

Oct. 7, 1941.

D. S. BENNETCH

2,257,724

TRANSMISSION

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17 Sheets-Sheet 1

Fig. 1

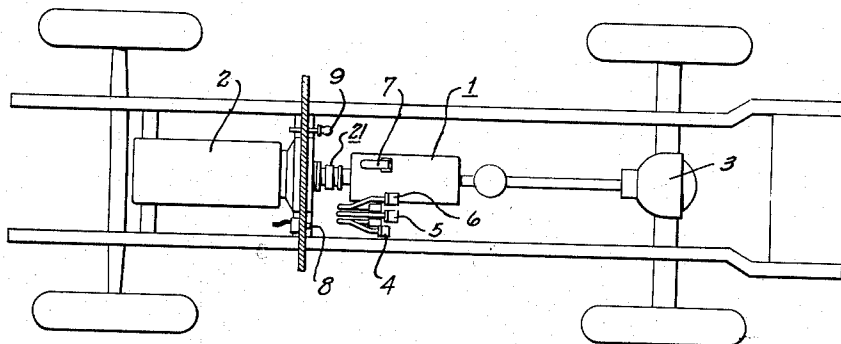
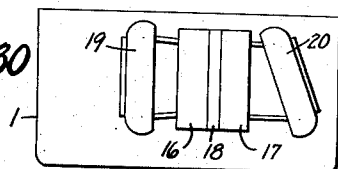
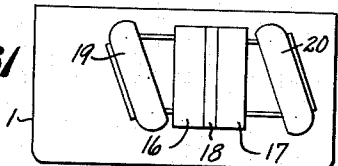


Fig. 30



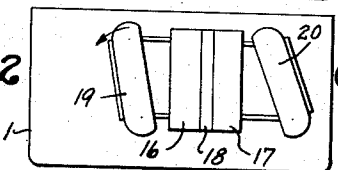
Stop.
Idle.
Brake.
Coast.

Fig. 31



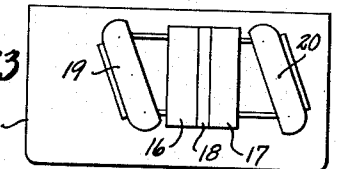
Start.

Fig. 32



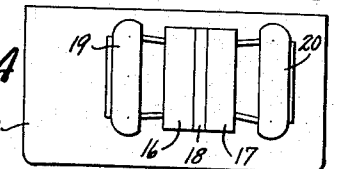
Low:
(From idle
and on way
to High)

Fig. 33



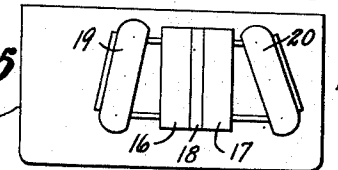
High.

Fig. 34



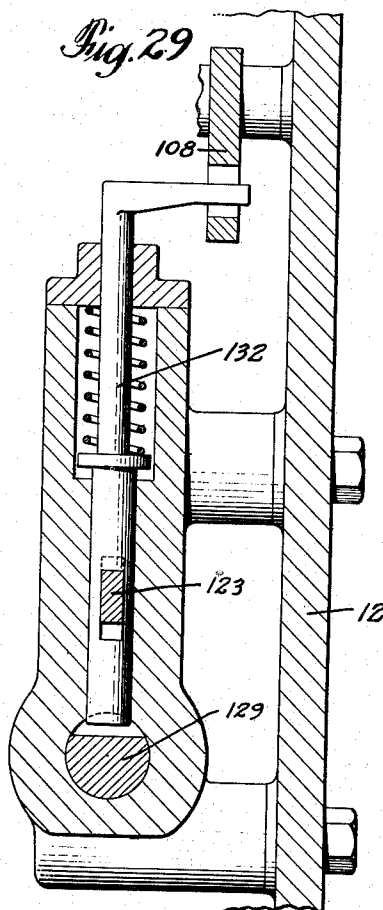
High:
(Mechanical
clutch)

Fig. 35



Reverse.

Fig. 29



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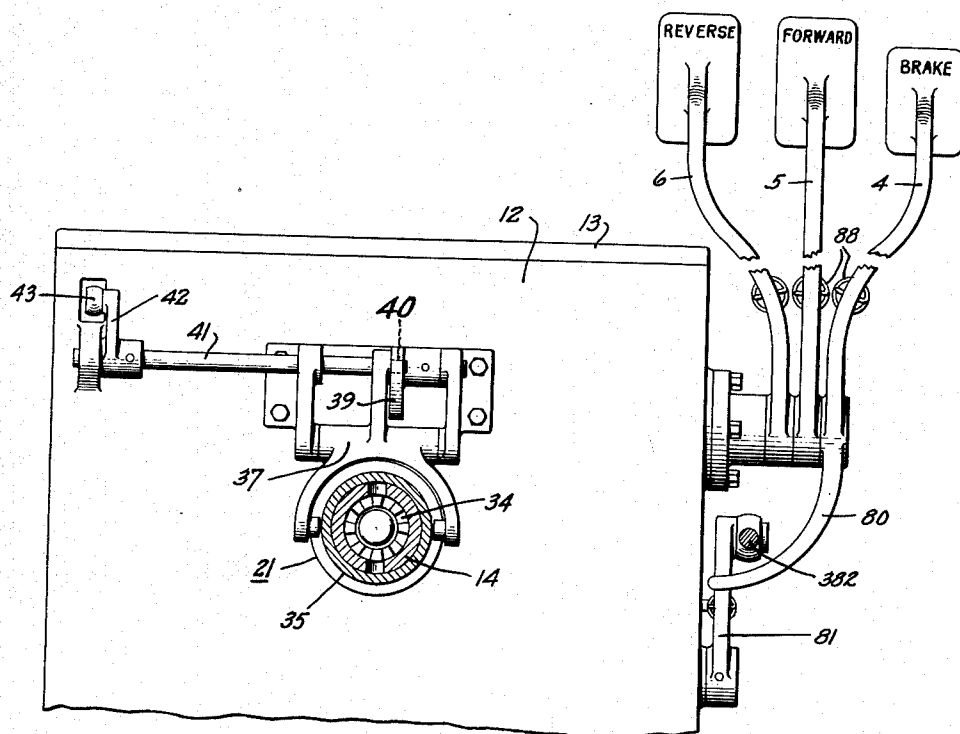
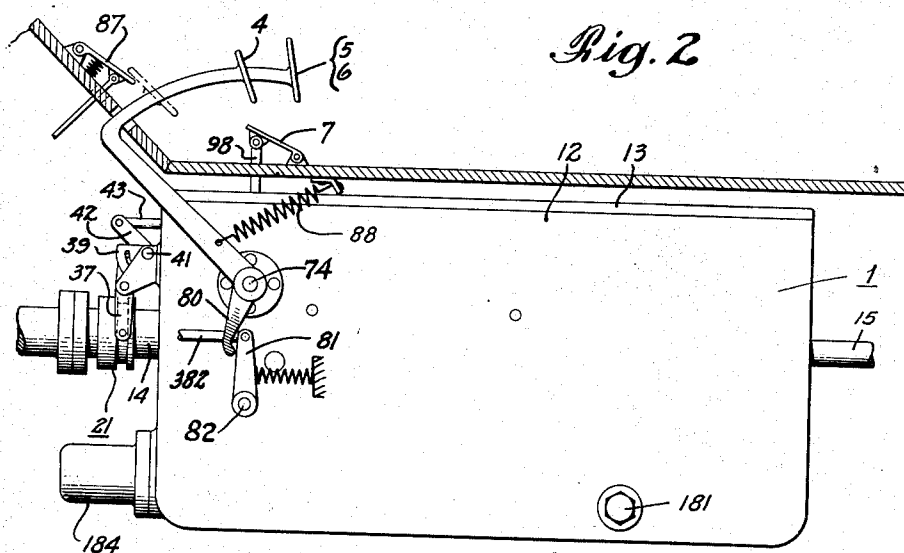


Fig. 3

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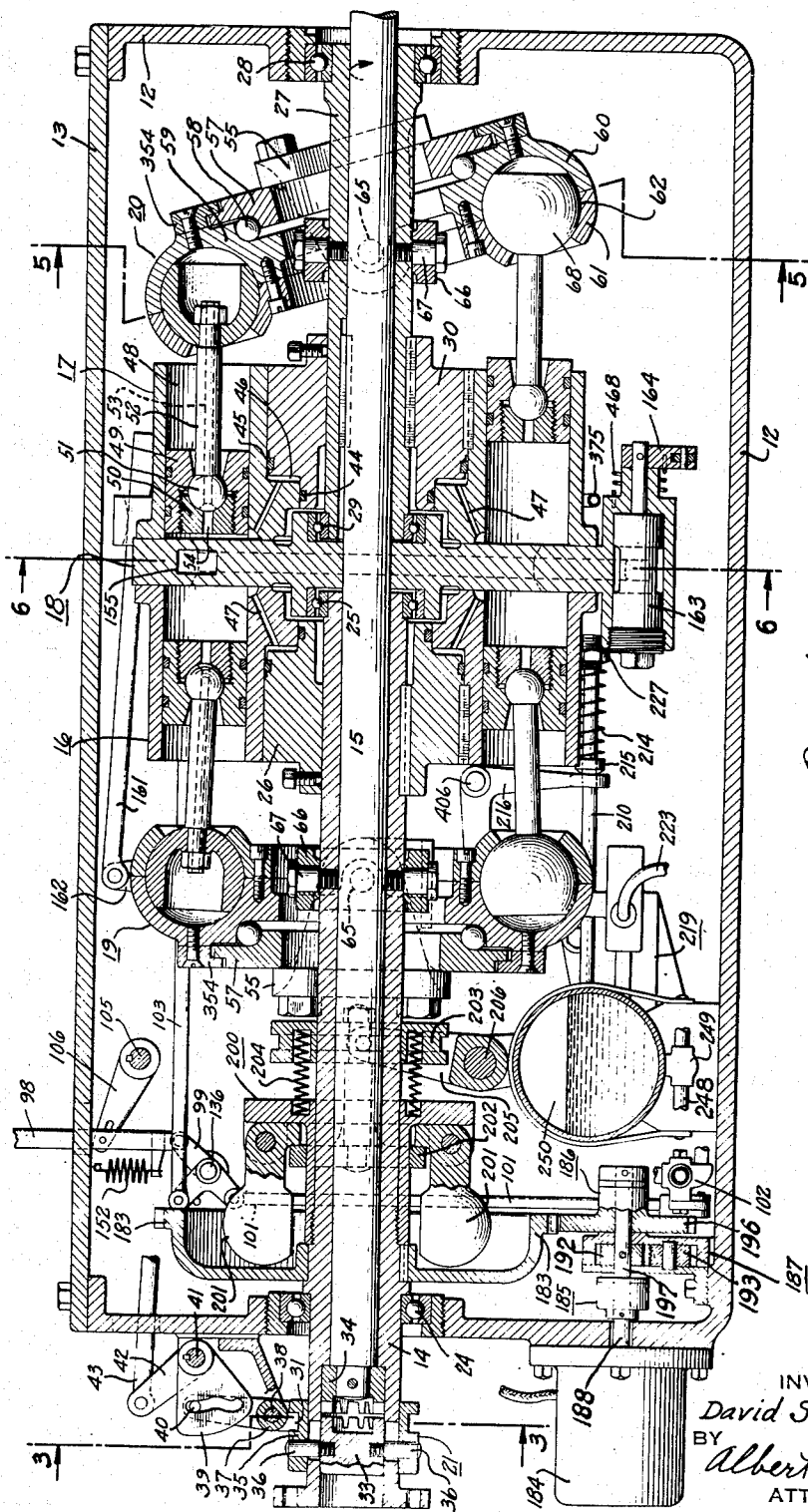


Fig. 4

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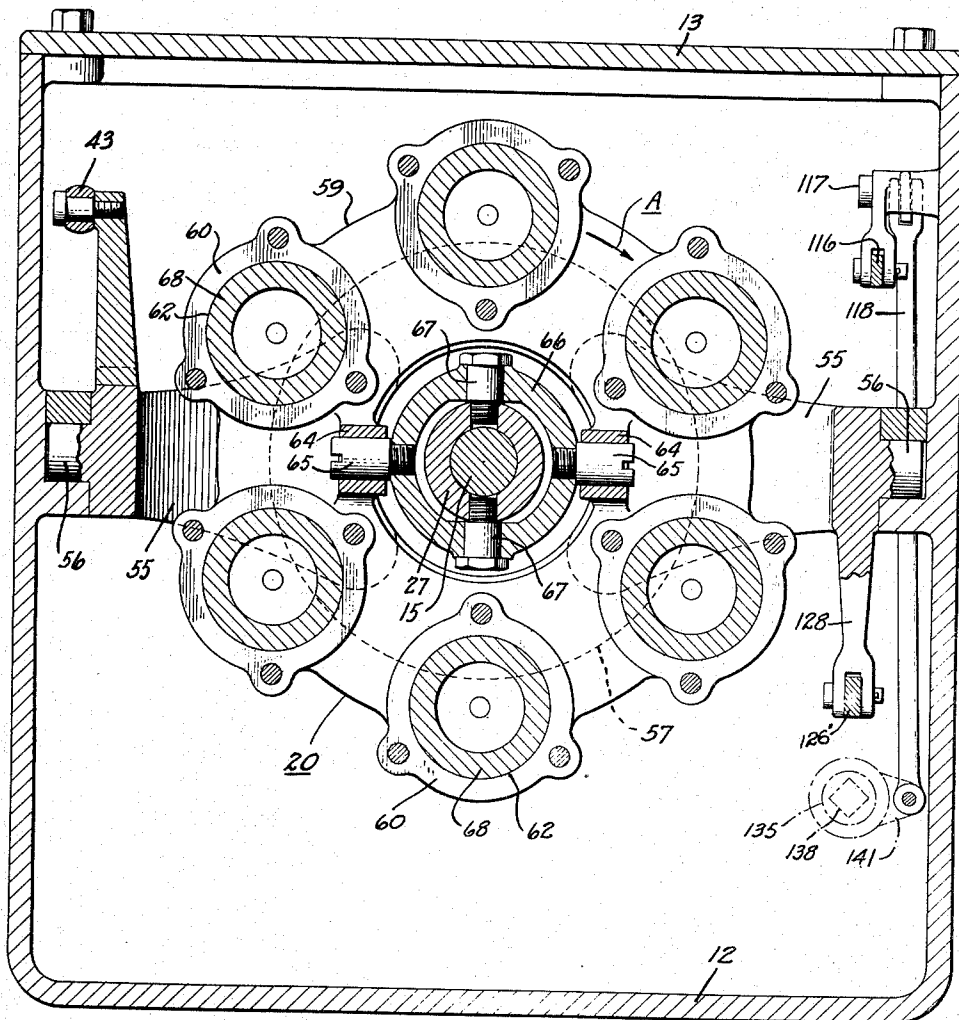


