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(54) **INTER-AXLE DIFFERENTIAL ASSEMBLY FOR A TANDEM DRIVE AXLE SET**

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**Related U.S. Patent Documents**

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(52) **U.S. Cl.** ..... **475/221**

(58) **Field of Classification Search** ..... **475/221,**  
**475/222**

See application file for complete search history.

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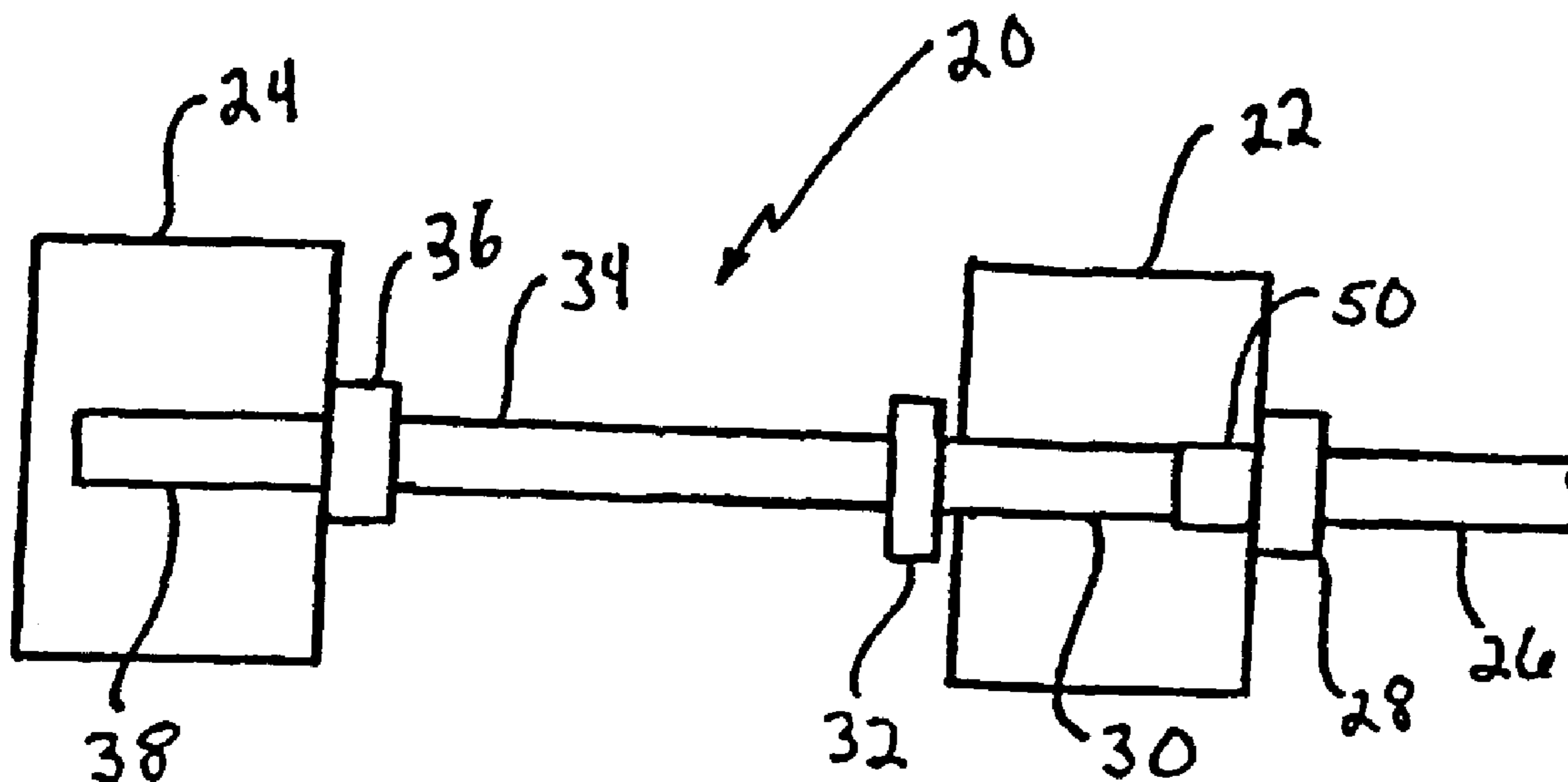
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(57) **ABSTRACT**

An inter-axle differential assembly for a tandem drive axle set is disclosed that permits a rear drive assembly and a forward drive assembly to have the same input axis. The forward drive assembly includes a hollow pinion gear. An inter-axle differential assembly receives input from a driveline connection and transfers this input to the hollow pinion gear and to a through shaft that extends through the hollow pinion gear. The hollow pinion gear drives a main differential assembly that in turn drives a forward axle. The through shaft extends toward a rear drive assembly and provides input to the rear drive assembly. The rear drive assembly utilizes a rear pinion gear to drive a rear differential. The rear differential in turn drives a rear axle. Thus, the present design permits a common axis to be shared by the input to the forward drive assembly and the input to the rear drive assembly. In addition, the present design eliminates the traditionally required helical gears from the forward drive assembly.

