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(54) **AIR MAINTENANCE TIRE ASSEMBLY**

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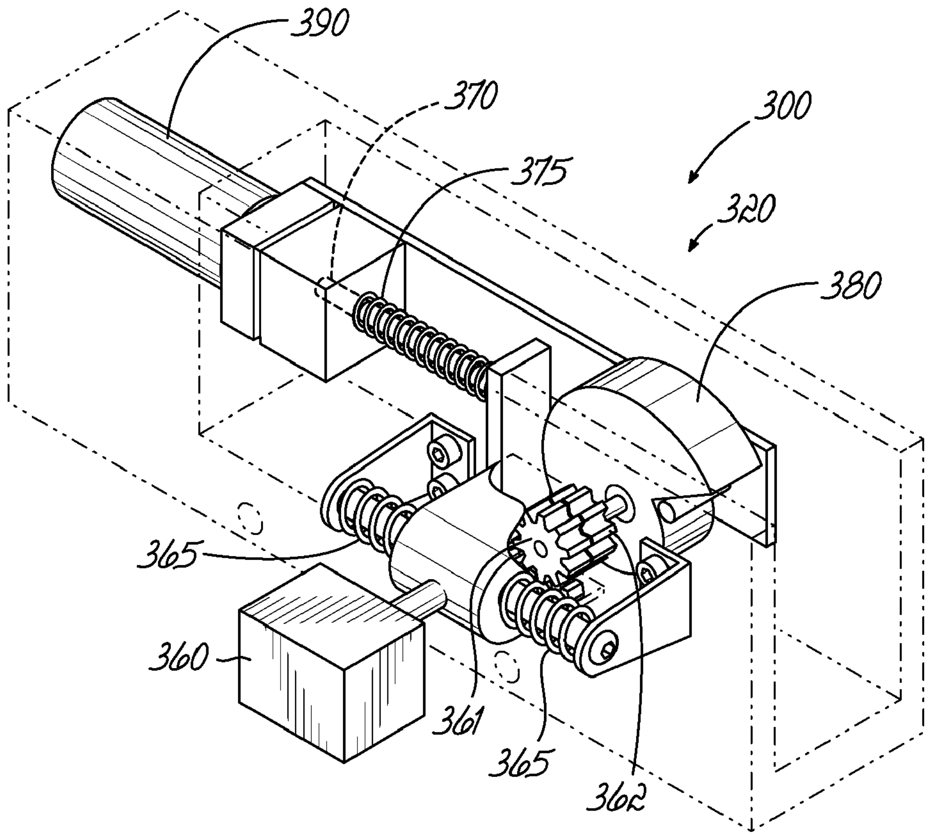
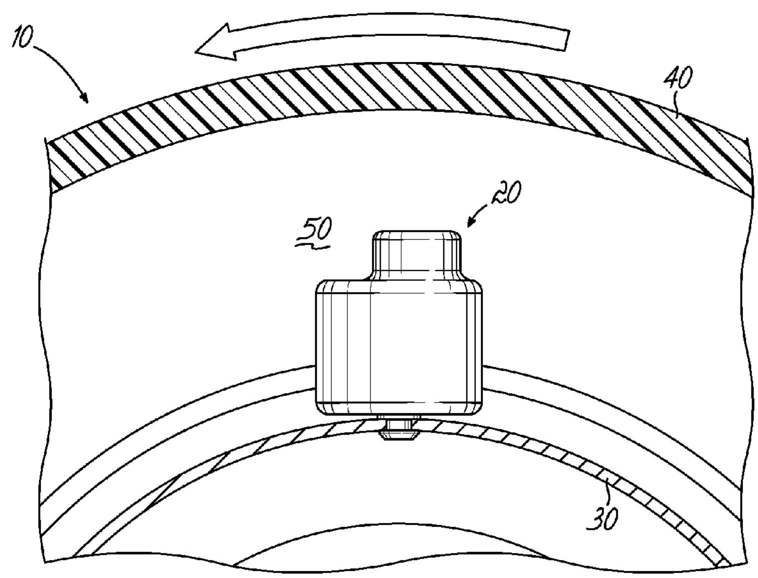
(57) **ABSTRACT**

A pumping device is used with a pneumatic tire mounted on a tire rim to keep the pneumatic tire from becoming underinflated. The pumping device includes a housing attached to the tire rim, a dynamic mass mechanically confined to linear movement relative to the housing and the tire rim, the dynamic mass moving in response to shock loads transferred from the tire rim to the dynamic mass and pumping ambient air into the housing, an intake port for ambient air to enter the housing, and an exhaust port for forcing pressurized air into a tire cavity of the pneumatic tire for restoring air loss from an inflation volume within the tire cavity.

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50
30

FIG. 1

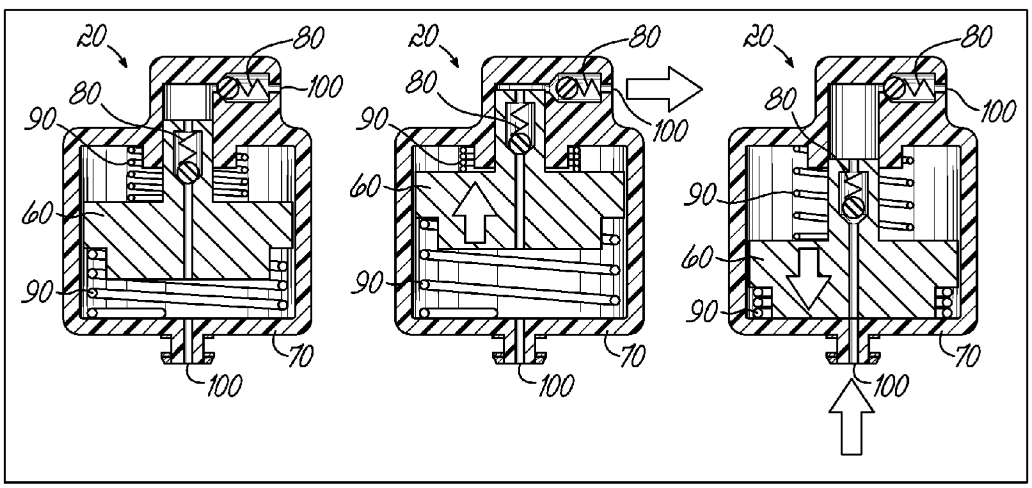
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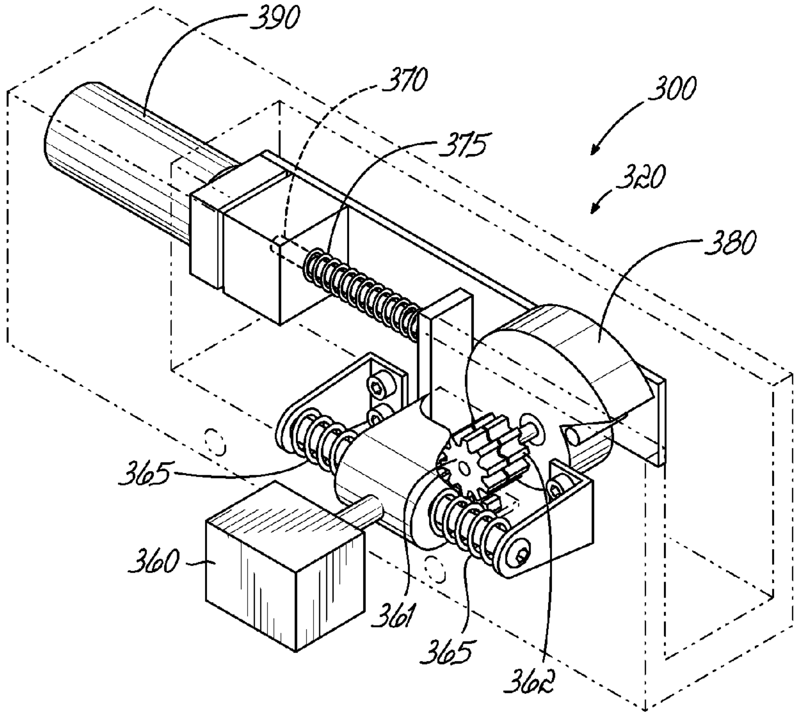
FIG. 2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370
300
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320
380
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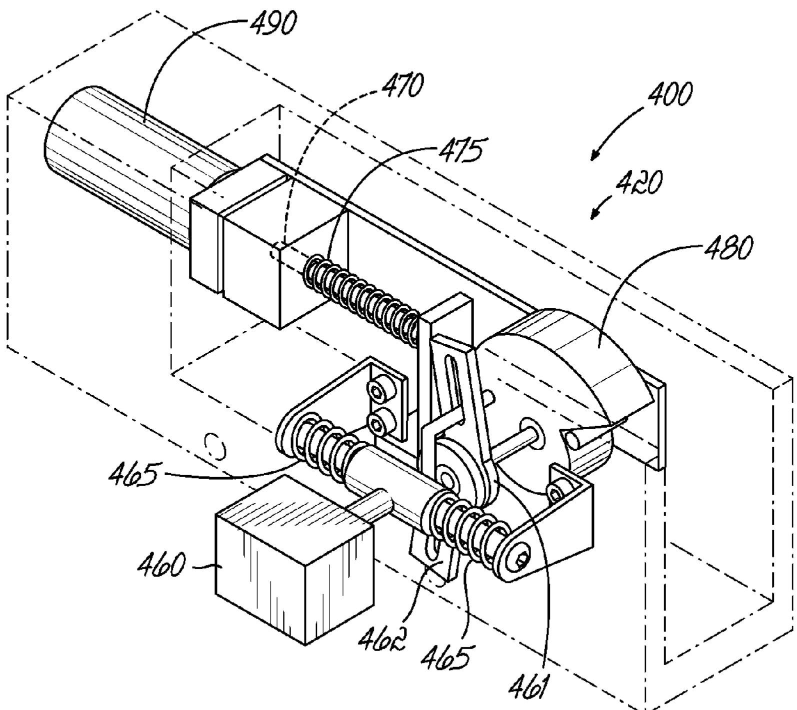
FIG. 3


