

[54] **ENGINES**

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[51] Int. Cl. **F02g 3/00**

[58] Field of Search..... 60/39.61, 39.63, 39.6, 60/468; 123/43 A; 91/6.5, 501

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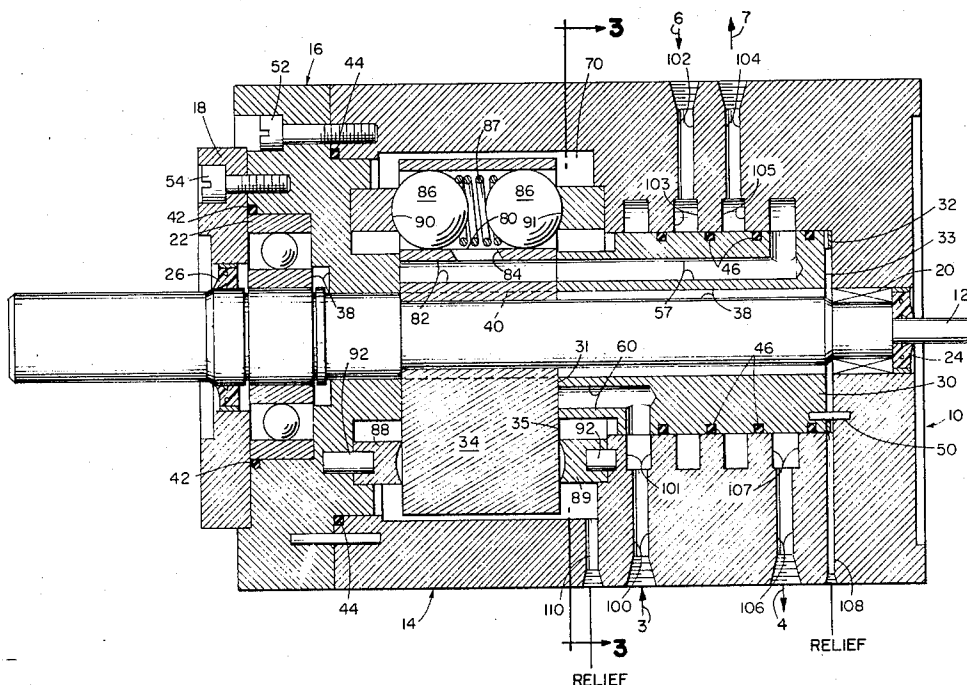
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ABSTRACT

An engine comprising a rotary piston support defining a piston bore, a porting surface and a conduit extending from the bore to the porting surface, a cam movable relative to the support and defining a generally annular cam surface of $2n$ cycles arranged in n sets each of two cycles, one cycle of each set being adjacent and having a displacement greater than that of the other cycle of the set, a piston mounted in the bore for movement relative to the support and engaging the cam surface, a manifold fixed with respect to the cam and defining at a porting surface thereof $4n$ ports arranged in n sets each of four conduits, each cycle having at least one manifold port associated therewith, a power chamber including means for increasing the internal energy of a gaseous fluid therein, and four conduits providing for, respectively, intake flow to the bore, flow from the bore to the chamber, and from the chamber to the bore, and for exhaust from the bore.

