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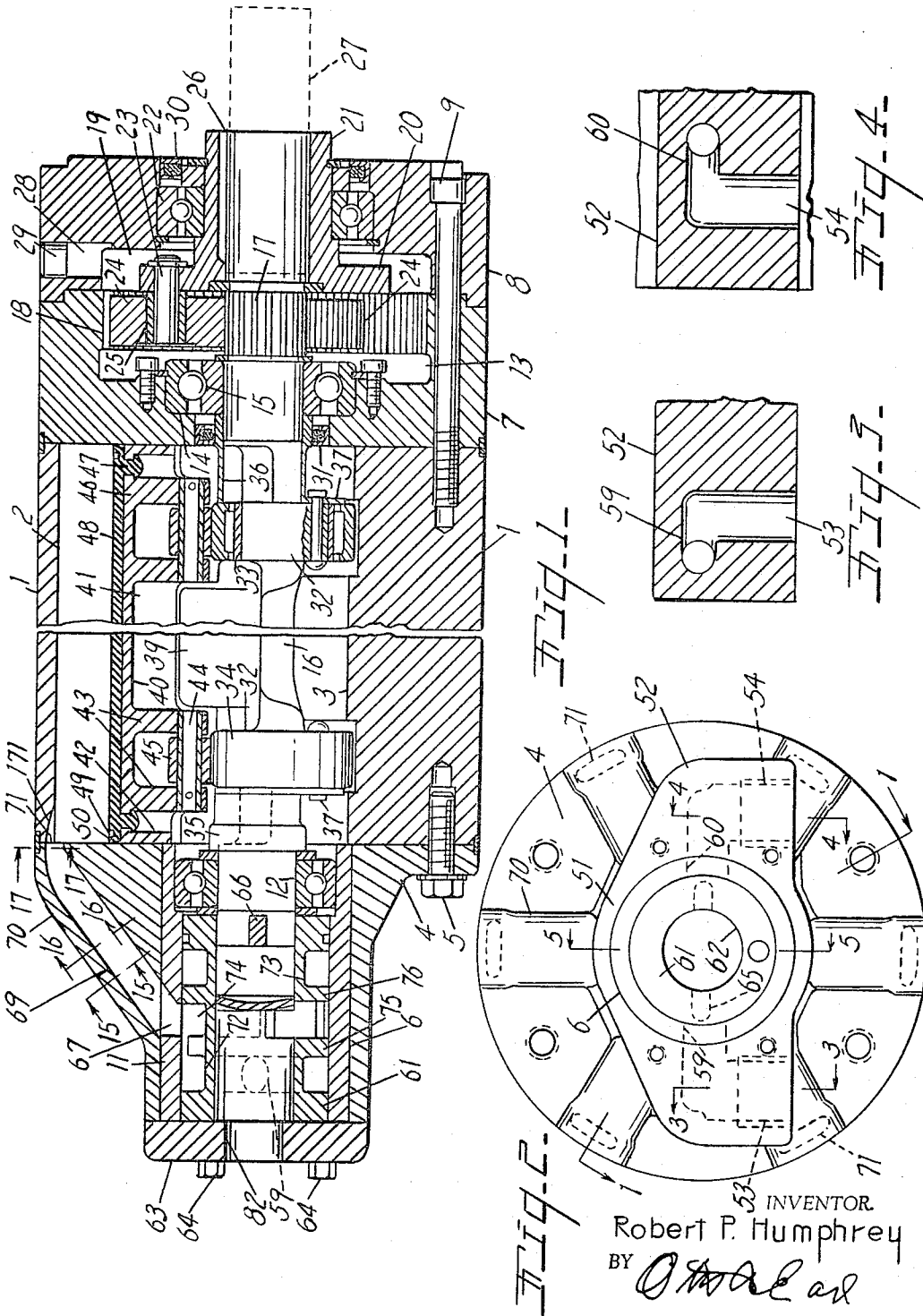
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3,280,703

