Dec. 13, 1938. O. LJUNGSTROM 2,139,965

HYDRAULIC TRANSMISSION SYSTEM

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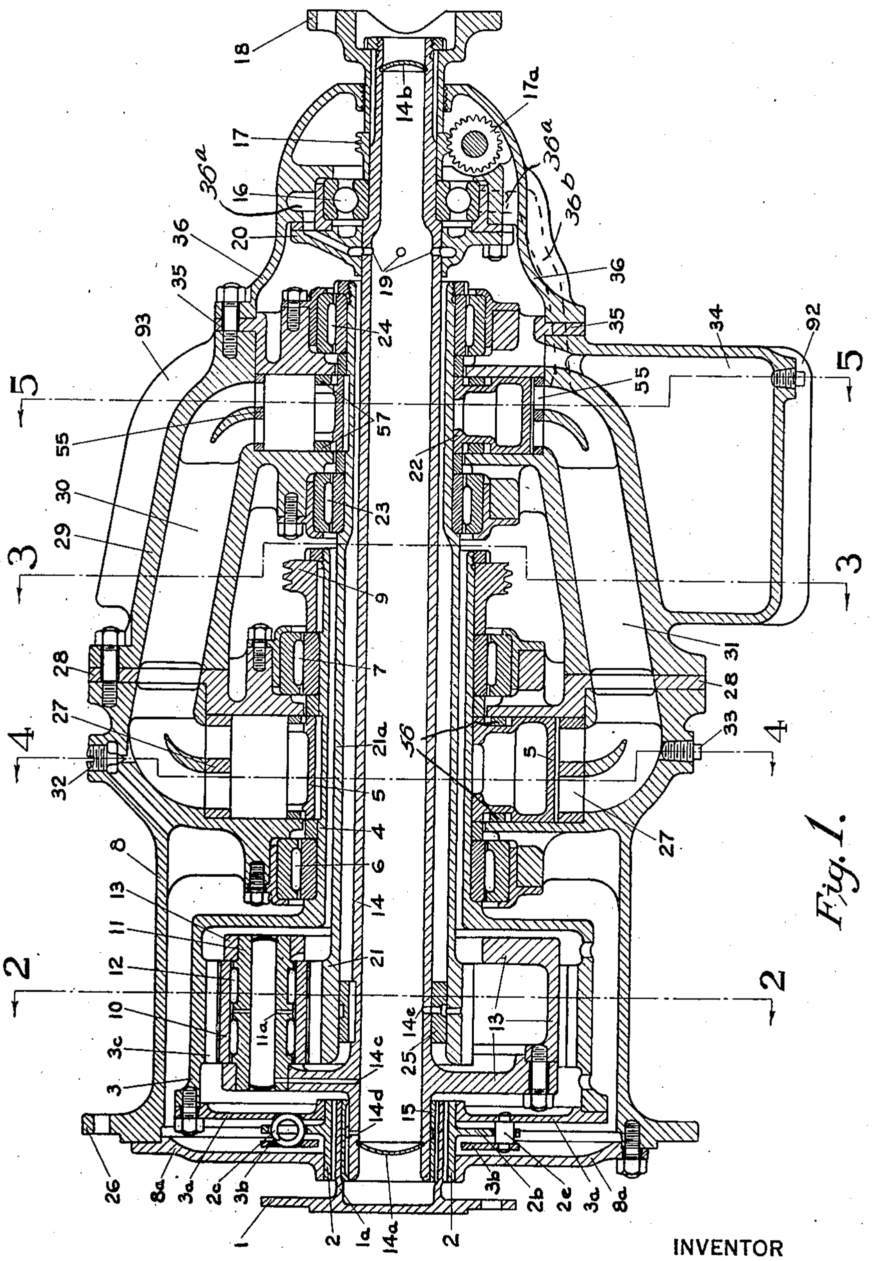

Fig. 1.

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Fig. 2.

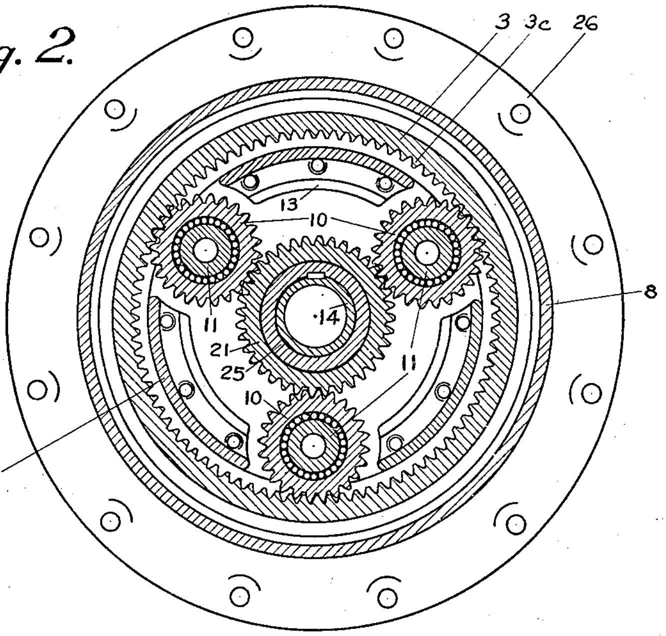
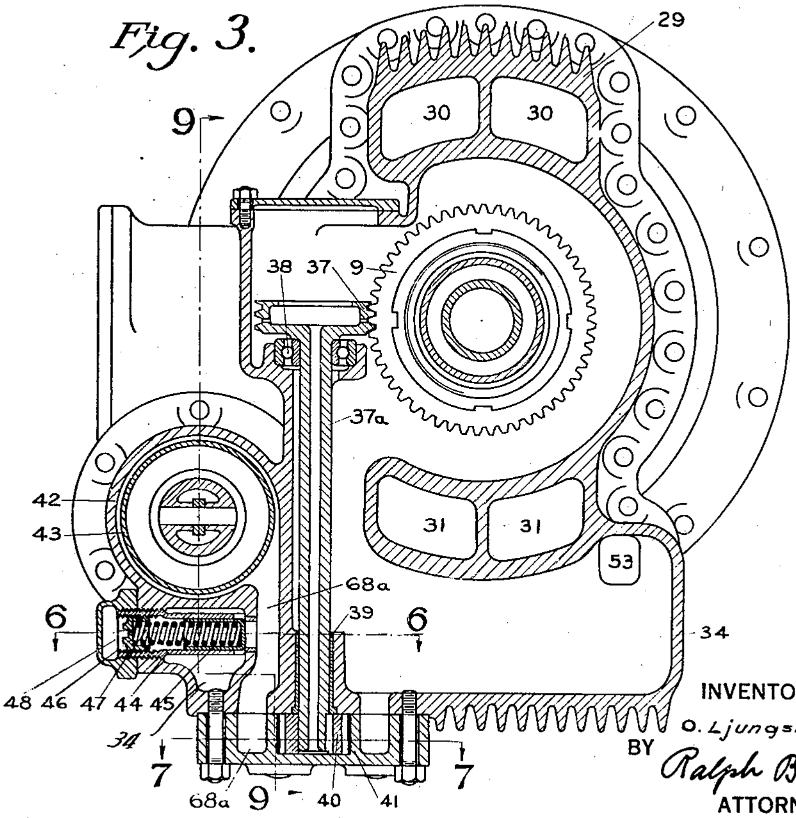


Fig. 3.



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HYDRAULIC TRANSMISSION SYSTEM

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Fig. 4.

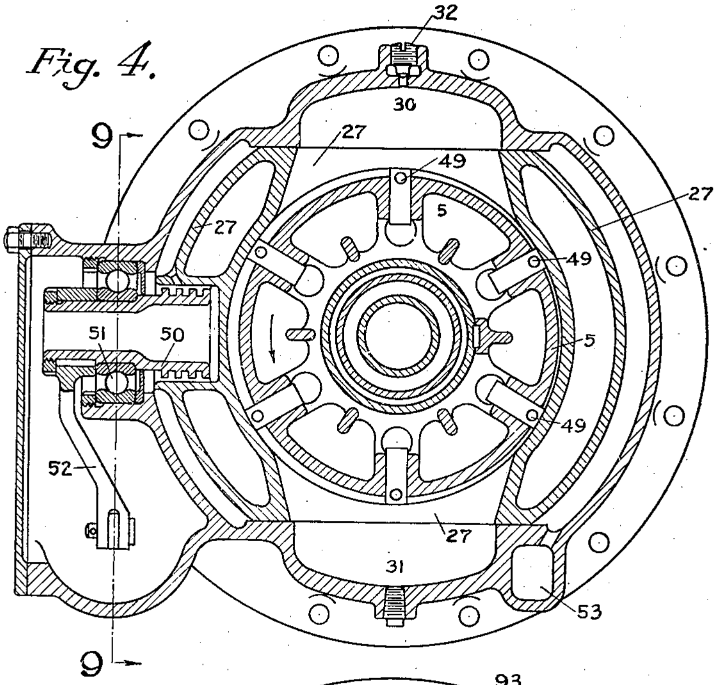
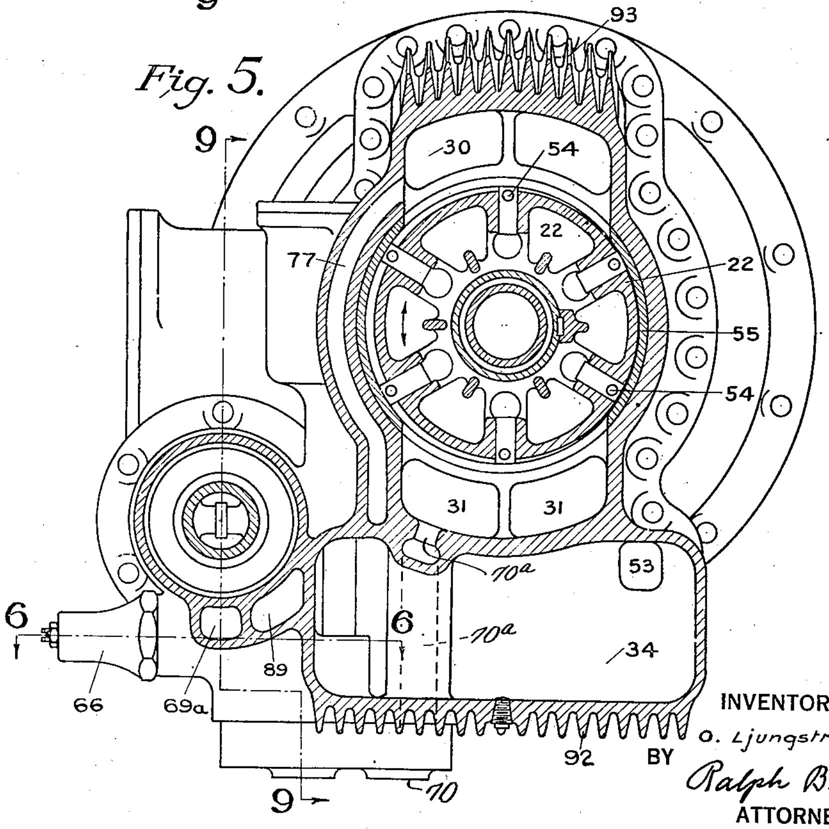