24 Claims, 6 Drawing Figures



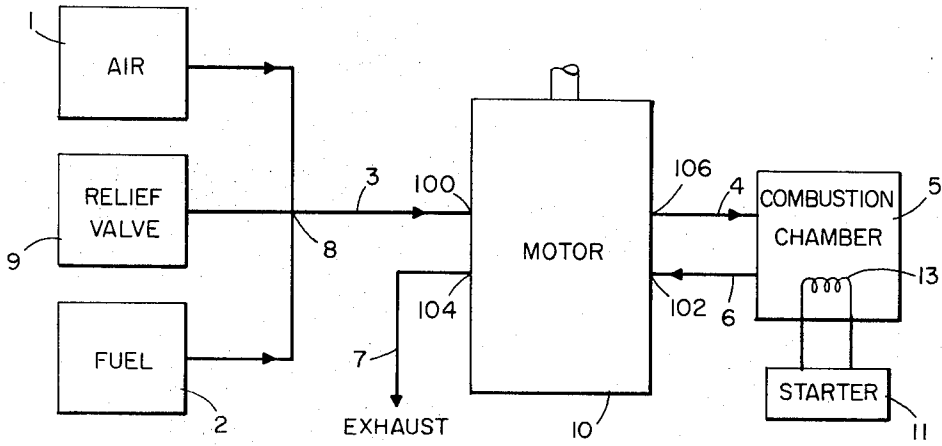


FIG. 1

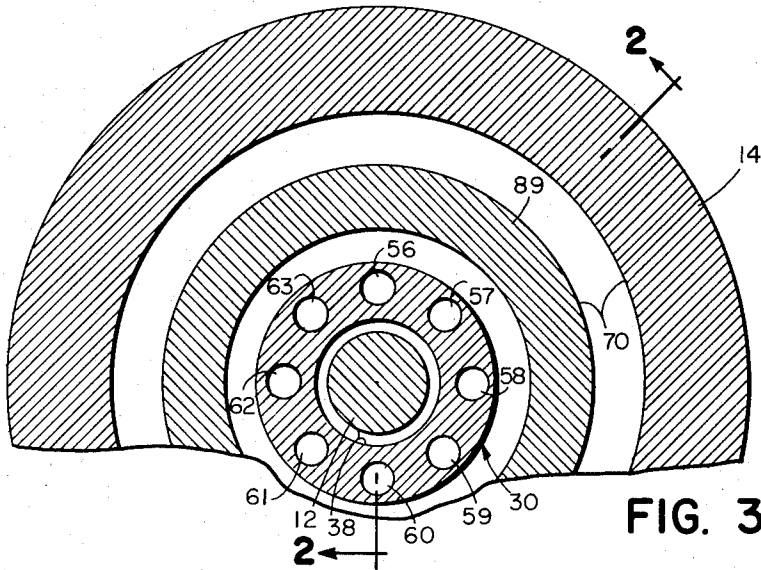


FIG. 3

