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(54) **SELF-INFLATING TIRE**

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(57) **ABSTRACT**

A self-inflating tire assembly includes an air tube connected to a tire and defining an air passageway, the air tube being composed of a flexible material operative to allow an air tube segment opposite a tire footprint to flatten, closing the passageway, and resiliently unflatten into an original configuration. The air tube is sequentially flattened by the tire footprint in a direction opposite to a tire direction of rotation to pump air along the passageway to an inlet device for exhaust from the passageway or to an outlet device for direction into the tire cavity. The inlet device is positioned within the annular passageway 180 degrees opposite the outlet device such that sequential flattening of the air tube by the tire footprint effects pumping of air along the air passageway with the tire rotating in either a forward or reverse direction of rotation. The invention further includes an outlet device for regulating the tire cavity pressure and flow into the cavity.

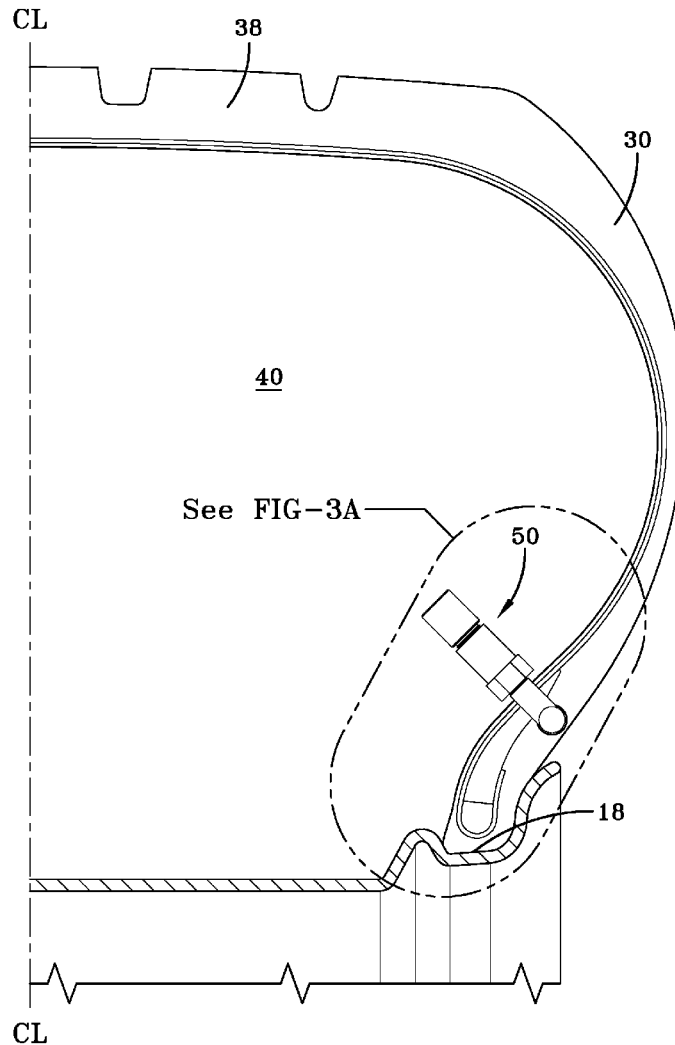
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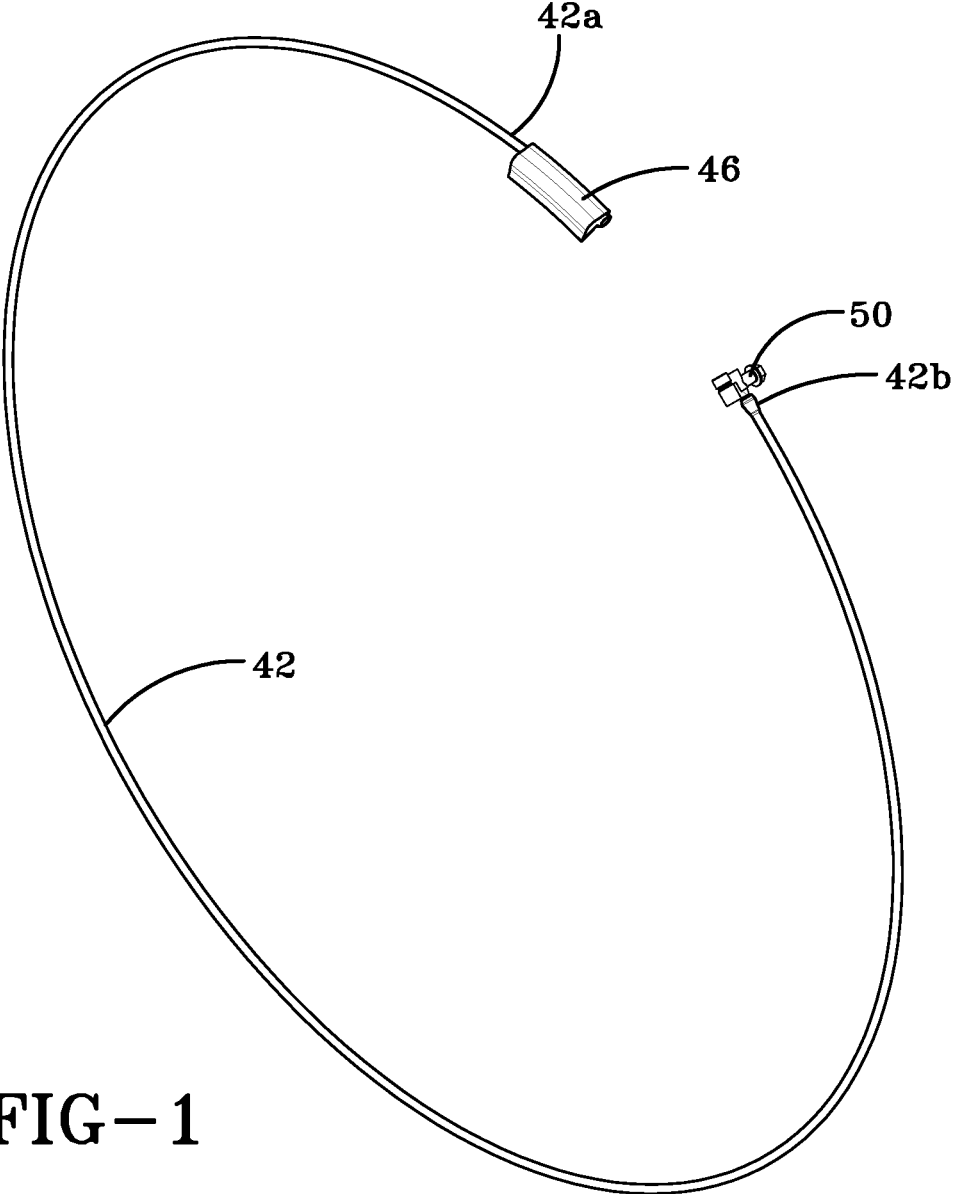


