(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
6 July 2017 (06.07.2017)

WIPO | PCT

(10) International Publication Number
WO 2017/116631 A1

(51) International Patent Classification:
B60S 5/04 (2006.01)

(21) International Application Number:
PCT/US2016/065143

(22) International Filing Date:
6 December 2016 (06.12.2016)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/272,144 29 December 2015 (29.12.2015) US

(71) Applicant: **BRIDGESTONE AMERICAS TIRE OPERATIONS, LLC** [US/US]; 535 Marriott Drive, Nashville, Tennessee 37214 (US).

(72) Inventors: **DUNCAN, Anthony B.**; 1454 Fixler Road, Wadsworth, Ohio 44281 (US). **STUCKEY, Jon I.**; 763 September Drive, Uniontown, Ohio 44685 (US).

(74) Agents: **JUPINA, Matthew W.** et al.; 10 East Firestone Blvd., Akron, Ohio 44317 (US).

(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

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(54) **Title**: RAPID TIRE INFLATION SYSTEM WITH AIR COMPRESSOR

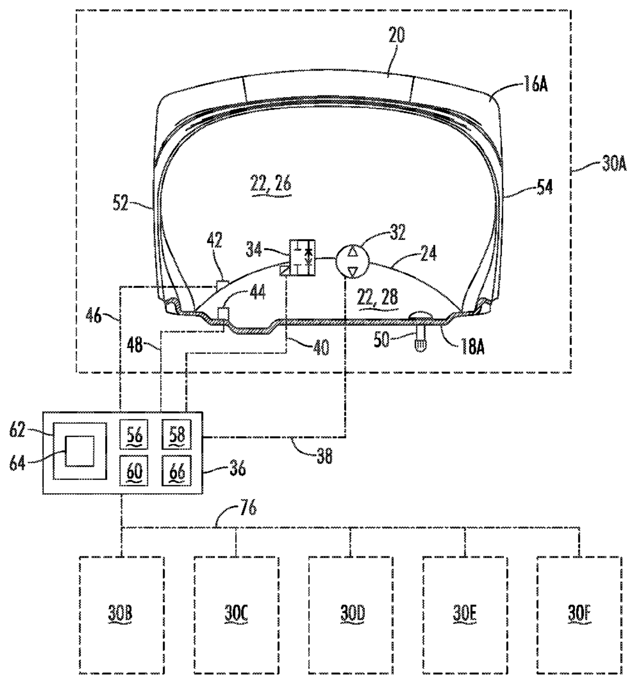


FIG. 3

(57) **Abstract**: An onboard inflation system for a vehicle such as an agricultural vehicle is disclosed, including a tire mounted on a wheel to form a wheel and tire assembly. The tire includes a tread portion and a tire cavity including an inflation chamber adjacent the tread portion of the tire. A storage chamber is carried by at least one of the wheel and the tire. A compressor arrangement is communicated with both the storage chamber and the inflation chamber. The compressor arrangement is configured to transfer air between the storage chamber and the inflation chamber.

WO 2017/116631 A1

Published:

— *with international search report (Art. 21(3))*

UNITED STATES PATENT APPLICATION

(PROVISIONAL 37 C.F.R. §1.53(c))

RAPID TIRE INFLATION SYSTEM WITH AIR COMPRESSOR

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present disclosure relates generally to a method and apparatus for adjusting air pressure within a tire. More particularly, the system provides for the rapid change between a field ready pressure and a road ready pressure for large agricultural tires when the agricultural vehicles on which the tires are used move from a field environment to a road environment and vice versa.

2. Description of the Prior Art

[0002] Large self-propelled agricultural equipment such as a tractor, combine harvester or high clearance sprayer spends most of its operational time in or around a cultivated field. As a result, the tires of the equipment are often adapted to address common concerns arising from using heavy machinery over a cultivated field. One of the common concerns is soil compaction. As large equipment travels over a given field, the soil beneath the equipment's tires will be compacted to increase in density. This soil compaction may be harmful to the production or yield of the field. As soil compaction increases, the yield will often decrease. In order to combat this problem, it is common for equipment operators to reduce the air pressure of the tires when the equipment is in the field. Experience has shown that a reduced tire air pressure can reduce the level of soil compaction in the field. As a result it can also increase the production and efficiency of the field.

[0003] While this reduced tire air pressure may be preferable in the field environment, an elevated tire pressure is still preferable when the equipment is traveling over a typical paved road. The elevated tire pressure allows each tire to roll more efficiently and achieve a higher maximum velocity. With many users being forced to transport their large agricultural equipment extended distances from one field to another, speed and efficiency during transport is important. However, the time needed to inflate or deflate a typical tire is often a hindrance to the ability to rapidly and efficiently move the agricultural equipment from the field environment to the road environment.

[0004] What is needed then is an improved tire inflation system addressing these concerns.

SUMMARY OF THE INVENTION

[0005] In one aspect of the disclosure an inflation system includes a wheel and a tire mounted on the wheel to form a wheel and tire assembly. The tire includes a tread portion and a tire cavity including an inflation chamber adjacent the tread portion of the tire. The system further includes a storage chamber carried by at least one of the wheel and the tire. A compressor arrangement is communicated with both the storage chamber and the inflation chamber. The compressor arrangement is configured to transfer air between the storage chamber and the inflation chamber.

[0006] In another aspect of the disclosure an onboard inflation system is provided for a vehicle having a plurality of wheels and tires. Each of the tires is mounted on one of the wheels to define a plurality of wheel and tire assemblies. The inflation system includes each of the tires having a tread portion and a tire cavity including an inflation chamber adjacent the tread portion of the tire. The system further includes a plurality of storage chambers, each storage chamber being carried by either the wheel or the tire of a respective one of the wheel and tire assemblies. The system further includes a plurality of compressors, each of the compressors communicating the storage chamber of a respective one of the wheel and tire assemblies with the inflation chamber of the respective one of the wheel and tire assemblies. Each compressor is configured to pump air between its respective storage chamber and its respective inflation chamber so that operating pressure in the inflation chamber can be changed by operation of the compressor.

[0007] In another embodiment of the disclosure a method of controlling inflation pressures of a plurality of tires mounted on a plurality of wheels of a vehicle is provided. Each of the tires is mounted on one of the wheels to define a plurality of wheel and tire assemblies. The method may comprise the steps of:

(a) providing each of the wheel and tire assemblies with a separate inflation system including an inflation chamber operatively located adjacent a tread portion of the tire, a storage chamber, and a compressor communicating the storage chamber with the inflation chamber;

(b) providing each of the inflation chambers with an initial inflation pressure greater than atmospheric pressure, and providing each of the storage chambers with an initial stored air pressure greater than atmospheric pressure; and

(c) selectively operating at least one of the compressors to increase pressure in one of its associated chambers by pumping air from the other of its associated chambers, thereby more rapidly providing the increased pressure than the same compressor could do if pumping additional air to said one of its associated chambers from an atmospheric pressure source.

[0008] In any of the embodiments the compressor arrangement may be configured to transfer air from the inflation chamber to the storage chamber so that operating pressure in the inflation chamber can be decreased by operation of the compressor arrangement.

[0009] In any of the embodiments a valve may be communicated with the storage chamber and the inflation chamber, so that the valve can be opened to allow air to flow from the storage chamber to the inflation chamber, the valve being located in parallel with the compressor arrangement.

[0010] In any of the embodiments the storage chamber and the inflation chamber may define a closed air storage system wherein operating pressure in the inflation chamber can be increased without adding air to the closed air storage system and decreased without discharging air from the closed air storage system.

[0011] In any of the embodiments the compressor arrangement may include a two-way compressor configured to transfer air from the storage chamber to the inflation chamber, and to transfer air from the inflation chamber to the storage chamber, so that operating pressure in the inflation chamber can be selectively increased or decreased by operation of the two-way compressor.

[0012] In any of the above embodiments the storage chamber may be located inside the tire cavity, and the system may include a divider wall separating the inflation chamber and the storage chamber.

[0013] In any of the above embodiments the divider wall may be substantially rigid so that volumes of the storage chamber and the inflation chamber of each wheel and tire assembly remain substantially constant with changing operating pressure in the associated inflation chamber.

[0014] In any of the above embodiments the compressor arrangement may be mounted on the divider wall.

[0015] In any of the above embodiments the storage chamber may be carried by the wheel outside the cavity of the tire.

[0016] In any of the above embodiments the compressor arrangement may be carried by the wheel outside the cavity of the tire.

[0017] In those embodiments having a plurality of wheel and tire assemblies, each compressor arrangement may be independently operable to control inflation of its respective wheel and tire assembly.

[0018] In any of the above embodiments a controller may be provided and configured to repeatedly change the operating pressure in each of the inflation chambers between a lower pressure and a higher pressure by transfer therebetween the storage chamber and the inflation chamber.

