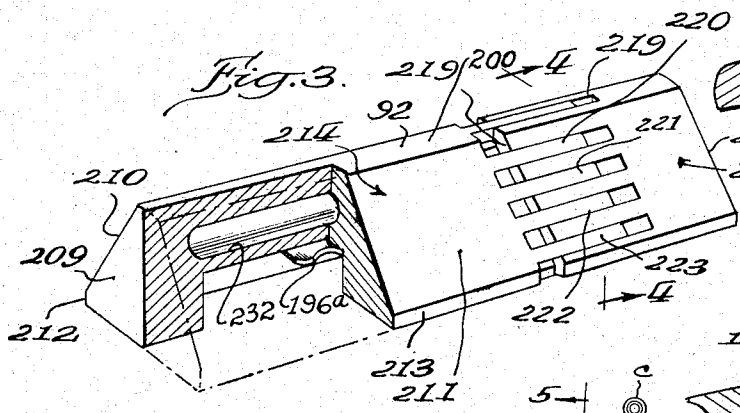
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INTERNAL COMBUSTION ENGINE

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Fig. 3.



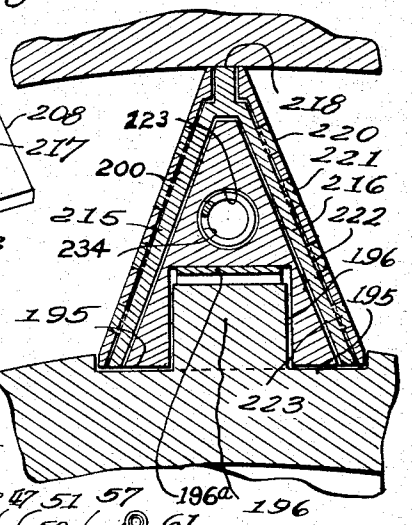


Fig. 4

Fig. 2.

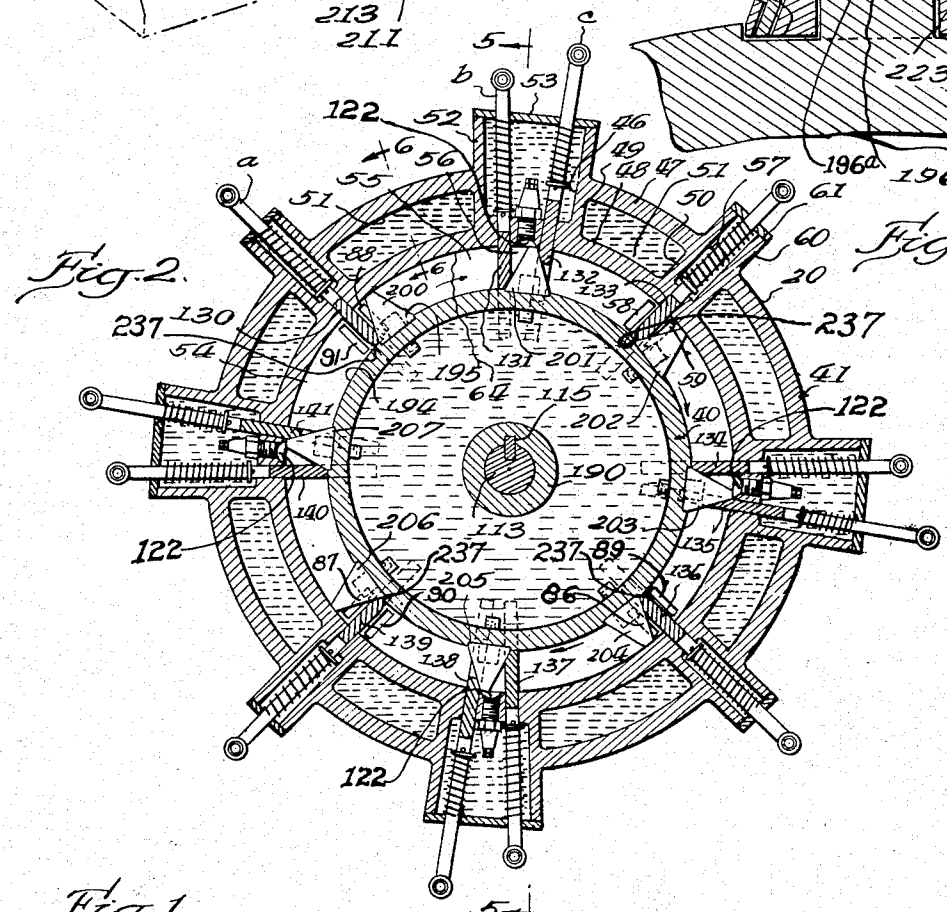
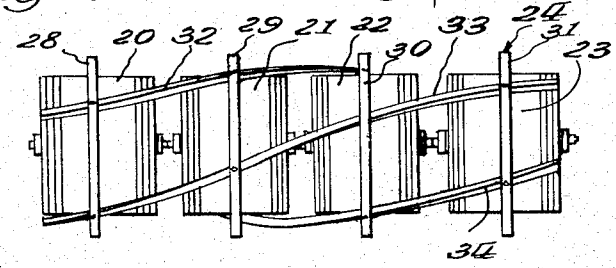


Fig. 1



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Fig. 5.

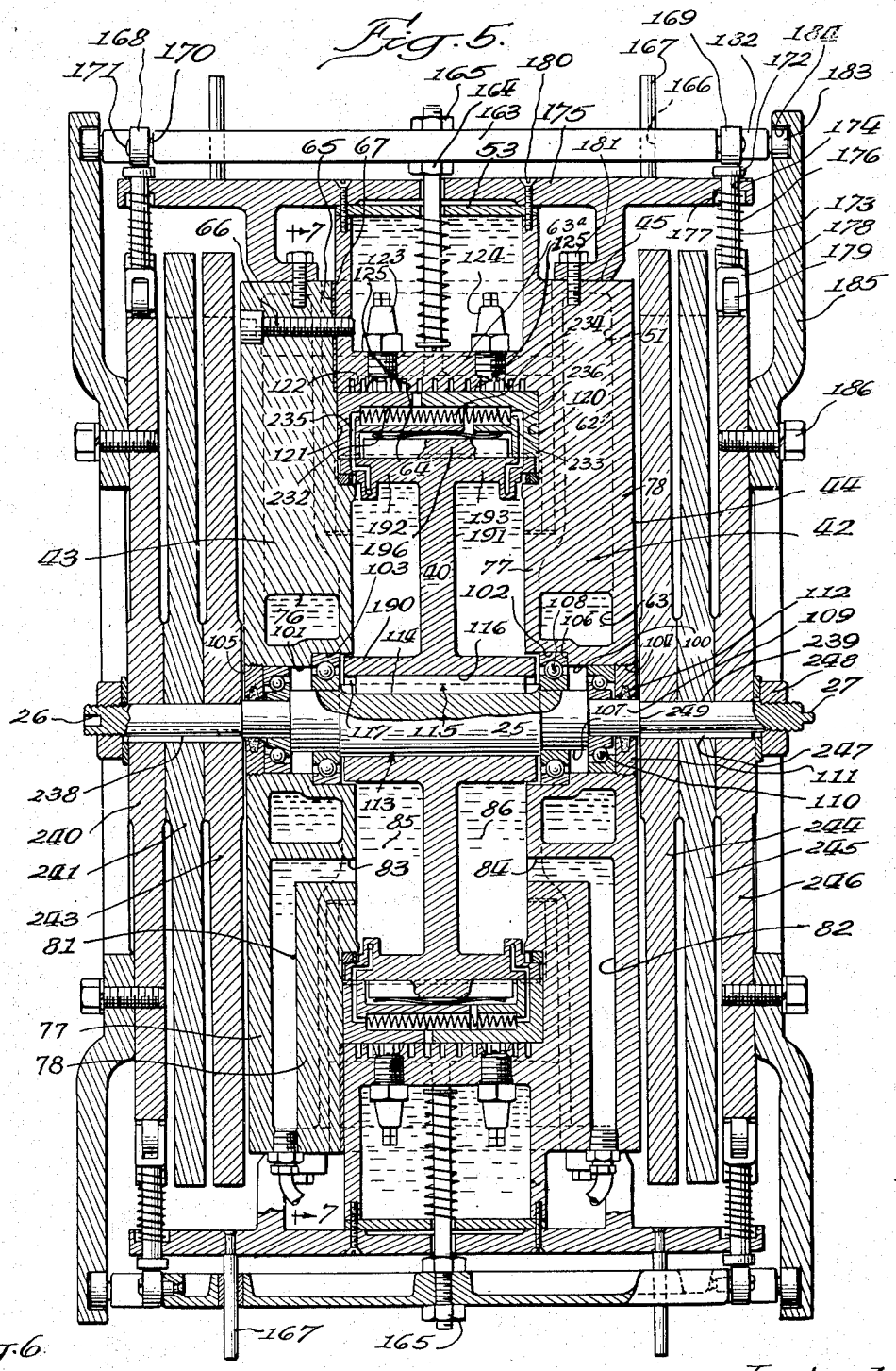
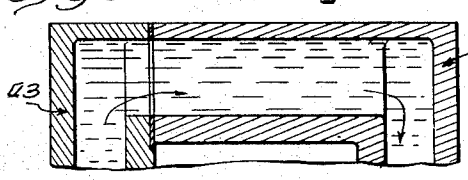


Fig. 6.



