US00RE39323E

(19) **United States**
(12) **Reissued Patent**
Oates

(10) **Patent Number: US RE39,323 E**
(45) **Date of Reissued Patent: Oct. 3, 2006**

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

(75) Inventor: **Jack Darrin Oates**, Fletcher, NC (US)

(73) Assignee: **Meritor Heavy Vehicle Systems, LLC**, Troy, MI (US)

(21) Appl. No.: **10/126,043**

(22) Filed: **Apr. 19, 2002**

Related U.S. Patent Documents

Reissue of:

(64) Patent No.: **6,200,240**
Issued: **Mar. 13, 2001**
Appl. No.: **09/248,411**
Filed: **Feb. 11, 1999**

(51) **Int. Cl.**
F16H 48/06 (2006.01)

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

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

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

RE25,269	E	*	10/1962	Christie	475/221
4,050,534	A	*	9/1977	Nelson et al.	475/221
5,860,889	A	*	1/1999	Schlosser et al.	475/221

OTHER PUBLICATIONS

Interwheel Differential Drive, Differentials of Wheeled Vehicles, Moscow Mashinostroyenie, 1987, pp. 35–45. Translation of above.

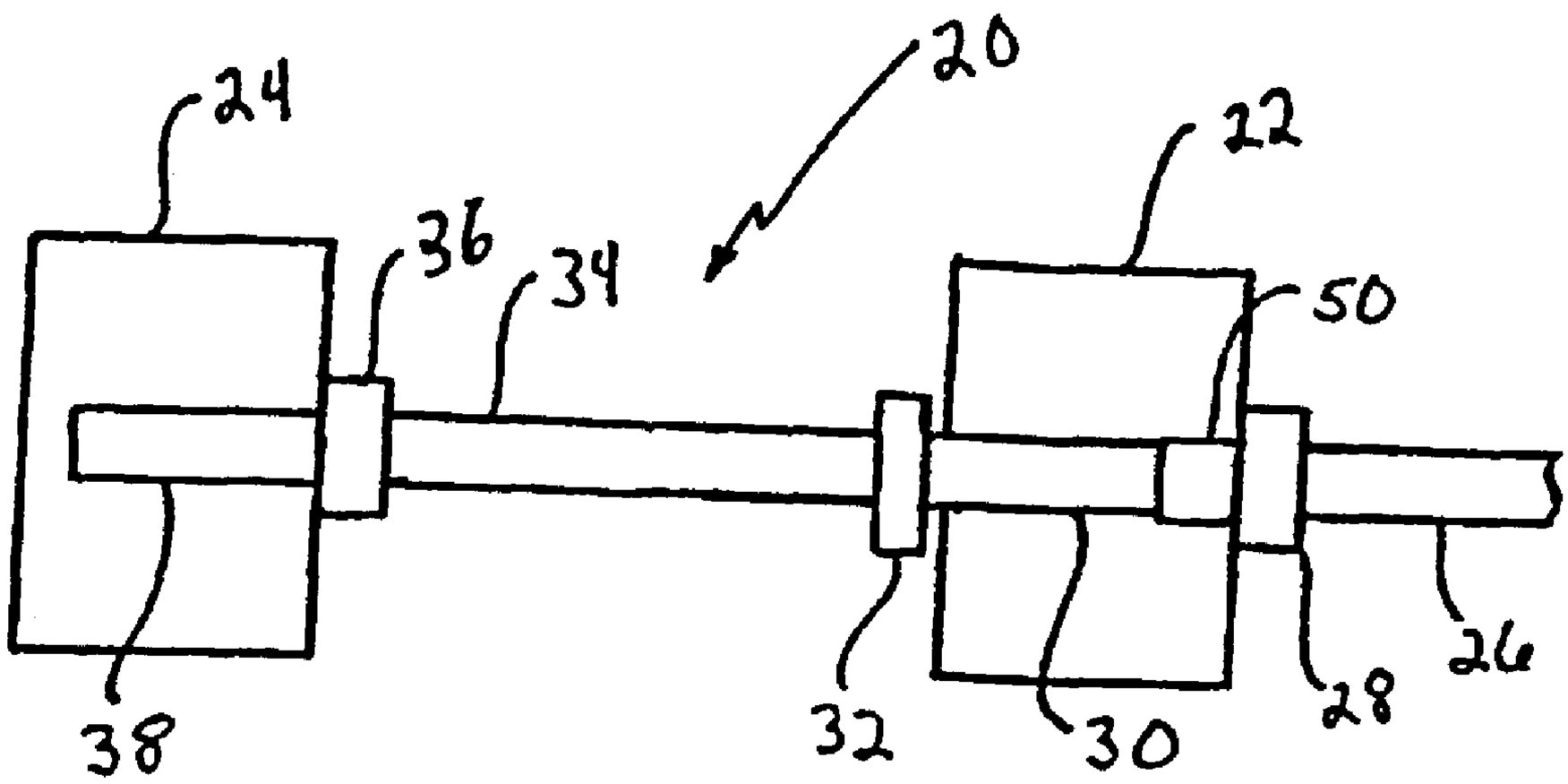
* cited by examiner

Primary Examiner—Dirk Wright
(74) *Attorney, Agent, or Firm*—Carlson, Gaskey & Olds

(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 tear 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



