Nov. 3, 1942. P. J. McLAREN 2,300,626

POWER AMPLIFIER

Filed April 26, 1941 3 Sheets-Sheet 1

FIG. 1

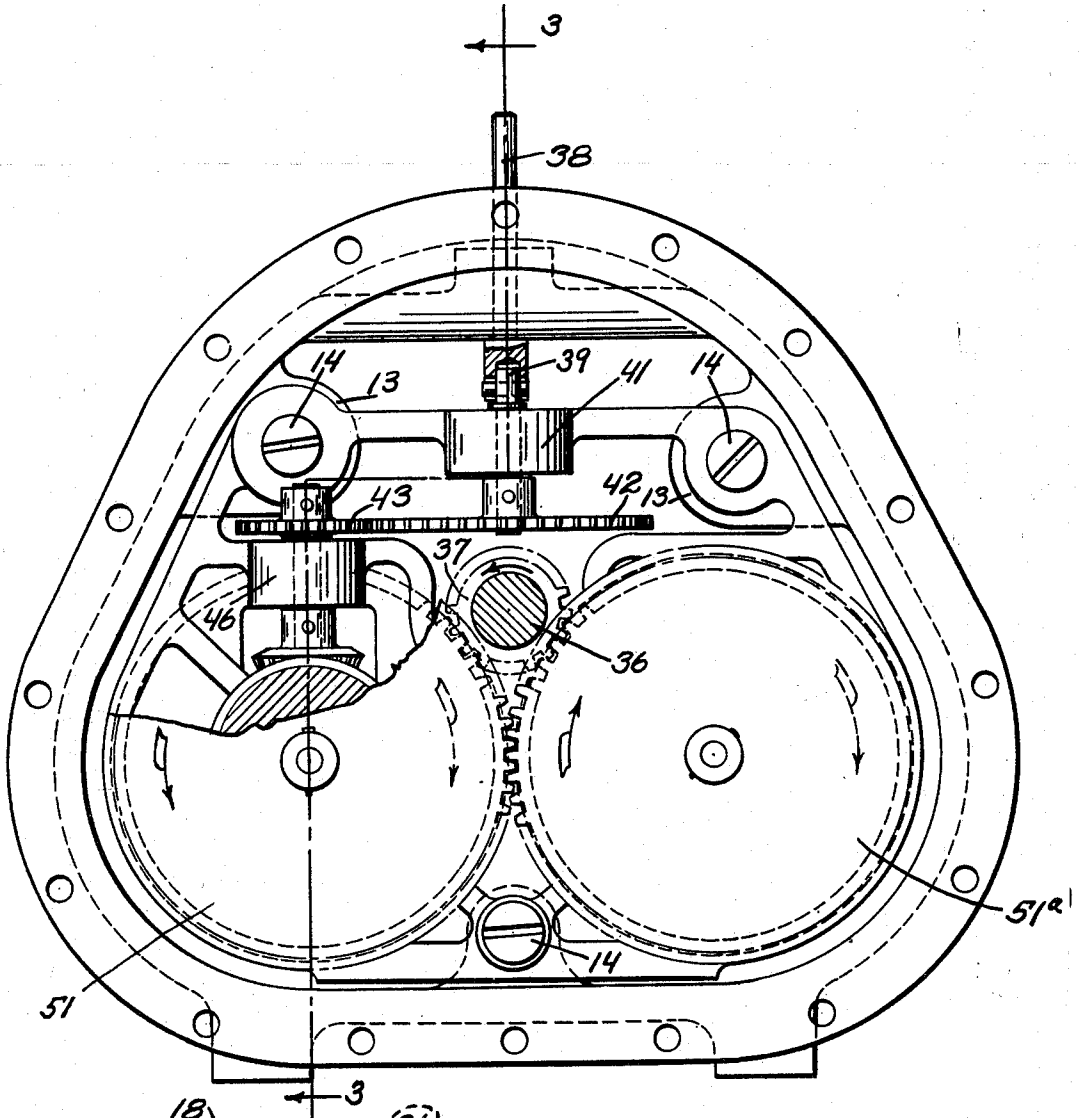
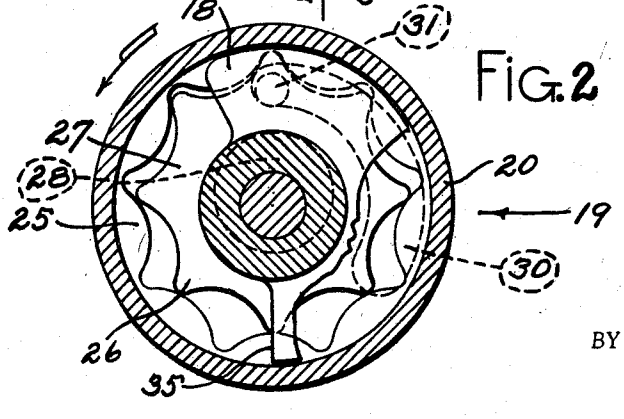