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Fig. 8.

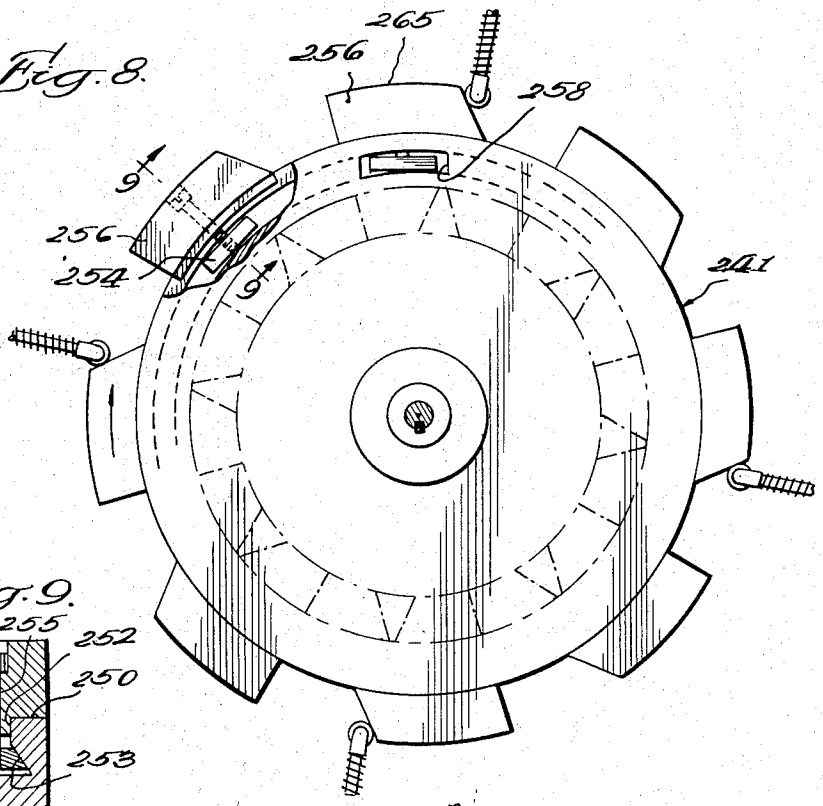


Fig. 9.

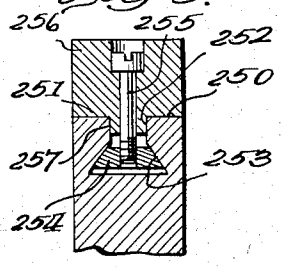
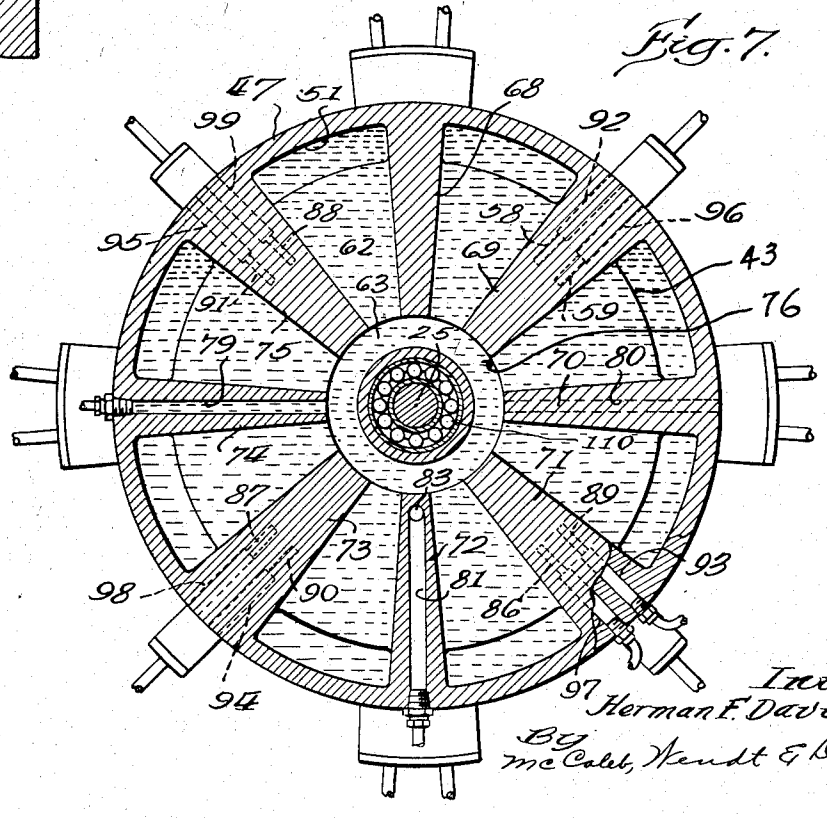


Fig. 7.



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Fig. 10.

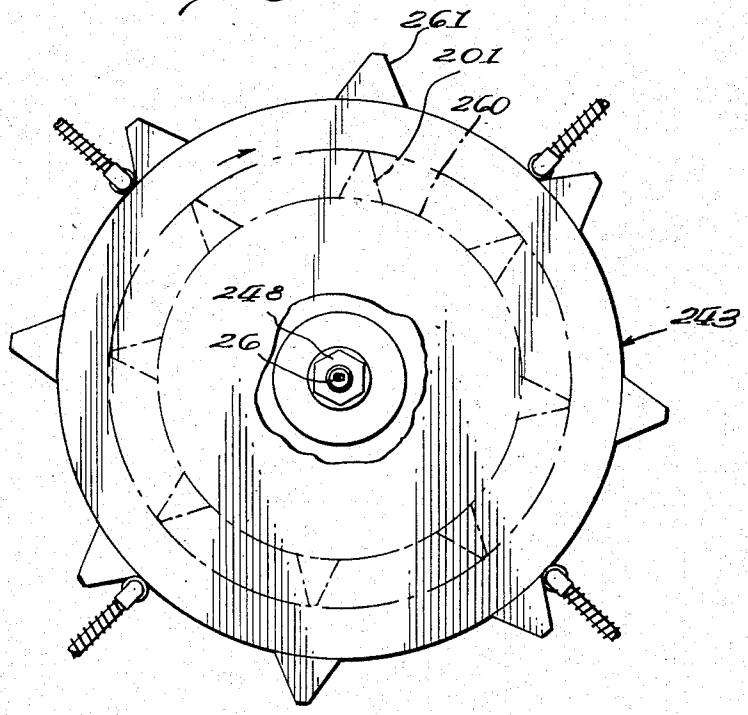
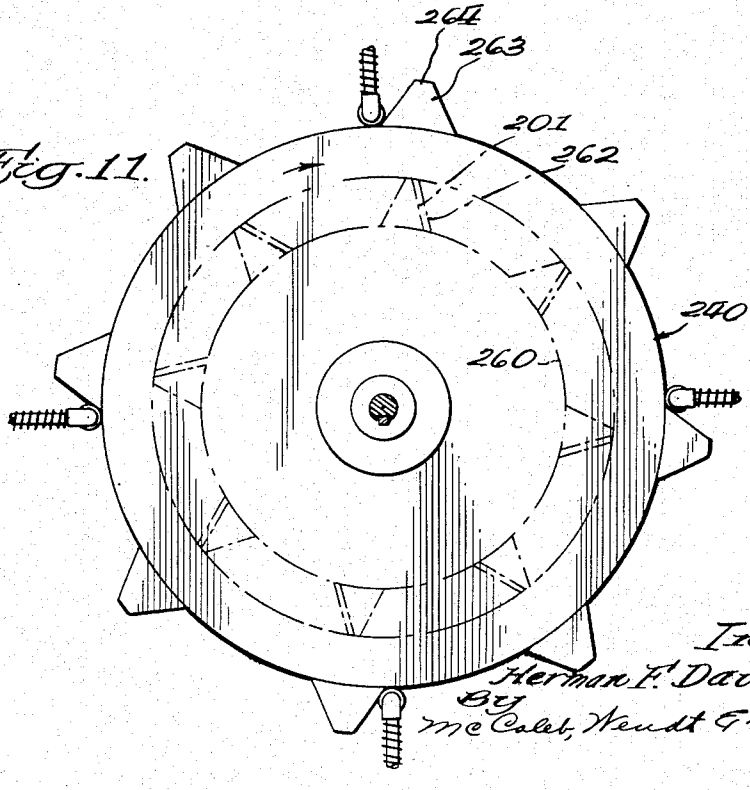


Fig. 11.