[0019] Numerous objects features and advantages of the invention will be readily apparent to those skilled in the art upon a reading of the following disclosure in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] Fig. 1 is a schematic plan view of an agricultural vehicle including a tractor and an implement pulled by the tractor.

[0021] Fig. 2 is a schematic side elevation view of the tractor of Fig. 1.

[0022] Fig. 3 is schematic drawing of one wheel and tire assembly in cross section, with an internal storage chamber and inflation chamber, with parallel valve and compressor arrangement between the chambers. A controller is schematically shown, as are a plurality of further wheel and tire assemblies of the vehicle of Fig. 1.

[0023] Fig. 4A is a graphical depiction of pressure versus time for a combined valve and compressor arrangement of a closed air system as in Fig. 3, as the inflation pressure in the tire is increased from a lower pressure to a higher pressure.

[0024] Fig. 4B is a continuation of the graphical depiction of Fig. 4A, at later times when the inflation pressure in the tire is decreased from the higher pressure to the lower pressure.

[0025] Fig. 5A is a graphical depiction of pressure versus time for the compressor arrangement acting without the parallel valve, as the inflation pressure in the tire is increased from a lower pressure to a higher pressure.

[0026] Fig. 5B is a continuation of the graphical depiction of Fig. 5A, at later times when the inflation pressure in the tire is decreased by action of the compressor from the higher pressure to the lower pressure.

[0027] Fig. 6 is a graphical depiction of pressure versus time for a system starting with a storage pressure higher than the high inflation pressure, then opening a valve to equalize the system to the high inflation pressure, then later using the compressor to transfer air from the inflation chamber back to the storage chamber.

DETAILED DESCRIPTION OF THE INVENTION

Definitions

[0028] Following are definitions of selected terms employed herein. The definitions include various examples and/or forms of components that fall within the scope of a term and that may be used for implementation. The examples are not intended to be limiting. Both singular and plural forms of terms may be within the definitions.

[0029] "Air" is understood to mean any inflating fluid suitable for use within a tire, including, but not limited to, gases containing some amount of nitrogen or oxygen. Consequently, "air pressure" is understood to mean the fluid pressure caused at least partially by the "air" contained within a body.

[0030] "Signal" may include any meaning as may be understood by those of ordinary skill in the art, including at least an electric or magnetic representation of current, voltage, charge, temperature, data or a state of one or more memory locations as expressed on one or more transmission mediums, and generally capable of being transmitted, received, stored, compared, combined or otherwise manipulated in any equivalent manner.

[0031] Directions are also stated in this application with reference to the axis of rotation of the tire. The terms "upward" and "upwardly" refer to a general direction towards the tread of the tire, whereas "downward" and "downwardly" refer to the general direction towards the axis of rotation of the tire. Thus, when relative directional terms such as "upper" and "lower" are used in connection with an element, the "upper" element is spaced closer to the tread than the "lower" element. Additionally, when relative directional terms such as "above" or "below" are used in connection with an element, an element that is "above" another element is closer to the tread than the other element. The terms "axially inward" and "axially inwardly" refer to a general direction towards the equatorial plane of the tire, whereas "axially outward" and "axially outwardly" refer to a general direction away from the equatorial plane of the tire and towards the sidewall of the tire. The term "when" is used to specify orientation for relative positions of components, not as a temporal limitation of the claims or apparatus described and claimed herein unless otherwise specified.

[0032] To the extent that the term "includes" or "including" is used in the specification or the claims, it is intended to be inclusive in a manner similar to the term "comprising" as that term is interpreted when employed as a transitional word in a claim. Furthermore, to the extent that the term "or" is employed (e.g., A or B) it is intended to mean "A or B or both." When the applicants intend to indicate "only A or B but not both" then the term "only A or B but not both" will be employed. Thus, use of the term "or" herein is the inclusive, and not the exclusive use. See, Bryan A. Garner, A Dictionary of Modern Legal Usage 624 (2d. Ed. 1995). Also, to the extent that the terms "in" or "into" are used in the specification or the claims, it is intended to additionally mean "on" or "onto." Furthermore, to the extent the term "connect" is used in the specification or claims, it is intended to mean not only "directly connected to," but also "indirectly connected to" such as connected through another component or multiple components.

Description

[0033] Terms such as "a," "an," and "the" are not intended to refer to only a singular entity, but rather include the general class of which a specific example may be used for illustration. The terminology herein is used to describe specific embodiments of the invention, but their usage does not delimit the invention, except as set forth in the claims.

[0034] Referring now to Figs. 1 and 2, a vehicle 10 is shown which may include a tractor 12 and a trailer 14. The trailer 14 may be a trailer for hauling goods, or it may be another agricultural implement including but not limited to free wheeling agricultural implements such as corn planters, tillage equipment, disk implements, field cultivators, air seeders and the like.

[0035] The tractor 12 includes first and second front tires 16A and 16B associated with the front axle 17, and first and second rear tires 16C and 16D located with the rear axle 19. The trailer may include first and second trailer tires 16E and 16F associated with a trailer axle 21. It will be understood that the vehicle 10 may include other arrangements and may include more than the 6 tires shown or less. Each of the tires such as 16A is mounted on an associated wheel 18 such as the wheel 18A seen in Fig. 3. Each of the tires such as 16A and its associated wheel such as 18A may be described as a wheel and tire assembly.

[0036] As best seen in Fig. 3, wherein a schematic cross-section is shown through a portion of the tire 16A and associated wheel 18A, includes a tread portion such as 20 and a tire cavity such as 22. In the embodiment shown in Fig. 3, a divider wall 24 separates the tire cavity 22 into an inflation chamber 26 and a storage chamber 28.

[0037] The inflation chamber 26 and the storage chamber 28 may also be alternatively referred to as an upper chamber 26 and a lower chamber 28. The inflation chamber 26 may be described as being between the tread portion 20 of the tire and the divider wall 24. The storage chamber 28 can be described as being between the divider wall 24 and the wheel 18A. The wheel and tire assembly 18A, 16A may be described as being associated with or as being part of an inflation system generally designated by the numeral 30A the components of which are located within the dashed box 30A indicated in Fig. 3.

[0038] The inflation system may include a compressor arrangement 32 communicated with both the storage chamber 28 and the inflation chamber 26. The compressor arrangement 32 is configured to transfer air between the storage chamber 28 and the inflation chamber 26.

[0039] In Fig. 3, the compressor arrangement 32 is schematically illustrated as being a bidirectional compressor which may either pump air from the storage chamber 28 into the inflation chamber 26 or from the inflation chamber 26 into the storage chamber 28. Alternatively, the compressor arrangement 32 may include two parallel unidirectional compressors, one of which is arranged to pump air from the inflation chamber 26 into the storage chamber 28 and the other of which is arranged to pump air from the storage chamber 28 into the inflation chamber 26. A further alternative may have the compressor arrangement 32 including only a single unidirectional compressor which may in one arrangement provide for the pumping air from the storage chamber 28 to the inflation chamber 26. In another embodiment a unidirectional compressor may be arranged to pump air from the inflation chamber 26 into the storage chamber 28.

[0040] The inflation system 30A may further include a valve 34 mounted in the divider wall 24 and communicated with the storage chamber 28 and the inflation chamber 26, and arranged parallel to the compressor 32. The valve 34 can be moved between an open position allowing communication between chambers 26 and 28, and a closed position.

[0041] Both the compressor 32 and the valve 34 are automatically controlled components which are associated with a controller 36. The controller 36 sends control signals to compressor 32 over communication line 38, and to valve 34 over communication line 40.

[0042] The inflation system 30A further includes first and second pressure sensors 42 and 44. The first pressure sensor 42 is arranged to be communicated with the inflation chamber 26, and the second pressure sensor 44 is arranged to be communicated with the storage chamber 28.

[0043] The first pressure sensor 42 is shown being located on an upper surface of divider wall 24, but it will be understood that the first pressure sensor 42 may be placed at any location so long as it is in communication with the inflation chamber 26. The first pressure sensor 42 may be physically mounted on the divider wall 24, on the tire 16A, or on the wheel 18A.

[0044] Similarly, the second pressure sensor 44 is shown as mounted on the wheel 18A, but it will be understood that it can be located in any way so long as it is in pressure communication with the storage chamber 28.

[0045] Pressure signals from the first sensor 42 and second pressure sensor 44 may be communicated to the controller 36 via communication lines 46 and 48.

[0046] It is noted that all of the communication lines 38, 40, 46 and 48 may be hard wired, or may comprise wireless communication paths between the controller 36 and the various associated components. Also each of the other wheel and tire assemblies have inflation systems 30B-30F associated therewith as schematically shown in Fig. 3. Controller 36 communicates with the inflation systems 30B-30F via communication lines schematically and collectively indicated as 76 in Fig. 3. It will be understood that each of the inflation systems 30B-30F may include all of the same features as illustrated for inflation system 30A.