AIR MOTORS

Filed Nov. 4, 1964

3 Sheets-Sheet 1



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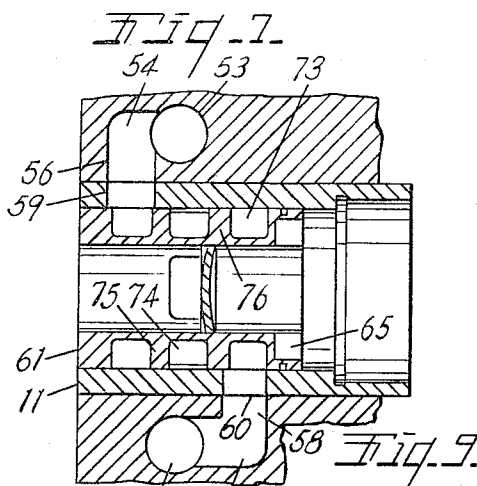
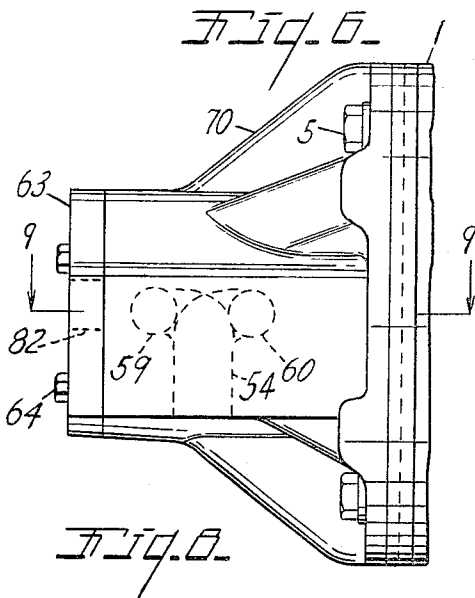
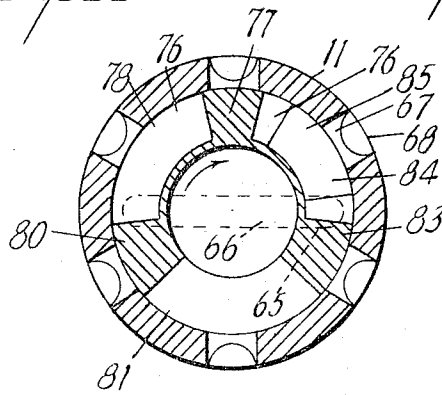
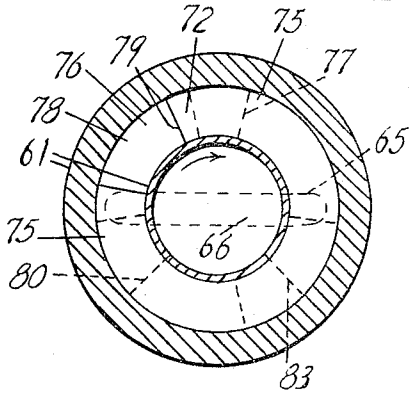
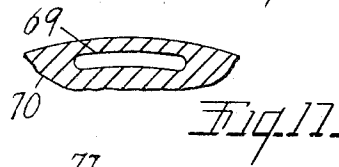
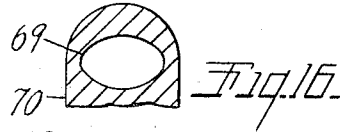
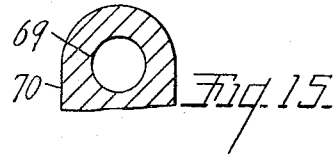
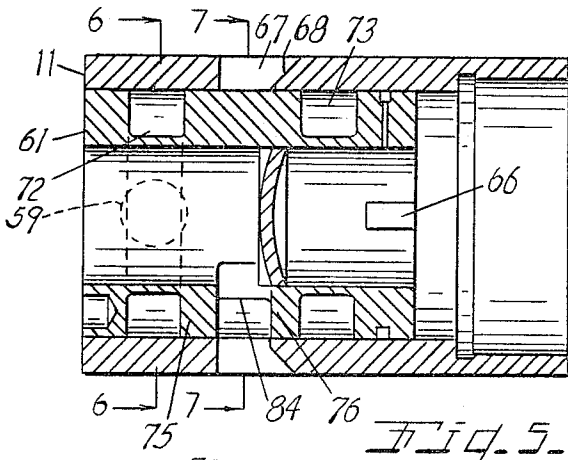
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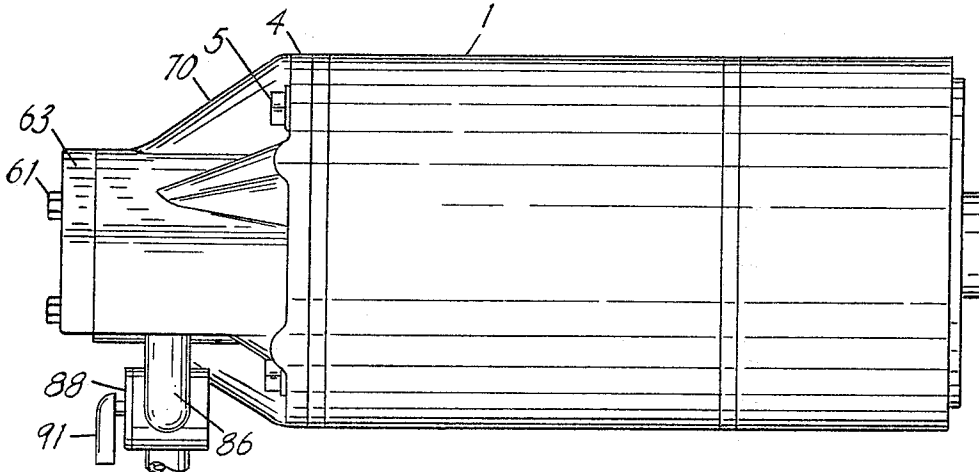


