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[Continued on next page]

(54) **Title:** AUXILIARY AXLE AND SUSPENSION ASSEMBLY

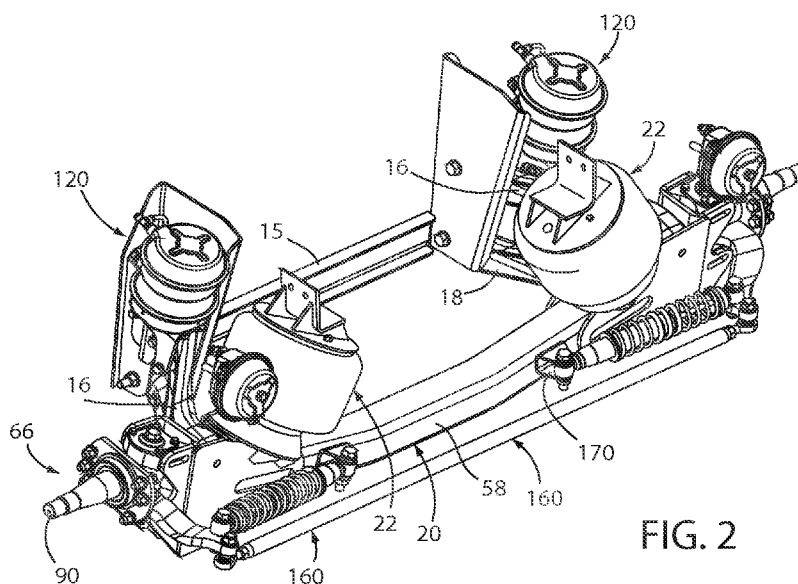


FIG. 2

(57) **Abstract:** A vehicle suspension assembly includes first and second mounting brackets each adapted to couple to a vehicle frame assembly, first and second trailing arms each having a first end pivotably coupled to the mounting brackets, and a second end located outboard of the first end of the associated trailing arm; an axle member having a first end and a second end; an integrated first mounting arrangement and an integrated second mounting arrangement coupled to the associated ends of the axle member, wherein the mounting arrangements pivotably couple the second end of the associated trailing arm to one of the ends of the axle member, and wherein the mounting arrangements couple one of the ends of the axle member to the spindle assembly.



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AUXILIARY AXLE AND SUSPENSION ASSEMBLY

BACKGROUND OF THE INVENTION

[0001] The present invention relates to heavy duty vehicle suspensions and assemblies, and particularly to suspension assemblies incorporating a trailing arm-type configuration. More particularly, the present invention relates to an auxiliary vehicle suspension assembly adapted for movement between an in-use position and a storage position, and incorporating a self-steer assembly.

BRIEF SUMMARY OF THE INVENTION

[0002] One aspect of the present invention is to provide a vehicle suspension assembly comprising a first mounting bracket adapted to couple to a vehicle frame assembly, a first trailing arm having a first end pivotably coupled to the first mounting bracket, and a second end, wherein the second end of the trailing arm is located outboard of the first end of the trailing arm, a second mounting bracket adapted to couple to the vehicle frame assembly, and a second trailing arm having a first end pivotably coupled to the second mounting bracket, and a second end, wherein the second end of the trailing arm is located outboard of the first end of the second trailing arm. The vehicle suspension assembly further comprises an axle member having a first end and a second end, an integrated first mounting arrangement coupled to the first end of the axle member, wherein the first mounting arrangement pivotably couples the second end of the first trailing arm to the first end of the axle member, and wherein the first mounting arrangement couples the first end of the axle member to the first spindle assembly, and an integrated second mounting arrangement coupled to the first end of the axle member, wherein the second mounting arrangement pivotably couples the second end of the second arm to the second end of the axle member, and wherein the second mounting arrangement couples the second end of the axle member to the second spindle assembly.

[0003] Another aspect of the present invention is to provide a vehicle suspension assembly that comprises an axle member having a first end and a second end, a first mounting bracket adapted to couple to a vehicle frame assembly, a first trailing arm

having a first end pivotably coupled the first mounting bracket, and a second end pivotably coupled to the axle member, a second mounting bracket adapted to couple to the vehicle frame assembly, and a second trailing arm having a first end pivotably coupled to the second mounting bracket, and a second end pivotably coupled to the axle member. The vehicle suspension assembly further comprises an integrated first mounting arrangement coupled to the first end of the axle member, wherein the first mounting arrangement couples the first end of the axle member to the first spindle assembly, and wherein the first mounting arrangement couples the first air spring to the first end of the axle member such that the first axle spring is adapted to extend between the first end of the axle member and the vehicle frame assembly, and an integrated second mounting arrangement coupled to the second end of the axle member, wherein the second mounting arrangement couples the second end of the axle member to the second spindle assembly, and wherein the second mounting arrangement couples a second air spring to the second end of the axle member such that the second air spring is adapted to extend between the second end of the axle member and the vehicle frame assembly.

[0004] Still another aspect of the present invention is to provide a vehicle suspension assembly that comprises an axle member having a first end and a second end, the axle member movable between a first position, wherein at least one tire coupled with the axle member contacts a ground surface, and a second position, wherein the at least one tire is spaced from the ground surface, a first mounting bracket adapted to couple to a vehicle frame assembly, a first trailing arm having a first end pivotably coupled to the first mounting bracket, and a second end pivotably coupled to the first end of the axle member, a second mounting bracket adapted to couple to a vehicle frame assembly, and a single trailing arm having a first end pivotably coupled to the second mounting bracket, and a second end pivotably coupled to the second end of the axle member. The vehicle suspension assembly further comprises a first lift arrangement comprising a first diaphragm chamber having a first push plate and a flexible bladder, the first push plate of the first diaphragm chamber dividing the first diaphragm chamber into a first compartment and a second compartment, the first compartment of the first diaphragm chamber being adjustably pressurized to move the first push plate of the first diaphragm

chamber, a second diaphragm chamber having a second push plate including a flexible bladder, the second push plate of the second diaphragm chamber dividing the second diaphragm chamber into a first compartment and a second compartment, the first compartment of the second diaphragm chamber being adjustably pressurized to move the second push plate of the second diaphragm chamber, and at least one push rod defining a single longitudinal axis and connected to the first push plate and the second push plate such that pressurization of the first and second diaphragm chambers cause a translational movement of the at least one push rod, wherein the at least one push rod is operably coupled with the vehicle suspension assembly such that translational movement of the at least one push rod causes the axle chamber to move between the first and second positions.

[0005] Still yet another aspect of the present invention is to provide a method of assembling a vehicle suspension assembly comprising providing an axle assembly having a first end including a first mounting structure and a second mounting end, providing a first bearing block and a second bearing block, forming a first aperture in the first bearing block and a second aperture in the second bearing block, attaching the first and second bearing blocks to the first mounting structure subsequent to forming the first and second apertures, and providing a first spindle assembly coupled to the first mounting structure by a first spherical bearing located within the first aperture and a second spherical bearing located within the second aperture, wherein a first kingpin assembly extends through the first and second spherical bearings, thereby coupling the first spindle with the first mounting structure.

[0006] Another aspect of the present invention is to provide a vehicle suspension assembly comprising an axle assembly having a first end and a second end, a first mounting bracket and a second mounting bracket each adapted to couple to a vehicle frame assembly, and a first trailing arm having a first end operably coupled to the first mounting bracket and a second end pivotably coupled to the first end of the axle assembly. The vehicle suspension assembly further comprises a second mounting bracket adapted to couple to a vehicle frame assembly, and a second trailing arm having a first end pivotably coupled to the second mounting bracket, and a second end pivotably coupled to the second end of the axle assembly. The vehicle suspension

assembly still further comprises a first air spring assembly coupled to a first end of the axle assembly such that the longitudinal axis of the first air spring assembly inclines inwardly from the first end of the axle assembly, and a second air spring assembly coupled to the second end of the axle assembly such that a longitudinal axis of the second air spring assembly inclines inwardly from the second end of the axle assembly, wherein a natural frequency of the suspension assembly is less than or equal to about 3Hz.

[0007] The present inventive vehicle suspension assembly provides a durable, uncomplicated design that can be easily and quickly assembled, while simultaneously reducing manufacturing costs. The invention is efficient in use, economical to manufacture, capable of a long operating life, and is particularly well adapted to the proposed use.

[0008] These and other advantages of the present invention will be further understood and appreciated by those skilled in the art by reference to the following written specification, claims, and appended drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Fig. 1 is a perspective view of a vehicle suspension assembly embodying the present invention;

[0010] Fig. 2 is a perspective view of the vehicle suspension assembly with wheel and hub assemblies removed;

[0011] Fig. 3A is a side elevational view of the vehicle suspension assembly in a lowered, in-use position;

[0012] Fig. 3B is a side elevational view of the vehicle suspension assembly in a raised, storage position;

[0013] Fig. 4A is a top plan view of the vehicle suspension assembly in an inline orientation;

[0014] Fig. 4B is a top plan view of the vehicle suspension assembly in a turning orientation;

[0015] Fig. 5 is a side elevational view of the suspension assembly;

[0016] Fig. 6 is a top plan view of a trailing arm;

- [0017] Fig. 7 is an exploded perspective view of a trailing arm assembly;
- [0018] Fig. 8 is an exploded perspective view of mounting arrangement and associated connections;
- [0019] Fig. 9A is a perspective rear view of the mounting arrangement;
- [0020] Fig. 9B is a perspective front view of the mounting arrangement;
- [0021] Fig. 10 is an exploded perspective view of a spindle assembly, wherein the components of the spindle assembly are shown in dashed in an exploded state and in solid in an assembled state;
- [0022] Fig. 11 is an exploded perspective view of bearing blocks and a portion of the mounting arrangement, wherein the bearing blocks are shown in dashed in the exploded state and in solid in an assembled state;
- [0023] Fig. 12A is a cross-sectional view of the spindle assembly and a portion of the mounting arrangement;
- [0024] Fig. 12B is a cross-sectional view of the vehicle suspension assembly;
- [0025] Fig. 13 is an exploded perspective view of an air spring assembly;
- [0026] Fig. 14 is a rear elevational view of the suspension assembly;
- [0027] Fig. 15A is a perspective view of a lift arrangement;
- [0028] Fig. 15B is an exploded perspective view of the lift arrangement; and
- [0029] Fig. 16 is a cross-section view of a dual diaphragm actuator, taken along the line XVI – XVI, Fig. 15.

DETAILED DESCRIPTION OF EMBODIMENTS

- [0030] For purposes of description herein, the terms “upper,” “lower,” “right,” “left,” “rear,” “front,” “vertical,” “horizontal,” and derivatives thereof shall relate to the invention as oriented in FIG. 1. However, it is to be understood that the invention may assume various alternative orientations, except where expressly specified to the contrary. It is also to be understood that the specific devices and processes illustrated in the attached drawings, and described in the following specification are simply exemplary embodiments of the inventive concepts defined in the appended claims. Hence, specific

dimensions and other characteristics relating to the embodiments disclosed herein are not to be considered as limiting, unless the claims expressly state otherwise.