**27 Claims, 3 Drawing Sheets**



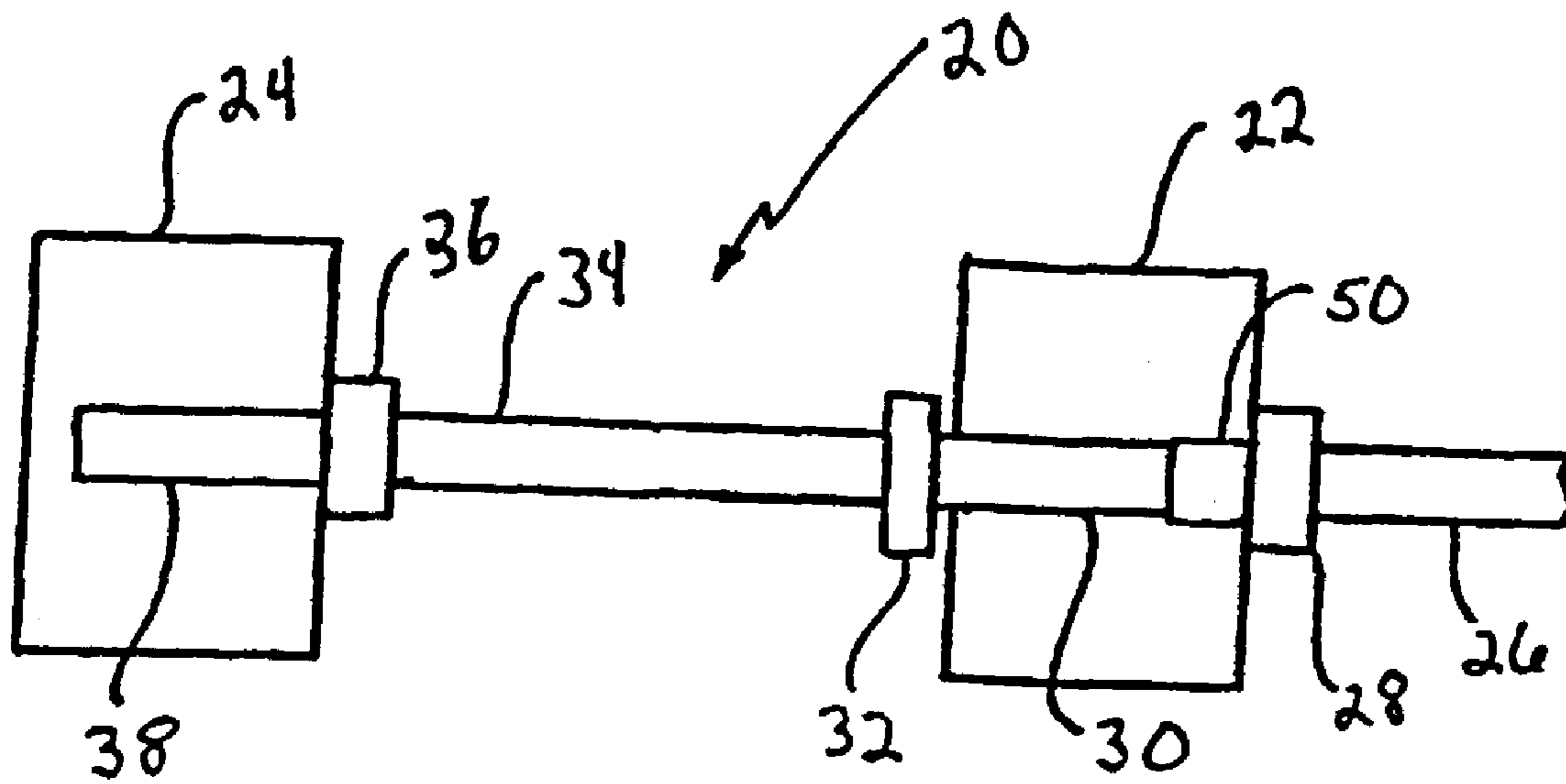