Fig. 5

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Fig. 6

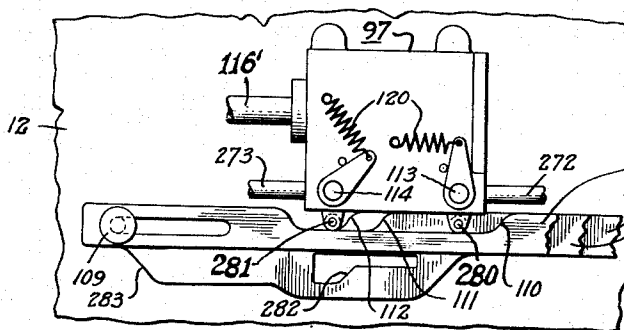
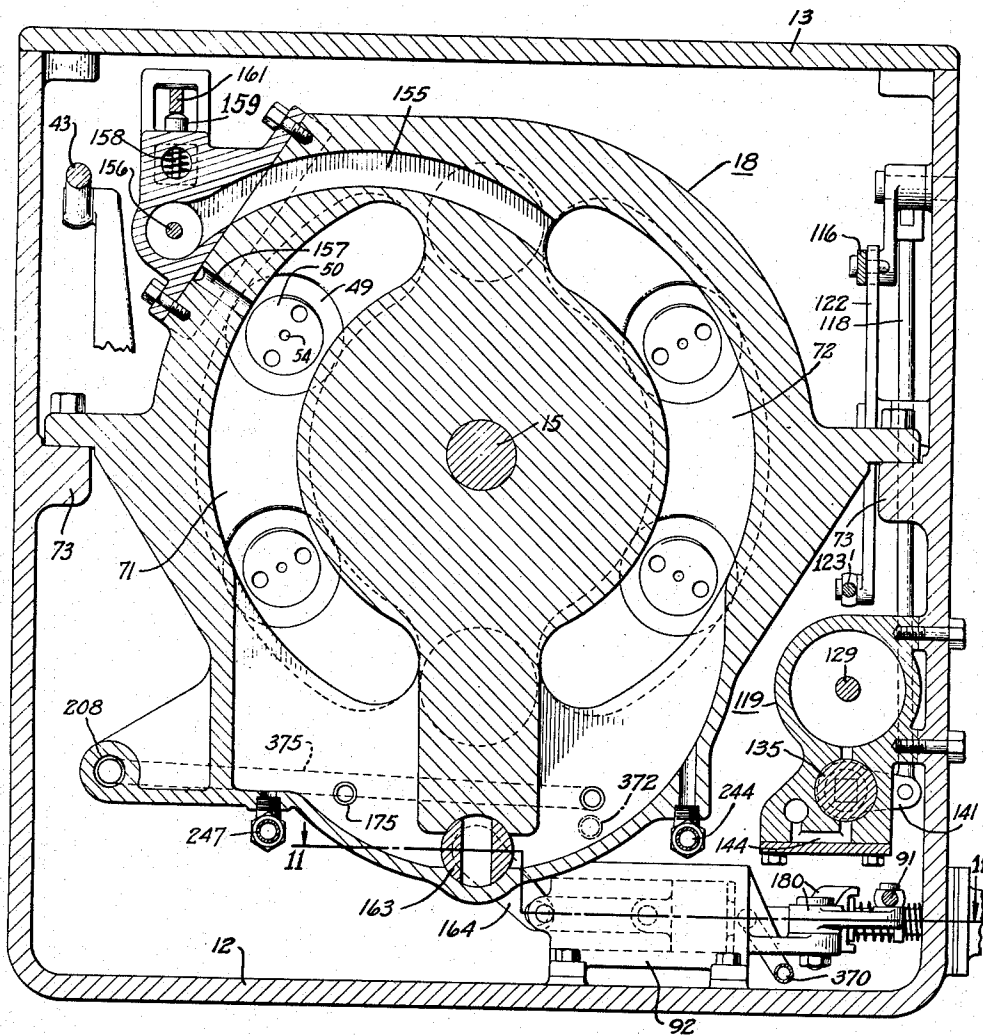


Fig. 10

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Fig. 7

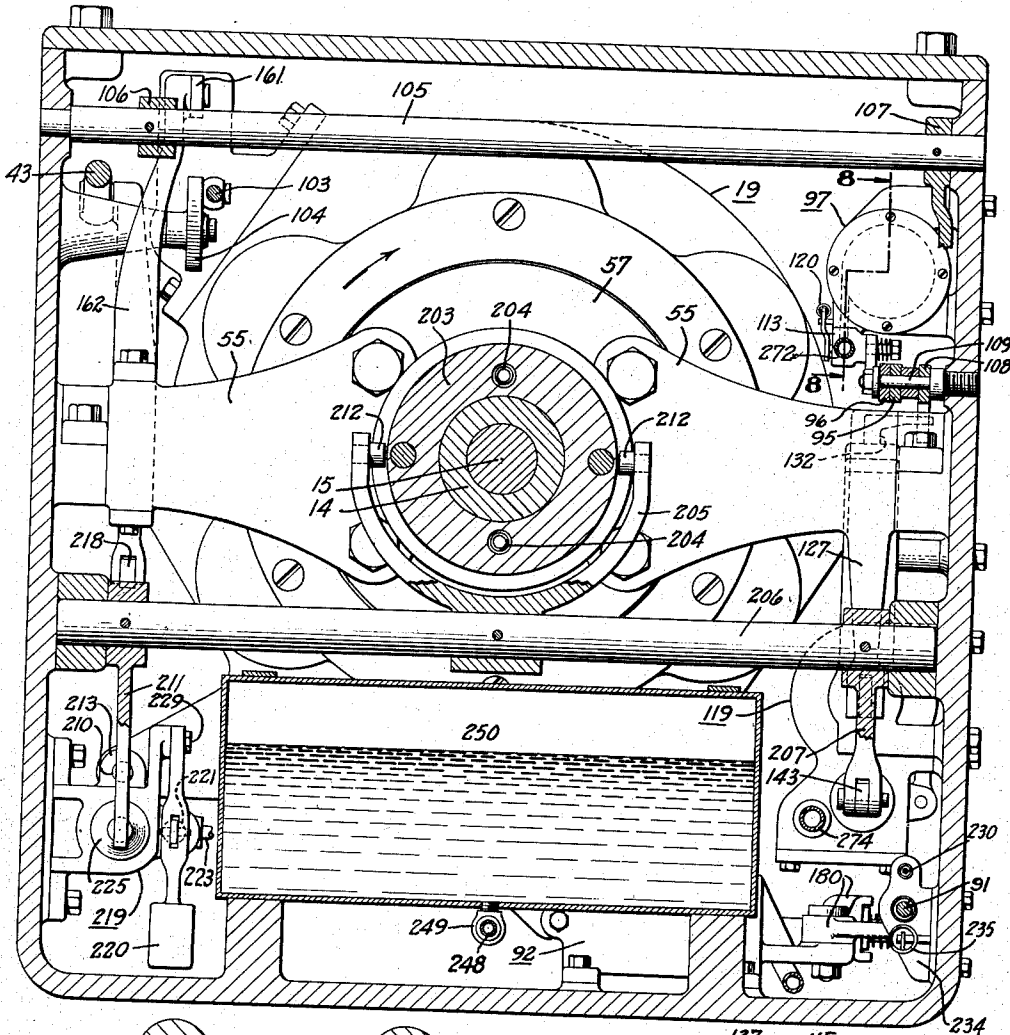


Fig. 8

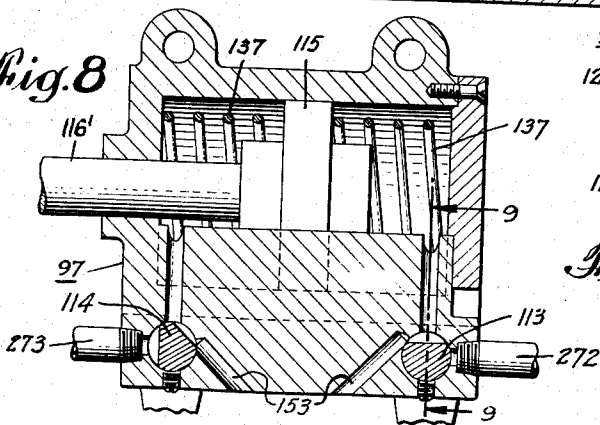
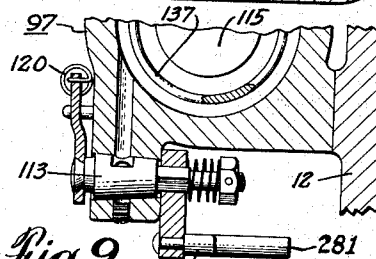


Fig. 9



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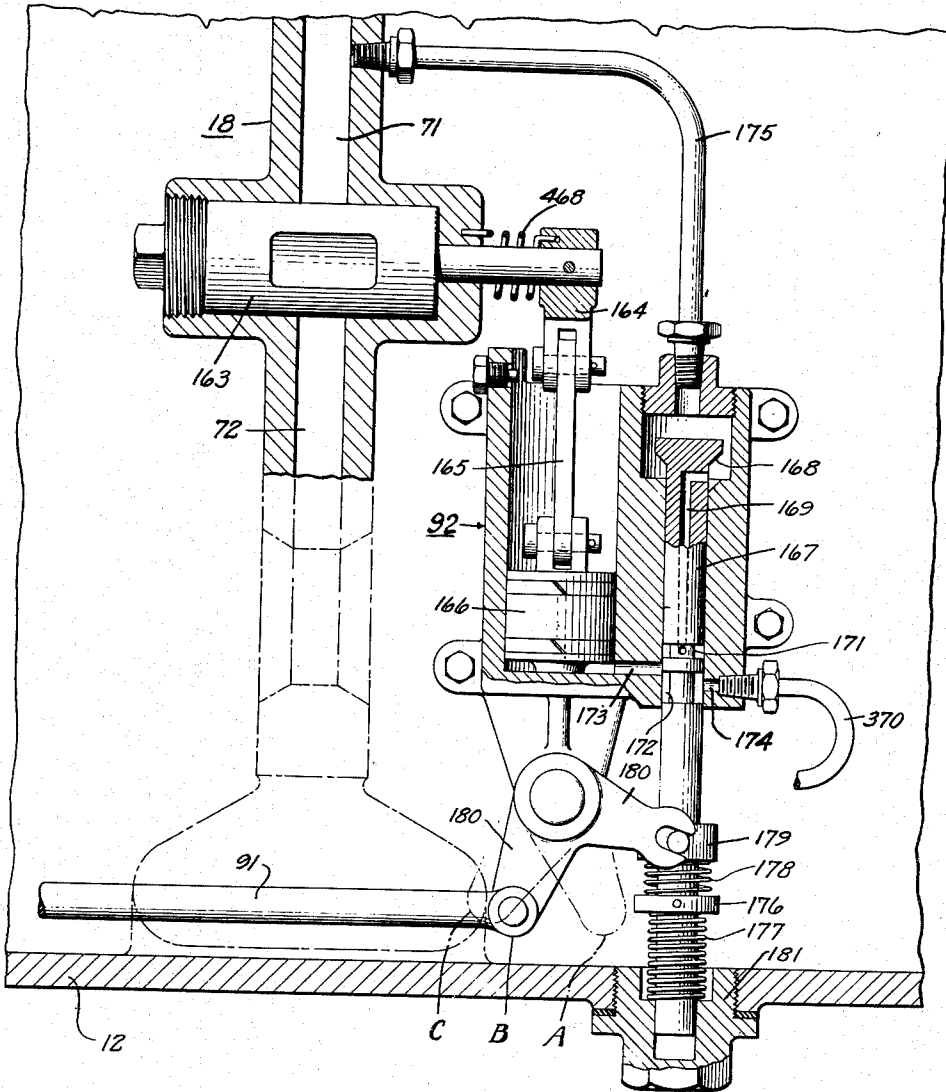


Fig. 11

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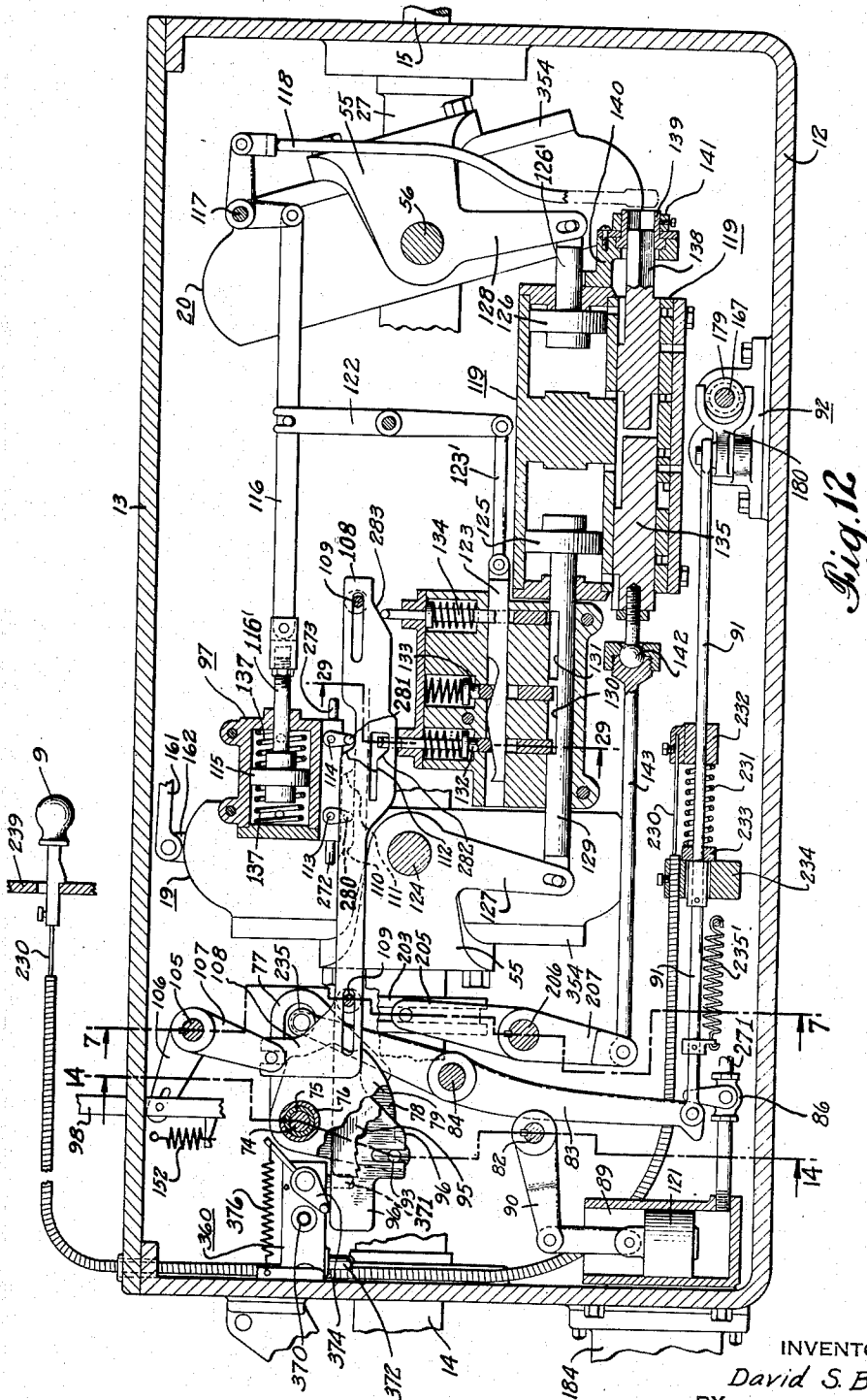