490
470
400
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420
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465
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462
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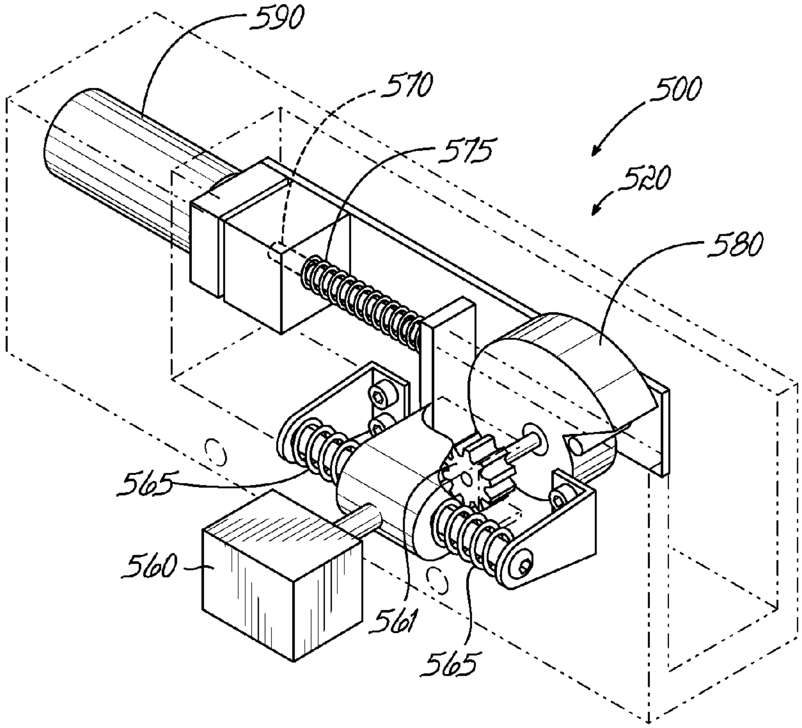
461

FIG. 4


590
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520
580
565
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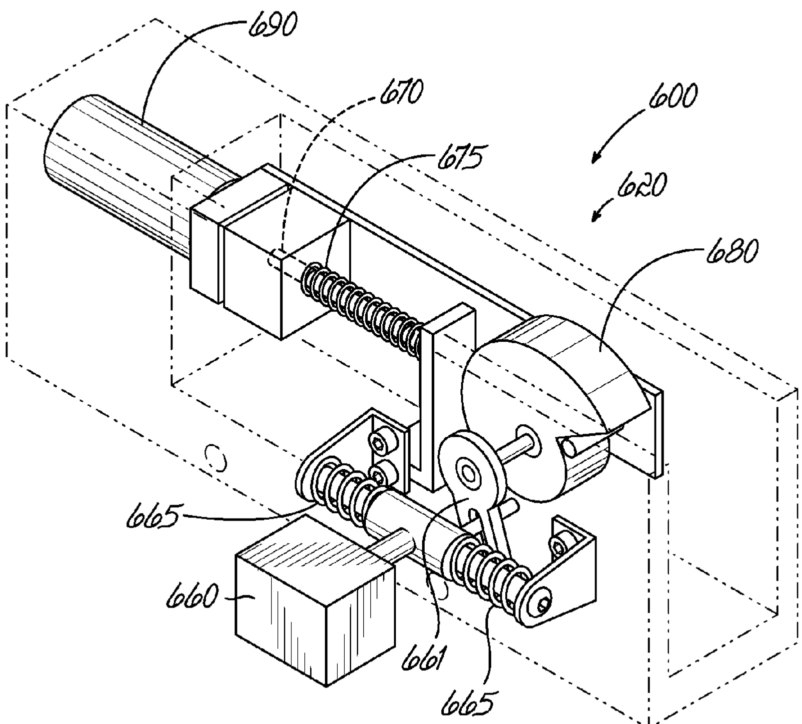
561
565

FIG. 5


690
670
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680
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665

