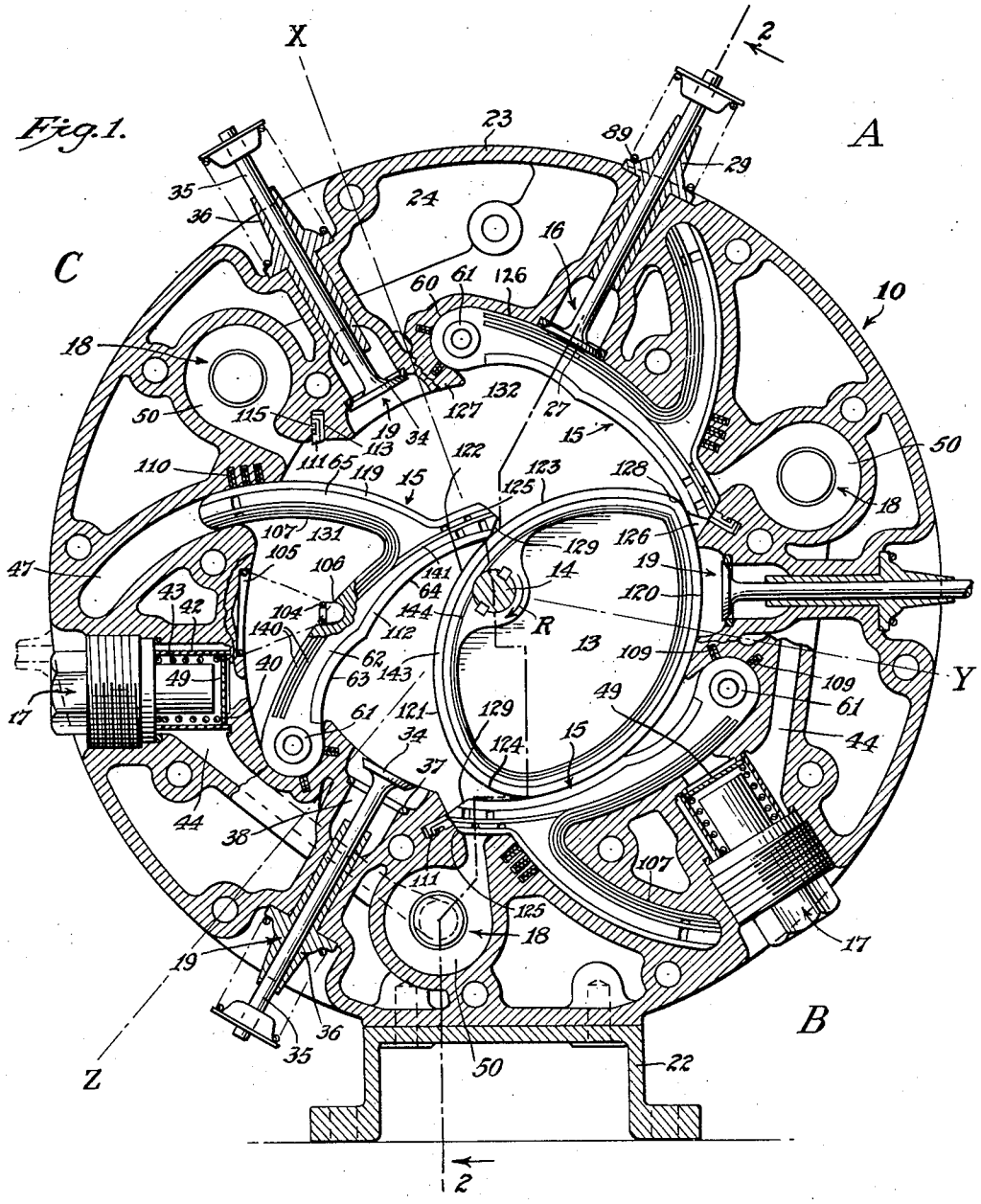
March 14, 1950 J. N. HINCKLEY 2,500,458

ROTARY INTERNAL-COMBUSTION ENGINE

Filed July 25, 1946 3 Sheets-Sheet 1

Fig. 1.



