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(54) INTERNAL COMBUSTION ENGINES

(71) We, TYLER ROAD ASSOCIATES, a partnership organised under the laws of the Commonwealth of Massachusetts, United States of America, of Suite 1200, 225 Franklin Street, Boston, Massachussetts, 02110, United States of America, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to internal combustion engines.

It is a general aim of this invention to provide an internal combustion engine with mechanical means for confining a rich fuel charge adjacent ignition means in the engine and for permitting unrestricted communication of said charge with the main combustion chamber of said engine upon initiation of fuel ignition.

According to the present invention there is provided an internal combustion engine having a combustion chamber, a member with an elongate passageway therethrough, the passageway having at one end an opening into the combustion chamber, a fuel injector arranged to inject fuel into the other end of the passageway, and a partition, the partition and member being relatively movable and the partition being arranged partially to block the opening and to define a fuel injection chamber with the passageway during injection of fuel into the passageway, and to be removed from, so as not to block, the opening after injection of fuel into the passageway.

Preferably, the member and partition are relatively rotatable, and the partition may block a major portion, for instance 80% of the area of the opening. Preferably, said opening is at least as large in area as the other end of the passageway and said passageway is not restricted from the one end to the other end.

In preferred forms, the engine includes a valve housing; a rotary valve member in said valve housing, the passageway extending through the valve member and the passageway having a valve port at said other end, said valve port, said opening and said passageway each being arranged to move in a circle on rotation of said valve member; the fuel injector being in said valve housing and in a sector of the circle traversed by said valve port for communication therewith and for injection of fuel through said valve port into said passage; the partition being positioned in the sector of the circle traversed by said opening when said valve port is in communication with said fuel injector; and being smaller than said opening in one dimension so as to define said fuel injection chamber during injection of fuel through said valve port into said passage; and said partition extending circumferentially to a greater extent than said opening.

In such preferred forms, the valve housing preferably comprises, in sectors of the circle traversed by said valve port and sequentially in the direction of rotation of said valve member, an intake passage, said fuel injector, ignition means and an exhaust passage, and said partition extends circumferentially in the sector of the circle traversed by said opening when said valve port is between said intake passage and said ignition means.

The combustion chamber will normally be a cylinder with the valve member rotatable about an axis preferably coincident with that of the cylinder, the opening extending generally radially with respect to the axis and the partition being smaller than the opening in a radial direction. The partition is preferably connected to a wall of the cylinder.

The invention will be more clearly understood from the following description which is given by way of example only with reference to the accompanying drawings in which:—

Fig. 1 is a schematic sectional view of a cylinder of one engine embodying the invention;

Fig. 2 is a reduced diagrammatic plan view of the head of the cylinder shown in Fig. 1 illustrating the relative positions of the ports and partition therein;

Fig. 3 is a reduced schematic plan view of the thrust bearing employed in the head of the cylinder;

Fig. 4 is an enlarged schematic sectional view of the fuel injector employed in the cylinder;

Fig. 5 is a view taken along the line 5-5 of Fig. 4;

Fig. 6 is a schematic sectional view of one cylinder of an engine employing an alternative embodiment of the invention;

Fig. 7 is a reduced schematic developed view of the interior cylindrical wall of the head of the cylinder illustrated in Fig. 6 showing the relative positions of the ports and partition therein;

Fig. 8 is a developed view along the line 8-8 of Fig. 6 illustrating the configuration of the opening of the rotary valve into the combustion chamber; and

Fig. 9 is a reduced schematic plan view of the valve drive arrangement employed with an engine according to the embodiment illustrated in Fig. 6.

Referring to the drawings, and more particularly to Fig. 1 thereof, there is shown one cylinder of a four cycle engine constructed according to the invention. The engine in the particular embodiment illustrated is of the rotary valve type.

The engine comprises a head generally designated 100 mounted on an engine block 110. Block 110 comprises a cylinder 111 having a piston 112 reciprocally mounted therein and defining together with the head 100 a main combustion chamber 113. Rings 114 seal the piston 112 to the cylinder wall 111. The crankcase, crankshaft, connecting rods and the like are as for a conventional engine and are not illustrated herein.

Head 100 comprises an adapter 118 mounted directly to block 110, a stationary valve housing 128 mounterd on adapter 118 and a cover 167. Adapter 118 has a cylindrical inner wall 119 of the same diameter as cylinder 111 and extends thereabove as a continuation thereof. Valve housing 128 has a hemi-spherical or dome shaped cavity defined by wall 139 overlying the cylindrical opening adapter 118.