[0031] A suspension assembly 10 (Figs. 1 and 2) comprises a pair of mounting brackets 12 fixedly connected to a pair of longitudinally extending frame members 14 of a vehicle frame assembly and coupled to one another by a cross member 15, a plurality of trailing arm assemblies including a pair of upper trailing arms 16 (Figs. 3A – 4B) and a pair of lower trailing arms 18, an axle assembly 20, and a pair of air spring assemblies 22 extending between the axle assembly 20 and corresponding frame members 14.

[0032] In the illustrated example, each upper trailing arm 16 (Fig. 5) includes a first end 24 pivotably coupled to one of the mounting brackets 12 for rotation about a pivot point 26 and a second end 28 pivotably coupled to the axle assembly 20 for rotation about a pivot point 30, as described below. Each lower trailing arm 18 includes a first end 32 pivotably secured to a mounting bracket 12 for pivoting about a pivot point 34, and a second end 36 pivotably coupled to the axle assembly 20 for pivotable movement around a pivot point 38, also as described below. Figs. 4A and 6 illustrate the generally outward-sweeping shape of the trailing arms 16, 18 along the length of the trailing arms 16, 18 from the first end 24, 32 to the second end 28, 36. As best illustrated in Fig. 7, each end 24, 28, 32, 36 of the trailing arms 16, 18 are pivotably secured to the mounting brackets 12 and axle assembly 20 by a bushing assembly 40 comprising a elastically resilient bushing member 42, a bushing pin 44 and nylon washers 46 received within a corresponding bore 48.

[0033] As best illustrated in Fig. 8, the second end 28, 36 of each trailing arm 16, 18 are pivotably coupled to an integrated corresponding mounting arrangement 50. Each mounting arrangement 50 (Figs. 9A and 9B) includes a triangularly-shaped rear plate 52, an L-shaped front plate 54 that cooperates with the rear plate 52 to form an inwardly-opening pocket 56 within which an end 57 of an axle member 58 of the axle assembly 20 is received. The rear plate 52 and the front plate 54 each include a welding aperture 60 about which a weld is formed to secure the end 57 of the axle 58 within the pocket 56. Each mounting arrangement 50 further includes a C-shaped spindle attachment plate 62 that is attached to the rear plate 52, and which cooperates with the rear plate 52 and the front plate 54 to form a pocket 64 within which the second ends 28, 36 of the

trailing arms 16, 18 are pivotably secured. As utilized herein, the term “integrated” means that the components of the mounting arrangement 50, including the rear plate 52, the front plate 54 and the spindle attachment plate 62 are brought together with one another such that the components form a single unit and are not spaced from one another. In the illustrated example, the rear plate 52, the front plate 54 and the spindle attachment 62 are welded to one another, however these components may also be formed as a single integral piece, or coupled together with various mechanical fasteners. Spindle assemblies 66 (Figs. 2 and 10-12A) are pivotably secured to the corresponding mounting arrangement 50 of the axle assembly 20 by a pair of bearing assemblies 68 each including a bearing block 70 having a bearing bore 72 that receives a corresponding bearing 74, each bearing 74 including a race 76 and a spherical bearing member 78. The spindle attachment plate 62 includes a plurality of elongated welding apertures 80 about which a weld is received to weld the bearing blocks 70 to the spindle attachment plate 62 of the mounting arrangement 50. It is noted that the bearing bore 72 of each of the bearing blocks 70 is machined prior to attaching the bearing block 70 to the mounting arrangement 50. A kingpin assembly 82 including an elongated kingpin collar 84 and a kingpin 86 extends through the bearings 74 and an aperture 88 of the spindle 90, thereby pivotably securing the spindle 90 to the axle assembly 20. Specifically, tightening of the kingpin 86 creates a load path extending through the kingpin collar 84, each of the spherical bearing members 78, an end of the spindle 90, and a collar member 92. Over-tightening of the kingpin 86 is prevented by a washer member 94 positioned between the lower of the spherical bearing members 78 and the spindle 90. It is noted that the lower of the bearing blocks 70 includes a collar portion 96 that abuts the race 76 of the corresponding bearing 74, thereby providing proper spacing and assisting during assembly. Specifically, the collar portion or lip 96 provides a stop for the bearing to be pressed to during assembly, thereby defining the vertical positioning for the entire spindle assembly. Further, the lip 96 is adapted to support the vertical load should the press-fit of the bearing fail. A pair of retainer plates 98 are secured to the corresponding bearing blocks 70 by a plurality of bolts 100. The hub assemblies 102, braking assemblies 103 and tires 104 are coupled to the associated spindle 90.

[0034] Each mounting arrangement 50 (Figs. 9A and 9B) includes forwardly and rearwardly extending air spring mounting brackets 108 to which the corresponding air spring assembly 22 (Fig. 5) is coupled. In the illustrated example, the air spring mounting brackets 108 are integrated with the rest of the associated mounting arrangement, including the rear plate 52, the front plate 54 and the spindle attachment bracket 62. As best illustrated in Fig. 13, each air spring assembly 22 includes a rolling lobe-style air spring 110 including an air bladder 112, an internal lobe member 114 and a top plate 116. A mounting plate 118 is secured to the lobe member 114 via a plurality of mechanical fasteners 120, with the mounting plate 118 being secured to the air spring mounting brackets 108 by a plurality of mechanical fasteners such as bolts 122. The top plate 116 is secured to an upper mounting plate 124 by a plurality of mechanical fasteners 126. The upper mounting plate 124 is attached to a corresponding vehicle frame rail 14. As best illustrated in Fig. 14, the mounting arrangements 50 are located and configured such that the air spring assemblies 22 are inwardly inclined from the mounting assemblies 50 towards the vehicle frame rails 14 at an angle α , thereby resulting in a lower spring rate and reducing the interaction between the suspension and chassis and improving the control in a vehicle jounce event. Further, the incline of the spring assemblies 22 reduces the overall travel thereof, thereby allow use of rolling-lobe type air springs and reducing the overall cost. Preferably, angle α is between 30° and 45° from vertical, and more preferably between 30° and 35° from vertical, thereby resulting in a natural frequency for the vertical displacement or vibrations of the suspension assembly of less than or equal to about 3Hz, and more preferably of between about 1Hz and 2Hz.

[0035] The outwardly-sweeping configuration of the trailing arms 16, 18 (Fig. 12B) in conjunction with the configuration and construction of the mounting arrangements 50, provides for attachment of the trailing arms 16, 18, the spindles 90, and the air spring assemblies 22 in close proximity to one another and in close proximity to the ends of the axle member 20. Preferably, the distance X between the center point of the connection of the trailing arms 16, 18 with the mounting arrangement 50 and the center point of the connection of the spindle 90 with the mounting arrangement 50 is less than or equal to about 6 inches, the distance Y between the center point of the connection between

the spindle 90 with the mounting arrangement 50 and the center point of the connection between the air spring assembly 22 with the mounting arrangement 50 is less than or equal to about 14 inches, and the total length Z of the mounting arrangement 50 is less than or equal to about 20 inches.

[0036] As best illustrated in Figs. 3A and 3B, the vehicle suspension assembly 10 is vertically adjustable. Specifically, the axle assembly 20 is movable from a lowered position A, wherein the tires 104 contact a ground surface, thereby assisting and supporting the load of the vehicle, and a raised position B, wherein the tires 104 are spaced from the ground surface, thereby reducing tire wear and fuel consumption. The vehicle suspension assembly 10 includes a pair of lift arrangements 120 operably coupled with the associated upper trailing arms 16 and mounting brackets 12. Each lift arrangement 120 includes a dual diaphragm chamber assembly 122 (Figs. 15A–Fig. 16) including first diaphragm chamber 124 and a second diaphragm chamber 126. Each diaphragm chamber 124, 126 includes a housing 128 divided into an upper chamber 130 and a lower chamber 132 by a deformable diaphragm 134 and a push plate 136, wherein the upper chamber 130 may be pressurized via an air inlet 138. Each push plate 136 is secured to a push rod 140 such that the push rods 140 are each forced in a direction 142 as the upper chamber 138 is pressurized. It is noted that in the illustrated example, the longitudinal axis 146 of each of the push rods 140 are aligned with one another. It is further noted that the dual push rods 140 may be replaced by a single push rod that extends through both the first diaphragm chamber 124 and the second diaphragm chamber 126. The diaphragm chamber assembly 122 is attached to a corresponding upper trailing arm 16 by a lift bracket 148, while the push rod 140 associated with the second diaphragm chamber 126 is pivotably coupled to an associated mounting bracket 12 by a push rod plate 150 that is fixedly coupled to the mounting bracket 12, and a clevis arrangement 152 that is attached to the end of the push rod 140 of the second diaphragm chamber 126 and pivotably coupled to the push rod plate 150. It is noted that the configuration of the diaphragm chamber assembly 122 results in a beveling of the force exerted on the associated push rods 150 while maintaining a reduced overall plan area required to house or position the diaphragm chamber assembly 122 within the overall vehicle suspension assembly 10.

[0037] The vehicle suspension assembly 10 further comprises a self-steer assembly which pivots the spindles 90 and the tires 104 between an inline orientation C, as illustrated in Fig. 4A, and a turning orientation B, as illustrated in Fig. 4B. In the illustrated example, the steering assembly 160 includes a tie rod 162 pivotably coupled to spindle arms 164 (Fig. 14) associated with each spindle 90. The steering assembly 160 further includes a pair of damper assemblies 166 pivotably secured to the spindle arms 164 and the axle 58 via a pair of mounting brackets 170 (Fig. 2).

[0038] In the foregoing description it will be readily appreciated by those skilled in the art that modifications may be made to the invention without departing from the concepts as disclosed herein. Such modifications are to be considered as included in the following claims, unless these claims by their express language state otherwise.

The invention claimed is:

1. A vehicle suspension assembly, comprising:
 - a first mounting bracket adapted to couple to a vehicle frame assembly;
 - a first trailing arm having a first end pivotably coupled to the first mounting bracket, and a second end, wherein the second end of the first trailing arm is located outboard of the first end of the first trailing arm;
 - a second mounting bracket adapted to couple to the vehicle frame assembly;
 - a second trailing arm having a first end pivotably coupled to the second mounting bracket, and a second end, wherein the second end of the second trailing arm is located outboard of the first end of the second trailing arm;
 - an axle member having a first end and a second end;
 - an integrated first mounting arrangement coupled to the first end of the axle member, wherein the first mounting arrangement pivotably couples the second end of the first trailing arm to the first end of the axle member, and wherein the first mounting arrangement couples the first end of the axle member to the a first spindle assembly;
 - and
 - an integrated second mounting arrangement coupled to the second end of the axle member, wherein the second mounting arrangement pivotably couples the second end of the second trailing arm to the second end of the axle member, and wherein the second mounting arrangement couples the second end of the axle member to the a second spindle assembly.
2. The vehicle suspension assembly of claim 1, wherein the first mounting arrangement couples a first air spring assembly to the first end of the axle member, the first air spring assembly adapted to extend between the first end of the axle member and the vehicle frame assembly, and wherein the second mounting arrangement couples a second air spring assembly to the second end of the axle member, the second air spring assembly adapted to extend between the second end of the axle member and the vehicle frame assembly.