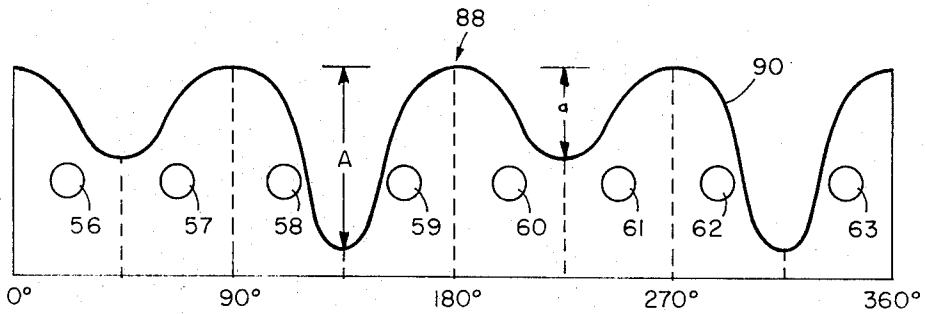
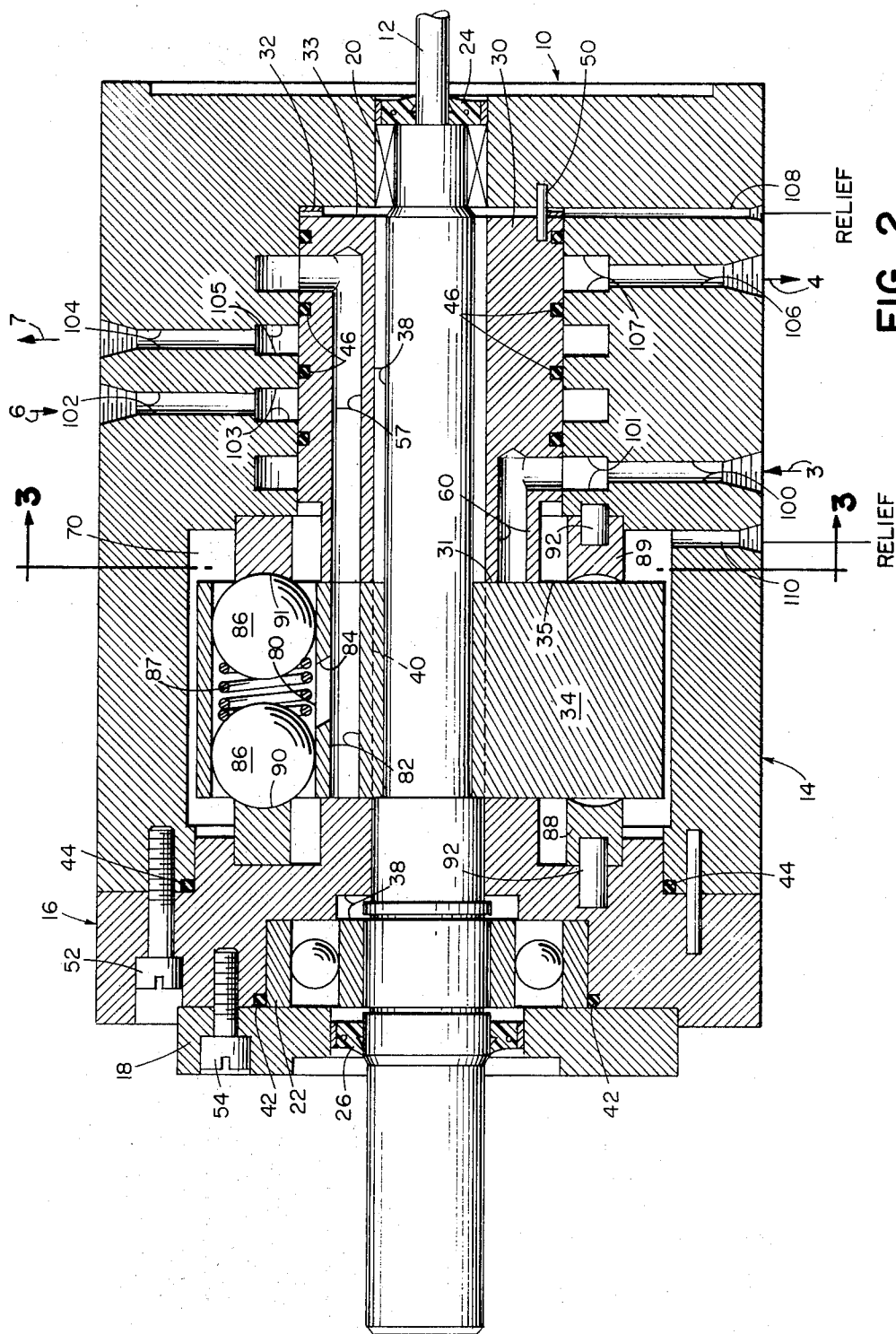
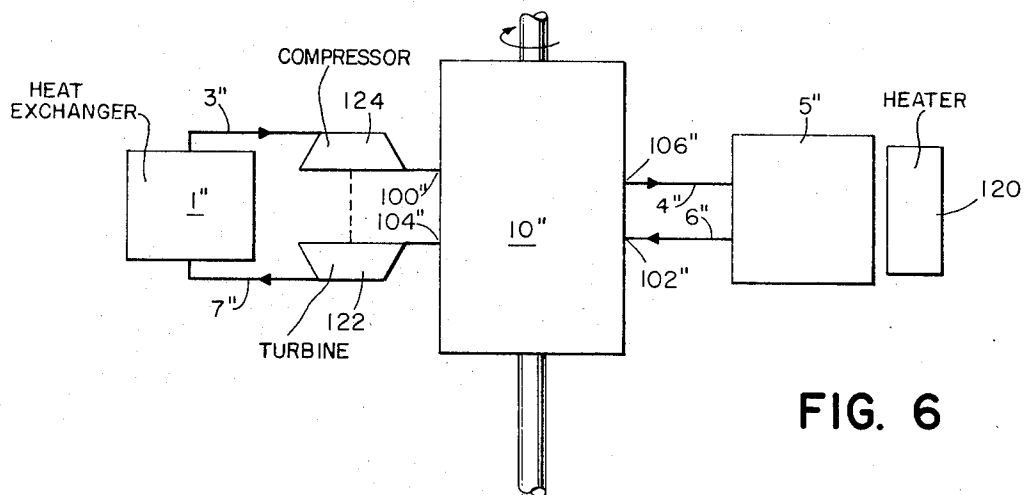
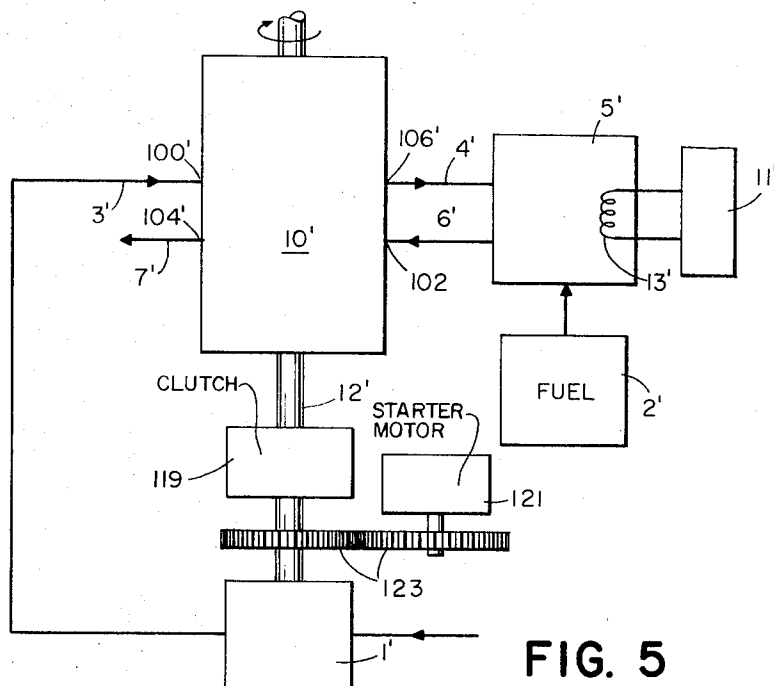


