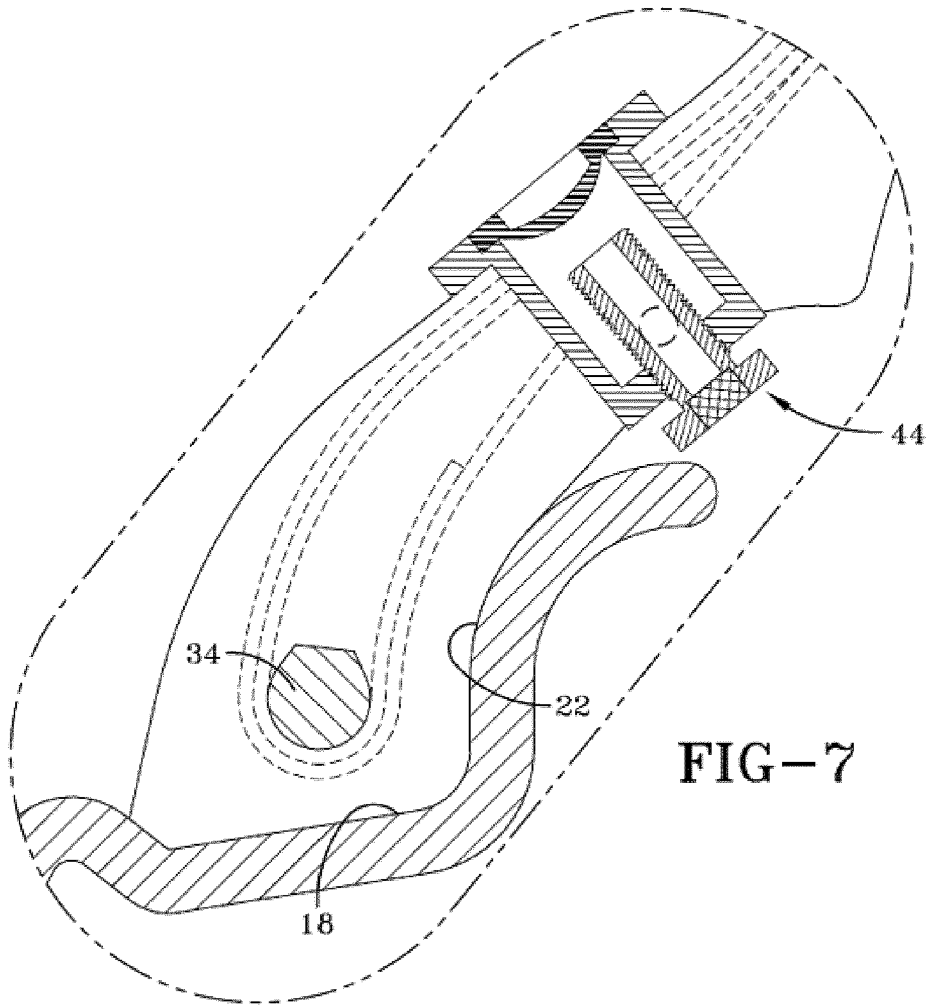
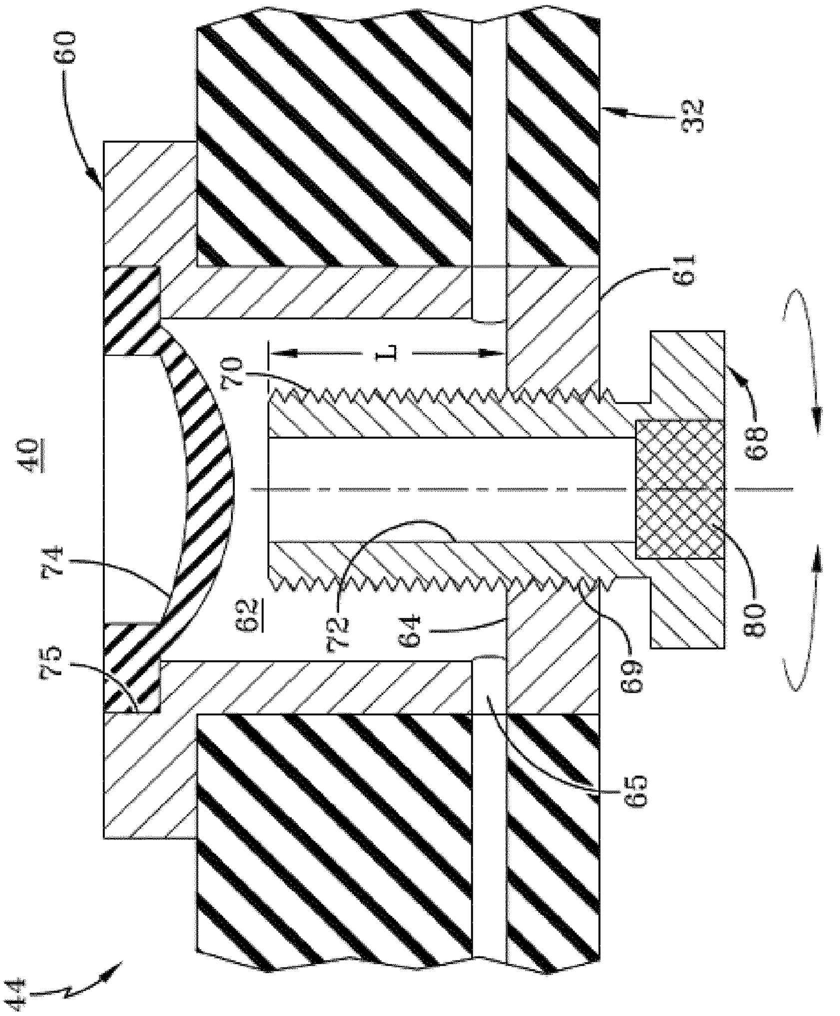


