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H. BENZ ET AL
COMBINED HYDRO-MECHANICAL GEAR
Filed Aug. 5, 1941

Serial No.
405,540
4 Sheets-Sheet 1

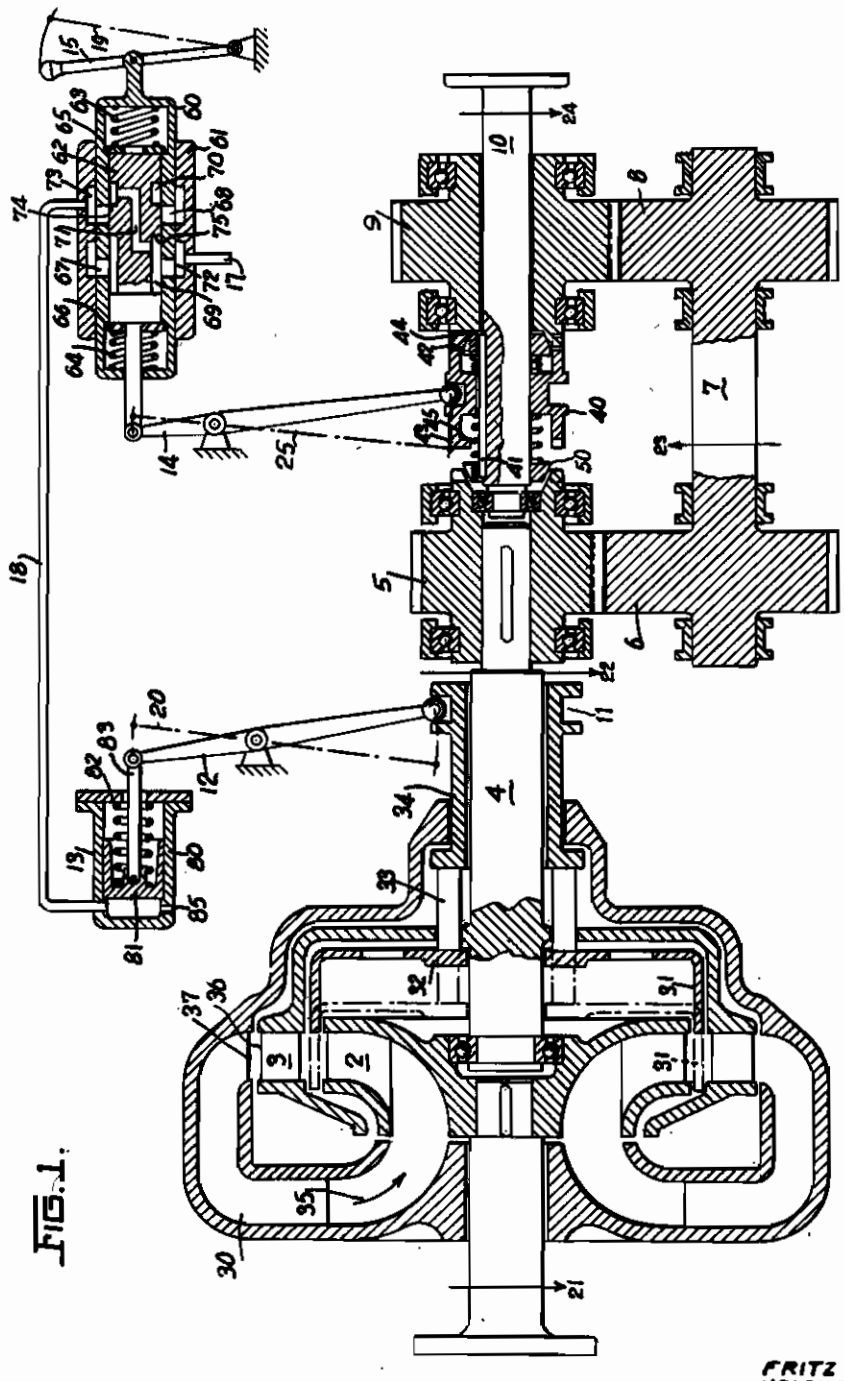

FIG. 1.

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FIG. 2.