FIG. 4





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ENGINES

This invention relates to engines. This application is a continuation-in-part of my copending application Ser. No. 185,727, filed Oct. 1, 1971, entitled "Fluid Devices."

It is a principal object of the present invention to provide a compact and efficient rotary, reciprocating piston device that is the steady flow equivalent of a turbine. Other objects include providing such a device, having either axially or radially movable pistons, in which the pistons are alternately subjected to high and low temperature and alternately act as compressors and as greater displacement expanders.

The invention features an engine comprising a rotary piston support defining a piston bore, a porting surface and a conduit extending from the bore to the porting surface, a cam movable relative to the support and defining a generally annular cam surface of $2n$ cycles arranged in n sets each of two cycles, one cycle of each set being adjacent and having a displacement greater than that of the other cycle of the set, a piston mounted in the bore for movement relative to the support and engaging the cam surface, a manifold fixed with respect to the cam and defining at a porting surface thereof $4n$ ports arranged in n sets each of four conduits, each cycle having at least one manifold port associated therewith, a power chamber including means for increasing the internal energy of a gaseous fluid therein, and four conduits providing for, respectively, intake flow to the bore, flow from the bore to the chamber, and from the chamber to the bore, and for exhaust from the bore. In preferred embodiments wherein the amplitude of the one cycle of each set is in the range of 1.5 to 3.0 times that of the other cycle of the set, n is not less than 2, the cam cycles are alternately arranged, each half-cycle has a manifold port associated therewith, and each set of manifold ports is associated with a set of cam cycles and communicates with the conduits, there is featured a source of gaseous fluid connected to the inlet; a source of fuel connected to the power chamber or the inlet, or alternately, a heater for heating fluid in the power chamber, a plurality of axial bores in the piston support, a pair of pistons in each bore, a pair of identical, oppositely facing annular cam surfaces, one piston in each bore engaging each cam surface, and a compressor for compressing the fluid prior to it being drawn into the inlet.

Other objects, features, and advantages will become apparent from the following detailed disclosure of a preferred embodiment of the invention, taken together with the attached drawings, in which:

FIG. 1 is a schematic diagram of an engine system including a rotary motor and constructed in accordance with the present invention;

FIG. 2 is a longitudinal cross-sectional view of the rotary motor of FIG. 1, the section taken at 2—2 of FIG. 3;

FIG. 3 is a partial transverse cross-section of the rotary motor of FIG. 1, taken at 3—3 of FIG. 2;

FIG. 4 is a developed, somewhat diagrammatic view, of a cam of the rotary motor of FIG. 1; and,

FIGS. 5 and 6 are schematic diagrams of other engine systems constructed according to the present invention and including rotary motors similar to that of FIG. 1.

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Referring now to the drawings, there is shown in FIG. 1 an engine system including and driving a rotary motor 10 to which four flow lines, designated 3, 4, 6 and 7, are connected as described hereinafter. Air from an air source 1 and fuel from fuel source 2 are fed into motor 10 through line 3. A combustion chamber 5 is connected to the motor by lines 4 and 6; and line 7 provides an exhaust to the atmosphere. A pressure relief valve 9 is connected to line 3 at the junction 8 of the lines extending from sources 1, 2. A starter 11, including a conventional glow plug 13, is provided for igniting the air-fuel mixture in combustion chamber 5.

As shown in FIGS. 2 and 3, rotary motor 10 comprises an output shaft 12 extending coaxially through a multi-part housing including, in coaxial alignment, a cylindrical main housing 14, a cylindrical support housing section 16 and end plate 18. At one end of the housing, output shaft 12 is journaled within a roller bearing 20 (whose inner face engages the shaft periphery and whose outer face engages the inner wall of housing section 14); at the other end of the housing, shaft 12 is journaled within a ball bearing 22 (whose inner face engages the shaft periphery and whose outer face engages the inner wall of housing section 16). Rubber lip seals 24, 26 are provided intermediate and prevent leakage between shaft 12 and, respectively, housing section 14 and end plate 18.