FIG. 6

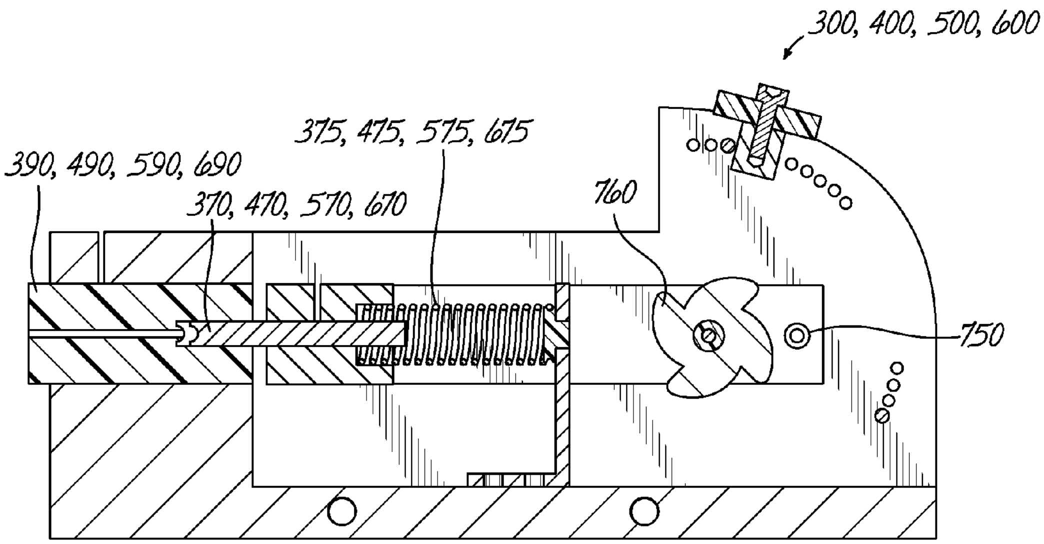
300, 400, 500, 600
375, 475, 575, 675
390, 490, 590, 690
370, 470, 570, 670
760
750

FIG. 7

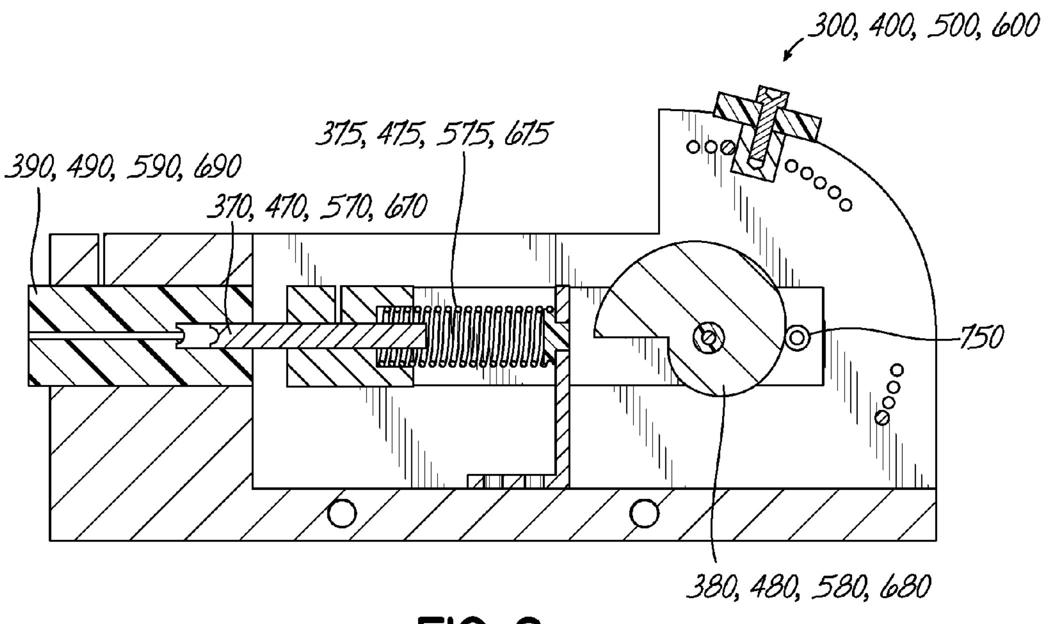
300, 400, 500, 600
375, 475, 575, 675
390, 490, 590, 690
370, 470, 570, 670
750
380, 480, 580, 680