Fig. 5.



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HYDRAULIC TRANSMISSION SYSTEM

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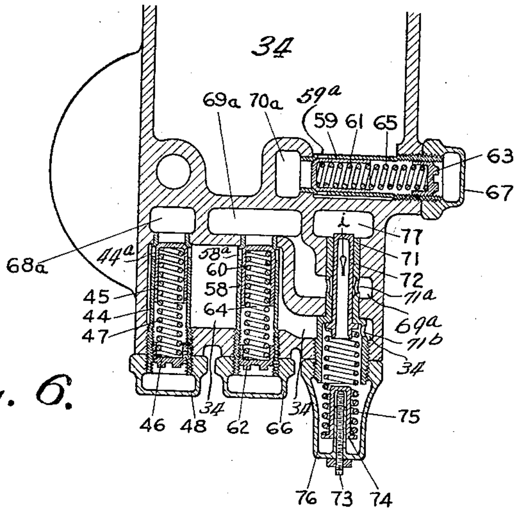

Fig. 6.

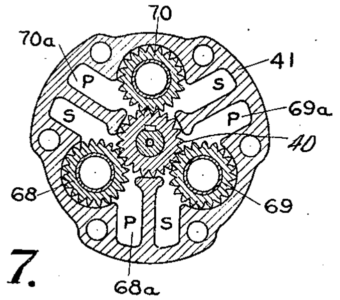

Fig. 7.

Fig. 8.

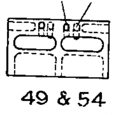

Fig. 8a

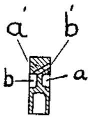

Fig. 8b

Fig. 8c

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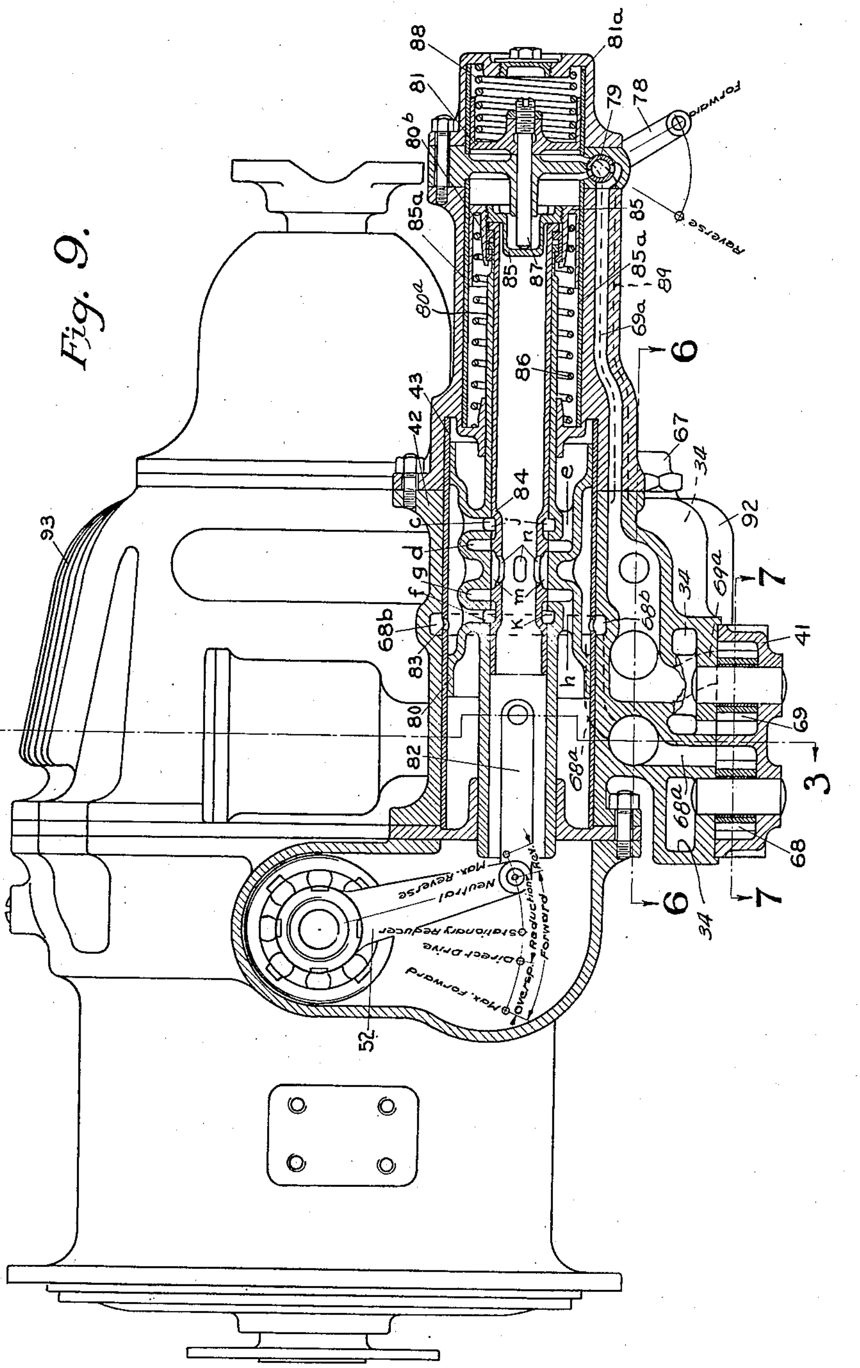
Fig. 9.



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HYDRAULIC TRANSMISSION SYSTEM

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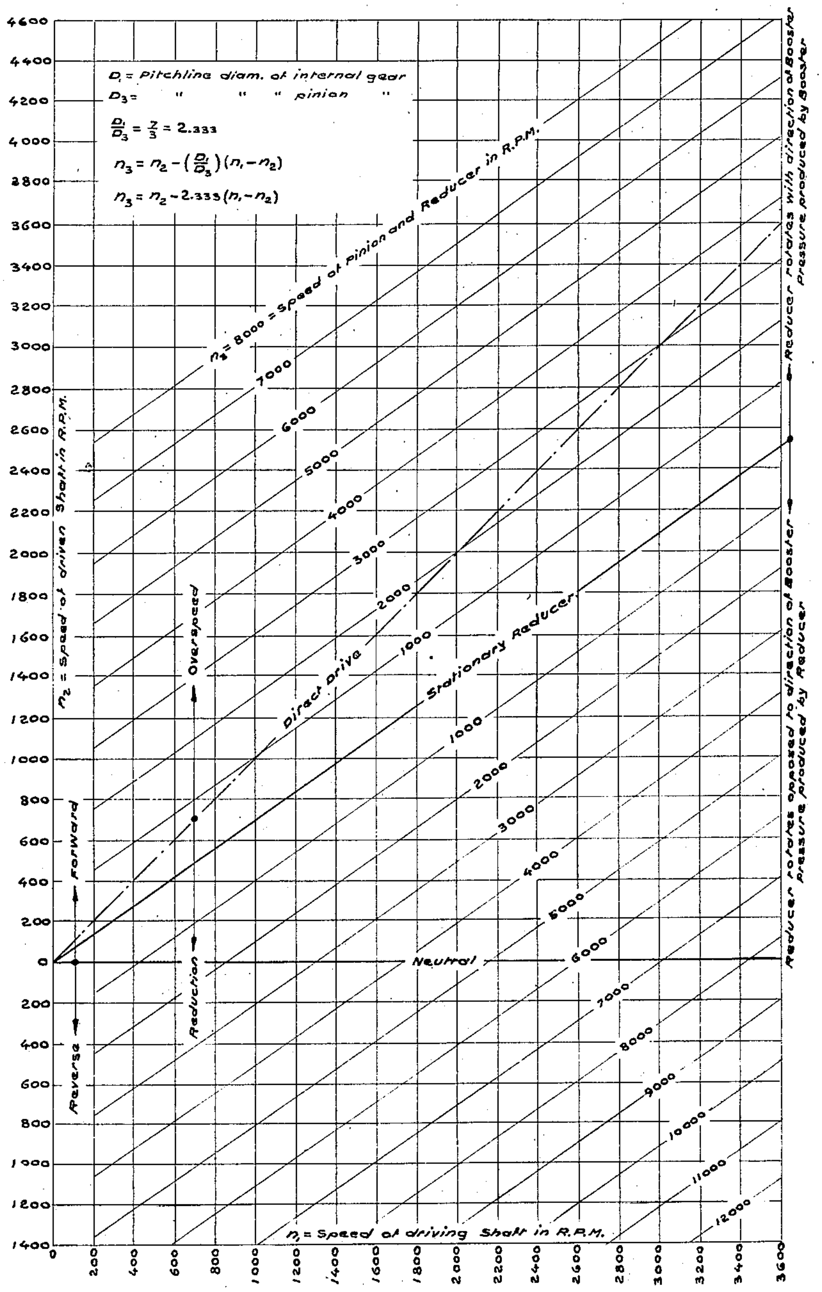

Fig. 10.