A cylindrical fluid distribution manifold 30 and rotor 34 are mounted within annular cavities within main housing 14 and surrounding shaft 12. One axial face 35 of rotor 34 is in face-to-face engagement with the adjacent face 31 of manifold 30. A wave washer 32 engages the other axial face 33 of manifold 30 and the portion of main housing 14 defining the adjacent end wall of the cavity. Rotor 34 is fixed on shaft 12 for rotation therewith by spline 40.

The inner cylindrical surfaces of housing 14, manifold 30 and housing section 16 are of slightly greater diameter than are the portions of the outer peripheral surface of shaft 12 they respectively surround, thereby providing annular chamber 38 about the shaft. Communication between the portions of chamber 38 on opposite sides of rotor 34 is provided by interstitial passages of spline 40.

The various interfaces between parts of the motor, that is, the interfaces between end plate 18 and support section 16, the interface between support section 16 and main housing 14, and the interfaces between main housing 14 and manifold 30, are sealed with a plurality of O-rings designated 42, 44, and 46, respectively. Pins 50 and bolts 52 and 54 locate and prevent relative rotation of manifold 30 and housing 14, housing 14 and housing section 16, and end plate 18 and housing section 16, respectively.

Main housing 14 includes six drilled conduits, designated 100, 102, 104, 106, 108, and 110, respectively, extending through the wall of the main housing section. The outer portion of each conduit is tapped for receiving a coupling. As shown schematically in FIG. 1, conduit 100 is connected to inlet line 3, conduit 104 to exhaust line 7; and lines 4 and 6 are respectively connected to conduits 106 and 102. Relief lines (not shown) are connected to the outer ends of conduits 110 and 108.

A total of four, radially inwardly facing annular channels, 101, 103, 105, and 107 are provided in housing section 14 at the periphery of manifold 30. Each chan-

nel communicates, as shown, with the inner end of a respective one of conduits 100, 102, 104, and 106. The inner end of conduit 108 communicates with the annulus in which wave washer 32 is mounted; that of conduit 110 with the annular chamber 70 in which rotor 34 is mounted.

As shown most clearly in FIG. 3, a total of eight drilled conduits, 56 through 63, arranged in a ring and spaced at regular 45° intervals therearound, extend axially within manifold 30 from surface 31. Conduits 56 and 60 (see FIG. 2) extend axially to points opposite and thence radially to channel 101. Similarly conduits 57 and 61, 58 and 62, and 59 and 63 extend axially to points opposite and thence radially to, respectively, channels 107, 103, and 105.

Rotor 34 includes a total of nine cylindrical bores 80 and nine cylindrical conduits 82 (arranged in a ring within the rings of bores 80) extending axially through the full thickness of the rotor. The bores and conduits of each ring are evenly spaced about the circumference of the ring with one conduit 82 and one bore 80 from each of the two rings in radial alignment. The rings of conduits 82 of rotor 34 (which terminate in respective ports at surface 35) and of conduits 56-63 of manifold 30 (which terminate in respective ports at surface 31) are of equal diameter. A drilled conduit 84 extends from each conduit 82 to the bore 80 aligned therewith. Two steel balls 86, urged apart by a helical spring 87 are fitted within each of bores 80 for movement within the bore.

As shown, annular chamber 70, which is defined by adjacent surfaces of rotor 34, housing 14 and housing section 16, is of substantially U-shaped cross-section and surrounds the portion of rotor 34 including bores 80 and balls 86. Annular wave cams 88, 89 each including a respective circular undulating ball-engaging surface 90, 91 are mounted on opposite axial sides of rotor 34, coaxially therewith, with the ball-engaging surface 90, 91 of each cam facing rotor 34 and engaging one of the balls 86 in each bore 80. The ball-engaging surfaces, 90, 91 of cams 88, 89 are identical; each is a multi-cycle trapezoidal acceleration cam surface comprising alternating parabolic and intermediate fairing sections. The period of each cycle is 90° (that is each entire annular surface includes four complete cycles each having one high point or peak or one low point or valley), and the high points (peaks) of all cycles of each cam lie in a common plane. As shown diagrammatically in FIG. 4, the amplitudes (peak-to-valley distance) of adjacent cycles are not equal. Rather cam 88 (and cam 89 which is identical) includes two cycles of amplitude A and two cycles of amplitude *a*. The cycles are alternately arranged and the displacement of a cycle of amplitude A is 1.5 to 3.0 (as shown, 2.0) times that of amplitude *a*.

Each of cams 88 and 89 is positioned within motor 10 coaxially with shaft 12 and with the low point of an A amplitude cycle of the respective cam aligned midway between conduits 58 and 59. Pins 92 hold the cam in position.