FIG. 8

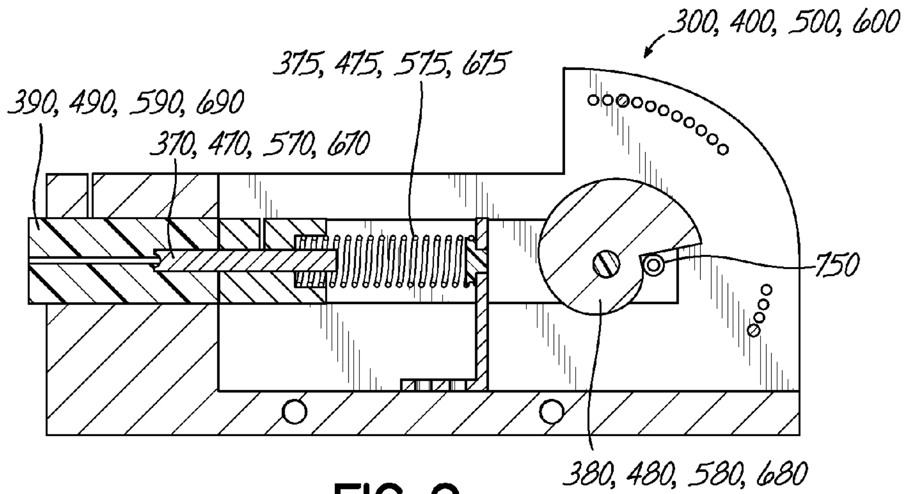

FIG. 9

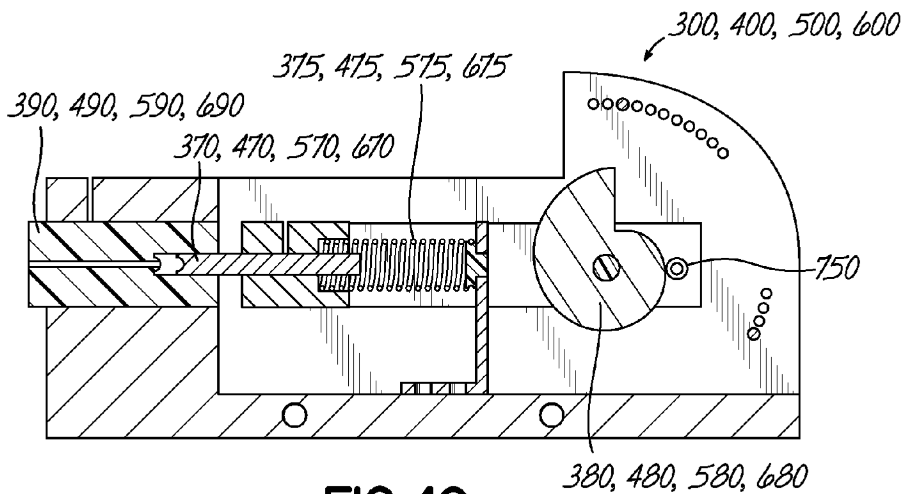

FIG. 10

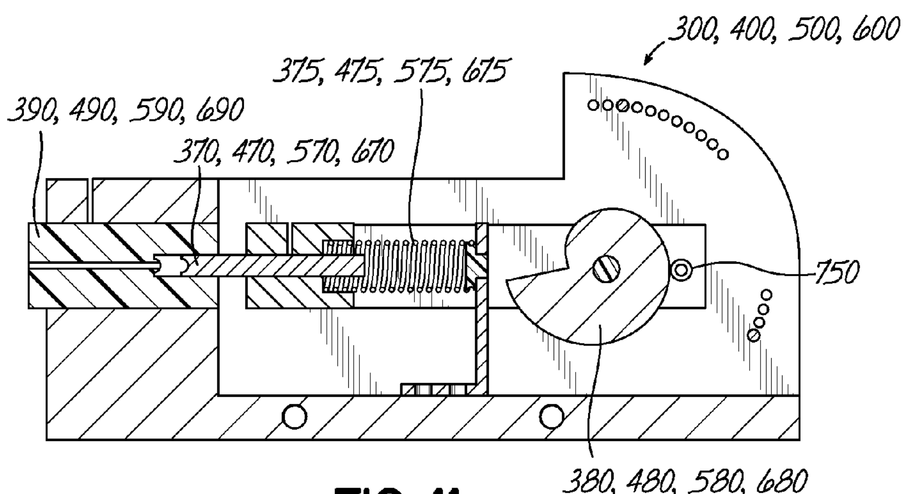

FIG. 11

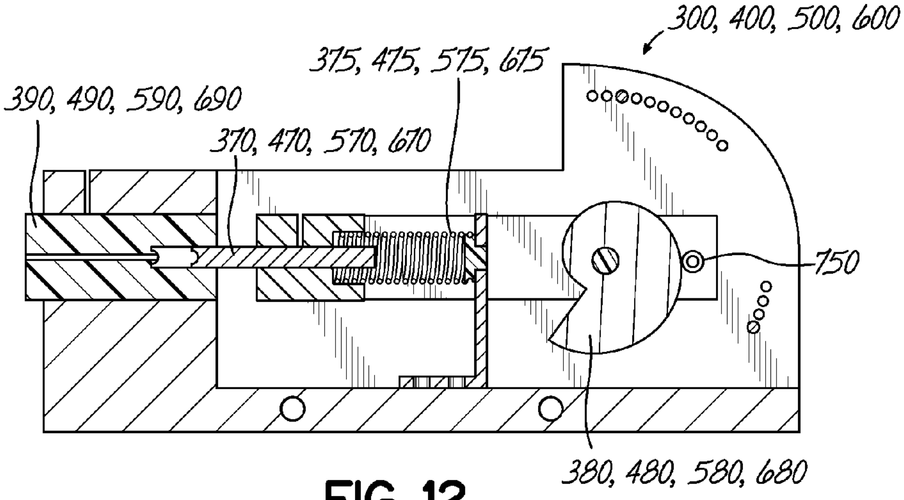

FIG. 12

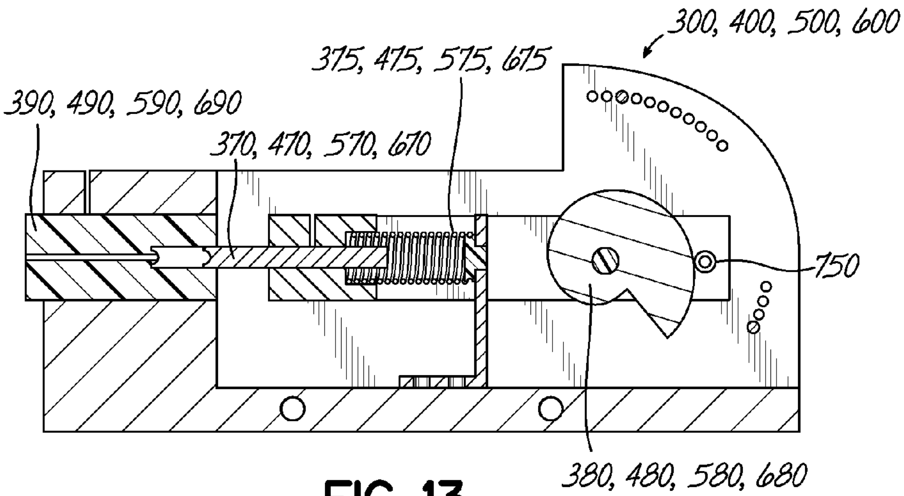

FIG. 13

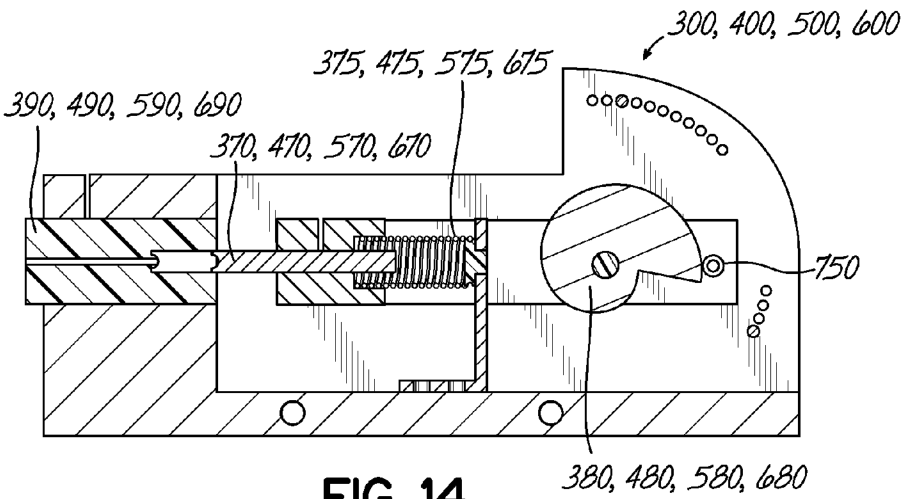

FIG. 14

AIR MAINTENANCE TIRE ASSEMBLY

FIELD OF THE INVENTION

[0001] The present invention generally relates to automotive and other vehicles, and more specifically, to a wheel for such a vehicle which includes a pump for automatically inflating a pneumatic tire mounted on the wheel.

BACKGROUND OF THE INVENTION

[0002] Low tire pressure is a major cause of excessive fuel consumption, tire wear, and impaired steerability. A typical pneumatic tire will leak about 25 percent of its pressure per year due to rubber's inherent permeability. It is thus good practice to check/maintain tire pressure on a regular basis.

[0003] However, even checking tire pressure every few weeks may not prevent these adverse affects when a slow leak is present, and the leak may go undetected unless a careful record is maintained of how frequently the pressure in each tire has to be replenished. A fast leak or flat condition may rapidly cause damage to the tire and even render it unusable in a short period of time even though this condition may go unnoticed by an inexperienced driver until it is too late.

[0004] It is thus desirable to have some mechanism that automatically replenishes the tire pressure when it is lower than its optimal amount. Conventional tire pumps may be mounted on vehicle wheels and utilize centrifugal force to automatically pump air from the atmosphere into a tire cavity and thereby maintain the tire pressure at a predetermined value.

[0005] These pumps may be two-stage pumps with a piston radially movable in a cylinder to draw air from the atmosphere into a primary chamber and pump air from a secondary chamber into the tire cavity when the piston is moved outward by centrifugal force resulting from movement of the vehicle and rotation of the wheels. The piston may be moved inward by a spring when the vehicle stops to transfer air from the primary chamber into the secondary chamber. In order to keep the mass of the piston and the force and size of the spring within practical limits, the piston and spring may be made small enough that the piston may begin to move outward in response to a small centrifugal force resulting from a low vehicle speed.

[0006] This causes a problem when the vehicle is operated at low speed in the rain, and/or on terrain including loose particulate matter such as dirt or sand. If the pump does not have an inlet filter, operation under such adverse conditions may cause contaminants to be drawn into the pump and clog the inlet and outlet valves and/or even be pumped into the tire. If the pump does have an inlet filter, the filter may become clogged. These conditions may render the pump inoperable.

[0007] Friction between the piston and the wall of the cylinder when the pump is operating also may cause wear and reduction of the service life of the pump. Since pneumatic tires typically leak slowly, an automatic tire pump may only be required to operate during a fraction of the time the vehicle is running to maintain the pressure at the optimal value. Conventional tire pumps may operate continuously, and are thereby subjected to more wear than is necessary.