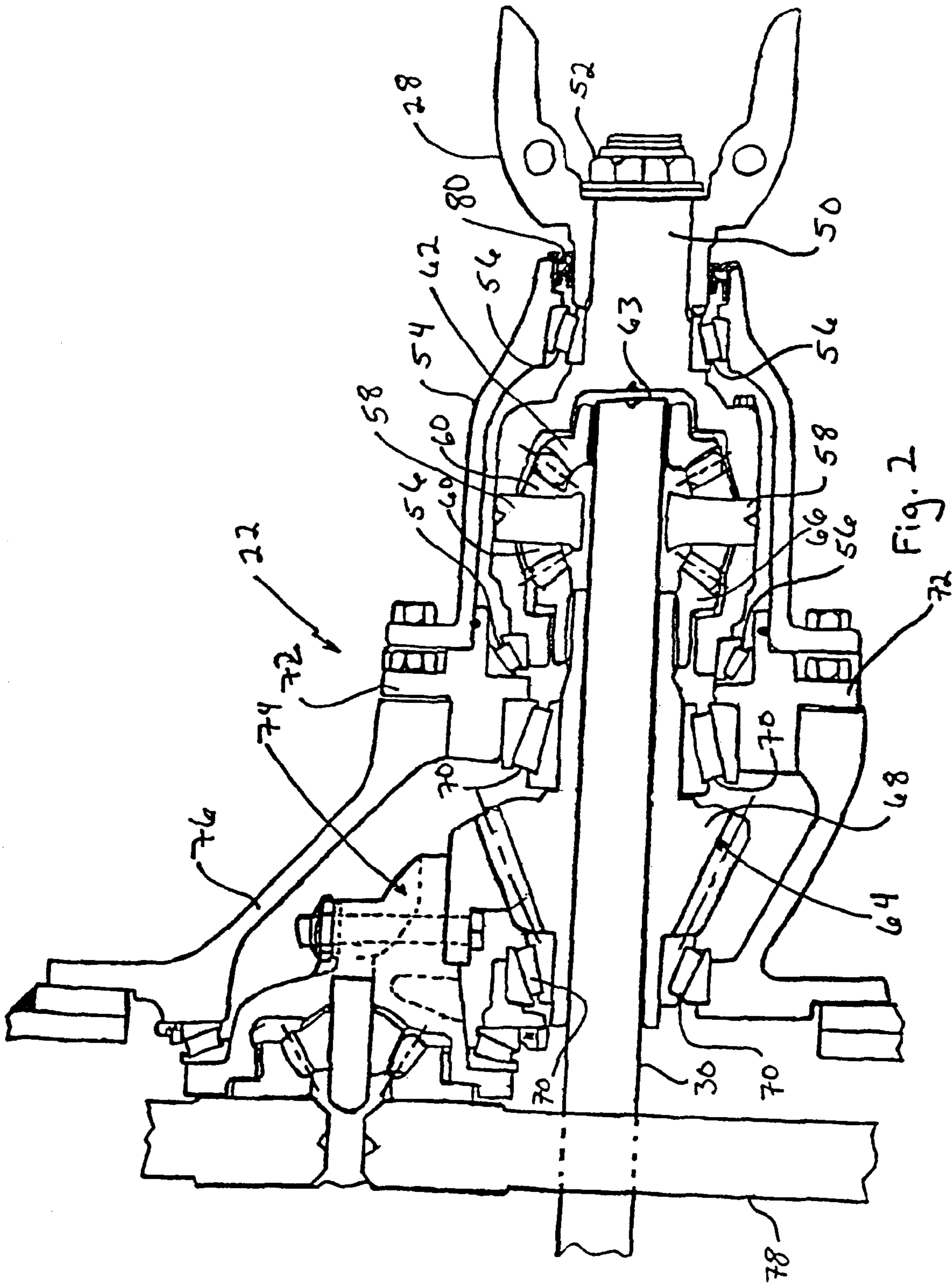
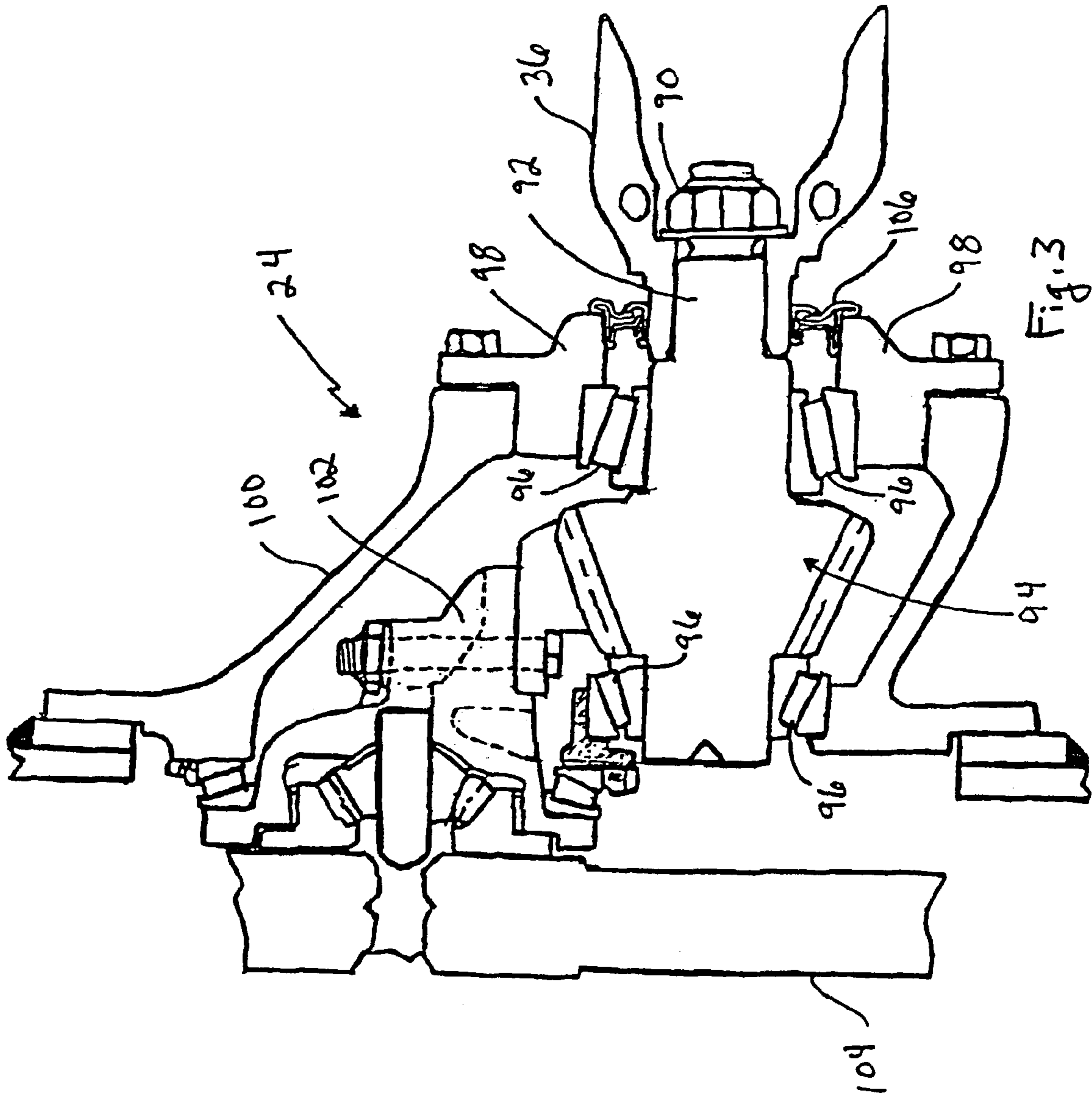