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Fig. 12

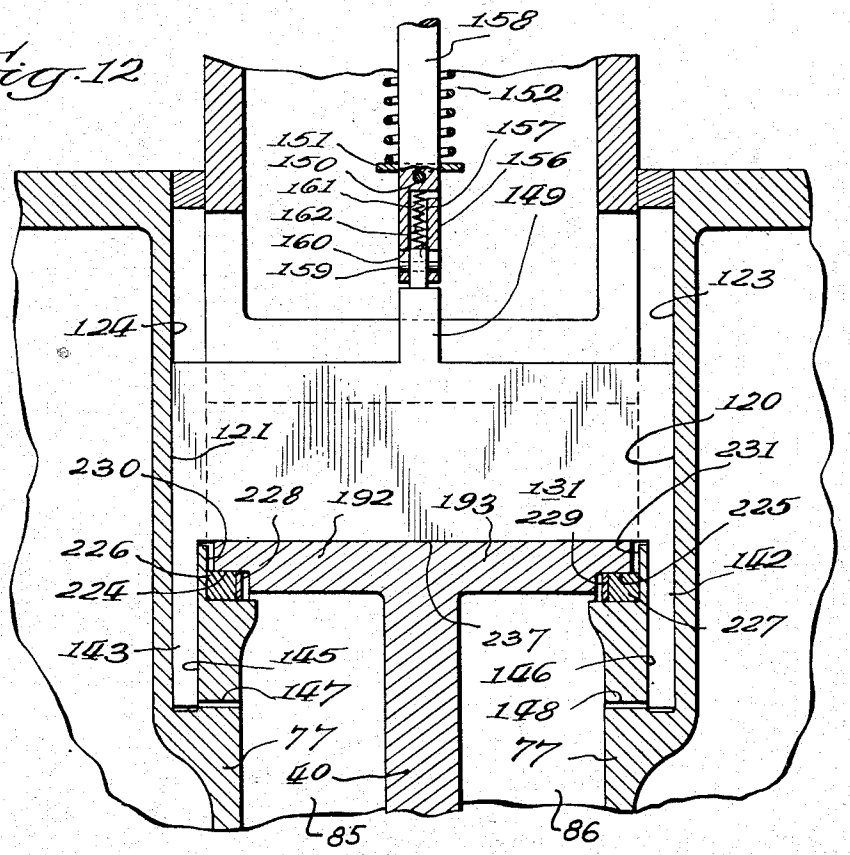
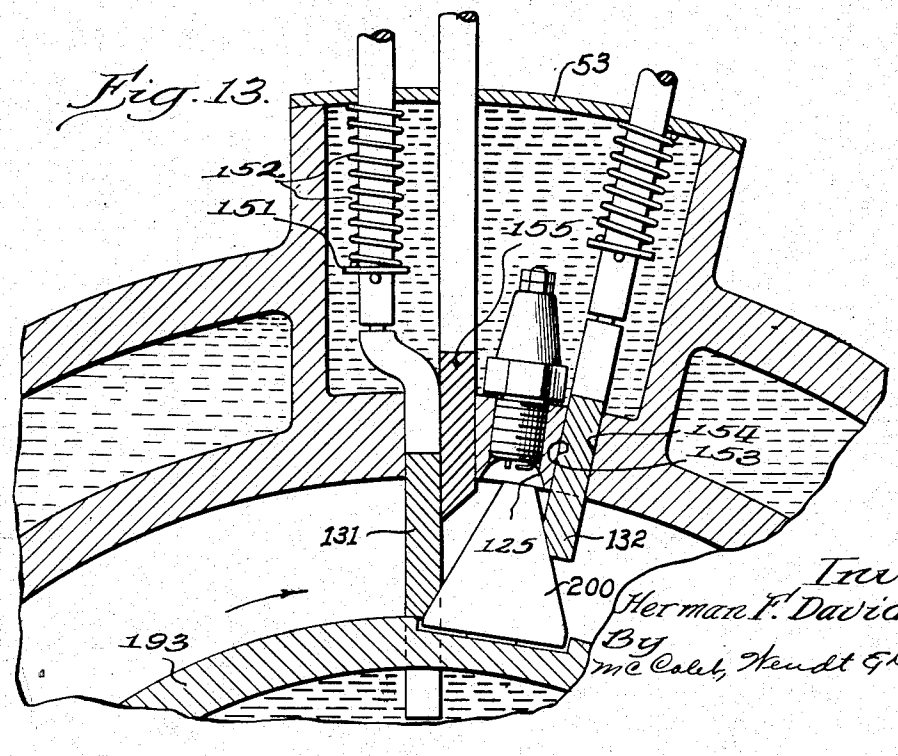


Fig. 13.



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Fig. 14.

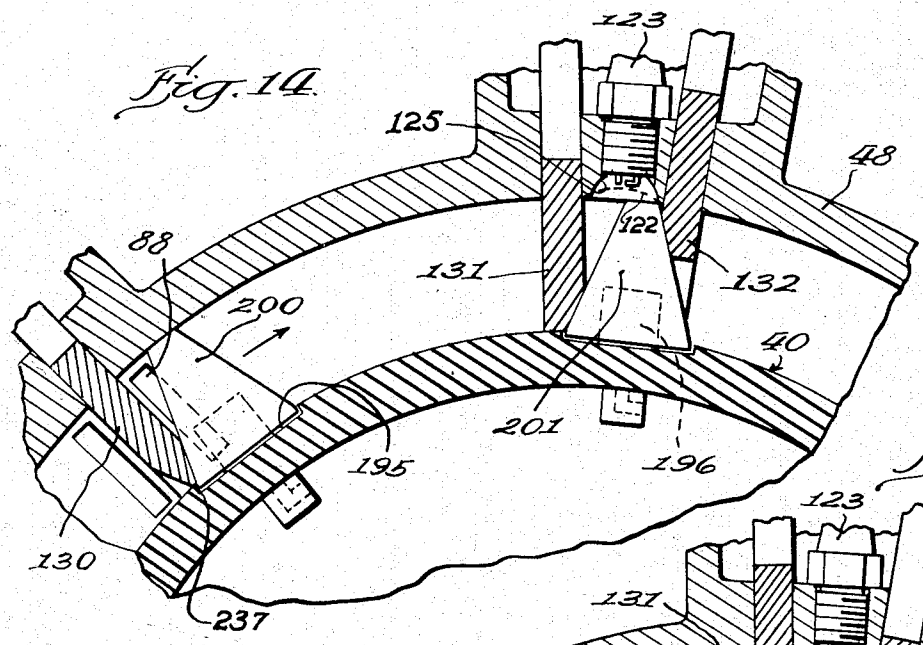


Fig. 15.

