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(54) **Title**: A DIFFERENTIAL GEAR ASSEMBLY AND A METHOD OF ASSEMBLY

(57) **Abstract**: A differential is disclosed, in which a casing of the differential is configured so that a crown wheel assembly can be introduced into the casing in a sideways motion to assemble moving parts of the differential within the casing. The structural casing is preferably a single body. The crown wheel assembly is preferably supported in the casing by a single crown wheel bearing. The crown wheel assembly is configured so as to have a short axial length, to fit through a relatively small crown wheel assembly opening of the casing. A non-structural cover may be provided to cover the crown wheel assembly opening.

A differential gear assembly and a method of assembly

BACKGROUND

The present invention relates to a differential gear assembly and a method of assembly therefore. In particular, the invention relates to a differential assembly having a more compact and low mass construction as compared to known differentials, and a method of assembling such a differential

Differential gear assemblies are known and generally comprise a housing, a crown wheel or ring gear for receiving a drive input to the differential and most commonly a pair of substantially opposing side gears for delivering the drive to a pair of rotatable output shafts extending from the differential. The differential allows power to be transferred to the rotatable output shafts while allowing the output shafts to rotate at different speeds to one another. Common differential assemblies comprise a carrier which is arranged to rotate about a principal axis of rotation of the differential. The principal axis is one about which the crown gear is configured to rotate when a drive is input to the crown wheel or ring gear. The carrier is generally fixed to the crown wheel and receives pinion gears, which are mounted on shafts which are arranged radially, so as to rotate about axes which extend away from the principal axis of rotation of the differential. The pinion gears engage the side gears to deliver torque from the input to the crown wheel to the side gears.

Assembly of pinion gears into the carrier can be a complex procedure requiring strength and dexterity and is time consuming during a manufacturing process of a differential. The traditional carrier into which pinion gears are mounted generally comprises a significant mass, adding weight to the differential and contributing to the moment of inertia of the differential, which can adversely affect its efficiency in use.

There is a need for improvements in differential assemblies.

The present invention provides an improved differential and assembly method therefore.

STATEMENTS OF INVENTION

A differential is disclosed, in which a casing of the differential is configured so that a crown wheel assembly can be introduced into the casing in a sideways motion to assemble moving parts of the differential within the casing. The structural casing is preferably a single body. The crown wheel assembly is preferably supported in the casing by a single crown wheel bearing. The crown wheel assembly is configured so as to have a short axial length, to fit through a relatively small crown wheel assembly opening of the casing. A non-structural cover may be provided to cover the crown wheel assembly opening.

According to an aspect of the present invention, there is provided a method of assembling a differential, comprising the steps of:

providing a differential casing having:

first and second opposed side gear openings;

a crown wheel cavity, for receiving a crown wheel assembly of the differential substantially between, and substantially coaxially with, the side gear openings; and

a crown wheel assembly opening, provided on the casing, between the first and second side gear openings, for allowing passage of the crown wheel assembly into the cavity;

introducing a crown wheel assembly into the crown wheel cavity by:

translating the crown wheel assembly, in a substantially radial direction of the crown wheel assembly, through the crown wheel assembly opening of the casing to substantially centre the crown wheel assembly on an axis of the side gear openings.

There is preferably provided a means of rotational support, to rotatably support the crown wheel assembly in the casing. The differential casing preferably further comprises an input drive opening. Of the side gear openings, the input drive opening, and the crown wheel assembly opening, only the crown wheel assembly opening is configured for allowing passage of the crown wheel assembly into the cavity in a substantially radial direction of the of the crown wheel assembly.

The method may further comprise translating the crown wheel assembly in a substantially axial direction of the crown wheel assembly to place it in a crown wheel receiving portion of the casing.

The method may further comprise:

a first arced translation of the crown wheel assembly at a non-zero angle relative to the axis side gear openings, to bring the crown wheel assembly into the crown wheel cavity; and

a second translation substantially parallel to the axes of the side gear openings, to seat the crown wheel assembly into a corresponding recess in the crown wheel cavity of the casing.

The method may further comprise:

fastening the crown wheel assembly to the casing with fixing means engaging a flange of the crown wheel assembly.

The method may further comprise:

introducing first and second side members carrying respective first and second side gears into the respective first and second side gear openings.

The method may further comprise:

engaging the first and second side gears with pinion gears of the crown wheel assembly, on opposing sides of the crown wheel assembly.

The method may further comprise:

providing an axial shaft in fixed engagement with the first side gear member and extending beyond the teeth of the first side gear member;

passing the shaft along a rotational axis of the crown wheel assembly and through an opening of the second side gear members; and

engaging the shaft with the second side gear member, via a thrust bearing, to retain the side gears in engagement with each respective side of the pinion gears and to allow relative rotation between at least the shaft and the second side gear member.

The method may further comprise:

providing radial bearings to radially support the side gear members in the side gear openings of the casing.

The method may further comprise:

providing a seal between the casing and an outer surface of at least one of the side gear members.

In exemplary embodiments, the differential comprises an output drive shaft, and the method further comprises:

providing a seal between the casing and an outer surface of the output drive shaft.

In exemplary embodiments, the seal comprises:

a sheath, the sheath being connected to the casing; and

a sealing member located between the sheath and the output drive shaft.

In exemplary embodiments, the method further comprises:

locating the sealing member on the output drive shaft; and

connecting the sheath to the casing, to create the seal.

In exemplary embodiments, the sealing member is a rotary seal.

In exemplary embodiments, the seal further comprises a rotary bearing, and

the method further comprises locating the rotary bearing on the output drive shaft, between the sheath and the output drive shaft.

In exemplary embodiments, the sheath is a flexible boot.

The method may further comprise:

locating output shafts in the side gear members, such that engagement features of the output shafts engage with corresponding engagement features of the side gear members to transmit rotational drive to the output shafts.

Engagement features of the output shafts may comprise any one of splines, channels or ball tracks for a constant velocity joint, a bolted flange, or any suitable engagement means for transferring rotational output from the side gears to drive shafts.

The crown wheel assembly opening of the casing may have a first width greater than the overall diameter of the crown wheel assembly and preferably a second width, in a direction substantially perpendicular to the first width, which is less than the overall diameter of the crown wheel assembly.

The differential casing may be a single structural component comprising the crown wheel cavity, the side gear openings, and the crown wheel assembly opening.

In exemplary embodiments, the differential casing is a multi-part structural component comprising the crown wheel cavity, the side gear openings, and the crown wheel assembly opening.

The differential casing may be formed from two parts, attached to one another to define the casing.

In exemplary embodiments, the differential casing comprises two split lines, to divide the differential casing into the two parts.

In exemplary embodiments, the differential casing comprises a first longitudinal split line, and a second transverse split line, to divide the differential casing into the two parts.

The method may further comprise providing a crown wheel bearing, arranged to rotatably support the crown wheel within the casing, the crown wheel bearing having an outer radius which is greater than an inner radius of the crown gear teeth.

A radius corresponding to a centreline of rolling elements of the crown wheel bearing may be greater than the inner radius of the crown gear teeth.

An inner radius of an inner race of the crown wheel bearing may be greater than the inner radius of the crown gear teeth.

The method may further comprise:

placing a shim between the flange of the crown wheel assembly and the casing.

A further aspect of the invention provides a differential, comprising:

a casing, comprising first and second opposed side gear openings in which side gear members carrying side gear teeth are located;

a crown wheel cavity, within which a crown wheel assembly of the differential is located substantially between, and substantially coaxially with, the side gear openings;

an input opening for receiving a drive input to the crown wheel; and

a crown wheel opening, provided on the casing, between the first and second side gear openings, for allowing passage of the crown wheel into the cavity in a direction substantially perpendicular to the axis of the side gear openings.

The differential may further comprise a side gear retention shaft fixedly connected to and extending from the first side gear member and rotatably connected to the second side gear member, so as to axially retain the first and second side gears in engagement with the pinion gears, while allowing relative rotation of the side gear members.

The side gears may be supported radially in bearings provided in side gear openings of the casing, and wherein axial location of the side gears is provided by their engagement with the pinion gears. The side gear members comprise an outer surface for engaging with a rotational seal. The side gear members may be substantially similar cup shaped members. They may have substantially similar inner and outer cup profiles to one another.

In exemplary embodiments, the differential comprises an output drive shaft, and a seal located between the casing and an outer surface of the output drive shaft.

In exemplary embodiments, the seal comprises:

a sheath, the sheath being connected to the casing; and

a sealing member located between the sheath and the output drive shaft.

In exemplary embodiments, the sealing member is a rotary seal.

In exemplary embodiments, the seal further comprises a rotary bearing, located between the sheath and the output drive shaft.

In exemplary embodiments, the sheath is a flexible boot.

The differential may further comprise a plurality of pinion gears located at respective radial positions within an inner radius of the crown gear teeth, each pinion gear having an axis of rotation which is substantially radial with respect to the crown wheel; the following features are preferably included, individually or in combination:

the side gear members being arranged to engage the pinion gears, such that drive input to the crown gear is transferred to the side gears via the pinion gears; and

a pinion mount comprising a plurality of radial members, the radial members each extending from the central portion and engaging the crown wheel;

wherein at least one of the pinion gears is rotatably mounted to a radial member of the pinion mount.

The radial members of the pinion mount may be arranged to directly transfer loads from the pinion gears to the crown wheel.

Sectors located between the pinion gears, in a principal plane of the pinion mount, may contain no pinion carrier components.

The pinion mount may comprise an opening to allow passage of the side gear retention shaft therethrough.

The opening of the pinion mount may be substantially central and substantially located about an axis of rotation of the pinion mount.

The differential may further comprise a crown wheel bearing, arranged to rotatably support the crown wheel within the casing, the crown wheel bearing having an outer radius which is greater than the inner radius of the crown gear.

A radius corresponding to a centreline of rolling elements of the crown wheel bearing may be greater than the inner radius of the crown gear teeth.

An inner radius of an inner race of the crown wheel bearing may be greater than the inner radius of the crown gear teeth.

The crown wheel assembly may be radially supported by a single crown wheel bearing.

The side gears may be axially retained in position in the casing via the crown wheel bearing.

The crown wheel bearing may be substantially located at a radial position relative to the rotational axis of the crown wheel between the inner and outer radii of the crown gear teeth.

The crown wheel bearing may be located at an axial position relative to the crown wheel, substantially within a diameter of the pinion gears of the crown wheel assembly.

In exemplary embodiments, the differential casing is a multi-part structural component comprising the crown wheel cavity, the side gear openings, and the crown wheel assembly opening.

The differential casing may be formed from two parts, attached to one another to define the casing.

In exemplary embodiments, the differential casing comprises two split lines, to divide the differential casing into the two parts.

In exemplary embodiments, the differential casing comprises a first longitudinal split line, and a second transverse split line, to divide the differential casing into the two parts.

In a further aspect, the invention provides a differential casing component, comprising:

first and second opposed side gear openings;

a crown wheel cavity, for receiving a crown wheel assembly of the differential substantially between, and substantially coaxially with, the side gear openings;

an input opening for receiving a drive input to the crown gear; and

a crown wheel assembly opening, located between one of the first and second side gear openings and the crown wheel cavity, for allowing passage of the crown wheel into the cavity in a direction perpendicular to the axis of the side gear openings.

In exemplary embodiments, the differential casing component comprises an output drive shaft, and a seal located between the casing and an outer surface of the output drive shaft.

In exemplary embodiments, the seal comprises:

a sheath, the sheath being connected to the casing; and

a sealing member located between the sheath and the output drive shaft.

In exemplary embodiments, the sealing member is a rotary seal.

In exemplary embodiments, the seal further comprises a rotary bearing, located between the sheath and the output drive shaft.

In exemplary embodiments, the sheath is a flexible boot.

In exemplary embodiments, the differential casing component is a multi-part structural component comprising the crown wheel cavity, the side gear openings, and the crown wheel assembly opening.

The differential casing may be formed from two parts, attached to one another to define the casing.

In exemplary embodiments, the differential casing comprises two split lines, to divide the differential casing into the two parts.

In exemplary embodiments, the differential casing comprises a first longitudinal split line, and a second transverse split line, to divide the differential casing into the two parts.

In a further aspect, the invention provides a differential comprising:

a casing; and

a crown wheel assembly, comprising:

a crown gear carrying crown gear teeth for receiving an input drive to the differential;

a plurality of pinion gears located radially within an inner radius of the crown gear, each pinion gear having an axis of rotation which is substantially radial with respect to the crown wheel;

first and second side gears arranged to engage the pinion gears, such that drive input to the pinion gear is transferred to the side gears via the pinion gears; and

a crown wheel bearing, arranged to rotatably support the crown wheel within the casing, the crown wheel bearing having an outer radius which is greater than the inner radius of the crown wheel.

In exemplary embodiments, the differential casing is a multi-part structural component comprising the crown wheel cavity, the side gear openings, and the crown wheel assembly opening.

The differential casing may be formed from two parts, attached to one another to define the casing.

In exemplary embodiments, the differential casing comprises two split lines, to divide the differential casing into the two parts.

In exemplary embodiments, the differential casing comprises a first longitudinal split line, and a second transverse split line, to divide the differential casing into the two parts.

In exemplary embodiments, the differential comprises an output drive shaft, and a seal located between the casing and an outer surface of the output drive shaft.

In exemplary embodiments, the seal comprises:

a sheath, the sheath being connected to the casing; and

a sealing member located between the sheath and the output drive shaft.

In exemplary embodiments, the sealing member is a rotary seal.

In exemplary embodiments, the seal further comprises a rotary bearing, located between the sheath and the output drive shaft.

In exemplary embodiments, the sheath is a flexible boot.

In a further aspect, the invention provides a differential comprising:

a casing; and

a crown wheel assembly, comprising:

a crown gear carrying crown gear teeth for receiving an input drive to the differential;

a plurality of pinion gears located at a radial position within an inner radius of the crown gear teeth, each pinion gear having an axis of rotation which is substantially radial with respect to the crown wheel;

first and second side gears arranged to engage the pinion gears, the side gears each having respective axes of rotation which are substantially perpendicular to the axis of rotation of the pinion gears, such that drive input to the crown gear is transferred to the side gears via the pinion gears; and

a pinion mount comprising a central portion and a plurality of radial members, the radial members each extending from the central portion and engaging the crown wheel, at least one of the radial members being integrally formed with the central portion;

wherein at least one of the pinion gears is rotatably mounted to a radial member of the pinion mount.

The radial spaces between the pinion gears may contain no pinion carrier components.

In exemplary embodiments, the differential casing is a multi-part structural component comprising the crown wheel cavity, the side gear openings, and the crown wheel assembly opening.

The differential casing may be formed from two parts, attached to one another to define the casing.

In exemplary embodiments, the differential casing comprises two split lines, to divide the differential casing into the two parts.

In exemplary embodiments, the differential casing comprises a first longitudinal split line, and a second transverse split line, to divide the differential casing into the two parts.

In exemplary embodiments, the differential comprises an output drive shaft, and a seal located between the casing and an outer surface of the output drive shaft.

In exemplary embodiments, the seal comprises:

a sheath, the sheath being connected to the casing; and

a sealing member located between the sheath and the output drive shaft.

In exemplary embodiments, the sealing member is a rotary seal.

In exemplary embodiments, the seal further comprises a rotary bearing, located between the sheath and the output drive shaft.

In exemplary embodiments, the sheath is a flexible boot.

In a further aspect, the invention provides a differential comprising:

a casing; and

a crown wheel assembly, comprising:

a crown gear carrying crown gear teeth for receiving an input drive to the differential;

a plurality of pinion gears mounted radially inward of the crown gear, each having an axis of rotation which is substantially radial with respect to the crown wheel;

first and second side gears arranged to engage the pinion gears, the side gears each having respective axes of rotation substantially perpendicular to the axis of rotation of the pinion gear, such that drive input to the crown gear is transferred to the side gears via the pinion gears; and

a shaft fixedly connected to and extending from the first side gear and rotatably connected to the second side gear, so as to axially retain the first and second side gears in engagement with the pinion gears, while allowing relative rotation of the side gears.

In exemplary embodiments, the differential casing is a multi-part structural component comprising the crown wheel cavity, the side gear openings, and the crown wheel assembly opening.

The differential casing may be formed from two parts, attached to one another to define the casing.

In exemplary embodiments, the differential casing comprises two split lines, to divide the differential casing into the two parts.

In exemplary embodiments, the differential casing comprises a first longitudinal split line, and a second transverse split line, to divide the differential casing into the two parts.

In exemplary embodiments, the differential comprises an output drive shaft, and a seal located between the casing and an outer surface of the output drive shaft.

In exemplary embodiments, the seal comprises:

a sheath, the sheath being connected to the casing; and

a sealing member located between the sheath and the output drive shaft.

In exemplary embodiments, the sealing member is a rotary seal.

In exemplary embodiments, the seal further comprises a rotary bearing, located between the sheath and the output drive shaft.

In exemplary embodiments, the sheath is a flexible boot.

In a further aspect, the invention provides a differential casing assembly, comprising:

a structural casing, comprising first and second opposed side gear openings;

a crown wheel cavity, for receiving a crown wheel assembly of the differential substantially between, and substantially coaxially with, the side gear openings;

an input opening for receiving a drive input to the crown wheel;

the structural casing configured to react loads generated between the crown wheel, side gears and input opening when the differential is driven; and

at least one substantially non-structural cover arranged to seal the crown wheel cavity by covering an opening of the casing, the opening being arranged to allow at least one component of the crown wheel assembly to be introduced into the cavity via the opening.

The substantially non-structural cover may be flexible. The substantially non-structural cover may be capable of deforming sufficiently to contact features of the structural casing covered by the cover, and preferably capable of elastically recovering from such deformation.

The substantially non-structural cover may be fixed to the casing by an undercut rim and a compressible gasket to provide a seal to the casing. The cover may be affixed to the casing via an adhesive.

The cover may comprise a material suitable for being melted locally to conform to features of the casing, to fix the cover thereto.

The cover may be fixed to the casing by staking and sealing.

The cover may comprise reinforcing fibres.

The fibres may comprise KEVLAR®.

The cover may comprise a material of lower density than the structural casing.

In a further aspect, the invention provides a non-structural cover for sealing openings of the differential casing assembly as described herein.

The cover is preferably capable of deforming sufficiently to contact features of the structural casing when assembled with the casing.

The cover is preferably capable of elastically recovering from such deformation.

The cover is made of an elastomer or flexible plastic. The cover is preferably of thinner cross section than the structural casing. The cover preferably includes reinforcement fibres. The cover is preferably fixed to the casing by an undercut rim and a compressible gasket to provide a seal to the casing.

Means for fixing the cover members to the housing may be through use of adhesive fastening means, or through the use of over-moulding or melting onto a receiving feature on the housing component.