Fig. 10

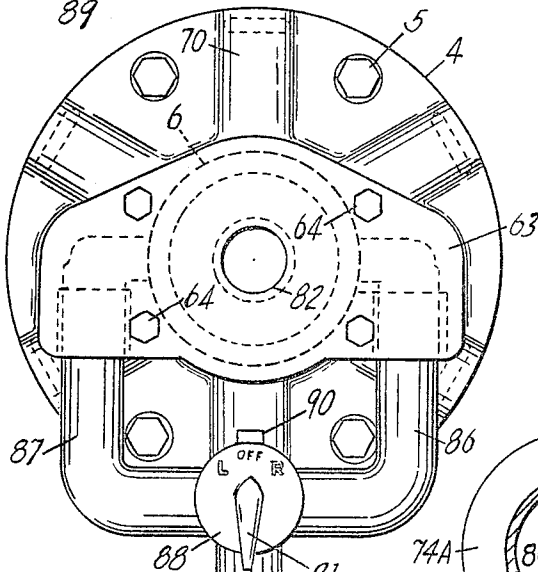
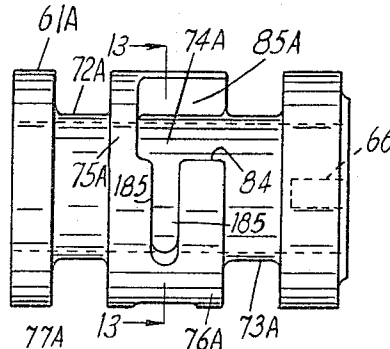


Fig. 11

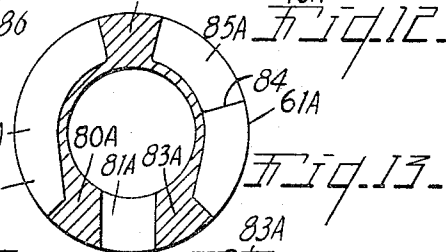


Fig. 12

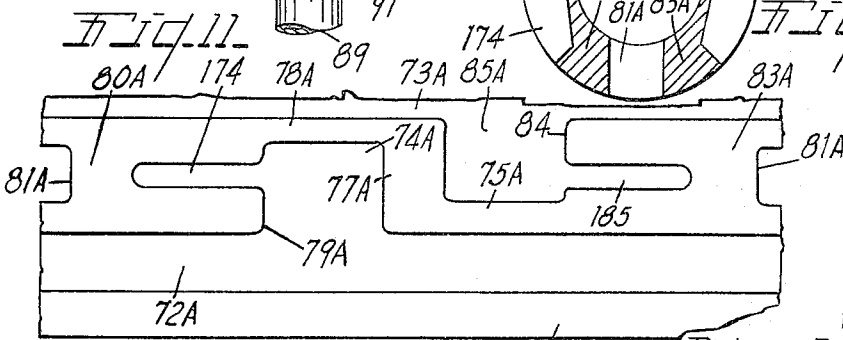


Fig. 13

Fig. 14

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3,280,703
AIR MOTORS

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12 Claims. (Cl. 91-180)

This invention relates to improvements in air motors. The principal objects of this invention are:

First, to provide an air motor having a high output capacity in a body having a minimum circular diameter and in which the output of the motor may be increased or decreased by lengthening or shortening the length of the motor.

Second, to provide an air motor operated by a plurality of radially reciprocating rigid rectangular pressure members actuating eccentrics on a central shaft in which the shaft is coupled through a planetary gearing for a speed reduction torque increase in the output shaft of the motor.

Third, to provide an air motor having an improved form of air inlet manifolding and inlet valve for producing a maximum power output with a given amount of compressed air.

Fourth, to provide an air motor having a plurality of axially elongated radially reciprocating pressure members with sealing faces which seal the edges of the pressure members to the pressure chambers without excessive frictional drag between the walls of the pressure chambers and the pressure members and their sealing faces.

Fifth, to provide an air motor which can be easily reversed as to its direction of rotation without loss of power or torque in either direction of rotation.

Sixth, to provide an air motor which is relatively simple to manufacture and assemble and which is adapted to have different valve spools inserted therein for producing either high speed rotation or lower speed rotation with higher torque.