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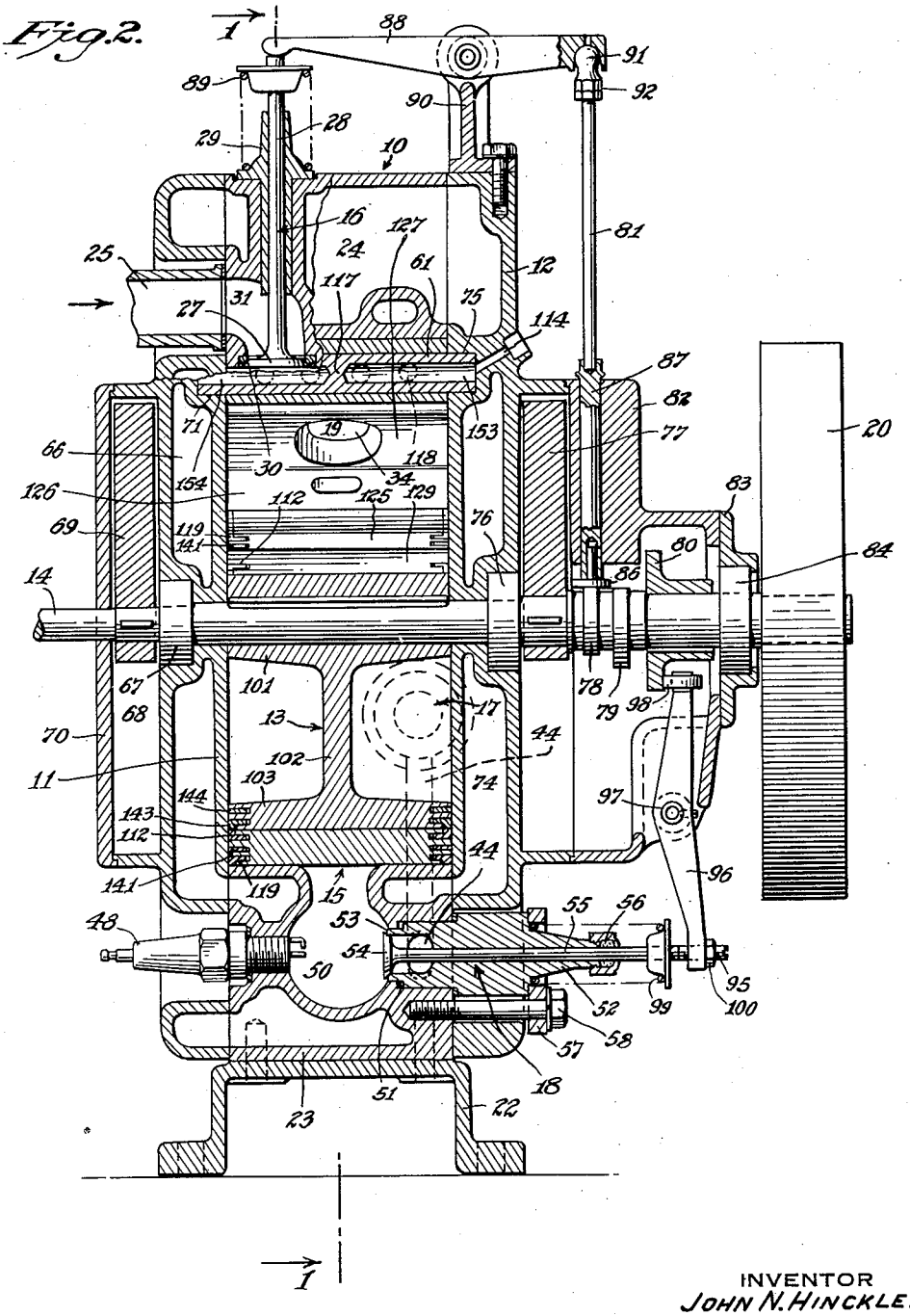
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ROTARY INTERNAL-COMBUSTION ENGINE

Filed July 25, 1946 3 Sheets-Sheet 2

Fig. 2.



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ROTARY INTERNAL-COMBUSTION ENGINE

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Fig. 3.

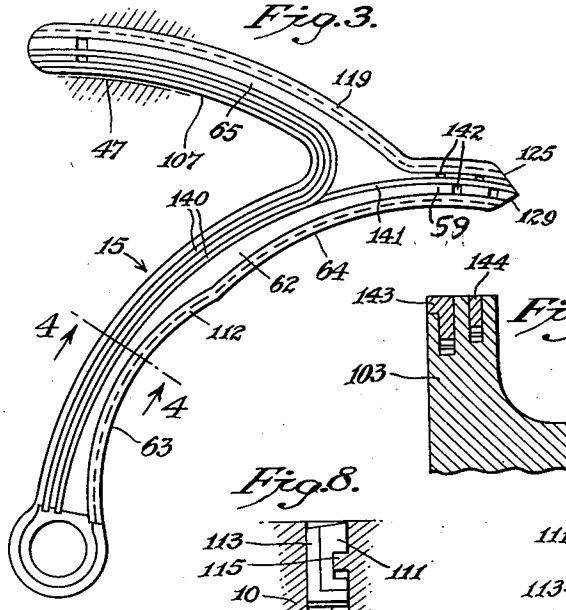


Fig. 4.

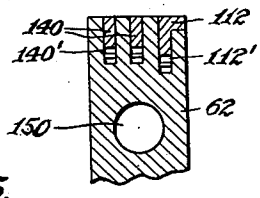


Fig. 5.

Fig. 8.

Fig. 6.