Fig. 1







## INTER-AXLE DIFFERENTIAL ASSEMBLY FOR A TANDEM DRIVE AXLE SET

**Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.**

### BACKGROUND OF THE INVENTION

This invention relates generally to tandem drive axle sets and, more particularly, to an inter-axle differential assembly for a tandem drive axle set.

A tandem drive axle set is used to distribute rotational power from a driveline input to a set of forward and rear wheels through a forward drive assembly and a rear drive assembly, respectively. Traditionally, the tandem drive axle set is designed such that the forward drive assembly has a ring gear and a pinion gear set that is a mirror image of the rear drive assembly ring gear and pinion gear set. Usually, the forward drive assembly has a right-hand pinion gear while the rear drive assembly has a left-hand pinion gear. It is necessary that the forward and rear drive assemblies be mirror images of each other because, traditionally, the forward drive assembly has included a set of helical gears that are used to transfer half of the rotational power from an inter-axle differential to the forward drive assembly pinion and ring gear set. That is, the forward and rear drives require distinct parts, which requires increased inventory.

The inter-axle differential receives rotational input from the driveline of the vehicle. In such a design, the pinion gear of the forward drive assembly rotates in the opposite direction to that of the inter-axle differential. The inter-axle differential transmits the other half of its input to a through shaft which sends the input back to the rear drive assembly. In the rear drive assembly the pinion gear rotates in the same direction as the inter-axle differential. Because the helical gears are necessary in the forward drive assembly, the axis of the input to the forward drive assembly is offset from the pinion gear axis in the forward drive assembly by the centerline-to-centerline distance of the helical gears. Therefore, the output of the forward axle is on the same axis as the input while the input of the rear drive assembly is on the same axis as the forward axle drive pinion gear.