Positioned within the dome shaped cavity of valve housing 128 and extending downwardly into adapter 118 is a rotary valve member 120 rotatable about an axis coincident with that 136 of cylinder 111. Rotary valve 120 comprises a body having a hemi-spherical or dome shaped upper wall 138, cylindrical peripheral wall 137, valve stem 144 and internal strengthening ribs 149. The upper and peripheral walls 138, 137, respectively, fit within wall 139 of valve housing 128 and within the cylindrical wall 119 of adapter 118. Valve stem 144 extends upwardly through valve housing 128 and is supported therein by plain journal bearing 140. A cooling tube 146 and baffle 155 are positioned within the valve 120. The body of the rotary valve 120 is preferably sand cast, drilled and tapped to accept the cooling tube 146 and baffle 155. The rotary valve 120 also comprises a flat plate 153 extending across the bottom thereof attached to the bottom of peripheral wall 137. The lower surface 152 of the plate 153 opposes the working face 124 of piston 112 and is spaced from the upper wall 138 of valve 120.

An elongated passage 121 extends through rotary valve 120 from the lower surface 152 to the upper wall 138 thereof. Passage 121 is offset from the axis of rotation of valve 120 to be substantially located on one side thereof. As best shown in Fig. 2, valve port 122 at upper wall 138 of valve 120 is generally circular and is offset from the axis of rotation. At its opening 123 into combustion chamber 113 passage 121 has a generally triangular shape, best shown in Fig. 2, side walls 125, 127 extending generally radially from the axis of rotation thereof, but has an enlarged throat 129 at the apex thereof adjacent the axis of rotation. The walls of passage 121 are smoothly curved to provide an unrestricted passage from one end to the other thereof and the cross-sectional area of opening 123 is at least as great as the cross-sectional area of valve port 122. Because of the changing shape of the passage 121 throughout its length it is preferred to make the passage by casting using fine sand for the core.

As best illustrated in Fig. 2, valve housing 128 has, sequentially in sectors of the circle traversed by valve port 122 on rotation of valve 120 for communication with passage 121, an intake port 126, a fuel injector 130, ignition means, i.e., spark plug 132, and an exhaust port 134. A partition or shelf 116 extends inwardly from adapter cylindrical wall 119 adjacent the sector of the circle traversed by opening 123 when valve port 122 is in communication with fuel injector 130 to cover a major portion of the area of opening 123. Partition 116 extends from a position before fuel injector 130 in the direction of rotation, between the position thereof and intake port 126, so that it will cover opening 123 to form a separate chamber during fuel injection. Partition 116 has a limited circumferential extent greater than that of opening 123 terminating at the position of spark plug 132 so that as ignition progresses to its maximum rate, opening 123 is opened completely to combustion chamber 113. Partition 116 extends radially inward to such an extent relative to opening 123 as to leave throat 129 open at all times, throat 129 comprising about 20% of the area of opening 123. The face 124 of piston 112 is contoured to match shelf 116 so that the space in combustion chamber 113 taken together with the volume of passage 121 will provide the desired compression ratio with the piston at top dead center (TDC).

The valve stem 144 is topped by a helical cut gear 156 which engages helical drive gear 158. Drive gear 158 is connected with the crankshaft via a mechanical linkage (not shown) designed to turn rotary valve 120 once for each two revolutions of the crankshaft.

A thrust bearing 166 is provided for valve 120 mounted on the end of gear 156 to cooperate with cap 167. Thrust bearing 166 is designed to operate both hydrostatically and hydrodynamically. Bearing 166 must take the thrust of the combustion chamber 113 pressure during the short period of maximum pressure when fuel is burning on the power stroke. The pressure over the area of the thrust bearing rises at this peak far beyond the pressure available from an ordinary oil pump. To balance this pressure, as shown in Fig. 1, the oil feed 170 to the bearing 166 is provided with a check valve 172 biased with a spring 174 set to open at a moderate oil feed pressure, e.g., 10 p.s.i., and to prevent any reverse flow of oil when the thrust bearing is under maximum pressure during combustion. To preclude any sludge or other matter which might cause check valve 172 to fail, the oil is passed through a filter 178 and preferably the engine is equipped with a separate oil supply tank and pump (not shown) for the thrust bearing oil system. In the event that check valve 172 should not operate properly, however, a restricted passage 180 is provided between the oil feed 170 and check valve 172. Thus, bearing 166 receives oil during alternate low pressure periods in the combustion chamber 113 and uses check valve 172 and backup restriction 180 to withstand high pressure during the power stroke. As a final backup to the hydrostatic system just described, bearing 166 has its surface facing cap 167 grooved with a plurality of spiral grooves 169, best illustrated in Fig. 3. The grooves 169 in bearing 166 are provided so that, if all else fails, oil in the grooves will move over the surface of bearing 166 to lubricate it and cap 167. Grooves 169 are shallow, for instance of a few thousandths of an inch in depth and may be formed by spark erosion or high frequency abrasive techniques.