Other objects and advantages of the invention will be apparent from a consideration of the following description and claims. The drawings of which there are three sheets illustrate a highly practical form of the air motor for producing slower speed and higher torque rotation of the output shaft.

FIG. 1 is a fragmentary longitudinal cross sectional view taken along the plane of the broken line 1-1 of FIG. 2 illustrating the position and action of one pressure member in one of the pressure chambers with the air distributing valve spool and manifold in one rotated position of the motor.

FIG. 2 is a rear end elevational view of the rear end member of the motor with the valve spool retaining cap removed.

FIG. 3 is a fragmentary cross sectional view through one of the connecting ports to the motor taken along the plane of the line 3-3 in FIG. 2.

FIG. 4 is a fragmentary cross sectional view taken along the plane of the line 4-4 in FIG. 2 showing the position of another of the air ports to the motor.

FIG. 5 is a fragmentary longitudinal cross sectional view through the manifold and valve spool portion of the motor taken along the plane of the line 5-5 in FIG. 2.

FIG. 6 is a fragmentary transverse cross sectional view taken along the plane of the line 6-6 in FIG. 5.

FIG. 7 is a fragmentary transverse cross sectional view taken along the plane of the line 7-7 in FIG. 5.

FIG. 8 is a fragmentary side elevational view of the rear valve and manifold end of the motor.

FIG. 9 is a transverse cross sectional view taken along the plane of the line 9-9 in FIG. 8.

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FIG. 10 is a side elevational view of the motor with an air supply connection and control valve connected thereto.

FIG. 11 is a rear end elevational view of the manifold and control valve shown in FIG. 10.

5 FIG. 12 is a side elevational view of a modified form of valve spool designed for slower speed higher torque operation of the motor.

FIG. 13 is a transverse cross sectional view taken along the plane of the line 13-13 in FIG. 12.

10 FIG. 14 is a developed view of the spool shown in FIGS. 12 and 13.

FIG. 15 is a cross sectional view through the inlet passages taken along the plane of the line 15-15 in FIG. 1.

15 FIG. 16 is a cross sectional view through the inlet passages taken along the plane of the line 16-16 in FIG. 1.

20 FIG. 17 is a cross sectional view through the inlet passages taken along the plane of the line 17-17 in FIG. 1.

The motor of the invention consists of a generally cylindrical body 1 having a plurality of radially and axially extending pressure chambers 2 formed therein and opening radially inwardly to a central bore 3 formed through the center of the body. The example of the motor illustrated has six pressure chambers which extend from end to end of the body. A first end member 4 is secured to the rear end of the body as by the cap screws 5 and defines a central manifold bore 6 concentric with the axis of the body 1 and closing the rear ends of the pressure chambers 2. A second end member at the front end of the body has an inner section 7 and an outer section 8 both secured to the end of the body by the screws 9 with the inner section 7 closing the front ends of the chambers 1. The rear end member 4 receives a cylindrical tubular manifold sleeve 11 which is nonrotatably press fitted within the end member 4 and supports a ball bearing 12 at its axially inner end. The inner section 7 of the second end member is axially recessed as at 13 and has a further recessed central bearing seat 14 supporting the ball bearing 15. The bearings 12 and 15 support a central crank shaft 16 with the ends of the shaft projecting into the manifold portion of the first end member and into the recess 13. The front end of the shaft 16 has teeth of a sun gear 17 cut or formed thereon within the recess 13 and the inner periphery of the chamber or recess 13 at the front end of the inner section 7 has internal ring gear teeth 18 cut therein.

The outer end section 8 is also recessed as at 19 cooperating with the recess 13 to form a gear chamber within which the carrier disc 20 is rotatably mounted. The disc 20 has a hollow central hub 21 rotatably supported in the ball bearing 22 coaxially with the crank shaft 16 and has three equal angularly and radially spaced pins 23 secured thereto and projecting into the recess 13 to support planet gears 24 on suitable bearings 25 with the teeth of the planet gears meshing between the internal ring gear 18 and the central sun gear 17 so that the crankshaft ring gear and carrier form a planetary gearing for reducing the speed of rotation of the hub 21 below that of the crankshaft 16. The hub 21 has a key way 26 cut therein for removably receiving the output or driven shaft of any tool or device to be driven by the motor, the shaft being indicated by dotted lines at 27.

65 A lubricant port 28 is formed in the outer end section 8 and closed by a suitable plug 29 to introduce lubricant into the planetary gearing and to the bearings 15 and 22. A front or outer lubricant seal is indicated at 30 and an inner lubricant seal is indicated at 31 to keep the lubricant within the planetary gear chamber.