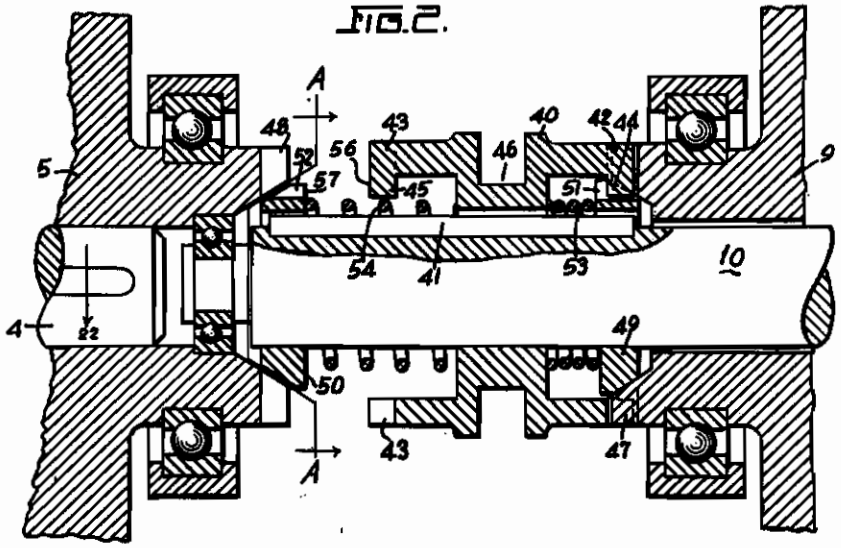

FIG. 3.

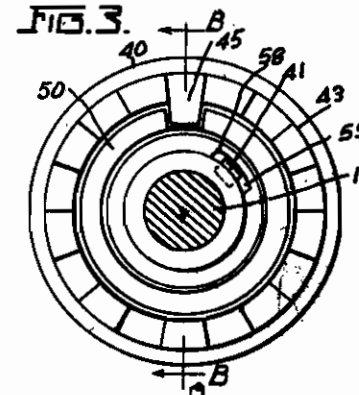

FIG. 6.

FIG. 7.

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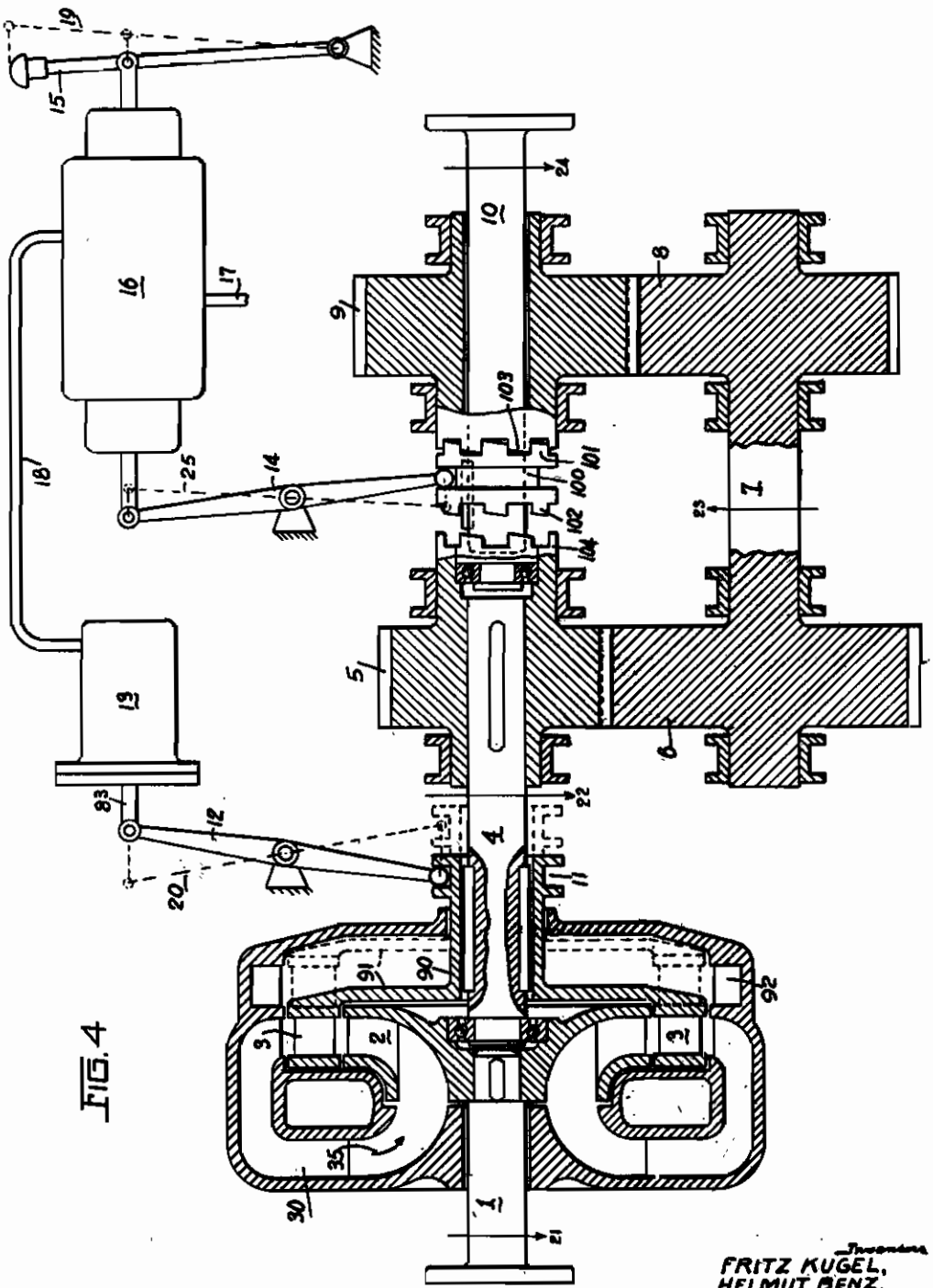

