

Feb. 28, 1967

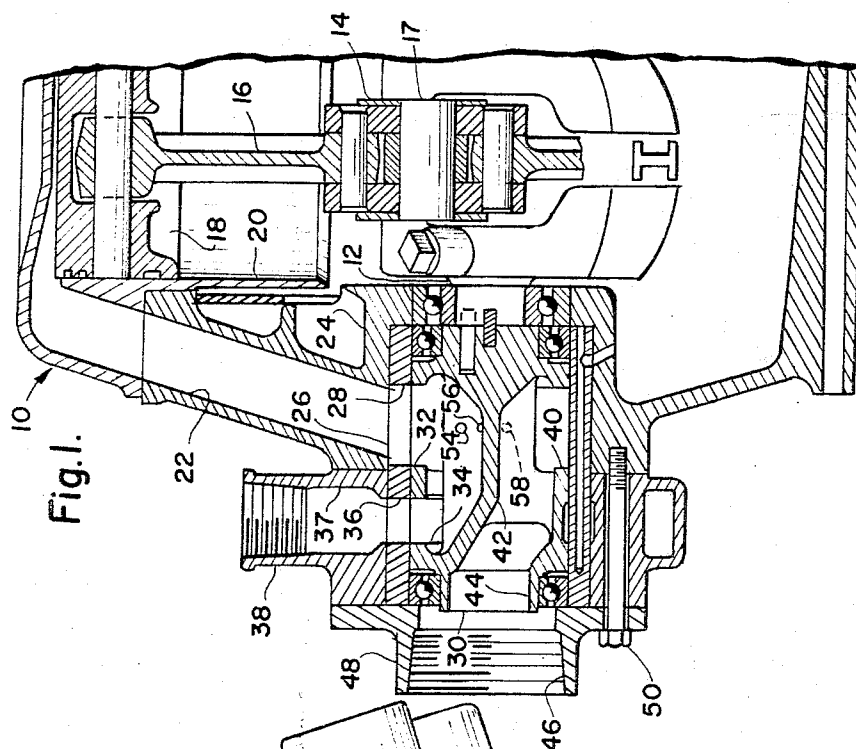
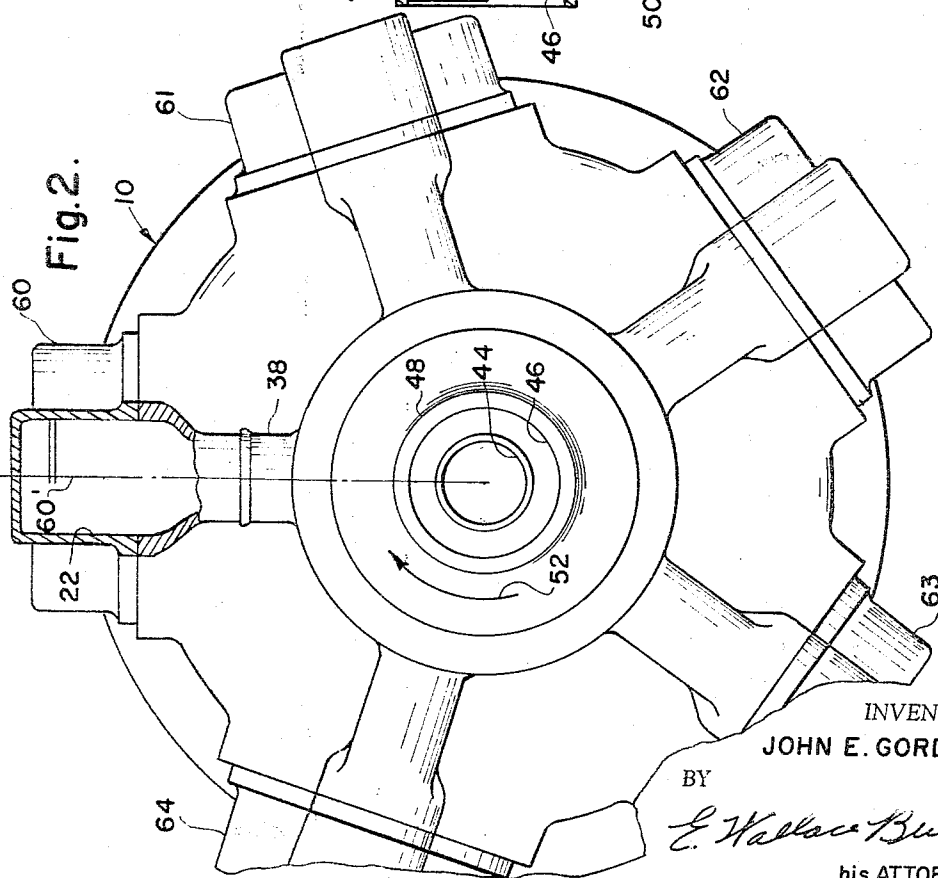
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3,306,171