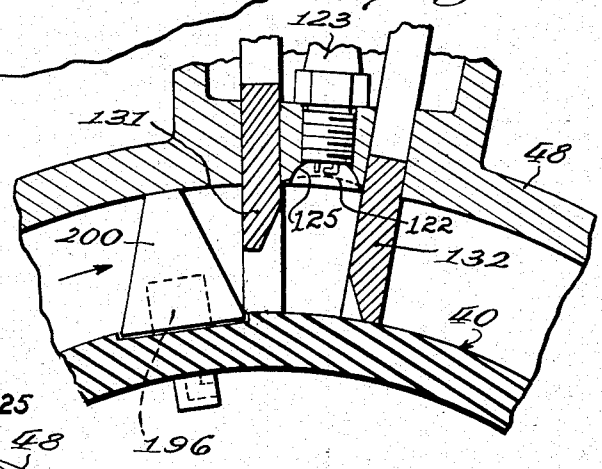


Fig. 16

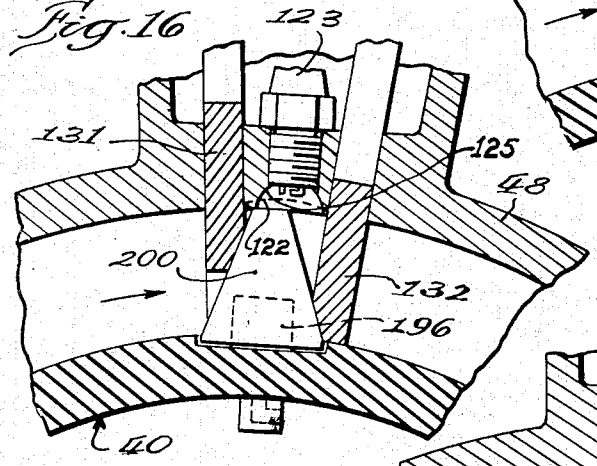
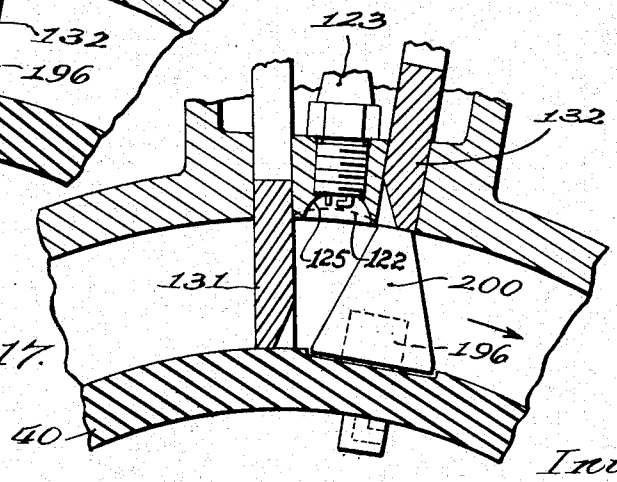


Fig. 17.



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UNITED STATES PATENT OFFICE

2,353,446

INTERNAL-COMBUSTION ENGINE

Herman F. Davidson, Sioux City, Iowa

Application June 17, 1942, Serial No. 447,332

4 Claims. (Cl. 123—14)

The present invention relates to internal combustion engines, and is particularly concerned with internal combustion engines of the rotary type.

One of the objects of the invention is the provision of an improved rotary combustion engine which will be simple to manufacture, efficient in operation, and which is adapted to produce tremendously more power per pound of weight than any of the motors of the prior art.

Another object of the invention is the provision of a rotary internal combustion engine which is particularly adapted to be used in airplanes, such as war planes, in which the savings in weight can be utilized either for carrying greater fuel load, greater bomb load, heavier armament, or a combination of these different loads.

Although by reason of its lighter weight per horse power the present motor is peculiarly adapted to have particular advantages when used in airplanes, I do not wish to limit myself to any particular use, as the motor is of general application and may be used for myriad other purposes, such as automobiles, motor driven generator power plants, locomotives, or for any other kind of work requiring a rotary source of power.

I desire it also to be understood that while the embodiment selected to illustrate the invention comprises a motor adapted to use carbureted gasoline for its fuel, ignited by spark plugs, certain of the structures of the engine are adapted to be used in other types of combustion engines, such as Diesel engines, in which the relatively lighter structure will be of particular advantage, since Diesel engines are known to be heavier per horse power than the other types of internal combustion engines.

Another object of the invention is the provision of a rotary combustion engine of the class described which may be constructed in a plurality of simple units adapted to be mounted end to end in a frame in such manner that if one of the units becomes displaced it may be taken out of the frame and quickly replaced by another motor unit.

Another object of the invention is the provision of an improved rotary internal combustion engine structure in which the charge is placed under a compression which increases from a minimum at the intake to a maximum at or near ignition, and in which there is no decrease in the compression or release of compression after compression has reached its maximum point, such as takes place in the devices of the prior art.

Another object of the invention is the provision of an improved rotary internal combustion engine with improved cooling arrangements whereby the stator may be cooled by means of water or other liquids and the rotor may be cooled by means of oil which may also be used for lubrication of various parts.

Another object of the invention is the provision of an improved rotary combustion engine having a novel type of cycle by means of which a greater efficiency is secured with the use of the same elements for simultaneous compression and intake and use of another of the same elements for simultaneous expansion and exhaust.

Another object of the invention is the provision of an improved rotary internal combustion engine, the rotor of which may be made by turning on a lathe and in which the inside of the stator may also be made by turning on a lathe so that easier and cheaper production may result.

Another object of the invention is the provision of an improved engine of the class described in which the valve actuating cams are so constructed as to permit convenient adjustment and in which the motor is so constructed as to permit simultaneous firing at any desired number of points equally spaced about the periphery of the motor, resulting in even torque on the shaft.

Another object of the invention is the provision of a motor assembly comprising various motor units which may be arranged with their firing points equally spaced about the periphery of a full circle so that the units may be fired in the same firing order as the individual cylinders of an automobile engine of the piston type, thereby securing a more even torque.

Referring to the drawings, of which there are six sheets,

Fig. 1 is an elevational view of a rotary internal combustion motor assembly, including a plurality of units embodying the present invention;

Fig. 2 is a sectional view, taken on a plane at right angles to the axis of the shaft of one of the units, showing the details of construction of the rotor and stator;

Fig. 3 is a view in perspective of one of the vanes carried by the rotor, which serves as the driving element for the rotor;

Fig. 4 is a transverse sectional view, taken on the plane of the line 4—4 of Fig. 3, looking in the direction of the arrows;

Fig. 5 is a sectional view, taken on the plane of the line 5—5 of Fig. 2, looking in the direction of the arrows, showing the details of structure of

the motor unit, on a plane passing through the axis of the shaft;

Fig. 6 is a fragmentary sectional view through a part of the stator, showing the details of construction of the water jacket at one of the points in the rotor, the section being taken on the plane of the line 6—6 of Fig. 2;

Fig. 7 is another sectional view, taken on the plane of the line 7—7 of Fig. 5, looking in the direction of the arrows, showing the various conduits for conducting cooling water to the stator, oil to the rotor, and the intake and exhaust conduits for the various stages of the unit;

Fig. 8 is a diagrammatic elevational view of one of the valve actuating cams, which may be called the transfer-expansion cam, shown in connection with a diagrammatic view of the rotor and its vanes;

Fig. 9 is a fragmentary sectional view, taken on the plane of the line 9—9 of Fig. 8, showing the details of construction and mode of securement of the adjustable parts of the cam of Fig. 8 and of the other cams used;

Fig. 10 is a diagrammatic elevational view of the exhaust-intake cam, shown in connection with the diagrammatic representation of the rotor and its vanes, to illustrate the position of the cam parts relative to the rotor;

Fig. 11 is a diagrammatic elevational view of the compression-transfer cam, shown in connection with the diagrammatic representation of the rotor and its vanes, to illustrate the relative positions between the cam and the rotor parts;

Fig. 12 is an enlarged fragmentary sectional view on a plane extending radially with respect to the drive shaft of the motor, taken at a point in front of one of the valves, carried by the stator, to show the structure of the valve;

Fig. 13 is a fragmentary sectional view, taken at the transfer and ignition chamber of one of the stages, showing the details of construction of the valves used for defining this chamber and the compression element, also preferably employed for raising the compression uniformly from minimum to maximum at the point of ignition or thereabouts;

Fig. 14 is a diagrammatic sectional view of a portion of the main elements of the internal combustion engine unit, showing the position of a vane at the beginning of the intake, the other vane being at the ignition point or thereabouts;

Fig. 15 is another similar diagrammatic view, showing the position of the same vane and the valves as the vane finishes intake and begins to complete compression against the second of two valves, the other vane being at a point where it is practically completing exhaust in front of it and expansion behind it;

Fig. 16 is a similar diagrammatic view, in which one of the vanes has reached the position where the first of the two valves at the transfer chamber has been lifted, but the second has been closed, and compression and transfer are taking place against the second of two valves;

Fig. 17 is a similar diagrammatic view, in which the transfer has been completed, and ignition has taken place, or is about to take place, of a charge between the first valve of the transfer chamber and the vane.

Referring to Fig. 1, wherein the internal combustion engine units are indicated by the numerals 20, 21, 22, and 23, they are held together in an assembly by a framework 24. Each of the units preferably has its shaft provided at one end (25, Fig. 5) with a non-circular socket 26, and at the other end with a complementary centrally located reduced portion 27 adapted to fit in the socket of another unit.

The framework 24 may consist of a plurality of annular members 28–31, inclusive, secured together with their parts parallel to each other by means of a plurality of longitudinally and spirally extending frame members 32–34, of which there may be others (not shown) appearing on the back side.

The spiral frame members 32–34 are like screw threads having a sliding fit in complementary spirally extending grooves in the motor units 20–23 for the screw threads so that when a motor is placed in the framework 24 by sliding and rotating it into place, it automatically assumes a rotative position with respect to the next and other motors so that the housings of the motor units are regularly spaced in an angular relation with respect to each other.