FIG. 4

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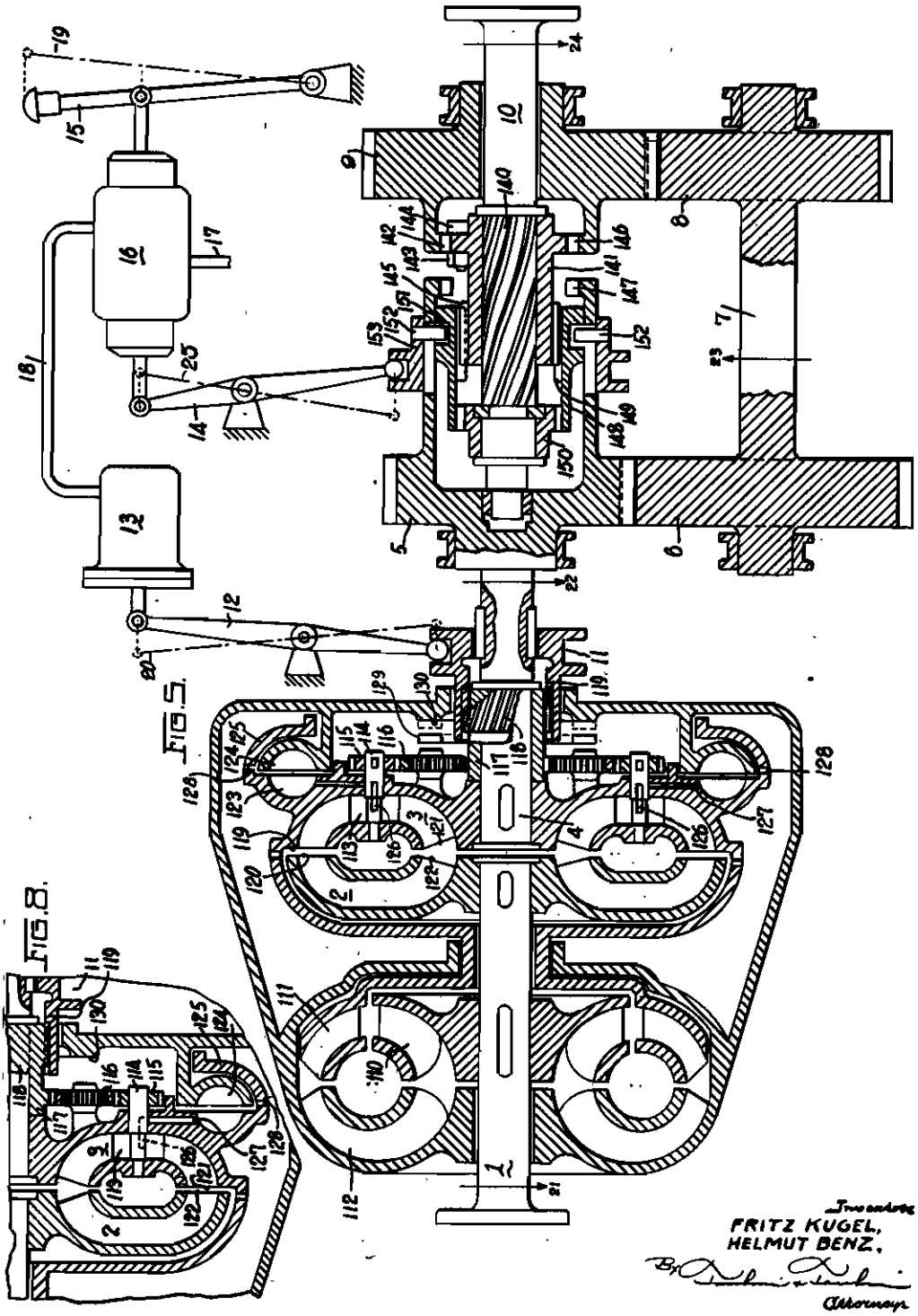