FIG-7



FIG–8

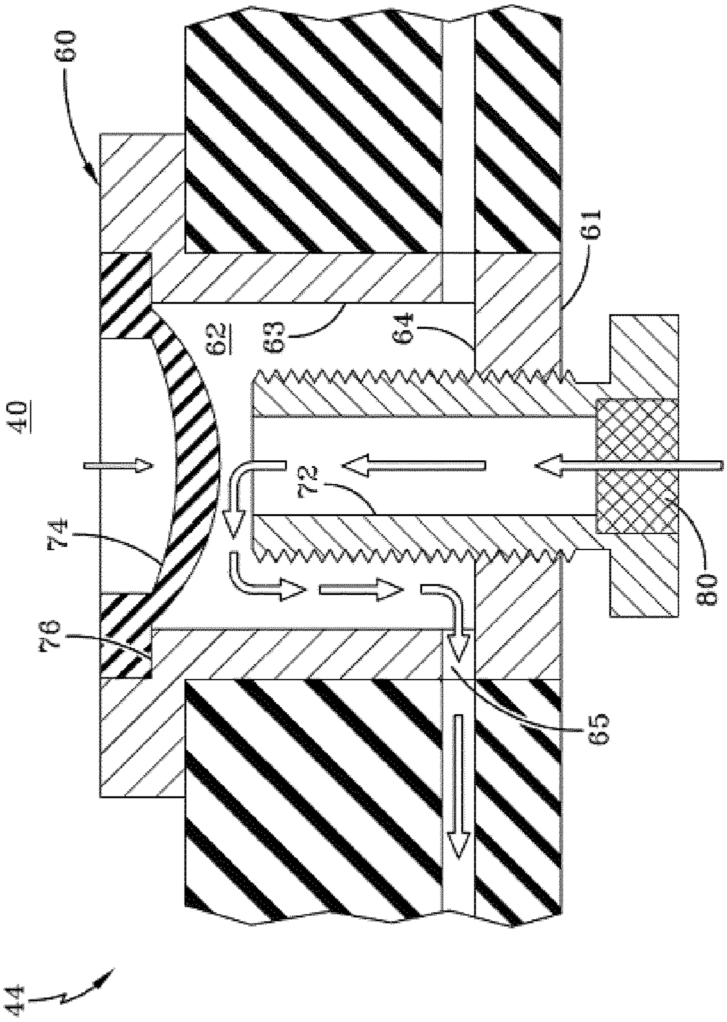