FIG. 2



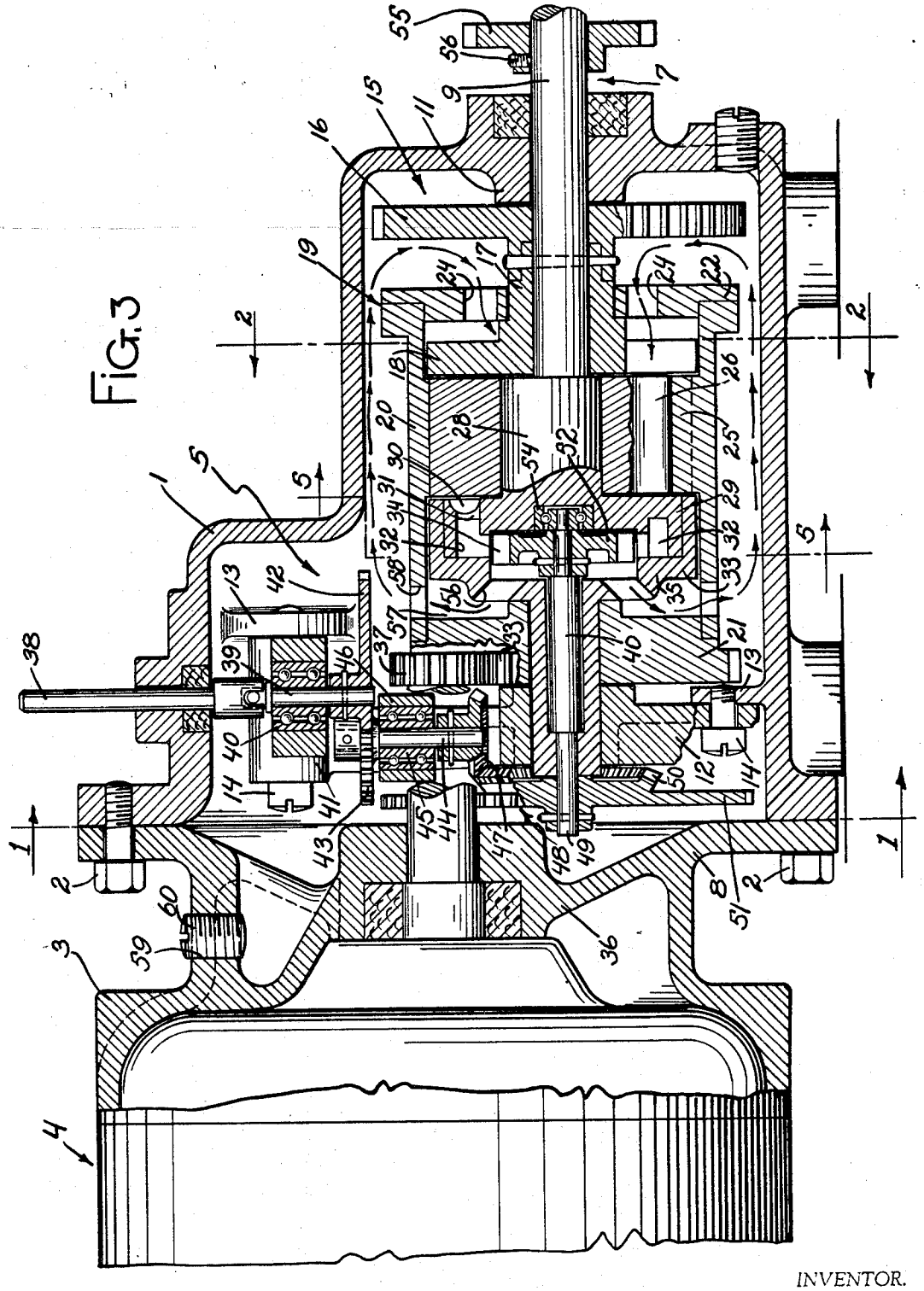
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POWER AMPLIFIER