3. The vehicle suspension assembly of either one of claims 1 and 2, wherein the first mounting arrangement couples the second end of the first trailing arm to the first end of the axle member at a first location, the first end of the trailing arm to the first spindle at a second location, and the first end of the axle to the first air spring at a third location, and wherein a maximum distance between any one of the first location, the second location and the third location is less than or equal to about 14 inches.
4. The vehicle suspension assembly of any one of the preceding claims, wherein the first mounting arrangement has a total length of less than or equal to about 20 inches.
5. The vehicle suspension assembly of either one of claims 1 and 2, wherein the first mounting arrangement couples the second end of the first trailing arm to the first end of the axle member at a first location, the first end of the trailing arm to the first spindle at a second location, and the first end of the axle to the first air spring at a third location, and wherein the first location is located outboard of third location.
6. The vehicle suspension assembly of either one of claims 1 and 2, wherein the first mounting arrangement couples the first air spring assembly to the first end of the axle member such that a longitudinal axis of the first air spring assembly is inwardly angled from the first mounting arrangement.
7. The vehicle suspension assembly of any one of the preceding claims, wherein the first mounting arrangement couples the second end of the first trailing arm to the first end of the axle member at a first location, and couples the first end of the trailing arm to the first spindle at a second location, and wherein a distance between the first location and the second location is less than or equal to about 6 inches.
8. The vehicle suspension assembly of any one of the preceding claims, wherein the first mounting arrangement includes a recess that receives a first bushing assembly therein, and wherein the first bushing assembly pivotably couples the second end of the first trailing arm to the axle member.

9. The vehicle suspension assembly of any one of claims 1-7, wherein the first mounting arrangement includes a recess that receives a first bearing assembly therein, and wherein the first bearing assembly couples the first spindle to the first end of the axle member.
10. The vehicle suspension assembly of any one of the preceding claims, wherein the first bearing assembly extends at least partial vertically above the first end of the axle member.
11. The vehicle suspension assembly of any one of the preceding claims, further comprising:
- a third trailing arm having a first end pivotably coupled to the first mounting bracket, and a second end located outboard of the first end of the third trailing beam, wherein the second end of the third trailing beam is pivotably coupled to the first end of the axle member by the first mounting arrangement; and
 - a fourth trailing arm having a first end pivotably coupled to the second mounting bracket, and a second end located outboard of the first end of the fourth trailing beam, wherein the second end of the fourth trailing beam is pivotably coupled to the second end of the axle member by the second mounting arrangement.
12. The vehicle suspension assembly of any one of the preceding claims, further comprising:
- a lift arrangement operably coupled with at least one of the first trailing arm and the second trailing arm, and adapted to move the axle between a first vertical position, wherein a tire coupled to one of the ends of the axle member contacts a ground surface, and a second vertical position, wherein the tire is spaced from the ground surface.
13. The vehicle suspension assembly of any one of the preceding claims, further comprising:
- a steering arrangement operably coupled with at least a select one of the first and second spindle assemblies, and adapted to move a tire coupled to one of the spindle

assemblies between a first position defining a first direction of travel, and a second position defining a second direction of travel that is different than the first direction of travel.

14. The vehicle suspension assembly of any one of the preceding claims, wherein the integrated first mounting arrangement comprises a plurality of individual components welded to one another.

15. A vehicle suspension assembly, comprising:

- an axle member having a first end and a second end;

- a first mounting bracket adapted to couple to a vehicle frame assembly;

- a first trailing arm having a first end pivotably coupled to the first mounting bracket, and a second end pivotably coupled to the axle member;

- a second mounting bracket adapted to couple to the vehicle frame assembly;

- a second trailing arm having a first end pivotably coupled to the second mounting bracket, and a second end pivotably coupled to the axle member;

- an integrated first mounting arrangement coupled to the first end of the axle member, wherein the first mounting arrangement couples the first end of the axle member to the a first spindle assembly, and wherein the first mounting arrangement couples a first air spring to the first end of the axle member such that the first air spring is adapted to extend between the first end of the axle member and the vehicle frame assembly; and

- an integrated second mounting arrangement coupled to the second end of the axle member, wherein the second mounting arrangement couples the second end of the axle member to the a second spindle assembly, and wherein the second mounting arrangement couples a second air spring to the second end of the axle member such that the second air spring is adapted to extend between the second end of the axle member and the vehicle frame assembly.

16. A vehicle suspension assembly of claim 15, wherein the second end of the first trailing beam is located outboard of the first end of the first trailing beam, and wherein

the second end of the second trailing beam is located outboard of the first end of the second trailing beam.

17. The vehicle suspension assembly of either one of claims 15 and 16, wherein the first mounting arrangement couples the second end of the first trailing arm to the first end of the axle member at a first location, the first end of the trailing arm to the first spindle at a second location, and the first end of the axle to the first air spring at a third location, and wherein a maximum distance between any one of the first location, the second location and the third location is less than or equal to about 14 inches.

18. The vehicle suspension assembly of either one of claims 15 and 16, wherein the first mounting arrangement couples the second end of the first trailing arm to the first end of the axle member at a first location, the first end of the trailing arm to the first spindle at a second location, and the first end of the axle to the first air spring at a third location, and wherein the first location is located outboard of third location.

19. The vehicle suspension assembly of any one of claims 15-18, wherein the first mounting arrangement couples the first air spring assembly to the first end of the axle member such that a longitudinal axis of the first air spring assembly is inwardly angled from the first mounting arrangement.

20. The vehicle suspension assembly of either one of claims 15 and 16, wherein the first mounting arrangement couples the first air spring assembly to the first end of the axle member at a first location, and couples the first end of the trailing arm to the first spindle at a second location, and wherein a distance between the first location and the second location is less than or equal to about 14 inches.

21. The vehicle suspension assembly of any one of claims 15-20, wherein the first mounting arrangement has a length of less than or equal to about 20 inches.

22. The vehicle suspension assembly of any one of claims 15-21, wherein the first mounting arrangement includes a recess that receives a first bearing assembly therein, and wherein the first bearing assembly couples the first spindle to the first end of the axle member.
23. The vehicle suspension assembly of claim 22, wherein the first bearing assembly extends at least partial vertically above the first end of the axle member.
24. The vehicle suspension assembly of any one of claims 15-23, further comprising:
a third trailing arm having a first end pivotably coupled to the first mounting bracket, and a second end pivotably coupled to the axle member; and
a fourth trailing arm having a first end pivotably coupled to the second mounting bracket, and a second end pivotably coupled to the axle member.
25. The vehicle suspension assembly of claim 24, wherein the second end of the third trailing arm is located outboard of the first end of the third trailing arm, and wherein the second trailing end of the fourth trailing arm is located outboard of the first end of the fourth trailing arm.
26. The vehicle suspension assembly of anyone of claims 15-25, further comprising:
a lift arrangement operably coupled with at least one of the first trailing arm and the second trailing arm, and adapted to move the axle member between a first vertical position, wherein a tire coupled to one of the ends of the axle member contacts a ground surface, and a second vertical position, wherein the tire is spaced from the ground surface.
27. The vehicle suspension assembly of any one of claims 15-26, further comprising:
a steering arrangement operably coupled with at least a select one of the first and second spindle assemblies, and adapted to move a tire coupled to one of the spindle assemblies between a first position defining a first direction of travel, and a second

position defining a second direction of travel that is different than the first direction of travel.

28. The vehicle suspension assembly of any one of claims 15-27, wherein the integrated first mounting arrangement comprises a plurality of individual components welded to one another.

29. A vehicle suspension assembly, comprising:

- an axle member having a first end and a second end, the axle member movable between a first position, wherein at least one tire coupled with the axle member contacts a ground surface, and a second position, wherein the at least one tire is spaced from the ground surface;

- a first mounting bracket adapted to couple to a vehicle frame assembly;

- a first trailing arm having a first end pivotably coupled to the first mounting bracket, and a second end pivotably coupled to the first end of the axle member;

- a second mounting bracket adapted to couple to a vehicle frame assembly;

- a second trailing arm having a first end pivotably coupled to the second mounting bracket, and a second end pivotably coupled to the second end of the axle member;

- a first lift arrangement, comprising:

- a first diaphragm chamber having a first push plate and a flexible bladder, the first push plate of the first diaphragm chamber dividing the first diaphragm chamber into a first compartment and a second compartment, the first compartment of the first diaphragm chamber being adjustably pressurized to move the first push plate of the first diaphragm chamber;

- a second diaphragm chamber having a second push plate including a flexible bladder, the second push plate of the second diaphragm chamber dividing the second diaphragm chamber into a first compartment and a second compartment, the first compartment of the second diaphragm chamber being adjustably pressurized to move the second push plate of the second diaphragm chamber; and

at least one push rod defining a single longitudinal axis and connected to the first push plate and the second push plate such that pressurization of the first and second diaphragm chambers cause a translational movement of the at least one push rod, wherein the at least one push rod is operably coupled with the vehicle suspension assembly such that translational movement of the at least one push rod causes the axle member to move between the first and second positions.

30. The vehicle suspension assembly of claim 29, wherein the first lift arrangement is connected to an actuator bracket, and wherein the actuator bracket is pivotably coupled to the first trailing arm.

31. The vehicle suspension assembly of either one of claims 29 and 30, wherein the at least one push rod is pivotably coupled to a mounting bracket extension member that is fixedly couple to the first mounting bracket.

32. The vehicle suspension assembly of any one of claims 29-31, wherein the at least one push rod comprises a first push rod connected to the first push plate and a second push rod connected to the second push plate.

33. The vehicle suspension assembly of any one of claims 29-32, further comprising:
a second lift arrangement, comprising:

a first diaphragm chamber having a first push plate and a flexible bladder, the first push plate of the first diaphragm chamber of the second lift arrangement dividing the first diaphragm chamber of the second lift arrangement into a first compartment and a second compartment, the first compartment of the first diaphragm chamber of the second lift arrangement being adjustably pressurized to move the first push plate of the first diaphragm chamber of the second lift arrangement;
a second diaphragm chamber having a second push plate including a flexible bladder, the second push plate of the second diaphragm chamber

of the second lift arrangement dividing the second diaphragm chamber of the second lift arrangement into a first compartment and a second compartment, the first compartment of the second diaphragm chamber of the second lift arrangement being adjustably pressurized to move the second push plate of the second diaphragm chamber of the second lift arrangement; and
at least one push rod defining a single longitudinal axis connected to the first push plate and the second push plate of the second lift arrangement such that pressurization of the first and second diaphragm chambers cause a translational movement of the at least one push rod of the second lift arrangement, wherein the at least one push rod of the second lift arrangement is operably coupled with the vehicle suspension assembly such that translational movement of the at least one push rod of the second lift arrangement causes the axle member to move between the first and second positions.