Valve 120 is cooled by water which enters from annular passage 191 in valve housing 128 encircling valve stem 144. Passage 191 communicates through perforations 142 in bearing 140 with a passage 192 in stem 144 which in turn communicates with the top of cooling tube 146. Water descends through tube 146 to plate 153, then flows outwardly below baffle 155 and returns annularly about tube 146 to passage 194 through perforations 143 in bearing 140 to annular return passage 196 encircling stem 144 in housing 128. Elastomeric O-rings 200, 201 and 202 are used to seal the rotating interfaces between the passages 191, 192, 194 and 196, the O-rings being lubricated by the cooling water. An elastomeric O-ring 203 is also provided adjacent the bottom of bearing 140 between bearing 140 and valve 120 to insure against water leakage therepast and to retain lubricant which is furnished to bearing 140 by oil feed lines (not shown).

Port 122 in valve 120 is sealed by a circular sealing ring 148 in groove 150. Hemispherical upper wall 138 of valve 120 has a radius several thousandths of an inch smaller than the radius of wall 139 of housing 128. Ring 148 bridges the gap. As shown in Fig. 1, port 122, ring 148, and groove 150 are inclined to the axis of rotation of valve 120. A spring 184 in the base of groove 150 forces ring 148 outwardly so that it offers a part-spherical face to engage wall 139 of housing 128, spring 184 providing the sealing force at low speeds whereas centrifugal force provides adequate sealing force at high speeds. Since the outer portion of ring 148 moves faster than the inner portion thereof, ring 148 is caused to rotate in groove 150 distributing wear on the ring. Preferably, ring 148 is made of self lubricating material such as molybdenum disulphide. Another possibility is a carbon-graphite material. It would also be possible to employ a more exotic type material such as copper or steel impregnated with diamond dust which has been run against another diamond impregnated surface until the diamond edges have been rounded and no longer cut.

Ring 148 is subject to axial motion of high frequency during the ignition in combustion chamber 113. In addition there must be an allowance for thermal expansion of the parts in an axial direction.

Some of this axial change is accommodated by thrust bearing 166. However, spring 184 must be long enough in an axial direction to carry considerable preload and is selected to accommodate axial motion on the order of about 0.005″ without change of force greater than about 20%.

Sealing rings 186 in groove 190 and 210 in groove 212 work radially rather than axially and do not require spring backing. Lubrication is supplied above sealing ring 186 by an oil feed (not shown). Ring 210 on the other hand is lubricated by the oil in thrust bearing 166 and requires no special lubricating features.

Fuel injection through valve port 122 into passage 121 of valve 120 must occur within an extremely short period of time, e.g., as short as 0.0015 second, as valve port 122 rotates past fuel injector 130. Accordingly, a simple solenoid pump is provided for each cylinder of the engine.

The fuel injector 130 is held in valve housing 128 by a lever 300, as shown in Fig. 1, rotatable for removal thereof. As best illustrated in detail in Figs. 4 and 5, injector 130 comprises an injector body 220 having a tapered surface 222 designed to tightly fit into a matching cavity in housing 128. A fuel exit slot 224 is provided in the injector 130 aligned with a slot 131 in housing 128 for communication with valve port 122. Slots 131, 224 extend in a plane including the axis of rotation of valve 120 (e.g., extending generally vertically in Fig. 1), thereby maximizing the time for injection of fuel through valve port 122 into passage 121. Slots 131, 224 are narrower than the width of sealing ring 148.