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FIG. 3



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POWER AMPLIFIER

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FIG. 4

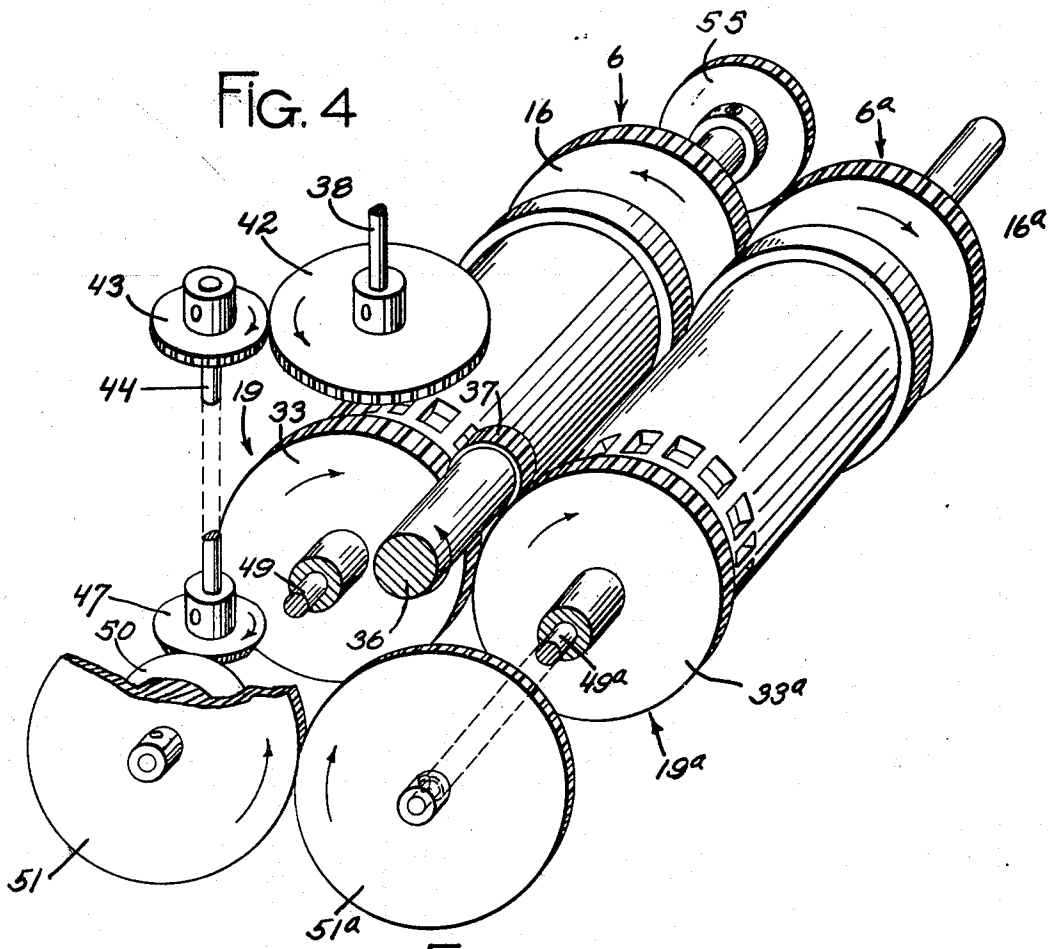
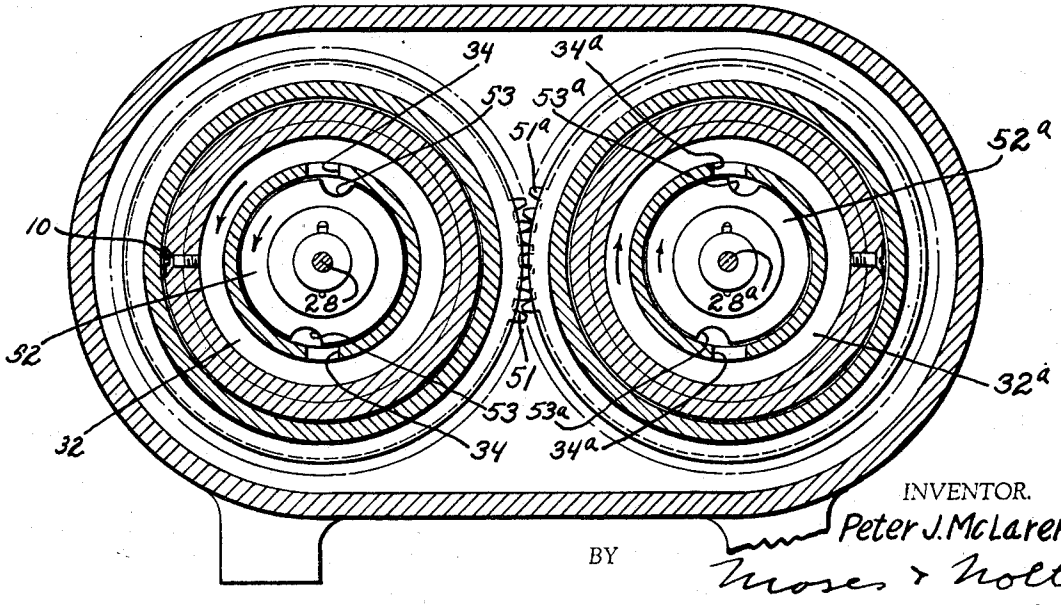