34. The vehicle suspension system of claim 33, wherein the at least one push rod of the second lift arrangement comprises a first push rod connected to the first push plate of the second lift arrangement and a second push rod connected to the second push plate of the second lift arrangement.

35. The vehicle suspension assembly of any one of claims 29-34, further comprising:
a steering arrangement operably coupled with at least a select one of the first and second spindle assemblies, and adapted to move a tire coupled to one of the spindle assemblies between a first position defining a first direction of travel, and a second position defining a second direction of travel that is different than the first direction of travel.

36. A method of assembling a vehicle suspension assembly, comprising:
providing an axle assembly having a first end including a first mounting structure and a second end;

providing a first bearing block and a second bearing block;
forming a first aperture in the first bearing block and a second aperture in the second bearing block;
attaching the first and second bearing blocks to the first mounting structure subsequent to forming the first and second apertures; and
providing a first spindle assembly coupled to the first mounting structure by a first spherical bearing located within the first aperture and a second spherical bearing located within the second aperture, wherein a first kingpin assembly extends through the first and second spherical bearings, thereby coupling the first spindle with the first mounting structure.

37. The method of claim 36, wherein the step of providing the axle assembly includes providing the second end of the axle assembly with a second mounting structure; and further comprising:

providing a third bearing block and a fourth bearing block;
forming a third aperture in the first bearing block and a fourth aperture in the second bearing block;
attaching the third and fourth bearing blocks to the first mounting structure subsequent to forming the third and fourth apertures; and
providing a second spindle assembly coupled to the third mounting structure by a third spherical bearing located within the third aperture and a fourth spherical bearing located within the fourth aperture, wherein a second kingpin assembly extends through the third and fourth spherical bearings, thereby coupling the second spindle with the second mounting structure.

38. The method of either one of claims 36 and 37, wherein the second bearing block includes a first surface abutting an outer surface of the second spherical bearing, and a second surface extending substantially perpendicular to the first surface and abutting an end surface of the second spherical bearing.

39. The method of any one of claims 36-38, further comprising:

tightening the first kingpin assembly to secure the first spindle to the first mounting structure, and such that a load exerted by the first kingpin assembly follows a load path through the first spherical bearing, the first spindle assembly, a spacer washer and the second spherical bearing.

40. A vehicle suspension assembly, comprising:
- an axle assembly having a first end and a second end;
 - a first mounting bracket and a second mounting bracket each adapted to couple to a vehicle frame assembly;
 - a first trailing arm having a first end pivotably coupled to the first mounting bracket, and a second end pivotably coupled to the first end of the axle assembly;
 - a second mounting bracket adapted to couple to a vehicle frame assembly;
 - a second trailing arm having a first end pivotably coupled to the second mounting bracket, and a second end pivotably coupled to the second end of the axle assembly;
 - a first air spring assembly coupled to a first end of the axle assembly such that a longitudinal axis of the first air spring assembly inclines inwardly from the first end of the axle assembly;
 - a second air spring assembly coupled to the second end of the axle assembly such that a longitudinal axis of the second air spring assembly inclines inwardly from the second end of the axle assembly;
 - wherein a natural frequency of the suspension assembly is less than or equal to about 3Hz.

41. The vehicle suspension assembly of claim 40, wherein the natural frequency of the suspension assembly is between about 1Hz and 2Hz.

42. The vehicle suspension assembly of either one of claims 40 and 41, wherein the first and second air spring assemblies are angled at between 30° and 45° from vertical.

43. The vehicle suspension assembly of any one of claims 40-42, wherein the first and second air spring assemblies are angled at between 30° and 35° from vertical.
44. The vehicle suspension assembly of any one of claims 40-43, further comprising:
a lift arrangement operably coupled with at least one of the first trailing arm and the second trailing arm, and adapted to move the axle between a first vertical position, wherein a tire coupled to one of the ends of the axle member contacts a ground surface, and a second vertical position, wherein the tire is spaced from the ground surface.
45. The vehicle suspension assembly of any one of claims 40-44, further comprising:
a first spindle assembly coupled with the first end of the axle assembly and a second spindle assembly coupled with the second end of the axle assembly; and
a steering arrangement operably coupled with at least a select one of the first and second spindle assemblies, and adapted to move a tire coupled to one of the spindle assemblies between a first position defining a first direction of travel, and a second position defining a second direction of travel that is different than the first direction of travel.
46. The vehicle suspension of any one of claims 40-45, wherein the axle assembly includes an integrated mounting arrangement coupled to the first end of the axle member, wherein the mounting arrangement couples the first end of the axle member to the a first spindle assembly, and wherein the first air spring is coupled to the mounting arrangement.
47. The vehicle suspension of claim 46, wherein the mounting arrangement pivotably couples the second end of the first trailing arm to the first end of the axle member.