This difference in axis height between the forward axle output to the rear axle input requires different axle pinion angles to be utilized in order to set the driveline angles in the u-joints used in the driveline. Setting and maintaining the driveline angles is difficult. When the driveline angles at the u-joints are not the same it creates adverse torsional loading and vibrations in the drivetrain assembly. Such torsional loading and vibrations can lead to premature failure of the drivetrain assembly. Even when the driveline angles are properly set at the factory, the air ride suspensions commonly found in heavy duty trucks can alter the driveline working angles in an adverse manner.

Therefore, it is desirable to provide a tandem axle drive set wherein the input power to the forward drive assembly is set on the same axis as the input power to the rear drive assembly. This eliminates the need to set driveline angles and to provide distinct drive components.

### SUMMARY OF THE INVENTION

In general terms, this invention provides a tandem axle drive set wherein the input power axis to the forward drive assembly of the tandem axle drive set is on the same axis as the input power axis to the rear drive assembly. In addition,

the present design eliminates the traditional need for a set of helical gears in the forward drive assembly and permits commonality of design for many components in both the forward and rear drive assemblies of the tandem drive axle set.

Preferably, the tandem axle drive set comprises a forward drive assembly including an inter-axle differential having a pair of outer side gears, a main differential, and a hollow pinion gear. A through shaft has a first end secured to one of the outer side gears and extends through the hollow pinion gear toward a rear drive assembly. The rear drive assembly includes a rear pinion gear and a rear differential. The through shaft drives the rear pinion gear. Rotation of the inter-axle differential rotates the through shaft, the hollow pinion gear, and the rear pinion gear. The hollow pinion gear drives the main differential and the rear pinion gear drives the rear differential.

Thus, a tandem drive axle set is provided wherein the input to the forward drive assembly is on the same axis as the input to the rear drive assembly. This design eliminates the need for setting driveline angles between the forward and rear drive assemblies.

These and other features and advantages of this invention will become more apparent to those skilled in the art from the following detailed description of the presently preferred embodiment. The drawings that accompany the detailed description can be described as follows.

### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic drawing of a driveline designed in accordance with the present invention;

FIG. 2 is a cross-sectional top view of a forward drive assembly designed in accordance with the present invention; and

FIG. 3 is a cross-sectional top view of a rear drive assembly designed in accordance with the present invention.

### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

A tandem drive axle set is generally indicated at **20** in FIG. 1. Tandem drive axle set **20** includes a forward drive assembly **22** and a rear drive assembly **24**. A driveline connection **26** provides rotational power input to forward drive assembly **22** through a yoke **28**. An inter-axle differential assembly **50** receives power from yoke **28** and transfers it to forward drive assembly **22**. A through shaft **30** transfers power from forward drive assembly **22** to rear drive assembly **24**. A yoke **32** connects through shaft **30** to a driveline connection **34** that is then connected to rear drive assembly **24** through a yoke **36**. An input **38** provides power to rear drive assembly **24** from driveline connection **34**. Notably, inter-axle differential assembly **50** and shafts **30**, **34** and **38** are coaxial. This design is contrary to the prior art wherein there was not a single axis for the drive. The use of this single axis eliminates many concerns forced by the prior art. Further, the single axis allows the use of common front and rear drive assembly components. As known by one of ordinary skill in the art, the inter-axle differential assembly shown at **50** combines the prior art use of a separate input shaft and inter-axle differential assembly.

In FIG. 2 a cross-sectional top view of forward drive assembly **22** is shown. Forward drive assembly **22** includes an inter-axle differential assembly **50** that is fastened to yoke **28** through a fastener **52**. Yoke **28** receives rotational input from driveline connection **26**. Inter-axle differential assem-



bly 50 is surrounded by an inter-axle differential cover 54. Inter-axle differential assembly 50 is supported within cover 54 by a plurality of roller bearings 56. Preferably, roller bearings 56 are tapered roller bearings as shown. Rotation of driveline connection 26 is transferred to inter-axle differential assembly 50 through yoke 28. Inter-axle differential assembly 50 in turn rotates a plurality of spider shafts 58 that rotate a series of spider gears 60. Spider gears 60 rotate a pair of inter-axle differential outer side gears 62 and 66.

Through shaft 30 includes a first end 63 that is secured to the inter-axle differential outer side gear 62. Through shaft 30 extends from inter-axle differential outer side gear 62 through a hollow pinion gear 64. Hollow pinion gear 64 includes a pinion gear head 68 and is rotated by the other outer side gear 66. Shaft 30 is not fixed to rotate with outer side gear 66 and gear 64. Outer side gear 66 and gear 64 are fixed to rotate together. Shaft 30, gear 64 and gear 66 do tend to all rotate at the same speed. A plurality of roller bearings 70 support hollow pinion gear 64 within a main differential cover 76. Preferably, roller bearings 70 are tapered roller bearings as shown. A pinion cage 72 is used to position a portion of the tapered roller bearings 70. Hollow pinion gear 64 drives a main differential assembly 74. The main differential assembly 74 is well known in the art and does not form a novel portion of the present invention.