FLUID OPERATED DEVICE

Filed May 11, 1964

2 Sheets-Sheet 1



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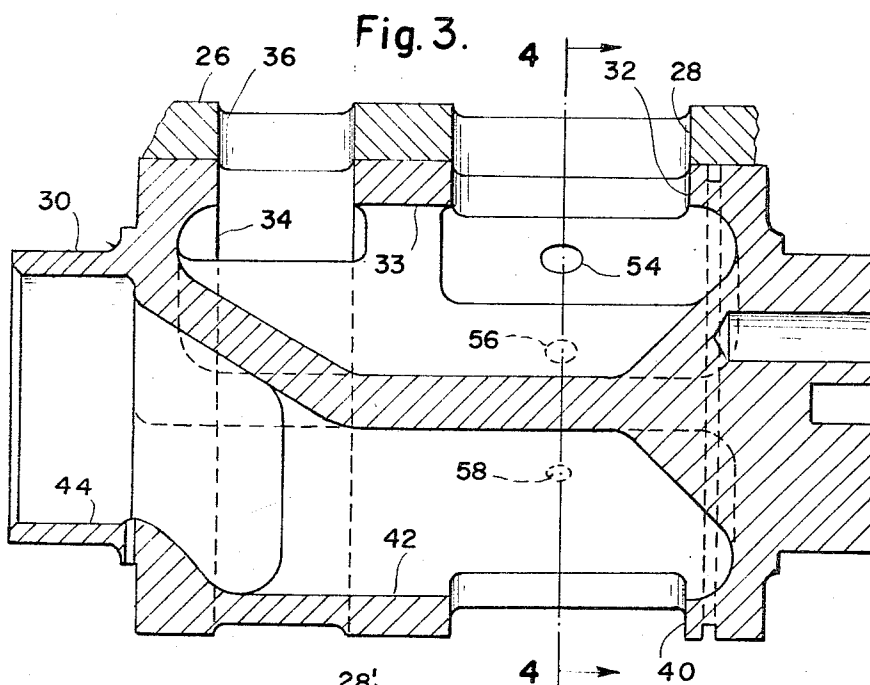
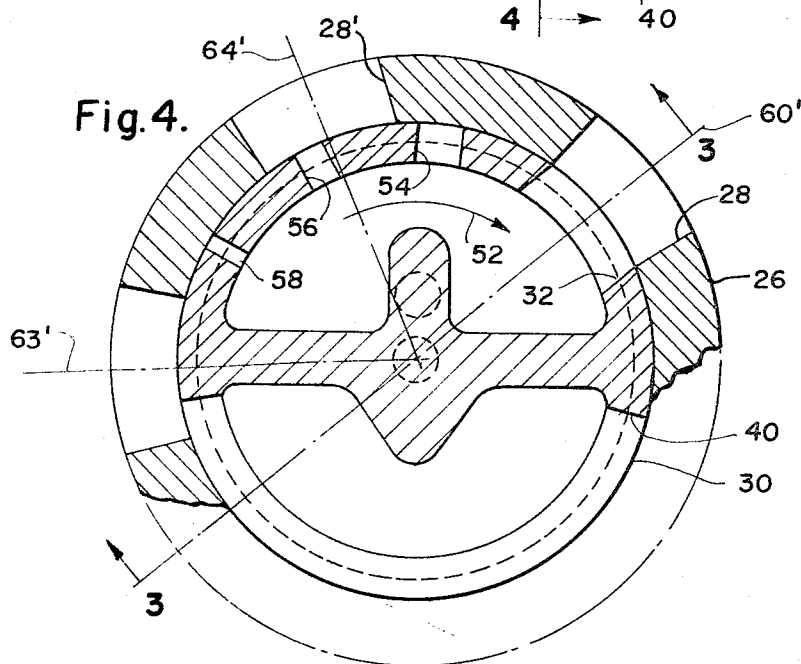
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2 Sheets-Sheet 2