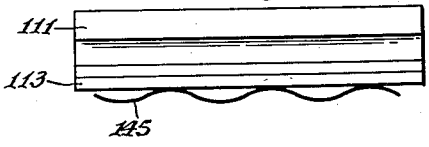
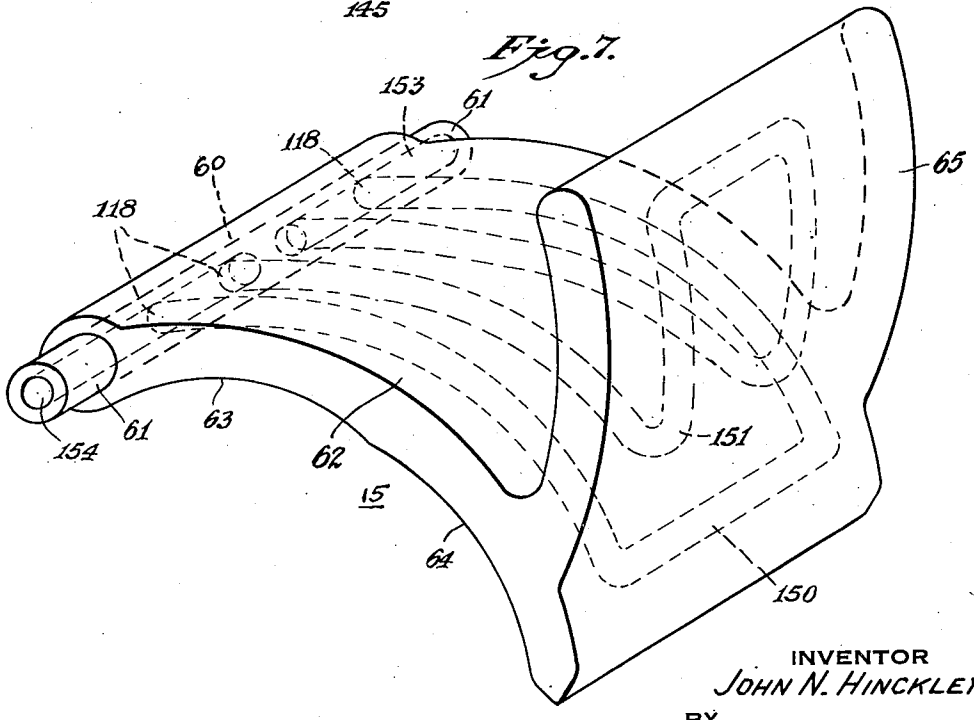


Fig. 7.



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Patented Mar. 14, 1950 2,500,458

UNITED STATES PATENT OFFICE

2,500,458

ROTARY INTERNAL-COMBUSTION ENGINE

John N. Hinckley, Belmont, Mass.

Application July 25, 1946, Serial No. 686,223

8 Claims. (Cl. 123—15)

1

This invention relates to internal combustion engines of the rotary type, such as disclosed in Hinckley and Clark Patent No. 2,060,937, patented November 17, 1936, although some features are not necessarily limited to such use.

The prior patent discloses a rotary engine made up of a plurality of short cylinders, each of which comprises a cylindrical casing with a cam-shaped rotor disposed therein; the casing has pivoted at its cylindrical wall two arms bearing upon the drum surface of the rotor. Each arm has a backwardly extending sector blade or horn which separates the expansion chamber from the compression chamber; each arm also has a blade portion riding on the rotor and sealing the combustion chamber at proper times. The admission of gas and the disposal of exhaust is accomplished by suitable valves located around the periphery of the casing. In general, inward movement of the arms caused by an explosion of gas draws fresh gas into the separate compression chambers while the outward movement of the arms compresses this fresh gas, after which the compressed gas is led through suitable valves to another and separate cylinder where the combustion chamber of an appropriate arm is ready to receive it. After the gas is exploded, pushing the arm inwardly and exerting pressure on the blade end of the arm and the rotor, an exhaust valve opens and further movement of the rotor scavenges the expansion chamber.

The present invention eliminates the transfer of compressed gas from one cylinder to another and makes each cylinder a complete operating unit in itself; it provides for three or more arms in each cylinder. Gas compressed in the combustion chamber of any arm is fed back to the combustion chamber of the immediately preceding arm which is ready for the explosion event. The present invention also provides for greater efficiency, smoother operation, simpler construction, improved sealing, lubrication, cooling, and valve action.

The invention also consists in certain new and original features and combinations hereinafter set forth and claimed.

Although the novel features which are believed to be characteristic of this invention will be particularly pointed out in the claims appended hereto, the invention itself, as to its objects and advantages, and the manner in which it may be carried out, may be better understood by referring to the following description taken in connection with the accompanying drawings forming a part hereof, in which

Fig. 1 is a section taken radially through the motor on the line 1—1 of Fig. 2, the section being irregular to show different details of construction in the various parts of the motor;

Fig. 2 is an irregular section on the line 2—2

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of Fig. 1 taken to illustrate different parts of the motor;

Fig. 3 is an edge view of one of the arms illustrating the sealing strips;

Fig. 4 is a section on the line 4—4 of Fig. 3 through the main stem of the arm;

Fig. 5 is a detailed section through the edge of the rotor to illustrate the sealing strips;

Fig. 6 is a longitudinal view of the combustion chamber sealing strips of Fig. 5 illustrating the wavy spring;

Fig. 7 is an isometric view of an arm to illustrate the cooling passages, the sealing strips being omitted for simplicity of illustration; and

Fig. 8 is a section through the seal for the combustion chamber.

In the following description and in the claims, various details will be identified by specific names for convenience, but they are intended to be as generic in their application as the art will permit.

Like reference characters denote like parts in the several figures of the drawings.

In the drawings accompanying and forming part of this specification, certain specific disclosure of the invention is made for purposes of explanation, but it will be understood that the details may be modified in various respects without departure from the broad aspect of the invention.

Referring now to the drawings, the motor is made up, generally, of a case comprising a cylinder block 10 having removable heads 11 and 12 enclosing a rotor chamber containing a cam-shaped rotor 13 mounted on main shaft 14 which is journaled in the heads. Overhanging on shaft 14 is an output element 20 which may be either a pulley or gear and which may also act as a flywheel. Journaled at the peripheral wall of the rotor chamber are three arms 15 bearing against the cam surface of the rotor 13. Suitable valves control the events, including intake valve 16 which controls the flow of fresh combustible gas mixture into the compression chamber; spring pressed automatic discharge valve 17 which controls entry of the compressed gas into the compression conduit; inlet valve 18 which controls entry of gas into combustion chamber, and exhaust valve 19.