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Fig. 11.

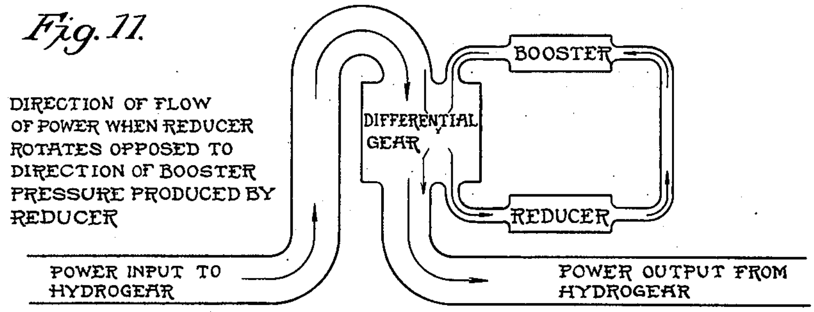

Fig. 12.

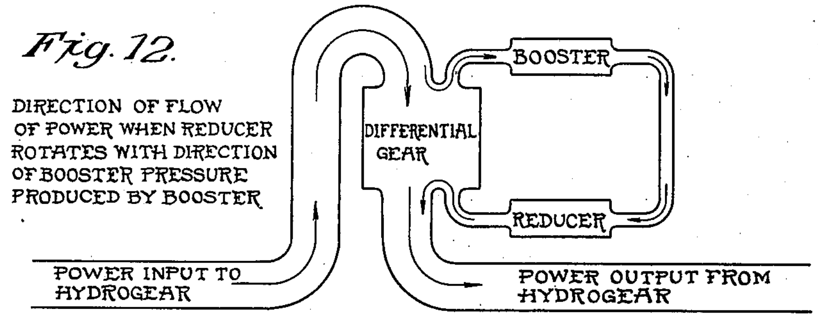

Fig. 13.

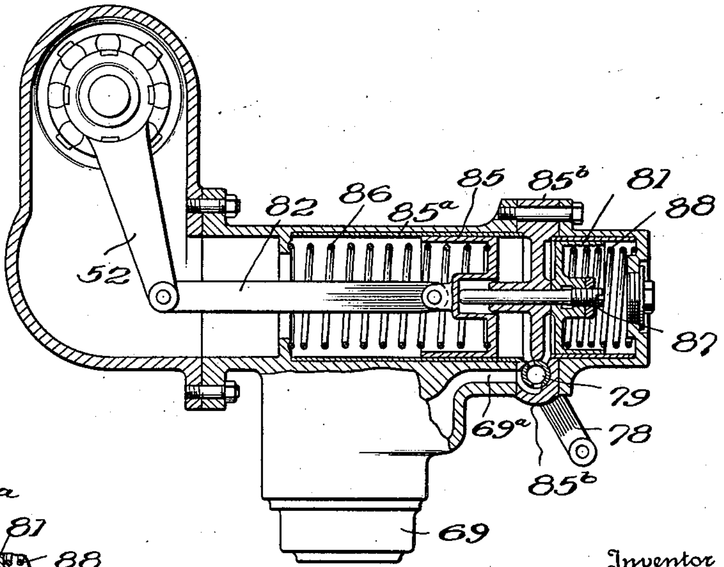

Fig. 13a

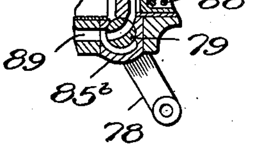

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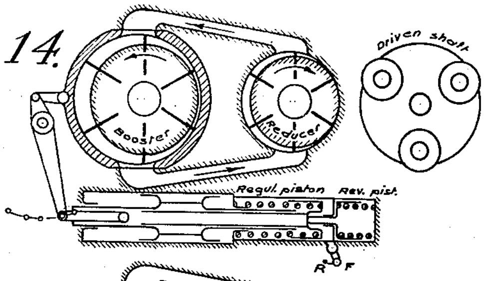
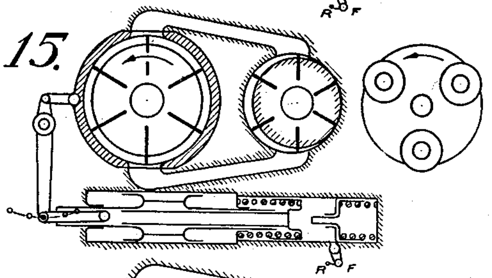
Fig. 14.



NEUTRAL

Engine and Booster rotate at idling speed.
Reducer rotating opposed to Booster, no pressure furnished.
Driven shaft and planet cage stationary.
Regulating piston resting on Reverse piston stop.

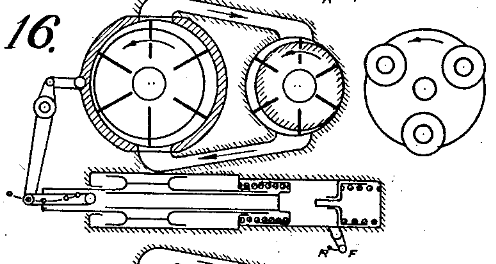
Fig. 15.



STATIONARY REDUCER

Engine and Booster rotate at moderate speed.
Reducer stationary, no pressure furnished.
Driven shaft and planet cage rotate with direction of Booster.
Regulating piston has left Reverse piston stop.

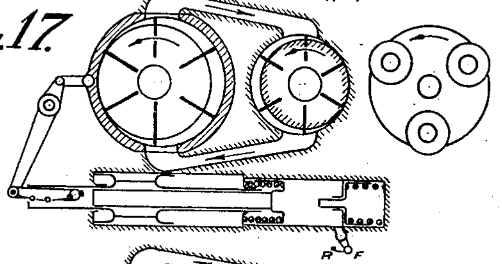
Fig. 16.



DIRECT DRIVE

Engine and Booster, Reducer and Driven shaft rotate with same speed and in same direction.
Pressure produced by Booster.

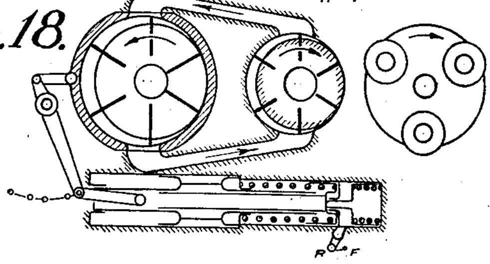
Fig. 17.



MAXIMUM FORWARD

Engine and Booster rotate at further increased speed
Reducer has increased rotation with direction of Booster, pressure produced by Booster.
Driven shaft and planet cage rotate at over speed with direction of Booster.

Fig. 18.



MAXIMUM REVERSE

Engine and Booster rotate at increased speed.
Reducer has increased rotation opposed to Booster, pressure produced by Reducer.
Driven shaft and planet cage rotate opposed to Booster.
Reverse piston moved against its spring, Regulator piston follows.

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UNITED STATES PATENT OFFICE

2,139,965

HYDRAULIC TRANSMISSION SYSTEM

Olof Ljungstrom, Detroit, Mich., assignor, by mesne assignments, to The Power Transmission Company, Incorporated, a corporation of Delaware

Application August 14, 1935, Serial No. 36,206

34 Claims. (Cl. 60—53)

This invention relates to transmission systems and in particular to variable speed transmission systems in which the speed of the driven shaft may be varied smoothly and progressively from zero to a maximum in either direction without the necessity of shifting gears. My invention is particularly suitable for use in driving vehicles from internal combustion engines, although it is not limited to such use, and may be used wherever it is necessary to start and accelerate heavy loads.

An object of my invention is to devise a transmission system in which the transmission ratio is automatically varied in accordance with the speed of the driving shaft.

A further object of my invention is to devise a transmission system in which the transmission ratio is dependent upon the torque being transmitted.

Another object of my invention is to devise a transmission system in which the transmission ratio is dependent both upon the speed of the driving shaft and upon the torque being transmitted.

Still another object of my invention is to devise a transmission system in which no power will be transmitted from the driving shaft to the driven shaft so long as the speed of the driving shaft is below a definite value, and driving power is automatically applied upon the speeding up of the driving shaft.