FIG-1

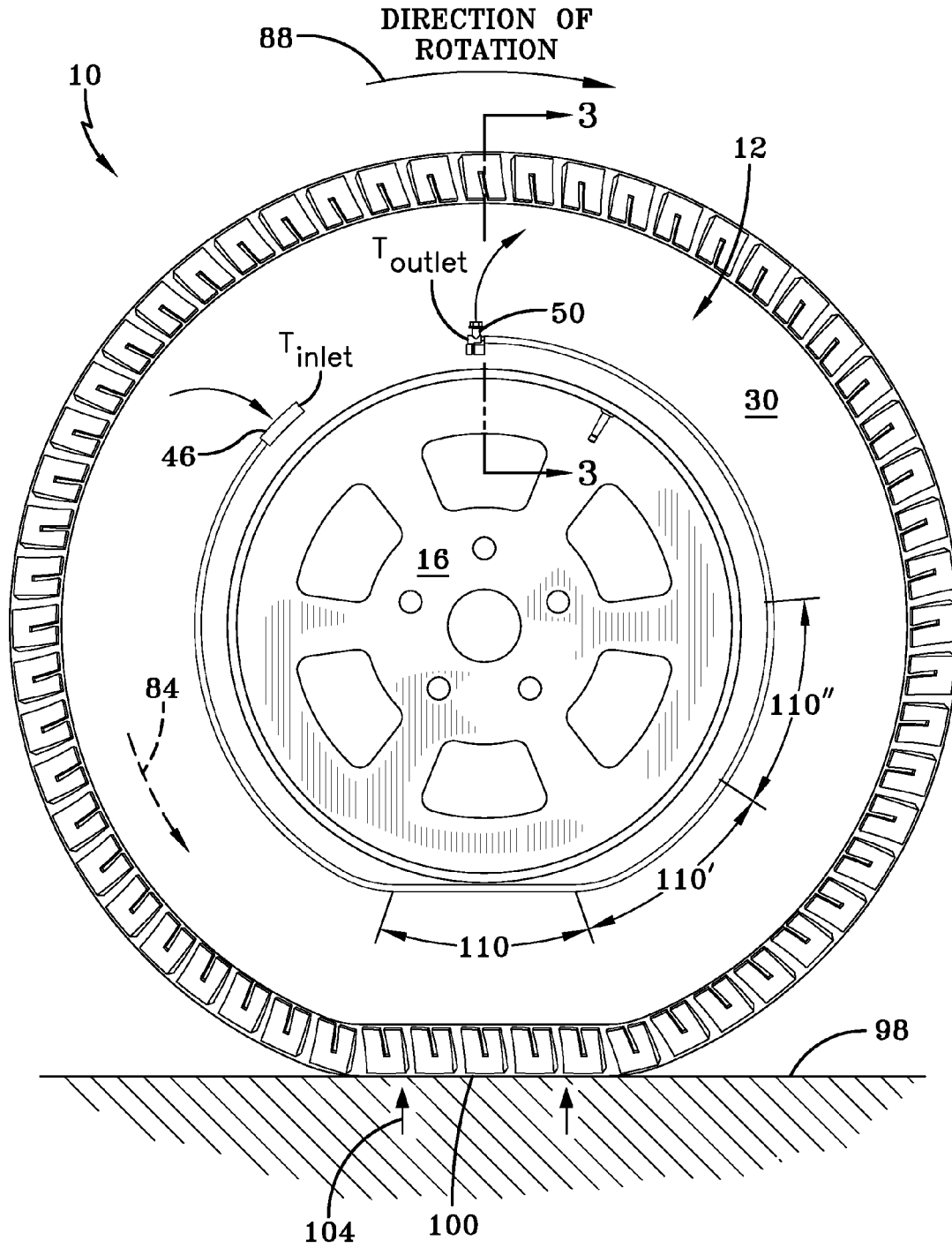


FIG-2

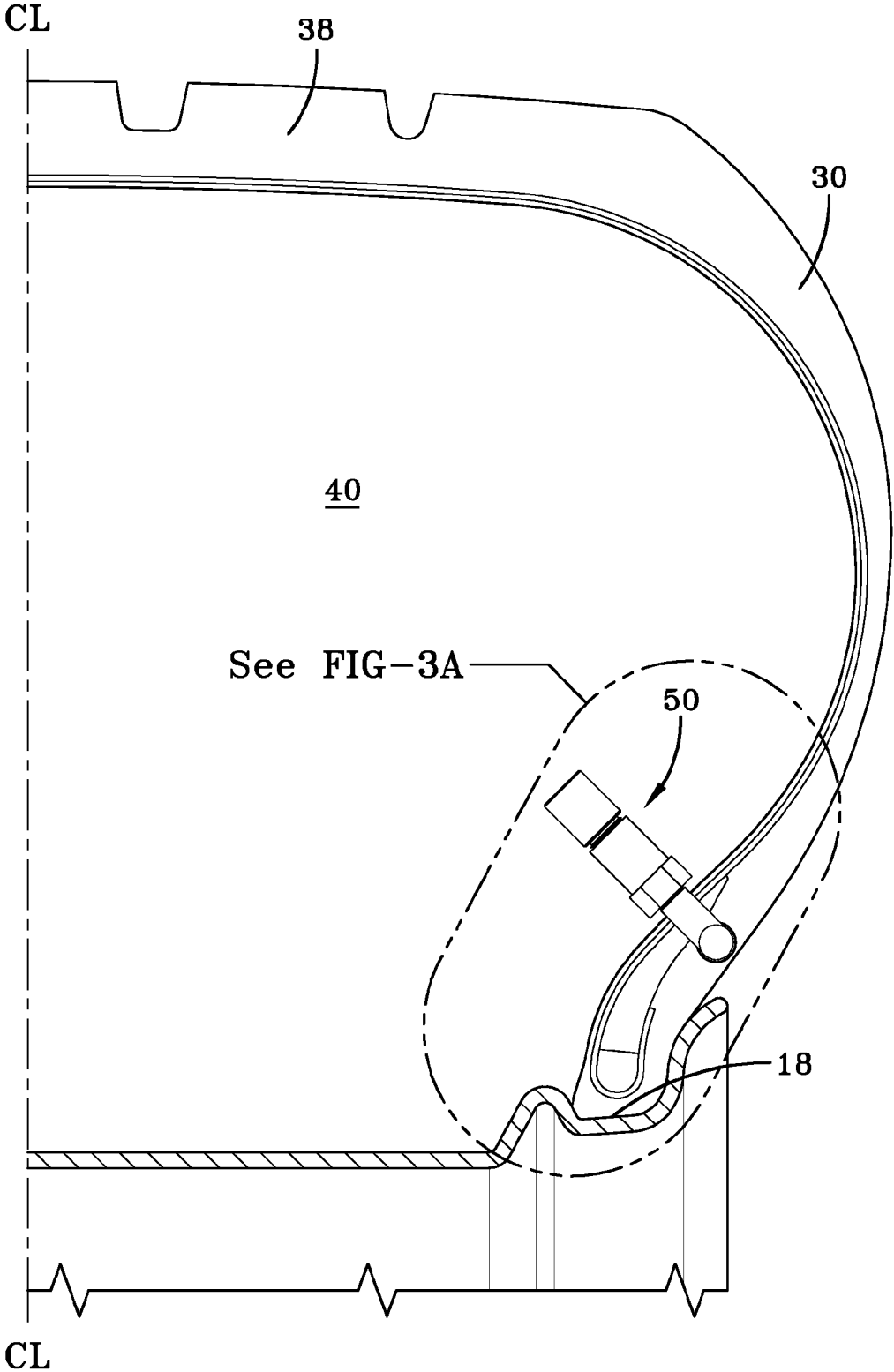


FIG-3