Fig. 12

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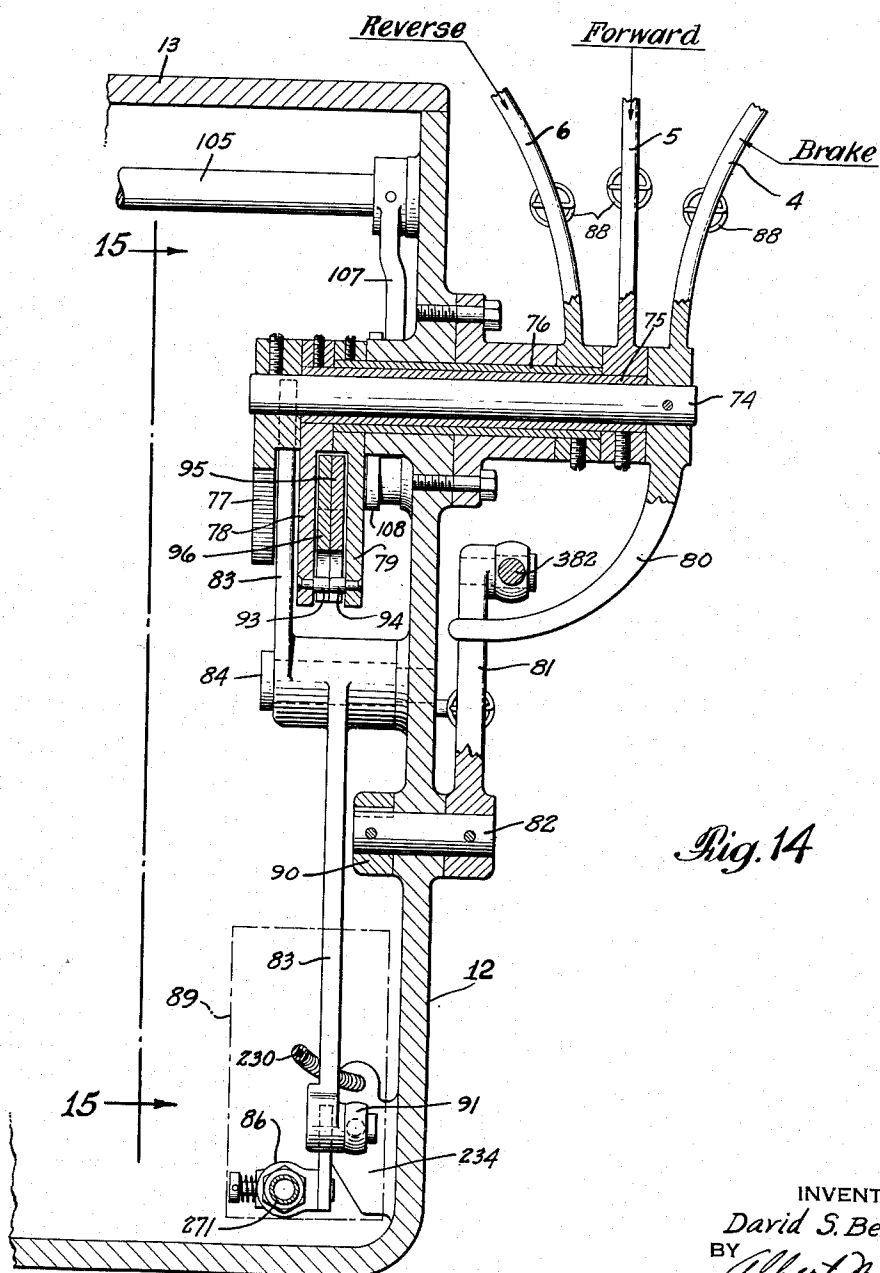


Fig. 14

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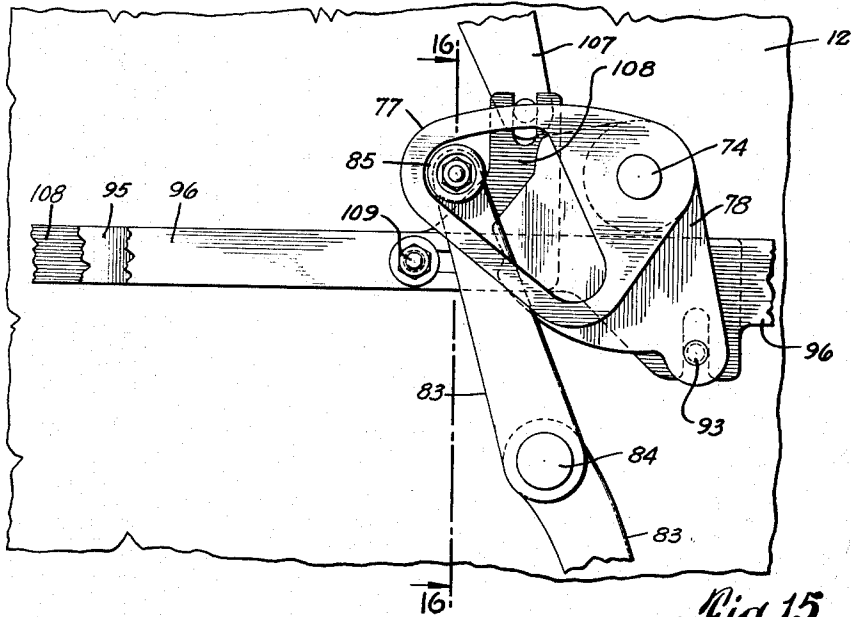


Fig. 15

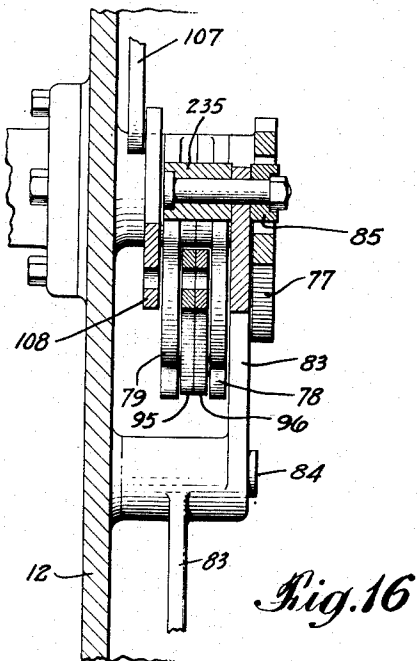


Fig. 16

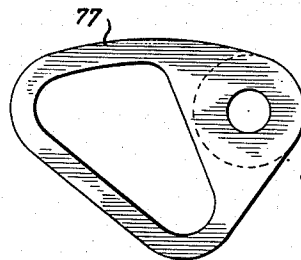


Fig. 17

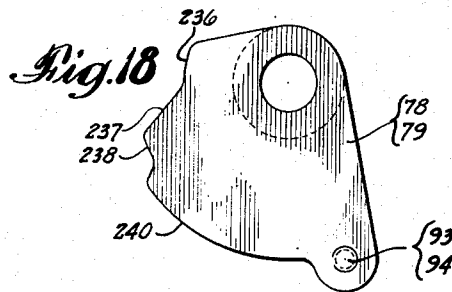


Fig. 18

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Fig. 19

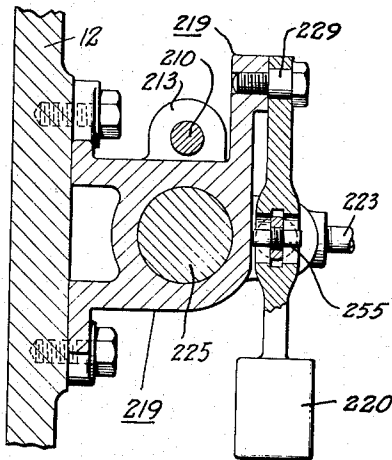


Fig. 20

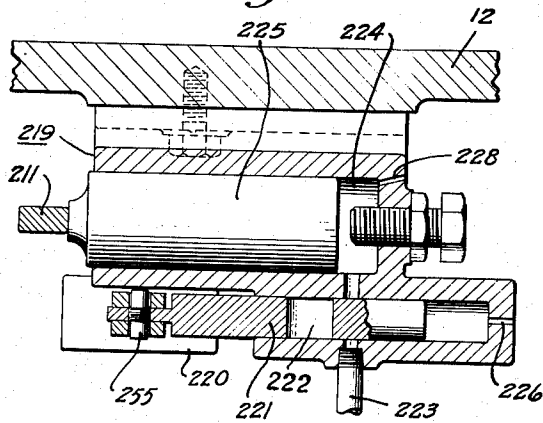


Fig. 21

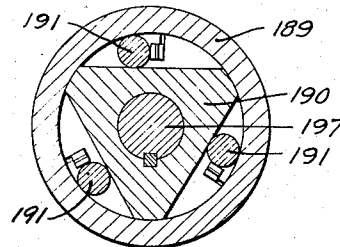
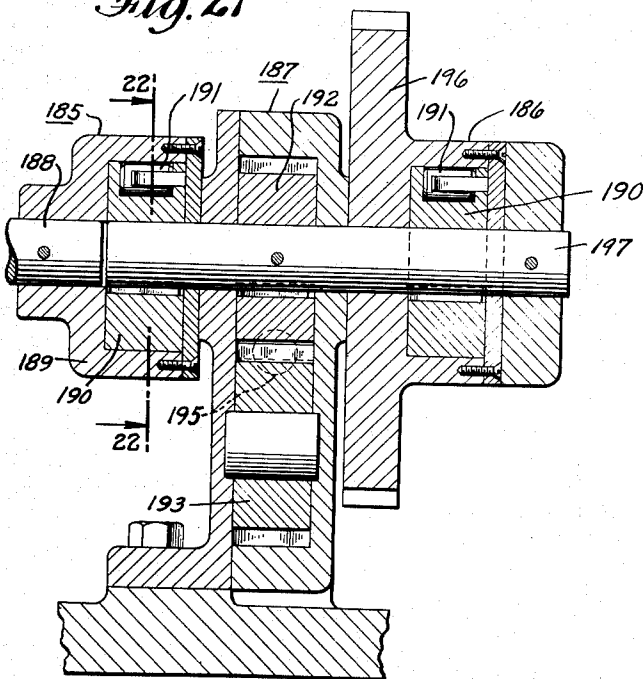


Fig. 22

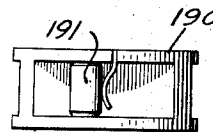


Fig. 23

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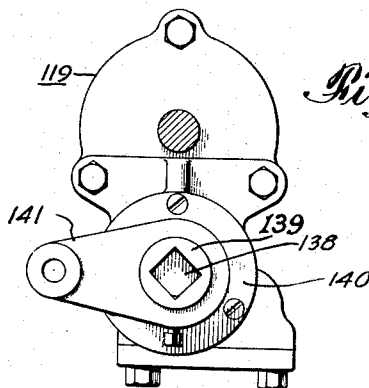
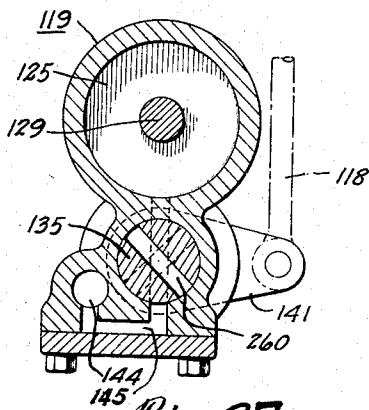
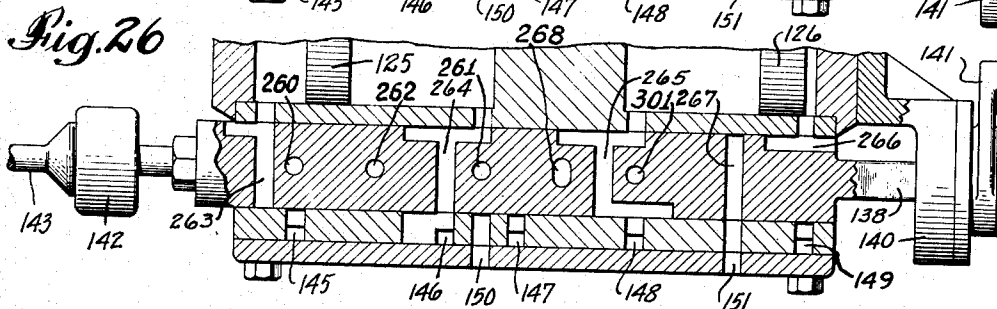
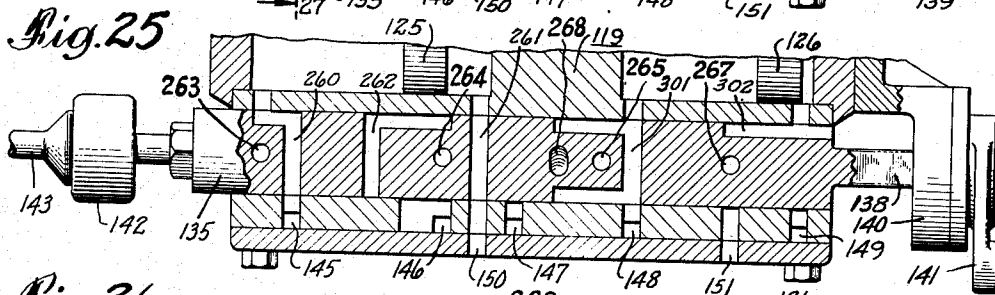
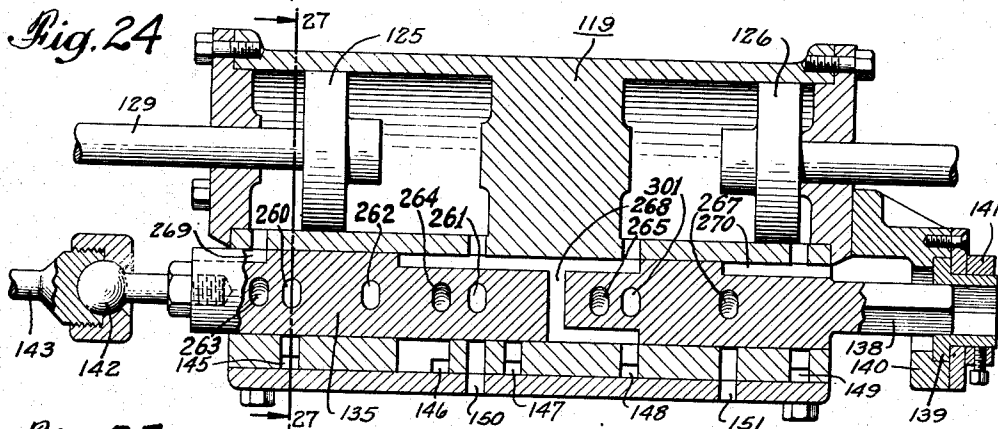