[0008] Another conventional pump may be mounted to a vehicle's wheel and be powered by the wheel's motion during normal vehicle operation thereby maintaining an optimal tire inflation pressure. The pump may be a positive displacement, piston-type compressor wherein the piston responds to the centrifugal force generated by the wheel's rotation or to the vertical acceleration generated by the wheel's response to bumps in the road. The piston may be a small diameter, but may include an upper extension made of dense material. Thus, there may be sufficient mass responding to rotation or the motion from bumps to move the piston and create the necessary pressure for inflation. The piston may be returned by a spring once the forces acting upon the piston decline due to a slow vehicle speed, a smooth driving surface, or both.

[0009] The pump may include inlet and outlet check valves. The pump/inflator may be mounted to the wheel either within the tire cavity or external to the tire. If the centrifugal forces of rotation are to propel the piston, the axis of the cylinder may be oriented radially. If the pump is designed to be energized by the wheel's reaction to bumps in the road, it may be oriented tangential to a circle centered at the wheel axis. It may also have a double acting piston. Compression would then take place when the compressor would be approximately at 3:00 o'clock or 9:00 o'clock in its rotation with the wheel as a bump would be hit by the wheel.

[0010] For the case of centrifugal force for piston action, there may be one compression stroke for each excursion of automobile speed from stationary or some minimum speed up to the automobile speed which translates into adequate rotational speed to generate the needed piston force to create air flow into the tire cavity. For the case in which bumps in the road actuate the piston, the compression strokes may be more random than the bumps themselves since the strokes would only occur when the axis of the compressor would be aligned in its rotation to a direction more or less parallel with the wheel motion caused by the bump.

[0011] Pressure regulation may be provided by designing the pump's compression ratio to limit the delivery pressure to that desired to be the maximum tire inflation pressure. Compression ratio may be the ratio of cylinder volume at the start of a piston stroke to the volume remaining in the cylinder at the end of the piston's stroke. Compression ratio for a given basic design may be set at the time of manufacture by either limiting the piston travel or by providing additional "dead" volume within the piston. One method for this may be to drill a hole in the bottom of the piston at the time of manufacture, the depth of the hole being set to obtain the desired pressure development.

[0012] When the pump is actuated by centrifugal force, the pump may work with the piston gradually progressing along the cylinder against the compressed charge of air in the cylinder as the vehicle accelerates and the wheel rotation rate increases. Once the charge of air exceeds the existing tire pressure plus the discharge valve cracking differential pressure, any increased vehicle speed causes additional stroke movement of the piston and discharge of the compressed air into the tire cavity. As the vehicle slows or stops, the piston return spring may have returned the piston to its location at the beginning of its stroke and the pumping process may begin again with new vehicle motion. With typical passenger car operation including many stops and starts, the pump may deliver a small charge of air each time the vehicle accelerates from a speed low enough to allow the piston return spring to return the piston to a speed high enough to force the piston to compress air and discharge compressed air into the tire cavity.

[0013] In order to maximize the force available for driving the piston to compress the air in the cylinder, the piston may have an enlarged end made of dense material. The enlarged end may be opposite the end of the piston that fits into the cylinder, with its diameter being larger than the piston diameter. The enlarged end may be constructed of brass, lead, and/or other high density material(s). This conventional pump may eliminate extra tire wear and fuel consumption caused by underinflated tires. Where only a small leak occurs, this pump may extend mileage before the tire becomes completely uninflated or flat.

SUMMARY OF THE INVENTION

[0014] A pumping device in accordance with the present invention is used with a pneumatic tire mounted on a tire rim to keep the pneumatic tire from becoming underinflated. The pumping device includes a housing attached to the tire rim, a dynamic mass mechanically confined to linear movement relative to the housing and the tire rim, the dynamic mass moving in response to shock loads transferred from the tire rim to the dynamic mass and pumping ambient air into the housing, an intake port for ambient air to enter the housing, and an exhaust port for forcing pressurized air into a tire cavity of the pneumatic tire for restoring air loss from an inflation volume within the tire cavity.

[0015] According to another aspect of the present invention, the dynamic mass is mechanically confined to radial movement relative to the pneumatic tire.

[0016] According to still another aspect of the present invention, the dynamic mass changes position corresponding to a shock loads from a contact surface to the pneumatic tire.

[0017] According to yet another aspect of the present invention, a plane about which the dynamic mass moves is coplanar with a rotational plane of the tire rim.

[0018] According to still another aspect of the present invention, movement of the dynamic mass transfers work energy to air pressure in the housing.

[0019] According to yet another aspect of the present invention, a first check valve is disposed proximate to the intake port for preventing air from flowing out of the housing.

[0020] According to still another aspect of the present invention, a second check valve is disposed proximate to the exhaust port for preventing air from flowing out of the tire cavity and into the housing.

[0021] According to yet another aspect of the present invention, a biasing element returns the housing from a high volume intake condition to a low volume exhaust condition.

[0022] According to still another aspect of the present invention, the first check valve and the second check valve are self checking ball-type check valves.

[0023] According to yet another aspect of the present invention, a gear rotates to pump pressurized air from the housing and forcing pressurized air into the tire cavity.

[0024] According to still another aspect of the present invention, the housing receives ambient air from an exterior of the housing and exhausts pressurized air into the tire cavity simultaneously.

[0025] According to yet another aspect of the present invention, a gear rotates by movement of the dynamic mass.

[0026] According to still another aspect of the present invention, a biasing member restores an actuation cam to an initial position.

[0027] According to yet another aspect of the present invention, a slot arm rotates by movement of the dynamic mass.

[0028] According to still another aspect of the present invention, two coaxial gears rotate by movement of the dynamic mass.

[0029] According to yet another aspect of the present invention, a second housing is attached to the tire rim diametrically opposite the first housing.

[0030] According to still another aspect of the present invention, the pumping device also restores air loss from an inflation volume within a second tire cavity of a second pneumatic tire.

[0031] According to yet another aspect of the present invention, two springs return the dynamic mass to a neutral position.

[0032] According to still another aspect of the present invention, an additional spring returns a cam to an initial position.

[0033] According to yet another aspect of the present invention, two slot arms rotate an actuation cam in a single direction.

BRIEF DESCRIPTION OF THE DRAWINGS

[0034] FIG. **1** is a schematic representation of an elevation view of a pump in accordance with the present invention.

[0035] FIG. **2** is an enlarged schematic representation of the pump of FIG. **1** showing the pump under three different conditions.

[0036] FIG. **3** is an enlarged schematic representation of the pump of FIG. **1** with another pumping mechanism.

[0037] FIG. **4** is an enlarged schematic representation of the pump of FIG. **1** with still another pumping mechanism.

[0038] FIG. **5** is an enlarged schematic representation of the pump of FIG. **1** with yet another pumping mechanism.

[0039] FIG. **6** is an enlarged schematic representation of the pump of FIG. **1** with still another pumping mechanism.

[0040] FIG. **7** is an enlarged schematic representation of the pump of FIG. **1** with yet another pumping mechanism.

[0041] FIG. **8** is an enlarged schematic representation of the pump of FIG. **1** with still another pumping mechanism.

[0042] FIG. **9** is an enlarged schematic representation of the mechanism of FIG. **8** under a first condition.

[0043] FIG. **10** is an enlarged schematic representation of the mechanism of FIG. **8** under a second condition.

[0044] FIG. **11** is an enlarged schematic representation of the mechanism of FIG. **8** under a third condition.

[0045] FIG. **12** is an enlarged schematic representation of the mechanism of FIG. **8** under a fourth condition.