FIG. 5



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UNITED STATES PATENT OFFICE

2,300,626

POWER AMPLIFIER

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Application April 26, 1941, Serial No. 390,487

8 Claims. (Cl. 74—377)

This invention relates to power amplifier means comprising a relatively high torque, rotary mechanism, an arbitrarily operated, low torque, rotary, control mechanism, and mechanical means for containing the high power mechanism to conform substantially in its operation to the operation of the low torque, control mechanism. By conformity of operation is meant the maintaining of a consistent relationship as to direction and speed of operation. The operation of the high torque mechanism may be maintained consistently in the same direction as the operation of the low torque mechanism, or consistently in the opposite direction. The speed of operation of the high torque mechanism may be maintained consistently the same as the speed of operation of the low torque mechanism, or consistently a multiple or a fraction thereof.

The present invention is in the nature of an improvement upon the invention disclosed and claimed in the copending application of William A. Black, Serial No. 284,644, filed July 15, 1939. for Power amplifier, now Patent No. 2,248,942. In that application disclosure is made of a power amplifier comprising a high torque input member, a high torque output shaft, a low torque control shaft for applying an extraneously imposed direction and speed of rotation, and hydraulic means comprising opposed slip drive trains, and responsive to the difference of rotation of the high torque output shaft and the low torque control shaft to compel the high torque output shaft to conform in either direction to the operation of the low torque control shaft.

It is an object of the present invention to provide amplifier mechanism of the same general class and capable of attaining the same general ends as the amplifier mechanism of the pending application referred to, but which embodies improvements from the standpoint of economy of manufacture, durability in use, and smoothness of performance.

It is an object of the invention to eliminate all need for differential gearing in the opposed slip drive trains of the amplifier. To this end it is a feature that each of the opposed slip drive trains includes a rotary hydraulic pump which comprises an input rotor, an output rotor, and an interposed rotary pumping member operated jointly by the rotors, and that valve means responsive to a rotary, low torque, control member is provided for inversely controlling the flow of liquid through the pumps to affect inversely the positiveness of the drives established by the opposed trains, and for thereby causing the amplifier to conform in its operation to the speed of the rotary, low torque, control member.

It is a further object of the invention to make the slip drive trains responsive to the joint effect of the low torque control shaft and a high torque output member without the necessity for employing differential gearing. This object is achieved by providing pump control ports in the output rotors of the pumps which turn with such rotors and rotary valves, driven by the rotary, low torque, control member, for inversely controlling obstruction of the control ports and for thereby controlling inversely the positiveness of the trains in accordance with the phase relationship of the output rotors and the associated rotary valves.

Other objects and advantages will hereinafter appear.

In the drawings forming part of this specification:

Figure 1 is a front view, partly broken away, of a power amplifier embodying the invention, with the motor removed, the view being taken along the plane of the line 1—1 of Figure 3, looking in the direction of the arrows;

Figure 2 is a detail, sectional view of a gear pump employed in the amplifier, the section being taken upon the line 2—2 of Figure 3, looking in the direction of the arrows;

Figure 3 is a vertical view in sectional elevation taken substantially along the line 3—3 of Figure 1, looking in the direction of the arrows;

Figure 4 is a diagrammatic perspective view of the torque amplifier; and

Figure 5 is a view in sectional elevation taken along the line 5—5 of Figure 3, looking in the direction of the arrows.

As best seen in Figure 3, the amplifier comprises a casing member 1 which is secured by bolts 2 to the rear end of the frame member 3 of a motor 4. The casing member 2 and the frame member 3 jointly form a chamber 5 which is filled or substantially filled with oil, and in which the operating parts of the power amplifier are contained.

The amplifier mechanism consists of a pair of identical gear pump units. Since the units are alike, only one of them will be described in detail, and the same reference characters will be applied to corresponding parts of the other, so far as such parts are illustrated, without further reference to the other unit except in so far as may be necessary to bring out the interconnection and the interrelation of the two units.

The pump unit 6 comprises an output rotor 7 which consists of a forward shaft section 8 and a rear shaft section 9 rigidly secured to one another in any suitable manner as by a screw 10 (see particularly Figure 5). The rear shaft section 9 is mounted in a bearing 11 at the rear of the casing 1, and the forward shaft section 8 is mounted in a bracket 12. The bracket 12 is secured to lugs 13 of the casing member 1 by means of screws 14. The rotor 7 serves as a support for all of the remaining elements of the unit 6.