FIG. 5.

FIG. 8.

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ALIEN PROPERTY CUSTODIAN

COMBINED HYDRO-MECHANICAL GEAR

Helmut Benz and Fritz Kugel, Heidenheim (Brenz), Germany; vested in the Alien Property Custodian

Application filed August 5, 1941

The invention relates to hydro-mechanical gears consisting of a turbo gear and gear box which is arranged behind the turbo gear. The turbo gear may consist of one or more circuits which can be turbo converters or turbo couplings at will. The mechanical gear of such a combination is generally equipped with speed changing mechanism working only at equal speed.

Generally such gears are provided with a positive clutch which may be disconnected at will; this clutch is installed between the turbo gear and the mechanical gear. With this clutch the two gears may be disconnected for a change of speed and for bringing the gear elements of the new speed to the same number of revolutions independent of the original speed. Sometimes an equalizing device is used for this purpose consisting of a friction clutch and brake for the retardation.

Furthermore the power flow in a turbo circuit from the primary to the secondary part may be interrupted by stopping the fluid circuit by shutting off a rim of turnable blades or by the insertion of ring gate, or the pump—or tubine wheel may be drawn out of the circuit in axial direction and thus the power flow is stopped. All these devices are combined in the following under the collective definition of power flow interrupting device.

The invention relates to a hydro-mechanical gear, one circuit of which has at least such a stopping device. The invention bases on the fact which has been fixed by experiments that an axially movable turbine wheel of a turbo converter does not only receive no driving momentum but is even braked according to the conditions entering into question when shifting gear, when it is completely disconnected and is at that time between the primary and secondary speeds. The same applies to converters with ring slides or adjustable blades. The turbo converter therefore is very useful constructional medium allowing at will the adjustment of torques between complete positive value and a negative part value. In lower limits namely between the full positive and a small positive part value a turbo coupling may be regulated in the same manner.

The easily regulable torque is used by the invention for the adaption to the speeds of the speed changing elements to be shifted by moving the interrupting device into various positions; a special mechanical synchronisation device together with its complicated control is superfluous. It is also not necessary to install a friction clutch between the turbo gear and the mechanical gear. All the constructional elements which are subjects to wear and tear are thus eliminated.

According to the construction of the interrupting device (e. g. in case of the movable turbine wheel) the power input of the turbo circuit stays constantly in interrupting position, leaving the motor uninfluenced of all operations on the driven side of the turbo gear and the control of the motor may stay unaltered. When with another construction (e. g. ring gate) the input power is reduced in interrupting position, the interrupting device reduces according to invention the full supply to the motor in order to avoid fluctuations of speed of the motor.

In such cases, the "natural" braking effect in braking position of the interrupting device not being sufficient, the invention provides the change of the position of the blades of the turbo converter in order to create sufficient braking forces. This not being possible, a device which creates a sufficient braking power is according to invention provided e. g. a fixed blade rim. Turbo couplings give for instance no braking power and in this case a braking device is added which acts in connection with the interrupting device giving in any case a negative momentum on a part of the total stroke of the interrupting device to the driven shaft.

The final position of the interrupting device for the completely undisturbed fluid circulation is called in the following the "operation position" the opposite position the "braking position" and the intermediate position, in which the turbine wheel receives no torque, the "zero position". The interrupting device may be kept in a certain position between the operation and zero position for the acceleration to create an uniformity of speeds for the necessary time; or it is let to move, over the whole stroke beginning at the zero position either with uniform speed or eventually in the neighbourhood of the zero position slower and later faster to avoid too quick an increase of speed and danger of shocks. During the interrupting movement the zero position may be locked and the passage to the braking position only opened in case the shifting makes it neeessary.