Flexible sealing gaskets may be fixed to the casing and may provide means of location and retention of the cover members in place. Such a gasket component may form a loop which enclosures the perimeter of a cover member and may have a re-entrant lip which engages with a corresponding feature on the cup member.

The cover is preferably fixed to the casing by an undercut rim and a compressible gasket to provide a seal to the casing, or via an adhesive, or by use of a material suitable for being melted locally to conform to features of the casing to fix the cover thereto, or by a process of staking.

In exemplary embodiments, the differential casing is a multi-part structural component comprising the crown wheel cavity, the side gear openings, and the crown wheel assembly opening.

The differential casing may be formed from two parts, attached to one another to define the casing.

In exemplary embodiments, the differential casing comprises two split lines, to divide the differential casing into the two parts.

In exemplary embodiments, the differential casing comprises a first longitudinal split line, and a second transverse split line, to divide the differential casing into the two parts.

Others aspects and features of the invention will be apparent from the claims and following description of embodiments, made by way of example only, with reference to the following drawings, in which:

BRIEF DESCRIPTION OF THE FIGURES

Figure 1 shows a cross-sectional view of a differential according to an embodiment of the invention;

Figure 2 shows a perspective view of a partially assembled differential of an embodiment of the invention;

Figure 3 shows an exploded view of part of a crown wheel assembly according to an embodiment of the invention;

Figure 4A shows a perspective view of a crown wheel assembly according to an embodiment of the invention;

Figure 4B shows a cross-section through the assembly of Figure 4A;

Figure 5A shows a cross-section through a crown wheel assembly engaged with side gears according to an embodiment of the invention;

Figure 5B shows an alternative embodiment of a side gear assembly suitable for the differential of the invention;

Figure 6 shows an exploded view of a side gear sub-assembly of an embodiment of the invention;

Figures 7A to 7G show steps in an assembly method for assembly of a differential according to an embodiment of the invention;

Figures 8 to 10 show a differential casing of an embodiment of the invention;

Figure 11 shows an exploded view of a casing assembly for a differential according to an embodiment of the invention.

Figures 12 to 14 illustrate preferred and alternative means for attaching a cover for a casing of the differential of the illustrated embodiments.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

Figure 1 shows a cross-sectional view through a differential 1 according to an embodiment of the invention. The differential includes a casing assembly, which includes a structural casing 90 and casing covers 901 and 902. Assembled within the structural casing 90 are moving components of the differential, including a crown wheel assembly 10 comprising a crown gear 101, along with other features discussed in the following. Teeth of the crown gear 101 are formed on a crown wheel member 102, which also may also incorporate other features as are described in the following. The crown wheel 102 is rotatably supported in the casing 90 via a crown wheel bearing 180. The crown wheel bearing comprises an inner race 181, an outer race 182 and roller elements 183. The roller elements may be provided in adjacent arrays 183 and 183', axially spaced from one another. At least a part of inner race 181 may be integrally formed with the crown wheel 102, but is preferably a separate component assembled to the crown wheel 102. The inner race may comprise two inner race sub-sections 181 and 181', one sub-section corresponding to each of two separate arrays of roller elements 183 and 183'. As can be seen in the figure, an inner diameter of the inner race of the bearing 180 is greater than the inner diameter of the teeth of the crown gear 101. In preferred embodiments, at least the diameter of the outer race 182 is greater than the inner diameter of the crown gear teeth. It is also preferable that a diameter of the bearing 180 corresponding to a substantially central axis of roller elements 183, 183', of the bearing, is also greater than the inner diameter of the crown gear teeth. The inner diameter of the inner race 181 may be greater than the inner diameter of the teeth of the crown gear 101. As can be seen in the diagram, a majority of the diameter of the bearing 180 is contained between the inner and outer diameters of the teeth of the crown gear 101. Preferably, at least the roller elements of the bearing remain between the inner and outer diameter of the teeth of the crown gear 101. These features can define the location of the bearing, its inner and/or outer races and its roller elements 183 relative to the crown gear 101. Provision of such a bearing arrangement relative to the crown gear 101 provides a beneficial local distribution of loads generated by drive input to the crown gear 101. The loads are reacted locally to the crown gear 101 by the crown wheel bearing 180. These and other factors help this differential arrangement to contribute to the general durability of the overall differential assembly.

Contained within the inner diameter of the crown gear 101 are a plurality of pinion gears 121 and 122. These pinion gears are supported on a pinion mount, such as a spider or cross-pin, which comprises radial members 111 and 112. Further radial members and pinion gears may be comprised in the assembly but are not shown in this cross-section. The pinion mounts can comprise a plurality of radial members 111 and

112 mounted to, or preferably integrally formed with, a central portion 115. The pinion gears 120 and 121 are rotatably mounted to the radial members 111 and 112, preferably via respective thrust washers or thrust bearings 121a and 122a. Further details of the assembly will be described in relation to Figure 3.

Side gear members 150 and 160 carry arrays of side gear teeth 151 and 161, which engage teeth of pinion gears 121 and 122, along with any other pinion gears which may be included in the assembly but which are not shown in Figure 1, as will be apparent from the later Figures. The side gear members also comprise respective cavities 152 and 162, into which output shafts can be received to deliver drive from the differential to those of output shafts. A shaft 140 is provided and extends from first side gear member 150 to second side gear member 160. The function of the shaft is to retain the side gear members axially towards the pinion gears 121 and 122 to ensure engagement of the side gear teeth 151 and 161 with the pinion gears 121 and 122. The shaft 140 is engaged with the first side gear member 141 at a first end, preferably in a fixed manner. A seal may be provided between the shaft and the side gear member 150 to prevent the egress of lubricant within the crown wheel assembly to the cavity 152 of the side gear member 150. Alternatively, the shaft 140 may be integrally formed as a single component with side gear member 150. At a second end 142, the shaft 140 is engaged with side gear member 160. The opposing side gear members 150 and 160 must be able to rotate relative to one another for the differential to be able to perform its intended function. To enable this, a rotatable connection is provided between the shaft 140 and the second side gear member 160. This rotatable connection may be provided via a thrust bearing 170, which can be arranged so that the axial force maintaining engagement of the side gear teeth 151 and 161 with pinion gears 121 and 122 may be maintained while permitting relative rotation of the shaft 140 and the side gear member 160. Thrust bearing or thrust washer 170 may be maintained in place by fixing means such as a threaded member or nut 171. Flexible boots 156 and 166 shown in figure 7G may be provided, as are generally known for drive shaft arrangements to prevent dust ingress and lubricant egress from recesses 152 and 162. Side gear bearings 157 and 167 are provided in order to radially rotatably support the side gear members 150 and 160 within the casing 90. In this way, radial location of the side gears is provided by the side gear bearings, while axial location is provided by a combination of retention of the side gear members by the shaft 140 and engagement of the side gear members with the pinion gears 121 and 122. If the shaft 140 allows sufficient space between the side gear teeth 151 and 161 for there to be a degree of play between those teeth and the teeth of the pinion gears, then the whole side gear assembly can move axially, along the axis of a rotation of the side gears and shaft 140, to enable loads to be balanced between the side gear members and pinion gears 121. The amount of movement should of course be no more than the depth of the teeth of the side gears and/or pinion gears, and preferably significantly less, for example 50% less, to ensure that the teeth remain engaged during any axial movement of the side gears.

Figure 2 shows a view of a sub-assembly of the differential of Figure 1. The perspective view shows the side gear 101 which is arranged with crown gear teeth suitable for receiving a drive input to the crown wheel assembly of the differential from an input shaft. A central portion 115 of the pinion mount is arranged located radially inward of the pinion gears. In this embodiment, four pinion gears 121, 122, 123, 124 are arranged radially within the inner diameter of the teeth of the crown gear 101 and are mounted to radial members of the pinion mount, although other numbers of pinion gears such as 2, 3, 5, 6 or more, can be beneficial in certain arrangements. A crown wheel assembly mount 20 can be seen in Figure 2 and, as can be seen in Figure 1, in this embodiment, assembly mount 20 is integrally formed with the outer race 182 of the crown wheel bearing 180. There is also provided a flange 184, to which fixing means 21 can be fixed and engaged with the casing 90 of the differential to retain the crown wheel assembly within the casing 90. Thrust bearing 170 is shown, while side gear member 160 is not shown in Figure 2, to enable the internal components of the crown wheel assembly to be seen. Shaft 140 can be seen extending through an opening in central portion 115 of the pinion mount.

Figure 3 shows an exploded view of part of a crown wheel assembly according to an embodiment of an invention. The crown wheel assembly includes crown wheel 102, which carries the crown gear 101 and also includes a plurality of pinion mount receiving portions 135, 136, 137 and 138. The crown wheel carries at least one of those pinion mount receiving portions. The pinion mount receiving portions are configured to receive a radial end of the radial members 111, 112, 113 and 114 of the pinion mount 1100. In this way, when assembled with the pinion mount, loads can be directly transferred to the crown wheel by the pinion mount. As illustrated with regard to receiving portion 136, each mount receiving portion of the crown wheel may comprise opposed radial abutment portions 136a and 136c for retaining the radial member 112 in a radial direction within the receiving portion 136. An axial abutment, 136b may also be provided to provide axial location of the radial member 112 within the crown wheel. In this manner, a rotational drive delivered to the crown gear 101 can be transmitted to the pinion gears via the radial members of the pinion mount. One or more inner thrust washers 121b, 122b, 123b, 124b and outer thrust washers 121a, 122a, 123a, 124a may be provided for one or more of the pinion gears.

Figure 4A shows a crown wheel assembly 40 in which the pinion gears and pinion mount 1100 shown in Figure 3 have been assembled with the crown wheel 102. In order to retain the pinion mount within the crown wheel 102, retaining members 401, 402, 403 and 404 may be provided. These can be configured to provide a second radial abutment feature opposite the abutment feature 136b illustrated in Figure 3. This can help to axially retain the radial members of the pinion mount in the radial member receiving portions 135 to 138 of the crown wheel 102. The retaining members may further comprise bearing nut engagement features 405, 406, 407 and 408. These can be configured to engage a threaded nut 410. The threaded nut engages with a corresponding threaded portion 103 of the crown wheel. Rotation of the threaded nut 410 can therefore vary a degree of compression applied to the inner race 181 of the crown wheel bearing 180. This provides a degree of adjustability to a preload applied to the inner race of the bearing 180. The retaining members 401, 402, 403, 404, may provide a dual function of retaining the pinion mount 1100 within the crown wheel 102 and also retaining a preload on the crown wheel bearing 180. Figure 4b shows a cross-section through the assembly of Figure 4a to more clearly illustrate the numbered features described in relation to Figure 4a. As can be seen, the nut 410 may include engagement features 411 for engaging with the retaining members 401, 402, 403, 404 to inhibit rotation of the nut relative to the crown wheel 102. These features may be provided in the form of castellations, preferably on an axially facing surface of the nut. Figure 4b also illustrates the relatively compact nature of the crown wheel assembly of this embodiment of the invention. This compact arrangement enables the insertion of the crown wheel assembly 40 through a relatively narrow opening in casing 90, for assembly of the crown wheel assembly into the casing 90. As can be seen, the crown wheel bearing is substantially axially coincident with the pinion gears 121 and 122. More particularly, the crown wheel bearing is located at a position on an axis of rotation of the crown wheel 101 which is within the diameter of the pinion gears 121 and 122. Further, the crown wheel bearing 180 occupies a radial position which falls substantially between the inner and outer radii of the teeth of the crown gear 101. In this way, the moving components of the assembly are all accommodated within the outer diameter of the crown gear 101 and substantially within the outer diameter of the pinion gears. As can be seen in the Figure, the assembly as a whole only extends beyond a diameter of the pinion gears by approximately 5 to 10% of the diameter of the pinion gears. This ratio could be up to 30% of the diameter of the pinion gears. The crown wheel bearing and pinion gears are therefore both accommodated within the outer diameter of the crown gear 101 and the crown wheel bearing is accommodated axially on an axis of rotation of the assembly within the outer diameter of the pinion gears 121 and 122.

Figure 5A shows a cross-section through a sub-assembly of the differential of Figure 1. In Figure 5A output shaft engagement features 153 and 163 can be seen in further detail in their preferred form. As illustrated, they optionally comprise an array of axially extending recesses, preferably formed on an inner surface of each of the side gear members 150 and 160. Figure 5A also illustrates how alignment of the various rotating components in axial and radial directions is provided. As will be appreciated, when a drive is delivered to crown gear 101, engagement of the drive teeth with the crown gear teeth will generally provide a meshing force in the direction of arrow 51. The radial component of this force can be reacted in the crown wheel bearing by a radial component of forces acting at arrow 52. The axial component of the force can be reacted by axial components of forces acting at both arrows 52 and 53 in the crown wheel bearing. Any axial forces occurring the opposite direction can be reacted through the ring bearing by axial components of forces acting in a direction of arrows 54 and 55. Substantially radial retaining forces may be provided in the direction of arrows 60 by the radial bearings 157 and 167 shown in Figure 1.

Transmittal of drive from the pinion gears 121 and 122 to the side gears will deliver axial forces to the side gears as illustrated by arrows 56, 57, 56' and 57'. These forces are reacted through the shaft 140 via the thrust bearing 170 in the direction of arrows 58 an at the connection point of the shaft 140 to side gear member 150 by arrows 59. Radial location of the side gear members 150 and 160 is provided by the side gear bearings' (not shown) acting as indicated at arrows 60.

As shown in Figure 5B, an alternative configuration for the side gear assembly can be envisaged in which either the shoulder 701 of the shaft 140, or an inboard race 703 of the thrust bearing 170, is provided with a part-spherical surface 7031 that may engage with a corresponding part-spherical surface 1531 on the side gear member. This arrangement will allow the side gears to rotate relative to one another around an axis perpendicular to the principal axis of rotation 500 of the side gears. This can enhance the capability of the side gears to assume a position of optimum load sharing between the pinion gear meshes. Otherwise stated, the respective side gear members may rotate, in operation of the differential, around different principal axes of rotation which are slightly non-parallel to one another. This additional flexibility can provide an improvement to the durability of the differential mechanism.

Figure 6 shows an exploded sub-assembly of side gear members with the connecting shaft 140 of an embodiment of the invention. A seal 155 as shown in Figure 1 may be located on a seal-receiving surface 716 of the side gear member 150. A corresponding seal may be provided for location in a similar manner on side gear member 160 at seal receiving surface 718. When assembled, the shaft 140 is retained within side gear member 150 as illustrated in Figure 5. The shaft may have a shoulder 701 for engaging the periphery of an opening 159 of the side gear member 150. The shaft 140 may alternatively be integrally formed as part of side gear member 150. The shaft is retained in side gear member 160. Shaft fixing means may be provided in the form of a nut or other threaded member 706. Fixing means 706 engages a thrust washer 706 which engages in turn an outboard race 705 of the thrust bearing, followed by roller element 704, an inboard race 703, to permit the shaft 140 to engage with side gear member 160 to transfer axial loads there between, while also permitting free rotation of the shaft 140 relative to side gear member 160. Figure 6 shows a preferred embodiment in which the side gears include integrated constant velocity joint outer races, which are also referred to herein as side gear members. The term side gear member can therefore refer to the side gear members, with or without the constant velocity joint outer races included. In one preferred embodiment, the side gears may comprise teeth, which are preferably cut around the inboard circumference of a cup. Such features may form the outer raceway for an inboard constant velocity joint being open at the outboard end of the cup. Internal features may be in the form of straight or angled tracks that receive the rolling or sliding elements of a constant velocity joint or may be in the form of spline teeth that transmit drive directly to a mating spline that is integral with, or attached to the driveshaft. Further detail of such an embodiment can be seen in Figure 7G.

Figures 7A to 7G illustrate an assembly process for a differential according to an embodiment of the invention. As shown in Figures 7A and 7B, the crown wheel assembly 80 is introduced into the casing 90 through a crown wheel assembly opening 91. In the preferred embodiment, the casing is arranged such that assembly of crown wheel assembly into the casing 90 is from above, but the orientation of the casing is not essential and the casing may be configured such that the crown wheel assembly can be introduced from substantially any direction relative to gravity. A more important factor is the direction of insertion relative to the axis of rotation of the crown wheel assembly and/or of the side gears once mounted in the side gear openings. The crown wheel assembly is introduced in a substantially radial direction with respect to the crown wheel assembly, i.e. sideways or perpendicular with respect to the axis of rotation 710 of the crown wheel assembly, in a direction indicated by arrow 700. The crown wheel assembly 80 also approaches the axis of rotation 92 of the side gear openings 93 and 94 from a direction substantially perpendicular to that axis. To correctly enter the opening 91 it can be seen that the direction of approach relative to the axis 92 is not perfectly perpendicular, but the angle of approach is non-parallel to the axis 92 and is generally from a non-zero angle with respect to the axis 92. The angle of approach is preferably more than 10 degrees, more preferably more than 30 degrees and more preferably more than 60 degrees, with respect to the axis of rotation 92 of the crown wheel once assembled in the casing 90.

As illustrated in Figure 7C, once the crown wheel assembly 80 is substantially located in alignment with the axis of rotation of the side gear openings 93 and 94, the crown wheel assembly 80 can be translated substantially along the axis of the side gear openings in the direction illustrated by arrow 801. This engages the crown wheel bearing 180 in a substantially annular crown wheel bearing receiving recess 98 provided in the casing 90.

Figure 7D illustrates the insertion of the side gear members 150 and 160 from opposing axial directions, through the side gear openings 93 and 94 of the casing. The side gear members are introduced along this axis of the side gear opening until the side gear teeth 151 and 161 are engaged with the pinion gears 121 and 122 of the crown wheel assembly 80.

As illustrated in Figure 7E, shaft 140 is then introduced through an opening of at least the second side gear member 160 to engage with the thrust bearing 170 as described in relation to Figures 1 and 6. As already mentioned, the shaft 140 may be integrally formed with side gear member 150 and may be introduced into the crown wheel assembly simultaneously with the step as shown in Figure 7D above. Figure 7E also illustrates the provision of a fixing means 706 on the shaft 140 to attach the shaft 140 to the side gear member 160 in a rotatable manner as previously described.

Figure 7F illustrates a further step in which radial bearings 157 and 167 are introduced between the casing and the side gear members 150 and 160. Seals 155 and 165 can then be provided to seal the internal crown wheel cavity from the external environment to the casing.

Figure 7G illustrates a step where the output shafts 710 and 720 are introduced into cavities 152 and 162 of the side gear members 150 and 160.

The connection between the output shaft 710 and 720 and the side gear members 150 and 160 may be by means of a homokinetic joint, otherwise known as a constant velocity (CV) joint. An outer race of the homokinetic joint may be included in the side gear members 150 and 160 by provision of internal, preferably axially extending, recesses. Preferred details of such an arrangement are also described in relation to Figure 6 above. Corresponding engagement members may be provided as projections 730 and 731, located on or attached to the output shafts, which projections engage with the axially extending grooves and are able to move along those grooves. The engagement projections provided on the output shafts may be spherical or at least substantially part-spherical to enable the output shaft to rotate with the side gear member to which it is connected while its axis of rotation is non-parallel to the axis of rotation of the side gear member 150.