The shaft section 9 has pinned to it a gear unit 15 which comprises a gear 16 for meshing with the corresponding gear 16*a* of the opposite unit, a sleeve portion 17, and a segmental disc 18. The function of the flange 18 will be explained presently.

The pump unit 6 also comprises an input rotor 19. The rotor 19 comprises a cylindrical member 20 and front and rear end plates 21 and 22. The end plate 21 is formed with external teeth to provide an input gear 23. This end plate is rotatably mounted upon the forward shaft section 8. The end plate 22 is formed with openings 24 for the admission of oil to the interior of the input rotor and is rotatably mounted upon the sleeve portion 17 of gear unit 15.

The cylindrical member 20 is formed with internal teeth 25 for coacting with external teeth 26 of a pinion 27. The pinion 27 is mounted upon an eccentric enlargement 28 of shaft section 9. The pinion 27 has one less tooth than the internal gear formed by the teeth 25. The shapes of the teeth of the pinion and of the internal gear are so chosen that all of the teeth of the pinion remain in sliding contact with the teeth 25 of the internal gear at all times. The pinion 27 is confined, with freedom for rotation, between the segmental disc 18 and a disc 29 which forms an integral concentric enlargement of the shaft section 9 at the forward extremity thereof. The disc 29 has an arcuate channel 30 formed in its rear face, which communicates at one end through a passage 31 with a circular channel 32 formed in the forward face of the disc 29.

The disc 29 is covered around its periphery and closed at its rear side by a cup-shaped enlargement 33 of the rear end of shaft section 8. The channel 32 is, therefore, a closed channel, save that it communicates through outlet ports 34 with a cylindrical valve chamber 35 formed jointly by the disc 29 and the cupped member 33 at the forward side of the disc.

The input rotor 19, the output rotor 7 and the pinion 27 combine to form a hydraulic pump, the input rotor being the driving member, the output rotor the driven member, and the pinion 27 being an interposed rotary pumping member responsive to relative rotation of the input and output rotors.

If it be assumed that the rotor 19 is driven counter-clockwise, as viewed in Figure 2, and that the rotor 7 is held stationary, the pinion 27 will be caused to rotate in a counter-clockwise direction about the axis of the eccentric 28. Because of the ratio and design of the teeth 25 and the pinion 27, the opening between the teeth is least upon the radius of the highest point of the eccentric, that is, at the upper vertical point as seen in Figure 2, becomes progressively larger as the teeth turn counter-clockwise from the upper vertical point to the lower vertical point at the intake side of the pump, this being the left-hand side where the pump chamber is not covered by the segmental disc 18, and becomes progressively less as the teeth continue to turn counter-clockwise from the lower vertical point to the upper vertical point at the discharge side of the pumping chamber.

Since the gear and the pinion are immersed in oil which enters the pumping chamber through the openings 24 of the plate 22 and through the open side of the segmental disc 18, some of the oil will flow into the pockets between the gear and pinion teeth and will be carried along until the gear and pinion surfaces defining such a pocket have rotated beyond the edge 35 of the segmental disc 18. The liquid will thereupon be confined by the discs 18 and 29, and will be forced out through the channel 30, the passage 31, the channel 32 and the outlet ports 34. In order that reverse flow shall not be permitted, the distance between the edge 35 of the segmental disc 18 and the nearest edge of the channel 30 is made approximately equal in extent to a tooth space of the pinion 27, as clearly seen in Figure 2.

It is to be noted that the pumping effect which has been described is the result of relative rotation of the rotors 19 and 7. If the rotor 19 were held stationary and the rotor 7 were turned in a clockwise direction, as viewed in Figure 2, the pumping effect would be the same as has just been described. In this connection it should be borne in mind that the segmental disc 18, the outlet channel 30 and the outlet passage 31 turn in unison with the rotor 7.

If, while the rotor 19 is being turned counter-clockwise, as viewed in Figure 2, the rotor 7 is turned clockwise, the rate of oil pumping will be substantially proportional to the sum of the speeds of rotation of the two rotors or, in other words, to their rate of relative rotation. Similarly, if, while the rotor 19 is being turned counter-clockwise as viewed in Figure 2, the rotor 7 is permitted or caused to turn counter-clockwise at a lesser speed, the rate of oil pumping will be substantially proportional to the difference in the speeds of rotation; still proportional to the relative rotation of the two rotors.

If the pump outlet is substantially unobstructed, there is little tendency for the rotor 19 to impart its rotation to the rotor 7. If, on the other hand, the pump outlet were completely obstructed, a substantially positive oil lock would be formed and the rotor 7 would be compelled to turn in unison with the rotor 19.