1

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FLUID OPERATED DEVICE

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7 Claims. (Cl. 91—180)

This invention relates to a fluid operated device and more particularly to a compressed gas operated motor having an improved rotary inlet and exhaust valve.

Compressed air motors of the multi-cylinder type having a unitary valve structure capable of providing timed inlet of compressed air to the individual cylinders and permitting exhaust air to flow from the individual cylinders are well known in the art. It is further well known that for efficient high speed operation an inlet port of relatively small angular dimension should be provided in the rotary valve so that the cut off of the inlet air occurs while the piston is somewhere in mid downstroke, allowing expansion of the air with consequent reduction in pressure as the piston continues its downward stroke. Thus, when the cylinder is opened to the surrounding atmosphere by action of the valve in providing the exhaust connection, a minimum amount of the energy of the compressed air is lost in the exhaust system. It is further well known that for high torque in low speed operation the inlet port of the rotary valve should be very much larger in angular dimension than the optimum size for efficient high speed operation as hereinabove described. It therefore follows that the angular size of the inlet port of the rotary valve for a compressed air motor, required to operate at a variety of speeds, is a compromise between the demands for a large port giving adequate slow speed torque and a small port giving high speed efficiency, with neither demand being fully satisfied.

Another limitation on the minimum angular size of inlet ports, that can be used in devices of the prior art, arises from the necessity of having a portion of the port open to a suitable cylinder for starting the motor from whatever position it was in when it was stopped. As a result of this latter requirement even those air motors which were designed only for high speed operation could not be provided with the desirably small inlet port which would give maximum high speed efficiency.

In the rotary valve of the present invention the angular size of the main inlet port (30°—35°) is largely determined by the desired cut off point in the downstroke of the piston operating at high speed and is sized so that after cut off a suitable amount of compressed air expansion takes place so that when the exhaust port is opened a minimum of energy is left in the compressed air to be lost in the exhaust system. The rotary valve of this invention in addition to the main inlet port is provided with a series of much smaller inlet ports or orifices through which compressed air can be supplied to the cylinders at a rate much less rapid than the supplying of air through the main port. These auxiliary ports are positioned in the valve so that they do not communicate with the cylinders until after the main port has nearly or completely closed and might be characterized as trailing auxiliary ports. These auxiliary ports are orifices of a suitable size so that at high speed operation of the air motor to which this rotary valve is applied the orifice effect ensures that there is time for very little air to flow through the auxiliary ports with the result that the air motor using the rotary valve of this invention operates as though it had only a relatively small main port and consequently has very good high speed operating efficiency because it utilizes the expansive energy of the compressed air.