[0046] FIG. **13** is an enlarged schematic representation of the mechanism of FIG. **8** under a fifth condition.

[0047] FIG. **14** is an enlarged schematic representation of the mechanism of FIG. **8** under a sixth condition.

DETAILED DESCRIPTION OF EXAMPLES OF THE PRESENT INVENTION

[0048] An air pumping device in accordance with the present invention may be utilized with a tire rim and pneumatic tire. The pumping device may affixed to the tire rim for the purpose of restoring air loss from an inflation volume of the pneumatic tire. The pumping device may include a dynamic mass mechanically confined to movement about a transmission mechanism and a pumping chamber.

[0049] The dynamic mass may change position in response to shock loads created between the pneumatic tire and the road surface as the pneumatic tire travels along a road having raised or depressed features (e.g., potholes, speed bumps, unevenness, etc.). The plane about which the dynamic mass moves may be coplanar with respect to the rotational plane of the tire rim, or only slightly askew, so as to be most responsive to the shock loads and vibration generated by traveling along the road. The change in position of the dynamic mass may in turn transfer work energy to an input element of a transmission device. The transmission device may in turn apply mechanical advantage to the work energy in any number of ways determined to be desirable to operate the pumping device, which is dynamically linked to an output element of the transmission device.

[0050] A shock sensitive air pumping device in accordance with the present invention may not rely on changes in tire rim rotation speed and may therefore harvest energy from a tire rim that is accelerating, decelerating, and/or at constant rotation speed as long as provided adequate road imperfection or unevenness is present to yield or produce a shock to the tire rim. By comparison, a device dependent upon RPM changes is limited in energy harvesting potential where vehicle driving routine is predominately constant velocity travel with few speed changes (such as in long haul trucking).

[0051] The dynamic mass may be configured with one or more biasing elements design to return the mass to a neutral position upon the cessation of shock loads. The neutral position may be substantially within the range of motion allowed by the mounting of the dynamic mass, about which the dynamic mass may move in either of two opposing directions in response to a shock acting generally in the rotational plane of the tire rim. The transmission element may be designed to harvest the work energy generated by the shock unrelated to the direction of movement of the dynamic mass, thereby increasing the efficiency of the air pumping device to harvest available energy from shock producing features available on the road surface. The movement path of the dynamic mass relative to the tire rim may be radial, tangential, axial, and/or a combination thereof. The movement path direction may define the rotational angular positions, relative to the tire contact patch, at which the most efficient energy harvesting may be expected.

[0052] The biasing means, specifically the means that returns the dynamic mass to a neutral position in the absence of shock loads, may be tuned relative to the mass, and vise versa, to establish an appropriate resonant frequency. Such a frequency may be established to increase or decrease the sensitivity of the bias-mass system to particular shock load profiles. Of particular interest may be the potential to tune the air pumping device to shock profiles offering a maximum energy to the air pumping device under nominal road conditions and vehicle driving routines.

[0053] The air pumping device may include one or more chambers and multiple valves. The chamber volume may be altered by the mechanical motion of the dynamic mass. One or more biasing elements, such as springs, may be incorporated to return the chamber volume from a high volume to a low volume, or vise versa. The valves may be configured to allow the chamber to intake air from the exterior of the inflation space and to exhaust the inspired air to the interior of the inflation space (e.g., a tire cavity). The valves may be self-checking, or may be mechanically opened and closed under the influence of an auxiliary mechanism (e.g., electrical, pneumatic, hydraulic, etc.). A pressure regulating element may be included for the purpose of limiting the ability of the air pumping device to elevate the pressure of the inflation space beyond a preferred level. Upon sensing a target pressure, or as the target pressure is approached, the regulating element may suddenly or progressively disable the air pumping device by locking, releasing, closing, opening, etc. any number of functional elements such as ports, valves, mechanical linkages, etc.

[0054] The transmission device may allow various interaction modes between the dynamic mass and the air pumping device. One such transmission device may result in the mechanical integration of numerous movement reversals of the dynamic mass to affect a single intake and exhaust cycle, thereby allowing a wide degree of shock magnitudes to be captured, stored, and/or periodically released to drive operation of the air pumping device. Another transmission device may allow a variable mechanical advantage profile to exist over a full range of movement of the dynamic mass, thereby allowing work energy from the dynamic mass to be balanced with the variable energy requirement of the air pumping device. Still another transmission device, particularly one in which a biasing element is present in the air pumping device, may utilize the work energy of the dynamic mass to affect the exhaust of air from the air pumping device or, alternatively, the intake of air into the air pumping device.

[0055] The air pumping device may be mounted to the tire rim in several ways. First, the air pumping device may utilize existing rim features and eliminate the need to modify the rim in any way. For example, the air pumping device may utilize the inflation valve access hole in the tire rim wall to provide both a fastening point and an ambient air intake port. Such a mounting may integrate the inflation valve function into its structure, or interface with an industry standard inflation valve. Second, the device may be configured to be mounted at any position on the tire rim and within the inflation space or tire cavity, generally, thereby not requiring modification of the tire rim to structurally ground the air pumping device to the tire rim and providing an access port for the intake of ambient air.

[0056] The air pumping device in accordance with the present invention may lead to lower operating costs for vehicle owners and provide tire manufacturers additional options for achieving government mandated performance measures.

[0057] FIG. **1** shows an example assembly **10** in accordance with the present invention mounted on a wheel rim **30** inside a tire cavity **50** of a pneumatic tire **40**. The assembly **10** may include an air pumping device **20** for use on the wheel rim **30** and within the tire cavity **50** of the pneumatic tire **40**. The device **20** may be affixed to the wheel rim **30** for restoring air loss from the inflation volume within the tire cavity **50**. As shown in FIG. **2**, the device **20** may include a dynamic mass **60** mechanically confined to movement within a pump housing **70**. The dynamic mass **60** may change position according to vibrations/shock incurred by the tire rim **30** traveling over a rough surface. The plane about which the dynamic mass **60** moves may be coplanar with the rotational plane of the tire rim **30**, or slightly askew of the rotational plane. The movement of the dynamic mass **60** may in turn transfer work energy to air pressure in the pump housing **70**.

[0058] The pump housing **70** may have one or more chambers and corresponding valves **80**. Biasing elements **90**, such as springs, may be incorporated to return the chamber volume from a high volume condition (FIG. **2**, right image) to a low volume condition (FIG. **2**, middle image), or vise versa. The valves **80** may be configured to allow the pump housing **70** to intake air from the exterior and to exhaust the inspired air to the tire cavity **50**. The valves **80** may be a self-checking type (FIG. **2**), or may be mechanically opened and closed under the influence of an auxiliary mechanism (not shown). A pressure regulating element (not shown) may be included for the purpose of limiting the ability of the device **20** to elevate the pressure of the tire cavity **50** above a predetermined recommended operating level. Upon sensing the target pressure, or as the target pressure is approached, the pressure regulating element may suddenly or progressively disable the device **20** by locking, releasing, closing, opening, etc. any number of functional elements such as intake and exhaust ports **100**, valves **80**, mechanical linkages (not shown), etc.

[0059] FIG. **3** schematically shows another example assembly **300** in accordance with the present invention which may be mounted on a wheel rim of a pneumatic tire. The example assembly **300** may include a two stage air pumping device **320** for use on the wheel rim **30** and within or outside the tire cavity **50** of the pneumatic tire **40**. The device **320** may be affixed to the wheel rim **30** for restoring air loss from the inflation volume within the tire cavity **50**. The device **320** may include a dynamic mass **360** mechanically confined to movement by a pump shaft **370**. The dynamic mass **360** may change position according to the shocks/vibrations to the dynamic mass by the wheel rim **30**. The plane about which the dynamic mass **360** moves may be coplanar with the rotational plane of the wheel rim **30**, or slightly askew of the rotational plane. The movement of the dynamic mass **360** may in turn transfer work energy to air pressure in the tire cavity **50**.