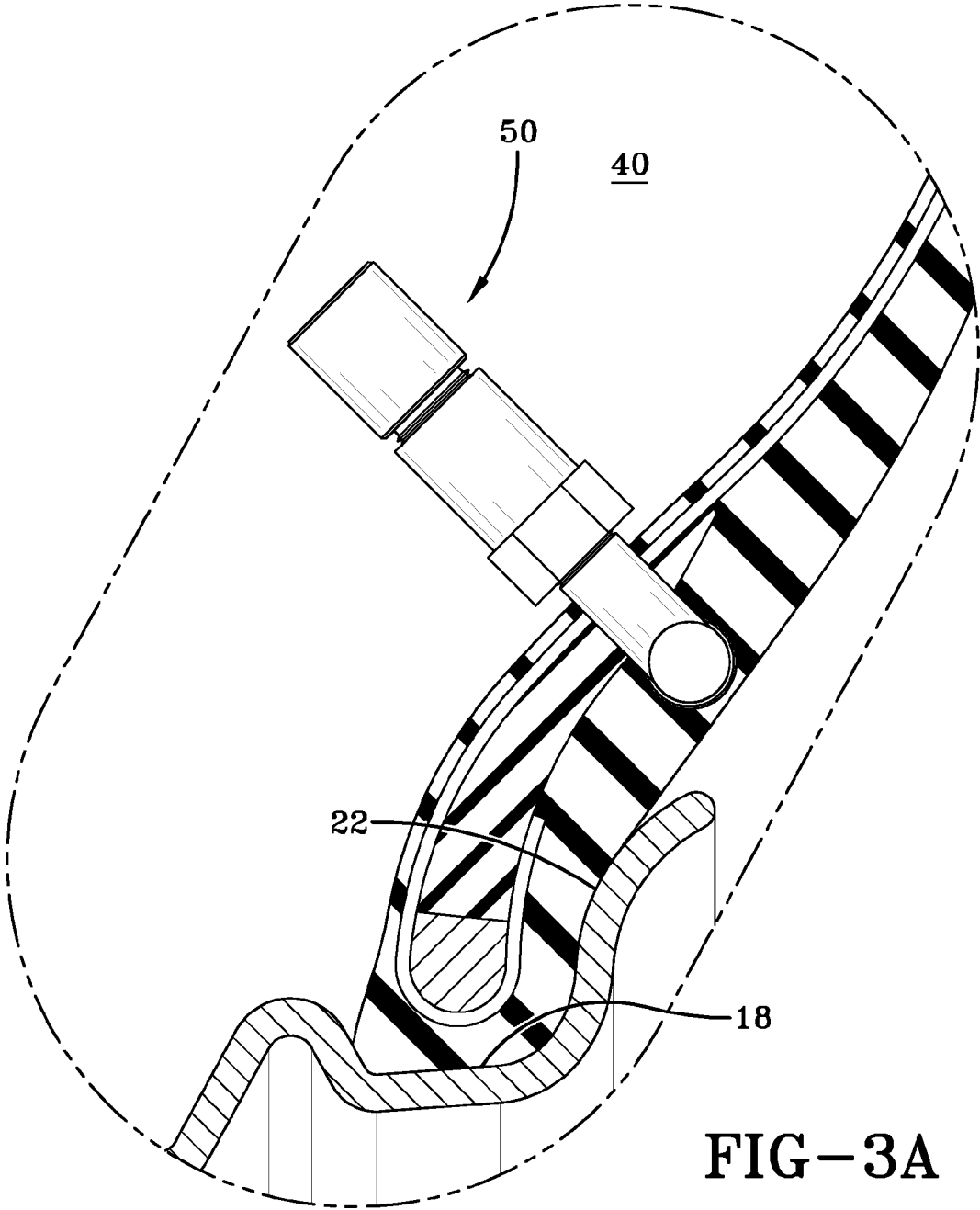
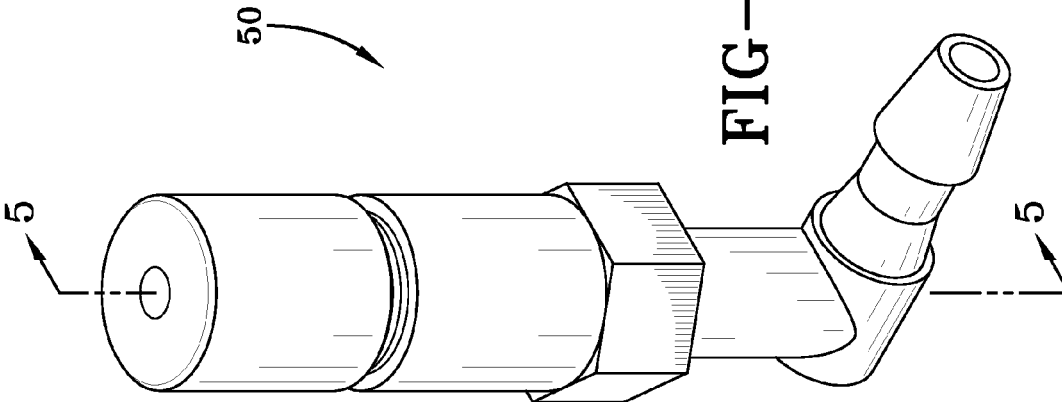
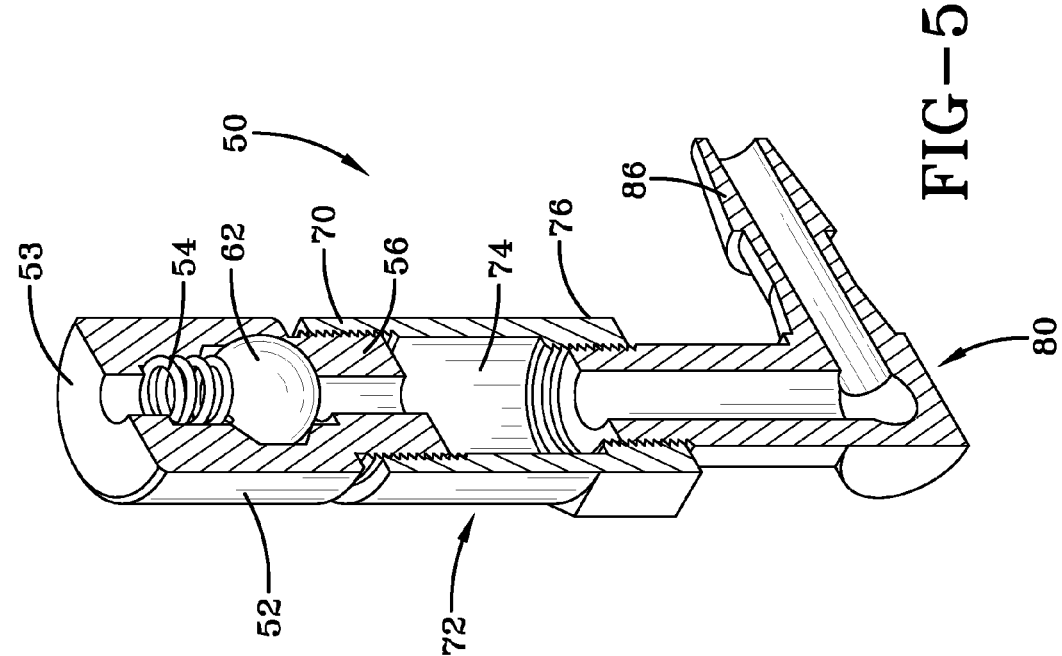