As can be appreciated from the above, the configuration of the differential to include a discreet sub-assembly, in particular the crown wheel assembly, allows the assembly process for a differential to be rendered more straight forward and efficient. Since the principal load bearing housing components are located between the single crown wheel bearing and the casing, the process of measurement and selection of appropriate adjustment members, such as shims, can be simplified as compared to the process where multiple load bearing connections are provided on plural housing components.

The size and position of the crown wheel bearing relative to the crown gear teeth can help to ensure that the crown wheel bearing is at least partially immersed in oil when the differential is at rest or performing slow manoeuvres at steep angles of pitch or roll of a vehicle in which it is installed. This can improve the overall lubrication supplied to the bearing and can improve its durability.

The arrangement of the pinion gears on the radial members illustrated in the figures allows for a simplified assembly process compared to known differential transmissions. A lesser degree of skill and physical strength is therefore required to assemble the crown wheel assembly described herein as compared to known differentials. The radial members may be tubes which are provided to react side gear mesh forces generated in the pinion gears.

The radial support of the side gear members described herein is generally stiffer than known differential mechanisms. This is due to the way in which the radial bearings are provided in the illustrated locations, while axial forces are dealt with via the crown wheel bearing as described earlier. The axial location of the side gears is determined only based upon their location relative to the crown wheel assembly and axial location of all rotating components of the differential is therefore set by the location of the crown wheel. This effect, combined with the reduction in overall mass of the assembly due to the configurations described, leads to a reduction in unwanted noise and vibration emitted by the mechanism in use.

The assembly steps described herein are simplified compared to known differentials and they also facilitate partial disassembly of the differential without the need to remove the differential from the vehicle. This can provide simpler and easier inspection of maintenance for the differential. The described arrangement also provides improved lubricant flow to the mesh and gears and a reduction in mass, rotation or inertia and size of the overall assembly.

Figure 8 shows a casing component for the differential of an embodiment of the invention. The casing 90 is preferably constructed as a single rigid load bearing component. The casing may be combined with additional covers to seal the internal cavity 95 of the casing once the differential mechanism has been assembled within the cavity of the casing 90. The casing 90 comprises a pair of substantially opposed side gear openings 93 and 94, between which there is provided crown wheel cavity 95. A drive input opening 96 is provided. The drive input opening 96 has its longitudinal axis oriented substantially perpendicularly to the axis of the side gear openings 93 and 94 and provides an opening into the crown wheel cavity 95. The casing provides a substantially closed structural side 97 which is substantially opposite the drive input opening 96. The casing has at least one crown wheel assembly opening 910, which has a width perpendicular to the axis of the side gear openings which is sufficient to receive the crown wheel assembly in the crown wheel cavity 95. The crown wheel assembly opening 910 must therefore have a width in that direction which is greater than the diameter of a crown wheel assembly receiving area 98 which is configured to receive and retain the crown wheel bearing of the crown wheel assembly 80. The casing 90 may also include plural mounting portions 920, 921 and 922, for mounting the casing to a chassis of a vehicle, for example. Cover attachment points 931, 932 and 933 cover may be provided for attaching a cover for covering the crown wheel assembly opening 910 in order to seal the crown wheel cavity 95.

Figure 9 shows a plan view of the casing 90 of Figure 8. Additional cover attachment point 934 can be seen in addition to those shown in Figure 8. It will be apparent that the receiving area for mounting the crown wheel bearing is provided in part by an arcuate cross-member 940, which extends from adjacent the drive input opening 96 to the opposing structural side 97 of the casing. A reinforcing member 941 may extend from a side adjacent one of the side gear openings 93 to the arcuate support member 940 to provide additional structural strength thereto. The crown wheel assembly opening 910 can be seen more clearly in Figure 9 and, as can be seen, its diameter at its widest point, between locations indicated as 911 and 912, has a width which is greater than the crown wheel assembly to be housed in the crown wheel cavity, and is also greater than the diameter of the substantially annular receiving portion into which the crown wheel is to be mounted. The structural casing may include further openings 901 and 902. A further opening on an opposing side of the crown wheel cavity 95 may be provided in addition to or instead of crown wheel assembly opening 910. This opening 915, seen as a lower opening in Figure 9, need not necessarily be sufficiently wide for the crown wheel assembly to pass through. Additional openings such as 901, 902 and 915 may be provided to reduce weight and material of the structural casing 90.

Figure 10 shows a further perspective view of the structural casing 90. Here it can be seen that a lower reinforcing member 942 may also be provided substantially opposite reinforcing member 941, so that the arcuate portions 940 and 943 are provided with additional structural support from the structural casing element which surrounds the crown wheel cavity 95. The casing therefore comprises a main structural element which substantially surrounds the crown wheel cavity in a plane perpendicular to the axis of the side gear openings 93 and 94 and the input opening 96. The casing may further comprise at least one arcuate member 940 which extends from a first side of the main structural casing to a second side of the main structural casing to provide a substantially annular support to the crown wheel bearing when the crown wheel assembly is mounted in the cavity 95.

The casing 90 is preferably a single rigid load bearing casing component, which includes no joints and requires no assembly in order to form the structural load carrying casing for the differential. The casing assembly may further comprise one or more non-load bearing covers. The covers may be combined with one or more sealing gaskets. In this manner, the load bearing housing can be made from a single component which is more efficient from a manufacturing and assembly point of view and the structural housing can be designed specifically with structural load bearing in mind. The provision of non-load bearing covers to seal the internal cavity of the differential casing assembly removes the need for the structural housing to provide a sealing function from the external environment and so this can reduce the usage of heavy materials required for structural casing elements. The non-structural housing components may be formed from different materials, preferably less dense materials, than the structural casing. The structural casing 90 provides location and support for the mechanisms of the differential and reacts substantially all significant loads produced in the differential mechanism and side gears during use. The cavity 95 provides an internal volume with an internal surface to which the differential mechanism can be mounted. The casing also includes at least one aperture sufficiently large to allow insertion of the crown wheel assembly into the cavity 95. Providing a casing consisting of a single component with no joints removes the need to accurately position bearings across a split line in the casing. This improves the ease with which bearing location features may be manufactured to provide accurate relative bearing positions. A single piece structural casing removes any need for a bolted flange between multiple load carrying housing components. This reduces the complexity of the assembly and can reduce a mass of the component compared to previous differential housing designs. Manufacturing costs are also reduced, since only one load carrying component per differential housing assembly is necessary. The structural casing may be constructed from a material which is conductive of heat. The casing may also include features such as fins to increase the external surface area and improve heat dissipation capability. The casing may provide features, pathways or channels for directing lubricating oil to and from the bearings mounted in the casing.

Figure 11 shows an arrangement of cover components 1101 and 1102 which may be used in conjunction with the structural casing 90 in order to provide a sealed internal crown wheel cavity 95 within the differential housing assembly. While the structural housing 90 has a primarily structural function, to react and transmit loads generated at the input opening 96 and side gear opening 93 and 94, the covers 1101 and 1102 have a primarily sealing function, to retain lubricants within the cavity 95 and to protect the components within the cavity 95 from the ingress of foreign matter such as grease, dirt, water or other unwanted materials from entering the crown wheel cavity 95.

The covers 1101 and 1102 may be manufactured from polymeric materials or an elastomer. The material may be reliably manufactured with a lower section thickness compared to the structural material used for the structural casing. This can allow an overall reduction in mass as compared to conventional differential casing assemblies. The cover members 1101 and 1102 may be flexible and so would not carry or react a significant proportion of loads transmitted through the casing assembly during use of the differential drive. The use of flexible covers may allow them to better tolerate or accommodate distortion of the structural casing due to elastic deformation under load, distortions due to the manufacturing process of the casing, or differential thermal expansion between the casing and the cover members. Since limited loads are provided in the cover members 1101 and 1102 during use, then when subjected to casing distortion or impact from foreign objects, then the overall stresses are reduced and the cover members can therefore be generally more resistant to shocks as compared to known structural housing components. One or more of the cover components may comprise an opening 1103 provided for drainage and/or refill of oil in the crown wheel cavity 95. One or more apertures may be provided for venting air or vapours from inside the cavity, or allowing air to enter the cavity to equalise any pressure differences between the cavity 95 and the environment external to the cavity 95. The cover members may comprise fins or other features for increasing surface area to enhance the dissipation of waste heat to the environment.

As can be seen in Figure 11, gasket members 1104 and 1105 may be provided between the structural casing and the cover members 1101 and 1102 to improve the seal created between the covers and the structural casing. In the illustrated example, the covers are configured to be fixed to the structural casing using removable fixing means such as bolts 1120, 1121, 1122, 1123, 1124, 1125 and 1126. The cover members include cover fixing arrangements 941, 942 and 943, for example, which may be configured to engage corresponding attachment points 931, 932 and 933 of the structural casing. The attachments points may be provided outside the periphery of the sealing gasket 1104 or 1105. The attachment means 1123 to 1126 therefore then engage the attachment portions 941 to 943 of the cover member 1101 and engage with the attachment points 931 to 933 of the structural casing to hold the cover in place.

Details of optional features for attaching the covers to the casing are shown in Figures 12 to 14. The arrangement of Figure 13 is preferred, but any of the illustrated means may be implemented. The cover components may be fixed to the housing component through the use of over-moulding or melting onto a feature on the housing component. As shown in Figures 12A and 12B, this may be achieved by manufacturing a cover component 1200 from a thermoplastic material that may be permanently deformed at high temperatures and by producing a feature, such as a cavity 1201 and a projection 1202 extending over the cavity 1201, on the housing component that can receive the cover component. The cover component may be fixed to the housing component by applying heat and pressure to the interface between the casing 90 and the cover 1200 until the cover component deforms and assumes the space available in the cavity on the casing 90. The deformation of the cover produces a conformal joint between the cover 1200 and the casing. This joint retains the cover and provides a seal function as illustrated in Figure 12B.

Each gasket 1104 and 1105 of Figure 11 may be formed of an elastomeric material that is elastically deformed by the fitment of the cover. A re-entrant lip may exert a force on the cover component once it is assembled onto the casing in order to retain the cover to the casing and gasket assembly. This may be achieved by manufacturing the cover such that it is too large to fit into the corresponding feature on the gasket and therefore the gasket must be elastically deformed in order to receive the cover component. The elastic deformation of the cover may cause a reaction force to be exerted by the gasket onto the cover. The form of the gasket profile directs this reaction force such that it holds the cover component in the correct position in the housing assembly. Such an arrangement is shown in Figure 13. As illustrated, the cover 1200 may engage the casing 90 via a gasket member 1301. The gasket member may comprise a first recess which engages a lip 1302 formed on the casing 90. A second recess 1303 of the gasket may extend substantially perpendicularly to the first recess to engage a lip 1304 of the cover member 1200. Compression of the gasket member in an outward direction by compression of the cover member 1200 causes the lip 1305 of the gasket to retain the lip 1304 of the cover in place. The gasket member 1301 may be deformed so as to surround the perimeter of the cover component 1200. The cross section of the gasket component may be designed in the manner described. Deformation of the gasket into a hoop shape causes circumferential compression in the inner portions of the gasket - for example at the tips of lips 1306 and 1305. This can cause the lips to tend to collapse toward the lip 1304 of the cover member which can cause the gasket to grip the cover component, thereby increasing the retention force on the cover component. Dust lip 1306 can act to prevent dust and/or foreign body ingress to the interior of the differential. The gasket 1301 may be retained on lip 1302 of the casing 90 by press fit, adhesive, and/or by removable retaining means as described in relation to Figure 11.

The gasket and cover components may be manufactured from a material that has a high damping coefficient. This property prevents the transmission of noise and vibrations from the housing component to the covers and thereby reduces the emission of noise from the differential transmission to the environment. This is achieved by using the elastic hysteresis of the gasket material to dissipate the kinetic energy of the covers into the environment as heat rather than sound.

Figure 14 shows an alternative configuration where the cover has been deformed to conform to a retaining feature on the casing 90. Here, the housing is deformed to conform to either side of a lip 1302 formed on the casing 90. Thus an inner lip 1401 is formed on the cover to engage an inner edge of a lip 1302 formed on the casing and an outer lip 1402 may additionally or alternatively be formed around an outer edge of the lip 1302 formed on the housing. The deformation may be induced by heating the cover member 1200 and forming the cover member over and around the lip 1302 of the casing. A primer may be applied to the lip 1302 prior to forming the cover around it to assist with adhering the cover to the lip 1302. The cover may alternatively be pre-formed to a shape which conforms to the lip 1302 and adhered to the lip using an adhesive. Lip 1302 may comprise an undercut such that an overhang of the lip prevents the gasket from lifting off the lip 1302.

Figure 15 illustrates how fins 901 may be provided on the casing 90 to increase its surface area to aid in the dissipation of heat to the surrounding area. Similarly, fins 1501 may be provided on the cover 1500 to provide the same effect.

Figure 16 illustrates cover members of the differential may have features that deflect impacts from foreign bodies and may minimise damage from such impacts. These features may take the form of external surfaces 1600 and 1601 which are convex in form and therefore have inherent strength in compression. The external surfaces may also have a low angle of incidence relative to the driven motion of the vehicle and hence the trajectory of impacting foreign bodies.

As described above, the casing component of Figures 8 to 11 is a one-piece component. However, in other embodiments, the casing component is formed from two or more separate pieces that are then fixed together to define the casing component.

Figure 17 shows one example; in this case a two-piece casing component. This two-piece casing component is functionally the same as the one-piece casing component of Figures 8 to 11. Therefore, the description for Figures 8 to 11 above substantially applies, and like features are indicated with like reference numerals, but with the prefix "2". Only the major differences between the two casing components will be described.

The casing 290 is again constructed to be a single rigid load bearing component, but is formed from two separate parts, a first part 291, and a second part 292, which together define the casing 290.

In this example, the casing 290 has a longitudinal split line 2923 and a transverse split line 2924. These split lines 2923, 2924 define the boundaries between the first and second parts 291, 292 of the casing. As will be described in more detail below, the casing 290 is arranged so that the first and second parts 291, 292 can be attached to one another at the split lines 2923, 2924 to define a single casing 290.

The casing 290 provides a substantially closed structural side 297 substantially opposite the drive input opening 296, but it can be seen that, unlike the casing 290 of Figure 17, the structural side 297 is defined across the two parts 291, 292. As can be seen most clearly in Figures 18 to 20, the longitudinal split line 2923 substantially bisects the structural side 297 of the casing 290 to define a first longitudinal planar surface 2925 on the first part 291 (see Figure 19), and a second longitudinal planar surface 2926 on the second part. When the first and second parts 291, 292 are brought together during assembly, the first longitudinal planar surface 2925 engages the second longitudinal planar surface 2926 (described in more detail below).

In this example, a first flange portion 2927 extends longitudinally outwardly from the first part 291 of the casing at the longitudinal split line 2923 and a second flange portion 2928 extends longitudinally outwardly from the second part 292 of the casing at the longitudinal split line 2923. The first and second flange portions 2927 and 2928 increase the longitudinal length of the first and second longitudinal planar surfaces 2925, 2926 respectively, to provide access and a means to enable the first part 291 to be fixed to the second part 292 at the longitudinal split line 2923. In this example, the first and second flange portions 2927, 2928 have corresponding apertures 2929, the apertures 2929 being arranged such that bolts 2930 can be inserted into the apertures to fix the first part 291 to the second part 292. The apertures 2929 may be threaded. In this example, the apertures 2929 of the first flange portion 2927 only extend from the first longitudinal planar surface 2925 part-way through the first flange portion 2927. In this example, the apertures 2929 of the second flange portion 2928 extend all the way through the second flange portion 2928, and include a wider section for locating a head of one of the bolts 2930 (see Figure 21).

The transverse split line 2924 defines a first transverse planar surface 2931 on the first part 291 (see Figure 20), and a second transverse planar surface 2932 on the second part 292. In this example, a first flange portion 2933 extends transversely outwardly from the first part 291 of the casing at the transverse split line 2924 and a second flange portion 2934 extends transversely outwardly from the second part 292 of the casing at the transverse split line 2924. The first and second flange portions 2933 and 2934 increase the transverse length of the first and second transverse planar surfaces 2931, 2932 respectively, and, in a similar way to the longitudinal flange portions 2927, 2928 described above, provide access and a means to enable the first part 291 to be fixed to the second part 292 at the transverse split line 2923. In this example, the first and second flange portions 2931, 2932 have corresponding apertures 2929, the apertures 2929 being arranged such that bolts 2930 can be inserted into the apertures to attach the first part 291 to the second part 292.

To assemble the casing 290, the second part 292 is brought towards the first part 291 in the direction of the arrow D (see Figure 20) so that the first longitudinal planar surface 2925 engages the second longitudinal planar surface 2926 and the first transverse planar surface 2931 engages the second transverse planar surface 2932. Bolts 2930 are then passed through the apertures 2929 of the flange portions 2927, 2928, 2933, 2934 to secure the first and second parts 291, 292 together to form the casing 290.

The split lines 2923, 2924 provide simple means to divide the casing 290 into first and second parts 291, 292. It is clear that the exact locations of the split lines 2923, 2924 in the longitudinal and transverse directions can be varied, as desired, without affecting the method of assembly of the casing 290.

Although the bolt arrangement described is preferable, it is clear that any suitable attachment arrangement can be used to attach the first part 291 to the second part 292. For example, the first and second parts 291, 292 could be attached to one another at the split lines 2923, 2924 with an adhesive, or by welding the two parts together.

The first and second parts 291, 292 are described as having planar surfaces arranged to engage each other when the casing 290 is assembled, but it is clear that it is not essential that the engaging surfaces of the first and second parts 291, 292 are planar;

the surfaces of the first and second parts 291, 292 must simply be suitable to engage each other. For example, the surfaces could be stepped, angled or rounded, provided they correspond to one another such that they can engage and enable the first and second parts 291, 292 to be attached together. Figures 22 to 24 show a particularly advantageous sealing arrangement. The arrangement, like the boots 156 and 166 shown in figure 7G, helps to prevent dust ingress and lubricant egress from recesses 152 and 162. Like features from the arrangement of Figure 7G are indicated with like reference numerals, but with the prefix "3".

Looking at Figure 23, an output drive shaft 302 (which is intended to be in communication with the wheels of a vehicle in a known manner) is connected to a side gear 3150 via a constant-velocity (CV) joint 304. The CV joint 304 enables articulation of the drive shaft 302 relative to the side gear 3150 in a known manner.

A sealing arrangement substantially seals the CV joint 304. A sheath is provided, in this case a flexible boot 3156, the boot 3156 being arranged to surround the drive shaft 302 and CV joint 304, to help prevent dust ingress into the differential, as well as help prevent lubricant egress out of the differential, from side gear recesses 3152 and 3162.