A forward axle 78 is driven by main differential assembly 74. Through shaft 30 extends beyond forward axle 78 and passes closely adjacent either above or below forward axle 78. A seal 80 is utilized to seal one end of inter-axle differential cover 54 to yoke 28. As would be understood by one of ordinary skill in the art, forward axle 78 may be located either below or above through shaft 30.

As shown in FIG. 2, through shaft 30 and hollow pinion gear 64 are on the same axis as the input to through shaft 30 from inter-axle differential assembly 50.

In FIG. 3, a cross-sectional top view of rear drive assembly 24 is shown. Rear drive assembly 24 includes a rear pinion gear 94 having an input end 92 that is secured via a fastener 90 to yoke 36. Yoke 36 receives rotational input from driveline connection 34. As mentioned above, input end 92 is on the same axis as through shaft 30. A plurality of roller bearings 96 and a pinion cage 98 support rear pinion gear 94 within a rear differential cover 100. Preferably, roller bearings 96 are tapered roller bearings as shown. Rotation of rear pinion gear 94 drives a rear differential 102. The design of rear differential 102 is well known in the art. A rear axle 104 is driven by rear differential 102. A seal 106 seals a gap between pinion cage 98 and yoke 36. Preferably, seal 106 and seal 80 comprise annular seals as are known in the art.

As shown in FIGS. 1-3, the present design permits a common axis to be shared by inter-axle differential assembly 50, through shaft 30, hollow pinion gear 64, and rear pinion gear 94. Thus, the present design eliminates the need to adjust driveline angles between yokes on the ends of any of the inputs or outputs to the tandem drive axle set 20. In addition, the present design enables the elimination of the traditional helical gear set in the forward drive assembly 22. As can be seen in the Figures, the present design permits a number of commonly designed elements to be used in both the forward drive assembly 22 and the rear drive assembly 24.

The present invention has been described in accordance with the relevant legal standards, thus the foregoing description is exemplary rather than limiting in nature. Variations and modifications to the disclosed embodiment may become apparent to those skilled in the art and do come within the

scope of this invention. Accordingly, the scope of legal protection afforded this invention can only be determined by studying the following claims.

What is claimed is:

1. A tandem axle drive set comprising:

a forward drive assembly including an inter-axle differential having a pair of outer side gears, a main differential, and a hollow pinion gear, *said inter-axle differential being rotatably supported by at least a pair of roller bearings;*

a through shaft having a first end secured to one of said outer side gears and extending through said hollow pinion gear, said through shaft not rotating with said hollow pinion gear;

a rear drive assembly including a rear pinion gear and a rear differential, said through shaft driving said rear pinion gear; and

rotation of said inter-axle differential [rotating] on said roller bearings resulting in rotation of said through shaft, said hollow pinion gear, and said rear pinion gear, with said hollow pinion gear driving said main differential and said rear pinion gear driving said rear differential.

2. A tandem axle drive set as recited in claim 1, wherein said hollow pinion gear is supported by at least one pair of roller bearings.

3. A tandem axle drive set as recited in claim 2 wherein said roller bearings comprise tapered roller bearings.

4. A tandem axle drive set as recited in claim 1 wherein said hollow pinion gear, said through shaft and said rear pinion gear all rotate about the same axis.

5. A tandem axle drive set as recited in claim 1 wherein said rear drive assembly and said forward drive assembly each include at least one annular seal.

6. [A tandem axle drive set as recited in claim 1,] *A tandem axle drive set comprising:*

*a forward drive assembly including an inter-axle differential having a pair of outer side gears, a main differential, and a hollow pinion gear, said inter-axle differential being rotatably supported by at least a pair of bearings;*

*a through shaft having a first end secured to one of said outer side gears and extending through said hollow pinion gear, said through shaft not rotating with said hollow pinion gear;*

*a rear drive assembly including a rear pinion gear and a rear differential, said through shaft driving said rear pinion gear wherein said rear pinion gear is supported by at least one pair of roller bearings; and*

*rotation of said inter-axle differential on said bearings resulting in rotation of said through shaft, said hollow pinion gear, and said rear pinion gear, with said hollow pinion gear driving said main differential and said rear pinion gear driving said rear differential.*

7. A tandem axle drive set as recited in claim 6 wherein said roller bearings comprise tapered roller bearings.

8. A tandem axle drive set as recited in claim 1 wherein said hollow pinion gear, said through shaft, and said rear pinion gear rotate in a first direction, said first direction based on the rotation direction of said inter-axle differential.