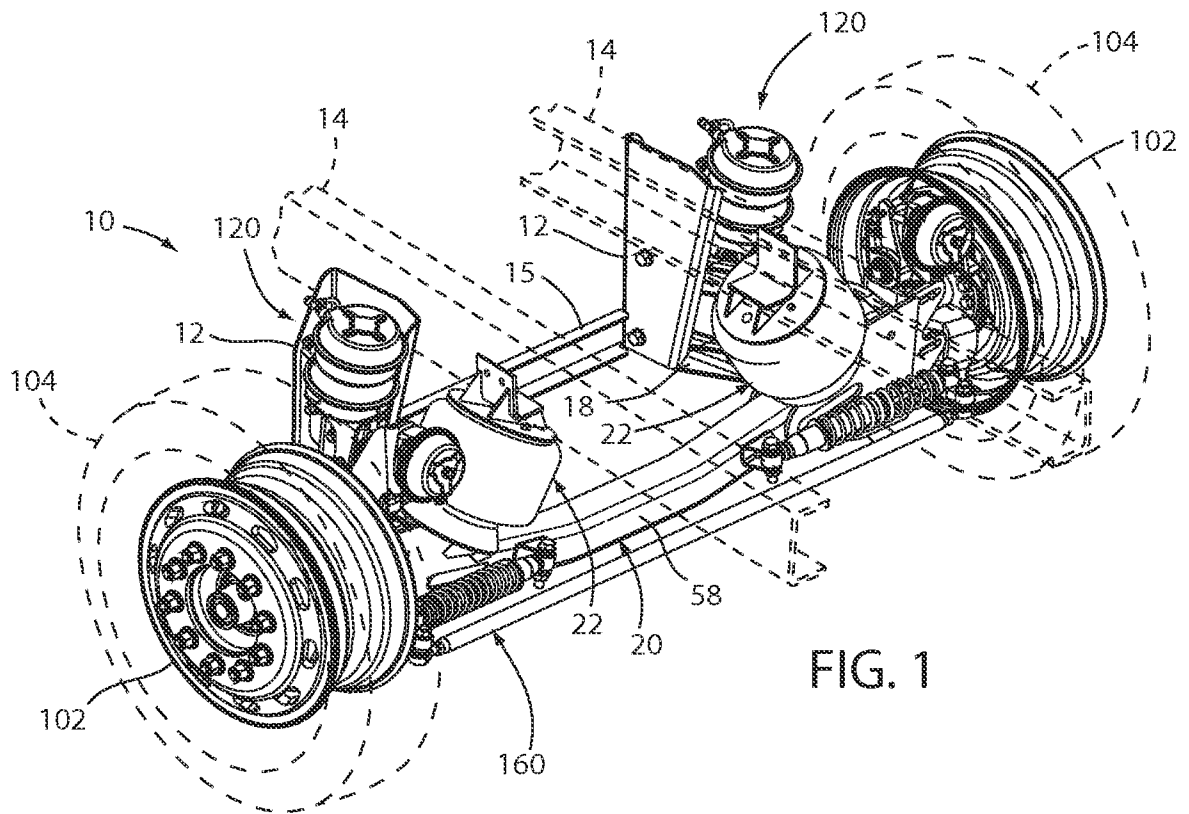


FIG. 1

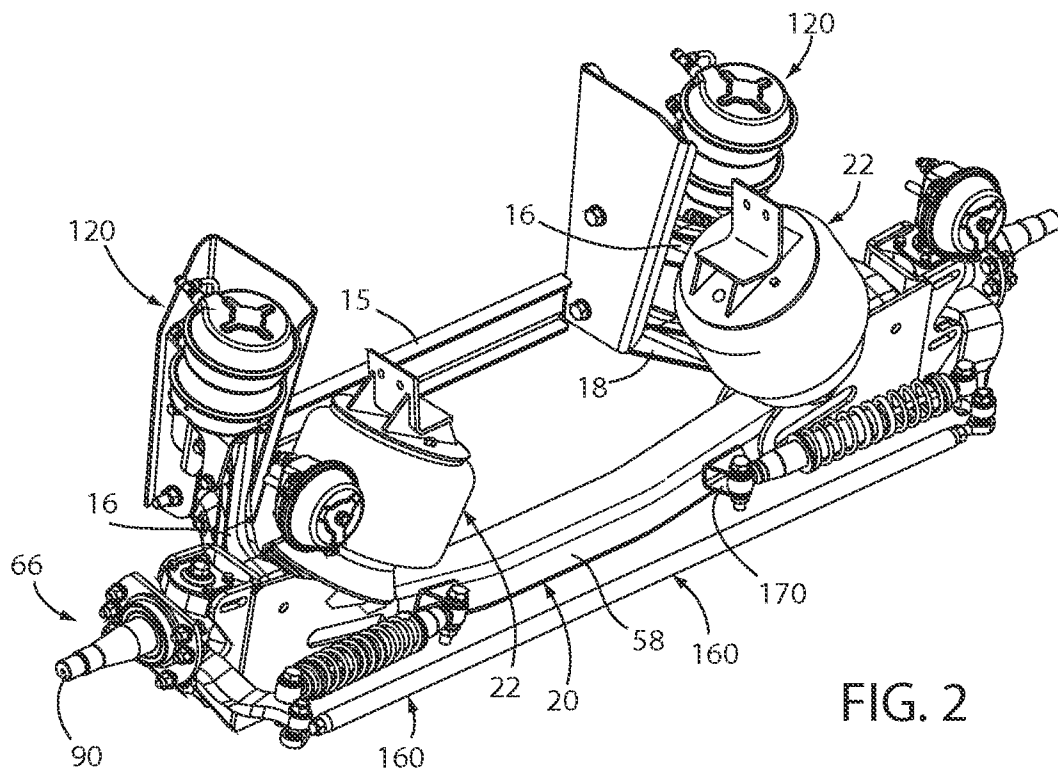
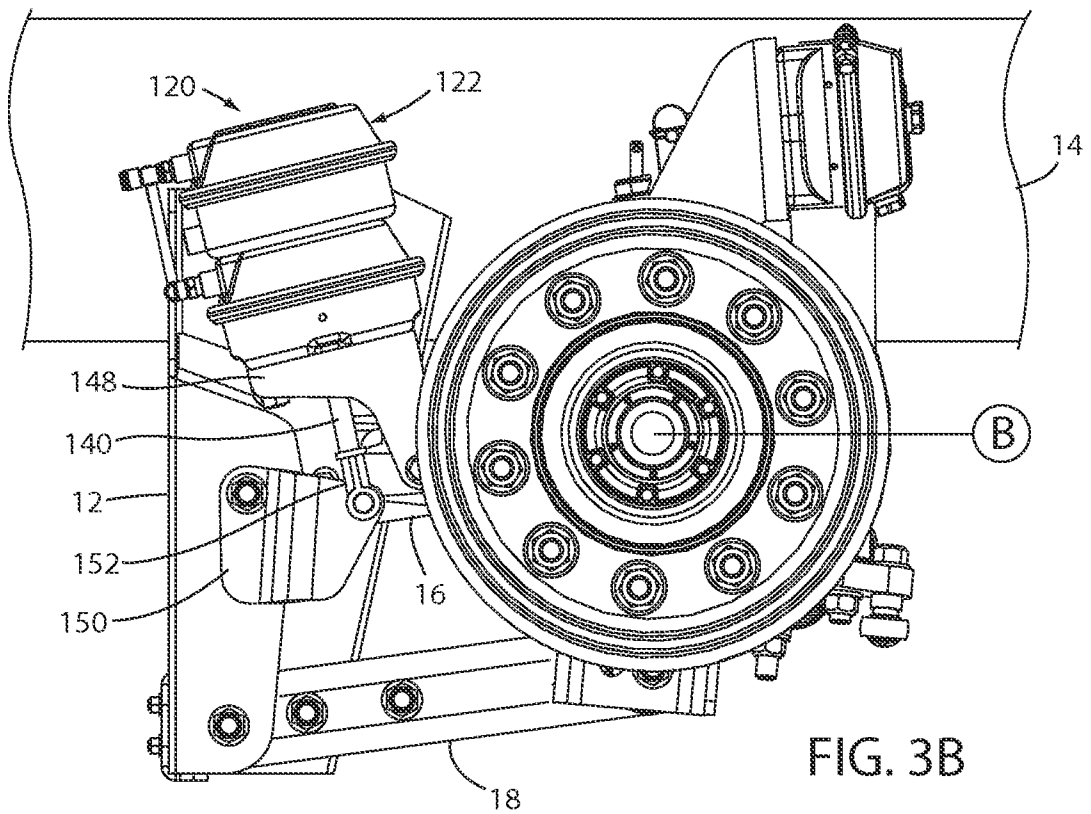
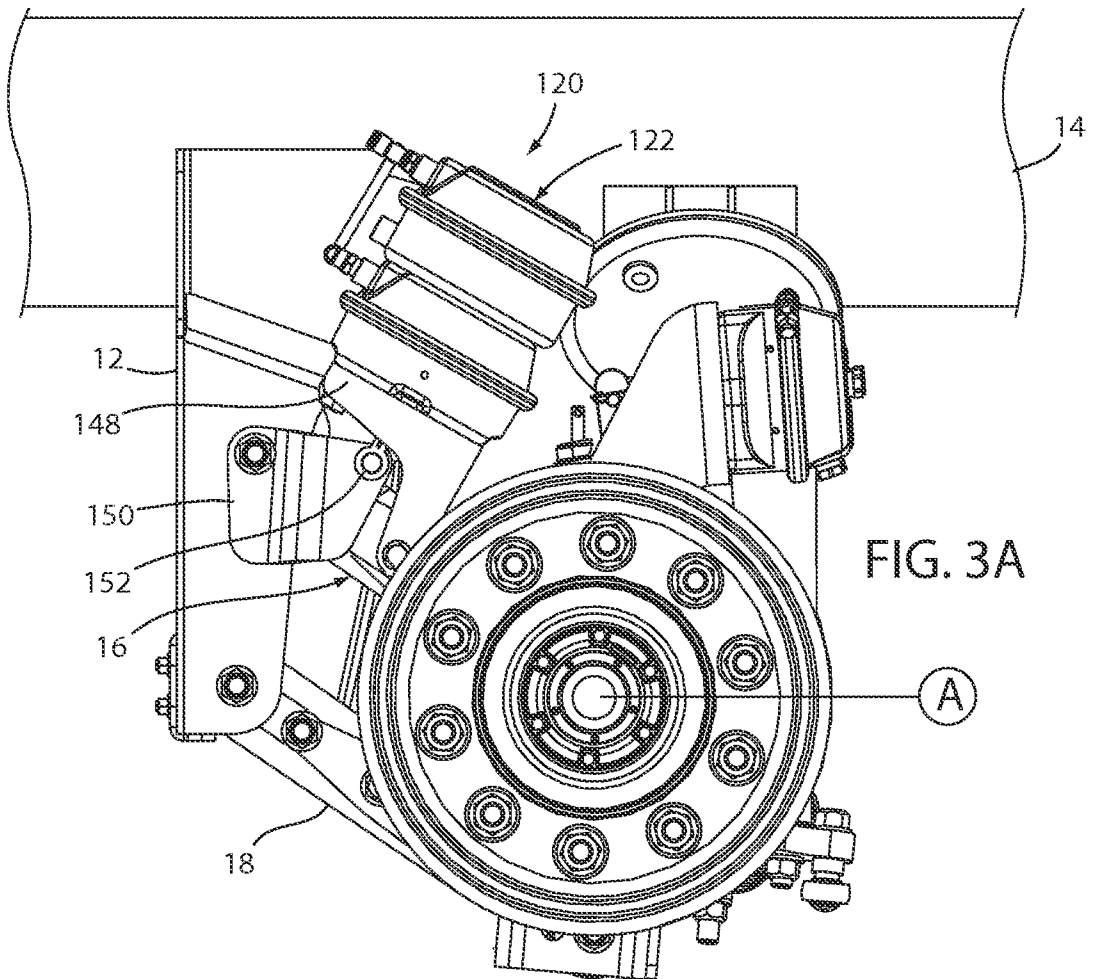