70 Within the central passage 3 of the body the crank

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shaft 16 is shaped by forging or machining to provide axially spaced eccentrics 32 of cylindrical outline which are shown in FIGURE 1 in their lowermost eccentric position. Press fitted around the eccentrics 32 are the inner races 33 of needle bearings 34 having circular outer surfaces. The bearings 33, 34 are retained in place by bearing brackets 35 which have cylindrical portions 36 embracing the cylindrical bearing portions of the shaft within the inner seal 31 and forwardly of the bearing 12 at the rear end of the crankshaft. The brackets 36 have elliptical flanges 37 which are secured to the eccentrics 32 by bolts 38. An integral counterweight 39 may be formed on the crankshaft in oppositely extending relation to the eccentrics 32 and located therebetween.

Each pressure chamber 2 has an elongated rigid drive element 40 radially reciprocally and slidably sealingly mounted therein. The drive elements are of rectangular cross section and are provided with side flanges 41 and end flanges 42 which guide them in the pressure chambers. Extending transversely between the side flanges 41 are pairs of cross flanges 43 which project inwardly further than the flanges 41 and support longitudinal pivot pins or axes 44 on which rollers 45 are rotatably mounted for rolling engagement with the outer races 34 of the needle bearings 33, 34. As will be apparent rotation of the eccentrics 32 causes the rollers 45 to be moved outwardly of the body 1 moving the drive elements with them.

The outer walls of the drive elements 40 have shouldered bores 46 formed therethrough near their ends which have snap connections with integral inwardly projecting plugs or stems 47 formed on the undersides of deformable flexible seal plates 48 which conform in outline to the faces of the drive elements. The deformable sealing plates have narrow grooves 49 formed therearound near their edges leaving flexible peripheral flanges 50 which are pressed outwardly into tight sealing engagement with all surfaces of the pressure chambers when the pressure chambers are under driving pressure but which tend to yield inwardly out of frictional engagement with the chamber walls when the pressure in the chambers is relieved.

The rear end member 4 has a central cylindrical portion 51 surrounding the manifold sleeve 11 and is transversely extended or thickened as at 52 on each side to provide space for the ports or connections 53 and 54 which open downwardly on the undersides of the thickened portions. As will be described presently either of these ports may be considered as an inlet port and the other as a secondary outlet port but for the present purpose of description the port 53 will be referred to as the inlet port. The ports extend upwardly with the inlet port 53 further extending rearwardly as at 55 in FIGURES 3 and 9 to a radially inwardly extending passage 56. The outlet port 54 connects with a forwardly extending passage 57 that turns radially inwardly at 58 to an exhaust port in the inner face of the bore 6. The inlet passage 56 opens through an inlet port 59 formed in the manifold sleeve 11 while the passage 58 opens through an exhaust port 60 formed on the opposite side of the manifold sleeve and positioned axially forwardly from the inlet port 59.

Rotatably and sealingly supported within the manifold sleeve 11 is the valve spool indicated generally by the numeral 61 and having an internal axial bore 62 formed therethrough. The spool 61 and the manifold sleeve 11 are retained in the end member 4 by an end cap 63 held in place by cap screws 64, see FIG. 8. The inner end of the valve spool 61 has a diametrically extending slot or notch 65 formed in its inner end which is adapted to receive the cross key 66 which also fits in a cross slot formed in the rear end of the drive shaft 16 which projects into the front end of the valve spool so that the spool rotates with the shaft.

The manifold sleeve 11 has six equiangularly spaced radially extending ports 67 formed therethrough, see

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FIGS. 1 and 7, which ports are beveled forwardly at their front edges as at 68 to open into radially and axially inclined passages 69 formed in the radial bosses 70 on the outer side of the end member 4. As appears most clearly in FIGS. 15, 16 and 17 the passages 69 start as circular passages adjacent the ports 67 and merge into elliptical passages intermediate of their ends and further merge into generally straight sided oval passages at their forward ends where they open through ports 71 into the ends of the pressure chambers 2. The outer walls of the pressure chambers 2 are beveled radially outwardly as at 71 in FIG. 2 to cover all of the ports 70. The cross sectional areas of the passages are designed to be of approximately equal cross section in FIG. 17 so that there is no restriction or reduction of pressure in the air moving inwardly or outwardly through the passages 69. Also, the beveled ends 71 of the pressure chambers provide for complete evacuation or removal of air from the chambers and for initial entrance of air under pressure into the chambers in the extremely extended positions of the drive elements.