When my transmission system is employed in an automobile, the usual clutch construction and its control pedal is eliminated, the usual gear shift lever is not needed, and the entire operation of the car is controlled simply by the operation of the engine throttle.

My invention also involves a novel speed-responsive servo-motor, and a novel arrangement for lubricating differential gearing.

In the preferred embodiment of my invention the major portion of the driving power is transmitted mechanically from the driving shaft to the driven shaft through gearing having fixed meshing relations, and the minor portion of the power is transmitted through a variable ratio hydraulic transmission link. The mechanical transmission elements consist of a differential gearing, the internal gear of which is driven by the driving shaft and the planet spider is connected with the driven shaft. The hydraulic link consists of a convertible pump (hereafter termed a booster) driven from the driving shaft and hydraulically connected with a second reversible pump (hereafter termed a reducer) mechanically connected with the pinion gear or floating element of the differential gear. One of the pumps, preferably the booster, is provided with means to vary its displacement, while the other pump has a fixed displacement. The two pumps are connected in a fluid circuit so that while one pump is acting as a fluid pump the other unit is acting as a fluid motor and vice versa. The working medium or fluid may be either a liquid or a gas, but I prefer a liquid.

The preferred embodiment of my invention is described herein with particular reference to its use as a transmission system for automobiles. In this particular use, the arrangement is such that with the car standing still and the engine operating at idling speed, both the reducer and the booster operate as pumps for circulating fluid in the same direction in the hydraulic circuit. The displacement varying mechanism for the booster is normally biased to a position so that the output of the booster will be equal to the output of the reducer, and there will be no reaction upon the rotors of these two units except that necessary to overcome the friction in the fluid circuit. Under these conditions, the reducer rotor rotates freely in a direction opposite to engine shaft rotation, and no power is transmitted from the engine to the propeller shaft. The displacement varying mechanism of the booster is automatically controlled by an arrangement which is responsive to the speed of the engine shaft, and the arrangement is such that as the engine shaft increases above idling speed, the displacement of the booster is gradually reduced to zero and then gradually increased in the opposite direction, in other words, the displacement of the booster is changed so as to reverse the flow of fluid in the fluid circuit.

As the engine speed is increased above idling speed, the displacement of the booster is first reduced, thereby decreasing the capacity of the booster below that of the reducer and causing a reaction upon the reducer rotor which in turn causes the application of driving torque to the propeller shaft. During this stage the reducer is acting as a pump, supplying fluid to the booster, and the booster is acting as a motor adding its torque to the engine torque. As the displacement of the booster is further reduced, the speed of the reducer rotor is further decreased, thereby causing the propeller shaft to increase in speed. When the displacement of the booster is reduced to zero, the fluid circuit is blocked and the rotor of the reducer is held stationary, and under this condition the drive ratio is determined by the ratio of the pitch diameters of the internal gear and the pinion gear in the differential gearing.

Upon further increase in engine speed, the displacement of the booster pump begins to increase in the opposite direction from the initial displacement, and the booster begins to act as a pump circulating fluid in the opposite direction in the circuit. The reducer rotor now reverses its direction of rotation and begins to operate as a motor. As soon as the speed of the reducer rotor attains the speed of the propeller shaft, the transmission ratio is one-to-one, or "direct drive" is obtained. Upon further increase in speed of the engine, the displacement of the booster is further increased, thereby driving the reducer rotor at increased speed and causing the propeller shaft to be driven at a speed in excess of the speed of the engine shaft.

By increasing the booster displacement above its normal or biased value and in the same direction, the propeller shaft is driven in a reverse direction.

In addition to the control of the booster displacement in response to the speed of the driving shaft, I provide means responsive to the pressure in the fluid circuit (which is proportional to the torque being transmitted) for opposing or reducing the action of the speed-responsive means, thus limiting the amount of pressure (or torque) which is developed at any given engine speed.

A preferred embodiment of my invention is illustrated in the accompanying drawings in which:

Figure 1 is a longitudinal section through the transmission;

Figure 2 is a sectional view of the transmission along the line **2—2** in Figure 1;

Figure 3 is a sectional view of the transmission along the line **3—3** of Figures 1 and 9;

Figure 4 is a sectional view of the transmission along the line **4—4** in Figure 1;

Figure 5 is a sectional view of the transmission along the line **5—5** in Figure 1;

Figure 6 is a sectional view along line **6—6** in Figures 3, 5 and 9 illustrating the details of the regulating valves;

Figure 7 is a sectional view taken along line **7—7** in Figures 3 and 9 illustrating the details of the control pumps;

Figures 8, 8*b*, and 8*c* show four views of a rotor vane employed in the pumps;

Figure 9 is a side elevational view of the transmission showing the regulating mechanism in section along line **9—9** in Figures 3, 4 and 5.

Figure 10 is a graph illustrating the operation of the transmission;

Figures 11 and 12 are diagrammatic representations of the transmission system indicating the direction of power flow;

Figure 13 is a fragmentary view, partly in section, showing a modified control arrangement;

Figure 13*a* is a fragmentary sectional view of the control valve of Figure 13 showing the position of the discharge port and passage;

Figures 14 to 18 are schematic diagrams illustrating the different stages of operation of the transmission.

Referring to the drawings: **1** is the driving flange of the transmission to be bolted to the shaft of the driving engine (not shown) or other source of power. The sleeve extension **1a** of the flange **1** has external splines on which the damper sleeve **2** is mounted, free to slide on sleeve **1a** so as to prevent any axial strains from being transmitted between the engine and the transmission.

One end of damper sleeve **2** is journaled in end-plate **8a** of housing **8**, while the other end of the sleeve has journaled thereon an end-plate **3a** of the rotatable gear housing **3**. The sleeve **2** is also provided with a flange **2b** located between plates **3a** and **8a**, and this flange is coupled to the plate **3a** by resilient coupling devices to prevent vibrations from being transmitted from flange **1** to the gear housing **3**. These coupling devices may be formed of helical springs **2c** mounted between plate **3a** and a ring **3b** carried by the plate **3a**, the springs being located in recesses or holes formed in flange **2b** and ring **3b** in such manner that the driving torque is transmitted through the springs from flange **2b** to plate **3a**. The ring **3b** is supported from the plate **3a** by a number of pins **2e** freely passing through holes formed in the flange **2b**. Other forms of resilient couplings may be used if desired, and a number of these devices are distributed around the sleeve **2**.

The rotatable gear housing **3** encloses a differential gear set, and the internal gear **3c** of the set is preferably formed integral with the housing **3**.

Gear housing **3** has a sleeve extension **4** to which the booster rotor **5** is keyed. Two needle roller bearings **6** and **7** are arranged one on each side of the rotor **5** for the purpose of locating the rotor and the gear housing **3** in housing **8**. Spiral gear **9**, which serves the purpose of driving the gear pumps, is also keyed to the extension sleeve **4**. The internal gear **3c** meshes with three equally spaced planet gears **10** of which only one is shown in the sectional view of Figure 1. The planet gears are mounted on planet pins **11** by means of needle rollers **12**. Planet pins **11** are located in planet cage **13** which is secured to and carried by the driven shaft **14**. A plain bearing **15** in the drive flange sleeve **1a** supports one end of shaft **14** and ball bearing **16** supports the other end of the shaft in the opposite end of the transmission. Mounted on the driven shaft **14** is the tachometer takeoff worm **17** and gear **17a** and the power takeoff flange **18**. Driven shaft **14** is made hollow for reduction in weight and for the purpose of carrying lubricant to the different points to be lubricated. Spring disks **14a** and **14b** are provided to close the ends of the shaft to prevent escape of the lubricant. The lubricant enters the shaft through holes **19** from an annular groove formed in gland **20**. A duct **14c** formed in planet cage **13** feeds lubricant from hollow shaft **14** to hollow pins **11**, which are also provided with spring disks closing the ends. Hollow pins **11** are provided with radial ducts **11a** for supplying lubricant to the needle roller bearings **12**. A duct or hole **14d** serves to supply lubricant from shaft **14** to the bearing **15** between sleeve **1a** and the shaft **14**.

The planets mesh with pinion **21** which is formed on the end of a hollow shaft **21a** surrounding driven shaft **14**. On pinion shaft **21a** is mounted the reducer rotor **22** supported in needle roller bearings **23** and **24** on opposite sides thereof. A sleeve **25** secured to shaft **14** forms a supporting bearing for the other end of shaft **21a**, and a duct or hole **14e** supplies lubricant to this bearing and to gear **21** from shaft **14**.

Housing **8** has a flange **26** for bolting to the frame of the driving engine. This housing surrounds the damper, differential gearing and booster rotor. The rotor **5** rotates inside of a movable liner **27** which is closed in by cover **28** containing bearing **7**. An intermediate housing **29** surrounds the pump driving gear **9** and reducer rotor **22** which rotates inside of the fixed liner **55**. This part of the housing has two passages **30** and **31** forming a fluid circuit for the transmission of the hydraulic medium between the booster and the reducer rotors. On the highest part of the passage **30** is placed a needle valve **32** for relieving the air when the unit is first filled with liquid. Passage **31** has in its lowest point a drain plug **33**. A sump **34** for storage of liquid is made part of the housing. The reducer rotor **22** is closed in by cover **35**. End housing **36** contains bearing **16** and gland **20**.

Figure 2 is a sectional view taken along line **2—2** in Figure 1, showing the differential gear construction including the internal gear **3c**, the three planet gears **10**, the planet cage **13** and the pinion gear **21**.