Thus a plurality of the units may be carried by a framework 24 in such manner that their rotative impulses are located at regularly spaced points about the circumference of the assembly so as to secure a uniform torque. The units may be secured in place in the cage 24 by appropriate set screws and other fastening devices; and whenever one unit is disabled it may be quickly removed and another substituted.

The rotary internal combustion engine units may be identical in construction. Reference is now made to Figs. 2 and 5 regarding the details of construction of each motor unit.

The motor unit 20, for example, comprises a rotor, indicated by the numeral 40, and a stator, indicated by the numeral 41.

The stator preferably comprises a pair of castings, one of which is the main housing 42, and the other of which is an end or cover plate 43.

The stator housing 42 is a generally cylindrical member, of which the end surface 44 may be a plane surface, and the periphery 45 may be cylindrical.

The present motor unit may be constructed with any desired number of stages, depending on the number of vanes employed on the rotor and the corresponding number of intake and expansion spaces. Each vane on the rotor is used for producing an intake of an explosive mixture behind it at one of the motor chambers and for simultaneously effecting a compression of the explosive mixture in front of the vane, the front being designated as the direction toward which the vane is turning.

At a later point in the cycle the same vane is adapted to effect a transfer of the explosive mixture from the front of the vane to a position behind the vane, while still effecting a further compression of the mixture. Thereafter ignition and expansion takes place behind the vane, while exhaust takes place in front of the vane.

Thus the absolute minimum number of vanes on a rotor would be one vane, but the rotor is preferably provided with a plurality, and even a multiplicity of vanes, so that there will be a plurality of stages in each motor unit.

The number of stages in the unit is preferably in any case equal to one-half the number of vanes, and the motor unit which has been selected to illustrate the invention includes four such stages.

For this reason the external housing 42 is provided at regularly spaced points about its periphery with the substantially cylindrical recesses 46 for receiving valves and spark plugs (Fig. 2).

The stator housing 42 preferably has an outer cylindrical wall 47 and an inner cylindrical wall 48, which, with the walls 49, 50 of the valve housings, form water chambers 51 in the stator housing between the valve recesses.

The valve recesses 46 may be increased in size by providing the stator housing 42 with outwardly extending cylindrical flanges 52 closed by bolted cover plates 53.

Referring to Fig. 2, certain zones or chambers of the motor are defined by the spaces between the vanes and the valves at certain times in the operation. For example, in the position in which the parts are in Fig. 2, the space 54 is an exhaust chamber, while the space 55 is at the moment a compression chamber. The space 56 is a mixture transfer chamber.

The valve recesses, which are located adjacent the mixture transfer chamber 56, are preferably large enough to house the spark plugs and two or more valves, while the valve recess 57, which carries a valve located between exhaust and intake ports 58, 59, is only large enough to house the valve located between these ports.

This recess 57 also has a cylindrically extending flange 60 with a bolted cover plate 61.

In addition to having the water space 51, already described, the stator housing 42 has conduits extending radially from the water space 51, the conduits being indicated by the numeral 62 (Figs. 5 and 7) and communicating with another annular water conduit 63 near the center of the stator housing 42.

The stator housing parts just described have secured to them an axially projecting cylindrical portion 63*a*, which forms the cylindrical wall of the stator chamber 64, and which carries the spark plugs and valves previously mentioned.

This cylindrical wall 63*a* terminates in a plane surface 65 for engagement with the end plate 43, which is secured to the cylindrical wall 63*a* by screw bolts 66. A gasket 67 is preferably interposed between the cover plate 43 and stator housing 42.

The end plate 43 is provided with the same water chambers 51, 62, 63 as the stator housing 42. Both of these series of water conduits communicate with each other through the annular chambers 51 which extend across the stator housing at the cylindrical portion thereof between the valve and spark plug chambers 46 and 57.

The water chambers 51 are seen in Fig. 2 as being located between the two curved walls 47 and 48, and there are apertures in the gasket 67 and registering apertures in the adjacent plane surfaces 65 on the stator housing 42 and end plate 43 so that the water may run from the recesses in the cover plate over into the recesses or water chambers of the housing 42.

Referring to Fig. 7, this is a sectional view, taken on the plane of the line 7—7, showing how the end plate 43, Fig. 5, as well as the end portion of the housing 42, is provided with radially extending metal bodies 68–75, extending from the outer wall 47 to the peripheral wall (Fig. 5) 76 of the annular water chamber 63.

These radial metal bodies serve to secure the inner and outer walls 77 and 78, Fig. 5, of the housing 42 together, and the same is true of the end plate 43. These radial metal bodies 68, 65 also serve to provide space for certain conduits for supplying water and oil and for exhaust and intake. For example, the body 74 of the housing may be cored out to provide the water conduit 79 by means of which cooling water is conducted from an appropriate radiator through the conduits 79 to the annular water chamber 63.

From thence it passes radially outward through the conduits 62 to the water chambers 51, then axially of the stator body into the stator housing 42, thence radially inward through the water chambers 62 of the stator housing 42 to the annular water chamber 63 of the stator housing 42.

Referring again to Fig. 7 the dotted conduit 80 in the radial metal body 70 may be the outlet conduit for the water leading the heated water from the annular chamber 63 back to a radiator. Of course, either the conduit 79 or 80 may serve as outlet or inlet, and the motor units are preferably provided with a suitable water pump and a radiator for cooling the water or other cooling medium.

The radially extending metal body 72 of the end plate 43 (Fig. 7) may be provided with a cored conduit 81, serving as an inlet for oil, which is used for cooling the rotor.

Another such conduit 82 is provided in the stator housing 42 (Fig. 5) for an outlet for the oil, which not only serves to cool the rotor but to lubricate its valves and moving parts of its vanes. Each of the conduits 81, 82 has a laterally turned inner portion 83 or 84 communicating with the annular oil space 85 or 86, respectively, surrounding parts of the rotor.

The remaining radially extending body portions of the end plate 43 may be cored out to provide intake and exhaust conduits leading to intake and exhaust apertures. The intake and exhaust apertures at one stage have already been designated by the numerals 59 and 58, respectively (Fig. 2).

The other intake apertures will now be designated in Fig. 7 by the numerals 86–88, and the other exhaust apertures or ports will be designated by the numerals 89–91 (Fig. 7). These ports may be substantially rectangular in shape, their length depending upon the radial width of the chambers 54, 55, 56, between the rotor and stator. Their width is preferably less than the width of the upper sealing surface 92 on any of the vanes (Fig. 3).

Each of the exhaust conduits 58, 89–91 communicates with a cored conduit 92–95, extending radially out of the end plate. The intake conduits 59, 86–88 communicate with a radially extending intake conduit 96–99. The intake and exhaust conduits preferably communicate with a suitable annular manifold.

Both the housing 42 and end plate 43 are provided with the centrally located through bore 100, 101, these bores communicating with counterbores 102 and 103, respectively. Bores and counterbores 100–103 are axially aligned with each other, and bores 100 and 101 communicate with larger threaded counterbores 104, 105, respectively, at each of their outer ends. The bore 102 may support the outer race of a ball bearing assembly against a shoulder 106, and the same is true of the bore 103.

The shaft 25 has a reduced cylindrical portion 107 receiving the inner race of a ball bearing assembly 108 so that the shaft 25 is thus rotatably mounted in the housing and end plate 42, 43. The races of the ball bearing assembly 108 may have a sliding movement upon either the shaft portion 107 or in the bore 102 for axial adjustment of the shaft.

At each end the shaft 25 carries a further reduced cylindrical portion 109, which carries the

inner race of a thrust ball bearing assembly 110. The outer race of this thrust ball bearing assembly is arranged to resist outward thrust of the shaft 25, and is carried in the bore 100 or 101.

A threaded member 111, threaded in the bore 104 or 105, engages the thrust ball bearing assembly 110 at each end, and is provided with suitable special wrench sockets so that it may be actuated to move the shaft 25, and with it the rotor 40, axially for adjustment of its clearances.

A suitable packing 112 is included in each of the threaded members 111 for engagement with the shaft to prevent the egress of oil from the bores containing the ball bearings. These bores are in communication with the oil spaces 85, 86 in the rotor or between the rotor and stator.

The central enlarged cylindical portion 113 of shaft 25 is provided with a slot or kerf 114 for receiving the key 115 by means of which it is nonrotatably secured to the rotor 40. The rotor 40 has a cylindrical bore 116 with a key-way 117 for receiving a part of the key 115.

The interior of the stator, which comprises the housing parts 42, 43, is provided with the accurately machined plane surface 120 on one side (Fig. 5) and a similar surface 121 on the opposite side for engaging the ends of the vanes of the rotor.