The spool member 61 has a continuous rear annular groove 72 which opens continually to the inlet port 59. Spaced substantially forwardly from the groove 72 and registering with the exhaust port 60 is a continuous front annular groove 73. Positioned between the grooves 72 and 73 is an interrupted valve groove 74; a wall 75 separates the groove 72 from the groove 74 while a wall 76 separates the exhaust groove 73 from the valve groove. A first blocking wall 77 extends transversely across the valve groove and extends angularly around the spool for a distance of approximately 30 degrees so as to successively close off the several ports 67 as the spool rotates in a clockwise direction as indicated in FIGS. 6 and 7. That portion of the valve groove trailing the first blocking wall 77 accordingly becomes an inlet chamber 78 which extends angularly around the spool or approximately 82 degrees and which opens to the inlet groove 72 through an opening or hole 79 in the wall 75. Trailing the inlet passage 78 is a second blocking wall 80 of approximately 35 degrees angular extent which closes off each port 67 successively and permits expansion of entrapped air in the pressure chambers during the period in which the blocking wall 80 passes ports 67. Following the blocking wall the valve groove 74 is opened completely radially through the spool from the inside of the manifold sleeve to the inner bore 62 of the spool forming a primary or first exhaust passage 81 of approximately 96 degrees angular extent around the spool. While this exhaust passage 81 is in registry with any given port 67 the corresponding pressure chamber in the body is open through the passage 69 and valve groove to the interior of the spool and through the end opening 82 in the end cap 63 at the end of the manifold. Following the primary exhaust passage 81 in the valve groove 74 is a second blocking wall 83 of approximately 35 degrees angular extent around the valve spool. Following the blocking wall 83 the valve groove 74 defines a secondary exhaust passage 84 with an axially forwardly opening 85 in the wall 76 communicating with the exhaust groove 73. It is thus apparent that after the main portion of the charge of air in any given pressure chamber is exhausted through the primary exhaust passage 81 the remaining small quantity of air is trapped for the short period during which the blocking wall 83 closes off the port 67 but after this short period the chamber is fully exhausted through the secondary exhaust passage 84. The short period of back pressure created while the blocking wall 83 is passing the port occurs as the blocking wall and the eccentric on the crankshaft are approaching 270 degrees rotation at which point there is little radial motion of the drive elements for each angle of rotation of the cam shaft so there is little power loss due to this back pressure.

After the blocking wall 83 passes the port 67 the secondary exhaust passage 84 comes into communication with the port 67 through the opening 85 in the wall 76 and

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completes evacuation or discharge of air from the pressure chamber through all but a few degrees of the final 360 degree rotation of the valve spool during which the blocking wall 77 closes off the port 67. This final closing takes place while the eccentric and the spool are at or near dead center of the drive elements and when radial motion of the drive elements is at a minimum.

The foregoing valve arrangement is symmetrical so that the action of the motor is equal in either direction of rotation. As appears in FIGS. 10 and 11 the first end member 6 of the motor containing the manifold portion and the valve spool is provided with two connecting pipes 86 and 87 which connect to a three-way manual valve 88 having an inlet pipe 89 and an exhaust opening 90. The manual control knob 91 permits the valve to be adjusted for either right or left hand rotation of the motor by directing air to either the pipe 86 or 87 respectively.

The deformable flexible sealing plates 48 mounted on the outer faces of the drive elements 40 cooperate with the valving arrangement in that the headed elastic retaining plugs 47 permit the sealing face or plate 48 to yield upwardly away from the driving element under the suction influence of the velocity of the mass of air being finally ejected from the pressure chamber as the rigid driving element approaches its minimum outward motion. The deflection of the seal plate 48 returns to the driving element 40 during the final outward motion of the driving element and is in position to receive the reverse flow of incoming air pressure for the succeeding pressure stroke as the eccentric passes dead center position. As a result the motor operates very efficiently and produces a maximum of horse power and speed with a minimum of compressed air.

The first form of the motor just described is designed for high speed operation and maximum power output in that the power stroke of each drive element is supplied with compressed air through either the chamber 74 or the chamber 84 through approximately 102 degrees of initial rotation of the valve spool and the eccentrics from their top dead center position and this positively charged mass of air is permitted to expand within the sealed chamber for approximately 15 more degrees of rotation until the primary exhaust port 81 opens to the pressure chamber. The primary exhaust port 81 opens the pressure chamber to the exhaust through approximately 116 degrees of rotation so that the air is easily and quickly discharged through the passage 69 after the eccentric has rotated about 122 degrees from top dead center and during the time when angular rotation of the eccentric will result in substantial radial displacing motion of the drive elements. The short period of closing of the exhaust passage by the blocking walls 80 or 83 takes place after the break of movement of the drive elements has passed its maximum so there is a minimum of back pressure created on the drive elements through about 15 degrees of rotation of the cam shaft and the valve spool. The further and complete exhausting of the charge of air in the chamber is effected during approximately 102 degrees of rotation of the spool as the eccentrics and the spool return to their dead center extending position of the drive elements.