For starting the air motor using the rotary valve of

2

this invention one or more of the auxiliary ports will always be open to a suitable cylinder wherein the piston has partially completed a downstroke so that air for starting the motor is supplied to a suitable piston to begin rotation of the crankshaft bringing other pistons into position to continue the action. For slow speed operation the auxiliary ports are open for a length of time great enough to allow for maintaining the pressure within the cylinder a greater length of time with resulting greater means effective pressure than would be possible with a single inlet port of the angular size hereinabove described. Therefore, an air motor using the rotary valve of this invention has good low speed torque characteristic, satisfactory starting from any stopped position and furthermore has better high speed operating efficiency than similar motors of the prior art.

It is therefore an object of this invention to provide a new and improved compressed gas motor having a novel rotary valve mechanism.

It is another object of this invention to provide a new and improved compressed gas motor having good high speed operating efficiency and also having good low speed torque characteristics and starting ability from any stopped position.

It is a more specific object of this invention to provide a new and improved rotary valve for a multi-cylinder compressed air motor wherein the rotary valve is provided with a large exhaust port, main inlet port and a plurality of trailing auxiliary inlet ports much smaller than the main inlet port.

It is a further specific object of this invention to provide a new and improved compressed gas motor having a rotary valve provided with a plurality of circumferentially spaced inlet ports of different sizes wherein the smaller ports or orifices spaced circumferentially to the rear of a larger main port with respect to the direction of rotation of the valve when the motor is operating and utilizing the orifice effect in relation to motor speed to make substantial use of the expansive power inherent in the compressed gas.

These and other objects and advantages of this invention will become more readily apparent upon consideration of the following description and drawings in which:

FIGURE 1 is a fragmentary sectional view of a portion of a multiple cylinder compressed air motor provided of this invention;

FIGURE 2 is an end elevation partially sectional view of the compressed air motor of FIGURE 1;

FIGURE 3 is a sectional view of a rotary valve constructed according to the principles of this invention and taken substantially along the line 3—3 of FIGURE 4; and

FIGURE 4 is a transverse sectional view taken substantially along the line 4—4 of FIGURE 3.

The following description is directed to a preferred embodiment of this invention as applied to a particular compressed air motor but should not be taken as limiting the application of this invention to a motor having a particular number of cylinders or a specific arrangement of such cylinders. The valve of this invention is also applicable to motors operated by compressed gases other than air.

In FIGURE 2 there is shown a five cylinder radial compressed air motor 10 of a type well known in the art provided with a suitable single throw crankshaft 12 (see FIGURE 1) suitably journaled in a suitable crankcase and having a master bearing 14 rotatably mounted on the single throw 17 thereof and suitably connected to a connecting rod 16 for each of the five cylinders, respectively. Each connecting rod 16 controls the motion of a piston 18 to provide reciprocating motion there-

3

to within a cylinder bore 20 in a manner common to radial engines and motors as is well known. Each cylinder bore 20 communicates with an inlet and outlet fluid conducting passageway 22 which in turn communicates with a substantially cylindrical, hollow manifold body 24 coaxial with the crankshaft 12 and having a hollow cylindrical, stationary valve body 26 rigidly secured within the manifold body 24, which valve body 26 has an opening 28 substantially mating with each passageway 22 to establish communication between passageway 22 and the interior of a generally cylindrical valve member 30 rigidly secured to one end of the crankshaft 12 for coaxial rotation therewith. With the valve in the position shown in FIGURE 1 a generally rectangular main port 32 mates with the opening 28 and establishes communication between the passageway 22 and the interior passageway 33 of the valve member 30 which in turn communicates with an inlet channel 34 extending circumferentially around the valve member 30 and communicating with a passageway 36 in the valve body 26. The passageway 36 in turn communicates with a passageway 37 in an inlet body 38 provided with a threaded pipe connection to which is secured fluid conducting means such as a pipe or hose (not shown) connected through suitable control devices to a source of compressed air (also not shown). Thus when the piston 18 of a particular cylinder is at the top of its stroke communication is established from the source of compressed air through the control device (not shown) to the inlet body 38 through the passageway 37, the inlet opening 36, the inlet channel 34, the passageway 33, the main port 32, the opening 28 and the passageway 22 to the top of the cylinder bore 20 above the piston 18. At the same time communication with the other cylinders is established through passageways similar to passageway 22 and openings similar to the opening 28 but associated with other cylinders to a main exhaust port 40 into an exhaust channel 42 which communicates with an axial exhaust opening 44 which in turn communicates with a central opening 46 such as a threaded axial bore in a flanged generally cylindrical end cap 48 shown as being coaxial with the valve body 26 and rigidly secured to the manifold body 24 as by elongated cap screws 50. The cap screws 50 extend through a flange portion of the end cap 48, through the inlet body 38 and are threadedly secured in the manifold body 24 to maintain these parts in rigid, fluid tight, relationship with each other and with the valve body 26 during operation of the motor 10. The end cap 48 is provided with suitable fluid conducting pipe or hose (not shown) connecting with any suitable sound reducing exhaust system or left open to the ambient atmosphere as desired.