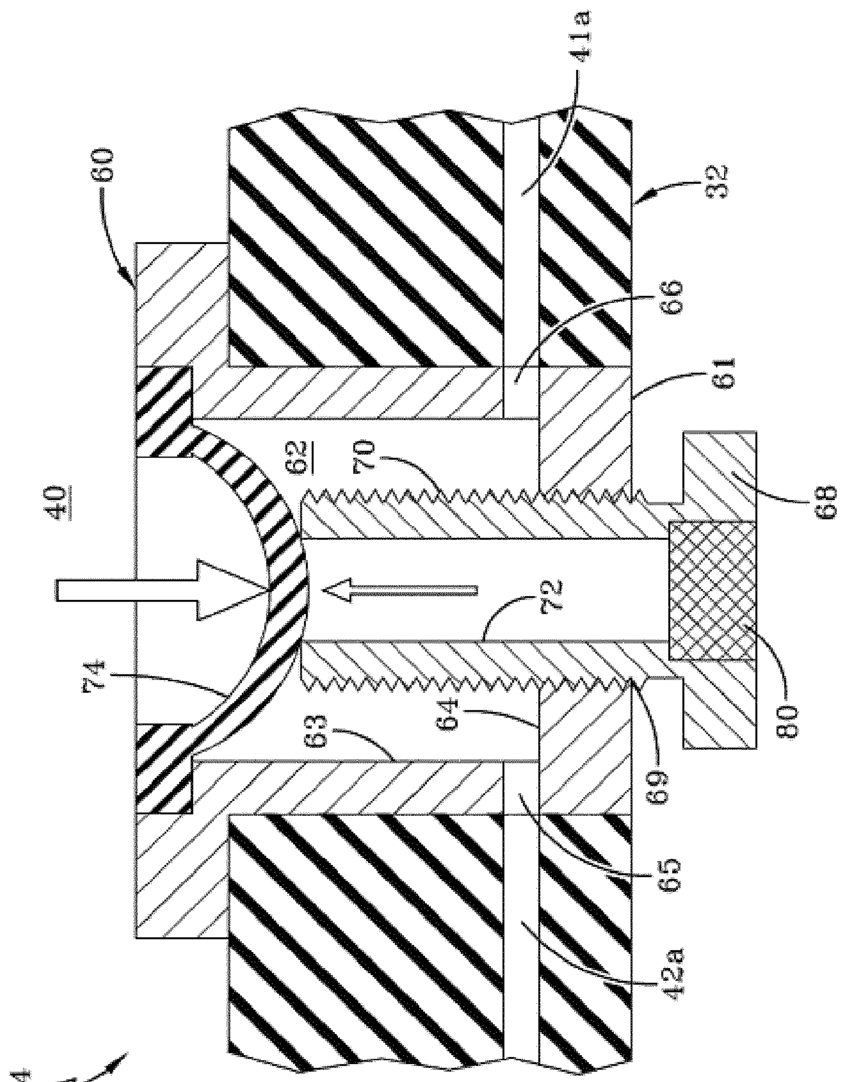
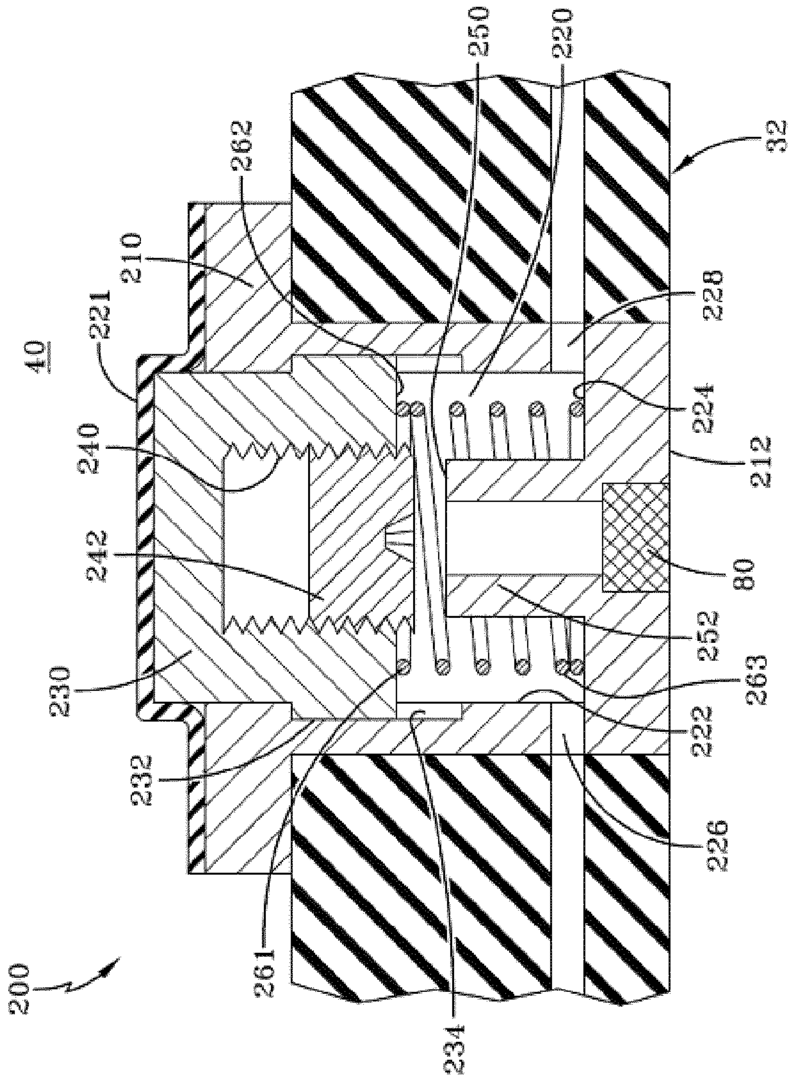