Above the nozzle assembly of injector 130 in a cavity 244 is a ball 248 and spring 250 which cooperate with an aperture in a valve plate 246 to form a check valve holding back the fuel, at a moderate pressure, e.g., 10 p.s.i., until the injector is activated. Above the check valve is the solenoid pump assembly comprising a pole piece 252 having a central passage 253 therethrough leading to the check valve assembly and having a coil 255 thereabout. The solenoid pump valve assembly also includes an armature piston or plunger 254 spaced above pole piece 252 and fitted within cylindrical member 258. Another coil 256 is positioned about piston stem 288 arranged to affect piston 254 oppositely from pole piece 252 for quick action upon establishment of the magnetic circuits. Electrical supply wires 280 and coil leads are connected by solderless connectors (not shown).

Fuel line 270 connects via passage 272 with the space between piston 254 and pole piece 252. A check valve comprising ball 274 and spring 276 is provided in the passage 272. Fuel is pumped under low pressure from an ordinary fuel pump (not shown) through check valve 274 which raises piston 254 away from pole piece 252, ball 248 functioning to contain the fuel in passage 253.

Piston 254 is free to move but is sealed to block 266 and cup 284 by membrane 260 which is of fabric or a reinforced elastomer preferably of the type known as "Bellofram" a trademark of Bellofram Corporation of Burlington, Massachusetts. The membrane 260 is sealed to the top of piston 254 by screw 262 and washer 264.

To adjust the axial excursion of piston 254 and hence the amount of fuel injected upon actuation of the injector 130, a screw 286 is provided in the top of cup 284 bearing on screw 262. Screw 286 is topped by pinion gear 290 engaged by a rack 292 for turning screw 286 and thus throttling the engine. Thus, as the magnetic circuits are established by coils 255, 256, piston 254 is pulled to pole piece 252 forcing fuel ahead of it and out of slot 224, the amount of fuel injected being controlled by the setting of screw 286 as rack 292 and pinion 290 are selectively moved.

The hemi-spherical shapes of the walls 138 and 139 of valve 120 and housing 128 are not common in automotive manufacture but are easily and accurately formed by simple machinery. The initial shape for wall 139 is formed in the casting pattern for the valve housing 128. This has a smaller radius than the final dimension. After finishing the lower face of the casting and preferably a parallel upper surface as well, the valve housing 128 enters a multi-station machine. Vertical spindles on this machine carry: at a first station, a boring bar which finishes the inside of the cavity for journal bearing 140 on the proper centre; at a second station an inclined shaft grinding spindle and motor, with a coarse roughing wheel which roughs out the partial spherical cavity to the same centre as the cavity for bearing 140 machined by the spindle at the first station; and at third and fourth stations a finer grinding wheel and a finishing wheel which give the interior of the cavity a finish comparable to the cylinder walls of the engine. Tolerance of the spherical radius and depth can be about 0.025″. As the wheels wear, the spindles are advanced deeper into the casting, until the proper dimension is achieved.

The upper wall 138 of valve 120 has a radius several thousandths of an inch smaller than the cavity in the head, as previously noted, and does not require such a good surface finish; hence it is made by casting and machining. The bottom portion of the valve body and the upper surface of plate 153, both cast, are rough machined to give a good fit before joining the two parts together.

The operation of the illustrated four cycle engine can best be visualized by reference to Fig. 2. Valve 120 rotates within valve housing 128 as piston 112 reciprocates between top dead centre and bottom dead centre, TDC and BDC, respectively, as indicated in Fig. 2. Opening 123 is completely open during the exhaust and intake strokes and hence the cylinder is free breathing. As the valve 120 rotates, valve port 122 is in communication with intake port 126 admitting air to combustion chamber 113 during substantially the entire intake stroke of piston 112 as it moves from top dead centre to bottom dead centre. As piston 112 reaches bottom dead centre on its intake stroke, intake port 126 is closed as valve port 122 moves therepast. During the compression stroke of piston 112, opening 123 of passage 121 is covered by partition 116 except at restricted throat 129 through which air is admitted in a turbulent flow during the compression stroke and valve port 122 is open to fuel injector 130 through slot 131. Fuel is then injected into passage 121 through slot 224 in injector 130 and through slot 131 and valve port 122, being confined in a rich mixture by partition 116 to passage 121 which forms with the partition a fuel injection-ignition chamber. The turbulent flow through throat 129 aids in the mixing of the fuel and its evaporation in the compressed air. The rich mixture in passage 121 has an air to fuel ratio of 8:1 to 14:1 as compared to an 18:1 to 30:1 ratio if the fuel were dispersed throughout the entire compression space above piston 112. Partition 116 terminates at spark plug 132 and as valve port 122 moves to spark plug 132, still during the compression stroke, opening 123 begins to be exposed to combustion chamber 113. Spark plug 132 ignites the rich mixture in passage 121 after valve port 122 passes and hence closes slot 131 and injector 130, while partition 116 only partially closes opening 123 still during the compression stroke, just before piston 112 reaches top dead centre. Ignition progresses to its maximum rate at which point opening 123 has completely passed partition 116 and is wide open to combustion chamber 113. Thus the burning fuel spreads into the combustion chamber 113 for substantially complete combustion forcing piston 112 downward during its power stroke. As piston 112 passes bottom dead centre valve port 122 communicates with exhaust port 134 and remains open thereto until piston 112 reaches top dead centre. The cycle is then repeated.