Motor 10 is the equivalent of two independent "submotors" of different displacements mounted on the same shaft. One submotor, submotor "a," comprises those of balls 86 which are in contact with cam cycles of amplitude *a* and has a displacement of about 2.5 cu. in. per revolution of rotor 34. The other submotor, submotor "A," comprises the balls in contact with the A-

amplitude cam cycles and has a displacement of about 5 cu. in. per revolution. Submotor *a* is connected between motor intake conduit 100 and combustion chamber inlet conduit 106 and acts as a compressor; submotor A, connected between combustion chamber outlet conduit 102 and exhaust conduit 104, acts as an expander. As indicated in FIG. 4, which is a developed view of cam 88 with the ports of conduits 56-63 superposed thereupon to illustrate the segment of the cam with which each conduit is associated, each pair of balls 86 in any particular rotor bore 80 forms a part of submotor *a* during the approximately 90° of rotor rotation that the bore communicates with conduits 56, 57 of manifold 30, and during the approximately 90° period of communication with conduits 60, 61. During the respective 90° rotation periods of communication with conduits 58, 59, and with conduits 62, 63, the balls in the bore form a part of submotor A.

In operation, air from source 1 and a combustible fuel from source 2 are introduced into motor 10 through line 3 and intake conduit 100. Any of a large number of fuels may, of course, be used. The choice will depend on such features as cost, availability, pollution effect, and the like. The air-fuel mixture is drawn into the bores 80 of submotor *a* during the rotational periods that the bores are in communication with manifold conduits 56, 60, and is compressed by submotor *a* and discharged in compressed condition into combustion chamber 5 through line 4 and combustion chamber inlet conduit 106 during the rotational period that the bores communicate with manifold conduits 57, 61.

In chamber 5, the compressed mixture is combusted, and increases greatly in temperature and pressure.

Generally, combustion in chamber 5 is continuous, and glow plug 13 is used only to ignite the mixture during engine starting. The hot, high pressure gas is then discharged from chamber 5 through line 6 and into the bores 80 of submotor A that are in communication with ports 58, 62. The gas expands against the balls 86 in these bores, forcing the balls outwardly against cam surfaces 90, 91 and causing rotation of rotor 34. When the bores move into communication with ports 59, 63 the expanded gas is exhausted from motor 10 through conduit 104 and line 7.

As is thus evident, each of bores 80 and the two balls 86 therein defines a working chamber, the volume of which expands and contracts as rotor 34 rotates and the balls move in and out in contact with cam surfaces 90, 91. In the preferred embodiment, the ports of manifold conduits 56, 60 are arranged so that fluid will be drawn into each of the working chambers of submotor *a* during the entire period that its volume is expanding. That is, conduits 56, 60 communicate with the bores 80 during the entire period that the balls 86 in the bore are moving outwardly on a cycle of amplitude *a*. Similarly, the ports of manifold conduits 59, 63 are arranged so that fluid will be exhausted from the working chambers of submotor A during the entire period that their volume is decreasing; that is, during the period that the balls in bores are moving inwardly on a cycle of amplitude A.

For efficient operation, it is desirable that the working chambers of submotor *a* be closed during an initial period during which their volume is contracting (and thus compressing the fluid therein), and that they be open to combustion chamber 5 (to force the com-

pressed fluid into the combustion chamber) during the remaining period of volume contraction. Accordingly, the ports of manifold conduits 57, 61 are arranged so that they are closed by rotor end face 35 during the initial period that balls 86 are moving inwardly in contact with a cycle of amplitude a , and communicate with rotor conduits 82 during the remaining period that the balls are in contact with the amplitude a cycle.

Similarly, it is desirable for the working chambers of submotor A to be open to combustion chamber 5 (to permit flow of high temperature and pressure fluid into the working chambers) during an initial period that the volume of the chambers is expanding, and to be closed (to permit adiabatic expansion of the fluid) during the remaining period of volume expansion. The ports of manifold conduits 58, 62 accordingly are arranged so that they communicate with rotor bores 82 during the initial period that balls 86 are moving outwardly in contact with a cycle of amplitude A and are closed during the remaining period of ball contact with the A amplitude cycle.

The exact period during which these ports are open and closed depends on the desired working cycle of the engine. Typically, the ports of conduits 57, 61 will open to combustion chamber 5 when the fluid in submotor a has been compressed to about half its original volume and to a pressure equal to that in combustion chamber 5. The ports of conduits 58, 62 similarly will typically remain open to combustion chamber 5 until the submotor A working chamber has reached about half its maximum volume.

Reference is now made to FIG. 5 wherein is illustrated an engine system including and driving a motor 10', which is identical to motor 10. Those portions of the FIG. 5 system corresponding to portions of the system of FIGS. 1-4 are identified by the same numbers as their counterparts, with a differentiating prime (') added thereto.