The motor 4 includes a shaft 36 which has fast upon its forward end a pinion 37. This pinion meshes with the gears 33 and 33*a*, driving them constantly at uniform speed and in the same direction (clockwise as viewed in Figures 1, 4 and 5, counter-clockwise as viewed in Figure 2). The input rotors of the units 6 and 6*a* are, therefore, driven in unison. The output rotors 7 and 7*a* of the units 6 and 6*a* are connected directly to one another through equal gears 16 and 16*a* and are, therefore, compelled to travel always at equal speeds but in opposite directions. The effect of this will be explained more fully after the low torque control mechanism has been described.

A low torque control shaft 38 drives a shaft 39 which runs in a ball bearing 40 carried by a bracket 41. The shaft 39 has affixed to it a gear 42 which drives a pinion 43 fast on a vertical shaft 44. The shaft 44 runs in a ball bearing 45 which is mounted in a bracket 46. A bevel pinion 47 fast on the shaft 44 drives a gear unit 48 fast on a shaft 49. The gear unit 48 comprises a bevel gear 50 driven by the bevel pinion

47 and a spur gear 51 fast with the bevel gear 50 and desirably made integral therewith.

The gear 51 drives a similar gear 51a fast on a shaft 49a.

The shaft 49 is mounted to pass axially through the forward shaft section 8 of the rotor 7 and has pinned upon a reduced forward end portion thereof a circular, rotary valve 52 which is formed with a plurality of recesses 53 in its periphery, one for each of the outlet ports 34 of the disc 29. The extreme forward end of the shaft 49 is supported in a ball bearing 54, the ball bearing being mounted centrally in the forward face of the disc 29. The shaft 49a is mounted in exactly the same manner as the shaft 49, but in the other pumping unit 6a, and carries a rotary valve 52a which is identical with the rotary valve 52.

The output operation of the amplifier is desirably delivered through an output gear 55 which may be detachably affixed either to the shaft section 9 or the shaft section 9a by means of a set screw 56, according to the direction in which the high torque mechanism (not shown) is to be driven in relation to the rotation of the low torque input shaft 38.

Liquid discharged past the valve 52 flows out through openings 56 of the member 33, thence through an annular chamber 57 between the members 33 and 20, and through openings 58 formed in the member 20.

A filling opening 59 in casing member 3 is normally closed by a threaded plug 60.

The operation of the amplifier will be readily apparent. As viewed in Figures 4 and 5, the input rotors 19 and 19a are constantly driven in a clockwise direction and at equal and uniform speeds by the high torque input shaft 36 of the motor 4. The output rotors 6 and 6a are connected to one another through the gears 16 and 16a, so that they are compelled, when they turn, to turn in opposite directions and at equal speeds. The valves 52 and 52a, because they are connected to one another by the gears 51 and 51a, are compelled to turn, when they turn, in opposite directions and at equal speeds.

It may be assumed initially that the gears 33 and 33a are being driven clockwise at uniform speed by the shaft 36, and that the other gear pump parts are stationary in the positions illustrated in Figure 5. The valves 52 and 52a obstruct the ports 34 and 34a equally. This will be the actual condition when the valves 52 and 52a are stationary, and there is no load on the gear 55 tending to turn the gear.

If now the shaft 38 is turned in a direction to turn the valve 52a clockwise, the valve will tend to close the ports 34a and will thereby increase the positiveness of the driving connection between the input rotor 19a and the output rotor 7a of the pump unit 6a. The concomitant counter-clockwise rotation of the gear 52 will tend to uncover the ports 34 and will thereby reduce the positiveness of the driving connection between the input rotor 19 and the output rotor 7 of the pump unit 6.

The output rotor 7a of the unit 6a will be caused to turn in a clockwise direction, and thereby to diminish the relative rotation of the rotors 19a and 7a, and will also serve through the gears 16a and 16 to drive the rotor 7 in a counter-clockwise direction, and thereby to increase the relative rotation of the rotors 19 and 7. Such increased relative rotation of the rotors 19 and 7 is consistent with the fact that the opening of the ports 34 has been increased.

So long as the valve 52a gains in phase on the rotor 7a, the obstruction of the ports 34a will be increased and the obstruction of the ports 34 will be reduced, with the consequence that the speed of the rotors 7 and 7a will be increased. When the rotors 7 and 7a have been accelerated to the speeds of the valves 52 and 52a, there will be no further increase in the lag of the rotors relative to the valves, and the rotors will run in unison with their associated valves until the valve speed is increased or diminished, whereupon the rotors 7 and 7a will again adjust themselves to the speeds of the valves.

It is not thought necessary to repeat in detail the action which will occur, starting from the same initial or balanced condition, when the shaft 38 is turned in a direction to rotate the valve 52 clockwise. Such rotation will cause the obstruction of the port 34 to be increased and the obstruction of the port 34a to be diminished, the result being that the unit 6 now becomes the dominant unit, just as the unit 6a was the dominant unit before.