Figure 3 is a sectional view of Figure 1 along line **3—3**, showing intermediate housing **29** containing spiral gears **9** and **37** for driving the gear control pumps. The pump drive shaft **37a** is an extension of gear **37** and is located in ball bearing **38** and plain bearing **39**, and to the lower end of the shaft is keyed pump gear **40**. The pump housing **41** is bolted to the underside of the sump. The intermediate housing further forms the cylinder **42** for the power piston which operates the movable liner **27** in Figure 1, and this cylinder is provided with a liner **43**. In the housing is also arranged the nearly constant pressure valve consisting of sleeve **44**, piston **45**, adjusting screw **46**, spring **47** and cap **48**. This valve regulates the pressure of the fluid supplied from one of the control pumps to cylinder **42** for operating the power piston. This pressure is relatively high.

Figure 4 is a sectional view along line **4—4** in Figure 1, and shows the booster rotor **5** and six rotor vanes **49** which are mounted radially and free to slide in radial direction in the rotor. The movable liner **27** can be moved to the right or to the left to form variable eccentricity with the rotor in both directions and is held in position by a square-thread screw **50**. The screw is located in the intermediate housing by ball bearing **51** and is operated by lever **52** which in turn is operated by the power piston by means of connecting rod **82** in Figure 9. Cored opening **53** conveys the lubricant from the differential gear housing **8** to the sump. Opening or duct **53** also serves to drain fluid from the space between the liner **27** and the casing wall, as shown by the passage connecting the space to the right of liner **27** with the duct **53** in Figure 4.

Figure 5 is a sectional view along line **5—5** in Figure 1, and shows the reducer rotor **22** and six rotor vanes **54** which are also movable radially in the rotor. Surroundng the rotor and vanes is a liner **55** mounted with fixed eccentricity with respect to the rotor. The upper passage **30** and the bottom of the sump **34** are equipped with cooling fins **93** and **92** to dissipate the heat of friction. The rotor vanes **49** and **54** are held against the liners **27** and **55** by means of spring rings **56** and **57** shown in Figure 1.

The details of the regulating valves for the control pumps are shown in Figure 6. The valve consisting of sleeve **44**, piston **45**, adjusting screw **46**, spring **47** and cap **48** is arranged to act as an over-flow or relief valve in the outlet passage **68a** leading from the pump **68** which supplied the working fluid to the power piston. When the pressure in passage **68a** exceeds a certain limit, piston **45** is moved against spring **47** and uncovers discharge apertures **44a** formed in sleeve **44** and allows the fluid to escape into the sump **34**. By proper design of the spring **47** and the discharge aperture of the valve, the valve operates to maintain a substantially constant pressure of relatively high value in the outlet passage **68a** regardless of pump speed.

The valve **58—60—62—64—66** is arranged to form an over-flow valve for the outlet passage **69a** from the control pump **69** which supplies a variable fluid pressure to the control piston of the servo-motor. Movement of piston **60** variably uncovers discharge aperture **58a** formed in sleeve **58** according to the pressure in passage **69a**, and the fluid escapes through the aperture into the sump **34**. By proper design of the spring **64** and the discharge aperture in the valve, the valve operates to regulate the pressure in the discharge passage **69a** so that it increases in proportion to the speed of the engine shaft. The discharge aperture for this valve is formed of a relatively long and narrow opening and the spring **64** has a relatively flat characteristic. The volume of fluid pumped by the pump **69** varies directly as the speed of the engine. As the engine speed increases the pressure in passage **69a** increases until it is sufficient to move the piston **60** and uncover enough of the discharge aperture **58a** to accommodate the output at that particular speed. As the engine speed increases further, the pressure existing in passage **69a** will correspondingly increase and force the valve open to uncover a larger area of the discharge aperture, and thus the pressure developed in the passage **69a** becomes a function of the engine speed.

The valve **59—61—63—65—67** is arranged to act as an over-flow valve for the outlet passage **70a** of the pump **70** which supplies lubricant to fill the fluid circuit **30—31** through the passage **70a**, Figure 5. The valve operates to maintain a substantially constant pressure output of the pump at relatively low value. Fluid from passage **70a** passes through discharge aperture **59a** formed in sleeve **59** and discharges into sump **34**. The aperture here is relatively wide and the spring **65** has a steep characteristic. The pump **70** also supplies lubricant under pressure through a cored passage **36b** which connects the low pressure fluid passage **31** with passage **36a** which in turn is connected to the gland **20**, from which point the lubricant passes into the shaft **14** and then to various parts of the transmission as described above.

The valve consisting of cylinder **71**, piston **72**, adjusting screw **73**, abutment **74**, spring **75** and cap **76** is arranged to be influenced by the pressure in passage **77** leading from the passage **30** in fluid circuit, see Figure 5. The aperture *i* in the piston **72** is arranged to relieve the pressure in outlet passage **69a** of pump **69** which supplies fluid pressure to the control piston of the servo-motor, and to thereby change the standard of operation of the servo-motor. An increase in pressure in chamber **77** causes piston **72** to move against spring **75** and variably uncover aperture *i* in accordance with the pressure and allows fluid from passage **69a** to escape through openings **71a** in cylinder **71**, through the aperture *i* into the hollow piston **72**, and back through the piston and out into the sump **34** through holes **71b** formed in the enlarged head of the piston.

The degree of control over the servo-motor by the valve **71—72** will depend upon the design of the spring 75 and the size and shape of the aperture *i*. I prefer to form this aperture with a tapered shape as shown in order to obtain a graduated control with the movement of the piston 72. The arrangement is such that increasing pressure in the fluid circuit causes a reduction in the pressure in the outlet passage 69*a* of the pump 69.

Any desired characteristic of the regulating valve may be obtained by proper design of the spring and the valve aperture. By using a spring with a flat characteristic and a wide aperture, a nearly constant pressure is obtained; whereas a spring of steep characteristic in combination with a narrow aperture will give a variable pressure characteristic. The pressure characteristic may be controlled by proper design of the sides of the aperture, that is, by proper design of the shape of the aperture.

Figure 7, a section along line 7—7 in Figures 3 and 9, shows the arrangement of control pumps 68, 69 and 70 which are driven by common gear 40 at a speed proportional to the engine speed. The suction and pressure sides are indicated on the drawings by S and P respectively. Pump 68 supplies fluid under pressure to the power cylinder 43 through cored passage 68*a* and annular passage 68*b*. Pump 69 supplies fluid of variable pressure to control cylinder 85*a* or to cylinder 81*a* through passage 69*a* and valve 79. Pump 70 supplies lubricant to section 31 of the fluid circuit through passage 70*a* and to gland 20 from section 31 through passages 36*b* and 36*a*. All pumps have a common housing 41 which is bolted to the underside of the sump as shown in Figure 3.

Figures 8, 8*a*, 8*b* and 8*c* show various views of a vane used in each of rotors 5 and 22 and are numbered 49 and 54. The vane is shown in side elevation in Figure 8, in end view in Figure 8*a*, in vertical sectional view in Figure 8*b*, and in bottom view in Figure 8*c*. These vanes are of the same construction but differ in size. The vanes are provided with cavities *a* and *b* on opposite sides below the surface of the rotor, and these cavities are connected to the pump spaces on opposite sides of the vane by holes *a'* and *b'* so as to balance the side pressures in order that the vanes will float freely in the slots. All other grooves and holes are for the purpose of weight reduction. The pressure of the vanes against their respective liners 27 and 55 if they were left heavy would be considerable at high rotor speeds due to centrifugal force.

The construction of the servo-motor for operating or varying the eccentricity or displacement of the booster is shown in sectional view in Figure 9. The power piston 80 is connected to lever 52 by means of link 82. This piston receives working fluid from pump 68 (Figure 7) at a relatively high pressure, which pressure is kept nearly constant by valve 45 (Figures 3 and 6) regardless of the speed of the pump. The fluid enters cylinder 43 through holes 83 from an annular passage 68*b* surrounding the cylinder and is directed to one side or the other of the piston by means of a pilot valve consisting of a movable sleeve 84 arranged in a cylindrical bore in piston 80 and cooperating with valve ports formed integral with piston 80. Annular ports *c* and *f* communicate with the annular space on the outside of piston 80 which is supplied with fluid under pressure, from passage 68*b*. Annular port *d* communicates with the right end of cylinder 43 through passage *e*, and annular port *g* communicates with the left end of the cylinder through passage *h*. Sleeve 84 is provided with an annular port *j* for connecting ports *c* and *d* to admit fluid to the right end of the power cylinder, and a second annular port *k* connects ports *g* and *f* to admit fluid to the left end of the cylinder. A third annular port *m* on sleeve 84 cooperates with either port *d* or *g* to drain fluid from either end of the cylinder to the sump through openings *n* formed in sleeve 84. The pilot valve 84 is moved by regulator or control piston 85 which is counterbalanced by the regulator or biasing spring 86, and is operated by means of liquid from pump 69, (Figure 7) supplied to control cylinder 85*a*. This liquid has a variable pressure, varied with the speed of the driving engine in such a manner that if the engine speed is increased the pressure will rise and move regulator piston 85 to the left against its spring 86 and pilot valve 84 will move into a position to admit fluid under pressure to the right end of cylinder 43 through ports *c*, *j*, *d* and *e* and to drain the left end of the cylinder through ports *h*, *g*, *m* and *n*. The power piston now moves to the left and by means of link 82 and lever 52 will rotate screw 50 (Figure 4), which in turn will change the eccentricity of the booster by moving liner 27 into a new position of less capacity. Movement of the power piston closes the passage *e* and the piston will remain in this position until further movement of part 84. If the sleeve 84 should return to its biased position, fluid pressure will be admitted to the left end of the cylinder through ports *f*, *k* and *g* and the right end would be drained through ports *d* and *m*, thus causing the piston to return to its original position. The arrangement is such that the power piston will follow the movements of the control valve sleeve 84. The piston 80 is provided with a sleeve extension 80*a* surrounding the valve sleeve 84, and the end of sleeve 80*a* is coupled to the control piston 85 by a lost-motion connection 80*b* which permits limited movement of the sleeve 84 with respect to the piston 80 in either direction from the normal position shown in Figure 9, the movement being sufficient to open the valve ports *g* or *d*.