Advantageously, hydrocarbons are substantially completely burned in the engine minimizing exhaust pollutants.

An alternative embodiment illustrated in Fig. 6 operates in the same manner as the embodiment just described. Although the alternative embodiment of Fig. 6 is similar to that of Fig. 1, it embodies a number of features to simplify its construction and to improve its operation. For convenience the same reference numerals with a prime indication, e.g., 120′; are used for corresponding parts of the two embodiments.

As shown in Fig. 6, the alternative embodiment includes a head comprising simply a valve housing 128′. Valve housing 128′ has a cylindrical interior wall 141′ housing a cylindrical rotary valve 120′ having facing cylindrical wall 137′. Facing horizontal surfaces 138′, 139′ of valve 120′ and housing 128′ are flat rather than spherical and surface 138′ comprises a hydrodynamic thrust bearing for the valve, being spirally grooved, 169′, and having a lubrication system feeding through filter 178′. The lubrication system in this embodiment omits the check valve and restricted passage employed in the embodiment of Fig. 1.

The lower surface 152′ of valve 120′ is of generally conically recessed configuration except for a central portion on the axis of valve 120′, which defines the throat 129′ of opening 123′. Opening 123′ has the configuration shown in Fig. 8, a developed view thereof taken along the line 8-8 of Fig. 6. Partition 116′ conforms to the conical configuration of surface 152′. Thus when valve port 122′ is adjacent fuel injector 130′ partition 116′ closes opening 123′ except at throat 129′ which is ideally located coaxially of and facing piston 112′. The face 124′ of piston 112′ is contoured to match the conical configuration of valve surface 152′ and partition 116′.

Valve port 122′ is altered as best shown in Fig. 7 to have a generally rectangular configuration for clean, rapid opening and closing of intake and exhaust ports 126′ and 134′ which also have rectangular openings. Seal 148′ in groove 150′ is circular, is made of molybdenum disulphide and is backed by a Belleville spring washer 184′ which serves to seal the bottom of groove 150′ as well as to bias seal 148′.

Valve stem 144′ extends through housing 128′ and thereabove has belt drive gear 156′ mounted thereon. As best shown in Fig. 9 a timing belt 302′, extends about gears 156′ of a plurality of rotary valves in an engine, and about a drive gear 157′ connected (not shown) to the engine crankshaft. Between gears 156′ and gear 157′, rollers 159′ pinch belt 302′ in to assure adequate wrap around the gears.

Cooling tube 146′ passes centrally up stem 144′ spaced from the interior walls thereof and held in position by ribs (not shown) extending from the interior walls of stem 144′. Above gear 156′, tube 146′ communicates with the water inlet passage 191′ of a cooling manifold. Immediately therebelow the passage defined between the interior wall of stem 144′ and tube 146′ communicates with the water outlet passage 196′ of the cooling manifold.

Because of its cylindrical design, the head of the embodiment illustrated in Fig. 6 may be easier to build by conventional engine building techniques than the design illustrated in Fig. 1 and may for that reason be preferred.

WHAT WE CLAIM IS:—

1. An internal combustion engine having a combustion chamber, a member with an elongate passageway therethrough, the passageway having at one end an opening into the combustion chamber, a fuel injector arranged to inject fuel into the other end of the passageway, and a partition, the partition and member being relatively moveable and the partition being arranged partially to block the opening and to define a fuel injection chamber with the passageway during injection of fuel into the passageway, and to be removed from, so as not to block, the opening after injection of fuel into the passageway.

2. An internal combustion engine as claimed in claim 1 in which the member and partition are relatively rotatable.

3. An internal combustion engine as claimed in claim 1 or 2 in which said partition can block a major portion of the area of said opening.