FIG-3A



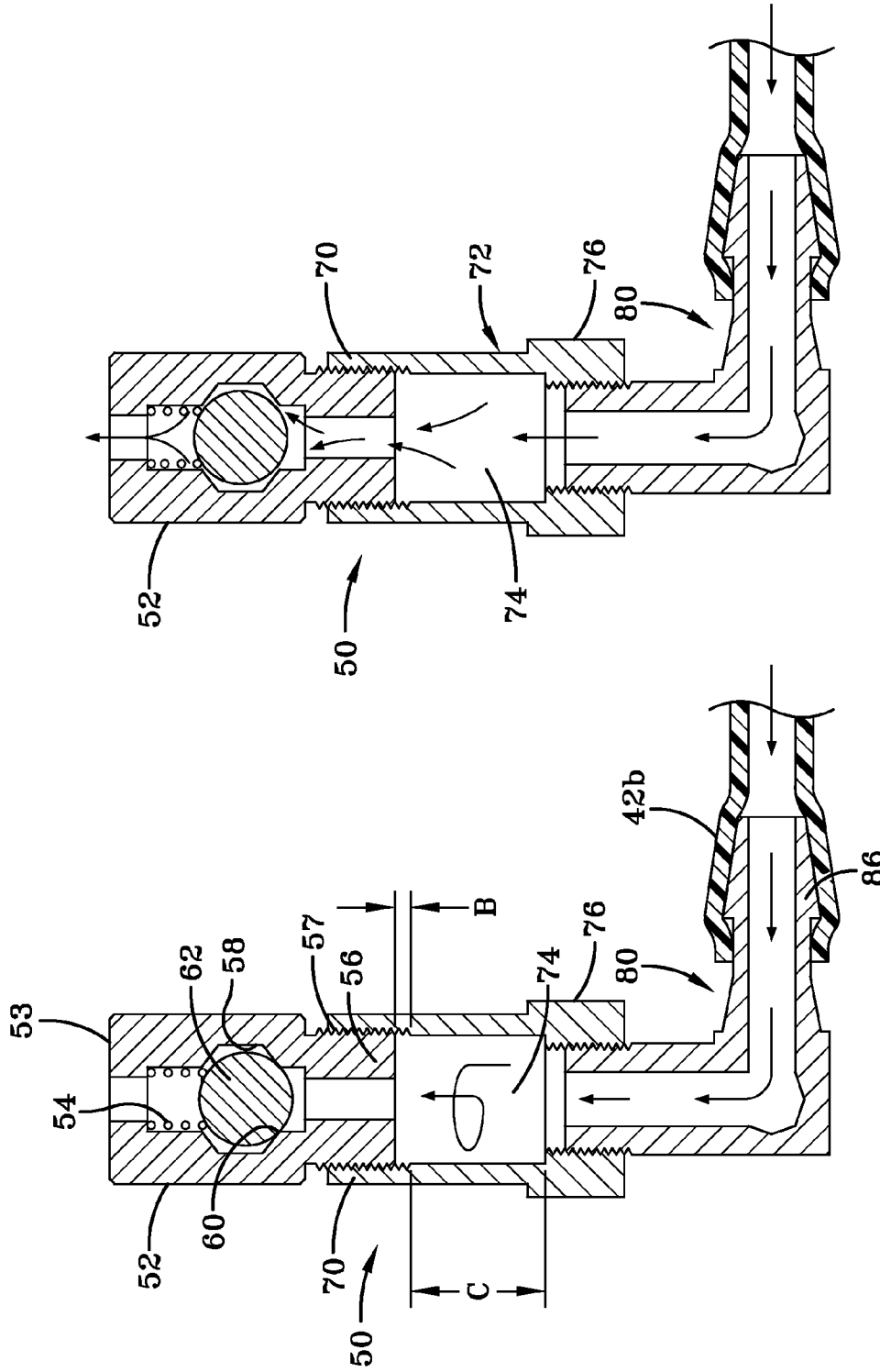
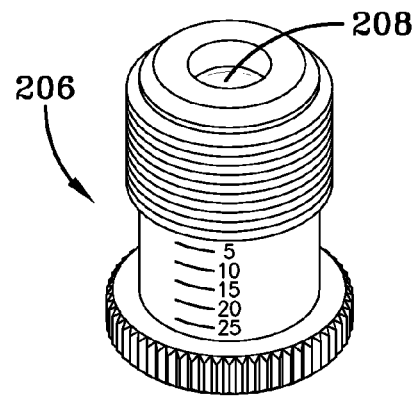
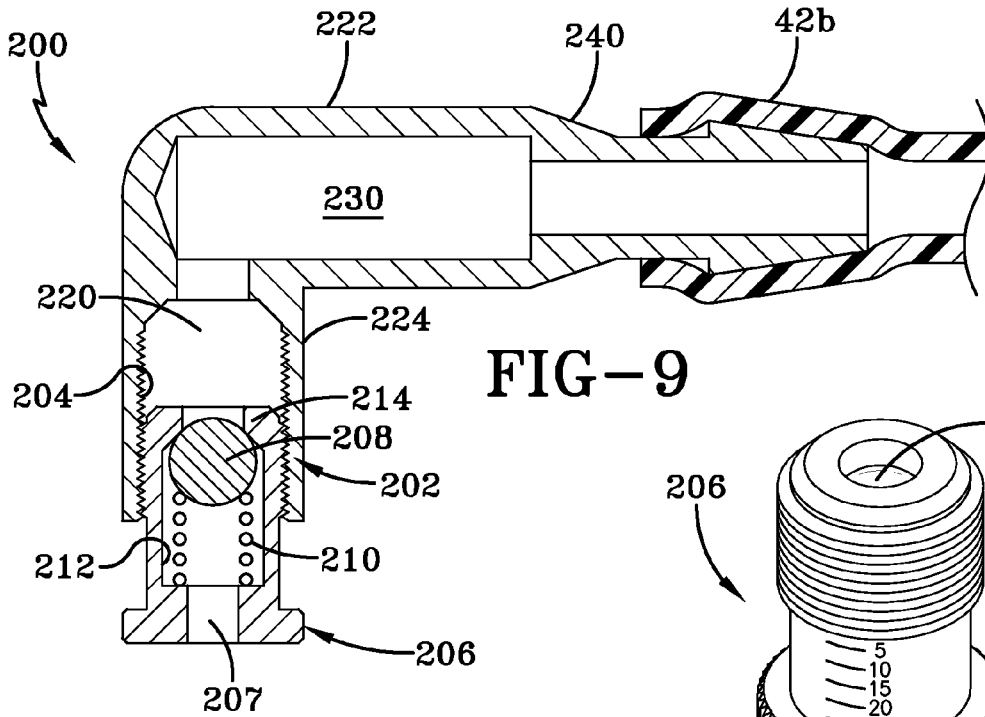
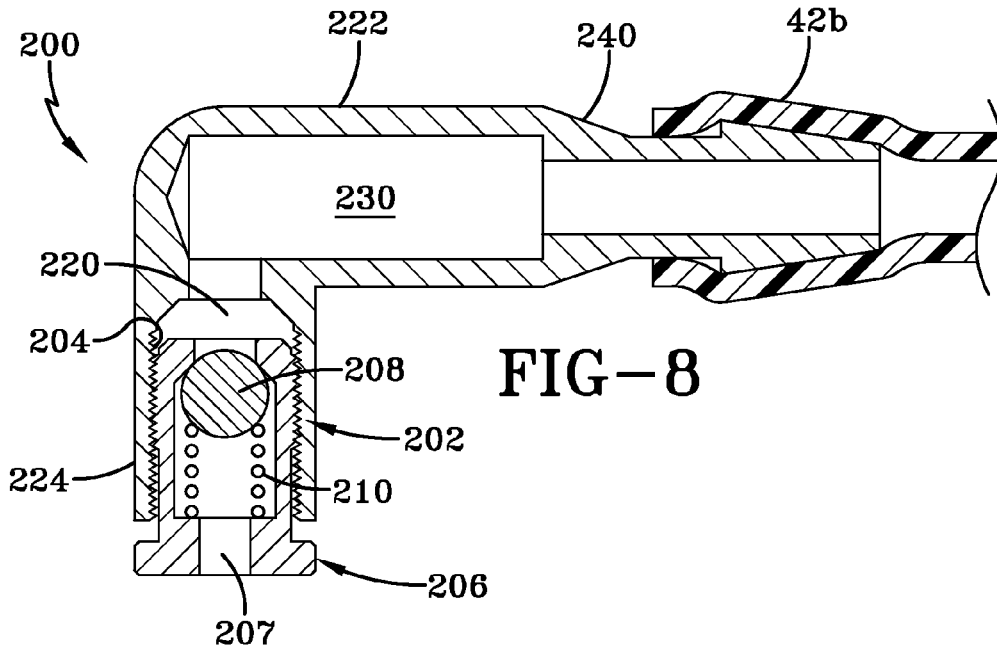