FIG-9



FIG—10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221
210
262
250
220
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224
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252
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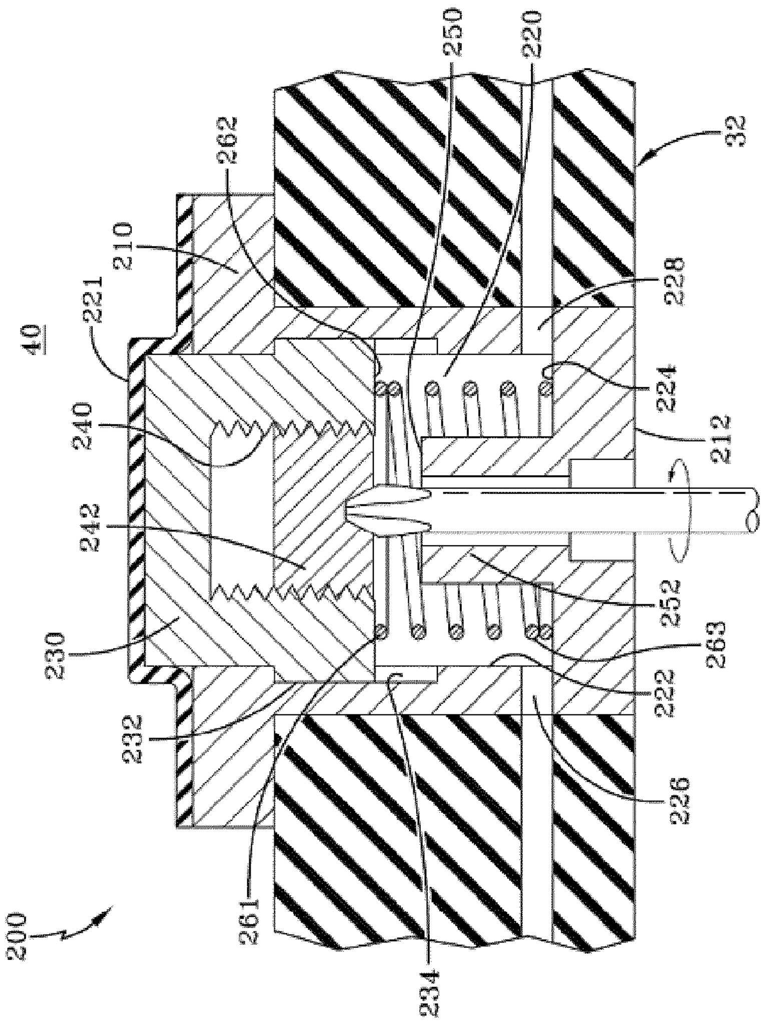
222
226
234
261
232
230
242
240