In this example, the boot 3156 engages the casing 390 of the differential at a first end 3158 and the drive shaft 302 at a second end 3164. It can be seen that the boot 3156 does not directly engage the drive shaft 302; a bearing 3168 and a rotary seal 3169 are provided between the second end 3164 and the drive shaft 302. In this example, the seal 3169 is located outwardly of the bearing 3168, to help prevent lubricant leakage and foreign object ingress. The bearing 3168 is a rotary bearing and the seal 3169 is a rotary seal member, such that the drive shaft 302 can rotate relative to the boot 3156.

The boot 3156 is rotationally fixed relative to the casing 390. In this example, the boot 3156 is directly attached to the casing 390, to form a seal between the boot 3156 and the casing 390. This is a preferable arrangement, as there is then no need for a further seal to be provided between the boot 3156 and the casing 390. However, in an alternative example, a seal could be provided between the casing 390 and the boot 3156, or between the side gear 3150 and the boot 3156, to further prevent lubricant leakage and foreign object ingress.

The boot 3156 is of a known design. It is preferable that the boot 3156 is made of a durable material so it can withstand the articulation of the CV joint 304 as well as the risk of impact with a foreign object in use. Therefore, the boot 3156 is typically made of rubber or a similar durable flexible material.

The benefit of the sealing boot arrangement of Figures 22 to 24, compared to the arrangement of Figure 7G, is that the large diameter seals (155 and 165) are no longer required. Instead a smaller diameter seal 3169 can be used, as it seals the boot at the drive shaft 302 rather than at the side gear 150. This reduces the frictional drag losses within the system and therefore improves the overall efficiency of the differential.

Although only one sealing boot arrangement has been described, it is clear that this arrangement is suitable for use at both sides of the differential, as shown in Figures 22 and 24.

Advantages of the invention are applicable to other types of transmission where internal components are housed within a structural casing, such as gearboxes, engine blocks and other rotating machinery.

CLAIMS

1. A differential casing assembly, comprising:

a structural casing, comprising first and second opposed side gear openings for locating side gears;

a crown wheel cavity, for receiving a crown wheel assembly of a differential substantially between, and substantially coaxially with, the side gear openings;

a crown wheel opening in the structural casing, the crown wheel opening being arranged to allow at least one component of the crown wheel assembly to be introduced into the crown wheel cavity via the crown wheel opening;

an input opening for receiving a drive input to the crown wheel assembly;

the structural casing configured to react loads generated between the crown wheel assembly, side gears and input opening when the differential is driven; and

at least one substantially non-structural cover arranged to seal the crown wheel cavity by covering the crown wheel opening.

2. A differential casing assembly according to claim 1, wherein the substantially non-structural cover is flexible.

3. A differential casing assembly according to claim 1 or claim 2, wherein the substantially non-structural cover is capable of deforming sufficiently to contact features of the structural casing covered by the cover, and of elastically recovering from such deformation.

4. A differential casing assembly according to any of claims 1 to 3, wherein the substantially non-structural cover is fixed to the structural casing by an undercut rim and a compressible gasket to provide a seal to the structural casing.

5. A differential casing assembly according to any of claims 1 to 4, wherein the cover is affixed to the structural casing via an adhesive.

6. A differential casing assembly according to any of claims 1 to 5, wherein the cover comprises a material suitable for being melted locally to conform to features of the casing to fix the cover thereto.

7. A differential casing assembly according to claim 6, wherein the cover is fixed to the structural casing by staking and sealing.

8. A differential casing assembly according to any of claims 1 to 7, wherein the cover comprises reinforcing fibres.

9. A differential casing assembly according to any of claims 1 to 8, wherein the cover comprises a material of lower density than the structural casing.

10. A non-structural cover for sealing openings of the differential casing assembly of any of claims 1 to 9.

11. A non-structural cover according to claim 10, wherein the cover is capable of deforming sufficiently to contact features of the structural casing when assembled with the casing.

12. A non-structural cover according to claim 10 or 11, wherein the cover is made of an elastomer or flexible plastic.

13. A non-structural cover according to claim 12, wherein the cover has a thinner cross section than the structural casing.

14. A differential according to any preceding claim, wherein the structural casing is a single structural component.

15. A differential according to any of claims 1 to 13, wherein the structural casing is a multi-part structural component.

16. A differential comprising:
a casing; and

a crown wheel assembly, comprising:

a crown gear carrying crown gear teeth for receiving an input drive to the differential;

a plurality of pinion gears located at a radial position within an inner radius of the crown gear teeth, each pinion gear having an axis of rotation which is substantially radial with respect to the crown wheel;

first and second side gears arranged to engage the pinion gears, the side gears each having respective axes of rotation which are substantially perpendicular to the axis of rotation of the pinion gears, such that drive input to the crown gear is transferred to the side gears via the pinion gears; and

a pinion mount comprising a central portion and a plurality of radial members, the radial members each extending from the central portion and engaging the crown gear , at least one of the radial members being integrally formed with the central portion;

wherein at least one of the pinion gears is rotatably mounted to a radial member of the pinion mount.

17. A differential according to claim 16, wherein the radial spaces between the pinion gears contain no pinion carrier components.

18. A differential comprising:

a casing; and

a crown wheel assembly, comprising:

a crown gear carrying crown gear teeth for receiving an input drive to the differential;

a plurality of pinion gears mounted radially inward of the crown gear, each having an axis of rotation which is substantially radial with respect to the crown wheel;

first and second side gears arranged to engage the pinion gears, the side gears each having respective axes of rotation substantially perpendicular to the axis of rotation of the pinion gear, such that drive input to the crown gear is transferred to the side gears via the pinion gears; and

a shaft fixedly connected to and extending from the first side gear and rotatably connected to the second side gear, so as to axially retain the first and second side gears in engagement with the pinion gears, while allowing relative rotation of the side gears.

19. A differential comprising:

a casing; and

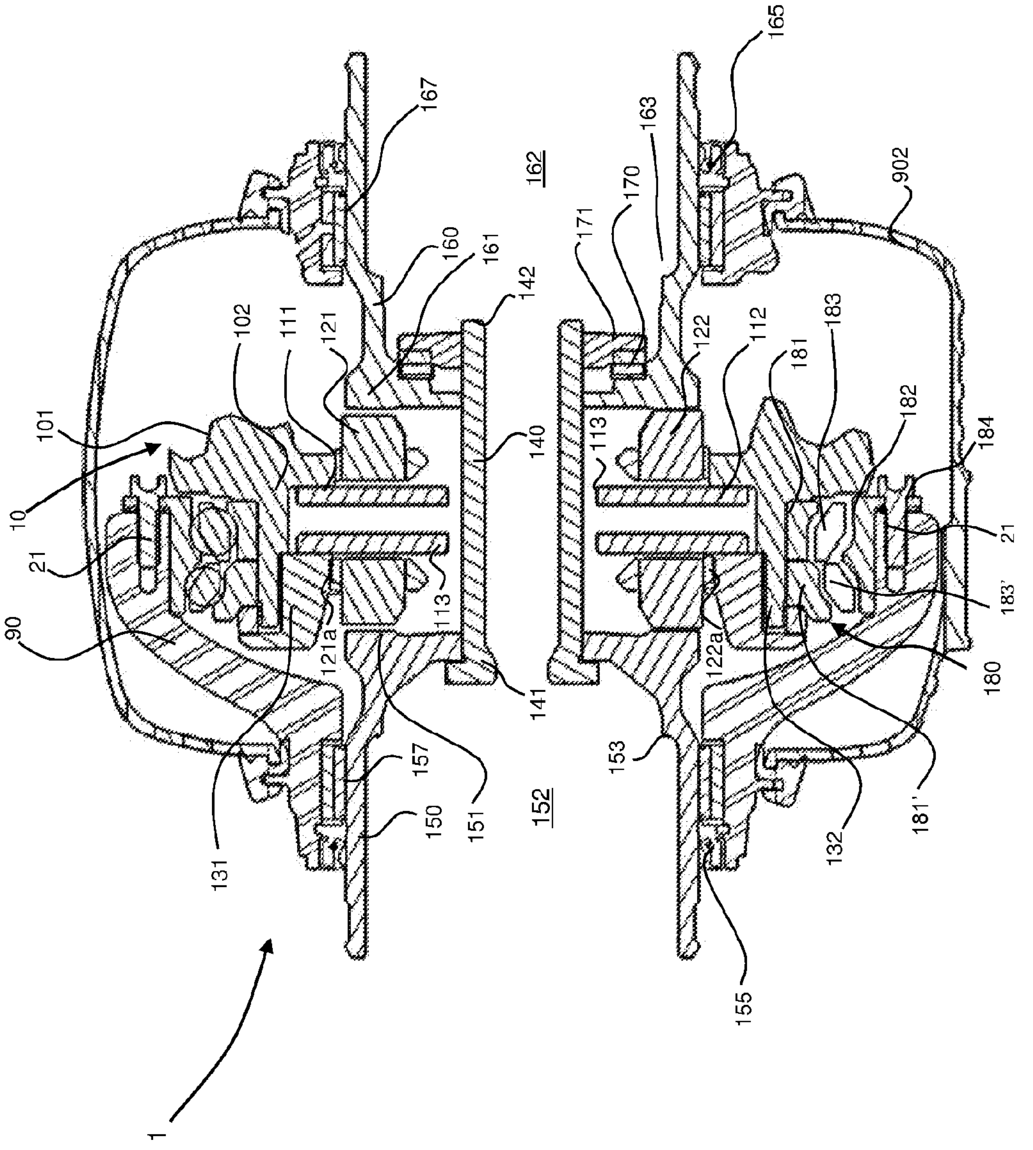
a crown wheel assembly, comprising:

a crown gear carrying crown gear teeth for receiving an input drive to the differential;

a plurality of pinion gears mounted radially inward of the crown gear, each having an axis of rotation which is substantially radial with respect to the crown wheel;

first and second side gears arranged to engage the pinion gears, the side gears each having respective axes of rotation substantially perpendicular to the axis of rotation of the pinion gear, such that drive input to the crown gear is transferred to the side gears via the pinion gears; and

a shaft integral with and extending from the first side gear and rotatably connected to the second side gear, so as to axially retain the first and second side gears in engagement with the pinion gears, while allowing relative rotation of the side gears.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165
167
170
171
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113
122
122a
132
153
155
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181'
182
183
183'
184
902

FIGURE 1

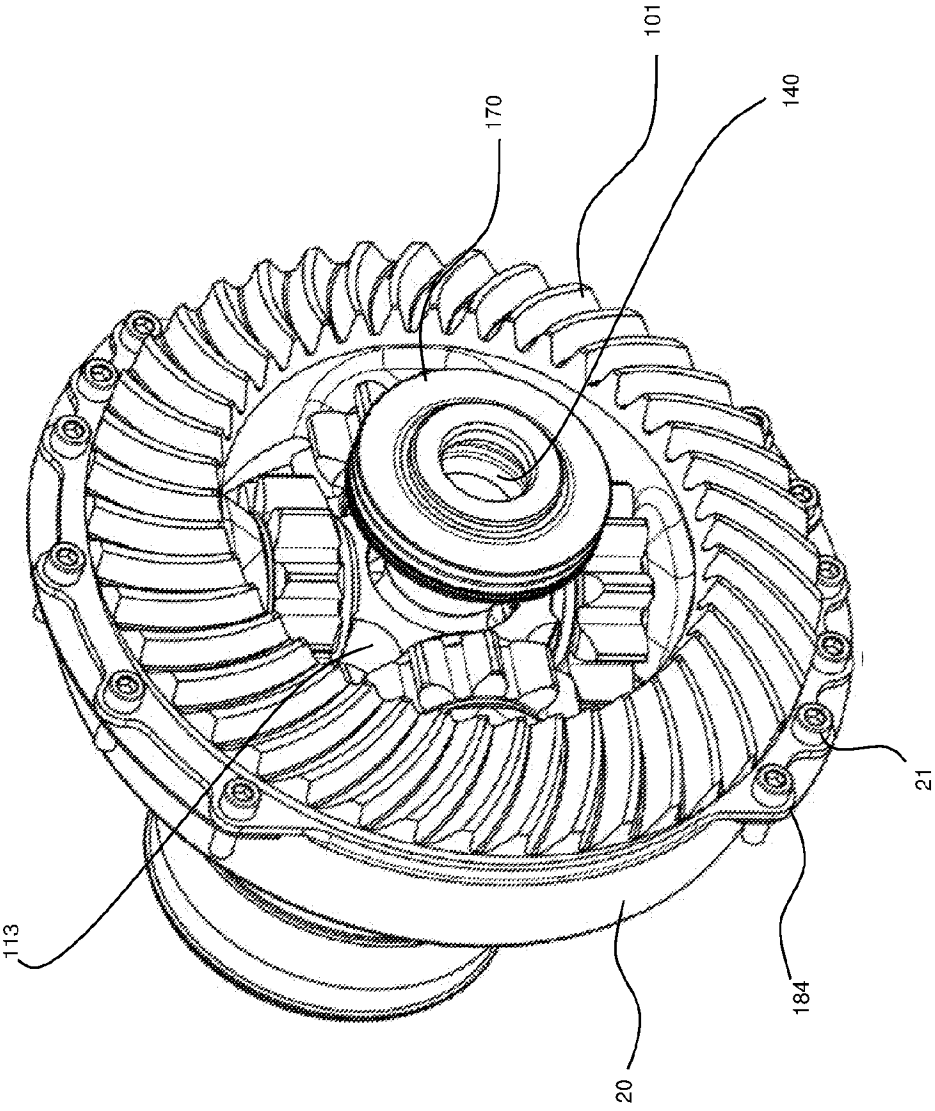
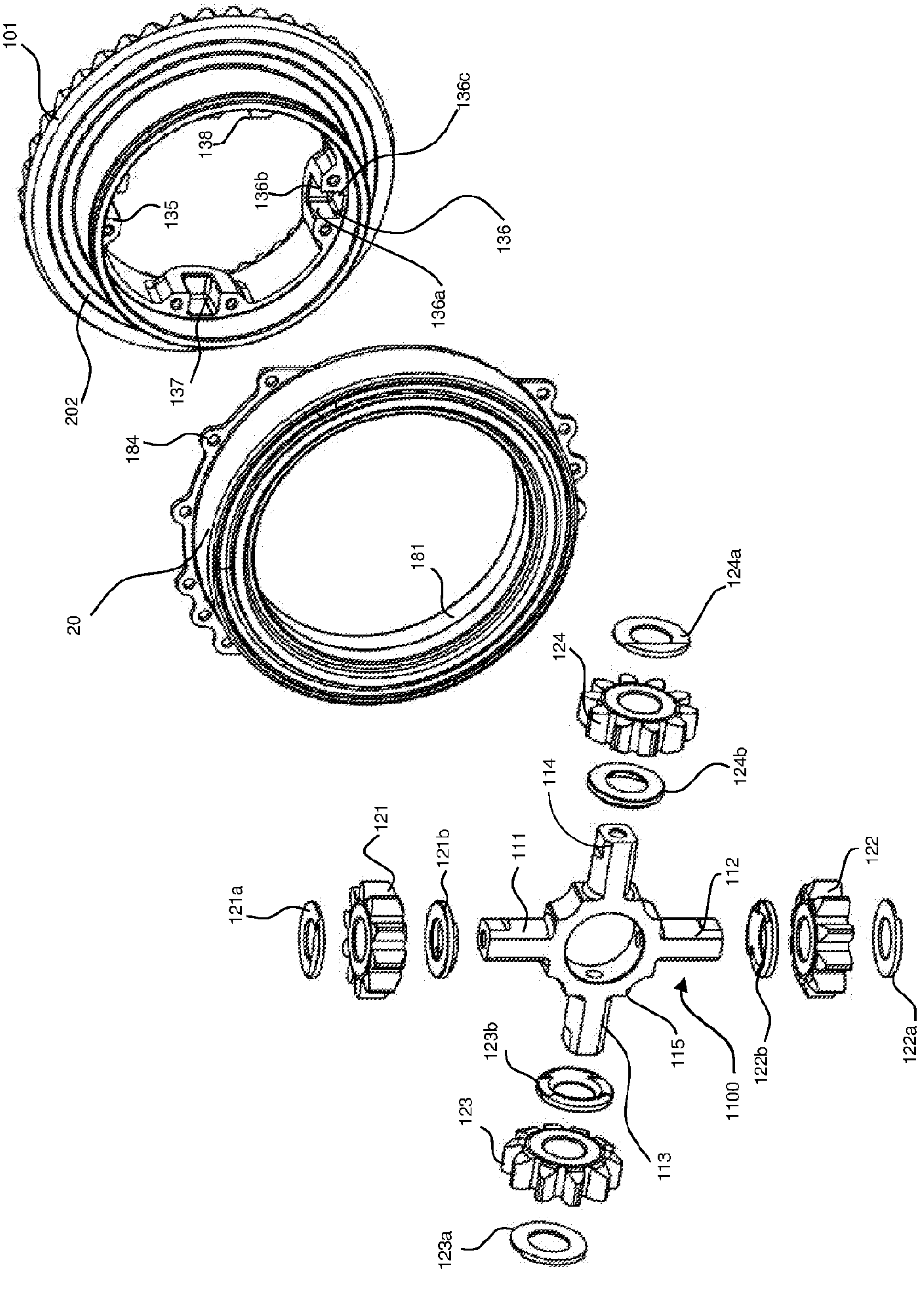


FIGURE 2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122
122a
122b
1100
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123b
123
123a