The peripheral surface 64, previously described, is machined to an accurately cylindrical surface, but is provided with a plurality of peripherally extending grooves 122 in the transfer chamber space 56 of each stage. This transfer chamber space may be defined as being the space between the two valves which are located in the valve recesses 46.

As one of the vanes progresses through this transfer chamber 56, the compressed mixture or charge, which is in front of the vane, passes upward into the grooves 122 and backward behind the vane into the space between the vane and the valve which is behind it. As the ignition chamber is relatively long, a pair of spark plugs 123, 124 are arranged in suitable threaded bores, communicating with the cup shaped space 125 below each spark plug, which also communicates with a multiplicity of the grooves 122.

The spark plugs are, of course, provided with suitable spark by means of a suitable distributor and ignition system, and the spark may be adjusted as in other combustion engines, to take place suitably in advance of maximum compression to secure greater efficiency and speed.

Referring to Fig. 12, the plane surfaces 120, 121 are preferably provided with radially extending grooves 123, 124 for receiving the edges of the valve members which are slidably mounted in the stator.

Referring to Fig. 2, the valves will now be designated by the numerals 130–141. Valves which are located between the intake and outlet ports, such as valves 130, 133, 136, and 139, may be called exhaust-intake valves. Exhaust is accomplished by movement of a vane toward one of these valves, driving the exhaust gases out of an exhaust port; and intake is accomplished by movement of a vane away from one of these valves, sucking in a new charge of explosive mixture into the enlarging space between the vane and one of these valves.

The valves 131, 134, 137, and 140 may be designated as compression-transfer valves because compression is initially accomplished by movement of a vane toward one of these valves, and these valves are also used after the vane has passed, to prevent the compressed charge from moving backward beyond the valve, as it is being transferred to a place behind the vane, while the vane is passing slots 122.

The valves 132, 135, 138, and 141 may be designated transfer-expansion valves for the reason that it is these valves which are used to effect a transfer of the explosive mixture from the space in front of a vane to the space in back of the vane, this transfer having been practically accomplished in Fig. 2.

These valves 132 adjoin the expansion space behind a vane, and this has been used as part of the name of the valve.

All of the valves 130–141 may be similar in structure, except that their sealing surfaces are sometimes of different shape; and in the preferred form of the invention, shown in Fig. 13, an additional plunger 155, similar in shape to a valve, is employed inside the transfer space 56 for assuring the continuous increase of compression from minimum to maximum, without any relapse or decrease of pressure.

In such case the valves 131, 134, 137 and 140 would be of offset construction, as shown in Fig. 13. The compression plunger is merely omitted from Fig. 2 for the purpose of clarity.

Referring again to Fig. 12, each valve may consist of a plate of metal, having front and back plane surfaces and plane edges. The valves, such as, for example, the valve 131, are substantially rectangular in their main body portions, but are provided with a pair of depending legs 142, 143, at each side, the legs being rectangular in shape and slidably fitting in the grooves 123, 124.

The stator wall 77 on each side may be provided with a rectangular recess 145, 146 for receiving the lower end of each leg 142, 143, and there may be bleed apertures 147, 148 providing communication between the recesses 145, 146 and the oil spaces 85, 86 of the rotor.

Each valve is preferably provided with an outwardly extending rectangular shank 149, engaged by push rod 158, which may be provided with a pin 150 and a washer 151, against which a helical coil spring 152 reacts. The coil spring in each case has its other end in engagement with a cover plate 53 or 61 so that the valve is urged inward by the spring 152.

The stator body is provided with a radially extending slot defined by the walls 153, 154 (Fig. 13) for each valve, and where the auxiliary compression plunger 155 is used the valve aperture in the stator is large enough to receive both the plunger and the adjacent valve 131, 134, 137, or 140.

In addition to being driven inward by the spring 152, each valve is preferably provided with a substantially cylindrical reduced shank 156 slidably mounted in a bore 157 in a push rod 158 located within the spring 152. A pin 159, extending through the small shank 156, into an aperture 160 of the push rod 158, prevents these parts from coming apart; and a coil spring 161 is located in a bore 162 in the push rod 158 and engages the end of the reduced shank 156. The coil spring 162 is of lighter construction than the main spring 152, as the main spring 152 is intended to return the valve into engagement with the cylindrical part of the rotor; but the smaller spring 162 is in the nature of an expander spring to produce a more effectual seal at all times.

The smaller spring 162 tends to urge the valve into contact with the rotor and its vanes at all

times, and effects a better seal because of this action. The heavier spring 152 urges the upper plunger 158 inward toward the center of the rotor, but its inward motion is limited by engagement with the cams and with the plungers 173, which actuate the cross arms outward. Thus the auxiliary light spring enables the valve to follow the contour of the rotor and its vanes more closely.

Each of the push rods 158 of each valve is preferably provided on its outer end (Fig. 2) with a threaded portion for supporting a cross head 163, which is secured on the threaded portion by means of two nuts 164, 165. The cross head has apertures 166 for slidably receiving fixed pins 167, carried by the stator so as to prevent the cross head from turning. At each end the cross head 163 is provided with a roller 168, 169. Each roller is mounted upon a trunnion 170 and secured by means of a screw bolt 171.

The rollers engage the heads 172 of a spring pressed plunger 173 slidably mounted in an aperture 174 in a bracket 175. The plunger 174 carries a compression spring 176 which engages in a spring seat 177 in the bracket 175 and engages a fork 178 on the lower end of the plunger.

The fork 178 has a transverse pin carrying a roller 179, the roller 179 riding on one of six cams carried by the drive shaft 25. The bracket 175 may comprise a cast metal member secured to the stator housing 42 by the same bolts 180 which secure the cover to the valve recess.

Each bracket 175 may have another foot flange at each side secured by another bolt 181 to the housing or end plate 43, 42. The cover plate 53 and bracket 175 have registering apertures for passing the push rod of each valve.

With regard to the compression plunger 155, this may be of similar construction and provided with a similar push rod secured to a second cross head 182, Fig. 5 which is provided at each end with the trunnion mounted rollers 183. The rollers 183 project into cam slots 184 in the offset cam plate 185, which is secured to the outermost cam by means of screw bolts 186.

The cross head 182 is thus caused to follow the shape of the cam groove 184, and it is positively actuated in both directions in order to assure its operation under conditions of high compression.

The rotor 40 is similar in shape to a wheel, having a centrally located hub 190 provided with the bore 116 for receiving the drive shaft 25. The hub 190 supports a circular web 191, which carries a pair of substantially cylindrical flanges 192, 193 extending in opposite directions. The peripheral surface 194 of these rotor flanges is accurately machined or ground to a truly cylindrical surface, but is provided with a plurality of grooves 195 of rectangular plan and cross section, the grooves being spaced by a radially projecting rib 196 of rectangular shape in plan and cross section (Fig. 4). The rib 196 is adapted to slidably receive one of the vanes, previously mentioned.

Between each rib 196 and each vane 214 there is a wavy spring 196a which is adapted to urge the vane into engagement with the wall of the stator. This wavy spring comprises a thin strip of spring steel bent to sinuous shape so that by its expansion transversely to the length of the spring it tends to urge the vane and rotor apart.

The vanes will be indicated by the numerals 200–207 (Fig. 2), and they are all identical in construction. One of them is illustrated in detail in Figs. 3 and 4. Each vane may consist of a pair of metal bodies, which are slidably mounted on each other so that the vane may extend longitudinally to effect a better sealing engagement between its plane end surfaces 208, 209; and the plane wall surfaces 120, 121 inside the main housing.

The vanes are preferably provided with the substantially flat ridge surface 92, but this surface is preferably curved slightly to correspond to the cylindrical curvature of the inside of the stator housing. Extending downward on each side from the ridge surface 92, each vane is provided with a plane diagonally extending surface 210, 211, and with a pair of vertical wall surfaces 212, 213.

The vertical surfaces permit the guiding of the vane radially outward in the grooves 195. The diagonal surfaces 210, 211 permit the valves to effect a seal between valves and vanes, as the vanes pass and the valves are being retracted or inserted.

The lefthand portion 214 of each vane may be solid, and may have a longitudinally projecting pair of V shaped flanges 215, 216 engaging in the complementary recesses in the right-hand portion 217 of the vane. The left-hand portion 214 is provided on its V shaped portions 215, 216 with an outwardly extending rib 218, which extends across the crack 219 between the two sections 214, 217, and constantly effects a seal with the cylindrical inner surface of the stator.

The righthand section 217 has a slot 219 for receiving the flange or rib 218. In the same way the lefthand section 211 may be provided with a plurality of additional vertically extending ribs 220–223 located at regularly spaced intervals and engaging in complementary slots in the righthand section 217.

These ribs 220–223 on each side of the vane serve to effect a seal between the diagonal surface 214 and the contacting surface on a valve, when the valve is riding up or down on the vane.