While a specific arrangement of the parts has been shown and described for the purpose of making the principle of operation clear, it should be noted that it is not necessary that the rotors 19 and 19a be driven in the same direction, that the rotors 7 and 7a be connected for rotation in opposite directions, nor that the valves 52 and 52a be connected for rotation in opposite directions. The illustrated arrangement is a particularly advantageous one because it obviates the need for making certain of the pump parts of the two units such as the segment discs 18 and 18a and the discs 29 and 29a of right-hand and left-hand construction. In other words, it enables the corresponding parts of the two units to be identical rather than complementary.

If the structure is to be varied, however, certain relationships must be observed. For example, if the rotors 19 and 19a are driven in opposite directions, the rotors 7 and 7a must then be connected to one another to turn in the same direction, so that the two drives from the motor 4 to the gear 55 will be opposed to one another. In such a case, also, the valves 52 and 52a would have to be connected for rotation in the same direction, so that the two valves may simultaneously turn in unison with the output rotors of the respective pumping units with which they are associated. The recesses 53 or 53a of one of the valves would require a phase adjustment relative to the associated output rotor to cause the ports 34 and 34a still to be inversely controlled by the valves 52 and 52a in the new relationship.

If, in the structure as illustrated, the motor 4 were driven in the opposite direction to turn the input rotors 19 and 19a in a counter-clockwise direction, as viewed in Figures 4 and 5, the flow of oil through the pump units would be reversed, the ports 34 and 34a becoming inlet ports, and the valves 52 and 52a acting inversely to control these inlet ports, the mechanism would still work in substantially the same manner and upon the same principle already described. The recesses 53 and 53a of the valves would, however, require readjustment as to phase so as to adhere to the principle that that valve which is turned relative to the associated output rotor in the direction of the associated input rotor tends to increase the obstruction of the pump ports controlled by it, while the other valve tends con-

comitantly to diminish the obstruction of the pump ports controlled by it.

I have described what I believe to be the best embodiments of my invention. I do not wish, however, to be confined to the embodiments shown, but what I desire to cover by Letters Patent is set forth in the appended claims.

I claim:

1. In a power amplifier for compelling high torque mechanism to conform in its operation to an extraneously imposed speed and direction of rotation, in combination, a rotary high torque input member, a rotary high torque output member to be driven thereby, a pair of opposed hydraulic slip drive trains between the high torque input member and the high torque output member, each comprising a hydraulic pump which includes an input rotor, an output rotor having a rotary control port of limited extent circumferentially of the rotor, a rotary, low torque control member, and rotary valve means cooperative with said rotary control ports and rotatable relative to them, and driven by the low torque control member to control said ports inversely, and thereby to secure rotation of each output rotor substantially in unison with the associated rotary valve means.

2. In a power amplifier for compelling high torque mechanism to conform in its operation to an extraneously imposed speed and direction of rotation, in combination, a rotary high torque input member, a rotary high torque output member to be driven thereby, a pair of opposed hydraulic slip drive trains between the high torque input member and the high torque output member, each comprising a hydraulic pump which includes an input rotor, an output rotor having a rotary control port of limited extent circumferentially of the rotor, a rotary low torque control member, and rotary valve means cooperative with the control ports and operated by the low torque control member for controlling the rotary control ports in accordance with the phase relation of the rotary valve means on the one hand and the control ports on the other, and thereby controlling inversely the flow of liquid through the pumps.

3. In a power amplifier for compelling a high torque mechanism to conform in its operation to an extraneously imposed speed and direction of rotation, in combination, a rotary high torque input member, a rotary high torque output member, means for driving the high torque output member from the high torque input member including a pair of hydraulic slip drive trains interposed between the high torque input member and the high torque output member, each such train comprising a hydraulic pump which includes an input rotor driven positively by the high torque input member, an output rotor provided with a rotary control port, and an interposed pumping member cooperative with the input and output rotors to pump liquids substantially in proportion to the relative speed of rotation of said rotors, said means for driving the high torque output member from the high torque input member also including means interconnecting the output rotors of the two pumps to compel a diminution of relative speed of the input and output rotors of one pump to be accompanied by a corresponding increase of relative speed of the input and output rotors of the other pump, a rotary, low torque, control member, and rotary valve means cooperative with said rotary control ports and driven by the low torque control member to control said ports inversely, for causing the speed and direction of rotation of the high torque output member to bear a prescribed relation to the speed and direction of rotation of the rotary, low torque, control member.