[0047] The inflation chamber 26 and storage chamber 28 collectively may be described as a closed air storage system wherein operating pressure in the inflation chamber 26 can be increased without adding air to the closed air storage system and decreased without discharging air from the closed air storage system. It is noted that a conventional valve stem 50 may be mounted in the wheel 18A so that air can be added to or discharged from the closed air system, but in normal operation of the tire the valve stem 50 is closed and thus the air storage system within the tire 16A is closed.

Divider Wall Construction

[0048] The structural construction of the divider wall 24 may take many different forms. For example, in the embodiment shown in Fig. 3, the divider wall 24 is an annular sheet-like member that extends axially between first and second sidewalls 52 and 54 of the tire 16A.
The divider wall 24 may be integrally attached to the sidewalls 52 and 54 of the tire 16A. Alternatively, the divider wall may a portion of a toroidal bladder which encloses the storage chamber 28. Any of the embodiments of the divider wall may have the divider wall constructed of one or more plies of rubber coated parallel cords. If multiple layers are utilized, the layers are preferably oriented in the manner of bias plies with cords of alternating layers running in alternate directions. Additionally, the divider wall 24 may be made of any other suitable materials. .

[0049] Additionally, it is noted that the divider wall 24 may be constructed in a sufficiently rigid manner that the divider wall serves as a structural member which biases the first and second sidewalls 52 and 54 of the tire 16A axially outward away from each other so as to aid in maintaining the seal of the bead portions of the sidewalls on the wheel 18A. The divider wall 24 may also provide a run-flat function. The divider wall 24 may be substantially rigid so that the volume of storage chamber 28 is substantially constant.

The Controller

[0050]Controller 36 includes a processor 56, a computer readable memory medium 58, a data base 60 and an input/output module or control panel 62 having a display 64.

[0051]The term "computer-readable memory medium" as used herein may refer to any non-transitory medium 58 alone or as one of a plurality of non-transitory memory media 58 within which is embodied a computer program product 66 that includes processor-executable software, instructions or program modules which upon execution may provide data or otherwise cause a computer system to implement subject matter or otherwise operate in a specific manner as further defined herein. It may further be understood that more than one type of memory media may be used in combination to conduct processor-executable software, instructions or program modules from a first memory medium upon which the software, instructions or program modules initially reside to a processor for execution.

[0052]"Memory media" as generally used herein may further include without limitation transmission media and/or storage media. "Storage media" may refer in an equivalent manner to volatile and non-volatile, removable and non-removable media, including at least dynamic memory, application specific integrated circuits (ASIC), chip memory devices, optical or magnetic disk memory devices, flash memory devices, or any other medium which may be used to stored data in a processor-accessible manner, and may unless otherwise stated either reside on a single computing platform or be distributed across a plurality of such platforms. "Transmission media" may include any tangible media effective to permit processor-executable software, instructions or program modules residing on the media to be read and executed by a processor, including without limitation wire, cable, fiber-optic and wireless media such as is known in the art.

[0053]The term "processor" as used herein may refer to at least general-purpose or specific-purpose processing devices and/or logic as may be understood by one of skill in the art, including but not limited to single- or multithreading processors, central processors, parent processors, graphical processors, media processors, and the like.

[0054]The controller 36 receives input data from the sensors 42 and 44. Based upon the programming 66 the controller 36 sends command signals to compressor 32 and valve 34 to control air pressure in the chambers 26 and 28 as is further described below.

[0055]In Fig. 2 an alternative embodiment is schematically illustrated in which external storage chambers such as 68B and 68D are carried on or mounted on their associated wheels 18B and 18D, and having associated therewith compressors 32 and valves 34 also carried by their respective wheels outside of the cavity of their associated tires. Storage chambers 68B and 68D as shown in Fig. 2 may be pancake shaped and mounted on their respective wheels to rotate with the wheels. The storage chambers 68B and 68D are communicated with their respective tire cavities with suitable conduits and connections through the wheel walls. The associated compressors 32 and valves 34 may be mounted on the outside of the pancake shaped chambers or at any other suitable location carried by the wheels.

[0056] It is noted that for all of the above embodiments, the compressors 32 and valves 34 may be electrically powered via batteries. Also, the compressors and valves may be powered by hydraulic or pneumatic power, or by hard wired electrical power, communicated to the compressors and valves via suitable rotating connections from a power source located elsewhere on the vehicle 10.

Example of Figs. 4A-4B

[0057] Figs. 4A-4B graphically depict one mode of operation of the system shown for example in Fig. 3. In Figs. 4A and 4B, the operating pressure in the inflation chamber 26 is depicted by dashed line curve 68. The pressure in the storage chamber 28 is depicted by the solid line curve 70. The horizontal axis represents time and the vertical axis represents pressure.

[0058] In the scenario illustrated in Fig. 4A, at a starting time T_0 the inflation pressure 68 is initially at a value P_F, which in one example may be a field ready inflation pressure. The storage pressure 70 in storage chamber 28 is initially at a level P_S. Both the pressure P_F and P_S are greater than atmospheric pressure which is represented by the value P_A.

[0059] In the scenario illustrated in Fig. 4A, both the valve 34 and the compressor 32 will be utilized. Initially, the valve 34 is closed and the compressor 32 is inoperative. At time T_1, the valve 34 is opened, thus allowing the pressure within the storage chamber 28 and the inflation chamber 26 to rapidly equalize to a pressure P_E at time T_2. At time T_2, the valve 34 is closed and the compressor 32 is actuated to pump additional air from the storage chamber 28 to the inflation chamber 26 thus causing the inflation pressure 68 in inflation chamber 26 to continue to rise until it ultimately reaches a higher inflation pressure which in this example may be a road ready pressure P_R at time T_3. During this same interval from time T_2 to time T_3, the pressure 70 in storage chamber 28 continues to drop and may go below P_A or to whatever the minimum pressure is that the compressor 32 is capable of drawing.

[0060] Thus through the combined operation of the valve 34 and the compressor 32, the inflation pressure 68 in inflation chamber 26 has been increased from a lower field ready pressure P_F to a higher road ready pressure P_R. Because the compressor 32 is pulling air from storage chamber 28 at an equilibrium pressure P_E when the compressor turns on at time T_2, the compressor 32 can much more rapidly increase the air pressure in inflation chamber 26, than it could if it were taking its low pressure air from an atmospheric pressure source.

[0061]The operations just described with regard to Fig. 4A may be performed by the controller 36 in an automatic manner in response to an operator input instruction to control panel 62 by the human operator driving the vehicle 10.

[0062]Thus at time T_3 shown in Fig. 4A the inflation pressure curve 68 has reached the level P_R.

[0063]Turning now to Fig. 4B, a subsequent reduction of the inflation pressure in inflation chamber 26 from the road ready level P_R to the field ready level P_F is illustrated. Thus as seen in Fig. 4B, at time T_3, the vehicle 10 is in the status wherein the inflation chamber 26 is at pressure P_R and the pressure in storage chamber 28 is at some minimum level which may in fact be below the level P_F.

[0064]At time T_4, the operations to reduce the inflation pressure from the road ready level P_R back to the field ready pressure P_F is illustrated. At time T_4 the valve 34 is opened allowing the pressure within inflation chamber 26 and storage chamber 28 to again equalize at the value P_E which occurs relatively quickly at a time T_5. Then at time T_5, the valve 34 is closed and the compressor 32 is activated to operate in the opposite direction so as to pump air from the inflation chamber 26 into the storage chamber 28. This reduces the pressure in inflation chamber 26 as shown by the dashed line curve 68 between time T_5 and T_6 until the pressure 68 in inflation chamber 26 reaches the desired field ready pressure P_F at which time the compressor 32 is deactivated.

[0065]Thus in the cycle represented by Figs. 4A and 4B combined, the closed air storage system including the inflation chamber 26 and the storage chamber 28 has been utilized along with the compressor 32 and the valve 34 so as to increase the pressure from the lower field ready pressure P_F at time T_1 to the higher road ready pressure P_4 at time T_3, and then later at time T_4 to reduce the inflation pressure from the road ready level P_R back to the lower field ready pressure P_F which is achieved at time T_6.

[0066]In one example of the scenario depicted in Figs. 4A and 4B, if the inflation chamber 26 and storage chamber 28 have equal volumes, and if the inflation chamber is initially charged at a field ready pressure of 10 psi and the storage chamber is initially charged at a storage pressure of 30 psi, upon opening of valve 34 the pressure in both chambers will equalize at 20 psi. Then the compressor 32 may be used to boost the pressure in inflation chamber 26 to for example a road ready inflation pressure of 25 psi. This will reduce the pressure in storage chamber 28 to about 15 psi.