The cylindrical flanges 192, 193 are preferably provided with recesses 224, 225 for receiving the split rings 226, 227, which have overlapping ends, and which spring out into sealing engagement with the cylindrical wall of recesses 224, 225. As a means to maintain the packing rings 226, 227, in position, an annular spring member 228, 229 is placed in the recess 224 or 225, behind each ring 226, 227, to cause it to have a sealing engagement at its plane outer surface with the plane surfaces 230, 231 on the interior of the stator housing.

Thus an effective seal is produced at the edges of each of the rotor flanges 192, 193. Each vane is preferably provided with a cylindrical recess 232, 233 in each of its sections for receiving a compression spring 234, which urges the sections apart.

The recesses 232, 233 communicate with each other and with radially inwardly extending conduits 235, 236, which also extend through the flanges 192, 193 into the spaces 85 and 86.

The oil, which comes in at a conduit 81 to the space 85, is thus conducted over into the space 86 by passing through suitable conduits and through the bores inside the vanes so that it may be carried out of the conduit 82 on the other side of the rotor.

The vanes 200–207 are equally spaced about the periphery of the rotor 40, with their ridge surfaces 92 engaging the inner cylindrical surface 64 of the stator. The inner edge 237 of each valve is suitably shaped to effect a seal when engaging the cylindrical surface 194 on the rotor, and also to effect a seal when riding up predetermined sides of the vanes.

Thus the exhaust intake valves have a narrow flat surface on their inner edge 237, as well as two beveled surfaces for engaging either side of a vane and effecting a seal. The narrow flat surface at the edge 237 of these valves effects a seal with the cylindrical portion 194 of the rotor, the valve 131, for example, having a relatively flat edge surface on its inner end and a bevel on one side for effecting a sealing engagement with a vane as it passes down one side of the vane.

The valve 132, for example, has a beveled surface on its left side (Figs. 2, 14 to 17) and a relatively flat surface at its lower edge, the reasons for which will appear hereinafter. The valves 131, 132, for example, are located as close together as possible in order to attain as high compression as possible.

Referring to Fig. 5, the reduced cylindrical end portions 238, 239 (Fig. 5) of the drive shaft 25 are adapted to support a plurality of cam disks 240 to 242 and 244 to 246. These discs are secured to the shaft against rotation by means of a key and key-way 247 at each end, and they are secured against axial motion by means of a washer and nut 248, which binds the cam discs against an annular shoulder 249 on each end portion 238, 239.

The cam disks 240 to 242 and 244 to 246 may be circular in shape, but are preferably provided with a slotted periphery. Thus the periphery has cylindrical surfaces 250, 251 on each side of a slot 252 of rectangular cross section, but the slot 252 preferably communicates with a dove-tailed slot 253, extending about the full periphery of the cam disc, or a suitable portion thereof.

A shoe 254 of dove-tailed shape has a threaded bore for receiving the threaded end of a screw bolt 255, which secures a cam shoe 256 to the cam disc. The cam shoe 256 has a longitudinally extending rib 257 fitting in the slot 252 so that a single bolt will secure the cam shoe 256 against rotation.

The cam shoe 256 bears the actual camming portion of the cam disc, and is thus adjustably mounted for movement relatively of the cam to effect a timing of the valves. In order to assume the parts, the cam disc may have a laterally extending aperture 258 communicating with the dove-tailed slot 253 so that the dove-tailed shoe 254 may be slid into the slot 253 laterally and then moved peripherally about the disc in the slot 253.

Referring now to Fig. 10, this is a disclosure of one of the cams, comprising the exhaust-intake cam, shown in connection with the diagrammatic disclosure of the rotor and its vanes.

The exact location on the shaft 25 of the particular cams is not of great importance except that the particular cam must be brought into position to engage the push rods 173 and the particular cross arms of the valves in question. The exhaust valve 130, for example, is to be opened only when a vane passes this valve, and at all times it effects a seal with the cylindrical surface of the rotor, the beveled surfaces of the vanes, and the ridge surface of the vanes.

Thus the inner circle 260 (Fig. 10) represents the rotor with its vanes, one of which is indicated at 201, and the camming portions 261 of the exhaust-intake cam 243 are located radially on the same lines which pass through the same points of the vanes, such as vane 201.

In other words, cam 243 lifts the exhaust-intake valve sufficiently so that it approximately follows the shape of the vane 201, which may be passing under it, but any slight irregularities in location and seal between the valve and the vane are taken up by means of the auxiliary sealing spring 162 (Fig. 12).

In addition to exerting a constant pressure urging the valve toward its seat, the spring 162, being of light weight, it has a quicker action and permits the valve to follow more closely the contour of the rotor and its vanes.

Fig. 11 illustrates what may be called the compression-transfer cam 240. Here again the rotor is represented by the inner circle 260 and its vanes by the number 201. It is desirable that the compression-transfer cam be lifted so that it will effect a seal with the trailing side of each vane, such as vane 201, as the valve descends the beveled surface of the vane. Therefore, valve 131 is beveled on the righthand side (Fig. 2).

This compression-transfer valve need not, however, effect a sealing engagement with the vane as it is lifted to pass the vane because at this time the valve 132, which is the transfer-expansion valve, is down into engagement with the cylindrical part of the rotor.

Therefore, the dotted line 262 (Fig. 11) indicates the amount of lead which the compression-transfer valve has by virtue of the shape of its camming member 263 over the arrival of the corresponding vane, such as the vane 201, underneath that cam.

The dimensions of the camming member 263 of the compression-transfer cam 240 are determined by using the proportions of the outer lines 262 and the left border of vane 201 (Fig. 11). The camming member 263, accordingly, has a wider dwell at its ridge portion 264.

Referring now to Fig. 8, this shows the transfer-expansion cam 241, and it is provided with camming members 256 for controlling the transfer-expansion valve, such as valve 132. This valve is designed to operate with respect to the vanes on the rotor so that the valve rides up the leading side of each vane and effects a seal as it does so.

Thus the valve 132 and other corresponding valves are beveled on the left side of Fig. 2.

As expansion takes place between the vane 201, for example, and valve 131, the valve 132 must be kept open, and thus the camming member 256 on the transfer-expansion cam 241 has a relatively long cylindrical portion 265, providing a long dwell for this cam to hold the transfer-expansion valve open while expansion takes place.

The annular cam plate 185, one of which is carried by each of the cam discs 240, 246, has its groove 184 so formed that as a vane passes a compression-transfer valve 131, and the space 56 behind the vane is filled with the compressed charge, the sum total of the volume of the space between the valves 132 and 131 never increases, but is uniformly decreased by the insertion of the valve plunger 155 at this time so as to further increase the compression of the mixture up to the time the vane rides under valve 132.

Ignition may, of course, take place at or before maximum compression for the same reasons as pre-ignition is brought about in other internal combustion engines.

The operation of one of my units is as follows: Each of the four stages of a unit of the type of Fig. 2 operates in substantially the same way so that only one of the stages need be explained in detail. Assuming the vane 200 to be at the point illustrated in Fig. 2, and assuming the rotor to be turning in a clockwise direction, the movement

of the rotor clockwise, as indicated by the arrow, will cause an enlargement of the space between the valve 130 and the vane 200; and intake will be effected by suction through the intake port 88.

At the same time it should be understood that the vane 200 is effecting a compression of a charge which was previously drawn into the space in front of the vane 200 by the passage of the vane 201 away from the intake port 88.

Thus, at the point at which the vane 200 now is located in Fig. 2, the vane 200 is beginning to compress a charge in front of it, and beginning to effect intake of another charge behind it.

As the vane 200 progresses toward the right, it will be noted that valve 132 is retracted and valve 131 is down, and compression is effected between the vane 200 and the valve 131.

It should be noted that as the vane 200 starts its intake, the cams which actuate the valve 132 must lift that valve to permit it to pass over the vane 201; but as it does so, valve 132 maintains a seal with the vane 201 for a purpose further to be described.

As the vane 200 approaches the valve 131, the valve 132 drops by virtue of its controlling cam behind the vane 201; and before vane 200 reaches valve 131, the valve 131 is lifted and the valve 132 has dropped so that compression can actually be effected against the valve 132.

As soon as the vane 200 passes into the compression chamber 56 beyond the valve 131, the valve 131 drops behind it; and as the vane passes through this compression-transfer chamber 56, the compressed gases are driven from the space in front of the vane through the grooves 122, to the space behind the vane.

As the vane progresses through the chamber 56, the valve 131 drops while maintaining a seal at all times, and valve 132 rises.