FIGURE 3

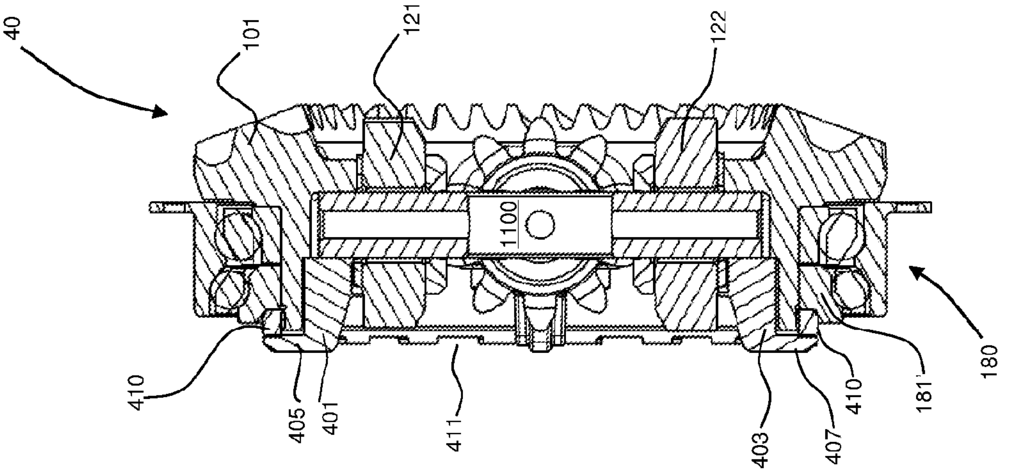


FIGURE 4B

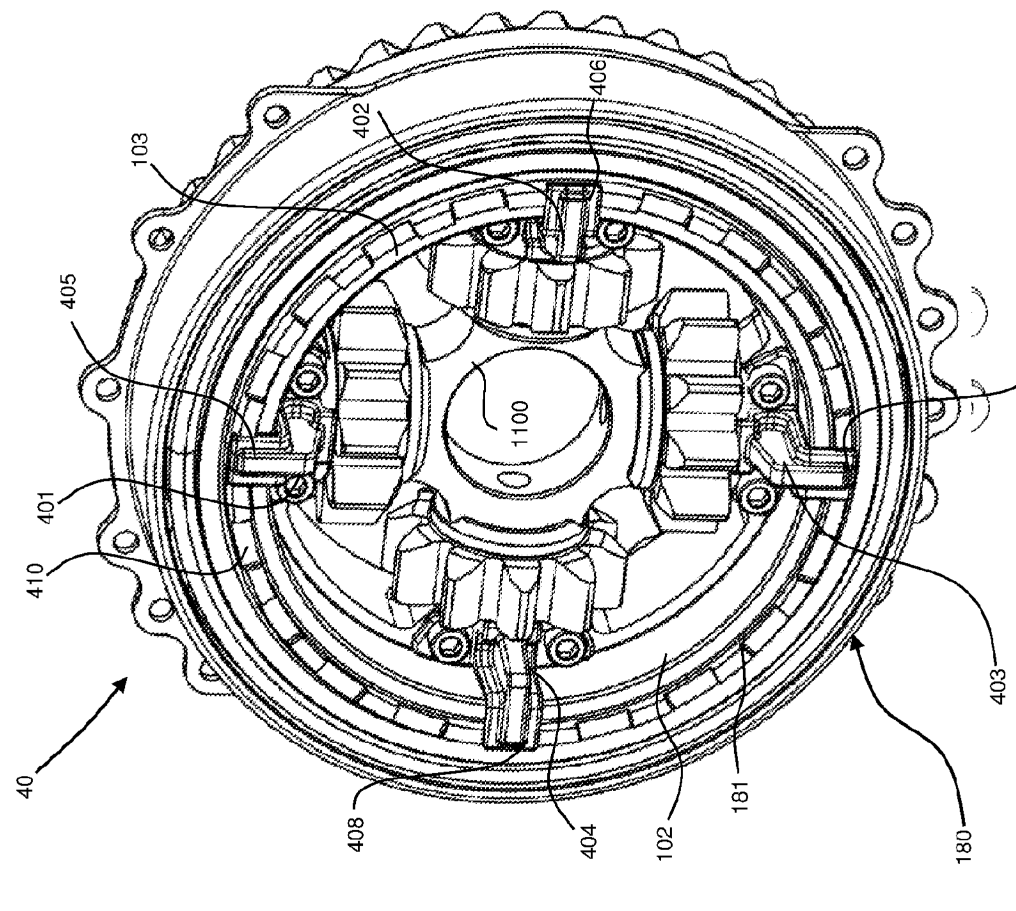
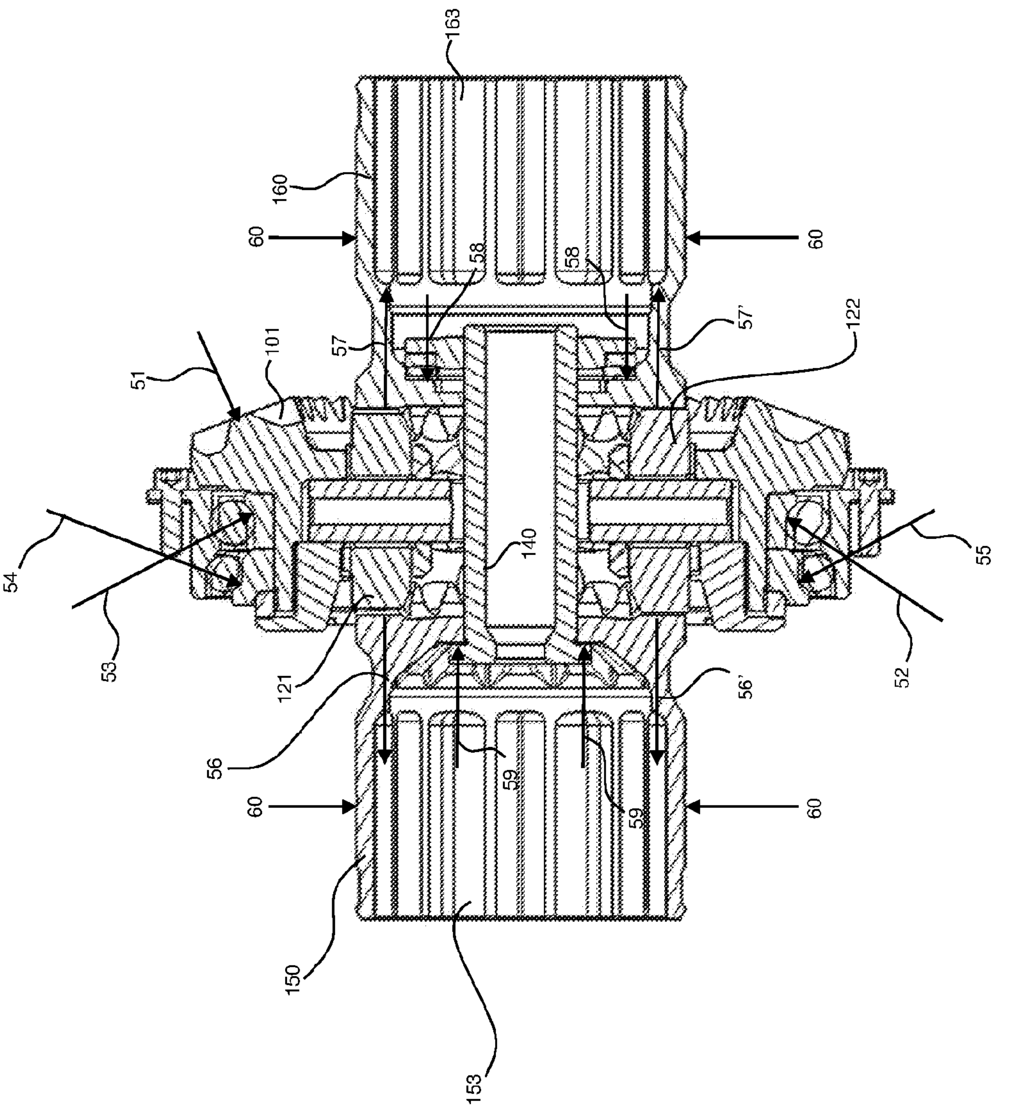


FIGURE 4A


163
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58
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57
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55
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59
59
60
60
150
153