As shown, the FIG. 5 system includes centrifugal air compressor 1' connected by line 3' to motor inlet conduit 100'; an exhaust line 7' extending from motor exhaust conduit 104'; and a combustion chamber 5; connected to motor conduits 102' and 106' by lines 6' and 4', respectively. Fuel from source 2' is sprayed directly into combustion chamber 5', rather than being mixed with air as in the FIG. 1 system. As in the previously described system, a starter 11' including a glow plug 13' is provided for igniting the fuel in combustion chamber 5'. An overdrive clutch 119 is mounted on motor shaft 12', which also is connected to and drives compressor 1'. For starting motor 10' a starting motor 121 drives shaft 12 through gears 123. The general operation of the FIG. 5 engine system is in substantially the same as that of the system of FIGS. 1-4.

FIG. 6 illustrates a heat engine system including and driving a motor 10''. As before, portions of the FIG. 6 system corresponding to portions of the FIGS. 1-4 system are identified by the same numbers with a differentiating double prime (') added thereto.

As shown, the FIG. 6 system includes a gaseous heat exchanger 1'' having its outlet connected by line 3'' to motor inlet conduit 100'' and its inlet connected by line 7'' to motor exhaust conduit 104''. A fluid heating chamber 5'' is connected to motor conduits 102'' and 106'' by lines 6'' and 4'', respectively. A heater 120, which may be powered by any fuel source, is provided closely adjacent chamber 5'' for heating the gaseous

fluid therein. As is evident, the system of FIG. 6 differs from the systems previously described in three major respects. First, there is no combustible fuel added to the gaseous fluid passed through motor 10''; second, since it is a closed loop system, helium may be used rather than air as the expansible fluid and, third, coupled turbine compressor 124 and expander 122 are provided in lines 3'' and 7'', respectively, to increase overall efficiency.

In operation, the gaseous fluid from heat exchanger 1'' is introduced into the motor through line 3'' and turbine compressor 124, drawn into the bores 80'' of submotor a where it is further compressed, and forced into chamber 5''. In chamber 5'', heat from source 120 is applied to the fluid, increasing its pressure and temperature. The high energy fluid is then discharged through line 6'' into the bores of submotor A, expands against the balls 86 in these bores, and is finally exhausted from the motor and back to heat exchanger 1'' through line 7'' and turbine expander 122.

Other embodiments within the scope of the following claims will occur to those skilled in the art.

What is claimed is:

1. An engine having an inlet port and an exhaust port and comprising:
 - a rotary piston support defining a piston bore, a porting surface, and a conduit extending from said bore to a port at said porting surface;
 - a cam defining a generally annular cam surface of $2n$ cycles, said cycles being arranged in n sets each of two cycles, one cycle of each set being adjacent and having a displacement greater than that of the other cycle of said each set, and said cam and said piston support being relatively rotatable;
 - a piston mounted in said bore for movement relative to said support and engaging said cam surface;
 - a manifold fixed with respect to said cam and having a porting surface engaging said support porting surface, said manifold porting surface defining a plurality of ports, each of said cycles having at least one of said manifold ports associated therewith, said manifold ports being arranged such that during the respective predetermined portions of the relative rotation of said manifold and said support that said piston engages each said cycle said port at said support porting surface communicates with said one manifold port associated with said each cycle, and said manifold and said support being relatively movable;
 - a power chamber including means for increasing the internal energy of a gaseous fluid therein;
 - a first conduit communicating with said inlet port and a first one of said manifold porting surface ports and providing for intake flow of fluid from said inlet port through said first one port to said bore;
 - a second conduit communicating with said power chamber and a second one of said manifold porting surface ports and providing for flow of fluid from said bore through said second one port to said power chamber;
 - a third conduit communicating with said power chamber and a third one of said manifold ports and providing for flow of fluid from said power chamber through said third one port to said bore; and,

a fourth conduit communicating with a fourth one of said manifold ports and said exhaust port and providing for exhaust of fluid from said bore through said fourth one port to said exhaust port.

2. The engine of claim 1 wherein said manifold porting surface defines $4n$ ports arranged in n sets each including four ports, and each of said manifold ports is associated with a respective predetermined half-one of said cycles and is arranged to communicate with said port of said support during the period of relative rotation of said support and said cam that said piston engages said respective predetermined half-one.

3. The engine of claim 2 wherein each manifold port of each set of said manifold ports communicates with a respective one of said first, second, third, and fourth conduits.

4. The engine of claim 3 wherein each set of said manifold ports is associated with a respective set of said cycles and communicates with said port of said support when said piston engages said respective set.