FIG. 2

2/11



3/11

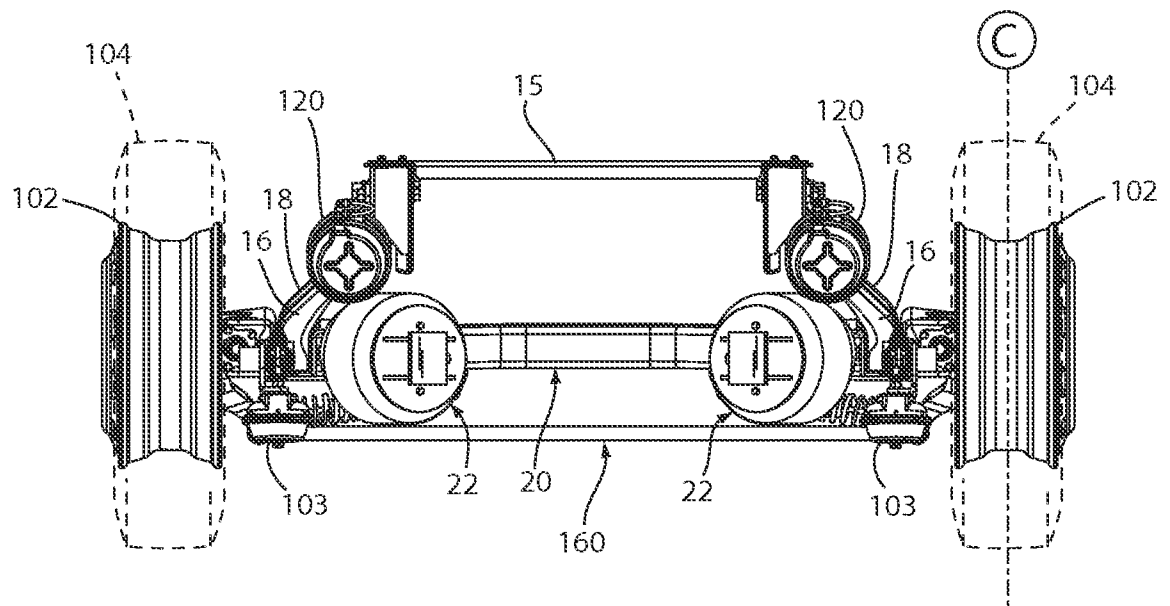


FIG. 4A

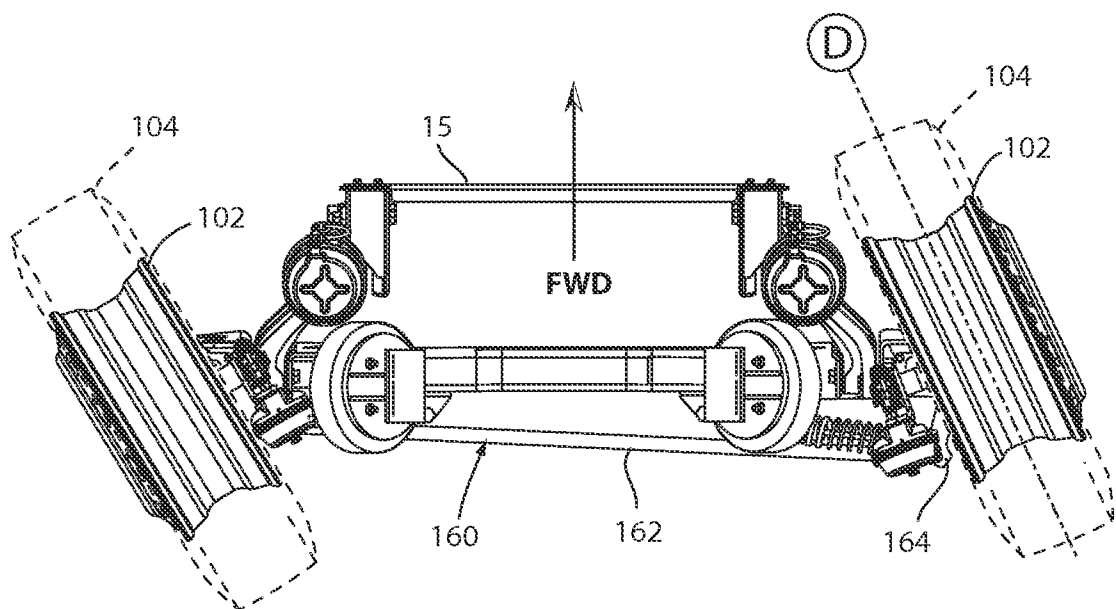


FIG. 4B

4/11

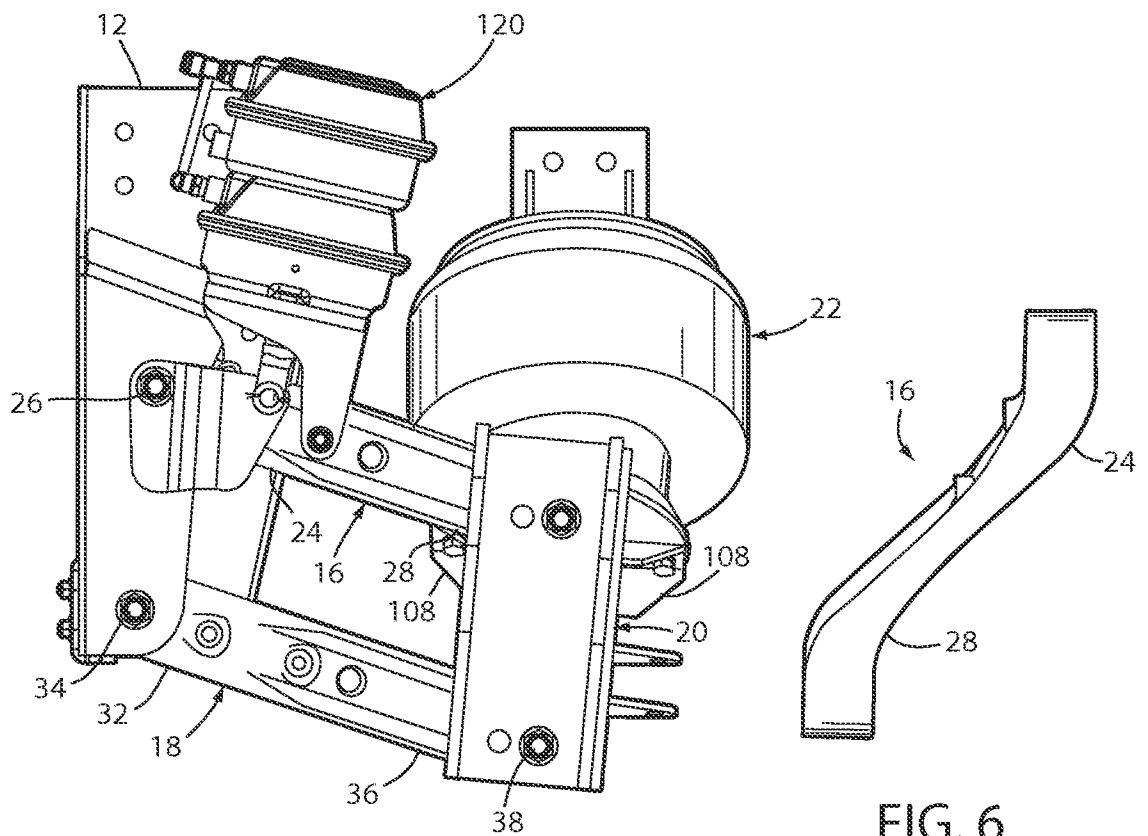


FIG. 5

FIG. 6

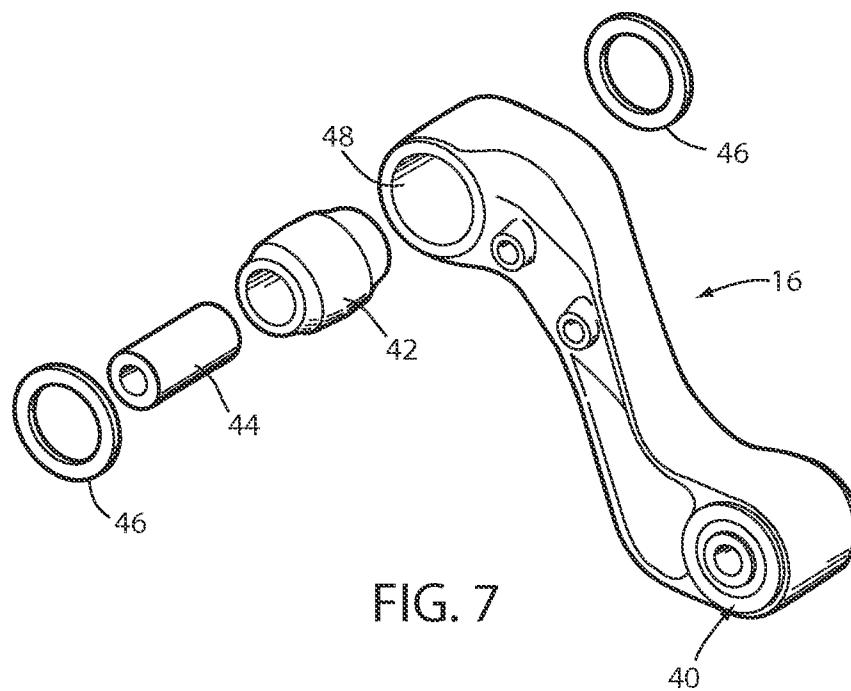


FIG. 7

5/11

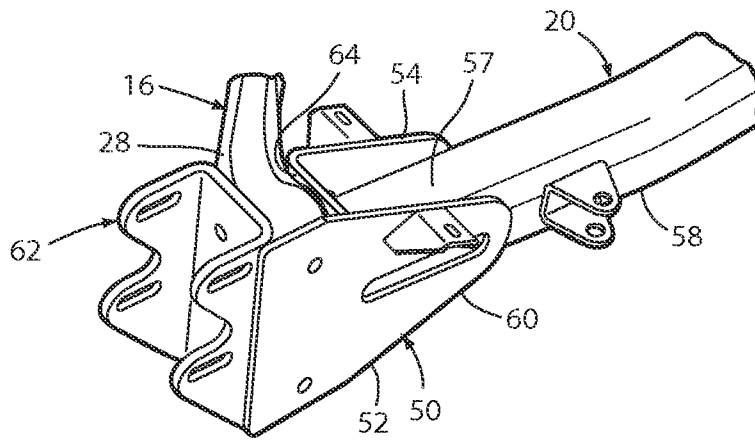


FIG. 8

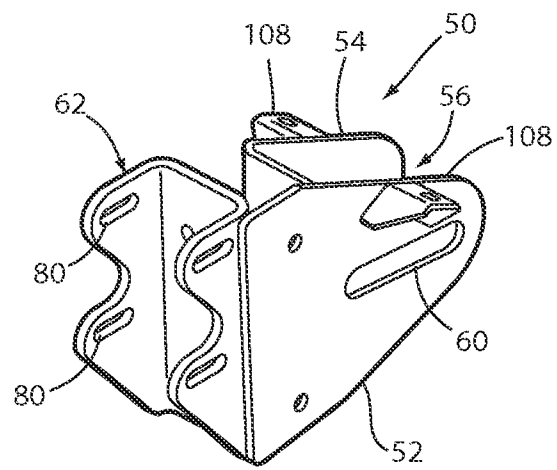


FIG. 9A

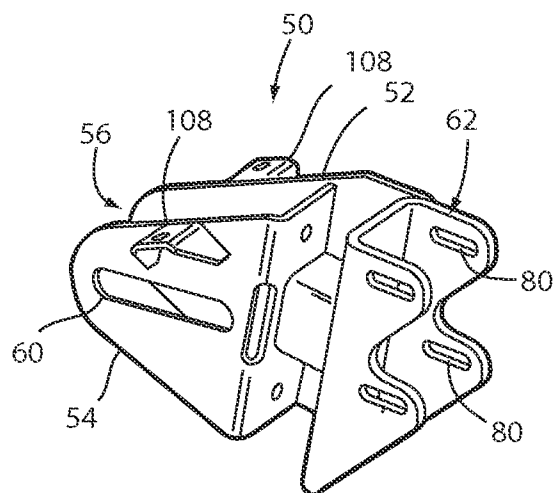
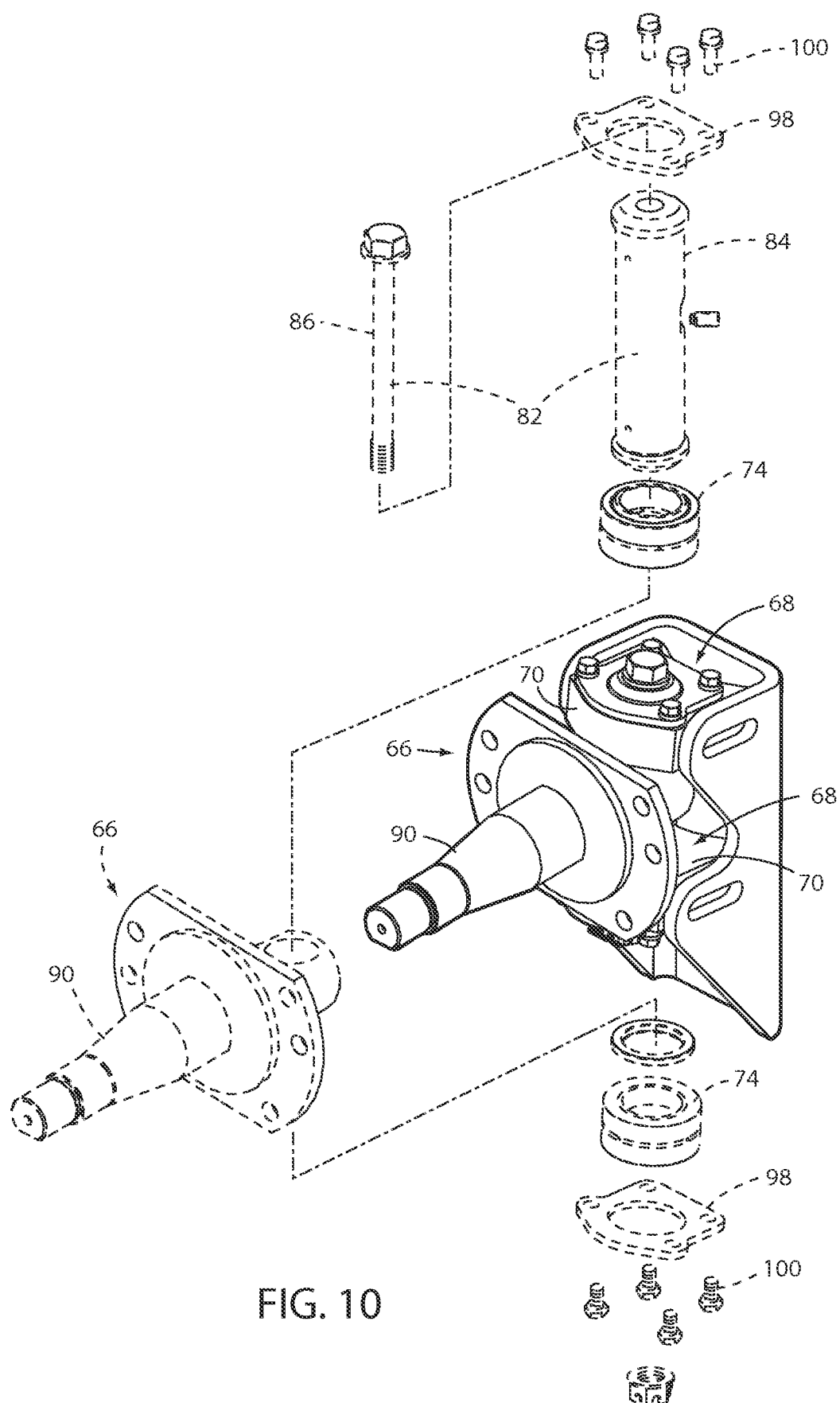