FIG—11A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FIG—11B

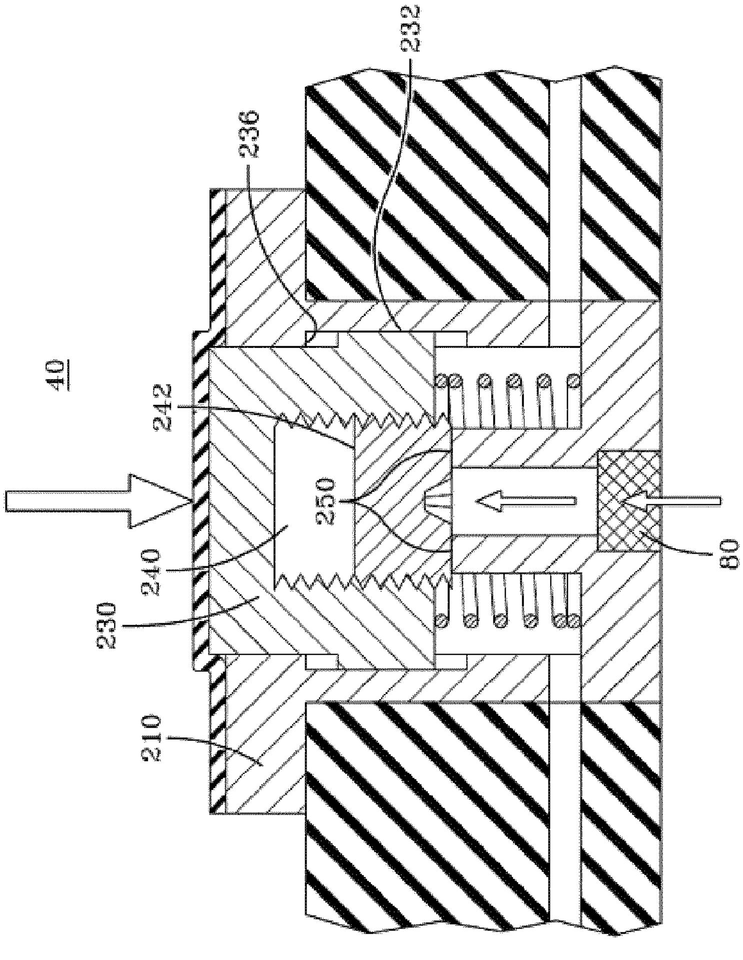

FIG-12

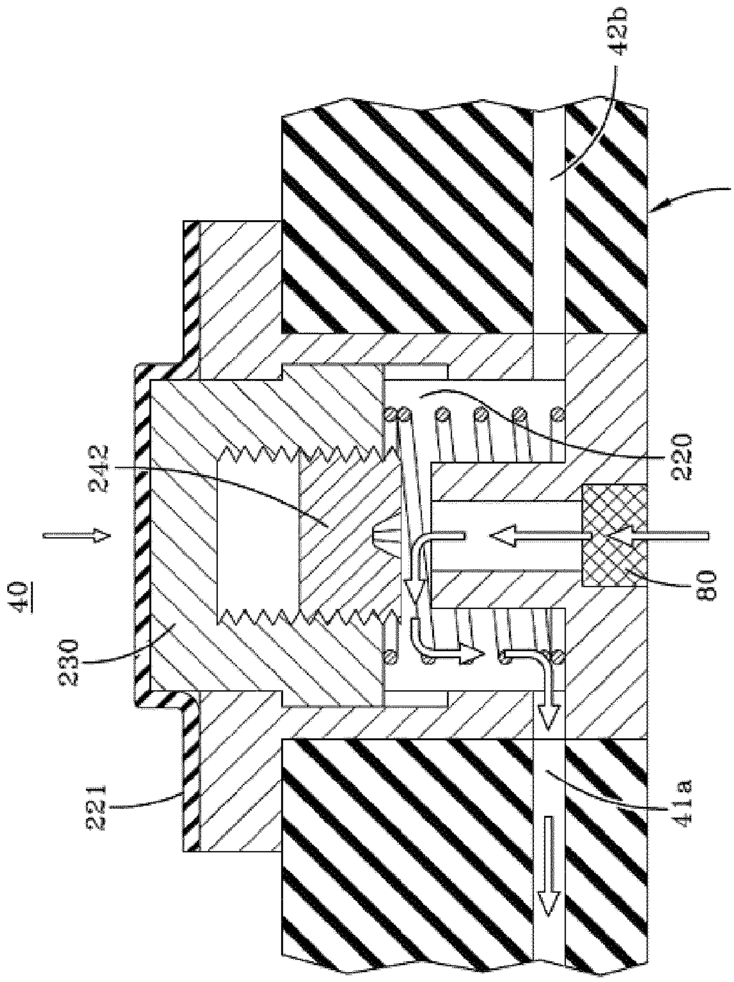