4. An internal combustion engine as claimed in claim 1, 2 or 3 in which said opening is at least as large in area as the other end of the passageway and said passageway is not restricted from the one end to the other end.

5. An internal combustion engine according to claim 1, 2, 3 or 4 and including a valve housing; a rotary valve member in said valve housing, the passageway extending through the valve member and the passageway having a valve port at said other end, said valve port, said opening and said passageway each being arranged to move in a circle on rotation of said valve member; the fuel injector being in said valve housing and in a sector of the circle traversed by said valve port for communication therewith and for injection of fuel through said valve port into said passage; the partition being positioned in the sector of the circle traversed by said opening when said valve port is in communication with said fuel injector; and being smaller than said opening in one dimension so as to define said fuel injection chamber during injection of fuel through said valve port into said passage; and said partition extending circumferentially to a greater extent than said opening.

6. An internal combustion engine as claimed in claim 5 in which said valve housing comprises, in sectors of the circle traversed by said valve port and sequentially in the direction of rotation of said valve member, an intake passage, said fuel injector, ignition means and an exhaust passage, and said partition extends circumferentially in the sector of the circle traversed by said opening when said valve port is between said intake passage and said ignition means.

7. An internal combustion engine as claimed in claim 6 in which said partition is provided between a position in the sector of the circle which, in use, is traversed by said opening when said valve port has passed said intake passage and a position terminates in the sector of the circle traversed by said opening when said valve port is adjacent said ignition means.

8. An internal combustion engine as claimed in any preceding claim in which the radial extent of said opening is greater than that of said partition.

9. An internal combustion engine as claimed in any preceding claim in which said partition is connected to a wall of said combustion chamber.

10. An internal combustion engine substantially as hereinbefore described with reference to and as shown by Figures 1 to 5 of the accompanying drawings.

11. An internal combustion engine substantially as hereinbefore described with reference to and as shown by Figures 6 to 9 of the accompanying drawings.

J. A. KEMP & CO.,
Chartered Patent Agents,
14 South Square,
Gray's Inn,
London, WC1R 5EU.

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1 479 347 COMPLETE SPECIFICATION

4 SHEETS

This drawing is a reproduction of the Original on a reduced scale.