The control piston 85 is held in its normal or biased position by an adjustable stop screw 87 carried by piston 81 arranged in an auxiliary control cylinder 81*a*. The auxiliary control cylinder 81*a* is mounted in axial alignment with cylinder 85*a* with a common cylinder head 85*b* interposed between the two, and the stop pin 87 extends through the head 85*b* into the cylinder 85*a*. The piston 81 is normally biased to the position shown in Figure 9 by a spring 88 which is stronger than the spring 86. A control valve 79 operated by a lever 78 serves to supply fluid either to the main control cylinder 85*a* for forward operation or to the auxiliary control cylinder 81*a* for reverse operation. A relief passage 89 arranged parallel with pressure passage 69*a* (Figures 5, 9 and 13*a*) is arranged to drain fluid from control cylinders 85*a* or 81*a*, depending upon the position of valve 79. In Figures 9 and 13 the valve 79 is set to drain the cylinder 81*a* and to supply fluid under pressure to cylinder 85*a*. Figure 13*a* is a fragmentary section through the head 85*a* along the axis of passage 89 showing how the valve 79 drains cylinder 81*a*. When the arm 78 is moved to "reverse position", the valve 79 will drain cylinder 85*a*.

In the operation of the system described above, the pressure developed by pump 69 at idling speed of the engine is insufficient to move the control piston 85 away from its biased position, and the normal position of the control elements is shown in Figure 9. Under this condition and with the vehicle standing still both the booster and the reducer operate as pumps to circulate fluid in the same direction and with equal capacities (see Figure 14) so that the reducer rotor rotates freely and there is no reaction on the reducer rotor, and hence no torque applied to the propeller shaft.

As the engine speeds up, the power piston moves the displacement lever **52** to the left from the neutral position and gradually decreases the displacement of the booster, thereby decreasing the capacity of the booster below that of the reducer and causing a reaction on the reducer rotor which in turn causes torque to be applied to the propeller shaft and the vehicle begins to accelerate.

During the stage in which the booster displacement is being decreased, the reducer rotor is rotating in a direction opposite to the engine rotation, and all of the power transmitted flows through the differential gear as shown in Figure 11.

When the displacement of the booster is reduced to zero the fluid circuit is blocked by the booster rotor, and the reducer rotor is held stationary, as shown in Figure 15.

Upon further increase in engine speed as the vehicle accelerates, the booster displacement is reversed, and the booster begins to supply fluid in the opposite direction to drive the reducer in the same direction of rotation as the engine, and under this condition, the major portion of the power is transmitted through the differential gearing, and a minor portion transmitted through the hydraulic circuit, as shown in Figure 12. Figure 16 illustrates the reversal in displacement of the booster and the reversal in flow of fluid in the circuit during this stage.

Figure 17 shows the operation of the system where the displacement of the booster has been increased to its maximum value for forward operation, and by proper design, the reducer rotor may be driven at a speed sufficiently high to produce over-speed drive of the propeller shaft.

If the driving shaft is brought down to idling speed, the pump drive will be accordingly reduced in speed, the liquid pressure in the regulator pump valve **58** will be lowered, the regulator piston **85** will return to the stop screw **87**, and the driven shaft will come to a stop with the driving shaft still rotating.

When it becomes necessary to reverse rotation of the driven shaft reverse lever **78** is moved to a position marked "Reverse" in Figure 9, thus moving rotary valve **79** to a position permitting the regulating liquid to operate reverse piston **81** against its spring **88** and thereby moving the stop screw away from regulating piston **85** which will now follow the stop screw under the action of the regulator spring **86**. The liquid pressure in the control cylinder **85***a* has been removed by means of a relief passage **89** parallel to pressure passage **69***a* Figure 5. This relief passage ends in the sump **34** Figure 1. The regulating liquid pressure now acts upon the reverse piston in exactly the same manner as on the piston **85** for forward operation.

It will be noted that the operation of the servo-motor is under the joint control of the variable pressure pump **69**, responsive to the engine speed, and under the control of the regulator valve **71**—**72** which is responsive to the pressure in the fluid circuit (or to the torque being transmitted). The pressure required in the fluid circuit to initiate operation of the valve **71**—**72** in modifying the speed responsive control is determined by the tension of the spring **75**, and, accordingly, the pressure at which the valve becomes effective may be varied by varying the tension of spring **75**. The arrangement is such that increase in pressure in the fluid circuit tends to reduce the fluid pressure output of the speed responsive pump **69**. This control feature is especially useful in allowing the engine to speed up and deliver its maximum horse power when increased torque is applied to the propeller shaft, as in case of driving the vehicle up steep grades. It also prevents the transmission ratio from changing too rapidly during acceleration, and prevents the building up of excessively high pressures in the fluid circuit. In case the car is accelerated quickly, and high pressures are developed in the circuit, the valve **71**—**72** retards the operation of the servo-motor until the car accelerates and the pressure decreases in the fluid circuit, whereas, if the car is accelerated gradually the operation of the servo-motor is governed principally in accordance with the engine speed.

Curve sheet Figure 10, illustrates the performance of the transmission system where the ratio of the pitch diameter of the engine gear to the pinion gear is 7 to 3. On it is indicated a neutral line, forward and reverse speeds, reduction and overspeed ranges as well as the direction of rotation of the reducer rotor, and by which rotor the liquid pressure is produced.

By assuming a certain engine speed, which is the speed of the driving shaft, and choosing a speed of the driven shaft, it is possible to determine from the diagram the speed of the reducer, the direction of rotation of same and whether reduction or overspeed is obtained.

In case the booster has a fixed displacement and the reducer has a variable displacement, the servo-motor should be arranged to increase the displacement from its normal or biased value for forward operation, but with this arrangement, overspeed drive cannot be obtained. For reverse operation, the displacement of the reducer would be decreased from its normal value, but it is never reduced to zero.

The novel control features disclosed in connection with the hydraulic transmission link are not limited to use in a mixed transmission of the type illustrated, but are useful in a straight hydraulic system where the reducer is connected directly to the propeller shaft and the differential gearing is omitted. In such an arrangement the normal or biased position of the servo-motor would be set for zero booster displacement, but otherwise the operation would be the same as described above. I prefer, however, to use the differential gearing in order to reduce the size of the hydraulic units and to obtain a wider range of speed and torque variations.

The specific construction disclosed herein is for the purpose of illustration only, and it will be clear to those skilled in the art that many changes may be made without departing from the scope of my invention. For example, other known pump constructions may be used in the fluid circuit having different arrangements for varying and reversing the displacement, and other known forms of speed responsive devices may be used to control the displacement varying means, such as a centrifugal regulator or a speed responsive electrical regulator. Also, the control arrangement may be simplified by omitting the power piston and pump **68**, making spring **86** strong enough to bias the lever **52** to the neutral position and designing pump **69** to have sufficient power to operate the lever **52** directly and without the aid of the power piston. This simplified arrangement is illustrated in Figure 13 which is a fragmentary sectional view showing the details of the control arrangement, using the same reference characters as Figure 9. In this arrangement, it will be seen that the power cylinder and piston of the servo motor and the pump **68** have been eliminated and the lever **52** is operated directly from the piston **85**, but otherwise the construction is substantially like that shown in Figure 9.

It will be understood that the speed responsive control arrangement disclosed herein for varying the displacement of the booster may be used without the pressure responsive control valve **71—72**, however, I prefer to use the joint control responsive to both speed and pressure.

The term "convertible pump" as employed herein denotes a pump which will operate either as a fluid pump or as a fluid motor. The term "reversible displacement" denotes that the displacement may be changed to reverse the direction of flow of fluid during pump operation without reversing the direction of rotation, or, for motor operation, to reverse the direction of rotation without reversing the flow in the fluid circuit.

I have herein described the principle of my invention and illustrated a preferred embodiment thereof. Certain modifications have been pointed out to indicate the broad scope of the invention. Various other modifications will occur to those skilled in the art, and I desire it to be understood that all modifications which fall within the terms of the appended claims are to be considered as falling within the scope of my invention.

I claim:

1. In combination, a variable speed power shaft, a driven shaft, differential gearing connecting said shafts, a convertible fluid pump connected with the floating member of said gearing, and means responsive to increasing speed of said power shaft for imposing an increasing load on said pump to decrease its speed and stop the rotation thereof and for thereafter driving said pump as a motor in the opposite direction.