The motor is shown for purposes of illustration as comprising three sections A, B and C (shown for convenience as divided by radial lines X, Y, Z) each one of which is subjected to a complete thermo-dynamic cycle. Since the parts of each section A, B and C are identical in construction, the same reference characters will be used in the several sections, and since the several sections are shown at various points in their thermodynamic cycles, they will also be used to illustrate the several events of a single section.

In general, as the rotor 13 rotates in the direction of the arrow R, the cam surface thereof

causes the several arms 15 to reciprocate back and forth. The movement of these arms, together with appropriate movement of the several valves, causes fresh gas to be drawn into the motor, the gas then to be compressed, exploded, expanded and exhausted at proper times.

Although three sections are shown for purposes of illustration, it will be understood that any multiple of three may be used. The three section form shown provides a power impulse at each 120° of revolution of the motor shaft and thus is similar in this respect to a conventional six cylinder internal combustion engine.

The case block 10 is shown as a one piece casting although it may be cast in sections separable along radial lines and suitably bolted together. It comprises an outer circumferential wall 23 having a suitable water jacket space indicated in general by 24 cast therein. This jacket space 24 communicates with jacket spaces cast in the heads and surrounds all critical parts of the case so as to provide proper cooling action. Suitable inlet and outlet passages are provided in the heads or block or in all three members for circulating the coolant. The cast block 10 is shown resting on a cast base 22 to which it is suitably bolted.

Secured to the block 10 is an intake manifold 25 leading to the several intake valves 16. The intake manifold 25 communicates with a suitable carburetor (not shown) for mixing air with the fuel gas which may be gasoline or illuminating gas, for example. The exhaust valves 19 are shown leading directly to atmosphere although it will be understood a suitable exhaust manifold may be provided for disposal of exhaust gases.

The block 10 is provided with passages 31 communicating with the intake manifold 25 and with the interior of the case. Each passage 31 has a seat 30 for the valve disc 27. Disc 27 has stem 28 slidable in a sleeve 29 suitably secured to the casting.

Suitably formed in the block 10 are exhaust passages 38 having seats 37 for the discs 34 of exhaust valves 19. The valve has a stem 35 slidable in sleeve 36 which is suitably secured to the casting.

The block 10 has seats 40 for automatic discharge valves 17. Seating against seat 40 is disc 49 slidable in sleeve 42 which is suitably affixed to the casting. Spring 43 normally urges the valve into closed position. Sleeve 42 has openings leading to compression passages 44 to convey compressed gas mixture to the combustion chamber as discussed below.

Compression passages 44 are cast into block 10 and lead from the automatic discharge valves 17 to inlet valves 18 of the preceding section; that is to say, from the automatic discharge valve 17 of section C, for example, to the inlet valve 18 of section B.

Case block 10 also has horn recesses 47, each recess being laid out with its corresponding wrist pin 61 as a center. These recesses are for the horns 65 of the several arms 15 for a purpose explained hereinafter.

Case block 10 also has seats for suitable spark plugs 48 which project into combustion chambers 50 opposite the gas inlet points controlled by the inlet valves 18.

The inlet valves 18 each comprises a valve housing 52 seated in a recess 51 in the block 10 opposite the spark plug 48. The valve housing 52 has a seat 53 for valve disc 54 having stem 55 which is slidably mounted in the valve housing

52. The passage of stem 55 through the valve housing 52 is sealed by a suitable gland 56 and the valve housing 52 is held in position by a hold-down ring 57 suitably bolted to the block 10, one of the bolts being indicated by 58.

Each arm 15 has a bearing portion 60 journaled on a hollow wrist pin 61 and a blade portion 62 having double curvature 63, 64 for special cooperation with the cam surface on rotor 13 as explained hereinafter. Projecting outwardly from the blade 62 is the horn 65 which reciprocates in the horn space 47.

As stated above, the heads 11 and 12 are detachably bolted to the block 10. Referring first to back head 11, this head is of generally flat or disc formation and has a water jacket space 66 communicating with the jacket space in the block. It has a shaft bearing 67 for the main shaft 14 and a recess 68 for the counter-weight 69 keyed to shaft 14. A detachable cover plate 70 closes the recess 68. The back head 11 has space for spark plugs 48 and for intake manifold 25. Back head 11 also has recesses 71 for the wrist pins 61.

The front head 12 is also bolted to the block and is generally plate or disc shaped. It has water jacket space 74 communicating with the water jacket on the block. It has a bearing 76 for main shaft 14 and seats 75 for wrist pins 61. It has a recess for counterweight 77 suitably keyed to main shaft 14.

The counterweights 69, 77 counter-balance rotor 13 to place the rotating parts in static and dynamic balance, thus minimizing need for a flywheel.

It will be noted that each section A, B, C is controlled by four valves, three of which are positively operated poppet valves and the other is an automatically spring operated check valve. A valve rigging is provided for operating the positively operated poppet valves. This valve rigging comprises two drum cams 78 and 79 affixed to the main shaft 14 and a face cam 80 keyed to main shaft 14. Drum cams 78, 79 are for the intake valves 16 and exhaust valves 19; face cam 80 is for inlet valves 18.

The valve rigging also comprises tappet housing 82 suitably bolted to the front head 12 and having a detachable outer plate 83. Plate 83 has a shaft bearing 84 for shaft 14 which supports the power transmitting gear or pulley 20 in overhanging relation.