Fig. 28

Fig. 27

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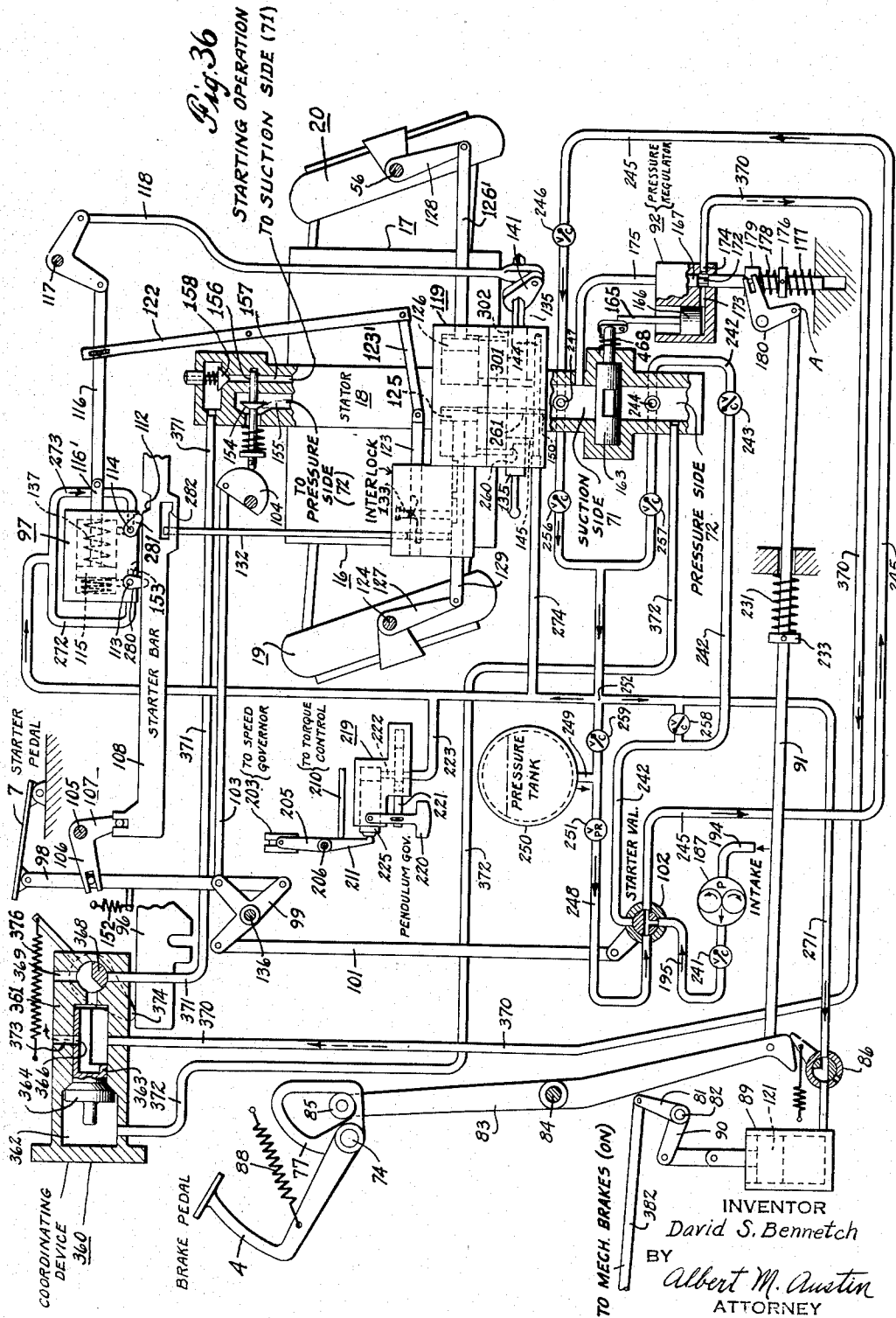
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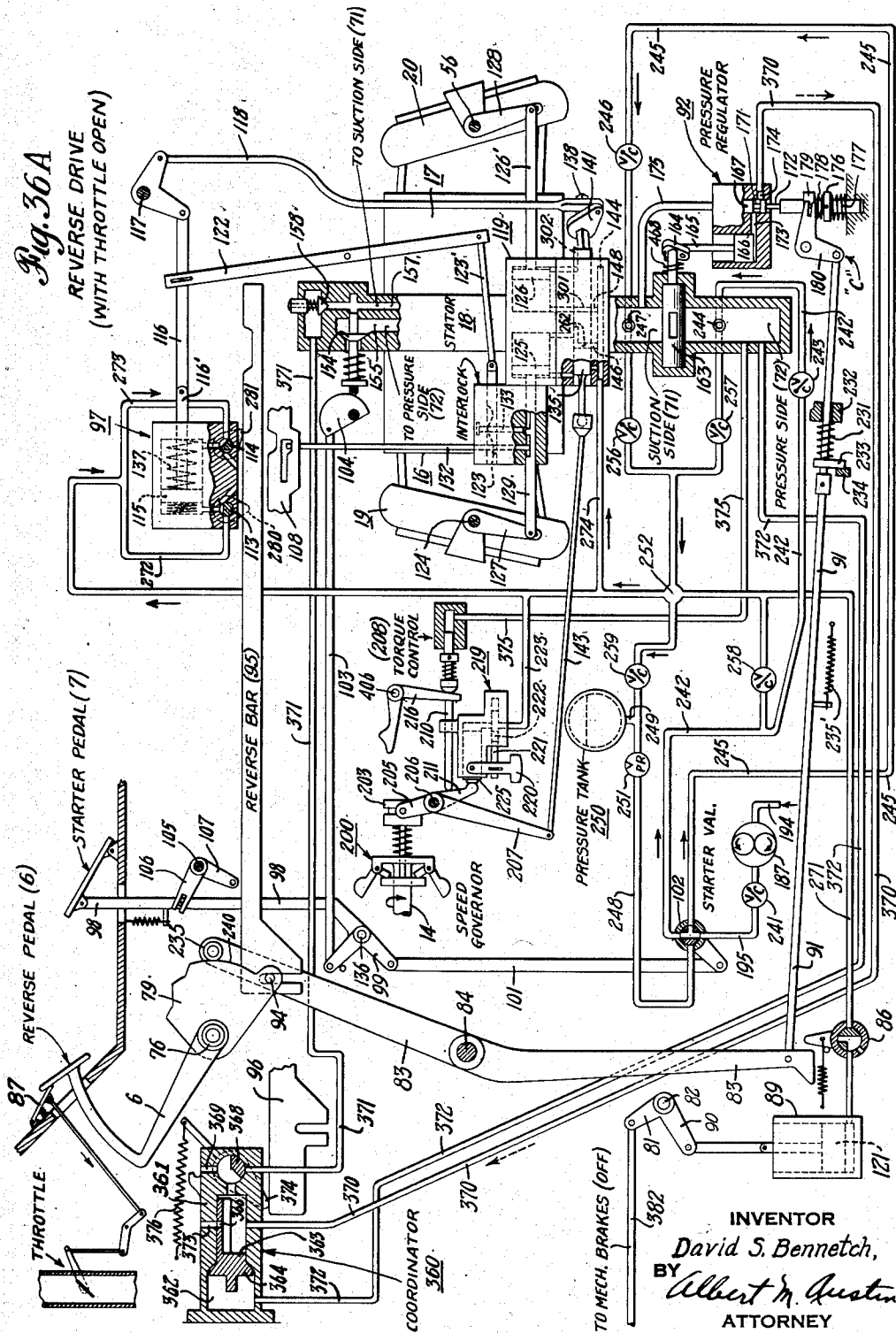
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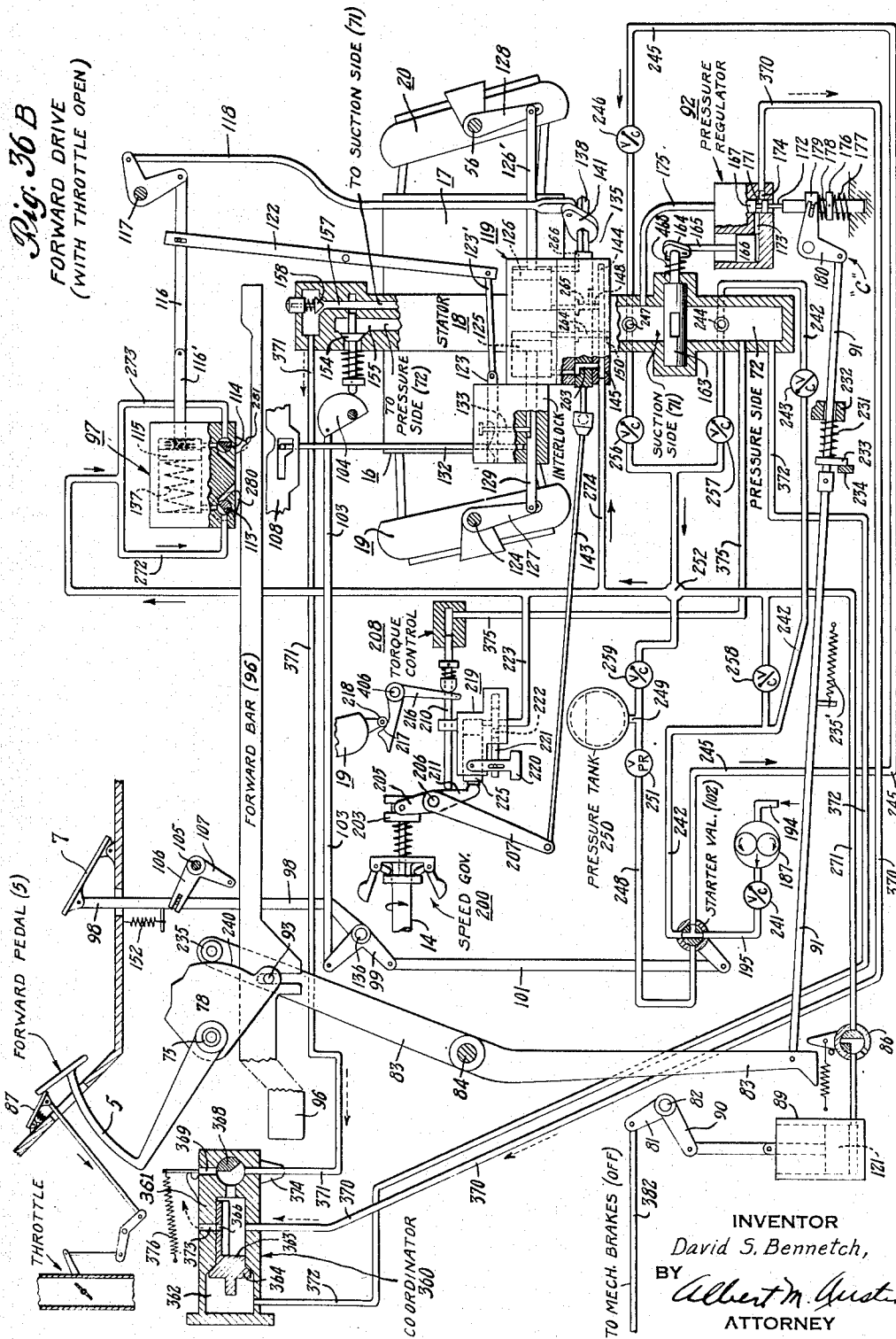
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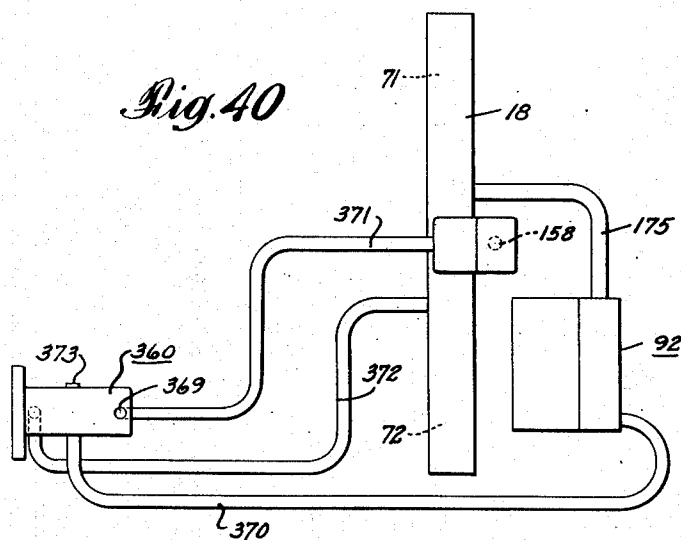
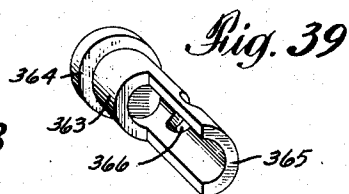
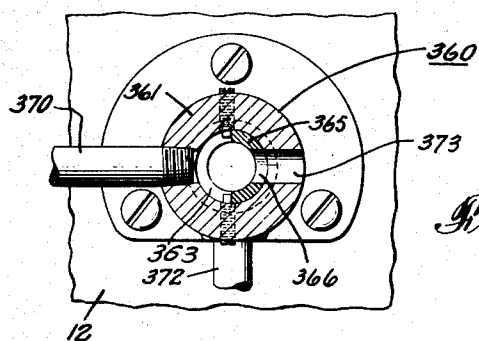
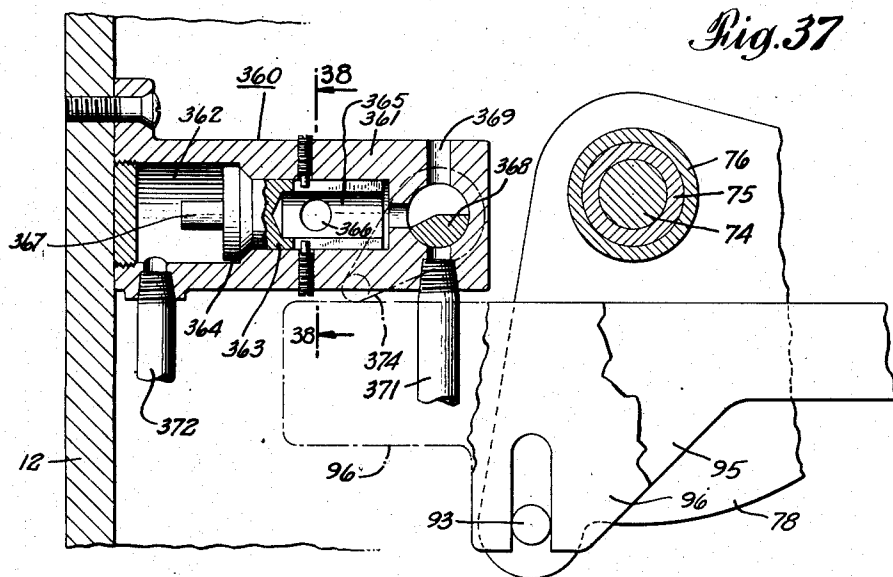
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UNITED STATES PATENT OFFICE

2,257,724

TRANSMISSION

David S. Bennetch, Sheridan, Pa.

Application September 12, 1936, Serial No. 100,460

16 Claims. (Cl. 60—19)

The invention relates to speed transmissions for automotive vehicles or the like and, more particularly, to a fully automatic control for such transmissions.

In the preferred form, the invention utilizes a variable speed hydraulic transmission comprising a variable stroke pump unit driving a similar variable stroke motor unit, the pump unit being driven by a prime mover, such as the ordinary automobile engine and the motor unit driving the load, such as the rear wheels of such automobile. Each unit may comprise a rotary cylinder block having a plurality of axially extending cylinders cooperating with a tiltable swash plate, the tilting of which varies the stroke of the pistons between zero and maximum. A suitable mechanical clutch may be provided for providing direct drive at which time the hydraulic transmission may be effectively cut out of operation.

In the preferred form, arrangement is made for fully automatically controlling the transmission, i. e. after the automotive engine is started, it is only necessary to depress the forward pedal, corresponding to the ordinary accelerator pedal, for complete operation at all speeds in a forward direction, the amount of speed being determined by the amount by which the forward pedal is depressed. If desired, a separate brake pedal may be provided, and a separate reverse pedal for backing up the vehicle, this providing three pedal control. If desired, control by the brake pedal may be eliminated by a suitable hand operated change over device for changing over to two pedal control. In the two pedal control, the forward pedal and the reverse pedal operate in the same manner as with the three pedal control, except that, with the two pedal control, permitting the pedal to rise above a predetermined point operates to apply the brakes. For full automatic control, the tilting of the swash plates and the operation of the mechanical clutch may be governed by a system of governors, one of which may be responsive to engine speed, another to torque exerted by the rear wheels, and the third to the inclination or grade on which the vehicle is moving. These controls insure smooth automatic operation under all conditions.

If desired, a pressure tank may be provided for storing up pressure which may be used for cranking the engine. For engine cranking, the forward swash plate may be tilted forward and the pump unit operated as a motor for cranking the car engine. In case the storage pressure

falls, a suitable emergency starter may be provided, including an electric motor for driving the transmission supercharger ordinarily used for overcoming foaming. A suitable overriding clutch system may be provided for permitting the supercharger to be driven by either the electric motor or by the drive shaft of the transmission without interference.