It is to be noted that the valve member 30 is suitably journaled in suitable bearings within the valve body 26 for coaxial rotation therein at crankshaft speed.

As more clearly shown in FIGURES 3 and 4, the valve member 30 is provided with a plurality of auxiliary inlet ports in addition to the main port 32. When the valve member 30 is provided for clockwise rotation as viewed in FIGURE 4, the auxiliary ports are circumferentially spaced along the periphery of the valve body 30 in a counterclockwise direction with the first and largest of the auxiliary ports indicated as 54, the intermediate port in size and location being indicated as 56 and the smallest port most distant from the main port 32 being indicated as 58. In the embodiment being described the main inlet port 32 is a substantially rectangular opening having an axial dimension of approximately $1\frac{3}{4}$ " and an angular dimension of approximately 32° or 1° of circumference while the auxiliary ports are radial bores or orifices of approximately $\frac{1}{4}$ " diameter for port 54, approximately $\frac{7}{32}$ " diameter for port 56 and approximately $\frac{3}{16}$ " diameter for port 58. The above dimensions are cited only for the purpose of establishing the great difference in size between the main port 32 and the auxiliary ports 54, 56

4

and 58. These dimensions, however, can be varied according to the design of the engine and the conditions under which it will operate especially with respect to the amount of high speed operation and low speed torque which is required in a particular application. The spacing of the ports as shown in FIGURE 4 positions the first auxiliary port 54 approximately 44° counterclockwise from the main port 32 while the second auxiliary port 56 is positioned approximately 77° counterclockwise from the port 32 and the smallest port 58 is positioned 110° counterclockwise from port 32 as measured between the centerlines of all the ports mentioned. Again it should be noted that the spacing in a particular design will be dependent upon the application for which the valve 30 is intended. The device of this embodiment as shown in the figures is set up for clockwise rotation as viewed in FIGURE 2 and for purposes of description the cylinder body extending vertically upward in FIGURE 2 and shown in detail in FIGURE 1 will be referred to as cylinder 60 having an axial centerline 60' with the other four cylinders identified as cylinders 61, 62, 63 and 64, respectively, proceeding in a clockwise direction from cylinder 60 as viewed in FIGURE 2 and having respective axial centerlines as 63' and 64' (see FIG. 4). It is to be understood that within each of the five above enumerated cylinders a piston 18 is connected by a connecting rod 16 to the master bearing 14 and consequently to the single throw 17 of the crankshaft 12 in a manner well known in the art.