2. In combination, a variable speed power shaft, a driven shaft, differential gearing connecting said shafts, a convertible fluid pump driven by said power shaft, a convertible fluid pump connected with the floating element of the differential gearing and connected in fluid circuit with the first pump, and means responsive to speed variations of said power shaft and operable at low speeds of the power shaft to cause the second mentioned pump to drive the first mentioned pump as a motor in the direction of power shaft rotation and operable at higher speeds of said shaft to cause the first pump to drive the second pump as a motor.

3. In combination, a variable speed power shaft, a driven shaft, differential gearing connecting said shafts, a fluid pump driven by said power shaft, a fluid pump driven by the floating element of the differential gearing and connected in fluid circuit with the first pump, one of said pumps having means for varying the displacement thereof, means for normally biasing said displacement varying means to a position to cause both pumps to circulate fluid in the same direction in said circuit, and means responsive to increase in speed of the power shaft to decrease the displacement of said pump.

4. In combination, a variable speed power shaft, a driven shaft, differential gearing connecting said shafts, a convertible fluid pump driven by said power shaft, a convertible fluid pump driven by the floating element of the differential gearing and connected in fluid circuit with the first pump, said first pump having means for varying and reversing the displacement thereof, means for normally biasing said displacement varying means to a position to cause the first pump to circulate fluid in the same direction in said circuit and at the same capacity as the second pump when the driven shaft is stationary, and means responsive to increase in speed of the power shaft to first decrease the displacement and then reverse the same and increase it in the opposite direction.

5. In combination, a variable speed power shaft, a load shaft, a fluid pump driven by said power shaft, means for varying the displacement of said fluid pump, a fluid motor mechanically connected with the load shaft and connected in fluid circuit with said pump, means for normally biasing the displacement element of said pump to a position to prevent the transmission of power between said pump and motor, and means responsive to increase in speed of the power shaft for varying the displacement of said pump to transmit power from the pump to the motor.

6. In combination, a variable speed power shaft, a load shaft, means for transmitting power from the power shaft to the load shaft comprising a fluid pump driven by the power shaft and connected in fluid circuit with a fluid pump connected with the load shaft, one of said pumps being provided with means for varying the displacement thereof, means for normally biasing said variable displacement element to a position to prevent the transmission of power between said shafts, and means responsive to increase in speed of the power shaft for varying said displacement element to transmit power between said shafts.

7. In combination, a variable speed power shaft, a driven shaft, differential gearing connecting said shafts, a convertible fluid pump connected with the floating member of said gearing, means responsive to increasing speed of said power shaft for imposing an increasing load on said pump to decrease its speed and stop the rotation thereof and for thereafter driving said pump as a motor in the opposite direction, and means for controlling the standard of operation of said speed responsive means in accordance with the pressure on said pump.

8. In combination, a variable speed power shaft, a load shaft, means for transmitting power from the power shaft to the load shaft comprising a fluid pump driven by the power shaft and connected in fluid circuit with a fluid pump connected with the load shaft, one of said pumps being provided with means for varying the displacement thereof, means for normally biasing said variable displacement element to a position to prevent the transmission of power between said shafts, means responsive to increase in speed of the power shaft for varying said displacement element to transmit power between said shafts, and means responsive to pressure in said fluid circuit for opposing the shifting of said variable displacement element.

9. In combination, a variable speed power shaft, a driven shaft, differential gearing connecting said shafts, a fluid pump driven by said power shaft, a fluid pump driven by the floating element of the differential gearing and connected in fluid circuit with the first pump, one of said pumps having means for varying the displace-

ment thereof, means for normally biasing said displacement varying means to a position to cause both pumps to circulate fluid in the same direction in said circuit, means responsive to increase in speed of the power shaft to vary the displacement of said pump, and means for varying the standard of operation of said speed responsive means in accordance with pressure variations in said fluid circuit.

10. In combination, a variable speed power shaft, a driven shaft, differential gearing connecting said shafts, a fluid pump driven by said power shaft, a fluid pump driven by the floating element of the differential gearing and connected in fluid circuit with the first pump, said first pump having means for varying the displacement thereof, means for normally biasing said displacement varying means to a position to cause the first pump to circulate fluid in the same direction in said circuit and at the same capacity as the second pump when the driven shaft is stationary, and means responsive to increase in speed of the power shaft to decrease the displacement of said first pump.

11. In combination, a variable speed power shaft, a driven shaft, differential gearing connecting said shafts, a fluid pump driven by said power shaft, a fluid pump driven by the floating element of the differential gearing and connected in fluid circuit with the first pump, said first pump having means for varying the displacement thereof, means for normally biasing said displacement varying means to a position to cause the first pump to circulate fluid in the same direction in said circuit and at the same capacity as the second pump when the driven shaft is stationary, means responsive to increase in speed of the power shaft to decrease the displacement of said first pump, and means responsive to increase in pressure in said fluid circuit for opposing the decrease in displacement of said pump.

12. In combination, a variable speed power shaft, a load shaft, means for transmitting power between said shafts comprising a fluid pump driven by the power shaft and connected in fluid circuit with a fluid motor mechanically connected with the load shaft, said fluid pump having a variable displacement, means responsive to increase in speed of the power shaft for increasing the displacement of said pump, and means responsive to increase in pressure in said fluid circuit for opposing the increase in displacement of said pump.

13. In combination, an engine having a variable speed power shaft, a driven shaft, differential gearing connecting said shafts, a convertible fluid pump connected with the floating member of said gearing, and means responsive to increasing speed of said power shaft for imposing an increasing load on said pump to decrease its speed and stop the rotation thereof and for thereafter driving said pump as a motor in the opposite direction, said means being operable to unload said pump at idling speed of said engine.

14. In combination, a variable speed power shaft, a driven shaft, differential gearing connecting said shafts, a fluid pump driven by said power shaft, a fluid pump driven by the floating element of the differential gearing and connected in fluid circuit with the first pump, one of said pumps having means for varying the displacement thereof, means for normally biasing said displacement varying means to a position to cause both pumps to circulate fluid in the same direction in said circuit and at the same capacity when the driven shaft is stationary, means responsive to the speed of the power shaft to operate said displacement varying means, and control means for said speed responsive means operable in one position to increase the displacement with increasing speed and in another position to decrease the displacement with increase in speed.

15. In combination, a variable speed power shaft, a driven shaft, differential gearing connecting said shafts, a fluid pump driven by said power shaft, a fluid pump driven by the floating element of the differential gearing and connected in fluid circuit with the first pump, one of said pumps having means for varying the displacement thereof, means for normally biasing said displacement varying means to a position to cause both pumps to circulate fluid in the same direction in said circuit and at the same capacity when the driven shaft is stationary, and means responsive to increase in speed of the power shaft to increase the displacement of said pump.

16. In combination, a variable speed power shaft, a load shaft, means for transmitting power between said shafts comprising a fluid pump driven by the power shaft and connected in fluid circuit with a fluid motor mechanically connected with the load shaft, said fluid pump having a variable displacement element, means for normally biasing the variable displacement element of the pump to a position to prevent the transmission of power between said shafts, means responsive to increase in speed of the power shaft for varying the displacement of said pump to drive the load shaft in one direction, and means responsive to increase in speed of the power shaft for varying the displacement of said pump in a direction to drive the load shaft in the opposite direction.

17. In combination, an engine having a variable speed power shaft, a load shaft, means for transmitting power between said shafts comprising a fluid pump driven by the power shaft and connected in fluid circuit with a fluid motor mechanically connected with the load shaft, said fluid pump having an element for varying the displacement thereof, means for normally biasing the variable displacement element of the pump to a position to prevent the transmission of power between said shafts, and means responsive to increase in speed of the power shaft above idling speed for varying the displacement of said pump to drive the fluid motor from the pump.

18. In combination, an engine having a variable speed power shaft, a driven shaft, differential gearing connecting said shafts, a fluid pump driven by said power shaft, a fluid pump driven by the floating element of the differential gearing and connected in fluid circuit with the first pump, said first pump having means for varying the displacement thereof, means for normally biasing said displacement varying means to a position to cause the first pump to circulate fluid in the same direction in said circuit and at the same capacity as the second pump when the driven shaft is stationary, and means responsive to increase in speed of the power shaft above idling speed to decrease the displacement of said first pump.

19. In combination, an engine having a variable speed power shaft, a driven shaft, differential gearing connecting said shafts, a reversible fluid pump driven by said power shaft, a convertible fluid pump driven by the floating ele-

ment of the differential gearing and connected in fluid circuit with the first pump, said first pump having means for varying and reversing the displacement thereof, means for normally biasing said displacement varying means to a position to cause the first pump to circulate fluid in the same direction in said circuit and at the same capacity as the second pump when the driven shaft is stationary, and means responsive to increase in speed of the power shaft above idling speed to first decrease the displacement and then reverse the same and increase it in the opposite direction, said biasing means being stronger than said speed responsive means at idling speed of said engine.

20. In combination, a variable speed power shaft, a driven shaft, differential gearing connecting said shafts, a convertible fluid pump driven by said power shaft, a convertible fluid pump driven by the floating element of the differential gearing and connected in fluid circuit with the first pump, said first pump having means for varying and reversing the displacement thereof, means for normally biasing said displacement varying means to a position to cause both pumps to circulate fluid in the same direction in said circuit, and means responsive to increase in speed of one of said shafts to first decrease the displacement and then reverse the same and increase it in the opposite direction.