If desired, arrangement may be made for moving the pump and motor blocks of the transmission away from the stator when the hydraulic transmission is not in operation. This may be done simply by providing an annular pressure space communicating with the cylinders, which operates to force the pump and motor blocks against the stator when there is any pressure in the cylinders, allowing the pump and motor blocks to retract when pressure in the cylinders is relieved. Provision may be made for using the transmission as a brake, a special regulating valve being provided in the suction side of the stator under control of the brake pedal for regulating the amount of back pressure to the braking action desired.

For controlling the supercharger pressure, a variable pressure relief valve may be provided whose operating pressure varies with the tilt of the forward swash plate. The greater the tilt of this swash plate the higher the pressure generated by the supercharger.

The invention also consists in certain new and original features of construction and combinations of parts hereinafter set forth and claimed.

Although the novel features which are believed to be characteristic of this invention will be particularly pointed out in the claims appended hereto, the invention itself, as to its objects and advantages, and the manner in which it may be carried out, may be better understood by referring to the following description taken in connection with the accompanying drawings forming a part thereof, in which

Fig. 1 is a diagrammatic view of an automobile with the transmission and controls embodied therein;

Fig. 2 is a side elevation of the transmission showing the several manual controls;

Fig. 3 is a front view of the transmission taken on the line 3—3 of Fig. 4;

Fig. 4 is a vertical section through the transmission;

Fig. 5 is a transverse section on the line 5—5 of Fig. 4;

Fig. 6 is a transverse section through the stator taken on the line 6—6 of Fig. 4;

Fig. 7 is a section taken on the line 7—7 of Fig. 12;

Fig. 8 is a section through the master control taken on the line 8—8 of Fig. 7;

Fig. 9 is a section taken on the line 9—9 of Fig. 8;

Fig. 10 is a back view of the master control mechanism;

Fig. 11 is a detail illustrating the pressure regulator taken on the line 11—11 of Fig. 6;

Fig. 12 is a vertical section through the transmission illustrating the master control interlocking device and trunnion control;

Fig. 13 is a vertical section through the transmission illustrating the automatic torque control; pendulum control; pressure release for starting and variable pressure relief valve;

Fig. 14 is a section through the pedal mounting taken on the line 14—14 of Fig. 12;

Fig. 15 is a detail of the pedal control taken on the line 15—15 of Fig. 14;

Fig. 16 is a section on the line 16—16 of Fig. 15;

Fig. 17 is a detail of the brake cam;

Fig. 18 is a detail of the reverse cam;

Fig. 19 is a section on the line 19—19 of Fig. 13 showing the pendulum control;

Fig. 20 is a section on the line 20—20 of Fig. 13;

Fig. 21 is a section through the supercharger and driving mechanism;

Fig. 22 is a section of the overriding clutch taken on the line 22—22 of Fig. 21;

Fig. 23 is a detail of the overriding clutch;

Fig. 24 is a vertical section through the trunnion control illustrating one position of the trunnion control valve;

Figs. 25 and 26 are similar sections of Fig. 24, but illustrating other positions of the trunnion control valve;

Fig. 27 is a section on the line 27—27 of Fig. 24;

Fig. 28 is an end view of the trunnion control;

Fig. 29 is a section through the interlock taken on the line 29—29 of Fig. 12;

Figs. 30—35 illustrate diagrammatically the various positions of the trunnions for various conditions of operation;

Fig. 36 is a diagrammatic view with some parts greatly exaggerated, illustrating the main hydraulic connections between the several pieces of apparatus, and illustrating the starting or cranking operation;

Fig. 36A is a diagrammatic view similar to Fig. 36, illustrating the backing operation or reverse drive;

Fig. 36B is a diagrammatic view similar to Fig. 36, illustrating forward drive;

Fig. 37 is a detail, partly in section, illustrating a coordinating device for insuring smoothness of operation;

Fig. 38 is a section on the line 38—38 of Fig. 37;

Fig. 39 is a perspective of the slide valve of the coordinating device; and

Fig. 40 illustrates the hydraulic hook up between the coordinating device, the stator, and the pressure regulator.

In the following description and in the claims, various details will be identified by specific names for convenience, but they are intended to be as generic in their application as the art will permit.

Like reference characters denote like parts in the several figures of the drawings.

In the drawings accompanying and forming part of this specification, certain specific dis-

closure of the invention is made for purposes of explanation, but it will be understood that the details may be modified in various respects without departure from the broad aspect of the invention.

General

Referring now to the drawings and, more particularly, to Fig. 1, the invention is shown as applied to a modern automobile. However, it will be understood that the invention may be applied to any installation requiring variable speed transmission, such as, for example, heavy duty busses and trucks and Diesel railway locomotives and the like. In Fig. 1, the transmission is denoted, in general, by 1, the ordinary internal combustion engine of the automobile by 2, and the rear end differential by 3. The transmission 1 is located in the space usually occupied by the clutch and sliding gear transmission of the conventional automobile.

In the form shown, the car is provided with four foot controls and two hand controls. The foot controls comprise brake 4, forward pedal 5, reverse pedal 6 and starter 7. The hand controls comprise an emergency starter button 8 and a change over knob 9 for changing over the foot controls from three pedal control to two pedal control. The use and operation of the several controls will be described in due course.

If desired, the engine flywheel may be omitted, the mass of rotating parts of the transmission serving the function of a flywheel.

Variable stroke transmission

Referring now to Figs. 3—6, the transmission, in general, comprises a casing 1 having a body 12 and cover 13; a drive shaft 14 and a driven shaft 15; and a pump unit 16 and a motor unit 17 having, respectively, the tiltable swash plate assemblies 19 and 20 to vary the stroke of the pistons. The transmission also includes the mechanical clutch 21 on the forward end of the casing.

The drive shaft 14 is connected to the engine 2 and the driven shaft 15 is connected to the differential 3 of the rear axle of an automobile. All parts of the transmission are supported by the body 12, as will be understood from an inspection of the drawings.

The drive shaft 14 is shown in the form of a sleeve and is journaled in a ball bearing assembly 24 in the forward wall of the body 12 and in a ball bearing assembly 25 in stator 18. The drive shaft 14 is keyed to the forward support 26 to which the pump block is further keyed so as to rotate with support 26, but to move axially thereon for a purpose hereinafter described.

This transmission is of the same general type as that disclosed in application Serial No. 24,353, filed May 31, 1935, now Patent No. 2,151,415 issued March 21, 1939, although differing somewhat in constructional features.

The driven shaft 15 is keyed to the driven sleeve 27 which is journaled in bearing assembly 28 supported by the rear wall of the housing. The sleeve 27 is also journaled in bearing assembly 29 supported by stator 18. Rear support 30 is keyed to sleeve 27 and has motor block 17 further keyed thereto.

The mechanical clutch 21 comprises an adjustable block 33 carrying a pair of pins 36 slidable longitudinally in slots in the drive sleeve 14. The clutch block 33 has dog teeth engaging similar dog teeth on a fixed block 34 pinned to the

driven shaft 18. The engagement of the mechanical clutch 21 is controlled by a sleeve 35 secured to the pins 30 and having an annular groove 31 in which ride bosses on yoke 37 (Fig. 3) pivoted on shaft 38. The yoke 37 is operated by a slotted cam 39 in which rides follower 40 (Fig. 4) secured to the yoke 37. Cam 39 is secured to shaft 41 to which is secured arm 42 pivoted to rod 43 extending to the rear trunnion for a purpose later described.

The motor block 17 has a plurality of cylinders 48 (six in number in the form shown) and the inner end of this block fits snugly against the end face of the stator 18. An annular pressure space 46 having a plurality of restricted ports 47, one for each cylinder, is provided for between the rear support 30 and the motor block 17, this space being sealed by rings 44 and 45. Thus, pressure in the cylinders is communicated to pressure space 46 to firmly press the motor block 17 against the stator 18. When pressure is relieved in the cylinders 48 (as when the mechanical clutch 21 is engaged and the swash plates 19 and 20 are in erect position), the motor block 17 may move away from the stator 18 thus relieving the friction between block 17 and stator 18 when no power is being transmitted between pump and motor blocks 16, 17.

Disposed within the cylinders 48 are pistons 49 having the usual piston rings. Each piston 49 may comprise a body and a removable head 50 forming therebetween a spherical socket for the ball 51 on the end of hollow connecting rod 52. The connecting rod 52 is provided with an oil hole 53 which cooperates with an opening 54 in the piston head 50 for a purpose hereinafter described more in detail.

The rear or motor swash plate 20 comprises a housing 55 having trunnions 56 (Fig. 5) seated in the casing body 12, so that the swash plate may be tilted as desired. The housing 55 includes a bearing plate 57 having an annular seat for a ball bearing assembly 58 comprising a plurality of balls separated by the usual spacer.

Rotatably mounted on the housing 55 is the swash ring 59 having an annular seat engaging the ball bearing assembly 58. The swash ring 59 also has an annular holding ring 354 riding over the bearing plate 57. It will be understood that in the ordinary operation of the transmission there is practically no engagement between the holding ring 354 and the bearing plate 57, all of the stress both axially and radially being withstood by the ball bearing assembly 58.

The swash ring 59 has secured thereto a pair of bearings 64 in which are journaled a pair of outer studs 65 secured in ring 66. Ring 66 is journaled on a pair of inner studs 67 supported by driven sleeve 27. Thus ring 66 and sets of studs 65, 67 form, in effect, a universal mounting for the swash ring 59 on driven sleeve 27, permitting the driven sleeve 27 to be driven by the swash ring 59 irrespective of the angle of tilt of swash housing 55.

To reduce friction between the connecting rods 52 and the swash ring 59, a "floating" connecting rod arrangement is provided. The swash ring 59 has a plurality of bearing bodies 60 and removable caps 61, one set for each cylinder. Each bearing body 60 and cap 61 forms a socket for a ball 62 secured to the end of a connecting rod 52 by a nut, forming connecting rod bearings 62.

The relative size and proportion of each connecting rod bearing 62 is so arranged that the

total force exerted by the liquid between the swash ring 59 and the ball 62 is equal to the force exerted by the liquid on the piston 49. It will be noted that the projection area of the space occupied by the liquid between ball 62 and socket 60 on a plane perpendicular to the connecting rod axis is substantially equal to the area of the piston. Thus, mechanical stress exerted between the swash ring 59 and the connecting rods is reduced to a minimum, all of this stress being transmitted by liquid pressure transmitted from the liquid above the piston.

The construction of the pump unit, including the cylinder block 16, swash plate 19, connecting rods, pistons and pressure space, is substantially the same as the corresponding parts relating to the motor unit and hence it is not necessary to describe these parts in detail. Similar parts have corresponding reference characters.

The stator 18 (Fig. 6) is supported by the casing body 12 on ledges 73. The stator 18 is provided with a pair of arcuate openings 71, 72 which are arranged on the line of movement of the centers of the cylinders. A greater space than the diameter of the cylinder is provided between the adjoining ends of these openings.

Assuming that both swash plates are tilted as in Fig. 33, and the transmission is rotating in the direction of the arrow A (Fig. 5), it will be seen that the pistons of the pump unit suck liquid as the cylinders move from the bottom of opening 71 to the top thereof. Thus, this opening in relation to the pump unit is a suction opening, the other opening 72 in relation to the pump unit being a discharge opening.

It will be understood by those skilled in the art that with both swash plates, for example, in full tilt position, the pump receives liquid from the motor through the suction opening 71, compresses this liquid and discharges it through the discharge opening 72, thus driving the motor unit hydraulically. The oil travels through a closed path, never getting out in the casing of the transmission except for leakage or positive discharge.

Pedals

Referring more particularly to Figs. 2, 3 and 14 to 18, the brake pedal 4, forward pedal 5 and reverse pedal 6 are concentrically mounted on the outside of the housing body 12 and are normally held in retracted position by a series of springs denoted by 88. The pedals 4, 5 and 6 are mounted, respectively, on concentric shafts 74, 75 and 76, which carry, respectively, a brake cam 77, forward cam 78 and reverse cam 79. Brake cam 77 has an internal cam surface as illustrated in Fig. 17. Reverse cam 79 has an external cam surface and carries pin 94 as illustrated in Fig. 18. Forward cam 78 is similar in shape to reverse cam 79 and carries a pin 93. The effects of the shapes of these cams will be explained in due course.

Brake pedal 4 has an extension 80 engaging with a lever 81 connected to shaft 82, which in turn supports arm 90 (Fig. 12) connected to piston 121 in brake cylinder 89. Arm 81 is connected to brake rod 382 (Fig. 2) extending to the ordinary mechanical brake linkage of the car. This construction represents a safety feature which permits straight mechanical operation of the car brakes by direct foot pressure in case the automatic braking feature fails.

The brake cam 77 cooperates with a roller or follower 85 (Figs. 12, 15 and 16) on brake arm

83 pivoted to shaft 84. The brake lever 83 engages a brake piston valve 86 which controls hydraulic pressure to brake piston 121. The brake piston valve 86 is a spring return valve which returns to closed position, releasing pressure on piston 121, upon removal of force exerted by brake lever 83. Connected to the lower end of brake lever 83 is a rod 91 extending to the pressure regulator 92 (Fig. 11) for controlling the pressure in the suction side 71 of the stator 18. This causes the transmission to operate as a transmission brake, as explained more in detail hereinafter.

The pins 93, 94 of the forward and reverse cams 78, 79 engage control bars 96, 95 for controlling master control 97 (Figs. 8, 9 and 10), as will be explained in due course. The forward and reverse pedals 5 and 6 are also adapted to engage the member 87 attached directly to the control throttle of the car engine. This permits a limited downward movement of the forward and reverse pedals with the engine idling before opening the throttle for speeding up the engine.

It will be noted, especially from Fig. 16, that followers 85 secured to the brake arm 83 is mounted on a pin which also carries a follower 235. Follower 235 is actuated by cam surfaces 236, 237, 238 and 240 on forward cam 78 and on reverse cam 79 as explained hereinafter.

The starter pedal 7 (Figs. 2, 4, 12 and 13), supported by the floor board of the car, is connected to rod 98 passing through the cover 13 of the transmission and operates against spring 152. The rod 98 engages arm 99 (Fig. 4) pivoted at 136 which operates arms connected to a vertical rod 101 and horizontal rod 103. The vertical rod 101 extends to starting valve 102. The rod 103 extends to starting cam 104 (Fig. 13) for a reason explained more in detail hereinafter.

The starter rod 98 also engages an arm 106 mounted on shaft 105 which operates an arm 107 engaging a starter bar 108 which operates the master control 97, as explained more in detail hereinafter.

Hydraulic control

Referring more particularly to Figs. 8, 9, 10 and 12, the hydraulic control comprises a master control 97 which operates the trunnion control 119 which automatically determines the tilt of the forward and rear swash plate assemblies 19, 20. The master control comprises a reverse bar 95, a forward bar 96 and a starter bar 108 slidably mounted on pins 109 passing through slots in the bars. Pins 109 are anchored in the casing as shown particularly in Fig. 7. These bars 95, 96 and 108 (Fig. 10) operate valves 113, 114 (Fig. 8) admitting pressure into opposite sides of piston 115 through pipes 272 and 273. Valve 113 is operated by a crank 280 engageable by an abutment 110 on forward bar 96. Valve 114 is operated by crank 281 engageable by an abutment 111 on reverse bar 95 and by an abutment 112 on starter bar 108 (Fig. 10). Valves 113 and 114 are returned to their initial positions by springs 120 attached to suitable levers on the valves.