Example of Figs. 5A-5B

[0067] Figs. 5A – 5B illustrate the operation of a system like that shown in Fig. 3, except in this example the valve 34 will not be used. The bi-directional compressor 32 will be used as the sole conduit for transfer of air between the chambers 26 and 28.

[0068] Thus in Figs. 5A – 5B, the pressure within the air storage chamber 28 is represented by solid line curve 72 and the pressure within inflation chamber 26 is represented by the dash line curve 74.

[0069] In Fig. 5A, at time T_0 the initial inflation pressure in inflation chamber 26 is at the lower field ready level P_F, and the storage pressure in air storage chamber 28 is at level P_S. At time T_1, the bi-directional compressor 32 is activated to pump air from the storage chamber 28 to the inflation chamber 26 so as to raise the pressure in inflation chamber 26 to the higher road ready level P_R. At some point during the process represented at time T_2 the curves 72 and 74 cross at equilibrium pressure P_E. Then the pressure in inflation chamber 26 increases and the pressure in air storage chamber 28 is drawn down to some minimum pressure which may or may not be below atmospheric pressure P_A. This is represented at time T_3 in Fig. 5A. Thus at time T_3, the inflation pressure in the tires 26 is at a road ready inflation pressure P_R.

[0070] The process continues as shown in Fig. 5B wherein at time T_4 it is determined to reduce the pressure in the tire from the higher road ready P_R to the lower field ready level P_F. The bi-directional compressor 32A is activated at time T_4 to pump air from the inflation chamber 26 into the air storage chamber 28, thus reducing the inflation pressure as represented by dash curve 74 to the lower field ready pressure P_F and returning the pressure in storage chamber 28 to the level P_S as represented by solid line curve 72, which final state is achieved at time T_6.

[0071] Thus during this process the inflation pressure in inflation chamber 26 may be repeatedly changed between its lower field ready level P_F and its higher road ready pressure P_R without adding air to or discharging from the closed air storage system defined by the inflation chamber 26 and the air storage chamber 28.

[0072] Although the processes described above have been described with regard to one of the tires 16 and its associated inflation system 30A, as schematically illustrated in Fig. 3, the controller 36 communicates with each of the inflation systems 30B – 30F associated with the other tires 16B - 16F of the vehicle 10, and the controller 36 may control each tire individually or any selected combination of tires simultaneously as desired.

Example of Fig. 6

[0073] Fig. 6 illustrates another manner in which the inflation system 30 of Fig. 3 may be used. In this example, the inflation pressure in inflation chamber 26 is represented by dash line curve 78 and the storage pressure in storage chamber 28 is represented by solid line curve 80.

[0074] In this example, sufficient compressed air is provided in the air storage chamber 28 so that upon opening of the valve 34 and equalizing of the pressure in the inflation chamber 26 and storage chamber 28, the equilibrium pressure will be at the desired higher road ready level P_R. Thus in the example of Fig. 6, at time T_0, the initial pressure stored in air storage chamber 28 is at a level P_S which is higher than the desired road ready inflation pressure P_R. The initial pressure in inflation chamber 26 is at the level P_F which is the lower field ready pressure.

[0075] At time T_1, the valve 34 is opened allowing the pressure within inflation chamber 26 and storage chamber 28 to equalize at the level P_R which will be the road ready inflation pressure at which the tire is desired to be operated. Thus between time T_1 and T_2 the inflation pressure represented by dash curve 78 will relatively rapidly increase, depending on the flow capacity of the valve 34 to reach the level P_R.

[0076] Between times T_2 and T_3, vehicle 10 has its tire inflated to the higher road ready inflation level P_R and may by operated on the roads. When it is desired to return the inflation pressure to the lower field ready pressure P_F, at a time as indicated at T_3, the valve 34 is closed and the compressor 32 can be activated to pump air from the inflation chamber 26 back into the storage chamber 28 thus increasing the storage pressure from valve P_R to P_S as represented by the solid line curve 80 between times T_3 and T_4. During that same interval, the inflation pressure represented by dash line curve 78 between times T_3 and T_4 will decrease from the higher road ready pressure P_R to the lower field ready pressure P_F.

[0077] Once again, the air storage system defined by inflation chamber 26 and air storage chamber 28 may be described as a closed air storage system, and the inflation pressure may be repeatedly changed between the lower field ready pressure P_F and the higher road ready pressure P_R by repeating the process illustrated in Fig. 6 without adding any air to the closed air storage system or discharging any air from the closed air storage system.

[0078] It is also noted that if the system is to be operated in the manner as shown in Fig. 6, the bi-directional compressor schematically illustrated in Fig. 3 could be replaced by a unidirectional air compressor which only pumps air from the inflation chamber 26 back in to the storage chamber 28.

[0079] In the scenario illustrated in Fig. 6, it will also be understood that the inflation system may be designed and controlled such the desired road ready pressure P_R in the inflation chamber 26 will be achieved before an equilibrium condition between the inflation chamber 26 and air storage chamber 28 is achieved. In that case, the valve 34 will be closed at a point in time when the remaining pressure in the air storage chamber 28 is still in excess of the road ready pressure P_R.

[0080] Several numerical examples are provided below to illustrate typical pressures and chamber volumes which could achieve the scenario of Fig. 6. In the examples below the assumption is that when it is desired to increase the pressure in the inflation chamber 26 from the field ready pressure P_F to a road ready pressure P_R, the valve 34 will be opened and the pressure within the cavities 26 and 28 will be allowed to equalize.

[0081] The pressure relationship between the pressure P_F in the inflation chamber 26 having a volume V_f, and the pressure P_x in the storage chamber 28 having a volume V_x may be described as follows. It is noted that the pressure P_x in the storage chamber 28 is analogous to the storage pressure P_S discussed above. The relationship is:

$$P_F \times V_f + P_x \times V_x = P_R \times V_r$$

wherein $V_r = V_f + V_x$.

[0082] The volumes V_f and V_x are determined by the construction of the tire 16 and wheel 18 and the construction of the divider wall 24 which determines the subsequent volumes into which the volume of the cavity 22 is divided. Thus the volumes V_f and V_x are determined by the construction of the divider wall 24. For a selected volume V_x which may be described as a percentage of the total volume V_r, then given any assumed desired field ready pressure P_F and road ready pressure P_R, the necessary pre-charged pressure P_x for the storage chamber 28 may be calculated by the formula:

$$P_x = \frac{P_R \times V_r - P_F \times V_f}{V_r - V_f}$$

[0083] Several examples of tire sizes and applicable field ready pressures and road ready pressures for which the inflation system 30A is designed may include the following:

TABLE I

Tire Size	Field Ready Pressure P_F (PSI)	Road Ready Pressure P_R (PSI)
480/80R50	12-14	35
480/80R46	12-14	35
710/70R42	6	29
800/70R38	6	23

[0084] Choosing the tire size 800/70R38 from Table I, the cavity 22 of such a tire has a total volume of 85,500 cubic inches. For such an 800/70R38 tire, and for various selections of the construction of divider wall 24 so as to define the volume V_x of the storage chamber 28 as a percentage of the total volume V_r of cavity 22, the relative magnitudes of the necessary reservoir pressure P_x within the chamber volume V_x in order to inflate from a field pressure P_F of 6 psi to a road ready pressure P_R of 23 psi, are shown in the following Table II:

TABLE II (800/70R38)

V_r = 85,500 in^3, P_F = 6 psi, P_R = 23 psi

V_x	% V_r	P_x
8550	10%	176
17100	20%	91
25650	30%	63
34200	40%	49
42750	50%	40

[0085] Another factor which must be considered in the design of the divider wall 24, is the height of the divider wall 24 above the wheel 18, which inversely determines the clearance between the divider wall 24 and the tread portion 20 of the tire 16. It will be understood that when operating the tire 16 in a field ready mode at very low inflation pressures there will be substantial deflection of the tread area 20 toward the wheel 18, and the divider wall 24 should be designed such that the tread portion 20 does not contact the divider wall 24. The amount of permissible deflection of any given tire will vary and will need to be considered when designing the appropriate inflation system 30A for that tire and when selecting inflation pressures and reservoir pressures to be utilized.

[0086] Additionally, safety and operational considerations may place upper limits on the desired pressures within the storage chamber 28. In general it is preferred that the pre-charged pressure P_x in the storage chamber 28 be no greater than about 100 psi.

[0087] Taking these factors into consideration, one suitable design of the inflation system 30A for a size 800/70R38 tire having a cavity volume of approximately 85,500 cubic inches is to design the divider wall 24 such that the volume V_x of the storage chamber 28 is approximately 23,900 cubic inches which is approximately 28% of the total volume of the cavity 22. For such a volume V_x, the necessary pre-charged pressure P_x is approximately 67 psi. Beginning with a field ready pressure P_F in the inflation chamber 26 of 6 psi, and a reservoir pressure P_x in the storage chamber 28 of 67 psi, upon opening of the valve 34 and allowing the pressure to equalize between chambers 26 and 28, the resulting equilibrium pressure P_R in the inflation chamber 26 and storage chamber 28 will be approximately 23 psi which is the desired road ready pressure for the tire size in question.