The modified form of valve spool shown in FIGURES 12, 13 and 14 may be easily substituted in the same end member 6 and manifold sleeve 11 by simply removing the end cap 63. This spool is designed to provide a higher torque output of the motor at a slower speed and may in fact be used as a speed governor. The spool 61A has the same outer groove 72A and inner groove 73A but the valve groove 74A and the opening thereto are varied as will be described. The central axial blocking wall 77A between the walls 78A and 75A extends for about 30 degrees around the periphery of the spool as in the first form of the spool and is about 10 degrees wider than the ports 67 in the manifold so that about 5 degrees rotation from dead center will open either the port 84 and chamber 85A or port 79A and chamber 74A to the port 67. The

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inward power stroke of each drive element is thus started in either direction depending upon the setting of the control valve 91 and continues under pressure for approximately 74 degrees rotation which is the angular length of the chambers 74A and 85A. However the modified spool has angular extensions 135 from the chamber 85A and 174 from the 74A which continue the supply of pressure to the pressure chambers through about 136 degrees of rotation of the spool and the cam shaft. The extensions 174 and 185 are axially narrowed and require less air to fill them while still transmitting pressure to the pressure chambers 2 so that less air is required to fill the valve chambers and the efficiency of the motor is increased. The angular length of rotation of the power stroke is also increased considerably over that in the first form of valve spool so that the motor produces a higher torque.

Due to the greater angular extent of the inlet chambers 85A, 185, 74A and 174 there is less angular space around the periphery of the spool for the remaining exhaust ports of the spool. Blocking wall 83A and 80A are reduced to approximately 30 degrees of angle around the spool as compared to the 35 degree angular extent of the corresponding blocking walls in the first form of spool and the primary exhaust port 81A is reduced to approximately 28 degrees angular length as compared with the 96 degrees length of the port in the first form of the spool. As a result of this variation in spool construction the cycle of each pressure chamber of the motor consists of 141 degrees of driven powered rotation following 5 degrees from dead center and in turn followed by 10 degrees of expansion of air in the closed chamber. The chamber then opens for a short period of 48 degrees during which primary exhausting of air from the chambers occurs before it is stopped off for 10 degrees rotation in which back pressure may be built up against the drive element. The final evacuation or expelling of the air occurs during approximately 141 degrees of rotation near the end of the rotational cycle of the spool. It will be appreciated that while one pressure chamber is being driven through the greater angular distance of 141 degrees the next preceding chamber which is 60 degrees advanced from the chamber under consideration will have already passed through its relatively short 48 degrees of exhausting rotation and will be in the back pressure area of rotation creating a back pressure on the motor. With the first form of spool the power stroke through 102 degrees of rotation will still be operating while the next preceding chamber is in full open exhaust position so there is no corresponding back load on the motor. Thus the second form of spool provides a motor with higher torque but with less speed and with some what less power where as the first form of motor provides a higher speed and higher powered motor but with less torque. The valving arrangements of the spools can of course be varied to meet different requirements and the planetary gear drive to the output chuck or sleeve 21 may be varied in ratio or eliminated as desired without departing from the theory of the invention.

What is claimed as new is:

1. An air motor of the type having a tubular body with a series of equi-angularly spaced radially and axially extending pressure chambers of rectangular cross section formed therein and opening to the radially inner side of the body and closed at their outer sides,

first and second end members secured to the ends of said body and rotatably supporting an out-put shaft concentrically between said pressure chambers, eccentric means on said shaft at longitudinally spaced points therealong, elongated rigid drive elements of generally rectangular cross section radially and sealingly reciprocable in said chambers, thrust means drivingly and rollingly engaged between the inner sides of said drive elements and said eccentric means, and valve means in one of said end members arranged

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to admit air under pressure successively to said pressure chambers and exhaust air therefrom, characterized by a manifold in said one end member and having a cylindrical central bore, individual axial passages formed in said one end member opening radially through said manifold at angularly spaced points therearound and angling axially to the face of the end member at the ends of said chambers,

a valve spool rotatably and sealingly fitted within said manifold and drivingly connected to said shaft, said one end member having two passages formed therein and connectable alternatively and selectively as inlet and exhaust passages,

said passages opening to continuous annular grooves spaced axially along said spool on opposite sides of the outer ends of said axial passages in said one end member,

and a valve groove formed in the periphery of said spool between said continuous grooves and in the plane of the outer ends of said axial passages in said one end member,

said valve groove having a first blocking wall extending angularly around the groove further than the angular width of the openings of said axial passages to said manifold,

other blocking walls extending across said valve groove in symmetrically spaced positions on angularly opposite sides of said first blocking wall and located over 90° from the center of said first blocking wall,

said other blocking walls extending angularly around the groove further than the angular width of the openings of said axial passages to said manifold,

a radially inwardly opening primary exhaust opening formed in said valve groove between said other blocking walls and continuously open to the exterior of said manifold,

a first axial opening formed in said spool between one of said axially spaced grooves and said valve groove on one side of said first blocking wall,

and another axial opening formed in said spool between the other of said axially spaced grooves and said valve groove on the opposite side of said first blocking wall.