The master control 97 comprises a casing having a piston 115 therein normally maintained in central position by springs 137. At each end of the cylinder is a port which communicates, under control of valves 113, 114, with hydraulic pressure through pipes 272, 273 on the one hand, and exhausts through ports 153 on the other hand. The fluid expelled through exhaust ports 153 flows into the reservoir in the bottom of the

transmission body 12. The piston 115 (Fig. 12) has a rod 116 connected to link 116, operating rock shaft 117 which operates link 118, the latter operating arm 141 (Fig. 27) on the valve 135 of trunnion control 119. The link 116 also operates a lever 122 connected to rod 123' which controls the position of interlock bar 123.

The forward swash plate 19 is mounted by trunnions 124 and the rear swash plate 20 is mounted by trunnions 56 (Fig. 12). The positions of these swash plates are determined by an arm 127 secured to the forward swash plate 19 and an arm 128 secured to the rear swash plate 20. Arm 127 is connected to rod 129 which is operated by piston 125. Arm 128 is connected to piston 126 by piston rod 126'. Hydraulic liquid admitted into the cylinders of trunnion control 119 determines the positions of swash plates 19 and 20.

For stopping the piston 125 in a position corresponding to erect position of forward swash plate 19, an interlocking arrangement is provided. This arrangement comprises a series of spring pressed plungers 132, 133 and 134. Plungers 132 and 133 engage in recess 130 of rod 129 and plunger 134 engages in recess 131 of rod 129. Plunger 132 is under control of cam 282 on starter bar 108 and is under control of cam surface on interlock bar 123. Plunger 133 is under control of cam surface on interlock bar 123 only. Plunger 134 is under control of cam surface 283 on starter bar 108 only. The manner of operation of these plungers and cam surfaces will be explained under operation.

Referring to Figs. 12 and 24-28, the trunnion control 119 comprises separate cylinders having pistons 125 and 126, respectively. It also comprises a valve casing having a cylindrical valve 135 which is both slidable and rotatable. For rotatable control, the valve 135 has a square shank 138 slidable in a hollow sleeve 139 journaled in bracket 140. Sleeve 139 supports arm 141 connected to the link 118.

For longitudinal control, the valve 135 has a ball and socket connection 142 with rod 143 connected to lever 207 mounted on shaft 206 and controlled by the several governors, as hereinafter explained more in detail.

The valve 135 has three rotary positions, as illustrated in Figs. 24, 25 and 26. It has three sets of ports, one corresponding to each position. The valve casing has a pressure duct 144 to which hydraulic pressure is supplied by pipe 274 (Fig. 36). The pressure duct 144 communicates with pressure ports 145-149. Exhaust ports 150 and 151 are also provided. In Fig. 24, the valve 135 has ducts 269, 268, 270; in Fig. 25, valve 135 has ducts 260, 262, 261, 301, 302; in Fig. 26, valve 135 has ducts 263, 264, 265, 267, 266.

From the above, it will be seen that the positions of pistons 125 and 126 and consequently the positions of the swash plates 19 and 20 are controlled, first, by the governor mechanism which moves valve 135 longitudinally and, second, by the master control 97 which rotates the valve 135.

Stator control

Referring now to Figs. 6 and 13, the stator 18 has a passage 155 connecting with the pressure side 72. This passage is normally closed by a spring pressed valve 154 under control of starting cam 104. The valve 154 has a plug extension 156 which closes the passage 157 leading to the suction side 71 of the stator. The passage 157 is also closed by a variable pressure relief

valve 158 normally held closed by a spring operating against the slidable abutment 159. The position of abutment 159 and consequently the tension on the spring is determined by a cam surface 160 on a cam bar 161 connected to arm 162 mounted on the forward swash plate 19.

The pressure exerted by the supercharger 187 on the suction side 71 of stator 18 is controlled by the variable pressure relief valve 158. The pressure at which valve 158 will open is determined by the tilt of forward swash plate 19. The greater the tilt of this swash plate, the higher the pressure which the supercharger is permitted to impress upon the suction side 71. The supercharger 187 may generate a pressure equal to the maximum pressure generated on the pressure side 72 of the stator in normal operation of the transmission which, for example, may be 300 pounds per square inch. The variable pressure relief valve 158, however, may be set to discharge at pressure from, say, 5 to 65 pounds, depending upon the tilt of the forward swash plate 19.

When cranking the engine in starting, pressure is admitted into the suction side 71, passage 157 is closed by plug extension 156 and the pressure side 72 of stator 18 is opened by valve 154. Valve 158 controls discharge into pipe 371 connected to coordinating device 360 (Figs. 37 and 40) whose operation is explained hereinafter.

All exhaust ports discharging liquid to atmosphere in this transmission drain into the reservoir in the bottom of the transmission casing.

For permitting the car to coast forward, i. e. for allowing the car to roll independently of the engine, and for making use of the transmission as a hydraulic brake, a pressure regulator 92 is provided (Figs. 6 and 11). The suction side 71 and pressure side 72 are connected by a passage normally closed by plug valve 163. This valve is opened by arm 164 operated by link 165 connected to piston 166. Spring 468 closes valve 163 when no pressure is applied under piston 166.

Piston 166 is controlled by a regulator cylinder having a plug valve 167 slidable therein. Valve 167 has a disc 168 seating on a conical seat and also has a passage 169 communicating with space 171. The valve also has a second valve space 172. Valve spaces 171 and 172 communicate with pressure port 173 and exhaust port 174. Exhaust port 174 connects with coordinating device 360 through pipe 370 (Figs. 36 and 40). Pressure connection 175 connects the suction side 71 of the stator with the regulator cylinder.

The valve 167 has a collar 176 rigidly secured thereto. A coil spring operates between a screw plug 181 and collar 176. A slidable collar 179 is mounted on valve 167 and is controlled by bell crank lever 180, which in turn is controlled by brake rod 91. Spring 178 is interposed between slidable collar 179 and fixed collar 176. Spring 177 is sufficiently strong to prevent the pressure in suction side 71, when cranking the car engine by the transmission, from moving valve 167 downwardly and thereby admitting pressure to piston 166 to open stator valve 163.

Referring now to Figs. 37 to 40, a coordinating device 360 is provided for preventing the suction side 71 of the stator from discharging through variable relief valve 158 in cranking the engine, backing the car, and when using the stator brake. It also insures the opening of stator valve 163 after removing the foot from the brake pedal 4 until the forward pedal 5 is depressed and the engine speeds up sufficiently

to generate pressure on the pressure side of the stator.

The coordinating device 360 comprises a casing 361 having a bore 362 in which slides a valve 363. Valve 363 is provided with a disc 364, a semi-circular shank 365 having a hole 366 adapted to register with an opening 373 in the casing 361. The valve 363 is arranged to move to right or left, depending upon whether the pressure in pipe 371 or 372 predominates. Extension 367 limits the movement of valve 363 in one direction.

The coordinating device 360 also comprises a valve 368 for closing communication with pipe 371. This valve has a discharge port 369 and is so arranged that the discharge port 369 is always open and in communication with the bore 362 of casing 361. Operation of valve 368 opens communication between pipe 371 on the one hand, and port 369 and bore 362 on the other hand. Valve 368 is operated by an arm 374 which engages the end of an extension of forward bar 96, spring 376 (Fig. 12) moving the valve 368 upon movement of forward bar 96.

The coordinating device 360 has three pipes communicating therewith; pipe 370 extending to regulating device 92 (Fig. 11); pipe 371 extending to variable pressure relief valve 158 (Fig. 13); and pipe 372 extending to the pressure side 72 of the stator (Fig. 6).

The bell crank lever 180 has three positions, indicated in Fig. 11 by A, B and C. Position A causes the transmission brake to be fully applied, locking the rear wheels of the car. Position B permits the car to coast forward with the car engine idling and little or no resistance to free coasting being offered by the transmission. Positions between B and A correspond to various degrees of braking effort. Position C insures the closing of stator valve 163 and corresponds to forward or reverse power transmitting condition of the transmission.

Considering position C, valve 167 will take its lowermost position, causing disc 168 to seat thus relieving piston 166 through port 173, valve space 171 and port 174. This insures the closure of stator valve 163 and the transmission of hydraulic power from pump block 16 to motor block 17. Port 174 discharges through pipe 370 to coordinating device 360 (Figs. 37-40). Pressure is vented through device 360 by way of valve 368 and port 369 (provided the car is in reverse) and by way of valve 363 and port 373 (provided car is in forward) since pressure in pipe 372 holds valve 363 in the position shown in Fig. 37.

Considering position B, for free coasting forward, with decrease in tension of spring 178, valve 167 rises under influence of spring 177 to such position that, alternately, pressure is communicated to piston 166 through duct 169, valve space 171 and pressure port 173, and, alternately, exhaust is communicated to piston 166 through port 173, valve space 171 and port 174, passage 169 being cut off from pressure at this time. Since port 174 discharges through pipe 370 to coordinating device 360, pressure is vented by way of valve 368 and port 369 and also valve 363 and port 373, i. e. through both discharge points, since valve 368 is in the position shown in Fig. 37. Coasting in reverse is impossible for reasons pointed out hereinafter.

The operation of regulator 92 for coasting depends upon a certain amount of pressure being generated in the suction side 71 of the stator, this pressure being low but sufficiently high to enable piston 166 to keep stator valve 163 open.

The valve 167 is thus "balanced" between the spring pressure and pressure generated in suction side 71, sufficient pressure being maintained under piston 166 to keep stator valve 163 open.

For braking, bell crank lever 180 will be positioned between B and A, depending upon the amount of braking effort desired. Applying the brake decreases the downward tension exerted by spring 178, giving more relief to piston 166. This tends to close stator valve 163, but as soon as too great a pressure is built up in the suction side 71, the regulator valve 167 is forced downwardly, giving more pressure to piston 166. Thus, a balance is maintained, depending upon the braking effort desired, maintaining constant hydraulic pressure in suction side 71, and hence constant braking effort, irrespective of speed of the car, with a given position of the brake pedal.

As the brakes are applied harder, less tension is exerted by spring 178, thus tending to give more relief to piston 166, resulting in further closing of stator valve 163.

Considering position A, the decreased tension exerted by spring 178 causes valve 167 to assume its uppermost position, connecting piston 166 with exhaust through port 173, valve space 172 and port 174. This insures complete closure of stator valve 163 necessary for locking the rear wheels of the car. Port 174 connected through pipe 370 to coordinating device 360 is connected to exhaust the same as described under position B.

Supercharger

Referring now to Figs. 4, 21-23 and 36, a supercharger 187 is provided for maintaining predetermined pressure in the suction side 71 of the stator 18. This supercharger may comprise an ordinary gear pump having a pair of gears 192, 193 having a suction inlet 194 (Fig. 36) communicating with the hydraulic reservoir in the bottom of the transmission casing 12 and having a discharge outlet 195 connected to the pipe network, as illustrated in Fig. 36. The supercharger overcomes troubles due to foaming, as explained at length in application Serial No. 24,353, above referred to.

The gear 192 is mounted on a shaft 197 which is driven by either a separate electric motor 184 (Fig. 4) mounted on the outside of casing body 12 or by a gear 183 secured to the drive sleeve 14. For permitting drive from either source without interference, a pair of overriding clutches 185 and 186 are provided. Clutch 185 comprises a casing 189 mounted on shaft 188 of electric motor 184.

Within casing 189 is a core 190 having a series of wedge-shaped openings in which are disposed spring pressed rollers 191. The overriding clutch 186 is similar in construction to that of 185, its core being connected to shaft 197 and its casing being connected to gear 196 meshing with gear 183. The overriding clutches are so arranged that, when gear 196 is driving the supercharger 187, clutch 186 engages and clutch 185 overrides. When the electric motor 184 is driving the supercharger 187, clutch 185 engages and clutch 186 overrides.

It will be understood that ordinarily the supercharger 187 will be driven from the main transmission drive shaft 14. However, in cases where the pressure in the storage tank 250 is insufficient for hydraulic cranking of the car engine, emergency button 8 may be operated to start electric motor 184, run by the car battery, to drive the

supercharger 187 to charge up the storage tank 250.

Governors

The transmission is automatically governed by the combined effect of three governors, i. e. a speed governor 200 (Fig. 4) responsive to engine speed; a torque governor 208 (Fig. 13) responsive to hydraulic pressure in the pressure side 72 of the stator 18 and a pendulum governor 219 (Figs. 13, 19 and 20) responsive to the angle of grade on which the car is traveling. It will be understood that these governors automatically change the condition of the transmission to suit road conditions without any attention from the driver of the car, the driver merely operating the forward pedal according to the speed at which he desires to travel.

The speed governor 200 (Fig. 4) comprises a frame attached to the drive shaft 14 having a plurality of balls 201 pivoted thereto. These balls operate upon a slidable collar 202 attached to a slidable collar 203. A plurality of springs 204 are interposed between collar 203 and the governor frame to oppose the centrifugal force exerted by the balls 201. A yoke 205 (see also Fig. 7) is attached to shaft 206 and carries studs 212 operating in the annular groove of collar 203. Shaft 206 carries arm 207 which is pivoted to link 143 for imparting longitudinal movement to the trunnion control valve 135 (Fig. 12).

It will be understood that as drive shaft 14 increases in speed, the balls 201 will fly outwardly describing increasingly larger circles, causing the collar 203 to move forward against spring pressure of springs 204 and causing the trunnion control valve 135 to move rearwardly.

Referring now to Figs. 6, 7 and 13, the torque governor 208 comprises a cylinder supported by stator 18 communicating with the pressure side 72 of the stator 18 through pipe 375. This cylinder carries a piston 209 attached to a piston rod 210 sliding in a guide 213 and abutting an arm 211 attached to speed governor shaft 206. The pressure exerted on piston 209 is proportional to torque exerted upon the rear wheels of the car. This pressure is opposed by a spring 214 operating between an adjustable nut 227 and a slidable collar 215, the latter abutting a bell crank lever 216 pivoted at 406. The lever 216 has a cam surface 217 engaging a follower 218 attached to the forward trunnion 19. It will thus be seen that tilting of the forward trunnion in either direction reduces the pressure exerted by spring 214 to permit the hydraulic pressure to exert increased effect on the arm 211 which is also under the control of the speed governor 200.

The pendulum governor 219 comprises a cylinder 224 (Figs. 19 and 20) bolted to the side of the transmission housing. The cylinder 224 contains a piston 225 which operates against the lever 211.

Piston 225 is controlled by a valve 221 slidable in the casing of the pendulum governor 219 and having a port 222 for connecting the cylinder 224 with a pressure supply pipe 223. The end of cylinder 224 has a small bleeder 228 which relieves pressure in the cylinder when the valve 221 disconnects pressure supply pipe 223. It will be noted that the cylinder beyond the end of valve 221 provides a dash pot action, having a bleeder opening 226. The weighted pendulum 220 is pivoted at its upper end by pivot 229 to the frame of pendulum governor 219 and has a connection 255 with the valve 221. It will be seen that both the torque governor 208 and pendulum governor

219 oppose the action of speed governor 200. The dash pot 220 steadies the pendulum 220 so that it is not affected by vibrations or short periods of acceleration or deceleration of the car.

Change over to two pedal control

Instead of using a separate brake pedal 4, if desired, all controlling by the operator in the ordinary driving of the car, may be done with two pedals, i. e. forward pedal 5 and reverse pedal 6. A change over knob 9 is provided for changing over from three pedal to two pedal operation.

Knob 9 is normally engaged with the dash 239 as indicated in Fig. 12. This knob is connected to a wire 230 extending through a flexible tube and connected to a slidable collar 232 on rod 91. A spring 231 is interposed between slidable collar 232 and a slidable collar 233 which in turn abuts support 234. An additional spring 235' connects rod 91 and a point on the casing body 12. For three pedal operation, the spring 231 overcomes the action of spring 235', holding the roller 85 on brake lever 83 in slightly spaced relation to the adjacent part of brake cam 77 as indicated in Fig. 15. With the operation of brake pedal 4, the brake cam 77 moves brake lever 83 against the tension of spring 231.