[0088] The preferred field ready pressures and road ready pressures for the four tire sizes shown in Table I may be described as a field ready pressure that is in a range of from 20% to 50% of the road ready pressure, and more preferably wherein the field ready pressure is in a range of from 25% to 40% of the road ready pressure.

[0089] For the example set forth in the above Table II, the system 30A may be described as having the wheel 18, the tire 16 and the divider wall 24 configured such that the inflation chamber volume V_x is in a range of from 20% to 40% of the total volume of the cavity 22, which would result in a pre-charged pressure in the range of from 49 psi to 91 psi.

Methods of Operation

[0090] Each of the scenarios illustrated above with regard to Figs. 4-6, and others described herein, may be described as a method of controlling inflation pressures of a plurality of tires 16 mounted on a plurality of wheels 18 of a vehicle 10, with each of the tires 16 being mounted on one of the wheels 18 to define a plurality of wheel and tire assemblies. The method may be described as including steps of:

(a) Providing each of the wheel and tire assemblies with a separate inflation system 30 including an inflation chamber 26 operatively located adjacent a tread portion 20 of the tire 16, a storage chamber 28, and a compressor 32 communicating the storage chamber 28 with the inflation chamber 26;

(b) Providing each of the inflation chambers 26 with an initial inflation pressure greater than atmospheric pressure, and providing each of the storage chambers 28 with an initial stored air pressure greater than atmospheric pressure; and

(c) Selectively operating at least one of the compressors 32 to increase pressure in one of its associated chambers 26 and 28, thereby more rapidly providing the increased pressure than the same compressor 32 could do if pumping additional air to said one of its associated chambers from an atmospheric pressure source.

[0091] In one embodiment of the method, in step (c) the pressure may be increased in the associated storage chamber 28 by pumping air from the associated inflation chamber 26.

[0092] The method may further include the step of selectively opening at least one of the valves 32 to allow air to flow from the associated storage chamber to the associated inflation chamber to increase inflation pressure in the inflation chamber.

[0093] In another mode of the invention, in step (c) the pressure may be increased in the associated inflation chamber by pumping air from the associated storage chamber.

[0094] In another mode of the invention, the storage chamber and the inflation chamber of each wheel and tire assembly may define a closed air storage system, and the method may include steps of selectively performing the functions of either increasing operating pressure in a selected one of the inflation chambers 26 without adding air to the associated closed air storage system, or decreasing operating pressure in the selected one of the inflation chambers 26 without discharging air from the associated closed air storage system.

[0095] All of the functions described above may be performed by an automatic controller 36 in response to operator input via the control panel 62.

[0096] Although the examples set forth herein have been described in the context of changing inflation pressure in the tires of an agricultural vehicle between a lower field ready pressure P_F and a higher road ready pressure P_R, it will be understood that these are only examples, and that the system described herein may be utilized in any situation where there is a need for periodically increasing and/or decreasing the inflation pressure of the tires of the vehicle.

[0097] Thus it is seen that the methods and apparatus of the present invention readily achieve the ends and advantages mentioned as well as those inherent therein. While certain preferred embodiments of the invention have been illustrated and described for purposes of the present disclosure, numerous changes in the arrangement and construction of parts and steps may be made by those skilled in the art, which changes are encompassed within the scope and spirit of the present invention, as defined by the appended claims.

CLAIMS

What is claimed is:

1. An inflation system, comprising:

a wheel;

a tire mounted on the wheel to form a wheel and tire assembly, the tire including a tread portion and a tire cavity including an inflation chamber adjacent the tread portion of the tire;

a storage chamber carried by at least one of the wheel and the tire; and

a compressor arrangement communicated with both the storage chamber and the inflation chamber, the compressor arrangement configured to transfer air between the storage chamber and the inflation chamber.

2. The system of claim 1, wherein:

the compressor arrangement is configured to transfer air from the inflation chamber to the storage chamber so that operating pressure in the inflation chamber can be decreased by operation of the compressor arrangement.

3. The system of claim 2, further comprising:

a valve communicated with the storage chamber and the inflation chamber, so that the valve can be opened to allow air to flow from the storage chamber to the inflation chamber, the valve being located in parallel with the compressor arrangement.

4. The system of claim 3, wherein:

the storage chamber and the inflation chamber define a closed air storage system wherein operating pressure in the inflation chamber can be increased without adding air to the closed air storage system and decreased without discharging air from the closed air storage system.

5. The system of claim 1, wherein:

the compressor arrangement is a two way compressor arrangement configured to transfer air from the storage chamber to the inflation chamber, and to transfer air from the inflation chamber to the storage chamber, so that operating pressure in the inflation chamber can be selectively increased or decreased by operation of the two way compressor arrangement.

6. The system of claim 5, further comprising:

a valve communicated with the storage chamber and the inflation chamber, so that the valve can be opened to allow air to flow from a higher pressure in one of the chambers to a lower pressure in the other of the chambers, the valve being located in parallel with the two way compressor arrangement.

7. The system of claim 5, wherein:

the storage chamber and the inflation chamber define a closed air storage system wherein operating pressure in the inflation chamber can be increased without adding air to the closed air storage system and decreased without discharging air from the closed air storage system.

8. The system of claim 1, wherein:

the storage chamber is located inside the tire cavity, and the system includes a divider wall separating the inflation chamber and the storage chamber.

9. The system of claim 8, wherein

the divider wall is substantially rigid so that volumes of the storage chamber and the inflation chamber remain substantially constant with changing operating pressure in the inflation chamber.

10. The system of claim 9, wherein:

the compressor arrangement is mounted on the divider wall.

11. The system of claim 1, wherein:

the storage chamber is carried by the wheel outside of the cavity of the tire.

12. The system of claim 11, wherein:

the compressor arrangement is carried by the wheel outside of the cavity of the tire.

13. The system of claim 1, further comprising:

at least one additional wheel and tire assembly including an additional inflation chamber and storage chamber, and an additional compressor arrangement communicated with the additional inflation chamber and the additional storage chamber, each compressor arrangement being independently operable to control inflation of its respective wheel and tire assembly.

14. The system of claim 13, further comprising:

a controller configured to repeatedly change the operating pressure in the inflation chamber between a lower inflation pressure and a higher inflation pressure by transfer of air between the storage chamber and the inflation chamber.

15. An onboard inflation system for a vehicle having a plurality of wheels and tires, each of the tires being mounted on one of the wheels to define a plurality of wheel and tire assemblies, the inflation system comprising:

each of the tires including a tread portion and a tire cavity including an inflation chamber adjacent the tread portion of the tire;

a plurality of storage chambers, each storage chamber being carried by either the wheel or the tire of a respective one of the wheel and tire assemblies; and

a plurality of compressors, each of the compressors communicating the storage chamber of a respective one of the wheel and tire assemblies with the inflation chamber of the respective one of the wheel and tire assemblies, each compressor configured to pump air between its respective storage chamber and its respective inflation chamber so that operating pressure in the inflation chamber can be changed by operation of the compressor.

16. The system of claim 15, wherein:

each of the compressors is configured to transfer air from its respective inflation chamber to its respective storage chamber so that operating pressure in its respective inflation chamber can be decreased by operation of the compressor.

17. The system of claim 16, further comprising:

a plurality of valves, each of the valves being associated with one of the wheel and tire assemblies and communicated with the storage chamber and the inflation chamber of its associated wheel and tire assembly, so that the valve can be opened to allow air to flow from the associated storage chamber to the associated inflation chamber, the valve being located in parallel with the compressor of its associated wheel and tire assembly.

18. The system of claim 16, wherein:

the storage chamber and the inflation chamber of each wheel and tire assembly define a closed air storage system wherein operating pressure in the inflation chamber can be increased without adding air to the closed air storage system and decreased without discharging air from the closed air storage system.

19. The system of claim 15, wherein:

each of the compressors is a two way compressor configured to pump air from its respective storage chamber to its respective inflation chamber so that operating pressure in the inflation chamber can be increased by operation of the compressor, and to pump air from its respective inflation chamber to its respective storage chamber so that operating pressure in the inflation chamber can be decreased by operation of the compressor.

20. The system of claim 19, further comprising:

a plurality of valves, each valve being communicated with the storage chamber and the inflation chamber of an associated one of the wheel and tire assemblies, so that each valve can be opened to allow air to flow from a higher pressure in one of the associated chambers to a lower pressure in the other of the associated chambers, each valve being located in parallel with its associated compressor.