FIG-7

FIG-6



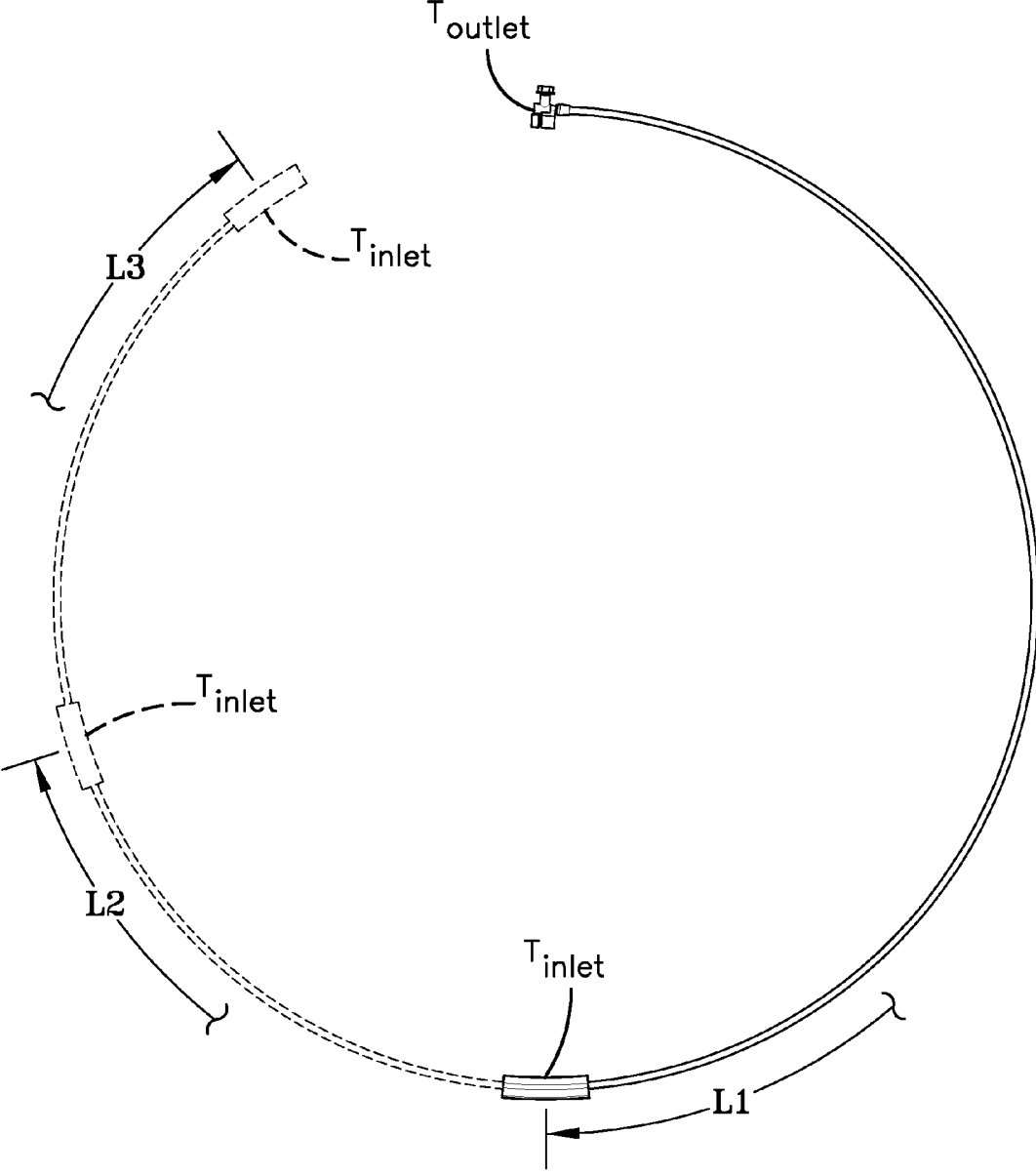


FIG-11

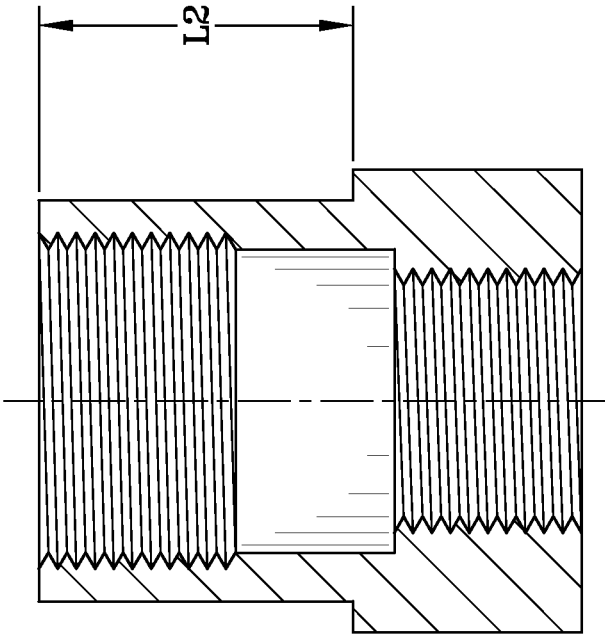


FIG-12B

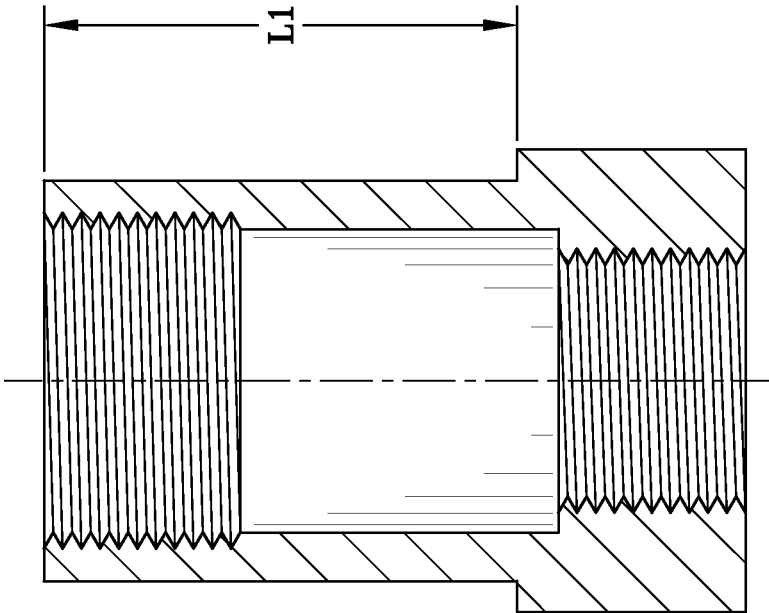


FIG-12A

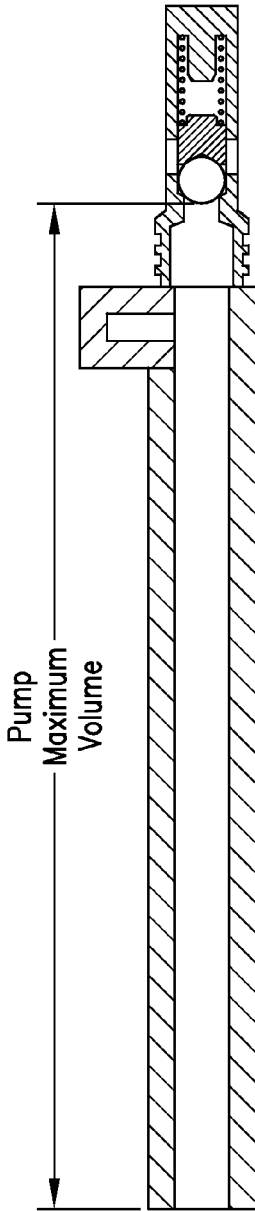


FIG-13A

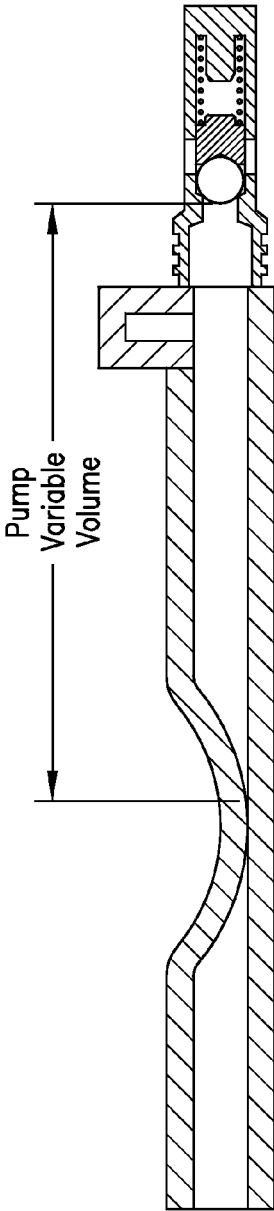


FIG-13B

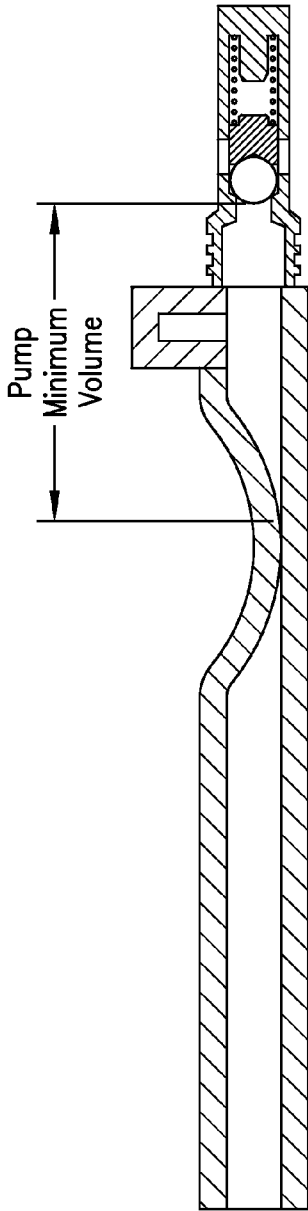


FIG-13C

SELF-INFLATING TIRE

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.

Definitions

[0003] "Aspect ratio" of the tire means the ratio of its section height (SH) to its section width (SW) multiplied by 100 percent for expression as a percentage. "Asymmetric tread" means a tread that has a tread pattern not symmetrical about the center plane or equatorial plane EP of the tire.

[0004] "Axial" and "axially" means lines or directions that are parallel to the axis of rotation of the tire.

[0005] "Buffer volume" means the pump minimum volume.

[0006] "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.

[0007] "Circumferential" means lines or directions extending along the perimeter of the surface of the annular tread perpendicular to the axial direction.

[0008] "Equatorial Centerplane (CP)" means the plane perpendicular to the tire's axis of rotation and passing through the center of the tread.

[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] "Inboard side" means the side of the tire nearest the vehicle when the tire is mounted on a wheel and the wheel is mounted on the vehicle.

[0011] "Lateral" means an axial direction.

[0012] "Lateral edges" means a line tangent to the axially outermost tread contact patch or footprint as measured under normal load and tire inflation, the lines being parallel to the equatorial centerplane.

[0013] "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.

[0014] "Non-directional tread" means a tread that has no preferred direction of forward travel and is not required to be positioned on a vehicle in a specific wheel position or positions to ensure that the tread pattern is aligned with the preferred direction of travel. Conversely, a directional tread pattern has a preferred direction of travel requiring specific wheel positioning.

[0015] "Outboard side" means the side of the tire farthest away from the vehicle when the tire is mounted on a wheel and the wheel is mounted on the vehicle.

[0016] "Peristaltic" means operating by means of wave-like contractions that propel contained matter, such as air, along tubular pathways.

[0017] "Peristaltic pump tube" means a tube formed or molded in a tire or an embedded tube which may be inserted post cure or pre-cure.

[0018] "Pump minimum volume" or "buffer volume" means the smallest value of the pump variable volume.

[0019] "Pump maximum volume" means the volume of fluid located between the peristaltic pump tube inlet and the outlet valve.

[0020] "Pump variable volume" means the volume of fluid located between the pinched tube path and the entry of the outlet valve.

[0021] "Radial" and "radially" means directions radially toward or away from the axis of rotation of the tire.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] The invention will be described by way of example and with reference to the accompanying drawings in which:

[0023] FIG. 1 is an isometric view of the valve, tube and filter for a peristaltic pump assembly.

[0024] FIG. 2 is a side view of the assembly of FIG. 1 shown mounted in a tire.

[0025] FIG. 3 is an enlarged partial cross sectional view of the tire and rim assembly with the pump valve mechanism shown mounted in the tire.

[0026] FIG. 3A is an enlarged perspective view of the pump valve mechanism of FIG. 3.

[0027] FIG. 4 is a perspective view of a first embodiment of a regulator mechanism of the present invention.

[0028] FIG. 5 is a partial section view through the regulator mechanism of FIG. 4 in the direction 5-5.

[0029] FIGS. 6 and 7 are cross-sectional views of the regulator mechanism in operation, in the closed position and the open position, respectively.

[0030] FIG. 8 is a perspective view of a second embodiment of a regulator mechanism of the present invention shown in a first position.

[0031] FIG. 9 is perspective view of the regulator mechanism of FIG. 8 shown in a second position.

[0032] FIG. 10 is a perspective view of the adjustable cap of the regulator mechanism of FIG. 8.

[0033] FIG. 11 is a perspective view of a second embodiment of a pump system of the present invention.

[0034] FIGS. 12A and 12B illustrate front views of an interchangeable valve body.

[0035] FIGS. 13A, 13B and 13C represent an illustration of the pump maximum volume, the pump variable volume, and the buffer or pump minimum value.

DETAILED DESCRIPTION OF THE INVENTION

[0036] Referring to FIGS. 1 through 3, 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 located adjacent outer rim flanges 20. The outer rim flanges 20 have an outer rim surface 22 that engages the bead area of the tire. The tire is of conventional construction, having a pair of sidewalls 30 extending from

opposite bead areas **34** to a crown or tire tread region **38**. The tire and rim enclose a tire cavity **40**.

[0037] As shown in FIGS. 1-2, the peristaltic pump assembly **14** includes a pump tube **42** that is mounted in a tire passageway **44**, which is preferably located in the sidewall area of the tire, preferably near the bead region. The tire passageway is preferably molded into the sidewall of the tire during vulcanization and is preferably annular in shape. The pump tube **42** has a first end **42a** joined together by an inlet device **46** and a second end **42b** joined together with an outlet device **50**. The pump tube **42** is comprised of a tube formed of a resilient, flexible material such as plastic, silicone, 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 or lens shape may be utilized. Alternatively, the passageway **44** molded or formed into the tire sidewall may serve as the pump tube **42**.

[0038] As shown in FIG. 2, the inlet device **46** and the outlet device **50** are spaced apart a desired distance typically in the range of approximately 90 degrees or more, typically about 180 degrees to 360 degrees. If 180 degrees is selected, two 180 degree pumps may be used. 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.