[0060] The device **320** may provide generally radially movement of the dynamic mass **360** to sequentially affect an intake stroke or an exhaust stroke, thereby eliminating a need for a biasing element to affect either an intake or exhaust stroke. The device **320** may include multiple and/or reversing RPM changes (such as an initial acceleration, deceleration and/or second acceleration) to affect one full intake/exhaust cycle of the device **320**. To affect this full stroke, the dynamic mass **360** may move in one direction or an opposite direction thereby rotating an actuation cam **380** that enacts linear movement of the pump shaft **370** for the intake/exhaust stroke of a pump chamber **390** to force air into the tire cavity **50**. The pump housing **370** may have one or more chambers and corresponding valves (not shown), similar to the arrangement of FIGS. **1-2**. The valves may be configured to allow the pump housing **370** to intake air from the exterior and to exhaust the inspired air from the pump housing **370** to the tire cavity **50**.

[0061] The dynamic mass **360** may transfer linear shock energy to a first gear **361** in one linear direction and a second gear **362** in a second opposite linear direction, each rotating the actuation cam **380** incremental amounts in a single rotational direction. Biasing elements, such as the springs **365** may return the dynamic mass **360** to its neutral position. A biasing element **375** may bias the shaft **370** in a single linear direction.

[0062] FIG. **4** schematically shows another example assembly **400** in accordance with the present invention which may be mounted on a wheel rim of a pneumatic tire. The example assembly **400** may include a two stage air pumping device **420** for use on the wheel rim **30** and within or outside the tire cavity **50** of the pneumatic tire **40**. The device **420** may be affixed to the wheel rim **30** for restoring air loss from the inflation volume within the tire cavity **50**. The device **420** may include a dynamic mass **460** mechanically confined to movement by a pump shaft **470**. The dynamic mass **460** may change position according to the shocks/vibrations to the dynamic mass by the wheel rim **30**. The plane about which the dynamic mass **460** moves may be coplanar with the rotational plane of the wheel rim **30**, or slightly askew of the rotational plane. The movement of the dynamic mass **460** may in turn transfer work energy to air pressure in the tire cavity **50**.

[0063] The device **420** may provide generally radially movement of the dynamic mass **460** to sequentially affect an intake stroke or an exhaust stroke, thereby eliminating a need for a biasing element to affect either an intake or exhaust stroke. The device **420** may include multiple and/or reversing RPM changes (such as an initial acceleration, deceleration and/or second acceleration) to affect one full intake/exhaust cycle of the device **420**. To affect this full stroke, the dynamic mass **460** may move in one direction or an opposite direction thereby rotating an actuation cam **480** that enacts linear movement of the pump shaft **470** for the intake/exhaust stroke of a pump chamber **490** to force air into the tire cavity **50**. The pump housing **470** may have one or more chambers and corresponding valves (not shown), similar to the arrangement of FIGS. **1-2**. The valves may be configured to allow the pump housing **470** to intake air from the exterior and to exhaust the inspired air from the pump housing **470** to the tire cavity **50**.

[0064] The dynamic mass **460** may transfer linear shock energy to a first slot arm **461** in one linear direction and a second slot arm **462** in a second opposite linear direction, each rotating the actuation cam **480** incremental amounts in a single rotational direction. Biasing elements, such as the springs **465** may return the dynamic mass **460** to its neutral position. A biasing element **475** may bias the shaft **470** in a single linear direction.

[0065] FIG. **5** schematically shows another example assembly **500** in accordance with the present invention which may be mounted on a wheel rim of a pneumatic tire. The example assembly **500** may include a one stage air pumping device **520** for use on the wheel rim **30** and within or outside the tire cavity **50** of the pneumatic tire **40**. The device **520** may be affixed to the wheel rim **30** for restoring air loss from the inflation volume within the tire cavity **50**. The device **520** may include a dynamic mass **560** mechanically confined to movement by a pump shaft **570**. The dynamic mass **560** may change position according to the shocks/vibrations to the dynamic mass by the wheel rim **30**. The plane about which the dynamic mass **560** moves may be coplanar with the rotational plane of the wheel rim **30**, or slightly askew of the rotational plane. The movement of the dynamic mass **560** may in turn transfer work energy to air pressure in the tire cavity **50**.

[0066] The device **520** may provide generally radially movement of the dynamic mass **560** to sequentially affect an intake stroke or an exhaust stroke, thereby eliminating a need for a biasing element to affect either an intake or exhaust stroke. The device **520** may include multiple and/or reversing RPM changes (such as an initial acceleration, deceleration and/or second acceleration) to affect one full single directional intake/exhaust cycle of the device **520**. To affect this full stroke, the dynamic mass **560** may move in one direction or an opposite direction thereby rotating an actuation cam **580** that enacts linear movement of the pump shaft **570** for the intake/exhaust stroke of a pump chamber **590** to force air into the tire cavity **50**. The pump housing **570** may have one or more chambers and corresponding valves (not shown), similar to the arrangement of FIGS. **1-2**. The valves may be configured to allow the pump housing **570** to intake air from the exterior and to exhaust the inspired air from the pump housing **570** to the tire cavity **50**.

[0067] The dynamic mass **560** may transfer linear shock energy to a single gear **561** in one linear direction and in a second opposite linear direction, only one direction rotating the actuation cam **580** incremental amounts in a single rotational direction. Biasing elements, such as the springs **565** may return the dynamic mass **560** to its neutral position. A biasing element **575** may bias the shaft **570** in a single linear direction.

[0068] FIG. **6** schematically shows another example assembly **600** in accordance with the present invention which may be mounted on a wheel rim of a pneumatic tire. The example assembly **600** may include a single stage air pumping device **620** for use on the wheel rim **30** and within or outside the tire cavity **50** of the pneumatic tire **40**. The device **620** may be affixed to the wheel rim **30** for restoring air loss from the inflation volume within the tire cavity **50**. The device **620** may include a dynamic mass **660** mechanically confined to movement by a pump shaft **670**. The dynamic mass **660** may change position according to the shocks/vibrations to the dynamic mass by the wheel rim **30**. The plane about which the dynamic mass **660** moves may be coplanar with the rotational plane of the wheel rim **30**, or slightly askew of the rotational plane. The movement of the dynamic mass **660** may in turn transfer work energy to air pressure in the tire cavity **50**.

[0069] The device **620** may provide generally radially movement of the dynamic mass **660** to sequentially affect an intake stroke or an exhaust stroke, thereby eliminating a need for a biasing element to affect either an intake or exhaust stroke. The device **620** may include multiple and/or reversing RPM changes (such as an initial acceleration, deceleration and/or second acceleration) to affect one full intake/exhaust cycle of the device **620**. To affect this full stroke, the dynamic mass **660** may move in one direction or an opposite direction thereby rotating an actuation cam **680** that enacts linear movement of the pump shaft **670** for the intake/exhaust stroke of a pump chamber **690** to force air into the tire cavity **50**. The pump housing **670** may have one or more chambers and corresponding valves (not shown), similar to the arrangement of FIGS. **1-2**. The valves may be configured to allow the pump housing **670** to intake air from the exterior and to exhaust the inspired air from the pump housing **670** to the tire cavity **50**.