It is another object of the invention to simplify the control of the combined gear. The interrupting device is controlled in this case in dependence of the difference between the "should be" position and the "actual" position marked by the selecting device of the coupling sleeve, and the interrupting device passes always the interrupt-

ing stroke until the control gives an impulse for the opposite movement. Thus it is possible to shift the gear simply by moving the selecting lever without having to do anything else.

The figures show different constructions of the invention without exhausting all possibilities.

Fig. 1 shows a turbo converter with ring gate as stopping medium and mechanical gear, the gear wheels of which are constantly meshed, and claw couplings to be locked by friction members.

Fig. 2 gives an enlarged detail of Fig. 1 showing the construction of the claw couplings as section through B—B in Fig. 3.

Fig. 3 shows a section through A—A in Fig. 2.

Fig. 4 shows a turbo converter with axial movable turbine wheel and a mechanical gear with claw couplings with inclined front faces.

Fig. 5 gives a view of a turbo gear with turbo converter and a turbo coupling, the turbine wheel of the latter being equipped with movable blades and a mechanical gear with a sleeve, movable on a threaded shaft as carrier of the claw coupling.

In the Figures 1, 4 and 5 the number 1 indicates the entering shaft of the turbo gear being driven by the motor. 2 is the pump wheel of the turbo circuit being equipped with a interrupting device, 3 is the turbine wheel of the same circuit, and 4 is the driven shaft of the turbo gear and at the same time the entering shaft of the connected mechanical gear.

In all cases a simple twospeed mechanical gear is shown as example. The adaption of the invention is naturally not only limited to twospeed gears but may include gear of more speeds and any design. The gear wheel 5 is in this case directly connected with the driving shaft 4. It meshes with the gear wheel 6 on the idling shaft 7 carrying the gear wheel 8. The latter meshes with gear wheel 9; the driven shaft 10 lies on the same center line as shaft 4 and is connected by couplings of any design either with the shaft 4 directly by the gear wheel 5 or with the slower as 4 running gear wheel 8. The sense of rotation of the various shafts are marked by the arrows 21—24 as example.

The interrupting device is actuated over a slide in all 3 figures and a lever 12 by a servo motor 13. This means of actuating is not the only possible way, e. g. it is possible to arrange the servo motor concentrically with the shaft 4. The rod system controlling the fuel supply to the motor may be connected if necessary to lever 12.

The coupling devices are actuated by lever 14 being connected elastically with the shifting lever 16. Lever 14 always represents the "actual" position of the sleeve, and the shifting lever 15 the "should be" position of the shift sleeve, i. e. the position which shall be attained by the shift sleeve through the shifting action, started at this moment. The control fluid for the servo motor 13 is depending by the controlling device 18 on the variation of the "should be" and "actual" position. The control fluid is brought through the line 17 to the controlling device 16 from a supply means (e. g. tooth wheel pump) and flows through the line 18 to the servo motor 13.

The shift lever 15 is shown as hand lever; but it may as well be actuated automatically by any other known control device; starting from one or more magnitudes of operation, e. g. the speed of the vehicle alone, or from its relation to the motor speed or from any other relation of speed, or from the speed in relation to a torque, or from its relation to the adjustment of the fuel supply to the motor, or for a relation of a torque.

In Fig. 1 a simple turbo converter is placed in front of the mechanical gear; in the turbo circuit the guide blades rim 30 follows the turbine blades rim 3 and the pump blades rim 2. The ring gate 31 is provided between the pump outlet and the turbine inlet as interrupting device, and is shown on the top in opened and at the bottom in closed position. It is carried by the disk 32 and connected to the sleeve 34 by the bolts 33, the sleeve has a groove 11. The converter is generally constantly filled with fluid. The fluid rotates in direction of the arrow 35 when the ring gate is in shut off position. In the engaged position of the ring gate 31 the flow of the fluid is interrupted. The driven shaft receives only such a momentum as the ring gate 31 is carried around on the inside by the rotating fluid. On the other side strong eddies are created between the outlet edge 36 of the turbine wheel 3 and the inlet edge 37 of the guide wheel 30 using up a greater torque as transmitted from the primary part. The braking effect therefore is usually sufficient with this arrangement without auxiliary device if the distance between the turbine outlet and the guide wheel inlet is not too large.

The speed change coupling of the mechanical gear is shown enlarged in Fig. 2, and in Fig. 3 as section. The sleeve 40 is movable in axial direction but fixed by the key 41 on the shaft 10 in circumferential direction. This sleeve carries two claw crowns 42 and 43: one claw of each crown has projections 44 or 45 respectively.