The drum cams 78 and 79 each operate three radially extending tappets, only one of which (81) is disclosed for purposes of illustration and that operating intake valve 16. The radial tappet 81 comprises a mushroom follower 86 secured to slide 87 which is slidable in the housing 82. The tappet 81 operates a rocker arm 88 fulcrumed on a bracket 90 secured to the front head 12. Rocker arm 88 abuts valve stem 28 to open the valve 16 against the tension of valve spring 89. Valve tappet 81 engages rocker arm 88 through a ball-socket joint 91 and has a suitable adjustment 92 for adjusting valve clearance, as will be understood.

It will be understood that, as the main shaft 14 rotates, suitable rise on cam 78 will raise the tappets 81 to open the several intake valves 16 at the proper times. Similarly, rise on drum cam 79 will operate similar tappets to open the several exhaust valves 19 at the proper times.

The face cam 80 for operating the axially extending inlet valves 18 drives a plurality of roller followers 98, one for each inlet valve, each roller

98 being journaled on a rocker arm 96. The three rocker arms 96 are each fulcrumed on a shaft 97 seated in the tappet housing 82. Each rocker arm 96 has a tappet 95 which engages the valve stem 55 to open the inlet valve 18 against the pressure of valve spring 99. A lock nut 100 locks the adjustable tappet 95 in adjusted position after tappet is adjusted to give proper valve clearance, as will be understood by those skilled in the art.

As the shaft 14 rotates, a rise on face cam 80 operates the three follower rolls 98 to open the three inlet valves 18 at proper times.

The rotor 13 comprises a hub 101 suitably keyed to the main shaft 14, a web 102 and a drum 103 having a specially shaped cam surface which cooperates with the internal surface of the block and the inner surfaces of the arms 15 as discussed below. Each arm has a conical spring 104 seated in a recessed seat 105 in the block and in a seat 106 in the arm to insure holding the arms against the rotor.

The moving parts are suitably lubricated and sealed against the gas pressures. The arm hubs 60 are sealed by a plurality of spring-pressed flat strips 109 seated in grooves in the block and bearing against the cylindrical surface on the hubs 60. Similarly, the outer surfaces of the horns 65 are sealed by a plurality of flat strips 110 seated in suitable grooves in the block. It will be noted that only the outer surfaces of the horns 65 remote from the wrist pins 61 are sealed and that there is a slight clearance between the near surface 107 of the horns 65 and the walls of the horn recess 47 (see Fig. 3).

The edges of the arms (Figs. 3–6) are sealed by sealing strips 112, 119, 140 and 141 which resiliently bear against the flat walls of the end heads. The strips 140 and 141 are of flat stock and seat in corresponding grooves in the arm as indicated by 140' in Fig. 4. The strips 112 and 119 are of angular cross section and seat in correspondingly shaped slots, as indicated by 112' in Fig. 4.

The two flat strips 140 follow the stem 62 of the arm and the horn 65 as indicated in Fig. 3. The flat strip 141 connects the flat strips 140 just mentioned and follows the end 59 of the arm. The angular strip 112 follows the stem and end of the arm. The angular strip 119 follows the horn and end of the arm. Additional seals indicated in general by 142 may be placed in the walls between the several strips.

The edge of the rotor drum 103 (Fig. 5) has a flat stock sealing ring 144 and an angular sealing ring 143 both following the periphery of the drum 103 and extending entirely around the rotor. These are seated in correspondingly shaped recesses and bear against the flat surfaces of the casing heads.

It will be understood that all of the several sealing strips have wavy spring strips seated in the bottom of their respective grooves for yieldably urging these strips against their cooperating surfaces to provide efficient sealing. The wavy spring is illustrated at 145 in Fig. 6 which illustrates the seal for the explosion chamber 50.

The seal for the combustion chamber 50 (see also Fig. 8) comprises a channel shaped strip 111 and an L-shaped strip 113 cooperating with a projection 115 on the casing to limit the outward movement of the combustion chamber seal under action of its wavy spring. The tip bevels 125 on the arms 15 seat against these seals 111, 113.

The motor may, of course, be lubricated by mixing lubricating oil with the gasoline or otherwise introducing it into the gaseous mixture fed into the intake manifold 25 in a manner similar to the lubrication of certain well-known two cycle engines used, for example, for outboard motors for boats. However, the motor may have a positive lubrication system which may be used either alone or in conjunction with a lubrication system depending upon mixing lubricating oil with fuel.

The positive lubricating system comprises a plurality of oil feed ducts 114 in head 12 leading to the three hollow wrist pins 61. Similar oil ducts (not shown) in head 11 lead from the wrist pins 61 so that constant oil circulation may be provided. The wrist pins are drilled only part way through, providing a partition 117 separating the axial hole into inlet and outlet ends 153 and 154 having suitable radial openings 118. Openings 118 lead oil to the bearing surface between arm bearing 69 and wrist pin 61 which is fast in heads 11, 12; they also communicate with cooling ducts 150, 151 (Fig. 7) opening into the said bearing surface and extending through the length and breadth of the arms and horns.

These cooling ducts may have any suitable arrangement but in general one duct 150 leads from one axial end 153 of the wrist pin, lengthwise of the arm, across the tip of the arm back the other side to the other axial end 154 of the wrist pin. A second duct 151 passes from one axial end 153 down the blade of the arm and into the horn 65, across the end of the horn and back to the other axial end 154. These cooling and lubricating passages may have suitable filamentary connections (not shown) with the several sealing strips and with the arm bevel 129 for lubricating the areas of contact of the arms with the case and rotor.