21. The system of claim 15, wherein:

each storage chamber is located inside the tire cavity of the associated wheel and tire assembly, and each wheel and tire assembly includes a divider wall separating each inflation chamber from its associated storage chamber.

22. The system of claim 21, wherein

each divider wall is substantially rigid so that volumes of the associated storage chamber and inflation chamber remain substantially constant with changing operating pressure in the inflation chamber.

23. The system of claim 21, wherein:

each compressor is mounted on its associated divider wall.

24. The system of claim 15, wherein:

each storage chamber is carried by its associated wheel outside of the cavity of its associated tire.

25. The system of claim 24, wherein:

each compressor is carried by its associated wheel outside of the cavity of its associated tire.

26. The system of claim 15, wherein:

the storage chamber and the inflation chamber of each wheel and tire assembly define a closed air storage system wherein operating pressure in the inflation chamber can be increased without adding air to the closed air storage system and decreased without discharging air from the closed air storage system.

27. The system of claim 26, further comprising:

a controller configured to selectively control each of the compressors to repeatedly change the operating pressure in each of the inflation chambers between a lower inflation pressure and a higher inflation pressure by transfer of air within each of the closed air systems between the associated storage and inflation chambers.

28. A method of controlling inflation pressures of a plurality of tires mounted on a plurality of wheels of a vehicle, each of the tires being mounted on one of the wheels to define a plurality of wheel and tire assemblies, the method comprising:

(a) providing each of the wheel and tire assemblies with a separate inflation system including an inflation chamber operatively located adjacent a tread portion of the tire, a storage chamber, and a compressor communicating the storage chamber with the inflation chamber;

(b) providing each of the inflation chambers with an initial inflation pressure greater than atmospheric pressure, and providing each of the storage chambers with an initial stored air pressure greater than atmospheric pressure; and

(c) selectively operating at least one of the compressors to increase pressure in one of its associated chambers by pumping air from the other of its associated chambers, thereby more rapidly providing the increased pressure than the same compressor could do if pumping additional air to said one of its associated chambers from an atmospheric pressure source.

29. The method of claim 28, wherein:

in step (c) pressure is increased in the associated storage chamber by pumping air from the associated inflation chamber.

30. The method of claim 29, wherein:

in step (a) each of the wheel and tire assemblies further includes a valve communicated with the associated storage chamber and the associated inflation chamber, the valve being located in parallel with the associated compressor; and

further comprising:

selectively opening at least one of the valves to allow air to flow from the associated storage chamber to the associated inflation chamber to increase inflation pressure in the inflation chamber.

31. The method of claim 28, wherein:

in step (c) pressure is increased in the associated inflation chamber by pumping air from the associated storage chamber.

32. The method of claim 28, wherein:

in step (a) the storage chamber and the inflation chamber of each wheel and tire assembly define a closed air storage system; and

further comprising:

selectively performing steps of:

increasing operating pressure in a selected one of the inflation chambers without adding air to the associated closed air storage system; and

decreasing operating pressure in the selected one of the inflation chambers without discharging air from the associated closed air storage system.