The groove 46 allows the connection with the control rod system 14. The gear wheel 9 carries the claws 47 and gear wheel 5 the claws 48. The two crowns of claws are cone-shaped on the inside the two stop collars 49 and 50 are in these recesses and are grooved (51 and 52) in longitudinal direction on the outside. The spiral springs 53 and 54 press the collars into the cones are carried around by the feather 41 and the shaft 10; but the groove 55 (Fig. 3) is larger than the key 41.

The outside piston 60 of the control device 18 slides in the housing 61 and is connected with the shift lever 15; the inner piston 62, connected to the lever 14 rests in the boring of the piston 60. The pistons 60 and 62 are positively kept together in a certain position by the springs 63 and 64; this position is called in the following the "center position." In this position the spring disks 65 and 66 rest against two rims of the boring in the piston 60. The two pistons may move against each other under compression of one of the two springs, the compressed spring then tries always to restore the center position. The piston 60 is provided with two rows of ports 67 and 68, the piston 62 has two circumferential grooves 69 and 70 being connected by the channel 71. In the housing 61 are two circumferential grooves 72 and 73 being connected with the lines 17 and 18.

The ports 67 serve only as connections between the groove 72, connected with line 17 and the groove 69. Through the channel 71 the groove 70 is also constantly under the pressure of fluid flowing through the line 17. In the center position of the pistons 60 and 62 the groove 70 is cut off by the piston 60; in every other position the groove 73 is in connection either with the groove 69 or 70 by the ports 68; the oil pressure of line 17 may then pass to the line 18.

The servo motor 13 consists of the cylinder 80, the piston 81 and the spring 82. The piston 81 is connected with the lever 12 by the connecting rod 83. The cylinder 80 has a port 85 being small in proposition to the supply line 18.

The device shown in Figs. 1–3 works in the following way: As shown normal operation in the first speed is presumed: The ring gate 31 is drawn out of the turbo circuit and is kept in this position by the spring 82; the sleeve 40 is on the right and meshes with the claws 47 of the gear wheel 9, and the flow of power goes thus from 4 over 5, 6, 7, 8, 9, 47, 42, 40, 41, to the shaft 10.

The lever 14 is in the shown position, the lever 15 as well, the pistons 60 and 62 are in center position. Now the shifting operation to the second i. e. faster speed is started by turning the lever 15 into the position shown by the line 19. This moves also the piston 60 to the right, the spring 64 receives tension, the piston 62 rests for the beginning in its original position, because the force of the spring 64 is not sufficient to disengage the sleeve 40 as the claws 42 and 47 are still pressed against each other by the torque. As the pistons 60 and 62 have moved against each other the ports 68 have passed the control edge 74 to the right and have opened the way for the control fluid to line 19 and to the servo motor 13. The piston 61 moves to the right and the lever 12 in the position marked by the line 20; i. e. the ring gate 31 moves to the left and shuts off the turbo circuit. Already before the piston 81 has finished the stroke completely the zero position of the ring has been attained, at the same moment the claws 42 and 47 become free, the sleeve 40 moves under pressure of the spring 64 to the left, but only until the front face 56 of the projection 45 touches the front face 57 of the stop collar 58. This is caused by the fact that while running in first speed the shaft 10 turns slower as the gear wheel 5. Alrrady during changing gear, about at the center position of the sleeve 40, the spring 54 receives a tension and presses the stop collar 50 against the gear wheel 5. The gear wheel tries to turn it by friction but succeeds only until the groove 50 rests with the face 58 against the feather.

In this position of the stop collar 50 the groove 52 has moved against the projection 45, and the shift sleeve 40 and the stop collar 50 touch with their front faces 56 and 57. The piston 62 moves at the same time by about ⅔ of its stroke towards the center position; the pressure fluid may just pass the control edge 74 to the line 18 letting the piston 81 move completely to the right and the ring gate 31 to the complete shut off. This causes the braking effect of the blade edges 36 and 37 and speed of the shaft 4 is reduced. As soon as the speed is the same as that of the driven shaft 10, meaning it has become slower, the stop collar 50 is carried around in the opposite direction; at the moment when the stop collar passes the relative position to the sleeve 40 shown in fig. 3, the projection 45 may pass the groove 52 and the claws 43 and 48 mesh. The sleeve 40 moves to its left final position, the lever 14 into the position marked by the line 25, and the two pistons 60 and 62 attain again their center position; the disk 66 rests again in the inside recess of the housing of the piston 60 and the control edge 74 lies opposite the edge of the port 68 letting no fluid flow to the line 18 and to the servo motor. The cylinder of the servo motor is emptied by the pressure of the spring 82 through the port 85, the piston 81 returns to the drawn position, the ring gate is drawn out of the circuit, the converter transmits again a torque passing now over 4, 5, 48, 43, 48, 41 directly to shaft 10.