Operation

It will be noted that the rotor 13 has a high portion or dwell 120 of substantially constant radius extending through an angle of approximately 120°. The remaining 240° comprises a rise 121 leading from the dwell 120 to low point 122 of the cam and a fall 123 leading from low point 122 to the dwell 120 of the cam. The outer curved portion 64 of the arms 15 cooperates with the dwell 120 of the cam, as shown at arm of B, while the inner curvature 63 on the arms cooperates with the nose 124 of the rotor cam during part of compression.

The tip of the arms 15 has a bevel surface 125 which cooperates with the tip seal 111 to seal the arm against the casing as illustrated in the position B of the arm. This closes the passage connecting with combustion chamber 50. The block has recesses 126 adjacent the intake valves 16 to house the arms when in outermost position while it has projecting portions 127 adjacent the exhaust valves 19 laid out on a radius equivalent to the maximum radius of the rotor.

In operation, as the rotor rotates in the direction of the arrow R, it causes the three arms 15 to execute an oscillating movement, the arms occupying an innermost position when engaging the low point 122 of the cam (near position C) from whence the arm rides up on the rise 121 of the cam until it occupies an outermost position, as shown in position B. Continued rotation of the rotor causes dwell 120 to hold the arm in substantially this outermost position until the tip 128 of rotor reaches the tip of the arm (near

position A) when the arm rides down on the fall 123 of the rotor to the lowermost position 122 (near position C).

It will be understood that each arm 15 forms part of a section which goes through a complete thermo-dynamic cycle. Each arm 15 has four valves associated with it. Intake radial valve 16 passes fresh gas drawn from the supply into the compression chamber 131. Automatic discharge valve 17 passes compressed gas from the compression chamber 131 through compression passage 44 to the inlet valve 18 of the next preceding section. Inlet valve 18 admits compressed gas to the combustion chamber 50 which gas is led to the expansion chamber 132, doing work against the arm 15 and against the rotor 13 until the gas reaches the end of its expansion, at which time the exhaust valve 19 opens, passing inert or burnt gas from the expansion chamber 132 to exhaust.

The three arm type turbo-motor as shown is equivalent to a conventional six cylinder reciprocating internal combustion engine using the Otto cycle. Each section A, B, C, fires once each revolution giving a power impulse every 120° of straight drive shaft rotation. The cycle of the present invention differs from the Otto cycle in that the gas is compressed on one side of the arm and exploded and expanded on the other side of the arm, which has certain advantages discussed below.

Each section A, B, C, goes through an identical cycle so only one cycle will be traced. However, the cycle of each section is not complete in itself but each section receives compressed gas from the next preceding section. Since the different arms 15 are shown at different points in their cycles, these arms will be used to illustrate the several events of a single cycle.

It will be noted that rise 121 pushes the arms outwardly for compression while fall 123, down which the arms ride, provides the pushing surface propelling the rotor during expansion.

It should be noted that rise 121 and fall 123 are independent so that various rates of compression and rates of expansion can be obtained as required by different octane fuel ratings.

It will be noted that section A is in a position where gas may already have been ignited and is almost ready to start its expansion cycle. As the arm of A moves inwardly (under force of expansion in combustion chamber 50) it will draw gas into the compression chamber 131. Section B is shown scavenging exhaust gas through its exhaust valve 19 and has just compressed gas in its compression chamber for use of section A. Arm of C is shown in the position of almost completing its expansion cycle and almost completing the drawing of fresh gas into its compression chamber 131.

As the rotor 13 revolves clockwise in the direction of arrow R, arm of A will follow the rotor under the impetus of an explosion in its combustion chamber 50 and draw fresh gas through intake valve 16 into compression chamber 131. After the arm of A reaches its innermost position, the intake valve 16 of A closes.

As the rotor continues to rotate, arm of A is forced back to its outer position which compresses the mixture in its compression chamber 131 and forces it through automatic discharge valve 17 and through compression duct 44 to the combustion chamber 50 of section C. The combustion chamber inlet valve 18 of section A is closed approximately 30° before the tip 128 of the rotor reaches the end of the compression arm of A. Ignition takes place by the spark plug 48 of A firing approximately 7 to 15° before the tip 128 of the rotor passes the end of the arm of A.

As the tip 128 of the rotor passes beyond the end of arm A, the force of the expansion in combustion chamber 50 acting upon the area of the arm and upon the area of the rotor, forces the arm to follow the rotor.

The exhaust function takes place by the forward surface 121 of the rotor sweeping before it the burnt gases out of the expansion chamber through the exhaust valve 19. As arm of A begins its inward movement, section C is almost ready for its exhaust valve 19 to open, the exhaust valve opening when the tip 128 of the rotor passes about 50° past the tip of arm of section A, thus providing overlapping expansions (of sections C and A) simultaneously on the rotor. Inlet valve 18 of section C may open just before arm of C seals against seal 111 to help scavenge combustion chamber and expansion chamber of C. The exhaust valve closes when the exhaust chamber volume becomes substantially zero.

Thus an internal combustion engine has been described which has a minimum of rotating and reciprocating parts. The simple oscillating arms acting on the rotor perform all of the functions of pistons, connecting rods, and bent up crank shafts of the conventional engine. There is less vibration, the drive shaft is straight and may be carried on ball or roller bearings. The one-rotor, three-arm motor fires as often as a conventional six cylinder engine with its six pistons, six connecting rods, six cranks, etc.