[0039] The inlet device **46** in its simplest form may be the inlet tube end exposed to the atmosphere. The inlet device may optionally comprise a check valve and/or an optional filter. The outlet device **50** is a pressure and flow regulating device, and regulates the tire cavity maximum pressure. The outlet device **50** also functions to regulate the flow into and out of the tire cavity. The outlet device is described in more detail, below.

[0040] As will be appreciated from FIG. 2, the inlet device **46** and the outlet device **50** are in fluid communication with the circular air tube **42**. 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**. Flattening of the segment **110** of the pump **42** forces a portion of air located between the flattened segment **110** and the outlet device **50**, in the direction shown by arrow **84** towards the outlet device **50**. The portion of air will then be regulated through the outlet device **50**. If the pressure at the inlet of the outlet device is sufficiently high, the internal valve will open and fill the tire cavity, as described in more detail, below.

[0041] As the tire continues to rotate in direction **88**, the previously flattened tube segments **110**, **110'**, **110''** will be sequentially refilled by atmospheric air flowing into the inlet device **46** along the pump tube **42**. The inflow of air from the inlet device **46** continues until the outlet device **50** rotating counterclockwise as shown with the tire rotation **88**, passes the tire footprint **100**.

[0042] The location of the peristaltic pump assembly will be understood from FIGS. 2-4. 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 **110** 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**.

Pressure Regulating Outlet Device

[0043] The regulator device **50** is a pressure and flow regulating device, and regulates the tire cavity maximum pressure. The regulator device **50** also functions to regulate the flow into and out of the tire cavity. The regulator device has a valve body **52** having a first end **53** that has a valve passageway **54** that extends from the first end to a second end **56**. The first end of the valve body **52** is mounted through the tire sidewall as shown in FIGS. 3, 3A so that the valve passageway **54** is in fluid communication with the tire cavity **40**. The valve passageway **54** has an expanded portion **58** and a narrow portion **60**. A large ball **62** is received in the expanded portion **58** and positioned for engagement with the narrow portion **60**. A spring **64** is positioned within the valve passageway for engagement with the ball **62**. The spring **64** biases the ball into engagement with the narrow portion **60**, so that flow is blocked in the interior passageway **54**.

[0044] The second end **56** of the valve body has an outer threaded portion **57** that is received within a first threaded end **70** of an adjustable housing **72**. The adjustable housing has an internal cavity **74** that extends from the first threaded end **70** to the second threaded end **76**. The internal cavity **74** has a fixed buffer volume portion and an adjustable buffer volume portion. The fixed volume portion is defined by the non-threaded inner wall of the internal cavity having a length *C*. The fixed volume is equal to the cross-sectional area of the internal cavity times the length *C*. The adjustable volume portion is defined by the amount of the threaded length that is exposed within the internal cavity and is indicated as distance *B*. The adjustable volume is determined from the distance *B* times the cavity cross-sectional area. The distance *B* may be zero if the valve body is fully received within the adjustable housing. The adjustable housing and respective internal buffer volumes may be modified by substituting the adjustable housing as shown in FIG. 12A in order to increase the fixed buffer volume or by substituting the adjustable housing as shown in FIG. 12b in order to decrease the fixed buffer volume.

[0045] The regulator device **50** further comprises an elbow fitting **80** having a first end **82** connected to the adjustable housing inlet end **76** and a second end **84** connected to the pump tube outlet **42b**. The second end of the elbow fitting **80** may comprise a flared fitting **86**.

[0046] The maximum air pressure delivered by the peristaltic pump can be fixed by setting the volume of the pump tube and the buffer volume located between the end of the tube and the check valve and the adjustable buffer chamber. The pump tube volume is selected by design with the tube dimensions and the tube length. As shown in FIG. 11, multiple pump tubes may be used, with the selection of the tube length and

inner tube dimensions to tune the system. The buffer or dead volume can also be set by design. The air in the buffer volume chamber is not compressed, but functions to tune or adjust the maximum air pressure of the pump system. The buffer volume acts as a storage chamber for accumulating air mass for transfer to the tire cavity. Increasing the buffer volume will decrease the tire pressure, while decreasing the buffer volume will increase the tire cavity pressure. Thus, by adjusting the buffer volume, one can adjust the desired tire final pressure.

[0047] The operation of the system and the outlet device **50** can now be described. As shown in FIG. 2, the tire rotates in a direction of rotation **88**, and 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**. Flattening of the segment **110** of the pump **42** forces a portion of air located between the flattened segment **110** and the regulator device **50**, in the direction shown by arrow **84** towards the outlet device **50**. The portion of air will then be regulated through the outlet device **50**. If the pressure at the inlet **86** of the regulator device is sufficiently high, the fluid pressure will overcome the spring pressure **54** (cracking pressure), thus opening the internal check valve. Thus fluid from the pump outlet **42b** will flow into the elbow fitting **80** and into the adjustable housing **72**.

[0048] If the pressure in the pump tube **42b** is less than the tire pressure, the ball **62** will engage the narrow portion **60** and block flow from either direction. The check valve **62** when closed, blocks flow from communicating from the pump **42b** into the tire cavity **40**, and also prevents back flow from the tire cavity into the pump **42**. When the check valve is closed, the pump compresses the air in the pump tube **42**. Air from the pump tube enters the elbow fitting **80** of the regulator device, and then enters the buffer volume chamber **74**. The buffer volume chamber will fill while the check valve remains closed. When the pressure in the inlet **56** of the regulator device exceeds the cracking pressure, the check valve opens and will allow air from the pump to fill the tire cavity. The check valve will close when the inlet pressure P_T falls below the cracking pressure. The cycle of opening and closing the check valve will allow the tire cavity to be filled as the tire rotates a specified distance. A maximum tire cavity will be reached based upon the pump volume and the buffer volume. The buffer volume may be adjusted by turning the valve body **52** relative to the adjustable housing. Increasing the buffer volume results in a decrease of tire final pressure, while decreasing the buffer volume results in an increase of the tire final pressure. The advantage of having an adjustable buffer volume allows the maximum system pressure of the tire cavity to be tuned for a specific tire.

[0049] FIGS. 8-10 illustrate a second embodiment of a pressure regulator **200**. The pressure regulator **200** comprises a valve body **202** having an internal passageway **204** that extends through the valve body **202**. The internal passageway **204** includes a movable check valve assembly **206**. The movable check valve assembly includes a ball **208**, a spring **210** housed within a receptacle **212**. The receptacle has a retainer **214** which retains the ball **208** within the check valve assembly. The outer edge of the receptacle may have external threads like a screw, so that the receptacle may be screwed into or out of the internal passageway **204**. A variable buffer volume **220** is located adjacent the movable check valve assembly, so that when the movable check valve assembly is rotated clockwise, the variable buffer volume decreases. The outer receptacle of the check valve may have notations on it to

indicate to a user to indicate the relationship of the number of turns to the volume adjustment. Alternatively, the movable check valve may slide within the passageway **204**, with retaining means located within the passageway which allow the position of the movable check valve to be repeatedly adjusted and then fixed in position.

[0050] The valve body **202** of the pressure regulator **200** further comprises a second portion **222** which is at right angles to the first portion **224** of the valve body. The second portion has an interior fixed dead volume **230** which is in fluid communication with the variable volume **220**. Located adjacent the interior fixed dead volume **230** is an outlet **240**. The outlet **240** is connected to the pump tube outlet **42b**. The second portion **222** is mounted in the tire, typically in the sidewall and connected to the pump tube outlet **42b**. The first portion **224** of the valve body is mounted through the sidewall and into the tire cavity **40**.