9. [A tandem axle drive set as recited in claim 1] *A tandem axle drive set comprising:*

*a forward drive assembly including inter-axle differential having a pair of outer side gears, a main differential, and a hollow pinion gear, said inter-axle differential being rotatably supported by at least a pair of bearings;*



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a through shaft having a first end secured to one of said outer side gears and extending through said hollow pinion gear, said through shaft not rotating with said hollow pinion gear;

a rear drive assembly including a rear pinion gear and a rear differential, said through shaft driving said rear pinion gear;

rotation of said inter-axle differential on said bearings resulting in rotation of said through shaft, said hollow pinion gear, and said rear pinion gear, with said hollow pinion gear driving said main differential and said rear pinion gear driving said rear differential; and

wherein said forward drive assembly further includes a forward axle driven by said main differential, said through shaft passing adjacent said forward axle and extending beyond said forward axle toward said rear drive assembly.

10. A tandem axle drive set comprising:

a forward drive assembly including an inter-axle differential having a pair of outer side gears, and a main differential having a forward pinion gear for supplying an input drive from said inter-axle differential to a pair of side gears;

a through shaft having a first end secured to one of said outer side gears and extending past said forward drive assembly, said through shaft rotating with said at least one outer side gear;

a rear drive assembly including a rear pinion gear and a rear differential, said through shaft driving said rear pinion gear;

at least one tapered roller bearing rotatably supporting said inter-axle differential with rotation of said inter-axle differential rotating said through shaft, said main differential, said rear pinion gear, and said rear differential; and

said inter-axle differential, said through shaft, said forward pinion gear, and said rear pinion gear being coaxial.

11. A tandem axle drive set as recited in claim 1 wherein said at least a pair of roller bearings comprises a first bearing set and wherein said hollow pinion gear is supported by a second bearing set separate from said first bearing set.

12. A tandem axle drive set composing:

a forward drive assembly including an inter-axle differential having a pair of outer side gears, a main differential, and a hollow pinion gear, said inter-axle differential being rotatably supported by at least a pair of bearings wherein said at least a pair of bearings comprises a first bearing set and wherein said hollow pinion gear is supported by a second bearing set separate from said first bearing set;

a through shaft having a first end secured to one of said outer side gears and extending through said hollow pinion gear, said through shaft not rotating with said hollow pinion gear;

a rear drive assembly including a rear pinion gear and a rear differential, said through shaft driving said rear pinion gear;

rotation of said inter-axle differential on said bearings resulting in rotation of said through shaft, said hollow pinion gear, and said rear pinion gear, with said hollow pinion gear driving said main differential and said rear pinion gear driving said rear differential; and

a pinion cage having a first portion for supporting at least one bearing from said first bearing set and a second

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portion for supporting at least one bearing from said second bearing set.

13. A tandem axle drive set as recited in claim 11 wherein said first bearing set comprises a first pair of tapered roller bearings and said second bearing set comprises a second pair of tapered roller bearings.

14. A tandem axle drive set as recited in claim 13 including a main differential carrier for substantially enclosing said main differential, an inter-axle differential cover for substantially enclosing said inter-axle differential, and a pinion cage wherein said first pair of tapered roller bearings includes a first tapered roller bearing supported between said inter-axle differential and said inter-axle differential cover and a second tapered roller bearing supported between said inter-axle differential and said pinion cage and wherein said second pair of tapered roller bearings includes a third tapered roller bearing supported between said hollow pinion gear and said pinion cage and a fourth tapered roller bearing supported between said hollow pinion gear and said main differential carrier.

15. A tandem axle drive set as recited in claim 14 wherein said first tapered roller bearing is positioned on an opposite end of said inter-axle differential from said second tapered roller bearing and wherein said third tapered roller bearing is positioned on an opposite side of a pinion gear head from said fourth tapered roller bearing.

16. A tandem axle drive set as recited in claim 15 wherein said pinion cage is mounted between said main differential carrier and said inter-axle differential cover.

17. A tandem axle drive set as recited in claim 11 wherein said first bearing set is solely comprised of a first pair of tapered roller bearings and said second bearing set is solely comprised of a second pair of tapered roller bearings.