The compression, combustion and expansion chambers are separate. This permits utilization of expansion to a much lower pressure and temperature thereby appreciably increasing the thermal efficiency. Expansion is not restricted by limitation of the compression ratio. The compression ratio may be made suitable for Diesel requirements. The expansion ratio may be greater than the compression ratio as in the Atkinson cycle. The expansion ratio may be double the compression ratio.

Due to the construction of the present turbo-motor, the efficiency of the Atkinson cycle may be obtained with the simplicity of Otto or Diesel cycles construction. Due to the greater expansion and consequently lower temperature, there is less heat flow from the combustion and expansion chambers to the water jacket.

The ideal cold spherical combustion chamber entirely contained in one casting is obtained. Firing is so controlled that the combustion is complete before the arm opens and releases the hot gases from the combustion chamber into the expansion chamber. The combustion chamber provides for maximum turbulence, thus minimizing detonation. It is completely surrounded by water and has only one valve, which is cooled by each incoming charge.

Improved scavenging is obtained. The inlet poppet valve may be opened slightly before the arm seals the combustion chamber, thus expelling burnt gases. After the gases in the expansion chamber have expanded to from nine to twelve times their original volume and are near atmospheric pressure, the exhaust valve opens and remains open until the rotor has expelled all the waste gases from the previous power impulse. The exhaust valves are not subjected to high pressure or to high temperatures when exhausting.

There is increased power overlap with the present construction. There are three power impulses for each revolution of the rotor and the gas in any section fires and expands before the expansion of a previous section is completed, thus providing two expansion chambers operating upon a rotor at the same time. Thus more uniform torque is obtained.

The increase in the number of arms to three gives more pumping volume than obtained with a two arm cylinder as in the prior patent above referred to.

The force required for compression by action of the forward side of the rotor upon the arms is obtained by expansion directly applied to the rearward side of the rotor. This reduces flywheel need and lessens stress on the main shaft. There is less likelihood of kickback because there is approximately a 195° lock. After each power impulse the arm is locked as by a toggle joint so that it is impossible to reverse the direction of rotation of the rotor by applying pressure on the compression arm. Compression takes place in about 90° of shaft rotation after which there is no pressure on the compression arm for about 120°.

The compression conduit connecting the compression chamber with the preceding combustion chamber may hold about one-fifth of a charge by volume. This mixture remains in the passageway under compression for about .02 of a second at 1200 R. P. M. It cannot burn until it is transferred to the combustion chamber. It is completely surrounded by water and there is no possibility of pre-ignition.

The arm and rotor surfaces are subjected to a minimum of wear. These surfaces may be made from extra hard material having long wearing and high heat resisting qualities. The free ends of the arms where they engage the rotor can wear considerably requiring only minor timing adjustments.

The wear on the arms, as well as vibration, is minimized by inherent construction of the motor. The suction, occurring simultaneously with the power stroke on the same arm, assists in reducing the bearing load of the free end of the arm against the rotor during the highest pressure period. Other provisions may be made to minimize wear and vibration, such as exhaust valve timing, compression arm design and ignition timing. For example, leaving the exhaust valve of any section closed until the power stroke of that section has expanded over 160° maintains a cushioning effect on the next arm as it is starting on a new power stroke. Making the free end of the arm of such size, that the pressure on the total area exposed is just great enough to compel the arm to follow the rotor and maintain a gas seal between the arm and rotor on the pressure side, minimizes initial power impulse pressure on the arm. As the end of the arm wears, such wear can easily be compensated for by advancing the ignition.

Sealing between the edges of the arms and the casing head is efficiently accomplished by the sealing strips carried by the arms; likewise sealing between the end faces of the rotor and the heads. Sealing between the cam surface of the rotor and the cylindrical surface of the block is of secondary importance since pressure areas on the rotor are always bounded by the arms. The arm bearing sealing strips 109, the horn sealing strip 110, the combustion chamber sealing strip 111, all extend axially of the block from head to head.

The intake compression, combustion and expansion chambers are sealed against leakage by the sealing strips being forced out against the opposing surfaces by the wave springs behind them. These sealing strips also take care of expansion of the relatively moving parts which retain proper working clearances at all times. The sealing strips on the rotor always travel in the same direction and thus are not subjected to increased friction due to sudden change in direction. The rotor does not do any of the pumping or compressing but all pumping and compressing is done in the separate compression chambers by the oscillating arms which act as built-in compressors.

The engine is adequately cooled both by water jackets and by oil flow through the arms. Heat transfer also takes place by contact of the arms and rotor, through their sealing strips, with the water cooled casing walls. All vital parts in the casing, including all passageways, combustion, compression and expansion chambers, are surrounded by water.

While certain novel features of the invention have been disclosed herein, and are pointed out in the annexed claims, it will be understood that various omissions, substitutions and changes may be made by those skilled in the art without departing from the spirit of the invention.

What is claimed is:

1. In a rotary internal combustion engine, a case having an annular wall with flat ends providing a central, generally cylindrical rotor space, said ends carrying central bearings, a main shaft journaled in said bearings, a rotor on said shaft having a cam surface, three arms, means pivoting said arms at the outer side of said rotor space at equi-spaced points, each said arm having a blade portion riding on said cam surface and an outer horn, said case having a horn recess for said horn, said horns dividing said space into three compression and three expansion chambers, ignition means for expanding gas in each expansion chamber while the gas in the preceding expansion chamber is still expanding.