FIGURE 5A

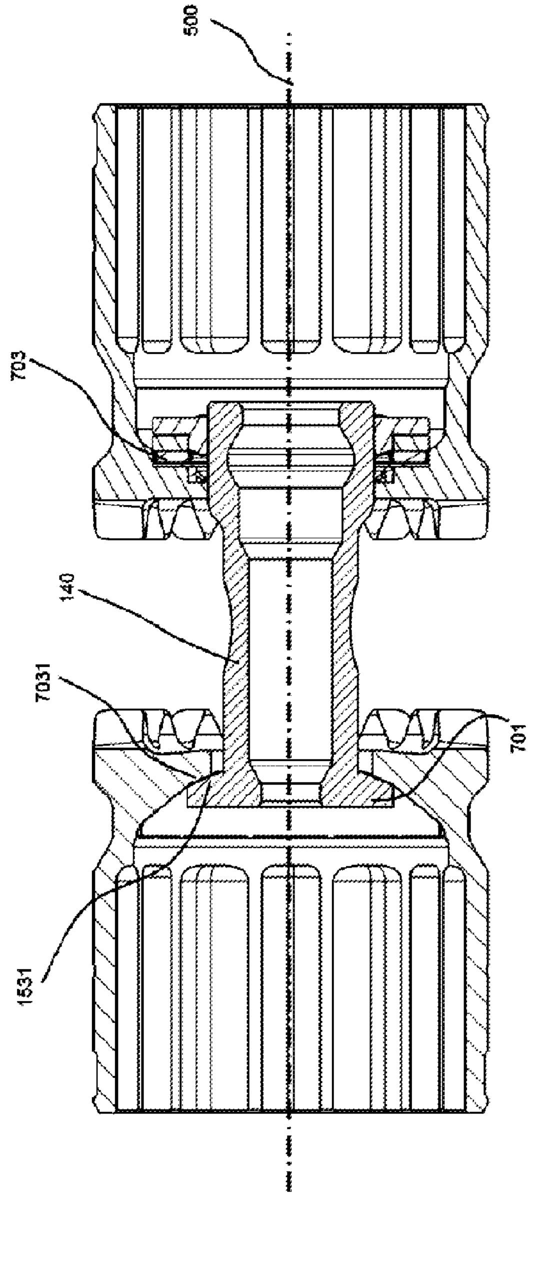

FIGURE 5B

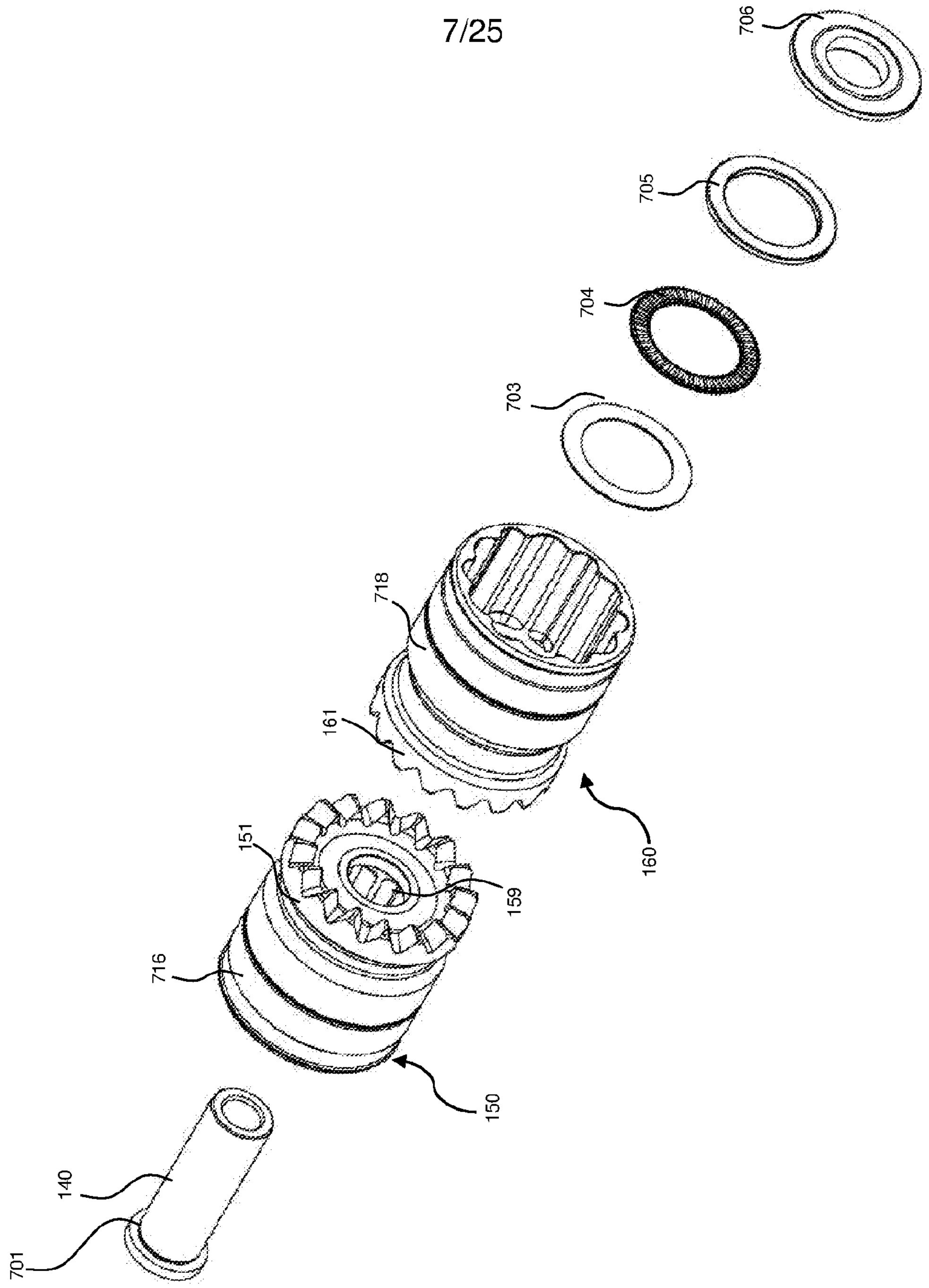

FIGURE 6

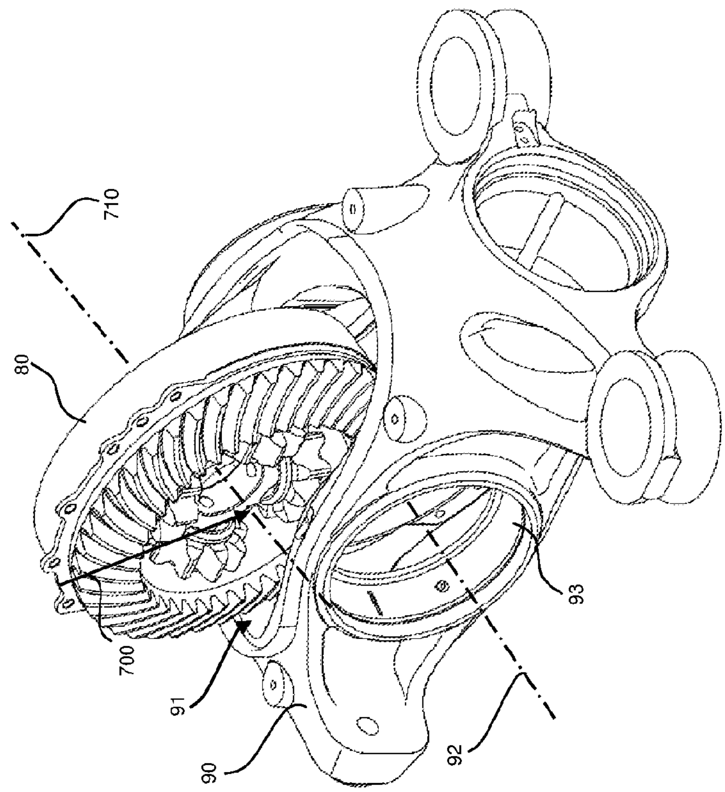

FIGURE 7B

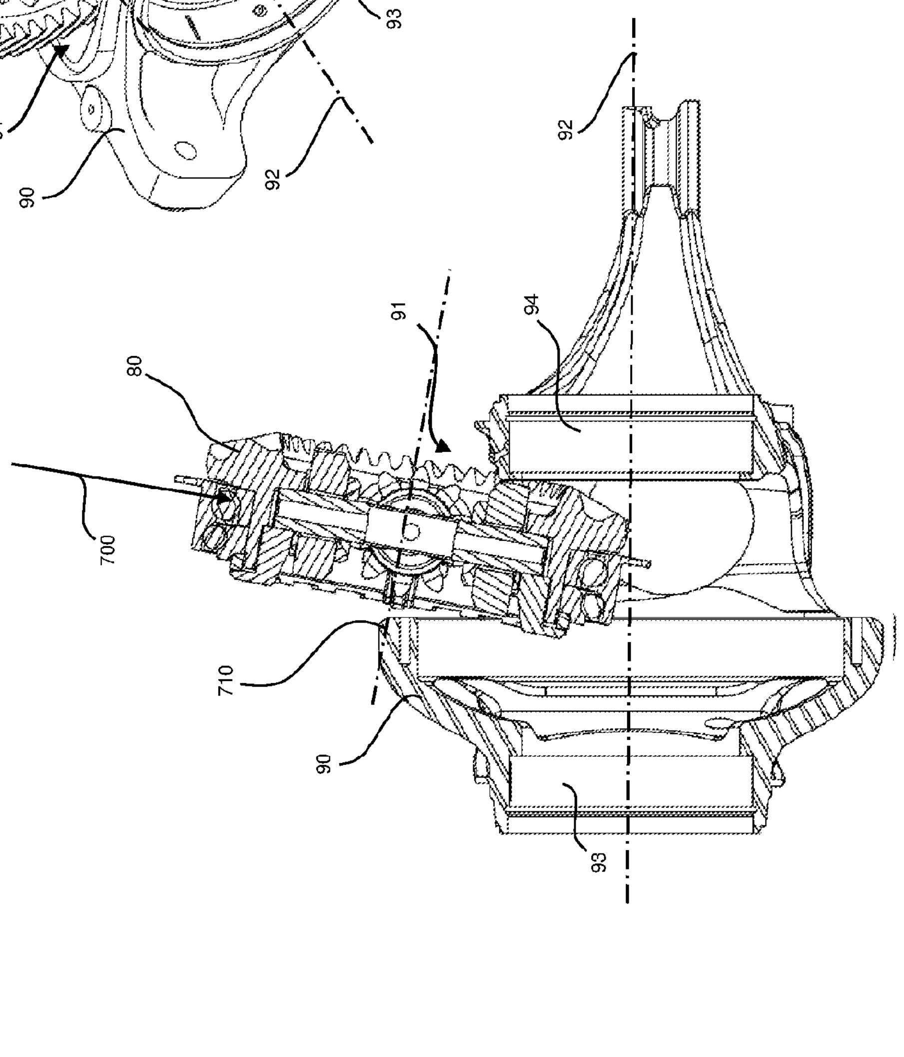

FIGURE 7A

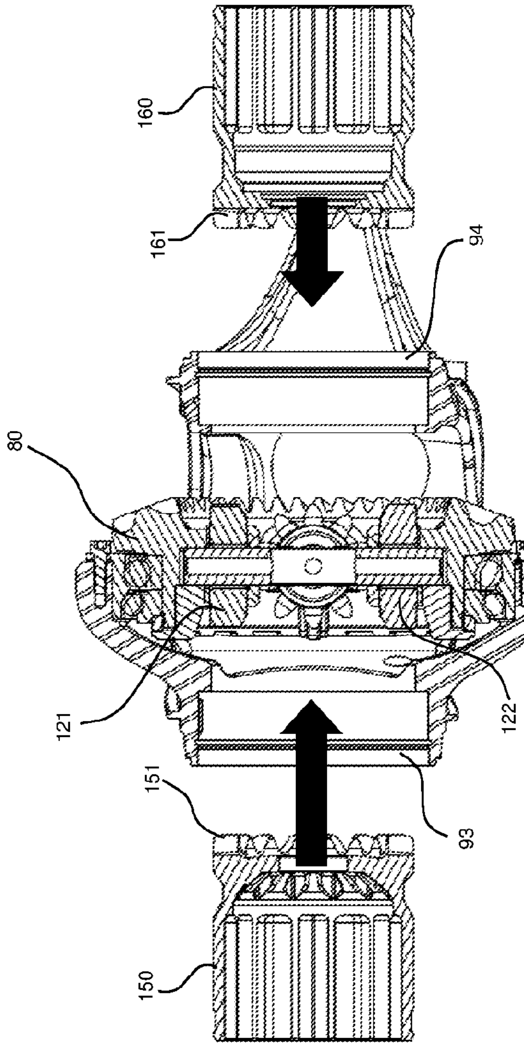

FIGURE 7D

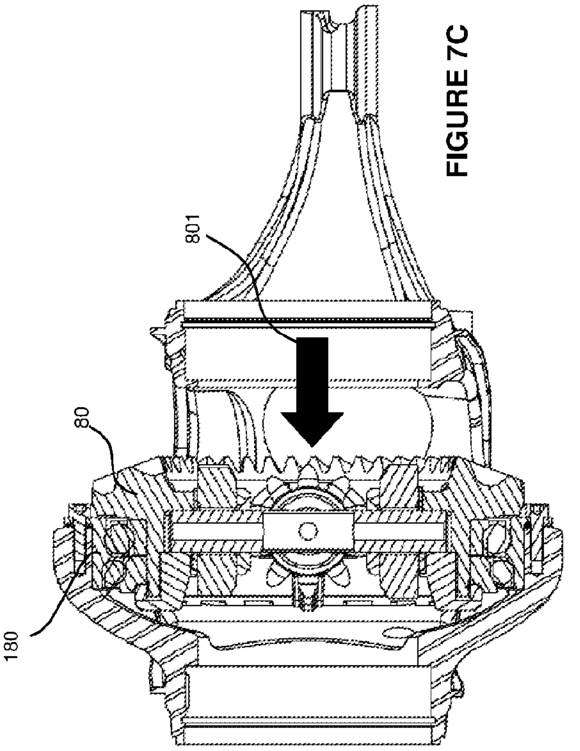

FIGURE 7C

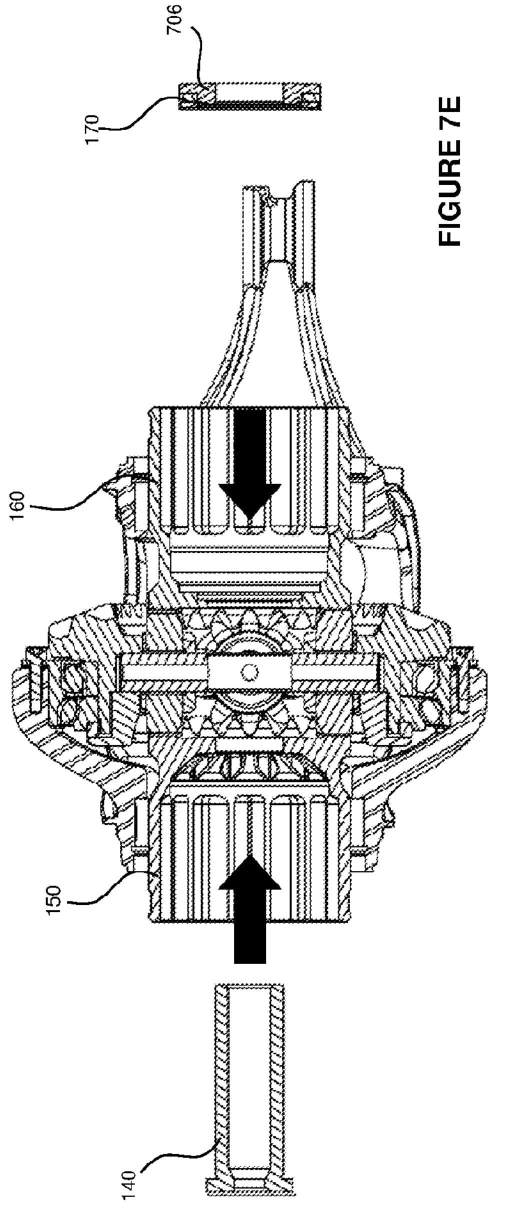

FIGURE 7E

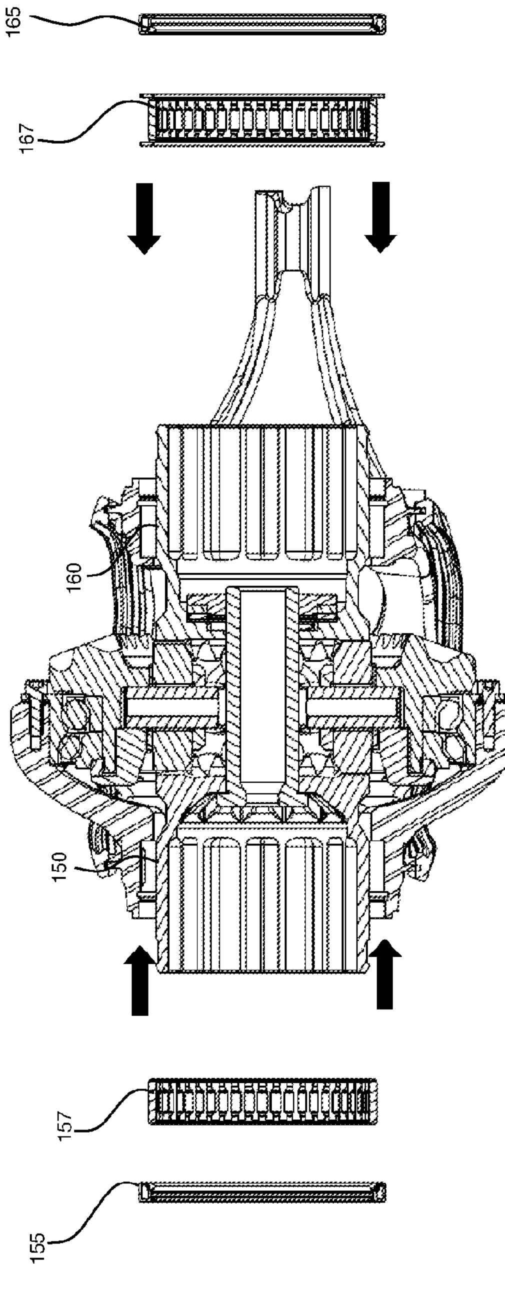

FIGURE 7F

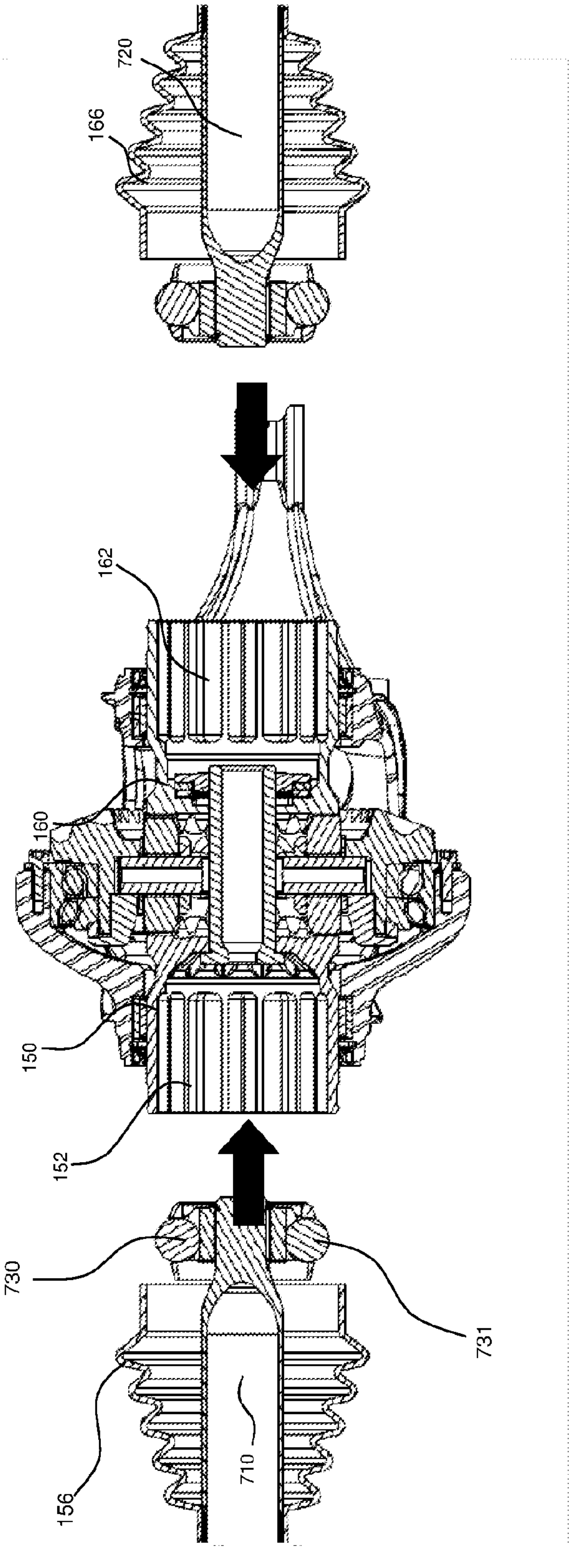

FIGURE 7G

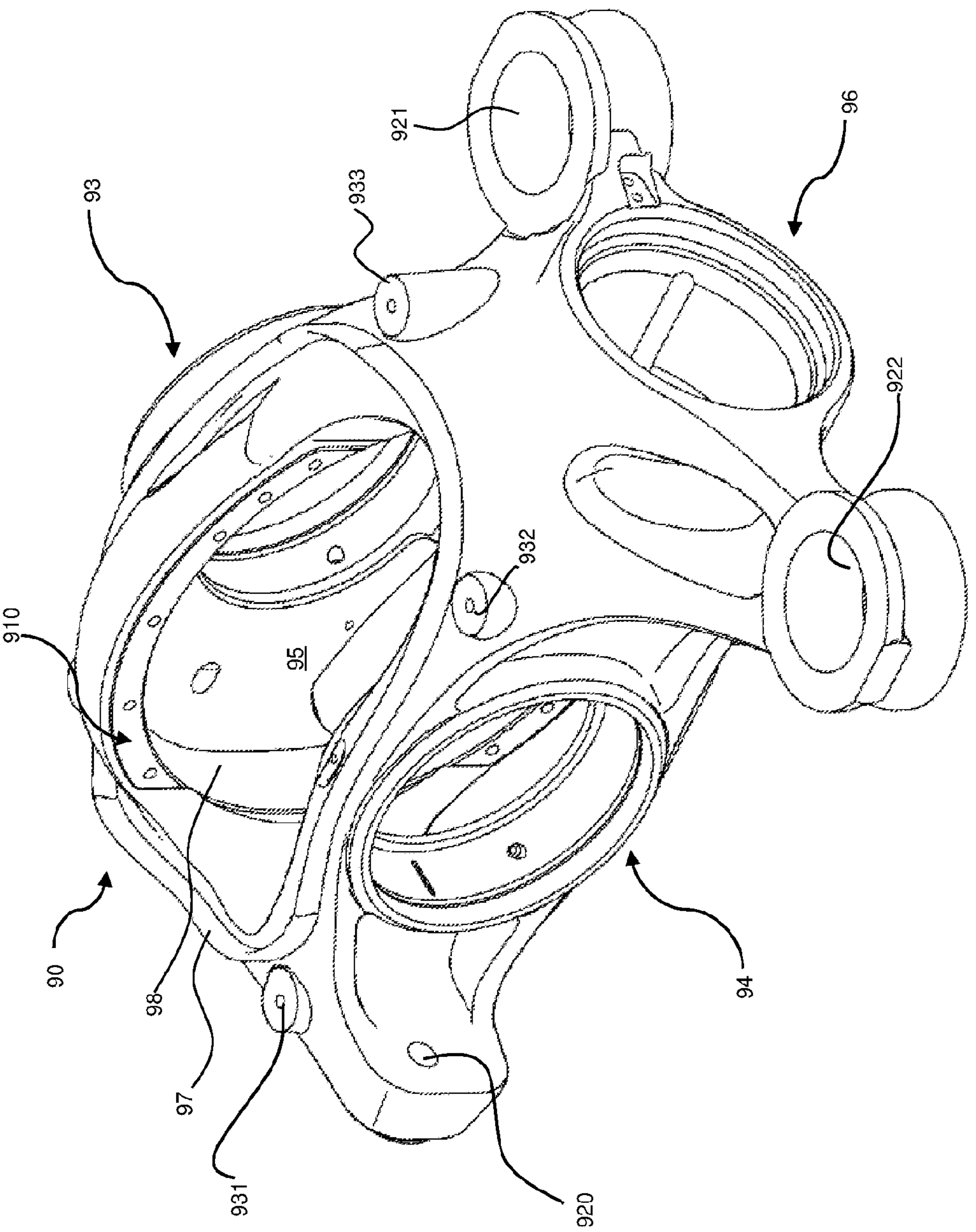

FIGURE 8

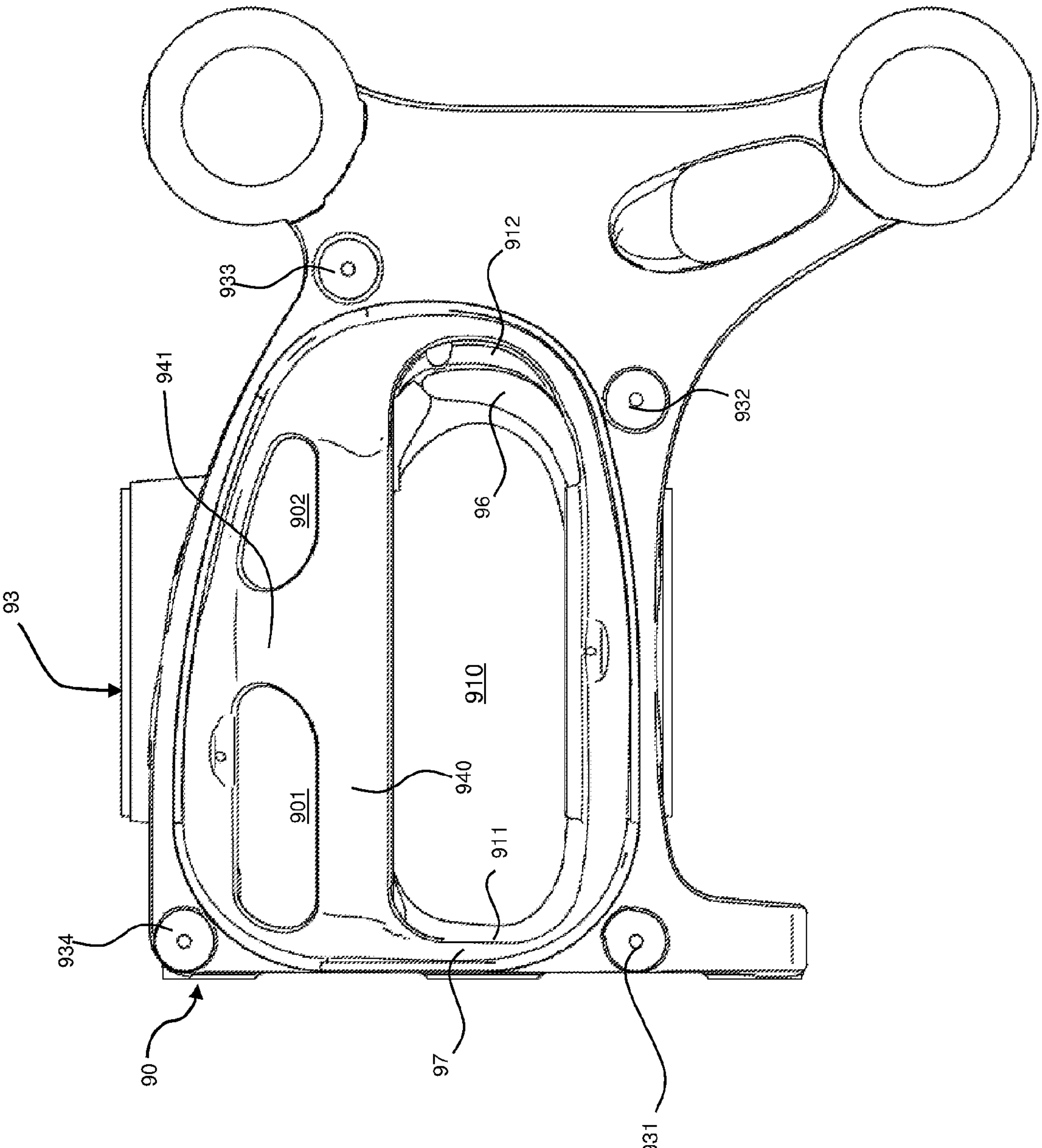

FIGURE 9

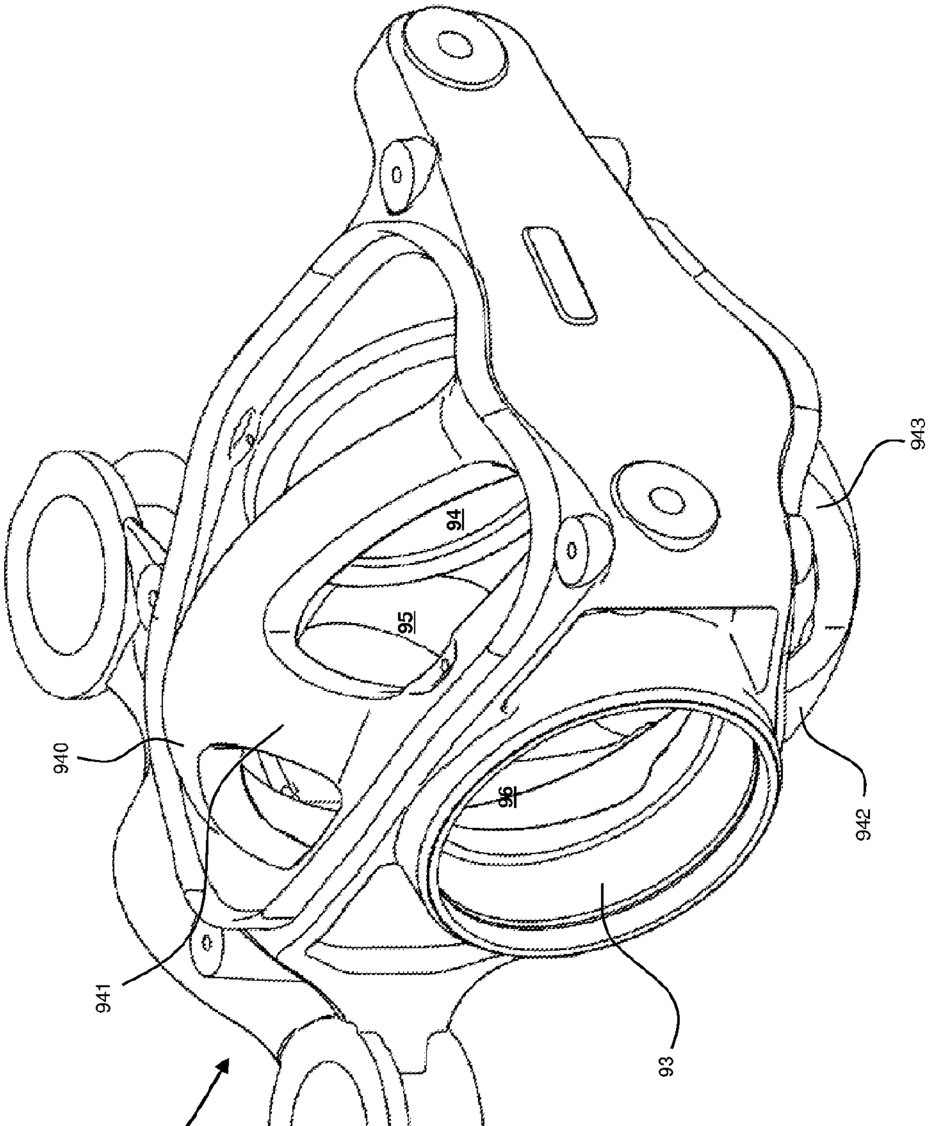

FIGURE 10

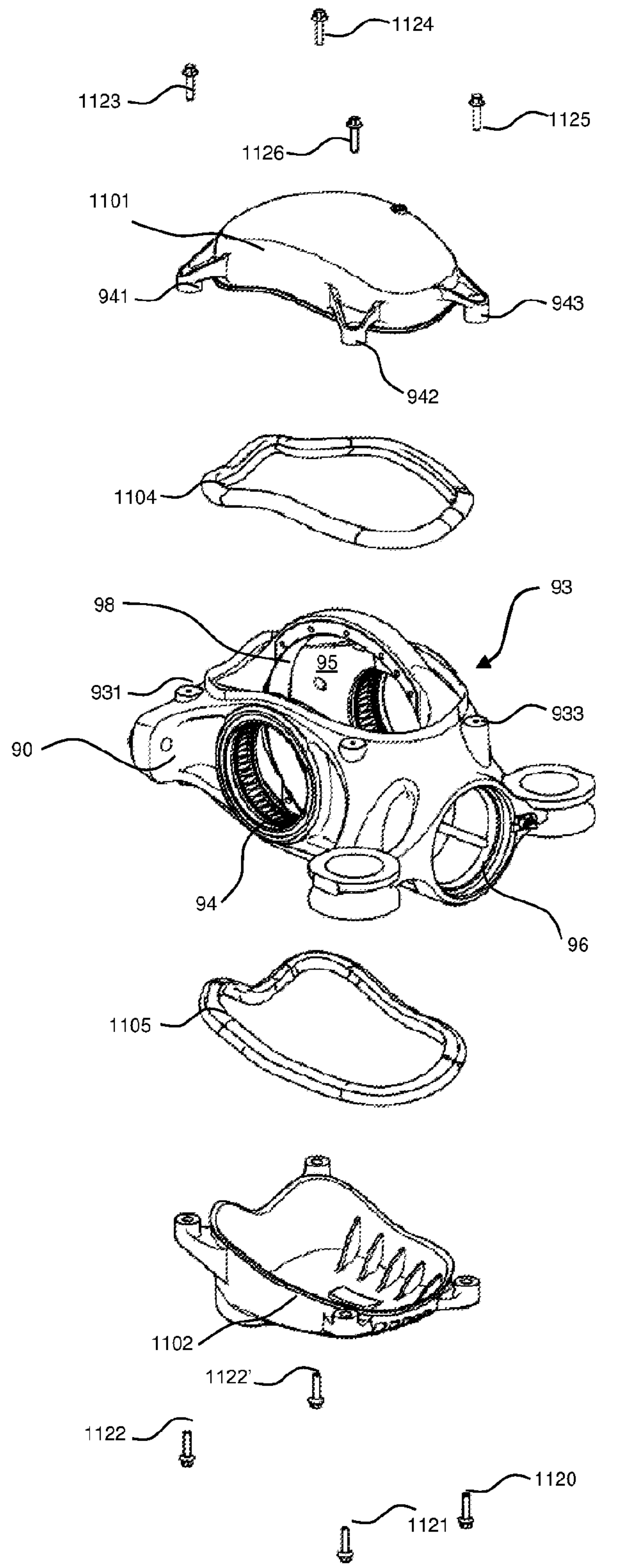