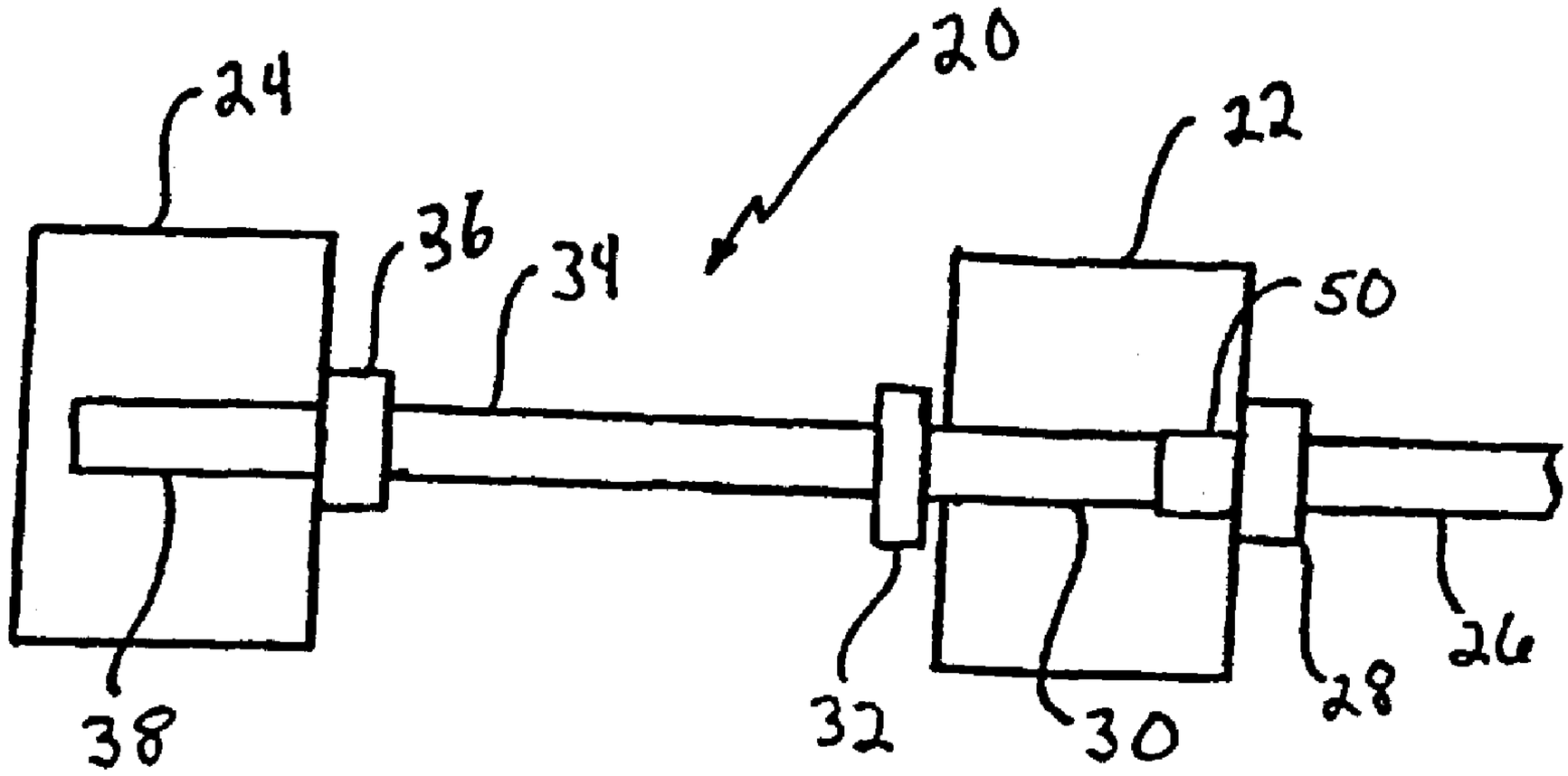


Fig. 1

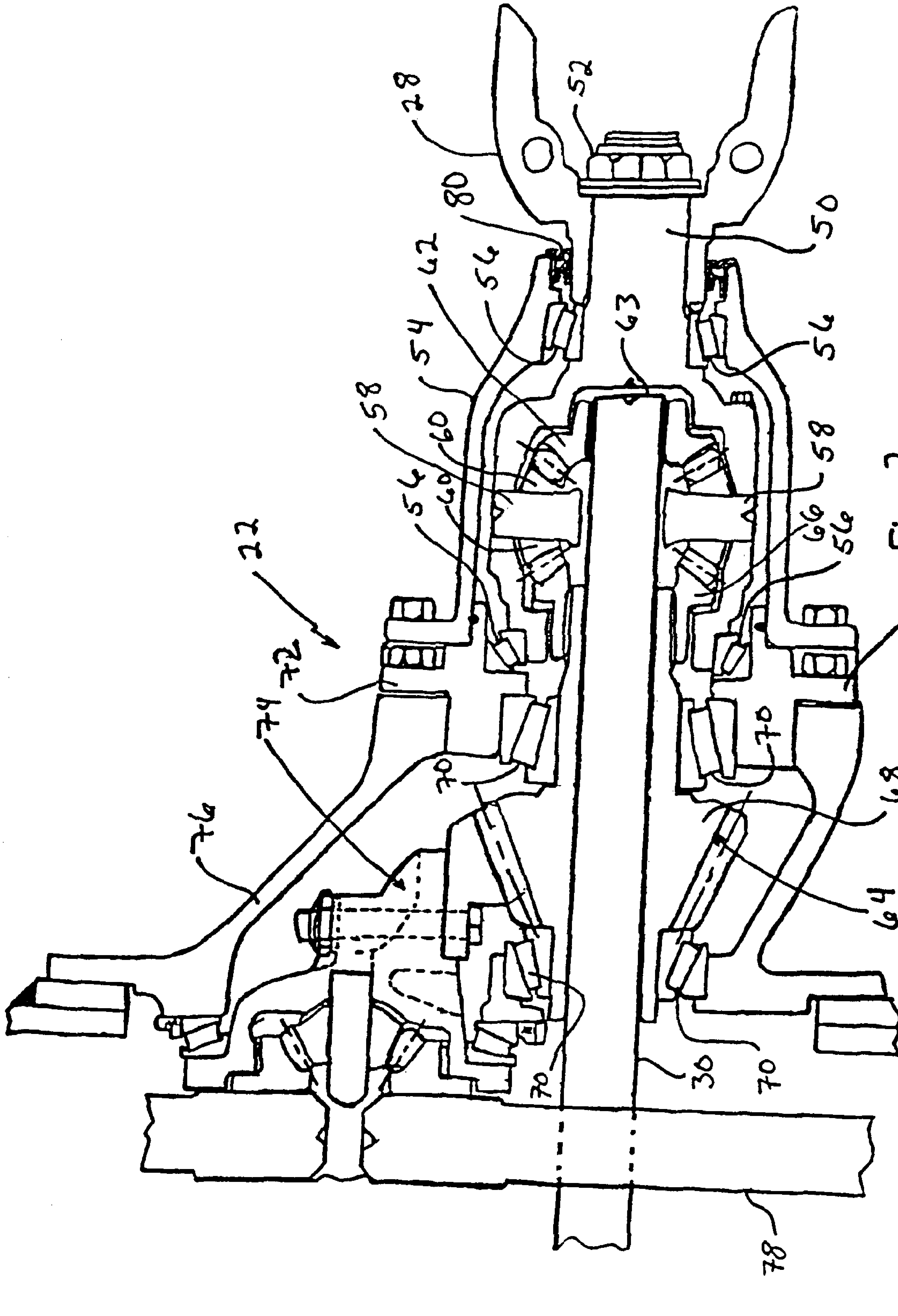


Fig. 2

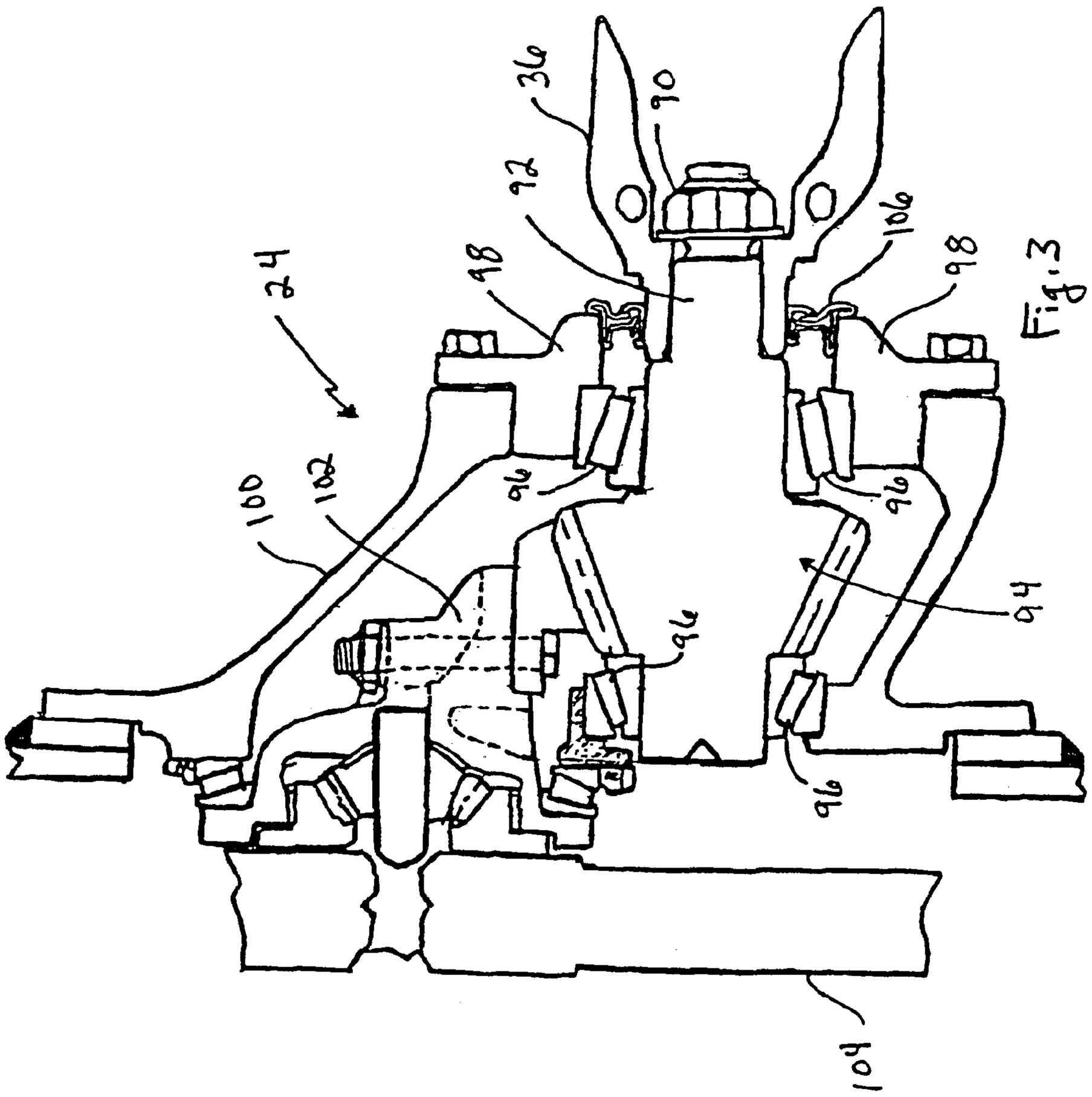


Fig. 3

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 minor 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 tear 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 tear 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**. An 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 then 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 **162** 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;

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 sporting at least one bearing from said first bearing set and a second 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

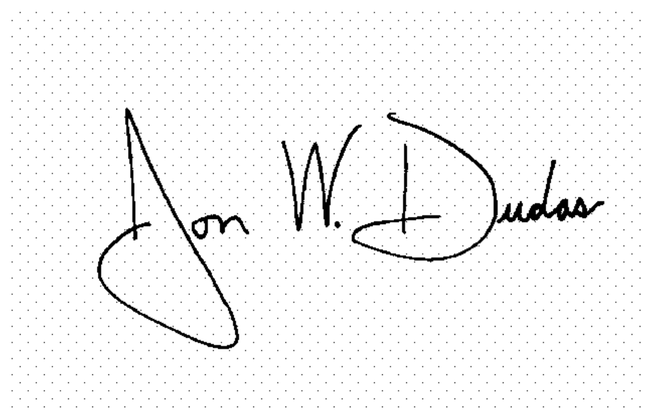
It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

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



JON W. DUDAS
Director of the United States Patent and Trademark Office