SHEET 1

FIG. 1

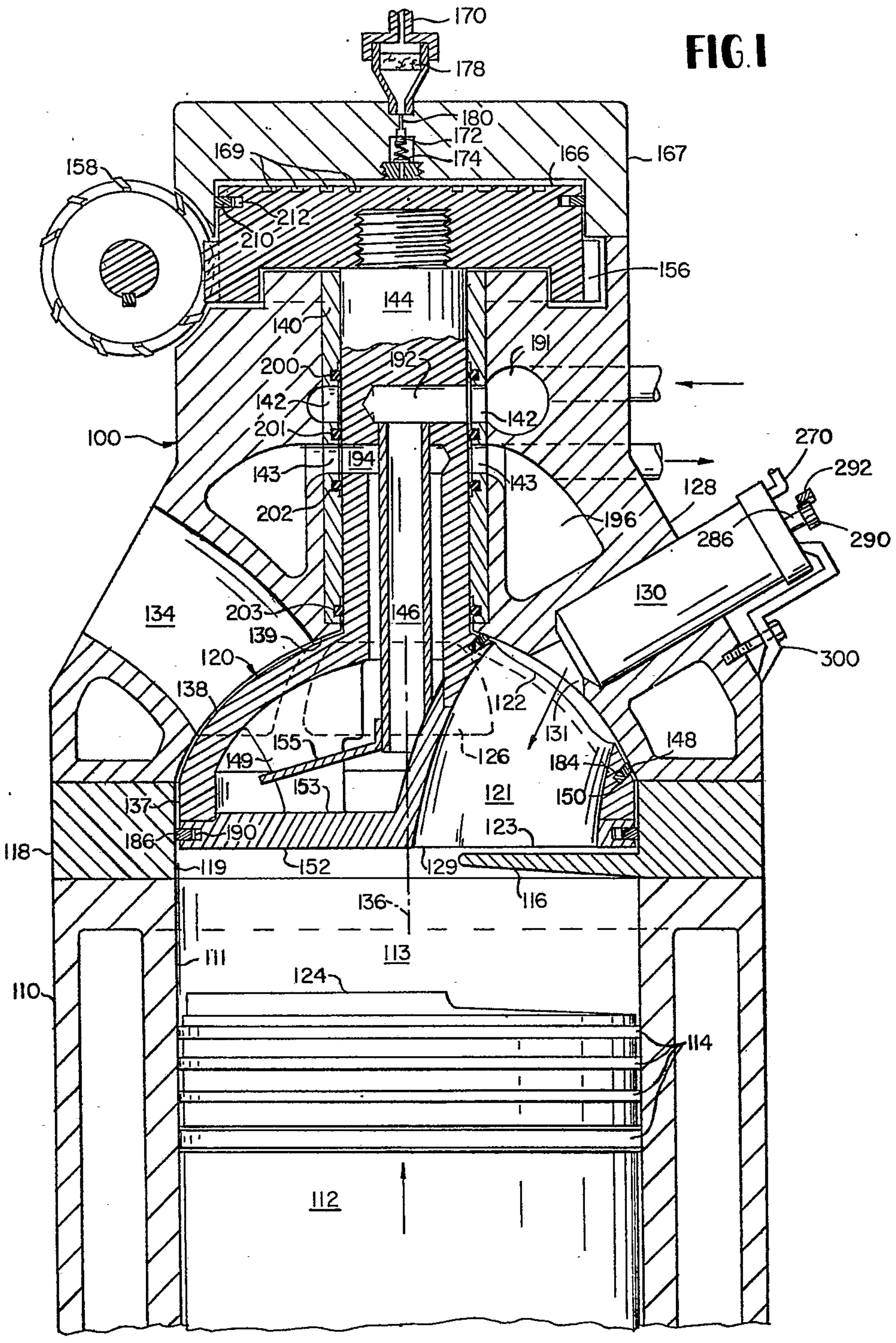


FIG.2

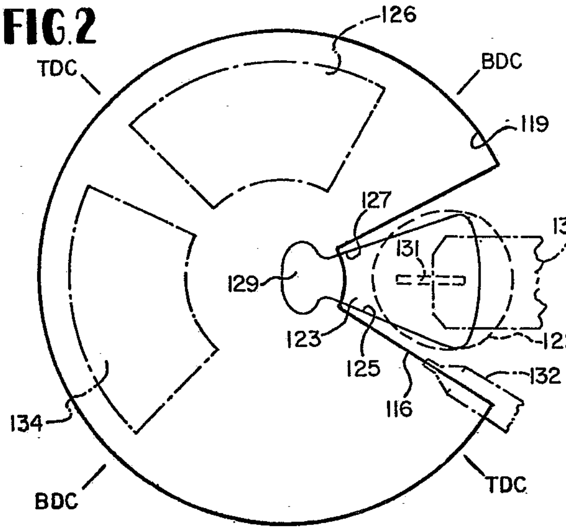


FIG.8

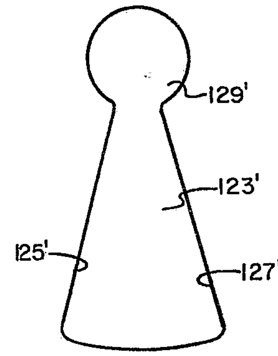
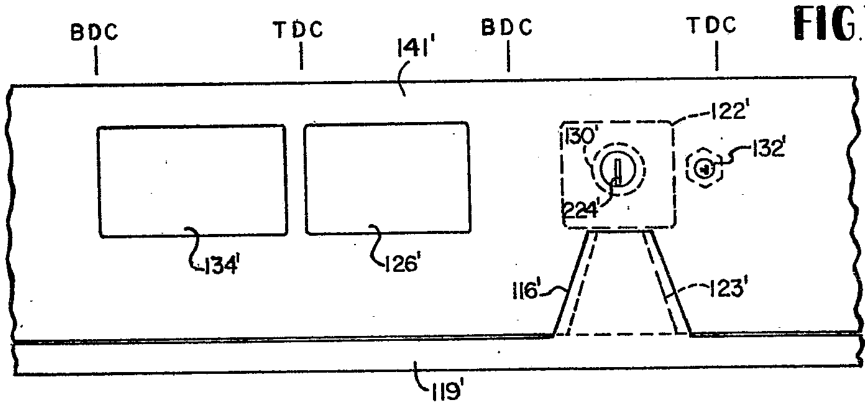