5. The engine of claim 1 wherein the displacement of said one cycle is in the range of 1.5 to 3.0 times the displacement of said other cycle.

6. The engine of claim 1 including a source of compressible fluid connected to said inlet port and means for increasing the internal energy of fluid in said chamber, whereby, in response to relative rotation of said cam and support, fluid from said source is drawn into and compressed in said bore, discharged in compressed condition into said chamber, and thereafter increased in internal energy and discharged from said chamber.

7. The engine of claim 6 wherein said fluid is a combustion supporting fluid and including a source of combustible fuel and means for intermixing fuel from said source with said fluid and for combusting said mixed fuel and fluid in said chamber prior to discharge of the same from said chamber.

8. The engine of claim 7 wherein said means includes an ignitor.

9. The engine of claim 7 wherein said fuel source is connected to said inlet port whereby said mixed fuel and fluid are drawn into said inlet port.

10. The engine of claim 7 wherein said fuel source is connected to said chamber and including means for injecting said fuel into said chamber.

11. The engine of claim 6 wherein said means for increasing said internal energy includes a heater for non-combustively heating fluid within said chamber.

12. The engine of claim 6 including a compressor intermediate said fluid source and said inlet port for compressing fluid from said source prior to said fluid being drawn into said inlet port.

13. The engine of claim 12 including an expander connected to said exhaust port and arranged to be driven by fluid from said exhaust port, said expander being coupled to and driving said compressor.

14. The engine of claim 1 wherein said support includes a plurality of piston bores and a conduit extending from each of said bores to a respective port at said support porting surface, each of said respective ports being arranged successively to communicate with said manifold ports during relative rotation of said support and said manifold, and a piston is mounted in each of said bores for movement therein in engagement with said cam surface.

15. The engine of claim 14 wherein n is not less than 2 and the displacement of each cycle of one set is equal to the displacement of a respective cycle of each of the others of said sets.

16. The engine of claim 15 wherein the displacement of said one cycle is in the range of 1.5 to 3.0 times the displacement of said other cycle.

17. The engine of claim 14 wherein said manifold porting surface defines $4n$ ports arranged in n sets each of four ports, each set of said cycles is associated with a respective one of said sets of manifold ports, and each of said pistons engages said each set of said cycles during the portion of relative rotation of said support and said cam that said port of said conduit associated with said each piston communicates with the manifold ports of said respective one of said sets of manifold ports.

18. The engine of claim 17 including a second cam identical to said first-mentioned cam, and a second piston mounted in each of said bores for movement therein in engagement with said second cam, each of said cams being fixed with respect to said manifold with corresponding cycles thereof in axial alignment with each other.

19. The engine of claim 17 wherein each of said piston bores and the piston therein provides a working chamber the volume of which changes during rotation of said rotor relative to said cam with said piston in contact with said cam, and

each port of said manifold communicating with said second conduit and the respective rotor port associated with said each bore are arranged such that flow therebetween is prevented during an initial portion of the period of said rotation that the volume of said working chamber is contracting with said piston in contact with a said other cycle and that flow therebetween is permitted during a remaining portion of said period.

20. The engine of claim 17 wherein each of said piston bores and the piston therein provides a working chamber the volume of which changes during rotation of said rotor relative to said cam with said piston in contact with said cam, and

each port of said manifold communicating with said third conduit and the respective rotor port associated with said each bore are arranged such that flow therebetween is permitted during an initial portion of the period of said rotation that the volume of said working chamber is expanding with said piston in contact with a said one cycle and that flow therebetween is prevented during a remaining portion of said period.

21. The engine of claim 20 wherein said initial period commences when said volume begins to expand and ends when said volume reaches about one-half its maximum volume.

22. The engine of claim 21 wherein each port of said manifold communicating with said second conduit and the respective rotor port associated with said each bore are arranged such that flow therebetween is prevented during the portion of said rotation with said piston in contact with a said other cycle commencing where said volume begins to contract and ending when said volume is about one-half the volume at such beginning, and that such flow is permitted during the remaining portion of said rotation with said piston in contact with said other cycle.

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23. The engine of claim 22 wherein each port of said manifold communicating with said first conduit and the respective rotor port associated with said each bore are arranged such that flow therebetween is permitted substantially throughout the portion of said rotation with said piston in contact with a said other cycle that said volume is expanding.

24. The engine of claim 23 wherein each port of said

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manifold communicating with said fourth conduit and the respective rotor port associated with said each bore are arranged such that flow therebetween is permitted substantially throughout the portion of said rotation with said piston in contact with a said one cycle that said volume is contracting.

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