FIG. 9B



7/11

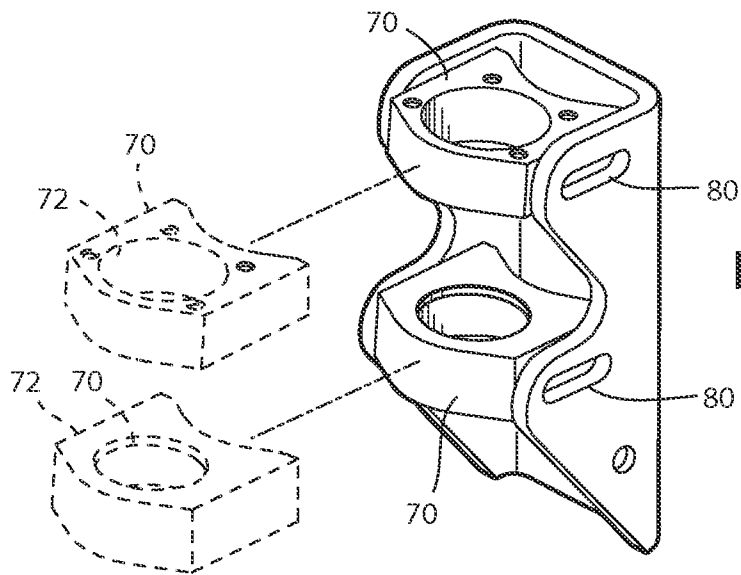


FIG. 11

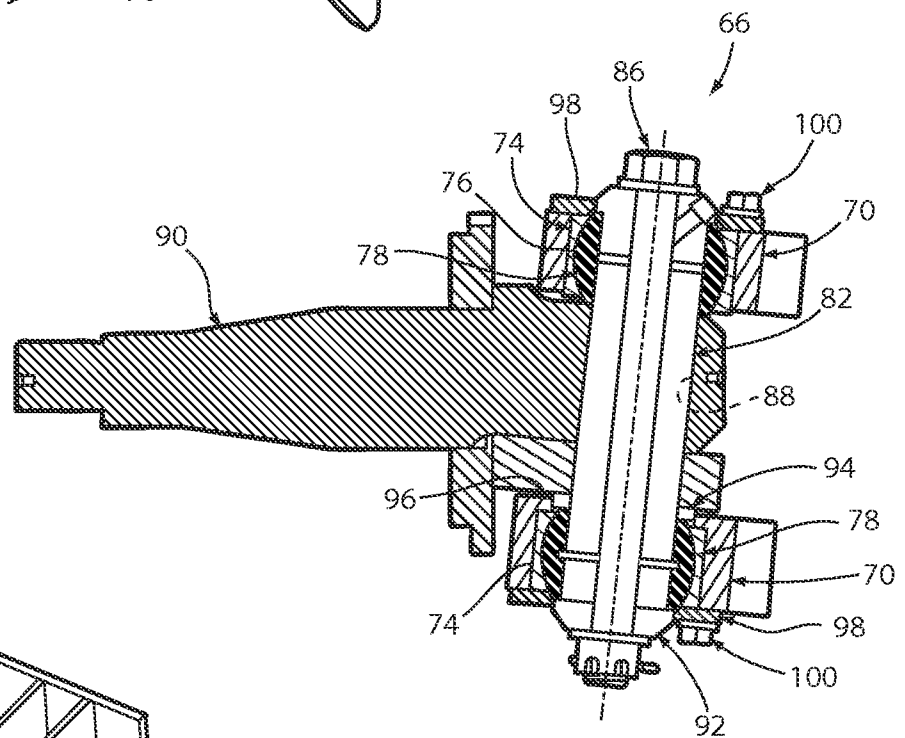


FIG. 12A

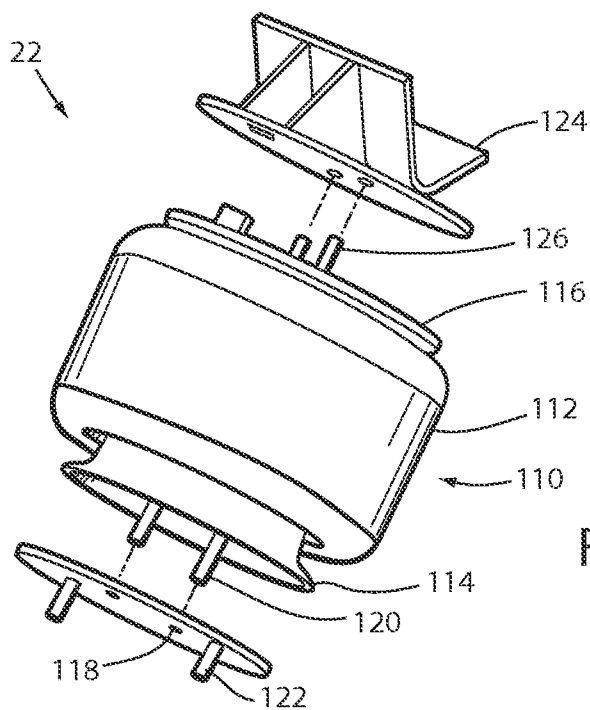


FIG. 13

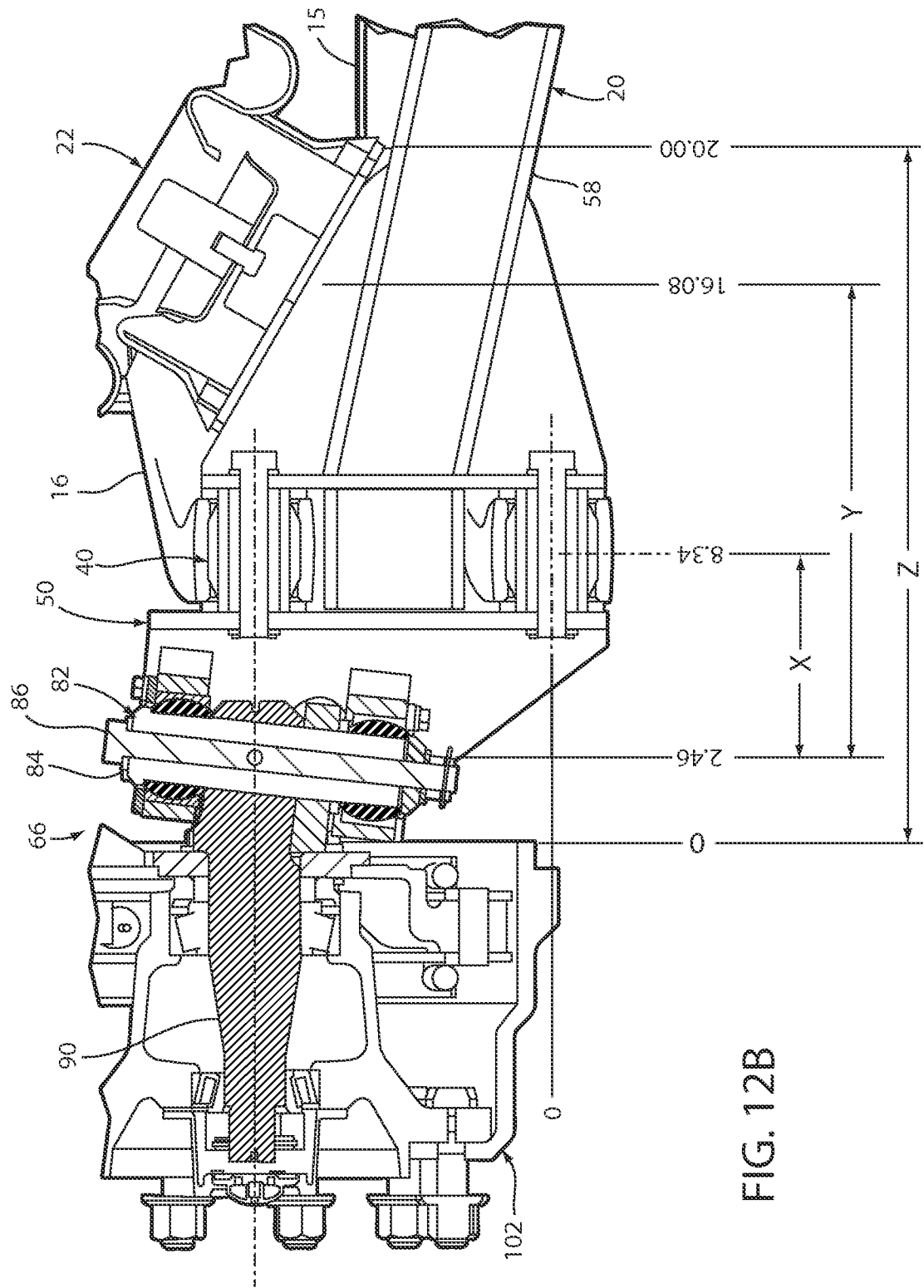


FIG. 12B