18. A tandem axle drive set comprising:

a forward drive assembly including a main differential having a forward pinion gear receiving input from an inter-axle differential, said inter-axle differential being rotatably supported by a first roller bearing set and having a first outer side gear and a second outer side gear;

a through shaft having a first end secured to said first outer side gear and a second end extending past said forward drive assembly, said through shaft rotating with said first outer side gear;

a rear drive assembly including a rear pinion gear and a rear differential, said through shaft driving said rear pinion gear;

said second outer side gear in driving engagement with said forward pinion gear with rotation of said inter-axle differential rotating said through shaft, said main differential via said forward pinion gear, said rear pinion gear, and said rear differential; and

said inter-axle differential, said through shaft, said forward pinion gear, and said rear pinion gear being coaxial.

19. A tandem axle drive set as recited in claim 18 wherein said forward pinion gear comprises a hollow pinion shaft with a pinion gear head, said through shaft extending through said hollow pinion shaft.

20. A tandem axle drive set as recited in claim 19 wherein said pinion shaft is rotatably supported by a second bearing set.

21. A tandem axle drive set as recited in claim 20 wherein said first roller bearing set solely comprises a first pair of tapered roller bearings.



22. A tandem axle drive set comprising:

a forward drive assembly including a main differential having a forward pinion gear receiving input from an inter-axle differential, said inter-axle differential being rotatably supported by a first bearing set and having a first outer side gear and a second outer side gear and wherein said forward pinion gear comprises a hollow pinion shaft with a pinion gear head, said through shaft extending through said hollow pinion shaft with said hollow pinion shaft being rotatably supported by a second bearing set solely comprising a pair of tapered roller bearings;

a through shaft having a first end secured to said first outer side gear and a second end extending past said forward drive assembly, said through shaft rotating with said first outer side gear;

a rear drive assembly including a rear pinion gear and a rear differential, said through shaft driving said rear pinion gear;

said second outer side gear in driving engagement with said forward pinion gear with rotation of said inter-axle differential rotating said through shaft, said main differential via said forward pinion gear, said rear pinion gear, and said rear differential; and

said inter-axle differential, said through shaft, said forward pinion gear, and said rear pinion gear being coaxial.

23. A tandem axle drive set comprising:

a forward drive assembly including a main differential having a forward pinion gear receiving input from an inter-axle differential, said inter-axle differential being rotatably supported by a first bearing set and having a first outer side gear and a second outer side gear;

said forward pinion gear comprising a hollow pinion shaft with a pinion gear head with said through shaft extending through said hollow pinion shaft, said hollow pinion shaft being rotatably supported by a second bearing set wherein first bearing set includes a first tapered roller bearing and a second tapered roller bearing and said second bearing set includes a third tapered roller bearing and a fourth tapered roller bearings;

a through shaft having a first end secured to said first outer side gear and a second end extending past said forward drive assembly, said through shaft rotating with said first outer side gear;

a rear drive assembly including a rear pinion gear and a rear differential, said through shaft driving said rear pinion gear;

said second outer side gear in driving engagement with said forward pinion gear with rotation of said inter-axle differential rotating said through shaft, said main differential via said forward pinion gear, said rear pinion gear, and said rear differential; and

said inter-axle differential, said through shaft, said forward pinion gear, and said rear pinion gear being coaxial.

24. A tandem axle drive set as recited in claim 23 wherein said first tapered roller bearing is positioned at an opposite end of said inter-axle differential from said second tapered roller bearing and wherein said third tapered roller bearing is positioned on one side of said pinion gear head adjacent to said second tapered roller bearing and said fourth tapered roller bearing is positioned on an opposite side of said pinion gear head from said third tapered roller bearing.

25. A tandem axle drive set as recited in claim 24 including a single piece pinion cage having a first cage portion for supporting said second tapered roller bearing and a second cage portion for supporting said third tapered roller bearing.

26. A tandem axle drive set as recited in claim 25 including a main differential carrier and an inter-axle differential cover wherein said first tapered roller bearing engages said inter-axle differential cover and said inter-axle differential and said fourth tapered roller bearing engages said main differential carrier and said hollow pinion shaft.

27. A tandem axle drive set as recited in claim 26 wherein said pinion cage is longitudinally positioned between said inter-axle differential and main differential carrier.

\* \* \* \* \*



UNITED STATES PATENT AND TRADEMARK OFFICE  
**CERTIFICATE OF CORRECTION**

PATENT NO. : RE 39,323 E  
APPLICATION NO. : 10/126043  
DATED : October 3, 2006  
INVENTOR(S) : Jack Darrin Oates

Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 4, line 63: Insert --an-- after “including”.

Column 5, line 66: “sporting” should be --supporting--

Signed and Sealed this

Nineteenth Day of December, 2006

A handwritten signature in black ink on a light gray dotted background. The signature reads "Jon W. Dudas" in a cursive style.

JON W. DUDAS

*Director of the United States Patent and Trademark Office*