Operation of the device of this invention begins with all parts of the air motor 10 at rest in the relative positions shown in FIGURE 1. Through the control device compressed air is applied to the passageway 37 in the inlet body 38 and, communicating through the valve member 30 as hereinbefore described, pressure is applied to the top of the piston 18 shown in FIG. 1 as standing at top dead center in the bore 20 in the cylinder 60. However, since the piston 18 in the cylinder 60 is at top dead center application of pressure to the top of the piston 18 in the cylinder 60 has no effect to rotate the crankshaft 12. However, since cylinder 64 is positioned 72° counterclockwise of cylinder 60, the second auxiliary port 56, trailing the main port 32 by approximately 77° is in a position to communicate with cylinder 64 through the valve body 26 by way of an opening 28' related to cylinder 64' in the same manner as opening 28 is related to cylinder 60. Due to the positioning of the cylinder 64 in a counterclockwise direction from the cylinder 60, the piston within the cylinder 64 is in an intermediate portion of its downward stroke with the crank throw 17 standing at an angle to the centerline 64' of the cylinder 64 so that pressure applied to the top of the piston in the cylinder 64 will be effective to cause rotation of the motor 10 so that the motor is effectively started. When the crankshaft 12 begins to rotate in a clockwise direction as viewed in FIGURE 2, the piston 18 in cylinder 60 will travel downwardly and the crank throw 17 will assume an angular position relative to the centerline 60' and the compressed air supplied to the cylinder 60 will create a downward force on the piston 18 translated into torque applied to the crankshaft 12 as is well known. Since the port 32 and the opening 28 have angular dimensions of approximately 32° each, cut off of the compressed air supplied through the main port 32 will occur at approximately 64° of crank rotation from first opening of port 32 at which time the piston 18 is in an intermediate portion of its downward stroke. The remaining downward motion of the piston makes use of the expansive energy of the compressed air already in the cylinder 60 at the time to cut off. Further rotation of the valve 30 brings the exhaust port 40 into communication with the opening 28 at or near the bottom of the stroke of piston 18 so that as piston 18 once more rises in the cylinder 60, the air within the cylinder is exhausted through the passageway 22, the opening 28, the exhaust port 40, the exhaust

channel 42, the exhaust opening 44 and the end cap 48 to a suitable exhaust system.

It is to be realized that the above described timing of valve 30 with respect to the motion of piston 18 is only illustrative and not necessarily the exact timing to be employed in any motor.

At high speed operation the ports 54, 56 and 58 although briefly in communication with the opening 28 have practically no influence on the above described operation because of the orifice effect due to their small size, but when the motor 10 is operating at slow speed the following actions take place. As the port 32 approaches the cut off position with relation to the opening 28 the first auxiliary port 54 begins to communicate with the opening 28 allowing additional compressed air to be added to the amount already in the cylinder 60 to maintain full compressed air pressure for a greater portion of the stroke than that outlined above for high speed operation. Continuing the slow speed operation as first auxiliary port 54 moves out of communication with the opening 28 the second auxiliary port comes into communication therewith so that pressure is at least partially maintained within the cylinder 60. Still further rotation of the motor in the clockwise direction moves the second auxiliary port out of communication with the opening 28, but at this time the third auxiliary port 58 comes into communication therewith to at least partially maintain the pressure within the cylinder 60. Thus, the auxiliary ports operate at low speed to increase the mean effective pressure of the motor 10 over that of prior art motors of comparable high speed efficiency.

While the above actions associated with slow speed operation are taking place within the cylinder 60, cylinders 61, 62, 63 and 64 are serially supplied with compressed air in the same manner with the same maintenance of pressure throughout a large portion of the downstroke of the piston and since each piston is effective through nearly one-half a turn of the crankshaft at least three of the pistons will at all times be applying torque to the crankshaft and, when the operation is slow enough for the above described maintenance of pressure, a very high torque will be applied to the crankshaft 12 as is necessary in many applications.

It is now possible to more specifically describe the advantages inherent in the device of this invention wherein: the angular size of the main intake port 32 is designed to give early cut off on the downstroke of the piston in high speed operation and the auxiliary ports 54, 56 and 58 are small enough to prevent any substantial amount of air entering the cylinder after main port cut off when the motor 10 is operating at high speed, thus giving the advantage of almost complete utilization of the energy of the compressed air and resulting in a low rate of air consumption per horsepower developed; for slow speed operation the size of the main inlet port 32 and the resultant early cut off would prevent the motor 10 from developing high torque necessary for good slow speed operation and the auxiliary ports 54, 56 and 58 are sized to allow the passage of enough air to substantially maintain the pressure of compressed air within the cylinder during a large part of the stroke of the piston; the auxiliary ports 54, 56 and 58 are also useful in providing for starting of the motor 10 from any position in which it has been stopped which again would not be possible with the main port 32 as the only source of compressed air for each cylinder. The use of multiple auxiliary ports gives smoothness of operation.