[0070] The dynamic mass **660** may transfer linear shock energy to a single slot arm **661** in one linear direction and in a second opposite linear direction, only one direction rotating the actuation cam **680** incremental amounts in a single rotational direction. Biasing elements, such as the springs **665** may return the dynamic mass **660** to its neutral position. A biasing element **675** may bias the shaft **670** in a single linear direction.

[0071] FIG. **7** shows an example four leafed actuation cam **760** for the assemblies **300**, **400**, **500**, **600**. This cam **760** may impart pumping strokes to the pumping chambers **390**, **490**, **590**, **690** more often than the cam of FIGS. **3-6**, but each pumping stroke may be less pressurized.

[0072] FIG. **8** shows the assemblies **300**, **400**, **500**, **600** of FIGS. **3-6** and the relationship of the actuation cam **380**, **480**, **580**, **680** to an actuation member, such as a pin **750** (not shown in FIGS. **3-6**). FIGS. **9-14** illustrate one complete stroke of the shaft **370**, **470**, **570**, **670** and the corresponding rotational position of the cam **380**, **480**, **580**, **680**. In FIG. **9**, the assembly **330**, **400**, **500**, **600** has completed a previous stroke and the shaft **370**, **470**, **570**, **670** has been linearly translated back to an initial position by the biasing element **375**, **475**, **575**, **675**.

[0073] In FIG. **10**, the cam **380**, **480**, **580**, **680** has been rotated about 90° counterclockwise from the position of FIG. **9** (e.g., by the dynamic mass **360** and gears **361**, **361**; or by the dynamic mass **460** and slot arms **461**, **462**; or by the dynamic mass **560** and the single gear **562**; or by the dynamic mass **660** and the single slot arm **661**). The cam **380**, **480**, **580**, **680** has thereby pushed the pin **750** and the shaft **370**, **470**, **570**, **670** a small amount to the right in FIG. **10** and compressed the biasing member **375**, **475**, **575**, **675** a small linear amount.

[0074] In FIG. **11**, the cam **380**, **480**, **580**, **680** has been rotated about 180° counterclockwise from the position of FIG. **9**. The cam **380**, **480**, **580**, **680** has thereby not pushed the pin **750** and the shaft **370**, **470**, **570**, **670** any amount to the right in FIG. **11** and compressed the biasing member **375**, **475**, **575**, **675** no linear amount from FIG. **10**.

[0075] In FIG. **12**, the cam **380**, **480**, **580**, **680** has been rotated about 225° counterclockwise from the position of FIG. **9**. The cam **380**, **480**, **580**, **680** has thereby pushed the pin **750** and the shaft **370**, **470**, **570**, **670** a relatively large amount to the right in FIG. **12** and compressed the biasing member **375**, **475**, **575**, **675** a larger amount from FIG. **11**.

[0076] In FIG. **13**, the cam **380**, **480**, **580**, **680** has been rotated about 300° counterclockwise from the position of FIG. **9**. The cam **380**, **480**, **580**, **680** has thereby pushed the pin **750** and the shaft **370**, **470**, **570**, **670** a relatively larger amount to the right in FIG. **13** and compressed the biasing member **375**, **475**, **575**, **675** a larger amount from FIG. **12**.

[0077] In FIG. **14**, the cam **380**, **480**, **580**, **680** has been rotated about 350° counterclockwise from the position of FIG. **9**. The cam **380**, **480**, **580**, **680** has thereby pushed the pin **750** and the shaft **370**, **470**, **570**, **670** a largest or maximum amount to the right in FIG. **14** and compressed the biasing member **375**, **475**, **575**, **675** to a minimum from FIG. **13**. As the cam **380**, **480**, **580**, **680** continues the final 10° counterclockwise back to the position of FIG. **9**, the biasing element **375**, **475**, **575**, **675** may linearly translate the shaft **370**, **470**, **570**, **670** back to the position of FIG. **9** to begin a subsequent pumping stroke.

[0078] While the rim mounted assemblies **10**, **300**, **400**, **500**, **600** have been shown in FIGS. **1-14** mounted to a rim exterior by a bolt and washer configuration, it might also be mounted by adhesive means. Another means may be with a bracket which fits under the wheel bolts. While only a single device **20**, **220**, **320**, **420**, **520**, **620** on a rim **30** is shown in the drawings, for the case of dual truck wheels, one wheel might have two devices mounted diametrically opposite each other for balance with each device feeding compressed air to each of the two tires of the dual wheel.

[0079] While a certain representative examples and details have been shown for the purpose of illustrating the present invention, it will be apparent to those skilled in the art that various changes and modifications may be made therein without departing from the spirit or scope of the present invention.

What is claimed:

1. A pumping device for use with a pneumatic tire mounted on a tire rim to keep the pneumatic tire from becoming underinflated, the pumping device comprising:

a housing attached to the tire rim;

a dynamic mass mechanically confined to linear movement relative to the housing and the tire rim, the dynamic mass moving in response to shock loads transferred from the tire rim to the dynamic mass and pumping ambient air into the housing;

an intake port for ambient air to enter the housing; and

an exhaust port for forcing pressurized air into a tire cavity of the pneumatic tire for restoring air loss from an inflation volume within the tire cavity.

2. The pumping device as set forth in claim **1** wherein the dynamic mass is mechanically confined to radial movement relative to the pneumatic tire.

3. The pumping device as set forth in claim **1** wherein the dynamic mass changes position corresponding to a shock loads from a contact surface to the pneumatic tire.

4. The pumping device as set forth in claim **1** wherein a plane about which the dynamic mass moves is coplanar with a rotational plane of the tire rim.

5. The pumping device as set forth in claim **1** wherein movement of the dynamic mass transfers work energy to air pressure in the housing.

6. The pumping device as set forth in claim **1** further including a first check valve disposed proximate to the intake port for preventing air from flowing out of the housing.

7. The pumping device as set forth in claim **6** further including a second check valve disposed proximate to the exhaust port for preventing air from flowing out of the tire cavity and into the housing.

8. The pumping device as set forth in claim **7** further including a biasing element for returning the housing from a high volume intake condition to a low volume exhaust condition.

9. The pumping device as set forth in claim **8** wherein the first check valve and the second check valve are self checking ball-type check valves.

10. The pumping device as set forth in claim **1** further including a gear rotating to pump pressurized air from the housing and forcing pressurized air into the tire cavity.

11. The pumping device as set forth in claim **10** wherein the housing receives ambient air from an exterior of the housing and exhausts pressurized air into the tire cavity simultaneously.

12. The pumping device as set forth in claim **1** further including a gear rotated by movement of the dynamic mass.

13. The pumping device as set forth in claim **12** further including a biasing member for restoring an actuation cam to an initial position.

14. The pumping device as set forth in claim **1** further including a slot arm rotated by movement of the dynamic mass.

15. The pumping device as set forth in claim **1** further including two coaxial gears rotated by movement of the dynamic mass.

16. The pumping device as set forth in claim **1** further including a second housing attached to the tire rim diametrically opposite the first housing.

17. The pumping device as set forth in claim **16** wherein the pumping device also restores air loss from an inflation volume within a second tire cavity of a second pneumatic tire.

18. The pumping device as set forth in claim **1** further including two springs for returning the dynamic mass to a neutral position.

19. The pumping device as set forth in claim **18** further including an additional spring for returning a cam to an initial position.

20. The pumping device as set forth in claim **1** further including two slot arms for rotating an actuation cam in a single direction.

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