33. The method of claim 28, wherein:
step (c) is performed by an automatic controller in response to an operator input.

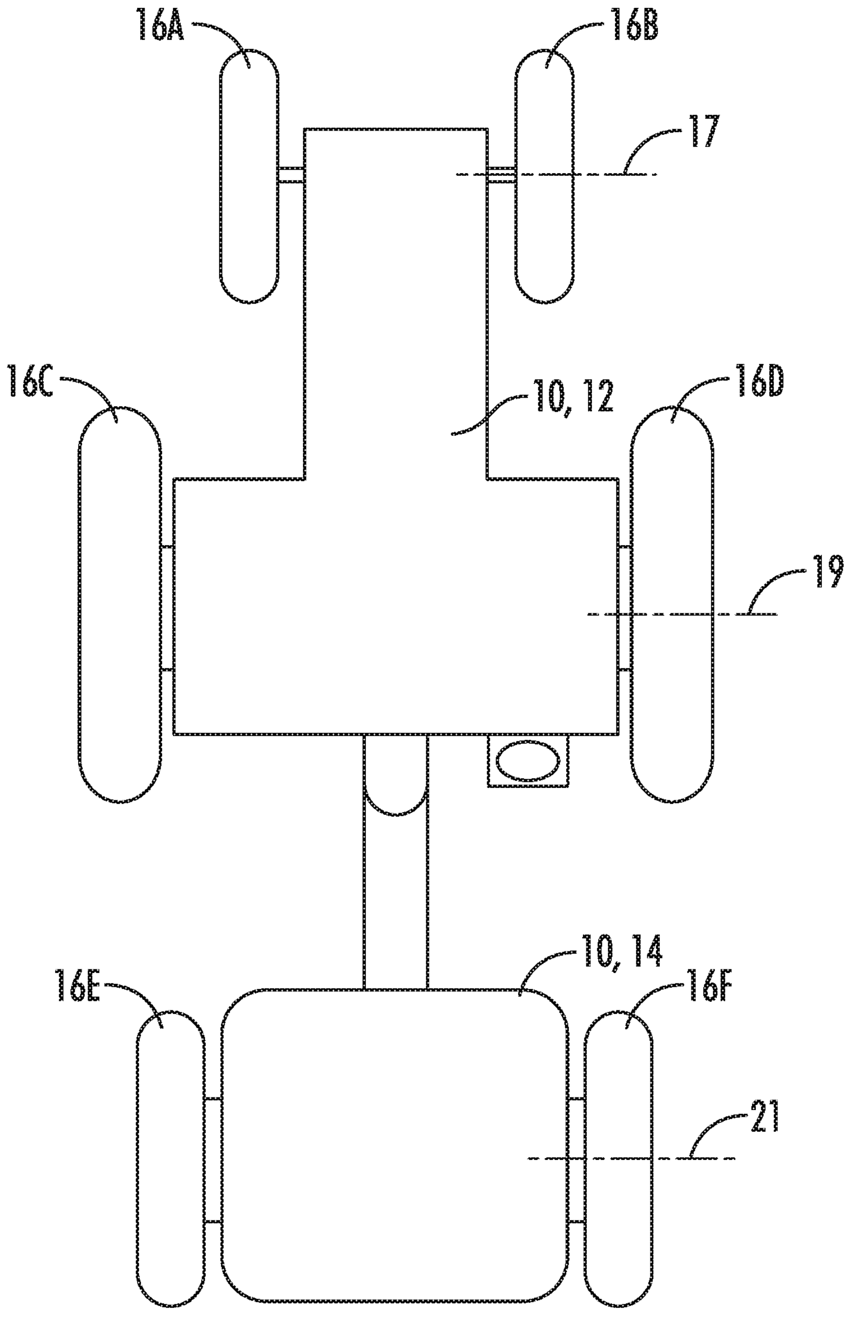


FIG. 1

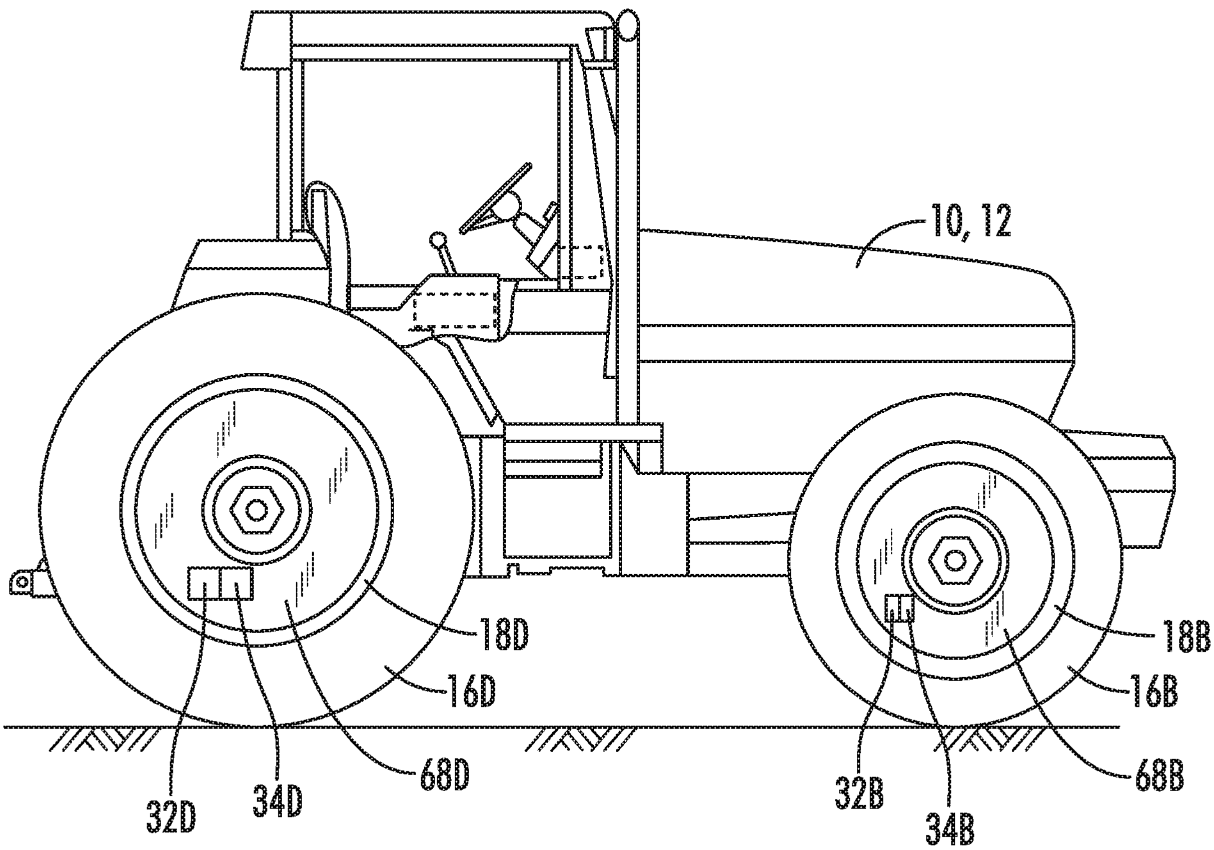
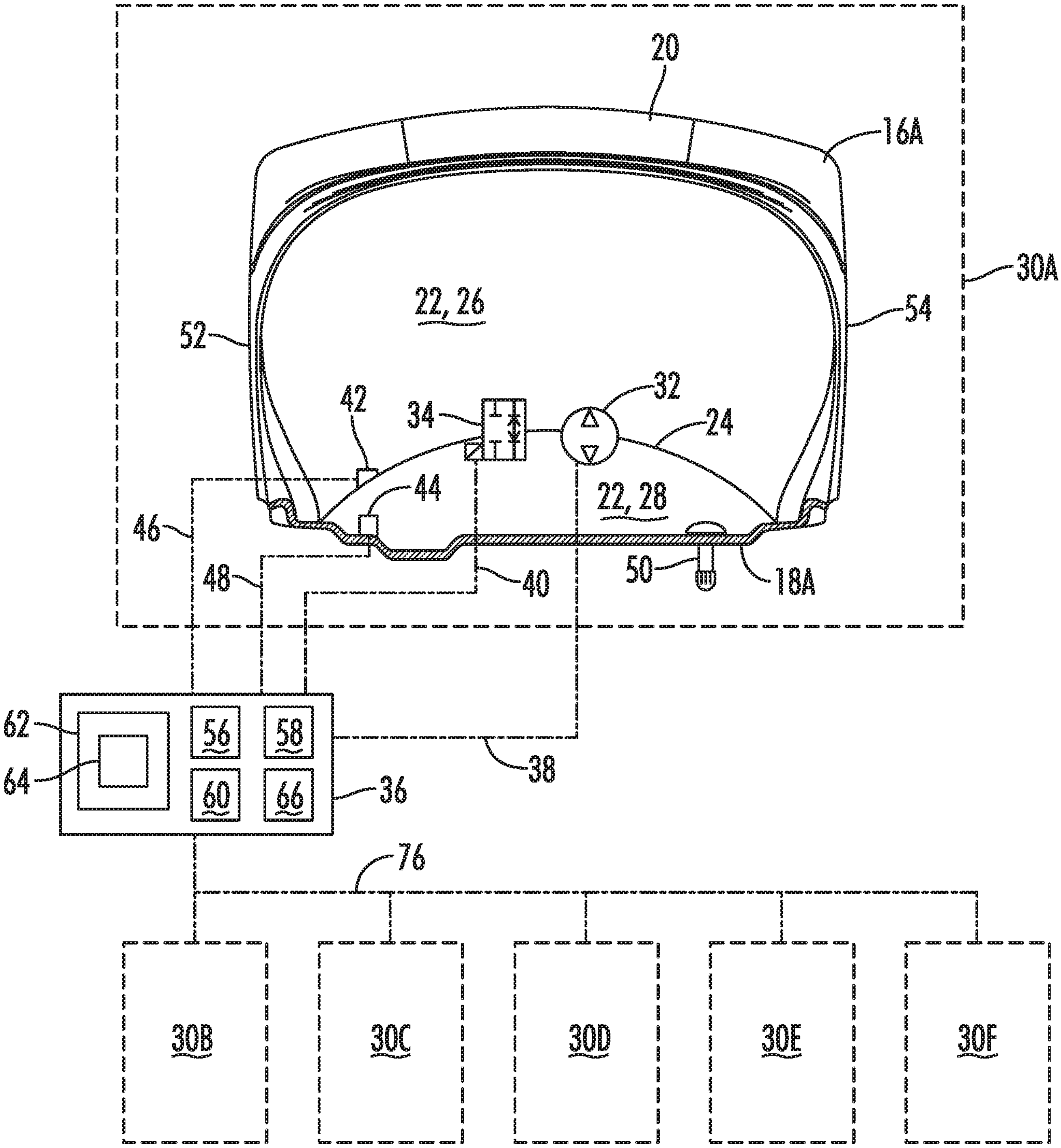


FIG. 2


20
16A
30A
22, 26
52
54
42
34
32
24
44
22, 28
46
48
40
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18A
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56
58
64
60
66
36
38
76
30B
30C
30D
30E
30F