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FIGURE 11

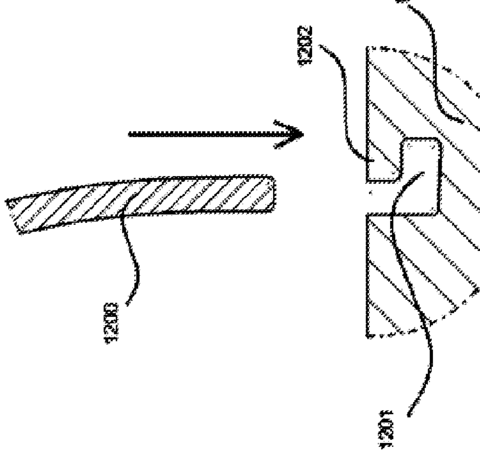

FIGURE 12A

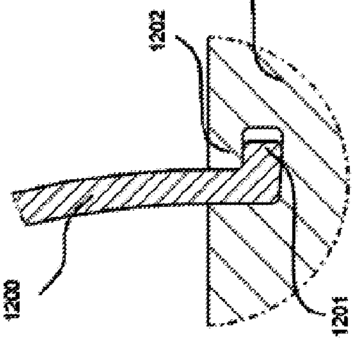

FIGURE 12B

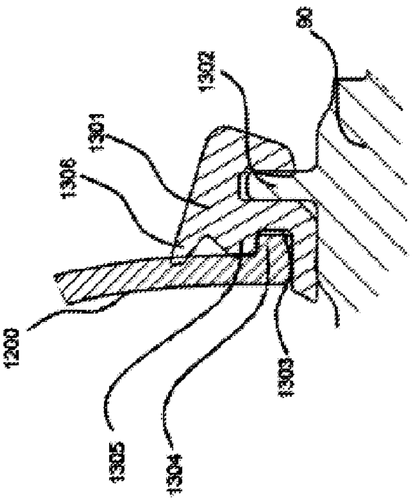

FIGURE 13

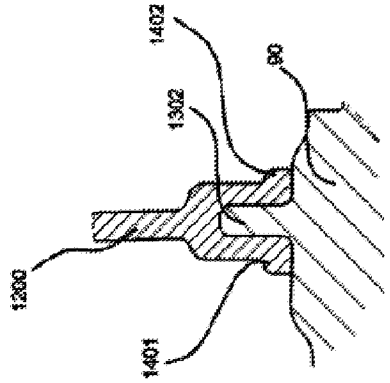

FIGURE 14

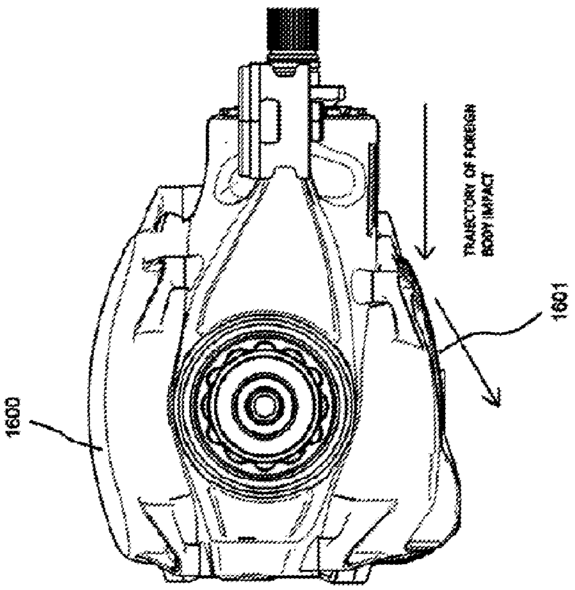

FIGURE 16

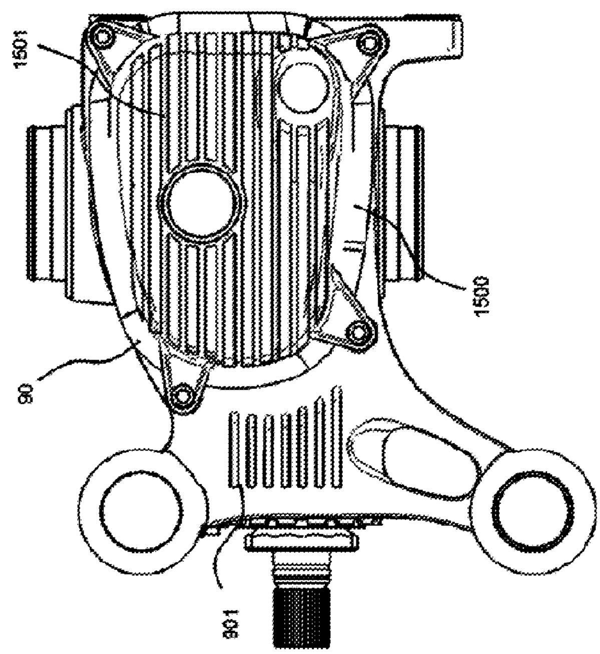

FIGURE 15

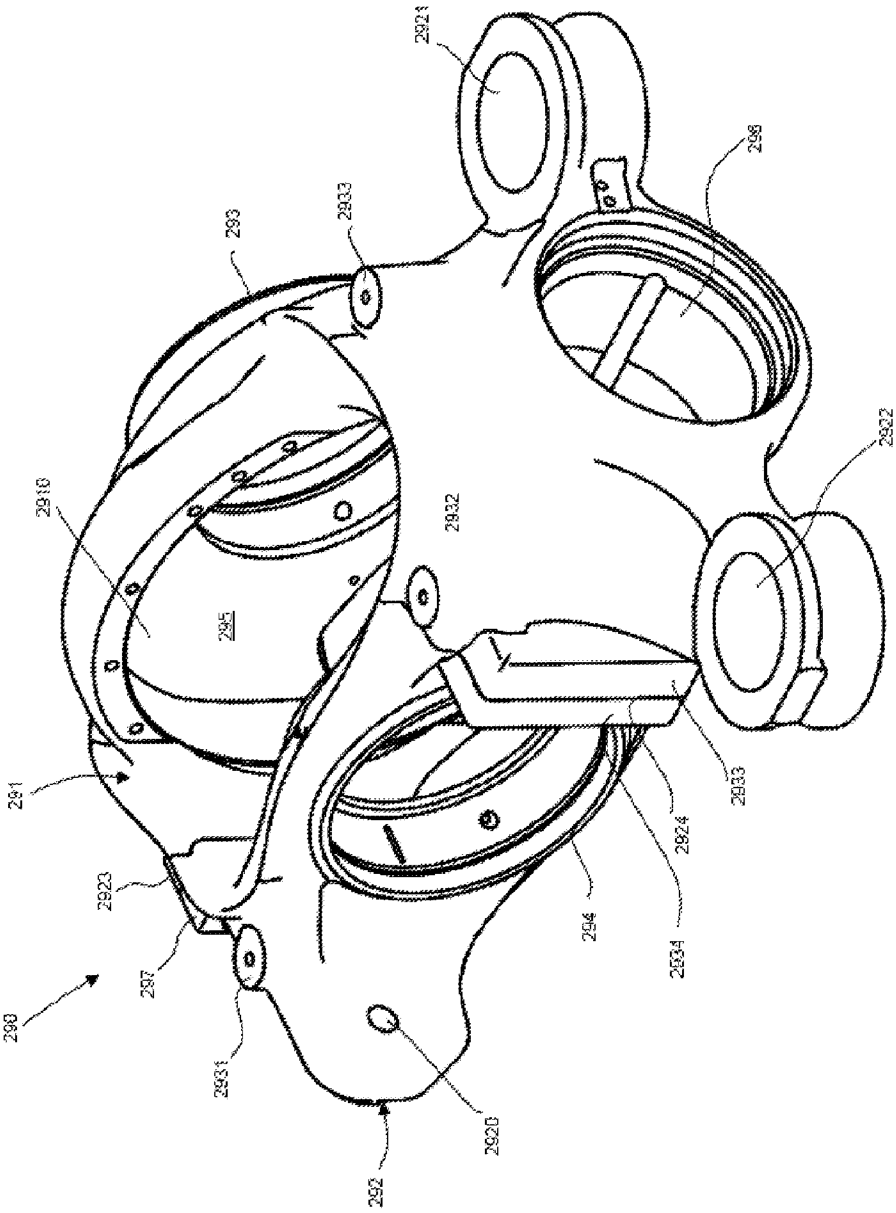
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FIGURE 17

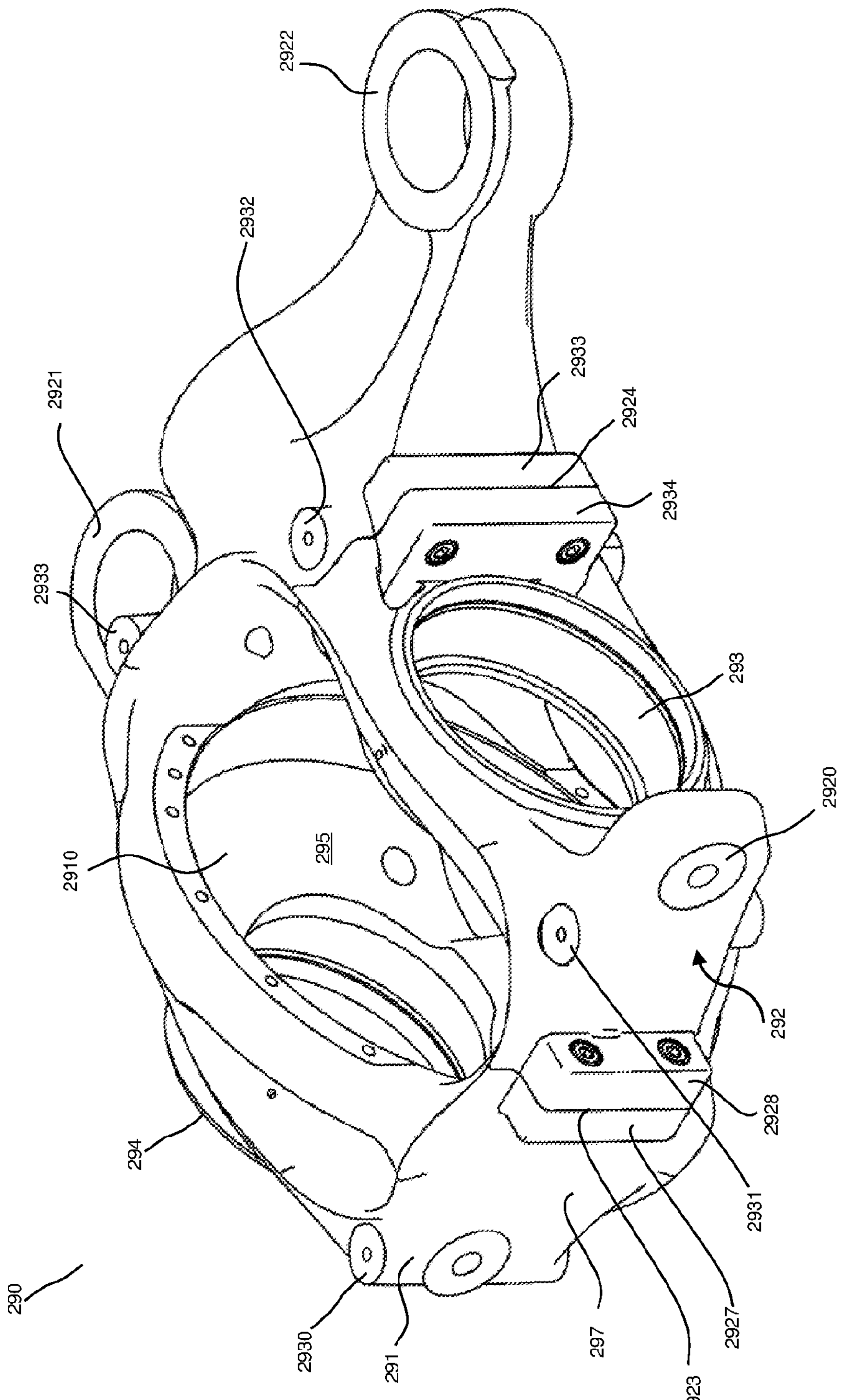
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FIGURE 18

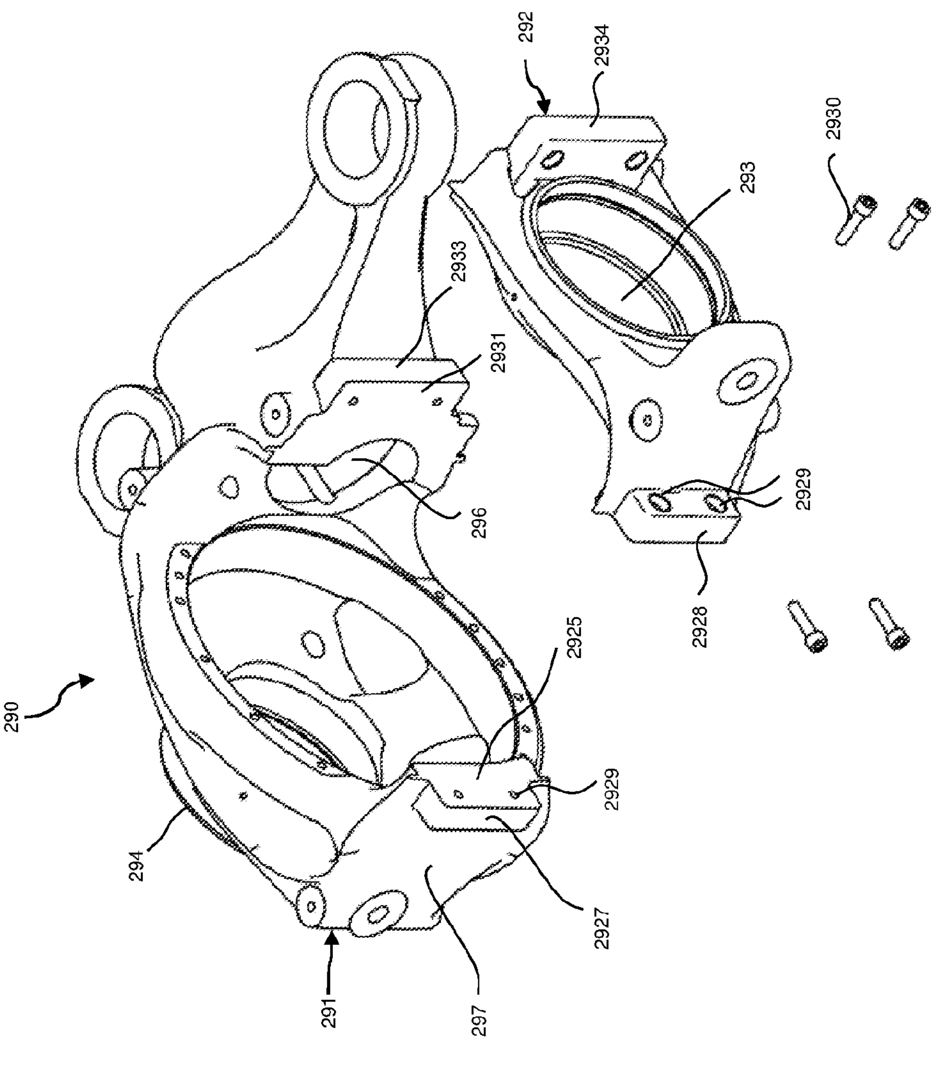
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FIGURE 19