2. A motor as defined in claim 1 in which said second end member has axially inner and outer sections defining a recess with an internal ring gear fixed therein, a sun gear on the end of said shaft, a carrier rotatably supported in the outer section of said other end member and adapted to be connected to an output shaft, and planet gears rotatably supported on said carrier and meshing between said ring gear and said sun gear.

3. A motor as defined in claim 1 in which the radially outer walls of said pressure chambers are beveled radially outwardly at the end to merge with the outer edges of the ends of the passages in said one end member, and said eccentric means are circular.

4. A motor as defined in claim 1 in which said drive elements have rectangular outer walls with holes formed therethrough, and deformable elastic seal plates on the outer sides of said walls with integral headed plugs on the seal plates pressed through said holes, said seal plates sealingly engaging the walls of said pressure chambers.

5. An air motor as defined in claim 1 in which said individual axial passages are of circular cross section where they intersect said cylindrical cross section of said manifold and merge axially into elliptical cross sections intermediate of their ends and merge further into oval cross sections of radially narrow width and a length transversely across said pressure chambers longer than the width of said chambers by at least twice the radii at the ends of the ovals,

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the cross sectional area of said passages being approximately equal throughout to the ends of said pressure chambers and excluding the rounded ends of the oval sections.

6. An air motor as defined in claim 5 in which said manifold is a tubular element fixedly fitted into a bore provided therefor in said one end member, and in which said alternative inlet and exhaust connection are formed in said one end member to open through said tubular manifold to said annular passages in said spool, and in which an end cap secured to said one end member retains said tubular manifold and said spool in said one end member and defines a central outlet for a secondary exhaust from within said spool.

7. An air motor as defined in claim 6 in which said spool has a bowed closure disc snapped therein inwardly from said alternate exhaust opening to keep said secondary exhaust from blowing into the interior of said body.

8. A motor as defined in claim 4 in which said elastic seal plates have grooves formed in their outer faces adjacent the edges thereof leaving narrow flanges deflectable by pressure against the walls of said pressure chambers.

9. A motor as defined in claim 1 in which the walls between said axially spaced grooves in said spool and said valve groove angularly overhang the ends of the blocking walls at the ends of the openings to the valve groove to increase the radial support of said spool in said manifold.

10. A motor as defined in claim 1 in which said valve groove between said first blocking wall and said other blocking walls is relatively wide axially of the spool adjacent said first blocking wall for symmetrical angles around said spool and are then narrowed axially and extended symmetrically and angularly within said other blocking walls.

11. A motor as defined in claim 10 in which the relatively wide portions of said valve groove extend about 90° from said first blocking wall and said narrowed portions extend about an additional 40°, and said primary exhaust opening extends angularly about 28° in symmetrical relation to the diameter through said first blocking wall.

12. An air motor of the type having a tubular body with a series of equi-angularly spaced radially and axially extending pressure chambers of rectangular cross section formed therein and opening to the radially inner side of the body and closed at their outer sides, first and second end members secured to the ends of said body and rotatably supporting an out-put shaft concentrically between said pressure chambers, eccentric means on said shaft at longitudinally spaced points therealong, elongated rigid drive elements of generally rectangular cross section radially and sealingly reciprocable in said chambers, thrust means drivingly and rollingly engaged between the inner sides of said drive elements and said eccentric means, and valve means in one of said end members arranged to admit air under pressure successively to said pressure chambers and exhaust air therefrom, characterized by a manifold in said one end member and having a cylindrical central bore, individual axial passages formed in said one end member opening radially through said manifold at angularly spaced points therearound and angling axially to the face of the end member at the ends of said chambers, a valve spool rotatably and sealingly fitted within said manifold and drivingly connected to said shaft, said one end member having two passages formed therein and connectable alternatively and selectively as inlet and exhaust passages,

said passages opening to continuous annular grooves, spaced axially along said spool,
 an annular valve groove formed in said spool registering with the radially inner ends of said axial passages,
 5 a first blocking wall in said valve groove of slightly greater angular extent than the ends of said axial passages,
 10 other blocking walls spaced angularly from each side of said first blocking wall and defining symmetrical and alternative inlet and outlet passages,
 said other blocking walls being of slightly greater angular extent than the ends of said axial passages,
 a pair of passages formed in said spool continuously connecting said axially spaced grooves to one each
 15 of said symmetrical passages in said valve groove, and a primary exhaust passage opening from said valve

groove in symmetrical and diametrically opposed relation to said first blocking wall.

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