FIG. 3

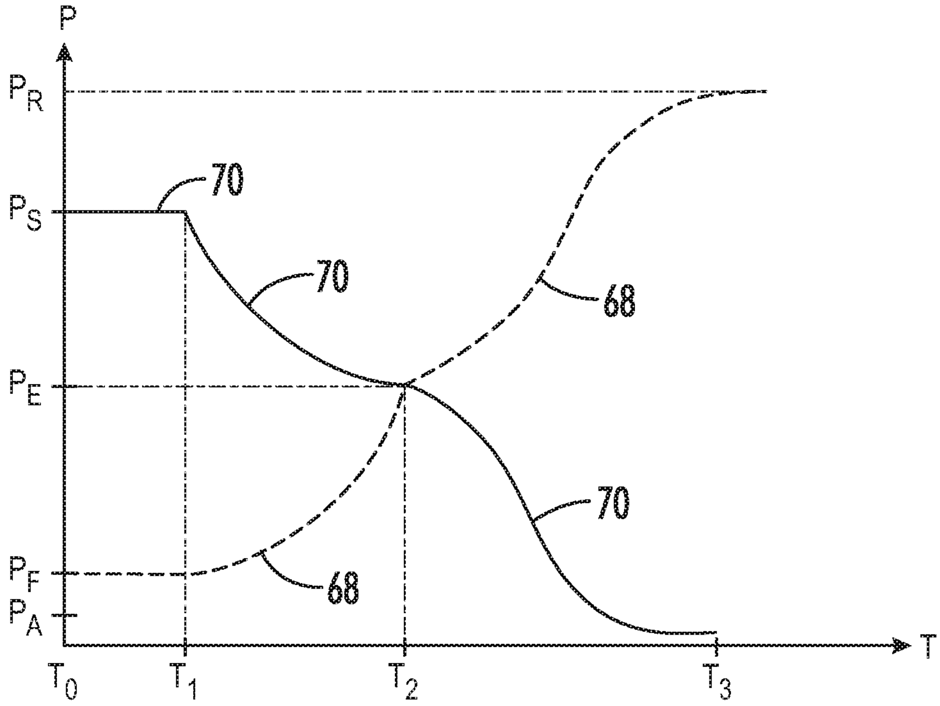

FIG. 4A

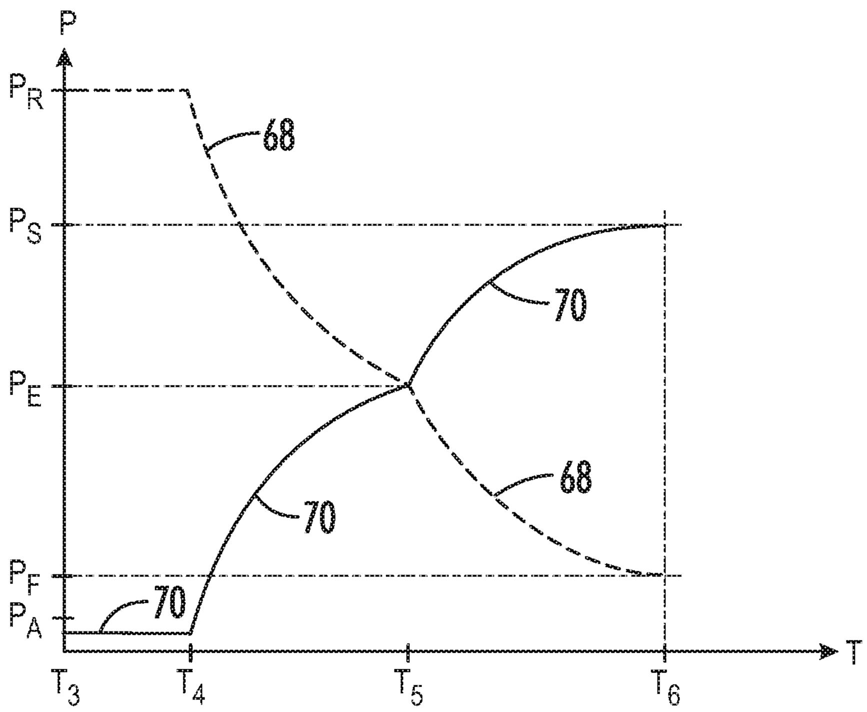

FIG. 4B

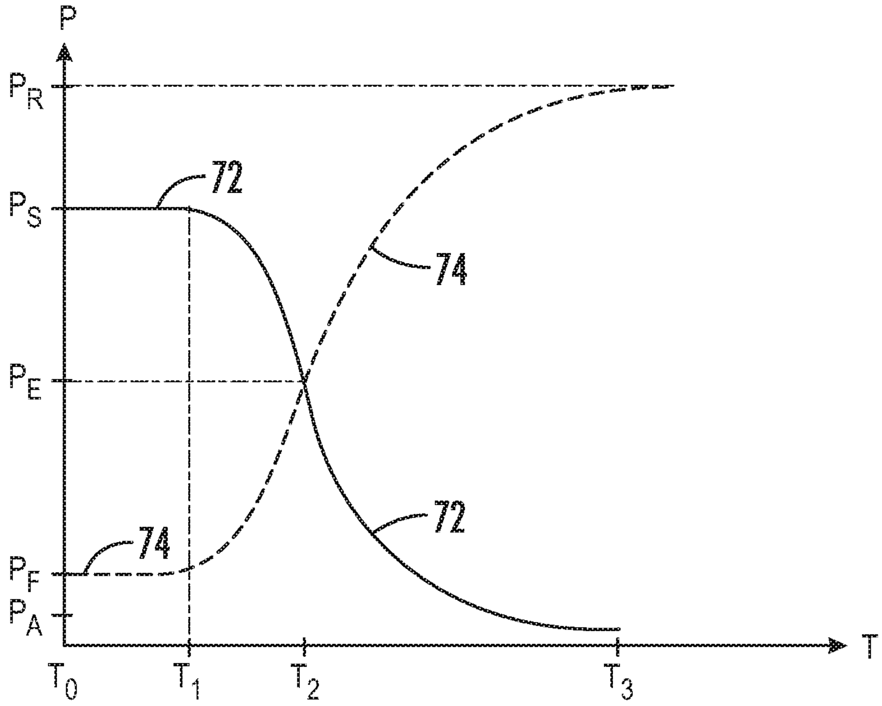

FIG. 5A

FIG. 4

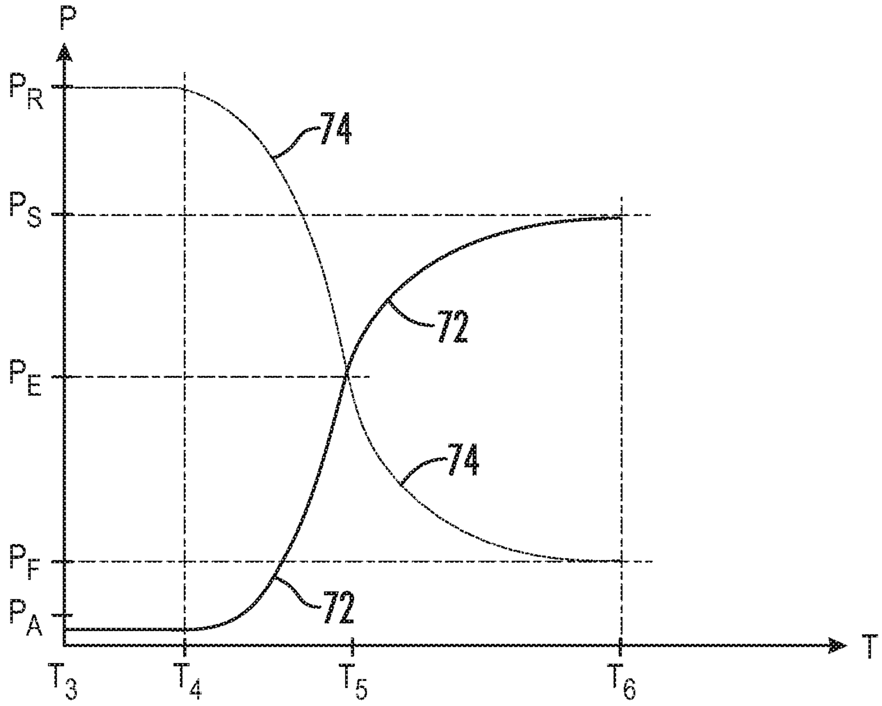

FIG. 5B

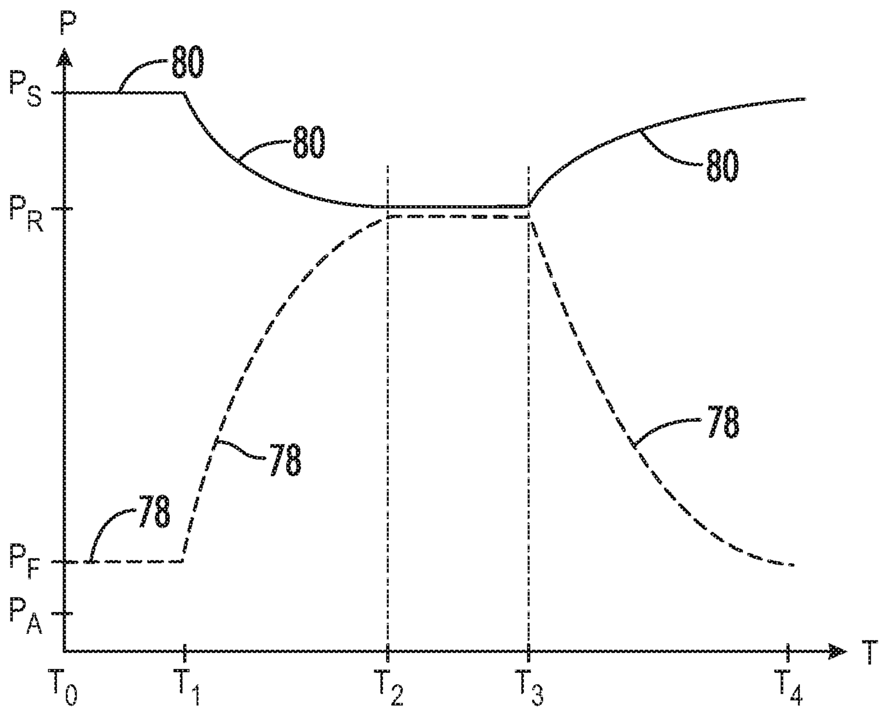

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/065143

A. CLASSIFICATION OF SUBJECT MATTER

B60S 5/04(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B60S 5/04; B60C 5/24; B60C 23/10; B60C 23/02; B60C 5/20; B60C 23/04

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & keywords: tire, wheel, compressor, inflation chamber, control, and pressure

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4570691 A (MARTUS, DONALD G.) 18 February 1986 See abstract, column 1, line 12 - column 4, line 25, column 7, lines 47-53, and figures 1, 4.	1-3,8-17,21-25,28,31,33
Y		5-6,19-20,29-30
A		4,7,18,26-27,32
Y	KR 10-2002-0088465 A (CHA, DONG MYUNG) 29 November 2002 See page 3, lines 44-57, claims 1-4, and figure 6.	5-6,19-20,29-30
A	US 2011-0272074 A1 (LOWERY, KENNETH ARLEN) 10 November 2011 See claim 1 and figures 2-3.	1-33
A	US 6857311 B2 (GONZAGA, TULLIO) 22 February 2005 See abstact and column 2, line 26 - column 3, line 20.	1-33
A	US 7784513 B2 (LOEWE, RICHARD THOMAS) 31 August 2010 See column 6, line 20 - column 8, line 37 and figures 1-7.	1-33

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
24 March 2017 (24.03.2017)	**24 March 2017 (24.03.2017)**

Name and mailing address of the ISA/KR
International Application Division
Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea
Facsimile No. +82-42-481-8578

Authorized officer
LEE, Chang Ho
Telephone No. +82-42-481-8288

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2016/065143

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