4. In a power amplifier for compelling a high torque mechanism to conform in its operation to an extraneously imposed speed and direction of rotation, in combination, a rotary high torque input member, a rotary high torque output member, means for driving the high torque member from the high torque input member including a pair of hydraulic slip drive trains interposed between the high torque input member and the high torque output member, each comprising a hydraulic pump which includes an input rotor driven positively and uniformly by the high torque input member, an output rotor having a rotary control port, and an interposed pumping member cooperative with the input and output rotors and jointly operated by them, means interconnecting the output rotors to cause either of them to turn in the direction opposite to its associated input rotor when the other is turned in the direction of its associated input rotor, a low torque, rotary, control member, a pair of rotary valves for inversely controlling the ports of the respective pumps, driving connections from the low torque, rotary, control member to the valves causing either of them to be turned in the direction of rotation of the input rotor of the pump associated with it, according to the direction of rotation of the low torque, rotary, control member, and the other to be simultaneously turned in the direction opposite to the direction of rotation of the input rotor of the pump associated with it, said valves being so constructed and arranged that rotation of either valve relative to its associated output rotor in the direction of rotation of its associated input rotor tends to increase the obstruction of the rotary port controlled by the valve and thereby to increase the positiveness of the driving connection between the input and output rotors associated with the valve, while the concomitant motion of the other valve relative to the associated output rotor in the direction opposite to the direction of rotation of the associated input rotor tends to diminish the obstruction of the rotary port controlled by such other valve and thereby to diminish the positiveness of the driving connection between the input and output rotors associated with the latter valve.

5. In a power amplifier for compelling high torque mechanism to conform in its operation to an extraneously imposed speed and direction of rotation, in combination, a rotary, high torque input member, a rotary, high torque output member adapted to be driven thereby, a pair of opposed hydraulic slip drive trains interposed between the high torque input member and the high torque output member, each comprising an input rotor, an output rotor having a rotary pump outlet, and an interposed pumping member cooperative with and responsive to said rotors, a low torque, rotary, control member, and rotary valves operated concurrently by said member for controlling the pump outlets inversely, the arrangement being such that each output rotor is caused to assume substantially the speed and direction of rotation of the rotary valve which controls the outlet thereof.

6. In a power amplifier for compelling high torque mechanism to conform in its operation to an extraneously imposed speed and direction

of rotation, in combination, a rotary, high torque input member, a rotary, high torque output member adapted to be driven thereby, a pair of opposed hydraulic slip drive trains interposed between the high torque input member and the high torque output member, each comprising an input rotor, an output rotor having a rotary pump outlet, and an interposed pumping member cooperative with and responsive to said rotors, a low torque, rotary, control member, and rotary valves operated concurrently by said member, one in the direction of rotation of the input rotor of the pump whose rotary outlet it controls, and the other in the opposite direction to the direction of rotation of the input rotor of the pump whose rotary outlet it controls, said valves when so operated acting inversely upon the outlets of the two pumps, the arrangement being such that each pump output rotor is caused to assume substantially the speed and direction of rotation of its associated control valve.

7. In a power amplifier, in combination, a rotary, high torque input member, a rotary high torque output member, a rotary hydraulic pump interposed between the high torque input and output members and forming a slip drive transmission train from the former to the latter, said pump comprising an input rotor, an output rotor having a pump outlet rotatable therewith, and an interposed rotary pumping member responsive to the relative rotation of the rotors, a rotary, low torque, control member, and a rotary valve driven thereby for controlling obstruction of the rotary outlet, said valve arranged to increase the obstruction of the rotary outlet and thereby to increase the positiveness of the driving connection from the input rotor to the output rotor when the valve is moved relative to the output rotor in the direction of rotation of the input rotor, and to diminish the obstruction of the rotary outlet and thereby diminish the positiveness of the driving connection from the input rotor to the output rotor when the valve is moved relative to the output rotor in the direction opposite to the direction of rotation of the input rotor.

8. In a power amplifier, in combination, a rotary, high torque input member, a rotary, high torque output member, a rotary hydraulic pump interposed between the high torque input and output members and forming a slip drive transmission train from the former to the latter, said pump comprising an input rotor, an output rotor having a pump outlet rotatable therewith, and an interposed rotary pumping member responsive to the relative rotation of the rotors, a rotary, low torque, control member, and a rotary valve driven thereby for controlling the obstruction of the rotary outlet to cause the output rotor to turn substantially with the valve when the valve is turned in the direction of rotation of the input rotor, said valve arranged to increase obstruction of the rotary outlet when the valve gains in phase on the output rotor in the direction of rotation of the input rotor, to reduce rotation of the output rotor relative to the input rotor, and to diminish obstruction of the outlet when the valve loses in phase on the output rotor in the direction of rotation of the input rotor, to permit increased rotation of the output rotor relative to the input rotor.

PETER J. McLAREN.