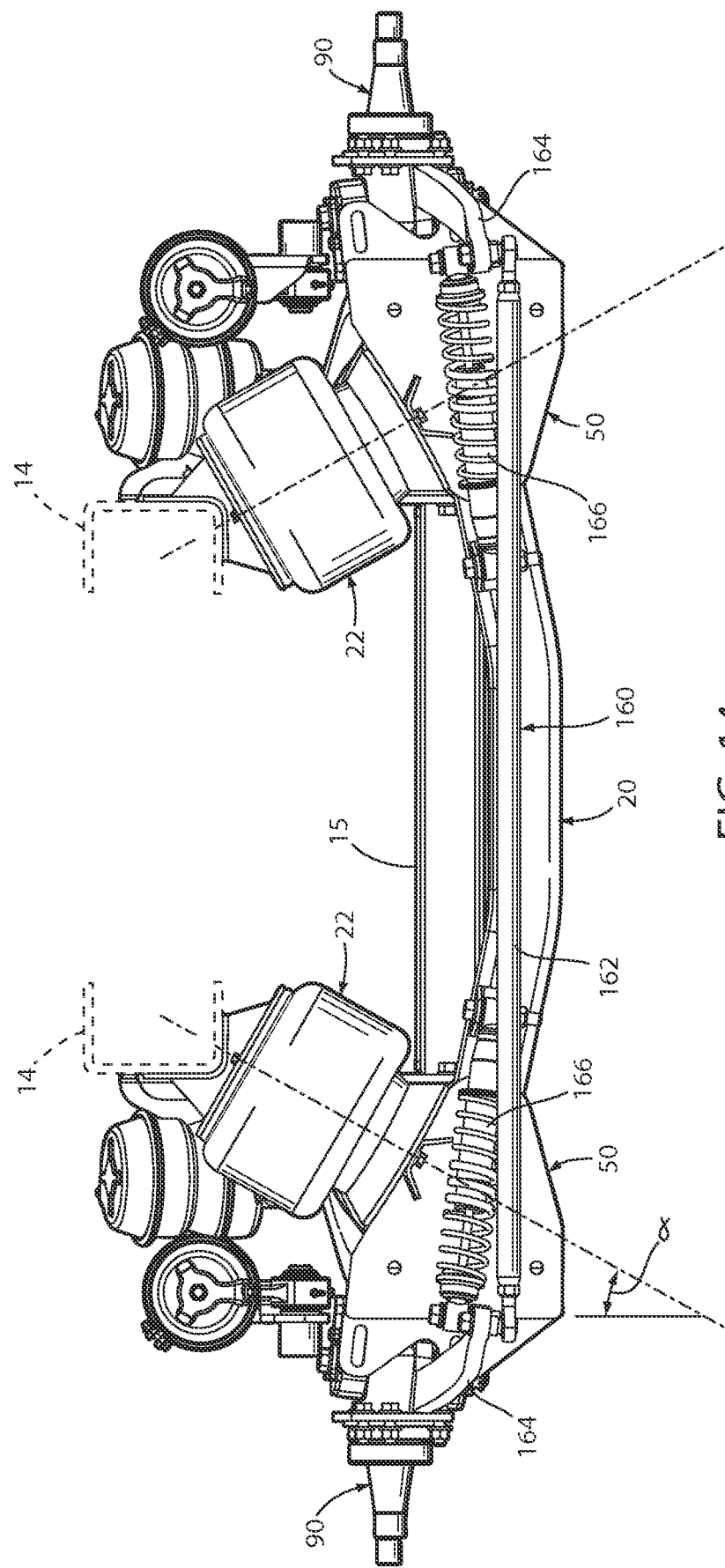


FIG. 14

10/11

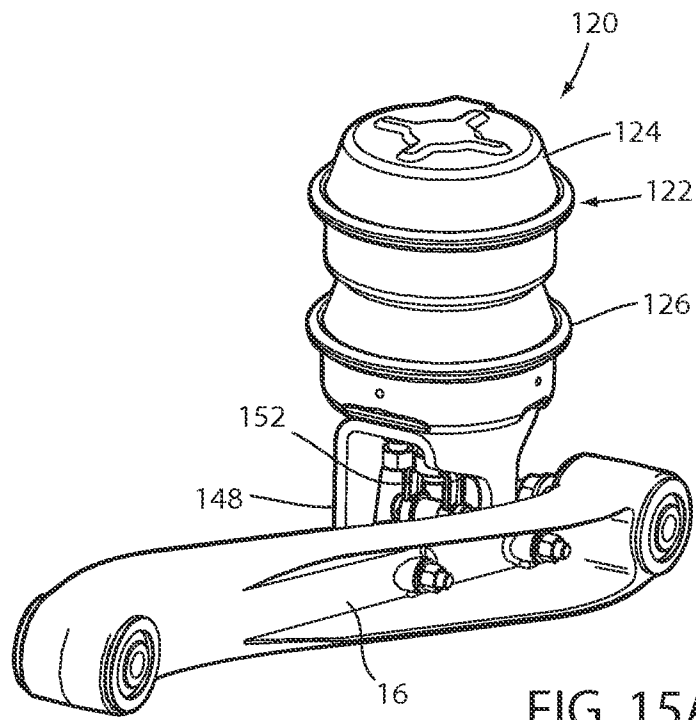


FIG. 15A

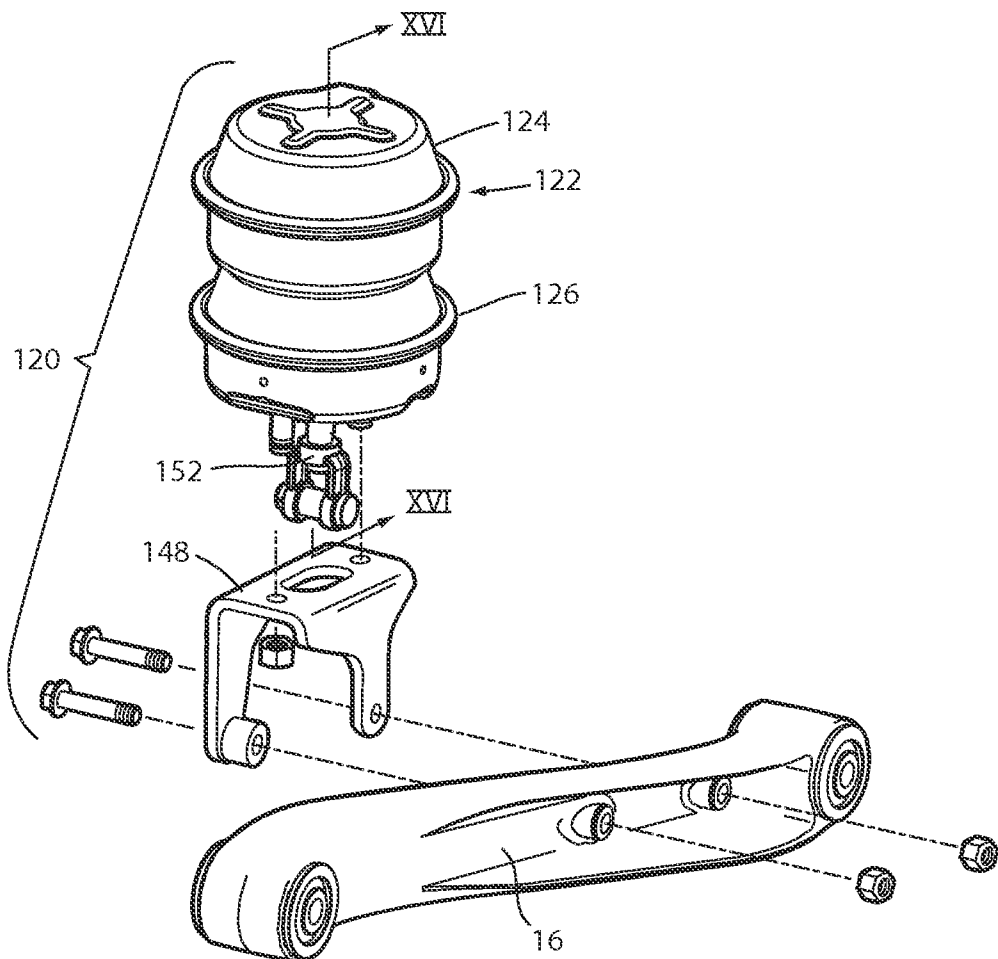


FIG. 15B

11/11

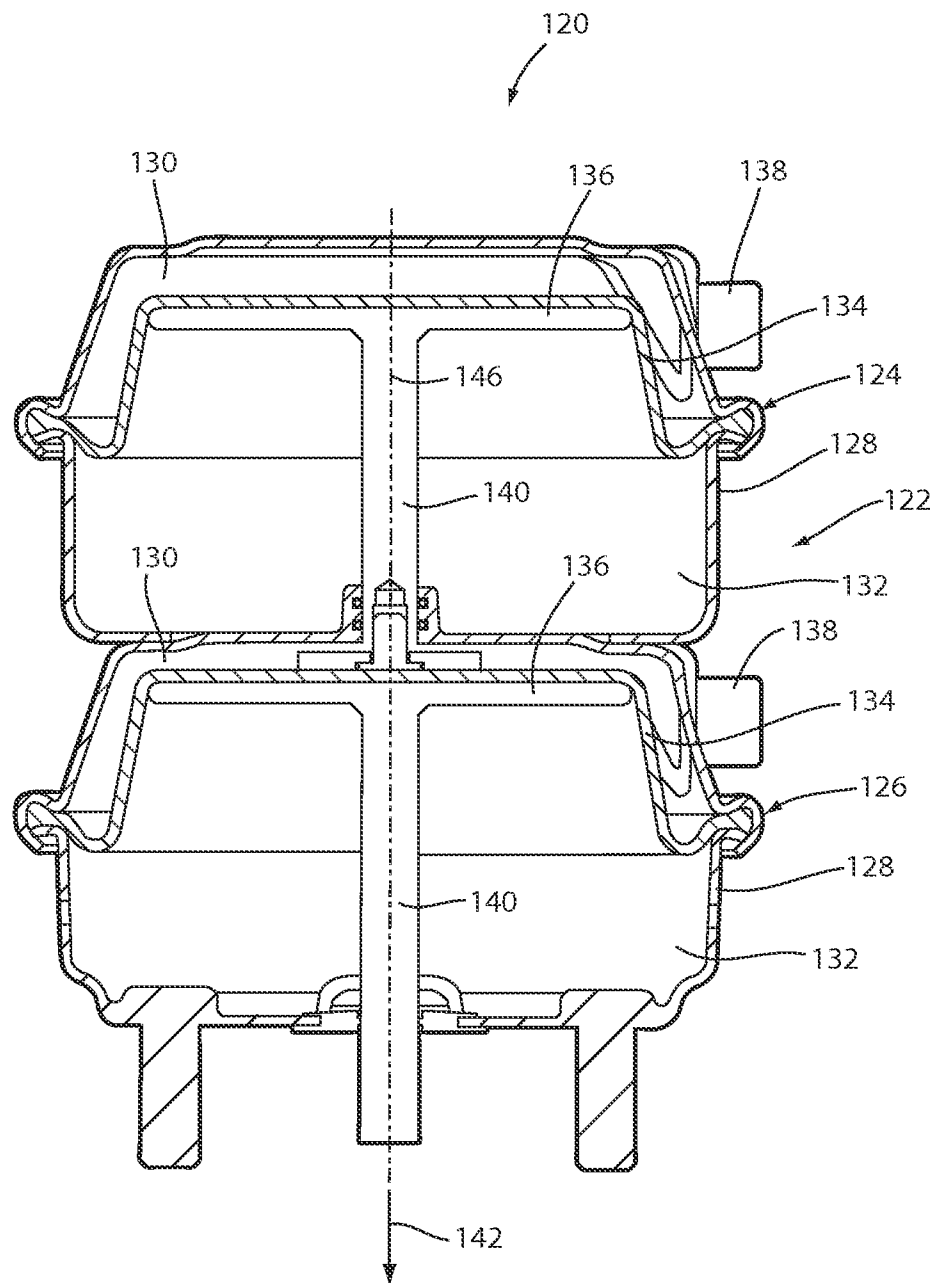


FIG. 16