FIG-13

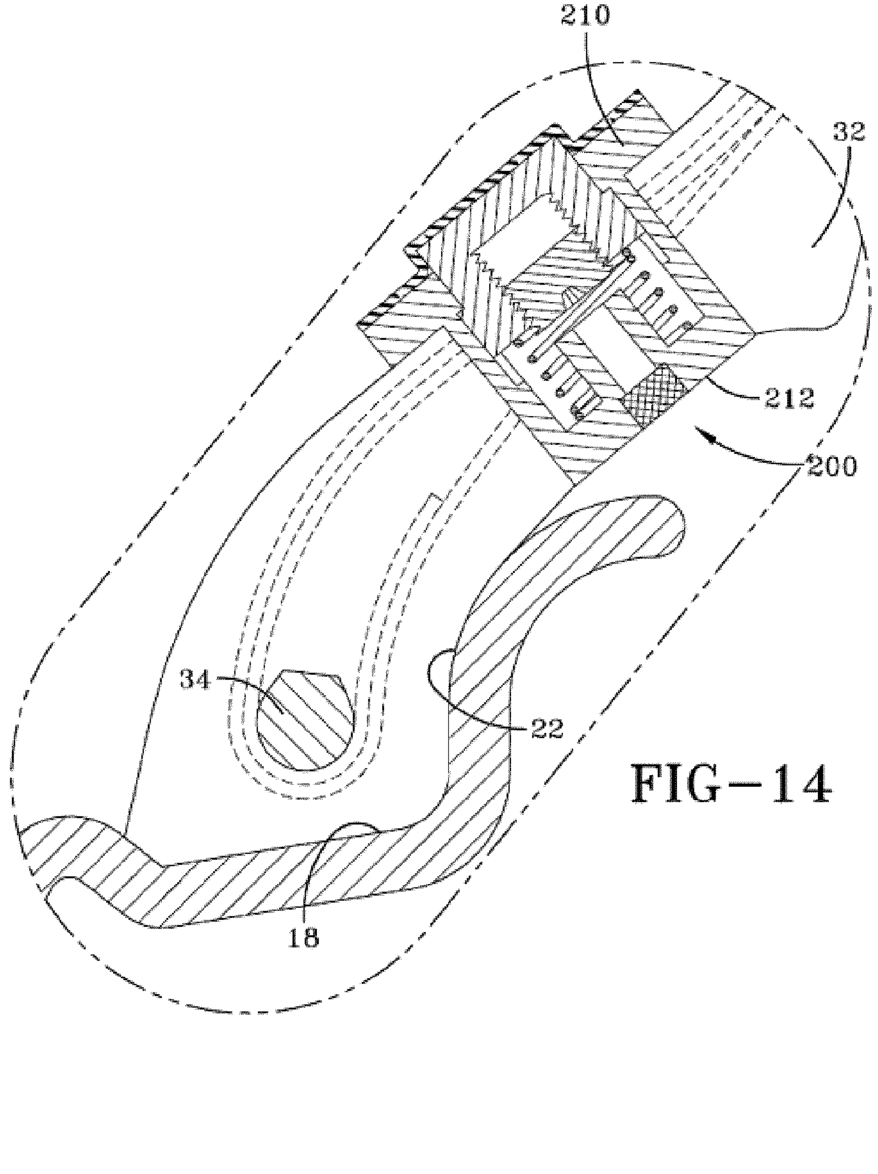

FIG-14

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- EP 2338703 A **[0002]**
- EP 2343200 A **[0002]**