The shifting of gear in the opposite sense i. e. from the fast speed to the slower works nearly in the same way. It differs only from the described shifting as already after the parting of the before engaged claws (43, 48), and after the sleeve has moved against the stop collar 49, the fluid passage between the control edge 75 and the ports 68 is closed and thus the opening movement of the ring gate starts. The reason is the necessity of acceleration of the shaft 4 with regard to its former state for the attaining and passing of speed uniformity; the braking effect of the completely closed ring is not needed in this case. After attaining uniformity of speed the claws 42 and 47 mesh and the still increasing torque is transmitted over the auxiliary shaft 7 to the shaft 10.

Only one example is given for the hydraulic operation of the gate valve by the control device 18 in fig. 1. It may also be possible to control the piston for double action creating two connecting lines between 18 and 13 and adapting the pistons 60 and 62 also for the control of the returning fluid.

In fig. 1 it has been supposed that the servo motor piston moves with uniform speed over the whole stroke. When the speed of the two directions of movement or parts of the stroke shall be varied, well known throttling device may be adapted working only for a part of the stroke or only for one direction.

In fig. 4 a simple turbo converter is placed in front of the mechanical gear, also in this case 3 blade rims are provided, the pump wheel 2, the turbine wheel 3 and the guide wheel 30. The power flow is interrupted in this case by retracting the turbine wheel out of the circuit in axial direction. For this purpose the hub 90, carrying the disk 91 and the blade rim 2, is movable in axial direction but fixed against rotation on the shaft 4, this hub has a circumferential groove 11 at its other end. Also in this case the converter is usually filled with fluid. As long as the drive shaft 1 turns, the fluid rotates in direction of the arrow 35. When the turbine wheel 3 is inserted (upper part of the figure 4) it is turned by the rotating fluid and can therefore transmit a torque, when the turbine wheel 3 is withdrawn (lower part of the figure) practical no torque is transmitted to the shaft 4. As the friction of the wall generally not becomes sufficient to reduce the speed of the shaft 4 sufficiently quick enough, stationary auxiliary blade rim 92 is provided, being opposite the blade wheel 3 in its interrupting position. This blade has a braking effect on the turbine wheel. The use of such a converter with retractable turbine wheel has the special advantage that fluid circulation continues in the converter, the motor may run with its full power, and suffers no speed fluctuation whatever.

For the speed change of the mechanical gear a double sided deflexion coupling of well known construction is provided. Its sleeve 100 is movable in longitudinal direction but cannot turn on the shaft 10. It carries two rows of claws 101 and 102 with sloped faces. The front faces of the claws 103 and 104 of the gear wheels 9 and 5 are also sloped. The aim of this form is to avoid the meshing of the claws as long as uniformity of speed is not attained. As the control device 18

and the servo motor 13 should be constructed exactly as shown in fig. 1 the gears are changed exactly as described above. At the place where the stop collar enters into effect in one case, the deflexion faces have the same task in the other case: after the disengaging of the claws 101 and 103 the front faces of the claws 102 and 104 slide against each other as long as the wheel turns quicker than the shaft 10. The coupling "ratches". As soon as the speed uniformity is attained and a little surpassed the sloped faces work vice versa and bring the claws 102 and 104 to mesh.

Fig. 5 shows a combined gear having besides two speeds of the mechanical also two speeds of the hydraulic gear. The turbo gear consists of a turbo converter with pumpwheel 110, turbine wheel 111 and guide wheel 112 and a turbo coupling with the pump wheel 2 and the turbine wheel 3. The turbo circuits are changed by emptying one and filling the other circuit. The mechanical gear is also in this case shown with two speeds; the change of speed of this gear is only considered with filled turbo coupling; the combined gear is supposed to work in the following manner:

(1) Converter, 1. speed of the mechanical gear
(2) Coupling, 1. speed of the mechanical gear
(3) Coupling, 2. speed of the mechanical gear.