It is to be realized that the above description has been rather closely restricted to a particular compressed air motor 10 but that the principles of this invention are applicable to other types of motors and to motors having different numbers of cylinders and that the relative sizes of the main port and the trailing ports can be varied according to the desired relationship between high speed efficiency and low speed torque.

A preferred embodiment of this invention having been described and illustrated, it is to be realized that variations in the design and structure of the valve of this invention are envisioned. Therefore, it is respectfully requested that this invention be interpreted as broadly as possible and limited only by the prior art.

I claim:

1. In a compressed gas operated motor: a rotatably mounted crankshaft; a hollow cylindrical rotary inlet and exhaust valve rotatable in timed relationship to said crankshaft and in a given direction; a plurality of cylinders; fluid conducting passageways communicating between said valve and said cylinders respectively, a plurality of circumferentially spaced inlet ports in said valve, one of said ports being larger than any other of said ports by a ratio greater than 20 to 1 and the others of said ports being spaced rearwardly of said one port relative to said direction of rotation.

2. In a compressed gas operated motor; a rotatably mounted crankshaft; a hollow cylindrical valve coaxial with and secured to said crankshaft for rotation therewith in a given direction; a plurality of inlet ports in said rotary valve, one of said ports being larger than any other of said ports, said inlet ports having respective coplanar radial centerlines and being circumferentially spaced by the angles between pairs of said centerlines being greater than the number of degrees in the angular dimension of said one of said ports, said other ports being spaced rearwardly of said one of said ports relative to said given direction.

3. A compressed gas operated motor as defined in claim 2 wherein said one of said ports is larger than any other of said ports by a ratio greater than 20 to 1.

4. In a multi-cylinder compressed gas operated motor having a plurality of cylinders, a rotatably mounted crankshaft, a hollow cylindrical rotary inlet and exhaust valve rotatable in timed relationship to said crankshaft, fluid conducting passageways communicating between said valve and said cylinders respectively, the improvement comprising a plurality of inlet ports in said rotary valve, one of said inlet ports being larger than any other of said inlet ports, said inlet ports having centers on respective radial centerlines and being circumferentially spaced by angles between pairs of said centerlines greater than the number of degrees in the angular dimension of said one of said ports.

5. In a compressed gas operated motor: a rotatably mounted crankshaft; a hollow cylindrical inlet and exhaust valve coaxial with and secured to said crankshaft for rotation therewith in a given forward direction; a main inlet port, at least one intermediate inlet port and a final inlet port in said rotary valve, said main port being larger than any other of said inlet ports, said inlet ports having respective coplanar radial centerlines and being circumferentially spaced, said intermediate port and said final port being spaced rearwardly of said main port relative to said forward direction, and the one of said intermediate ports immediately adjacent said main port being spaced from said main port by an angle greater than the angular dimension of said main port, said angle being measured between the respective centerlines of said main port and said one intermediate port.

6. A compressed gas operated motor comprising; a motor housing; a plurality of cylinders within said housing; inlet means having compressed gas supplied thereto; exhaust means communicating with the ambient atmosphere; a fluid conducting passageway communicating with each of said cylinders; a rotatably mounted crankshaft; a hollow cylindrical valve coaxial with and secured to said crankshaft for rotation therewith in a given direction; a first passageway in said valve communicating with said inlet means; a second passageway in said valve communicating with said exhaust means; a plurality of inlet ports in said rotary valve intermittently establishing communication between respective ones of said fluid con-