To change over to two pedal operation, the knob 9 is pushed up to permit spring 231 to pull it against the dash board 239. This releases sufficient tension from spring 231 to permit spring 235' to dominate, this spring moving brake lever 83 so that the roller 85 (Fig. 16) on the brake lever 83 engages the step 236 on the forward cam 78 and reverse cam 79 (Figs. 15 and 18). This movement of the brake lever 83 opens brake piston valve 86, operating brake piston 121, putting on the mechanical brake and also operates regulator 92 (Fig. 11) to put on the stator brake, the bell crank 180 moving to the position A and putting the stator brake full on.

If either the forward pedal 5 or reverse pedal 6 be depressed, it causes the brake roller 235 to ride up the cam inclination 237, gradually releasing both the mechanical brake and the stator brake until the brake roller 235 reaches the step 238 when both brakes are fully released. This corresponds to neutral position with the brakes released and with the car engine idling, pedals 5 or 6 not yet engaging throttle operating member 87 (Fig. 2). The position of brake lever 83 here is the same as indicated in Fig. 15 with three-pedal operation when none of the three foot operating pedals 4, 5 or 6 is depressed, viz: with the follower 85 in slightly spaced relation to the adjacent part of brake cam 77. Further depressing of either of these pedals 5 or 6 operates the master control 97 to set the transmission shifting mechanism automatically into operation, as will be explained hereinafter. Further depressing of these pedals also causes the brake roller 235 to ride up onto concentric portion 240 moving the regulator 92 (Fig. 11) to position C.

Hydraulic connections

Referring now to Fig. 36, the various pieces of apparatus are denoted diagrammatically with the piping or hydraulic connections between the parts also indicated diagrammatically. The supercharger 187 is connected to a hydraulic reservoir, such as the bottom of the casing body 12, by pipe 194 and discharges through pipe 195 through a non-return check valve 241 to starting valve 102. The check valve 241 and all of

the other check valves (to be referred to) are standard oneway valves which permit the passage of fluid only in one direction.

Starting valve 102 is connected by pipe 242 to connection 244 on the pressure side of the stator through check valve 243; starting valve 102 is connected by pipe 245 through check valve 246 to connection 247 on the suction side of the stator; starting valve 102 is connected to connection 249 under storage tank 250 by pipe 248. Pipe 248 has a safety valve 251 which relieves the system if accidental unsafe pressures are reached.

A common connecting point 252 connects with connection 247 through check valve 256 and with connection 244 through check valve 257. Common point 252 connects with pipe 242 through check valve 258 and connects with connection 249 through check valve 259.

The common point 252 supplies pendulum control 219 through pipe 223; it supplies valves 113, 114 of master control 97 through pipes 272, 273; it supplies trunnion control 119 through pipe 274 and it supplies brake piston valve 86 through pipe 271.

Operation (with three pedals)

The cranking operation will first be described, attention being called to Fig. 36 which shows the essential parts involved in the cranking operation in the positions they assume with the starter pedal 7 depressed. The other figures referred to in the following description show the structural parts in detail.

Assuming that the car has been left standing in the garage over night with pressure still maintained in the pressure tank 250, the parts will be substantially in the positions shown in Figs. 4, 12 and 13. The swash plates will be in the position shown in Fig. 30. To start the engine, using the transmission as a starter, the starter lever 7 is depressed. This does three things: (1) It rotates starting valve 102 (Figs. 4, 13 and 36) clockwise ninety degrees to the position shown in Fig. 36 connecting the pressure tank 250 with the suction side 71 of the stator; (2) it moves starting cam 104 (Fig. 13) to open valve 154, opening the pressure side 72 of the stator to the atmosphere (Fig. 6) and preventing the operation of variable pressure relief valve 158; and (3) it also moves starter bar 108 (Fig. 12) to the right.

Movement of starter bar 108 releases lock 132, releasing piston 125 for tilting movement of forward swash plate 19 to the position shown in Fig. 31. Movement of starter bar 108 also turns valve 114 of master control 97, moving piston 115 to the left, this rotating trunnion control valve 135 to cranking position (Fig. 25). This causes pressure to be admitted through ports 145, 260, causing piston 125 to move to the right, the cylinder exhausting through ports 261, 150. Pressure is also admitted through ports 148, 301, but since piston 126 is already to the right nothing happens. The forward swash plate 19 tilts to forward position, the positions of the swash plates being indicated in Figs. 31 and 36.

In cranking, it is also necessary to depress brake pedal 4 to hold the car stationary. This operates brake cam 77 (Figs. 12 and 15) moving brake lever 83, which operates brake piston valve 86, which in turn operates brake piston 121, putting on the mechanical brakes of the car. Movement of brake lever 83 also operates the pressure regulator 92 (Figs. 11 and 36) to the position indicated by A, this raising valve 167, insuring

valve space 172 connecting with ports 173 and 174, this in turn insuring the closure of stator valve 163.

Port 174 is insured relief through pipe 370; valve opening 366 and port 373; and valve 368 and port 369 (Figs. 36-40). Since valve 368 closes pipe 371, when in the position shown in Fig. 37, the pressure in the suction side 71 of the stator caused by cranking cannot blow off through the variable release valve 158.

Since pressure is admitted into the suction side of the stator and since the rear side of the transmission is held stationary and since the forward swash plate is tipped in the same direction as normal forward operation, the pressure in the suction side of the stator will drive the forward side of the transmission as a hydraulic motor, turning over the car engine in its normal direction of rotation and starting it. The speed governor 200 is so arranged that idling speed of the car engine is insufficient to impart any appreciable movement to trunnion control valve 135.

Removing the foot from the starter 7 closes valve 114, permitting the springs 137 to return piston 115 of the master control 97 to central position, this rotating the trunnion control valve to the rotative position shown in Fig. 24 and permitting lock 133 to return to its locking position. Pressure is admitted through ports 148, 268 to the right hand side of piston 125 moving it to the left, the cylinder exhausting through port 269. The lock 133, having been released by interlock bar 123, limits the movement of piston 125 to that corresponding to erect position of forward swash plate 19. Pressure is also admitted to the left side of piston 126 through ports 148, 268, but since the piston 126 is already in extreme rear position, nothing happens.

Starting valve 102 also goes back to original position and starting cam 104 permits valve 154 to close and valve 156 to open. Removing the foot from brake pedal 4 closes brake piston valve 86 to pressure and opens it to exhaust, relieving pressure from brake piston 121, and moves regulator 92 (Fig. 11) to position B. The position of the swash plates is indicated in Fig. 30.

The car is now in "neutral" with the engine 2 idling. The rear wheels are locked against backward movement since the stator valve 163 is closed and any pressure generated in the pressure side 72 of the stator due to the car tending to roll back cannot operate regulator 92 to open stator valve 163. Thus a "no-back" arrangement is provided which is of assistance in stopping for traffic on an up grade.

Referring now more particularly to Fig. 36A, the figure shows diagrammatically the essential parts involved in the backing or reversing operation. The other figures referred to in the following description show the structural parts in detail.

To back out of the garage reverse pedal 6 is depressed. This moves reverse cam 79, which in turn moves reverse bar 95 (Figs. 10, 12 and 14). Movement of reverse bar 95 operates valve 114, this in turn operating master control piston 115 (Fig. 12) to the left. This rotates trunnion control valve 135 to the rotative position shown in Fig. 25 and operates interlock bar 123 to remove plunger 133 from the path of rod 129. Since the reverse pedal 6 has not yet been depressed far enough to engage throttle control member 87 (Fig. 2), the car engine is still idling. Pressure is admitted to the left side of piston 125 (Fig. 75

25) through ports 145, 260, but piston 125 cannot move because of interlock 132 (Fig. 12). Pressure is supplied to pressure duct 144 of trunnion control 119 from the pressure side 72 of the stator 18 through fitting 244, check valve 257 and pipes 252 and 274 (Fig. 6). Pressure is supplied to pressure side 72 of the stator 18 from supercharger 187 through pipe 195, check valve 241, starting valve 102, pipe 242 and check valve 243. Pressure from supercharger 187 is also supplied through check valve 258.

As reverse pedal 6 is further depressed, it engages throttle member 87 (Fig. 2) speeding up the car engine above idling speed. The speed governor 200 then moves the trunnion control valve 135 to the right sufficiently to admit pressure to the right of piston 125 through ports 262, 146 and to exhaust the left side of piston 125 beyond the left hand end of valve 135, the valve 135 overrunning the cylinder port. This causes the piston 125 to move all the way to the left hand end of the cylinder, interlock 133 having been removed, tipping the forward swash plate 19 to the position shown in Figs. 35 and 36A. This reverses the operation of the transmission, causing the car to back out.

As the reverse pedal 6 engages throttle member 87, the brake roller 235 (Figs. 15, 16 and 36A) rides up onto cam surface 240 moving brake lever 30 83 which operates regulator valve 92 to position C in Figs. 11 and 36A. This insures closure of stator valve 163.

As the foot permits reverse pedal 6 to rise, the car engine slows down to idling speed, moving trunnion control valve 135 to the left from the position shown in Fig. 36A to the position shown in Fig. 25. Pressure is admitted to the left side of piston 125 through ports 145, 260, the cylinder exhausting through ports 261, 150 thus moving piston 125 to the right until forward swash plate 19 reaches erect position, interlock 132 limiting movement of these parts to this position.

Upon removing the foot from the reverse pedal 6, the reverse bar 95 moves back the valve 114 and master control piston 115 regains central position; trunnion control valve 135 rotates to idle rotative position shown in Fig. 24. This admits pressure to the right hand side of piston 125 through ports 148, 268, the left side of piston 125 exhausting through port 269. Piston 125 does not move, however, because of interlock 133. The car is again in neutral with the engine 2 idling and the swash plates in the position shown in Fig. 30.

Referring now more particularly to Fig. 36B, this figure shows diagrammatically the essential parts involved in the operation of forward drive. The other figures in the following description show the structural parts in detail.

To go forward, the forward pedal 5 is depressed. This rotates the forward cam 78 (Figs. 12 and 14), operating forward bar 96. This in turn operates valve 113 of master control 97, moving master control piston 115 to the right in Figs. 12 and 36B, rotating trunnion control valve 135 to the rotative position shown in Fig. 26. Pressure is admitted to the right side of piston 125 through ports 146, 264, but it does not move because of interlock 133.

Movement of forward bar 96 also causes lever 374 to ride off the end of the bar 96 (Fig. 37) moving valve 368, connecting pipe 371 with port 369 and also the interior of valve casing 361.

Speeding up of the engine moves trunnion con-

trol valve 135 to the right from the position shown in Fig. 26 to the position shown in Fig. 36B admitting pressure through ports 145, 263 to the left hand side of piston 125, the right hand side of piston 125 exhausting through ports 264, 150. This slowly tilts the forward swash plate 19, the movement of interlock bar 123 having raised plunger 132 permitting the necessary movement of rod 129. Movement of forward pedal 5 for speeding up the engine above idling speed also moves regulator 92 to position C in Figs. 11 and 36B. Pressure on the pressure side 72 of the stator being greater than pressure on the suction side 71, valve 363 gains the position shown in Figs. 37 and 36B.

As the engine and car speeds up, the piston 125 will move slowly to the right in Fig. 12. When the forward swash plate 19 reaches its full tilt position, as illustrated in Fig. 33, the governor will have moved trunnion control valve 135 sufficiently to the right to admit pressure to the right hand side of piston 126 through ports 149, 267 (Fig. 26). This causes piston 126 to move to the left, the cylinder exhausting through ports 265, 151.

Pressure will also be admitted to the right hand side of piston 125 through ports 147, 264, the left hand side of piston 125 exhausting beyond the left hand end of trunnion control valve 135. Thus, both the forward swash plate 19 and the rear swash plate 20 moves to erect position. The movement of rear swash plate 20 to erect position operates link 43 (Figs. 4 and 13) operating clutch cam 39 and engaging the mechanical clutch 21 to give a direct drive from drive shaft 14 to driven shaft 15. While in direct drive both swash plates maintain their erect position so there is no movement of the pistons 49 in the cylinder blocks.

To automatically shift from direct drive to a lower speed, because of a hill with the forward pedal 5 fully depressed, when the engine reaches a predetermined lower speed, the governor moves trunnion control valve 135 to the left from its extreme right hand position to a position a lesser distance to the right of the position in Fig. 26. This admits pressure to the left of piston 125 through ports 145, 263, moving piston 125 to the right, the cylinder exhausting through ports 264, 150. Pressure is also admitted to the left of piston 126 through ports 148, 265, this piston being moved to the right and exhausting through port 266. This places both swash plates in full tilt position, disengaging the mechanical clutch 21. As the engine further decreases in speed and the valve 135 is moved further to the left toward the position shown in Fig. 26, piston 125 moves back towards the left, pressure being admitted through ports 146, 264 and the cylinder exhausting through port 263.

To apply the brake going, say, at forty miles per hour, the foot is removed from forward pedal 5 and brake pedal 4 is depressed. As brake roller 235 (Figs. 15, 16) rides off cam surface 240, regulator 92 goes from position C to position B in Fig. 11. As brake pedal 4 is depressed, brake piston valve 86 is operated, causing the car brakes to be applied. As brake pedal 4 is depressed, brake cam 77 (Figs. 15 and 17) is rotated clockwise in Figs. 15 and 17 engaging roller 85 which moves brake lever 83 clockwise in Fig. 15 (counterclockwise in Fig. 12). Push rod 91 moves to the right in Figs. 11 and 12 moving regulator 92 from position B toward A in Fig. 11, depending upon how far brake pedal 4 is depressed.

Removing the foot from forward pedal 5 causes forward bar 96 to move back, permitting master control valve 113 to move back and allowing master control piston to regain mid-position. This rotates trunnion control valve 135 to the rotative position shown in Fig. 24, causing hydraulic pressure to be applied to the left of piston 126 through ports 149, 268, the cylinder exhausting through port 270. This moves piston 126 (which was at the left hand end of its travel) to the right, moving rear swash plate 20 to full tilt position for obtaining the desired transmission braking action.

Removing the foot from the forward pedal 5 and the consequential backward movement of forward bar 96 operates lever 374 (Fig. 37) causing valve 368 to return to the position shown in Fig. 37, closing pipe 371. This insures relief to exhaust port 174 of regulator 92 (Fig. 11) through coordinating device 360 as described above.

To coast, for example, when running in high speed, simply take the foot off the forward pedal 5. The master control piston 115 will move to mid-position, moving trunnion control valve 135 to the position shown in Fig. 24; the forward trunnion 19 already has an erect position and hence will not move, but the rear trunnion 20 will go to full tilt position and the mechanical clutch 21 will be disengaged.

The forward swash plate 19 being in erect position and the rear swash plate being under full tilt position, the transmission is in condition for acting as a powerful brake. Pressure will immediately be built up in the suction side 71 of the stator which operates the regulator valve 92 (Fig. 11) to open stator valve 163, thus permitting local circulation of the liquid.

It will be understood that during the coasting operation sufficient pressure will be maintained in the suction side 71 to balance spring 177 and to apply enough pressure under piston 166 to keep the valve 163 open.

To coast after applying the brake, simply take the foot off the brake pedal 4. This returns brake pedal cam 77 and brake lever 83, opens brake piston valve 86 and moves pressure regulator bell crank lever 180 back to position B. This is the coasting position of the regulator, causing it to operate as above described under "Stator control."