I have discovered that without the auxiliary compression plunger 155 (Fig. 13) the compression in the chamber 56 will reach a maximum, and then be slightly released. Therefore, I have provided an auxiliary plunger 155 actuated by suitable cams to take up the space in the chamber 56 as the vane progresses through the chamber so that compression reaches a maximum at or just after ignition.

Ignition takes place by means of a suitable source of electrical energy and a distributor energizing the spark plugs. Thereafter the ignited charge expands behind the vane as the vane passes clockwise away from the valve 131. Expansion continues until the vane passes exhaust opening 58. Thereafter the next vane effects a scavenging of the expansion space by driving exhaust gases in front of it out of the exhaust port 58.

It should be noted that about the time that vane 200 passes the valve 131 the valve 130 must be lifted, while still maintaining a seal, to pass the next vane 201.

The operation of the device is illustrated in Figs. 14 to 17, and is further explained in connection with these figures, as follows:

In Fig. 14, the outer cylindrical member, a fragment of which is shown at 48, is the stator; and the inner cylindrical member, a fragment of which is shown at 40, is the rotor. The vanes 200 and 201 are shown on the rotor to explain its operation, and the valves 130, 131, and 132 are shown on the stator for this purpose. The spark plug is shown at 123, and the inlet is shown at 88.

In Fig. 14 the vane 200 is shown at the beginning of its intake, that is, just after it has passed the intake port 88 in the stator; and the vane 200 is moving toward the right. The vane 201 is approximately at the ignition point, the valve 131 having closed behind it, and the charge, which was being compressed in front of vane 201, has been transferred to the back of vane 201 through the recesses in the stator at the outer end of the vane.

Referring now to Fig. 15, vane 200 is now finishing the intake and is ready to complete compression of the gas which was taken in behind the vane 201. This compression is accomplished against the valve 132, which is closed.

Referring to Fig. 16, compression has now been completed, and vane 200 has reached a point where valve 132 must now begin to open. As the vane 200 progresses further from the position of Fig. 16, the gas, which is compressed in front of it, at the right, will be transferred over to the back of the vane 200, and compression will be maintained by means of the valve 131, which slips down behind the vane 200 as it progresses.

The transfer of the gas from the front to the back of the vane is facilitated by the movement of the vane against the valve 132, which forces the gas up over the edge of the vane.

Referring now to Fig. 17, the transfer of the gas from the front to the back of the vane 200 has now been completed and ignition has taken place and the gas in the space behind the vane 200 and in front of the valve 131 is now undergoing expansion.

Referring again to Fig. 15, it should be noted that as vane 200 is accomplishing compression in front of it, intake is also being accomplished behind it, and the gas which is taken in behind the vane 200 will be compressed by the next vane.

When any particular vane is being driven by expansion of ignited gases behind it, it is also effecting a discharge of the exhaust gases which impelled the preceding vane.

While the present motor is constructed with four sets of spark plugs and eight vanes, it should be understood that it can also be constructed with one set of spark plugs and two vanes, two sets of spark plugs and four vanes, or three sets of spark plugs and six vanes, or any desired number of stages.

Since there are four explosion chambers and eight vanes and each vane must pass each explosion chamber, there will be four times eight, or thirty-two, explosions for each rotation of the rotor. With eight series of chambers and sixteen vanes in the larger motor, there would be one hundred twenty-eight explosions per revolution. Thus a more uniform torque can be secured because a multiplicity of different impulses are provided at regularly spaced points at the periphery of the rotor in the course of each revolution.

By virtue of the relatively large projected area of the vanes, which is effective as a piston, a much greater rotative force can be secured, acting on the present rotor, than in any of the engines of which applicant is aware. By virtue of the greater number of explosions secured in each revolution, a far greater amount of fuel can be handled and a greater amount of power generated than with any of the devices of which applicant is aware.

Since an engine assembly can be provided by utilizing a plurality of separate units of my motor, it will be easier to make replacements and repairs by simply removing one unit of the motor

rather than the whole motor. Then, if one section should break down, the other sections may carry on with only a slight loss of power.

Since the main parts of the rotor and stator have their machined surfaces concentric with the centers, the parts can be turned upon a lathe and cheaper production will result. The cams can also be made more economically by utilizing cylindrical discs and securing the camming members thereto. The amount of compression secured can be regulated by the size of the vanes and the distances through which they travel, and by the volume of the ribbed indentations in the transfer-explosion chamber.

While I have illustrated a preferred embodiment of my invention, many modifications may be made without departing from the spirit of the invention, and I do not wish to be limited to the precise details of construction set forth, but desire to avail myself of all changes within the scope of the appended claims.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent of the United States, is:

1. In an internal combustion engine, the combination of a stator having a cylindrical chamber, with a rotor rotatably mounted in said chamber, and having a cylindrical wall spaced from the wall of said chamber, a plurality of vanes carried by said rotor and engaging the walls of said stator and adapted to serve as pistons, said stator having inlet and exhaust conduits, a plurality of valves carried by said stator, said valves being slidably mounted in the outer wall of said stator and engaging the end walls of the stator and the cylindrical surface of the rotor, one of said valves serving as an exhaust-intake valve and being located between the exhaust and intake openings, the other of said valves being located close to each other to form a compression-transfer chamber, said stator having conduits for passing a compressed charge from a point in front of the vane to a point behind the vane as the vane passes through said latter chamber, and ignition means in said latter chamber, and an auxiliary compression plunger mounted in said latter chamber and adapted to be projected into said latter chamber behind a vane in the chamber to increase the compression uniformly to a maximum without relapse of compression.

2. In an internal combustion engine, the combination of a stator having a cylindrical chamber, with a rotor rotatably mounted in said chamber, and having a cylindrical wall spaced from the wall of said chamber, a plurality of vanes carried by said rotor and engaging the walls of said stator and adapted to serve as pistons, said stator having inlet and exhaust conduits, a plurality of valves carried by said stator, said valves being slidably mounted in the outer wall of said stator and engaging the end walls of the stator and the cylindrical surface of the rotor, one of said valves serving as an exhaust-intake valve and being located between the exhaust and intake openings, the other of said valves being located close to each other to form a compression-transfer chamber, said stator having conduits for passing a compressed charge from a point in front of the vane to a point behind the vane as the vane passes through said latter chamber, and ignition means in said latter chamber, and an auxiliary compression plunger mounted in said latter chamber and adapted to be projected into said latter chamber behind a vane in the chamber to increase the compression uniformly to a maximum without relapse of compression, said vanes being outwardly tapered, and said valves and compression plunger having beveled surfaces for engaging complementary surfaces on said vanes to effect a seal.

3. In an internal combustion engine, the combination of a stator having a cylindrical chamber, with a rotor rotatably mounted in said chamber, and having a cylindrical wall spaced from the wall of said chamber, a plurality of vanes carried by said rotor and engaging the walls of said stator and adapted to serve as pistons, said stator having inlet and exhaust conduits, a plurality of valves carried by said stator, said valves being slidably mounted in the outer wall of said stator and engaging the end walls of the stator and the cylindrical surface of the rotor, one of said valves serving as an exhaust-intake valve and being located between the exhaust and intake openings, the other of said valves being located close to each other to form a compression-transfer chamber, said stator having conduits for passing a compressed charge from a point in front of the vane to a point behind the vane as the vane passes through said latter chamber, and ignition means in said latter chamber, and an auxiliary compression plunger mounted in said latter chamber and adapted to be projected into said latter chamber behind a vane in the chamber to increase the compression uniformly to a maximum without relapse of compression, the said vanes being slidably mounted on said rotor for radial motion, and resilient means urging said vanes radially outward into engagement with the stator.

4. In an internal combustion engine, the combination of a stator having a cylindrical chamber, with a rotor rotatably mounted in said chamber, and having a cylindrical wall spaced from the wall of said chamber, a plurality of vanes carried by said rotor and engaging the walls of said stator and adapted to serve as pistons, said stator having inlet and exhaust conduits, a plurality of valves carried by said stator, said valves being slidably mounted in the outer wall of said stator and engaging the end walls of the stator and the cylindrical surface of the rotor, one of said valves serving as an exhaust-intake valve and being located between the exhaust and intake openings, the other of said valves being located close to each other to form a compression-transfer chamber, said stator having conduits for passing a compressed charge from a point in front of the vane to a point behind the vane as the vane passes through said latter chamber, and ignition means in said latter chamber, and an auxiliary compression plunger mounted in said latter chamber and adapted to be projected into said latter chamber behind a vane in the chamber to increase the compression uniformly to a maximum without relapse of compression, the said vanes being slidably mounted on said rotor for radial motion, and resilient means urging said vanes radially outward into engagement with the stator, the said vanes being formed of two axially movable parts for engaging the end portions of the stator, and resilient means for urging said parts into such engagement.

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