[0051] The operation of the system and the outlet device **200** can now be described. As shown in FIG. 2, the tire rotates in a direction of rotation **88**, and 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**. Flattening of the segment **110** of the pump **42** forces a portion of air located between the flattened segment **110** and the regulator device **200**, in the direction shown by arrow **84** towards the outlet device **200**. The portion of air will then be regulated through the outlet device **200**. If the pressure at the inlet of the regulator device is sufficiently high, the fluid pressure will overcome the spring pressure (cracking pressure), thus opening the internal check valve. Thus fluid from the pump outlet **42b** will flow into the regulator and out into the tire cavity through a hole in the adjustable check valve assembly.

[0052] If the pressure in the pump tube **42b** is less than the tire pressure, the ball **208** will engage the narrow portion **214** and block flow from either direction. The check valve when closed, blocks flow from communicating from the pump **42b** into the tire cavity **40**, and also prevents back flow from the tire cavity into the pump **42**. When the check valve is closed, the pump compresses the air in the pump tube **42**. Air from the pump tube enters the regulator device, and fills the buffer volume chambers **220,230**. When the pressure to the inlet of the regulator device exceeds the cracking pressure, the check valve opens and will allow air from the pump to fill the tire cavity. The check valve will close when the inlet pressure P_T falls below the cracking pressure. The cycle of opening and closing the check valve will allow the tire cavity to be filled as the tire rotates a specified distance. A maximum tire cavity will be reached based upon the pump volume and the buffer volume. The buffer volume may be adjusted by turning the adjustable check valve relative to the housing. Increasing the buffer volume results in a decrease of tire final pressure, while decreasing the buffer volume results in an increase of the tire final pressure. The advantage of having an adjustable buffer volume allows the maximum system pressure of the tire cavity to be tuned for a specific tire.

[0053] The table below indicates exemplary tires, all having the same internal tire volume of 38 L and initial tire pressure of 1.8 Bar. All of the exemplary pumps have a circumferential length of 180 degrees. Examples 1 and 2 have a pump size of 2x1 with a pump volume of 1036 mm³. For example 1 the buffer volume is selected to be 459 mm³, resulting in a desired final tire pressure of 2.2 bar. A distance of 241 km is needed to achieve the final tire pressure. If the

buffer volume is decreased to 351 mm³, with all other variables being equal, the final tire pressure will be 2.9 bar (Ex. 2) as compared to 2.2 bar for Ex. 1. A longer distance of 490 km will be needed to achieve a higher final tire pressure of 2.9 bar.

[0054] Examples 3 and 4 illustrate a smaller tube size resulting in a smaller pump volume of 700 mm³. For a buffer volume of 310 mm³ (Ex 3) results in a final tire pressure of 2.2 bar and a needed distance of 355 km to achieve the final tire pressure. Ex 4 illustrates all the properties of Ex. 3, except for a smaller buffer volume of 237 mm³, resulting in a higher final tire pressure of 2.9 bar achieved in 727 km.

[0055] Examples 5-8 have the same properties as examples 1-4, with example 5 corresponding with example 1, etc. the cracking pressure of the valve is higher for examples 5-8 as compared to 1-4. A slightly lower buffer volume is needed in examples 5-8 to achieve the same final tire pressure as examples 1-4. The higher cracking pressure also results in a significantly shorter distance to be traveled by the pump/tire in order to result in the final tire pressure. The volume ratios of the buffer volume to pump volume may be used to determine a new buffer volume should the pump volume or cavity volume change. The buffer volume may be adjusted by rotating screw 66. The number of turns of the screw (e.g. 5 turns) would result in a distance of 4 mm with a screw pitch of 75 mm.

Cracking Pressure	Cavity		Volume [mm ³]	Tire Volume	Initial Tire pressure	Buffer Volume [mm ³]	Final Tire pressure	Needed Distance	Volumes Ratio
	Angle	Size							
0.1 bar	180	2 × 1	1036	38 L	1.8 bar	459	2.2 bar	241 km	0.443
	180	2 × 1	1036	38 L	1.8 bar	351	2.9 bar	490 km	0.339
	180	2.7 × 0.5	699.5	38 L	1.8 bar	310	2.2 bar	355 km	0.443
	180	2.7 × 0.5	699.5	38 L	1.8 bar	237	2.9 bar	727 km	0.339
0.3 bar	180	2 × 1	1036	38 L	1.8 bar	422	2.2 bar	137 km	0.407
	180	2 × 1	1036	38 L	1.8 bar	329	2.9 bar	324 km	0.318
	180	2.7 × 0.5	699.5	38 L	1.8 bar	285	2.2 bar	203 km	0.407
	180	2.7 × 0.5	699.5	38 L	1.8 bar	222.5	2.9 bar	485 km	0.318

[0056] The maximum air pressure delivered by a peristaltic pump embedded in a tire can be fixed by setting the right volume of the pump tube and the buffer volume. The pump tube volume can be set by design with the dimensions of the tube sections and tube length. The buffer volume can also be set by design but can also be easily manually changed by the mean of a dedicated device or by interchanging appropriate parts before the valve. This can be implemented with either a set of tube with different lengths or a set of small tanks to be inserted before the valve.

[0057] Variations in the present invention are possible in light of the description of it provided herein. While certain representative embodiments and details have been shown for the purpose of illustrating the subject invention, it will be apparent to those skilled in this art that various changes and modifications can be made therein without departing from the scope of the subject invention. It is, therefore, to be understood that changes can be made in the particular embodiments described which will be within the full intended scope of the invention as defined by the following appended claims.

What is claimed is:

1. A self-inflating tire assembly comprising:
 - 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;
 - an air tube connected to the tire and being composed of a flexible material operative to allow a portion of the air tube segment near a tire footprint to substantially open and close the air tube,
 - a regulator device connected to an end of the air tube, the regulator device includes an elbow fitting mounted in the tire sidewall, the elbow fitting having a first end for connecting to an end of the air tube and a second end for connecting to a first end of an adjustable housing, said adjustable housing having a buffer volume therein defined by a movable wall, said movable wall being connected to a valve body, wherein the valve body has an outer threaded surface that is received within the adjustable housing.
2. The self-inflating tire assembly of claim 1 wherein the volume of the buffer chamber is adjustable.
3. The self-inflating tire assembly of claim 1 wherein the buffer chamber has an adjustable outer wall.

4. The self-inflating tire assembly of claim 1 wherein the buffer chamber is formed in the void formed by a threaded fastener mounted in a chamber.
5. The self-inflating tire assembly of claim 1 wherein the regulator device is mounted in the tire cavity.
6. The self-inflating tire assembly of claim 1 wherein the inlet regulator device is mounted in the tread of the tire.
7. The tire assembly of claim 1, wherein the air tube is sequentially flattened by the tire footprint to pump air along the air passageway in either a forward tire direction of rotation or a reverse tire direction of rotation.
8. The tire assembly of claim 1, wherein the pump inlet and the regulator device are mounted to the annular air tube substantially 180 degrees apart.
9. The tire assembly of claim 1, wherein the pump inlet and the regulator device are mounted to the annular air tube substantially 360 degrees apart.
10. The tire assembly of claim 1, wherein the cross-sectional shape of the air tube is elliptical.

11. A self-inflating tire assembly comprising:
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;
an air tube connected to the tire and being composed of a flexible material operative to allow a portion of the air tube segment near a tire footprint to substantially open and close the air tube,
a regulator device connected to an end of the air tube, the regulator device includes a regulator body mounted in the tire sidewall, the regulator body having first end located within the tire cavity, wherein the first end has an internal passageway that is in fluid communication with the tire cavity, said regulator device having a second end having an internal pump passageway for connecting to an end of the air tube; a check valve in fluid communication with the internal passageway and the pump passageway, wherein the regulator device further comprises a channel located between the second end and the check valve, wherein the channel is in fluid communication with a buffer chamber.

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