Assume the brake has retarded the car down to, say, 30 miles per hour, to regain direct drive, depress forward pedal 5. This moves the regulator 92 to position C before the car engine accelerates. This would ordinarily close stator valve 163 and would lock the rear wheels of the car, but, as soon as pressure begins to build up in suction side 71 of the stator, this pressure acts through variable relief valve 158, pipe 371, through valve 368 and port 369 (Fig. 37). However, port 369 is not large enough to accommodate the liquid discharged from the suction side 71 of the stator and, therefore, this pressure operates valve 363, moving it to the left in Fig. 37, closing port 373. This pressure is then communicated to pipe 370, through port 174 (Fig. 11), valve space 171 and port 173 to piston 166, opening stator valve 163. This condition exists only so long as the car speed exceeds the engine speed and permits free coasting until the engine speed equals the car speed and the engine takes up the load. Pressure is then built up on the pressure side 72 of the stator, the suction side 71 again dropping to lower pressure.

Stator valve 163 will automatically close, since no more pressure is communicated to piston 166 of regulator 92. Pressure being greater in pipe 372 than in pipe 371 (Fig. 37) the valve 363 will move back to the position shown. But now the engine has taken hold and the rear swash plate 20 is tilted back to vertical and direct drive had been established.

Considering again the operation of cranking, in case the car has been idle a sufficiently long time for the pressure in storage tank 250 to leak away, the emergency starter button 8 may be operated to cause the electric motor 184 driven by the car battery to drive the supercharger 187 to charge up the storage tank 250. The storage tank 250 is charged by the supercharger 187 as follows, Fig. 36. Oil is sucked from the sump through pipe 194, forced through pipe 195, check valve 241, valve 102, pipe 242, check valves 258, 259 into tank 250. After the supercharger 187 has charged the storage tank to a sufficiently high pressure to crank the car engine 2, the starter pedal 7 may be depressed in the ordinary manner to start the car as described above.

Or, if desired, the starter pedal 7 may be held down while the supercharger 187 is charging the storage tank 250. The car engine 2 will not turn over until sufficient pressure is built up in the storage tank 250 to overcome the initial compression of the car engine, but upon this occurrence the car engine will thereafter turn over until it starts under its own power.

Operation (with two pedals)

To change over to two pedal operation, it is only necessary to push up change over knob 9 from the position shown in Fig. 12 to cause it to directly engage dash 239, as explained in the chapter entitled "Change over to two pedal control."

The operations of starting, applying the brake, backing and going forward are quite similar to the operations under three pedal control except that the brake pedal 4 is no longer used, the brake being applied by operation of the forward and reverse pedals 5 and 6. When the forward and reverse pedals 5 and 6 are in their normal raised position, regulator 92 (Fig. 11) is operated to apply the stator brake and in addition brake piston valve 86 is operated to apply the mechanical brakes full on.

As either the forward or reverse pedal 5 or 6 is depressed, the roller 235 on brake lever 83 (Fig. 16) rides up inclined surface 237 (Figs. 15 and 18), gradually releasing both brakes until the step 238 is reached. In this position the regulator 92 is in position B (Fig. 11). Further movement of either the forward or reverse pedals 5 or 6 operates to start the car in the same manner as explained above under two pedal operation.

Advantages

Thus a fully automatic hydraulic transmission is disclosed which is rugged in construction and dependable in operation. All transmission movement for changing speed is controlled positively, but automatically, merely by operating a single operating pedal similar to the ordinary accelerator pedal. The variable stroke hydraulic transmission gives infinitely variable speed ratios from neutral to one to one speed ratio for direct drive and the mechanical clutch gives a positive direct drive while the hydraulic transmission is cut out of operation, thereby saving wear and tear on these parts.

The use of a pressure tank for storing hydraulic pressure is important since by this means the transmission may be used for cranking the engine, thereby obviating the conventional starting arrangement and permitting the use of a smaller automobile battery.

The full automatic control governed by speed, car torque and pendulum takes care of all conditions met in ordinary operation. If it is desired to accelerate quickly from stationary position, it is only necessary to press hard on the forward pedal. This opens the engine throttle wide and the engine exerts increased torque; which in turn increases the hydraulic pressure in the transmission. The increase in hydraulic pressure causes the torque governor to modify the effect of the speed governor so that the sequence of events controlled by the trunnion control valve 135 takes place at increased car speeds. This permits accelerating to higher car speeds before the transmission moves to high or direct drive. A similar condition occurs on an up grade, in which case, the pendulum governor modifies the operation of the speed governor to permit the transmission to require a higher car speed before the transmission will assume the position of direct drive.

The pressure regulator is of great utility. It insures closing of the stator valve for transmission braking; it insures closure of the stator valve when transmitting power hydraulically; it insures opening of the stator valve for coasting; and it serves to control the stator valve for applying any desired braking effort by means of the transmission. The regulator, furthermore, insures the generation of constant pressure and hence constant braking effort for any particular brake pedal setting, irrespective of car speed.

The use of the master control; the trunnion control and the mechanical interlock is of great advantage to cause the forward and rear swash plates to take the proper positions required for the various conditions met in the ordinary operation of the car. The trunnion control valve and the mechanical interlock insure movement of the swash plates in the proper direction and to the proper extent.

The use of the supercharger overcomes troubles due to foaming. It maintains a constant pressure in the suction side of the stator above atmosphere, insuring the discharge of any air which may get into the hydraulic transmission. The variable pressure relief valve controlled by the tilt of the forward swash plate regulates the pressure generated in the suction side of the stator to that required for good operation, but no higher, since too great a supercharger pressure produces undesirable forces on the swash plates. Consequently, the relief valve is arranged so that minimum supercharger pressure is applied to the suction side of the stator when the forward swash plate is in erect position and that this pressure is increased with increase in tilt of the forward swash plate, since troubles due to foaming are greater with large tilt.

While certain novel features of the invention have been disclosed and are pointed out in the annexed claims, it will be understood that various omissions, substitutions and changes may be made by those skilled in the art without departing from the spirit of the invention.

What is claimed is:

1. In a vehicle, a hydraulic transmission comprising a pump unit, a motor unit driven thereby, means rendering said pump unit inoperative for

pumping when coasting forward, a regulating device responsive to pressure generated in the motor unit by coasting forward for permitting liquid circulation through said motor unit during coasting, means preventing circulation through said motor unit when the vehicle tends to coast backward, and means for manually adjusting said regulating device to variably permit circulation through said motor unit to obtain braking effort in forward speed.

2. In a control device, a cylinder, a piston in said cylinder, fluid pressure devices for moving said piston in said cylinder, an interlocking device comprising a block having three plungers slidable therein, a locking bar connected to said piston and having a first notch and a second notch, two of said plungers fitting in said first notch, one of said plungers fitting in said second notch, a starter bar having a first cam for removing said first plunger from said first notch and a second cam for moving said third plunger into said second notch, a reverse bar, a forward bar, control valves operated by movement of said bars, a master piston operated by said control valves, a cam bar operated by said master piston, said cam bar controlling the operation of said first and second plungers only, whereby said plungers, when engaged in said notches, either prevent operation of said piston or limit the movement of said piston to the desired extent.

3. In a hydraulic swash plate type transmission having a pump unit driven by a prime mover and a motor unit driven by said pump unit, a supercharger for maintaining the minimum pressure in the low pressure side of said transmission above atmospheric and a variable pressure relief valve on said transmission for varying the supercharger pressure according to the position of the pump unit swash plate providing a greater supercharger pressure with the greater tilt of the swash plate.

4. In a hydraulic transmission, a stator, a shaft passing through said stator, a forward sleeve on said shaft, a rearward sleeve affixed to said shaft, forward and rearward block supports affixed to said forward and rearward sleeves, respectively, said sleeves being journaled on said stator, forward and rearward piston blocks surrounding their supports, respectively, said blocks each having a plurality of axially extending cylinders, said supports having radial shoulders and said blocks having radial shoulders, respectively, forming annular pressure spaces, each pressure space connecting with the cylinders of its particular block, and piston rings between said blocks and their respective supports for sealing said pressure spaces.

5. In a variable speed transmission, a hydraulic pump unit, a hydraulic motor unit driven thereby, a supercharger connected to the pump unit, a pressure tank connected to said supercharger, a prime mover connected to said pump unit, a normal starter control for causing pressure in said pressure tank to drive said pump unit as a motor to start the prime mover, an electric motor, an emergency starter control for starting said electric motor to drive said supercharger to charge up the system, if the pressure in said pressure tank is below a predetermined amount.

6. In a power plant, a transmission, a hydraulic pump unit, a hydraulic motor unit driven thereby, a main prime mover driving said pump unit, a supercharger driven by said prime mover, a pressure tank connected to said supercharger and to said transmission, an auxiliary prime mover, a normal starter control for causing the

pressure in said pressure tank to drive said pump unit as a motor to start the main prime mover, an emergency starter control for starting said auxiliary prime mover to drive said supercharger to charge up the system, if the pressure in said pressure tank is below a predetermined amount.

7. In an automotive vehicle, an engine, a vehicle driving element, a hydraulic transmission therebetween, said hydraulic transmission comprising a pump unit connected to the engine and a motor unit connected to the driving element, a high pressure path and a low pressure path connecting said motor unit and pump unit, a bypass valve connecting said paths for bypassing the motor unit, a manual device, means operated by said manual device for governing the position of said bypass valve, said manual device having a power-transmitting position for effecting closure of said bypass valve, said manual device having a coasting position for effecting substantially full opening of said bypass valve, said manual device having a braking range for variably closing said bypass valve, and means closing said bypass valve to cause said transmission to prevent backward movement of the vehicle when said pump unit is transmitting no power to said motor unit.

8. In a hydraulic transmission having a governor, forward and rearward swash plates, a swash plate control comprising a forward control cylinder and a rear control cylinder, each having a piston connected to its respective swash plate, said cylinders having ports at each end, a swash plate control valve for leading pressure to or exhaust from said ports and comprising a valve cylinder, a valve plunger, said plunger having rotary and longitudinal motions, control devices under direct control of the operator for controlling the car and determining the rotary position of said plunger, said plunger having a first rotary position corresponding to stop, idle and brake, a second rotary position corresponding to start and reverse and a third rotary position corresponding to forward, said governor being controlled by change in one or more components of power transmitted by said transmission, said components including speed and torque, means for shifting said plunger longitudinally by operation of said governor, and means operated by said manual control devices cooperating with said trunnion control to effect the conditions corresponding to the aforesaid positions of said rotary plunger.

9. In a transmission system, a variable stroke hydraulic transmission comprising a pump unit adapted to be driven by a prime mover and a motor unit driven by said pump unit, at least one of said units having a variable stroke, a supercharger for maintaining minimum pressure in said transmission above atmospheric, a variable pressure relief valve, and means for connecting said relief valve, said supercharger and said transmission for varying the supercharger pressure according to the length of stroke of said variable stroke unit, providing a greater supercharger pressure with the greater stroke and vice versa.

10. In a control for automotive vehicles, an engine, a driving element, a hydraulic transmission connecting said engine and said driving element, said hydraulic transmission comprising a variable stroke pump unit and a motor unit driven by said pump unit, a first servo-motor for variably controlling the stroke of said pump unit, a second servo-motor for controlling the action of said motor unit, a control member subject to

control by the operator of the vehicle, a governor automatically responsive to change in one or more components of the power transmitted by said transmission, said components including speed and torque, and a control device governed jointly by said control member and by said governor for operating said servo-motors.

11. In a transmission, a hydraulic unit comprising a stator, a pump piston block and a motor piston block, each block having a plurality of axially extending cylinders, a mechanical clutch comprising elements connected respectively to said piston blocks, and means operative by pressure within said stator for holding said blocks against said stator when pressure exists and the mechanical clutch is disengaged and the drive is through the hydraulic unit, said means permitting said blocks to leave said stator when pressure is removed and the drive is through said mechanical clutch.

12. In an automotive vehicle, a prime mover, a vehicle driving element, a hydraulic transmission having variable speed ratio, said transmission being located between said prime mover and said driving element, a hydraulic control valve having a plurality of rotary positions and adapted to move lengthwise, an operator's control for controlling said prime mover, devices responsive to said operator's control for setting the rotative position of said valve, governor devices responsive to change in one or more components of power transmitted by said transmission for automatically controlling the longitudinal position of said valve, said components including speed and torque, and hydraulic devices operated by said control valve for adjusting said transmission speed ratio.

13. In a vehicle, a prime mover, driving wheels, a hydraulic transmission comprising a stator, a driving cylinder block connected to said prime mover and a driven cylinder block connected to said wheels, said stator having first and second openings connecting the cylinders of said blocks, said first opening being the low pressure opening and said second opening being the high pressure opening when said driving cylinder block drives said driven cylinder block, a bypass connecting said first and second openings, a stator valve in said bypass, a regulator valve governed by pressure in said first opening for opening said stator valve to permit coasting of the vehicle, and control devices changing the adjustment of said regulator valve to variably close said stator valve to obtain braking action on said wheels.

14. In an automotive vehicle, an engine, a driving element, a hydraulic transmission therebetween, said hydraulic transmission comprising a first unit connected to the engine and a second unit connected to the driving element, said first unit being the pump unit and said second unit being the motor unit when said engine drives said driving element, a first path and a second path connecting said first and second units, said first path being the low pressure path and said second path being the high pressure path when said engine drives said driving element, a bypass valve connecting said paths for bypassing said second unit, a pressure regulator comprising a cylinder and a piston in said cylinder connected to said bypass valve, a control valve for controlling pressure on said piston, a duct connecting said first path and said control valve,

spring means on said control valve for balancing the pressure from said first path, a control device for varying the effective pressure exerted by said spring means on said control valve, said control device having a power-transmitting position, whereby, when said effective spring pressure is minimum, the bypass valve is closed, said control device having a coasting position, whereby, when said effective spring pressure is intermediate, said regulator is balanced, said control device having a braking range, whereby, when said effective pressure is between intermediate and maximum, said bypass valve is variably closed, said first path also having a relief valve, and means for preventing hydraulic fluid in said first path from discharging through said relief valve when using the transmission as a brake, said transmission acting to prevent backward movement of the vehicle when no power is transmitted from said engine to said driving element.

15. In a power system, a prime mover, a load, a variable speed transmission connecting said prime mover and said load, said transmission comprising a pair of units, each of which is made up of a cylinder block and a tiltable swash plate, one of said units constituting a pump unit when said prime mover is driving said load, said pump unit being connected to said prime mover, the other of said units constituting a motor unit when said prime mover is driving said load, said motor unit being connected to said load, a stator between said blocks and having a first and second opening connecting the cylinders of the blocks, said first opening being the low pressure opening and said second opening being the high pressure opening when said prime mover drives said load, a pressure tank, means for placing said pressure tank in communication with said first opening, means for placing said second opening in communication with atmosphere, means for tilting said pump swash plate to ahead position, and means for preventing rotation of said motor unit, all said means causing said pump unit to operate as a motor to crank said prime mover.

16. In a power system, a prime mover, a load, a variable speed transmission connecting said prime mover and said load, said transmission comprising a pair of units, each of which is made up of a cylinder block and a tiltable swash plate, one of said units constituting a pump unit when said prime mover is driving said load, said pump unit being connected to said prime mover, the other of said units constituting a motor unit when said prime mover is driving said load, said motor unit being connected to said load, a stator between said blocks and having first and second openings connecting the cylinders of the blocks, said first opening being the low pressure opening and said second opening being the high pressure opening when said prime mover drives said load, a bypass between said stator openings, a pressure tank, means for placing said pressure tank into communication with said first opening, means for placing said second opening into communication with atmosphere, means for tilting said pump swash plate to full ahead position, means for preventing rotation of said motor unit, and means for closing said bypass, all said means causing said pump unit to operate as a motor to crank said prime mover.

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