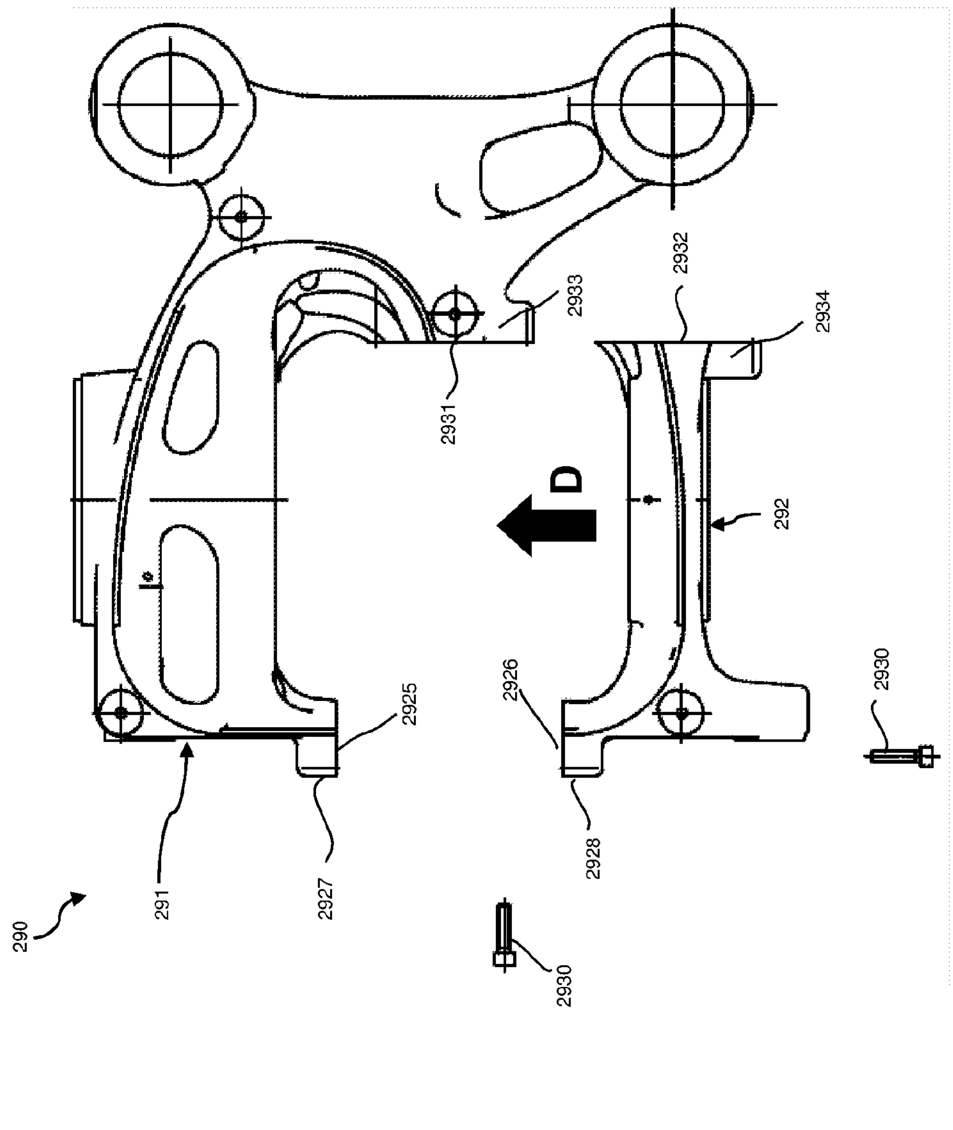
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FIGURE 20

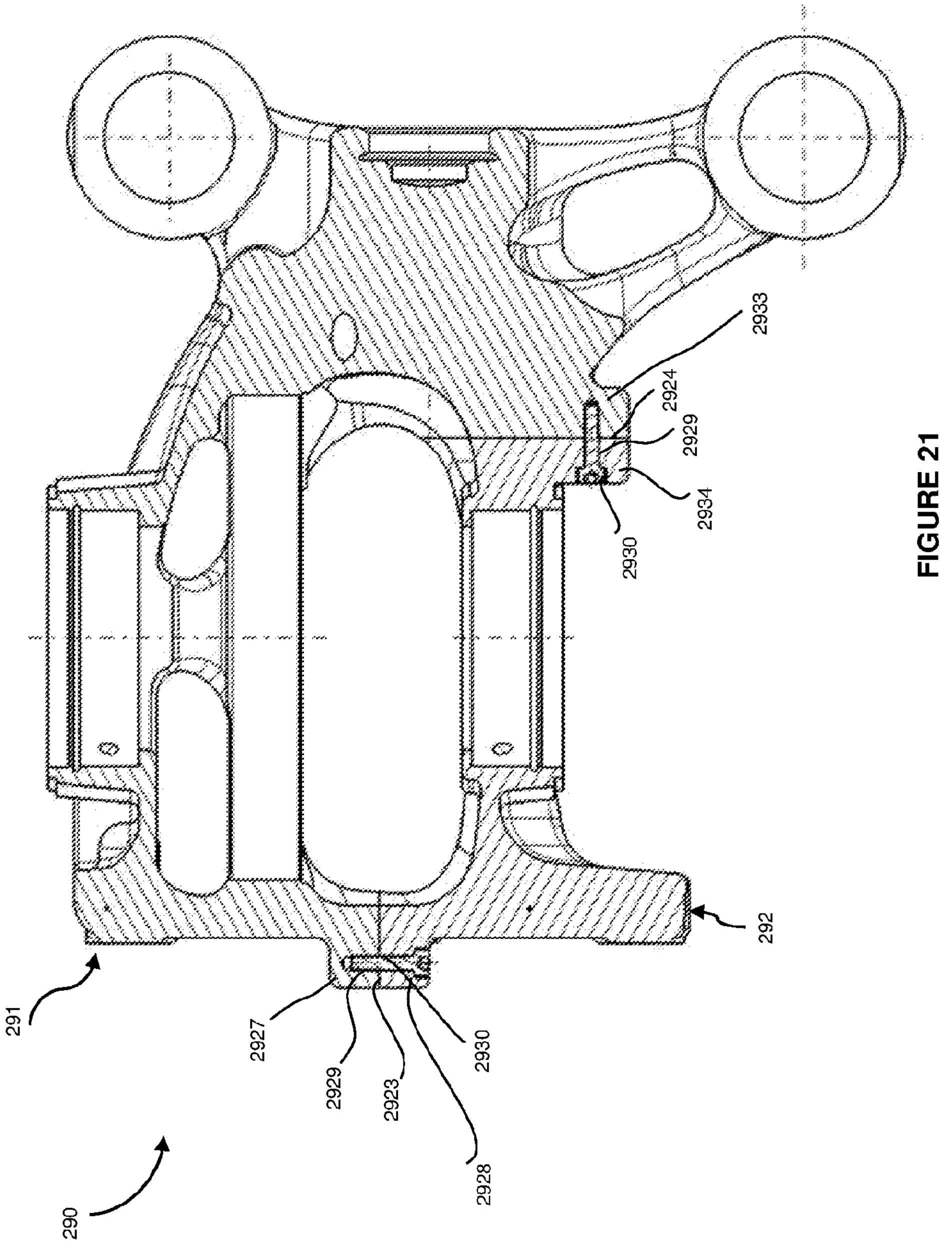

FIGURE 21

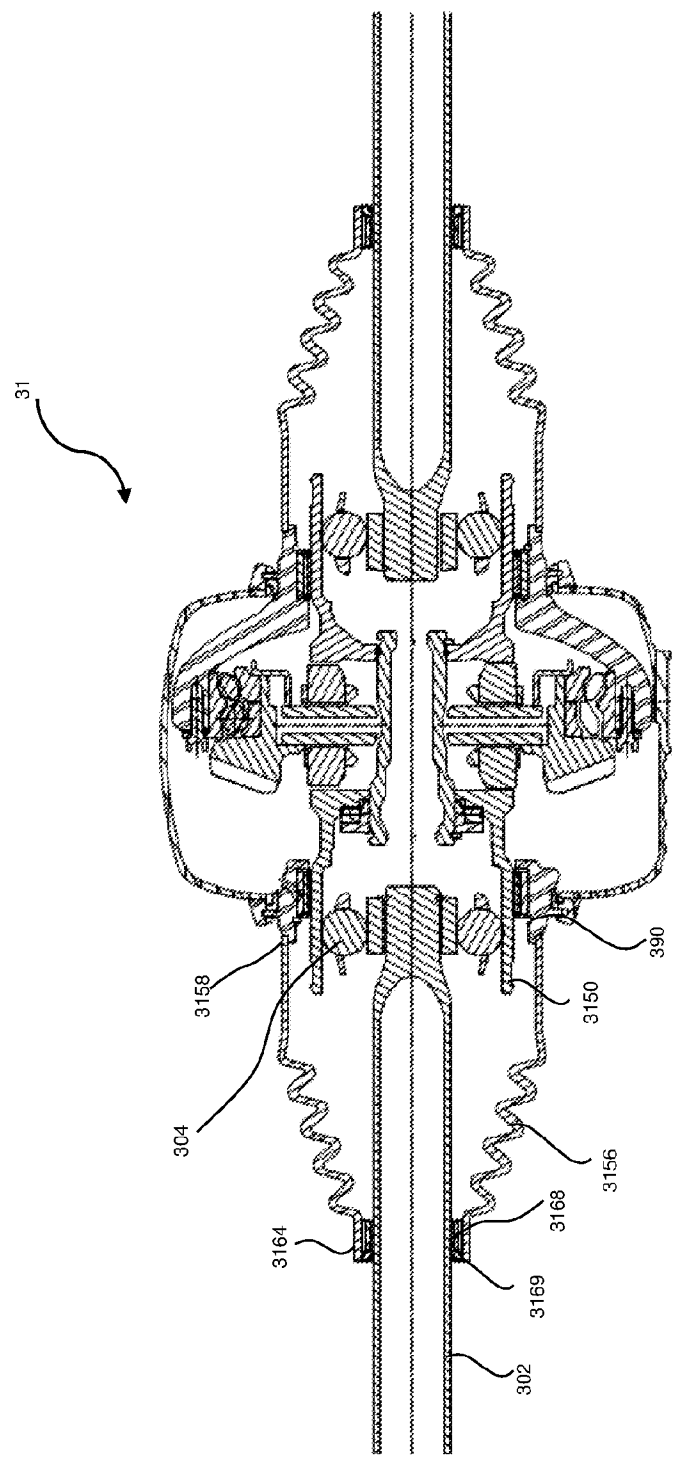

FIGURE 22

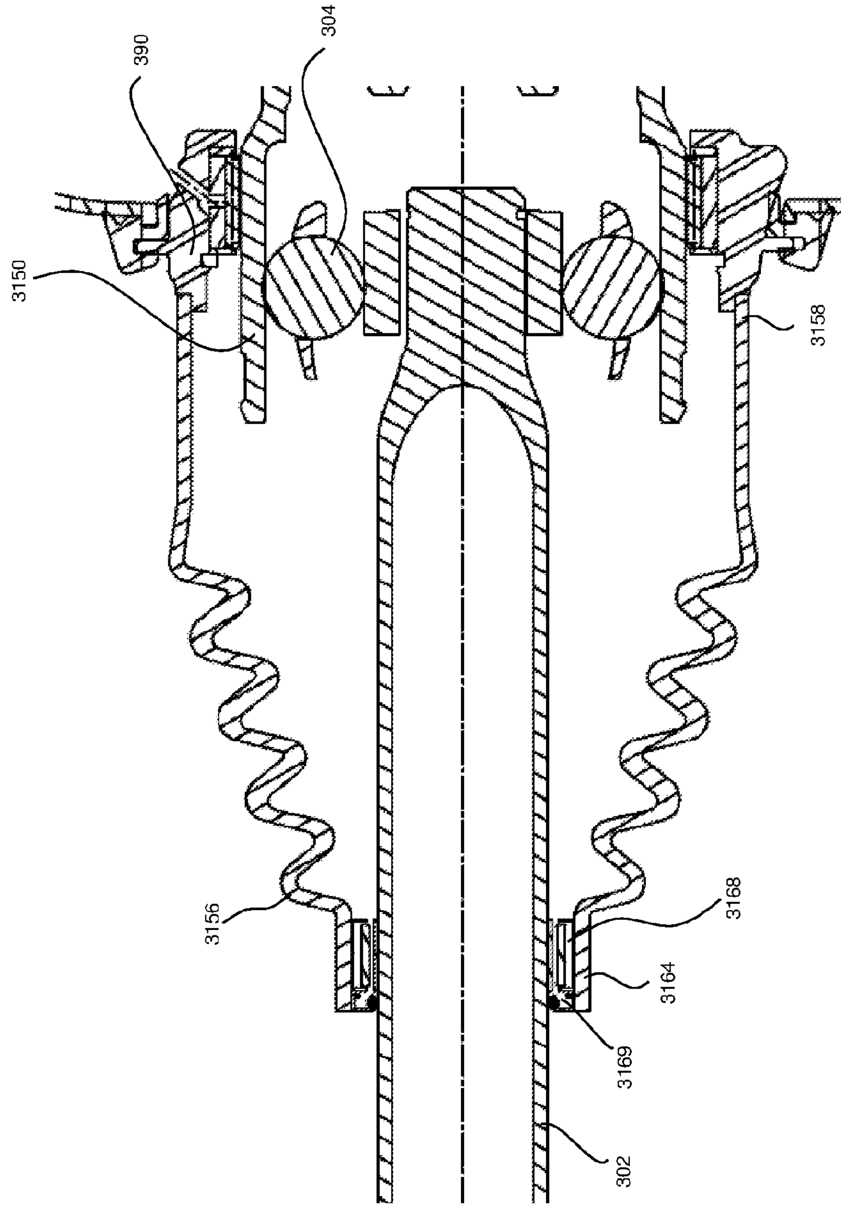

FIGURE 23

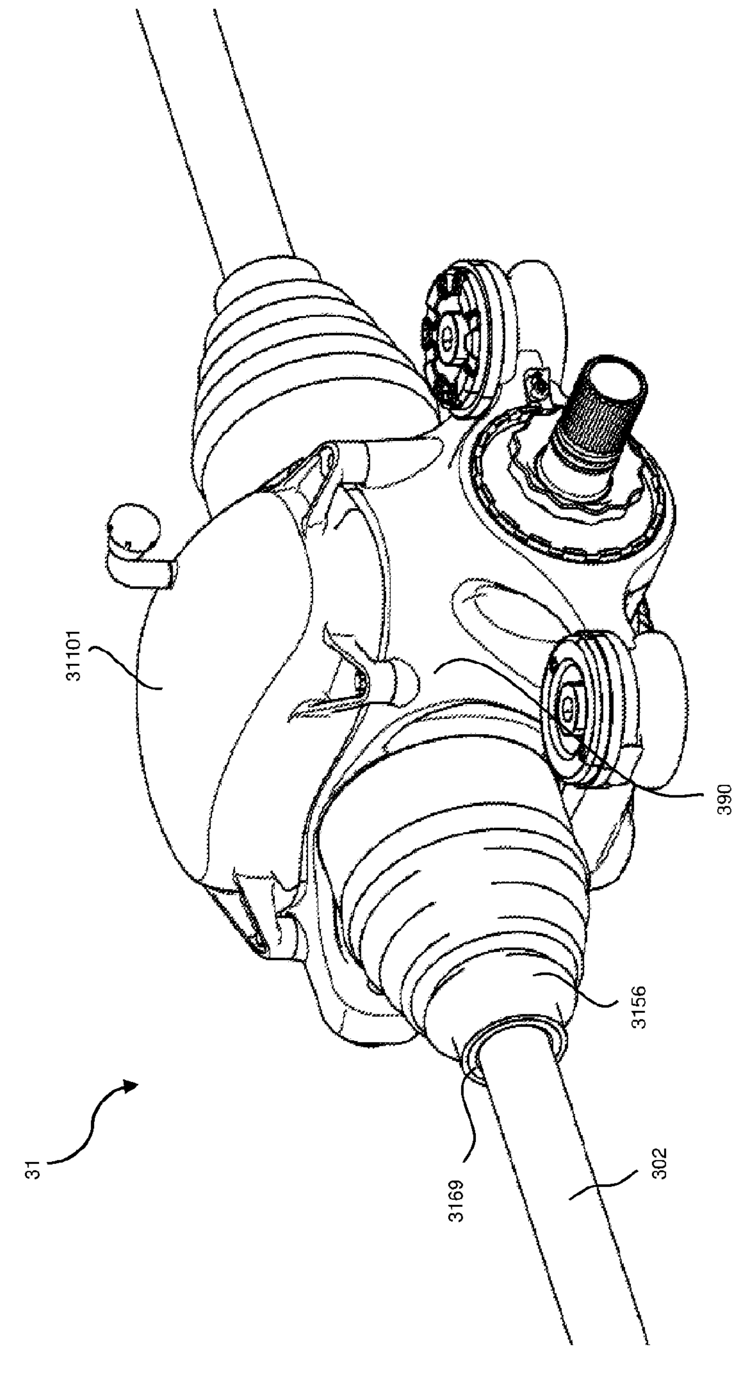

FIGURE 24