2. In a rotory internal combustion engine, a case having an annular wall with flat ends providing a central, generally cylindrical rotor space, said ends carrying central bearings, a main shaft journaled in said bearings, a rotor on said shaft having a cam surface, three arms, means pivoting said arms at the outer side of said rotor space at equi-spaced points, each said arm having a blade portion riding on said cam surface and an outer horn, said case having a horn recess for said horn, said horns dividing said space into compression and expansion chambers, conduits to enable the compression chamber of each arm to feed the combustion chamber of the next preceding arm.

3. In a rotary internal combustion engine, a case having a block with a central, generally cylindrical rotor space, heads enclosing said rotor space, said heads carrying central bearings, a main shaft journaled in said bearings, a rotor on said shaft having a cam surface, said heads having seats, hollow wrist pins in said seats, arms each of which has a hub journaled on its respective wrist pin and a blade portion riding on said cam surface and a horn, said block having recesses for said horns, said hollow wrist pins having central walls forming inlet and outlet passages, radial inlet and outlet openings in said

wrist pins connecting said passages, said hubs having inlet and outlet openings adapted to register with corresponding wrist pin openings, said arms each having conduits connecting hub inlet and outlet openings, at least one of said conduits extending to the free end of said blades, at least another of said conduits extending to the free ends of said horns.

4. In a rotary internal combustion engine, a case having a generally cylindrical wall with flat heads forming a rotor space, a main shaft centrally journaled in said heads, a rotor on said shaft and having a cam surface, said cam surface comprising a rise, a dwell and a fall, said cylindrical surface having three recesses, three wrist pins in said recesses secured to said case, three arms on said wrist pins, each said arm having a blade riding on said cam surface, each said arm having a horn laid out with its wrist pin as a center, said block having three horn recesses for said horns, said case having three spherical combustion chambers, said horns dividing said rotor space into three compression chambers and three expansion chambers, compression passages connecting the combustion chambers with the next preceding compression chambers, valves at the junction of said compression passages and combustion chambers, said case having three inlet passages, inlet valves in said inlet passages at the junction of said inlet passages and the compression chambers, valves in said compression passages at their junction with said compression chambers, said rotor chamber having beveled seats at the junctures of the expansion and combustion chambers, sealing devices in said seats, said blades having beveled surfaces seating against said seats to seal off periodically the combustion chambers, said arms riding down said fall during expansion, said arms riding up said rise during compression and riding on said dwell to hold said combustion chambers sealed.

5. In a rotary internal combustion engine, a case having a generally cylindrical wall with flat heads forming a rotor recess, a main shaft centrally journaled in said heads, a rotor on said shaft and having a cam surface, said cylindrical surface having a plurality of recesses, wrist pins in said recesses and secured to said case, arms on said wrist pins, each said arm having a blade riding on said cam surface and having an outer curvature concentric with the main shaft and an inner curvature separated by a high point, said arm having a horn laid out with its wrist pin as a center, said block having horn recesses for said horns, said case having spherical combustion chambers entirely cast therein, said horns dividing the chamber space into compression chambers and expansion chambers, compression passages connecting the combustion chambers with the next preceding compression chambers, axial poppet valves at the junction of said compression passages and combustion chambers, said case having inlet passages, radially extending inlet poppet valves in said inlet passages at the junction of said inlet passages and the compression chambers, radially movable check valves in said compression passages at their junction with said compression chambers, said rotor chamber having beveled seats at the junctures of the expansion and combustion chambers, sealing devices in said seats, said blades having beveled surfaces seating against said seats to seal off periodically the combustion chambers.

6. In a rotary internal combustion engine, a case having an annular wall with end walls providing a central, generally cylindrical rotor space, a rotor journaled in said space and having a cam drum surface, a plurality of arms, means pivoting said arms at the outer side of said rotor space, each said arm having a blade portion riding on said cam surface and an outer horn, said case having a horn recess for said horn, said horns dividing said space into compression and expansion chambers, said case having conduits with means to enable the compression chamber of each arm to feed the combustion chamber of the next preceding arm, whereby the single case houses a complete operating unit.

7. In a rotary internal combustion engine, a case having an annular wall with end walls providing a central, generally cylindrical rotor space, a rotor journaled in said space and having a cam drum surface, a plurality of arms, means pivoting said arms at the outer side of said rotor space, each said arm having a blade portion riding on said cam surface and an outer horn, said case having a horn recess for said horn, said horns dividing said space into compression and expansion chambers corresponding to the number of arms, said engine having means for causing the gas to expand in each expansion chamber while the gas in the preceding expansion chamber is still expanding.

8. In a rotary internal combustion engine, a case having an annular wall with end walls providing a central, generally cylindrical rotor space, a rotor having a cam surface journaled in said rotor space, an arm pivoted to the outer side of said rotor space, said arm having a blade portion riding on said cam surface and an outer horn, said case having a horn recess for said horn, said horn dividing said space into a compression and an expansion chamber, said case having a combustion chamber adjacent said horn recess and communicating with said expansion chamber, said case having a recess adjacent said combustion chamber to house said arm, the tip of said arm being beveled to seat against a corresponding beveled seat on the case, said beveled seat having a slot extending from end to end of the rotor space, said slot having a projection on a side wall thereof, a sealing strip of L-shaped cross section seated in said slot, a sealing strip of channel shaped cross section nested in the L-shaped strip and having its channel surrounding said projection, and a wavy spring between the L-shaped strip and the bottom of the slot to urge said sealing strips against said tip.

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