21. In combination, a variable speed power shaft, a driven shaft, differential gearing connecting said shaft, a convertible fluid pump driven by said power shaft, a convertible fluid pump driven by the floating element of the differential gearing and connected in fluid circuit with the first pump, said first pump having means for varying and reversing the displacement thereof, means for normally biasing said displacement varying means to a position to cause both pumps to circulate fluid in the same direction in said circuit, means responsive to increase in speed of one of said shafts to first decrease the displacement and then reverse the same and increase it in the opposite direction, and means responsive to increase in pressure in said fluid circuit for opposing the change in displacement of said pump.

22. In combination, a differential gearing having three rotary elements, a power shaft connected to one of said rotary elements, said differential gearing having three co-axial shafts connected to the rotary elements thereof and extending from said gearing in axial alignment with said power shaft, the center co-axial shaft comprising a driven shaft, a pair of fluid pumps connected in fluid circuit and having rotor elements mounted co-axially with said driven shaft, one of said rotors being connected to the intermediate co-axial shaft while the other rotor is connected to the outer co-axial shaft.

23. In combination, a drive shaft, a rotary housing connected to said drive shaft and provided with an internal ring gear, a spider journaled in said housing and provided with a plurality of planet gears engaging said ring gear, a driven shaft connected with said spider and extending out of said housing in axial alignment with said drive shaft, a sun gear journaled in said housing and engaging said planet gears, said sun gear being provided with a sleeve extending out of said housing co-axially with said driven shaft, a pair of fluid pumps connected in fluid circuit and having rotor elements mounted co-axially with said driven shaft, one of said rotors being mounted upon the sleeve extension of said sun gear, and the other rotor being mounted upon a hollow shaft surrounding said sleeve extension and connected with said ring gear housing.

24. In combination, a variable speed power shaft, a driven shaft, differential gearing connecting said shafts, a fluid pump driven by said power shaft, a fluid pump driven by the floating element of the differential gearing and connected in fluid circuit with the first pump, one of said pumps having means for varying the displacement thereof above and below the displacement of the other pump, means for normally biasing said displacement varying means to a position to cause both pumps to circulate fluid in the same direction in said circuit and at the same capacity when the driven shaft is stationary, means responsive to increase in speed of one of said shafts to operate said displacement varying means to decrease the displacement of said pump below its biased value, and means for at will operating said displacement means to increase the displacement of said pump above its biased value.

25. In combination, a variable speed power shaft, a driven shaft, differential gearing connecting said shafts, a fluid pump driven by said power shaft, a fluid pump driven by the floating element of the differential gearing and connected in fluid circuit with the first pump, one of said pumps having means for varying the displacement thereof above and below the other pump, biasing means for normally biasing said displacement means in one direction, a stop for limiting the movement of said displacement varying means by said biasing means to a position to cause both pumps to circulate fluid in the same direction in said circuit and at the same capacity when the driven shaft is stationary, said stop including a second biasing means opposing the first biasing means and being of greater strength than the first biasing means, means responsive to increase in speed of one of said shafts for moving said displacement means against said first biasing means to drive the driven shaft in one direction, and means for at will moving said displacement means against the second biasing means to reverse the direction of operation of said driven shaft.

26. In combinaiton, a fluid pump having means for varying the displacement thereof, biasing means for normally biasing said displacement varying means in one direction, operating means for moving said displacement means in the opposite direction, a stop for limiting the movement of said biasing means to a predetermined position, said stop including a second biasing means opposing the first biasing means and being of greater strength than the first biasing means, and operating means for moving said stop in opposition to the second biasing means.

27. In combination, a variable speed power shaft, a fluid pump driven by said power shaft and having means for varying the displacement thereof, biasing means for normally biasing said displacement varying means in one direction, fluid pressure operating means for moving said displacement means in the oposite direction, a stop for limiting the movement of said biasing means to a predetermined position, said stop including a second biasing means opposing the first biasing means and being of greater strength than the first biasing means, fluid pressure operating means for moving said stop in opposition to the

second biasing means, a control pump driven by said power shaft and having a pressure variable with the speed of said shaft, and means for at will connecting said control pump for operation of either of said fluid presssure operating means.

28. In combination, a variable speed power shaft, a fluid pump driven by said power shaft and having means for varying the displacement thereof, biasing means for normally biasing said displacement varying means in one direction, fluid pressure operating means for moving said displacement means in the opposite direction, a stop for limiting the movement of said biasing means to a predetermined position, said stop including a second biasing means opposing the first biasing means and being of a greater strength than the first biasing means, fluid pressure operating means for moving said stop in opposition to the second biasing means, a control pump driven by said power shaft and having a pressure variable with the speed of said shaft, means for at will connecting said control pump for operation of either of said fluid pressure operating means, and means responsive to the pressure developed by said fluid pump for decreasing the output pressure of said control pump.

29. In combination, a variable speed power shaft, a driven shaft, differential gearing connecting said shafts, a convertible fluid pump driven by said power shaft, a convertible fluid pump driven by the floating element of the differential gearing and connected in fluid circuit with the first pump, said first pump having means for varying and reversing the displacement thereof, a servo-motor for operating said displacement varying means and having a variable control element, means for normally biasing said variable control element to a position to maintain said displacement varying means in a position to cause the first pump to circulate fluid in the same direction in said circuit and at the same capacity as the second pump when the driven shaft is stationary, fluid pressure operating means for moving said control element from its biased position to first decrease the displacement and then reverse the same and increase it in the opposite direction, and a control pump driven by one of said shafts for operating said fluid pressure operating means in accordance with the speed of said shaft.

30. In combination, a variable speed power shaft, a driven shaft, differential gearing connecting said shafts, a convertible fluid pump driven by said power shaft, a convertible fluid pump driven by the floating element of the differential gearing and connected in fluid circuit with the first pump, said first pump having means for varying and reversing the displacement thereof, a servo-motor having a power piston for operating said displacement varying means, a valve element carried by and cooperating with said piston to control the movement thereof, means for normally biasing said valve element to a position to maintain said displacement varying means in a position to cause the first pump to circulate fluid in the same direction in said circuit and at the same capacity as the second pump when the driven shaft is stationary, a control piston for operating said valve element from its biased position to first decrease the displacement and then reverse the same and increase it in the opposite direction, and a control pump driven by the power shaft and supplying operating fluid to said control piston at a pressure variable in accordance with the speed of said power shaft.

31. In combination, a variable speed power shaft, a driven shaft, differential gearing connecting said shafts, a convertible fluid pump driven by said power shaft, a convertible fluid pump driven by the floating element of the differential gearing and connected in fluid circuit with the first pump, said first pump having means for varying and reversing the displacement thereof, a servo-motor having a power piston for operating said displacement varying means, a valve element carried by and cooperating with said piston to control the movement thereof, biasing means for normally biasing said valve element in one direction, a stop for limiting the movement of said valve element to a position to cause the first pump to circulate fluid in the same direction in said circuit and at the same capacity as the second pump when the driven shaft is stationary, a control piston for operating said valve element from its biased position to first decrease the displacement and then reverse the same and increase it in the opposite direction, said stop being carried by a second control piston having biasing means for maintaining said stop in its normal position against said first biasing means, a control pump driven by the power shaft and supplying operating fluid at a pressure variable in accordance with the speed of said power shaft, and a control valve for connecting said control pump to operate either of said control pistons.

32. In combination, an engine having a variable speed power shaft, a driven shaft, differential gearing connecting said shafts, a convertible fluid pump driven by said power shaft, a convertible fluid pump driven by the floating element of the differential gearing and connected in fluid circuit with the first pump, said first pump having means for varying and reversing the displacement thereof, means for normally biasing said displacement varying means to a position to cause the first pump to circulate fluid in the same direction in said circuit and at the same capacity as the second pump when the driven shaft is stationary, means responsive to increase in speed of the power shaft above idling speed to first decrease the displacement and then reverse the same and increase it in the opposite direction, said biasing means being stronger than said speed responsive means at idling speed of said engine, and means responsive to the pressure in said fluid circuit for opposing the change in displacement of said first pump.

33. In combination, an engine having a variable speed power shaft, a driven shaft, differential gearing connecting said shafts, a convertible fluid pump driven by said power shaft, a convertible fluid pump driven by the floating element of the differential gearing and connected in fluid circuit with the first pump, said first pump having means for varying and reversing the displacement thereof, means for normally biasing said displacement varying means to a position to cause the first pump to circulate fluid in the same direction in said circuit and at the same capacity as the second pump when the driven shaft is stationary, means responsive to increase in speed of the power shaft above idling speed to first decrease the displacement and then reverse the same and increase it in the opposite direction, said biasing means being stronger than said speed responsive means at idling speed of said engine, means responsive to the pressure in said fluid circuit for opposing the change in dis-

placement of said first pump, and means for at will operating said displacement varying means to increase the displacement of the first pump above its biased value to operate the driven shaft in reverse direction.

34. In combination, a power shaft, a driven shaft, differential gearing connecting said shafts, a fluid pump driven by said power shaft, a fluid pump driven by the floating element of the differential gearing and connected in fluid circuit with the first pump, one of said pumps having means for varying the displacement thereof above and below the other pump, biasing means for normally biasing said displacement means in one direction, a stop for limiting the movement of said displacement varying means by said biasing means to a position to cause both pumps to circulate fluid in the same direction in said circuit and at the same capacity when the driven shaft is stationary, said stop including a second biasing means opposing the first biasing means and being of greater strength than the first biasing means, means for moving said displacement means against said first biasing means to drive the driven shaft in one direction, and means for at will moving said displacement means against the second biasing means to reverse the direction of operation of said driven shaft.

OLOF LJUNGSTROM.