Only the coupling is therefore equipped with a stopping device, i. e. the blades 113 are shown as turnable ones. These blades are inserted in the secondary wheel with blade journals 114. On these journals 114 small spur wheel 116 are fixed meshing through intermediate wheels 116 with the spur wheel 117, idling on shaft 4. The hub of the spur wheel 117 is threaded, 118; the inside thread belonging to it, is cut into the sleeve 118 which has circumferential groove and does not turn on the shaft but may be moved in longitudinal direction. The upper half of the figure shows the working position of the movable blades. The coupling itself has no stationary parts, therefore it cannot create any brake effect. On the contrary the coupling effect does never completely disappear as eddies occur at the blade edges 119 and 120 or 121 and 122 respectively, causing the wheel to turn.

For this reason according to invention an additional braking device has been provided by installing at the rotating coupling housing a blade wheel 123 as a small turbo brake. The blade wheel 124 being enclosed by the shell 125 is fixed to the housing and lies opposite the blade wheel 123. In normal operation the braking device 123, 124 is emptied; during the speed changing operation of the mechanical gear, while the fluid circulation is shut off, fluid is led from the coupling to the braking device through the slots 126 in the blade journal 114 and the borings 127 in the coupling housing; the blade journal 114 works also at the same time as turning slide valve for the fluid. As soon as the movable blades return to the operating position, the fluid flow to the brake stops, and the brake is emptied through the ports 128.

Another way to install a brake has been indicated by the dash and dot line. A brake disk 129 may be fixed on the sleeve 119 by inserting a flexible member. This disk 120 touches in the right hand final position of the sleeve 119 a face 130 in the housing and works thus as a friction brake.

The speed change clutch for the mechanical gear is in this case an automatic working clutch of well known design of which only the locking of the change sleeve is controlled from the outside. The shaft 10 has a steep pitched thread 140 on which runs a sleeve 141. This sleeve has crown of claws 142 and 2 pawls 143 and 144 as well as a tooth rim 145. The crown of claws 142 may mesh with those 146 at the wheel 9 or 147 at wheel 5. The pawl 143 is directed with its point against the onlooker; at the center position of the sleeve 141 it is opposite the claw crown 147; when this crown turns faster than the shaft 10 it ratches; when it turns slower the pawl grips and induces the sleeve 141 to its left end position. The pawl 144 belongs to the ratchet rim 146 and is directed with its point away from the onlooker it ratches as long as the wheel turns slower than the shaft 10, as soon as it turns faster, the pawl grips and draws the sleeve into its right hand end position. On the teeth 145 of the sleeve 141 the locking sleeve 148 slides with its teeth 149. On the shaft the hub 150 is fixed, having, teeth for locking purposes. The bolts 152 grip the circumferential groove 151 of the locking sleeve. These bolts are fixed in the sleeve 153 and pass through slots in the cylindrical part carrying the claw rim 147. The sleeve 153 itself is moved by the lever 14.

The changing from low to higher speed works as follows: beginning at the shown position of all parts: The locking sleeve 148 with the sleeve 153 and the lever 14 follow the moving of the shift lever 15 immediately to the left until the front face of the teeth 149 touch the right hand front face of the hub 150. The servo motor 13 is supplied with pressure fluid by the control device 16, the lever 12 and with it the whole controlling mechanism up to the blades 113 go into the shutting off position of the fluid circulation. The power transmission is interrupted, the brake 123, 124 fills itself. The braking momentum turns the sleeve 141 into its center position and the pawl 143 ratches against the claws 147. But the tooth wheel 5 turns still faster than the shaft 10 corresponding to the speed difference. As soon as its speed has been reduced by the brake to that extent that it begins to turn slower than the shaft 10, the pawl 143 grips and draws the sleeve 141 to the left, until the claws 142 and 147 mesh. When the sleeve 141 has attained its left end position the teeth 149 and 158 mesh; 148 and 153 go to the left, the lever 14 takes a position as per line 25. The pistons of the control device 18 return to their center position, the servo motor 13 loses its pressure. The lever 12 returns into the drawn position; the blades 113 open, the torque passes now over 4, 5, 147, 142, 141, 145, 149, 148 and 150 to the shaft 10.

When changing from higher to lower speed the lever 14 does not follow the lever 15 in the beginning as the locking sleeve 146 is charged with torque. Only after the torque ceases by shutting of the movable blades 113, the locking sleeve jumps out but is not yet able to take its shown position. As described for Fig. 1, the servo motor already looses its pressure at this moment causing thus to open the blades 113 again. This again causes an increase of speed of shaft 4 and after passing the speed uniformity of 9 and 10 all parts regain their drawn position.

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