FIG.7



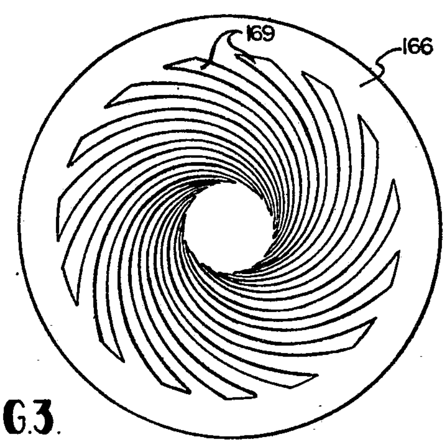


FIG.3

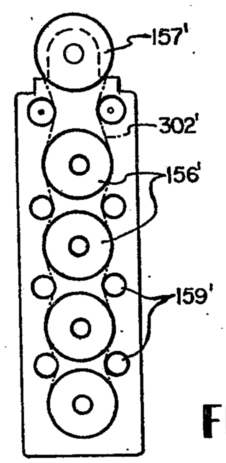


FIG.9

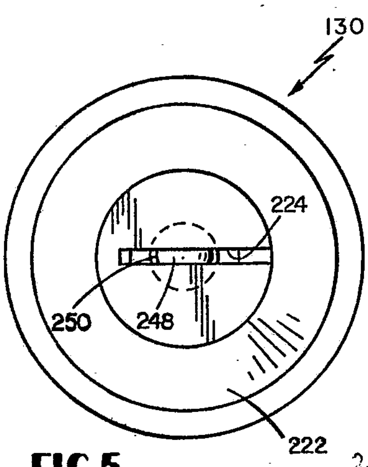

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FIG.5

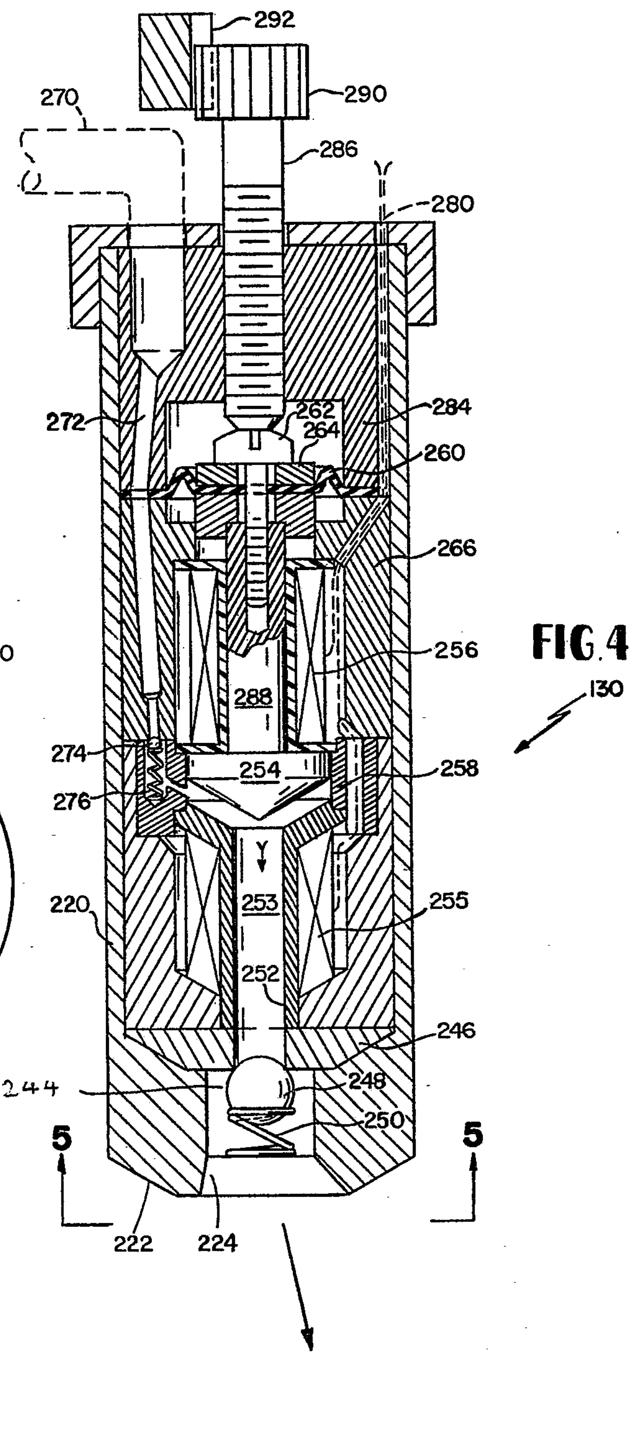
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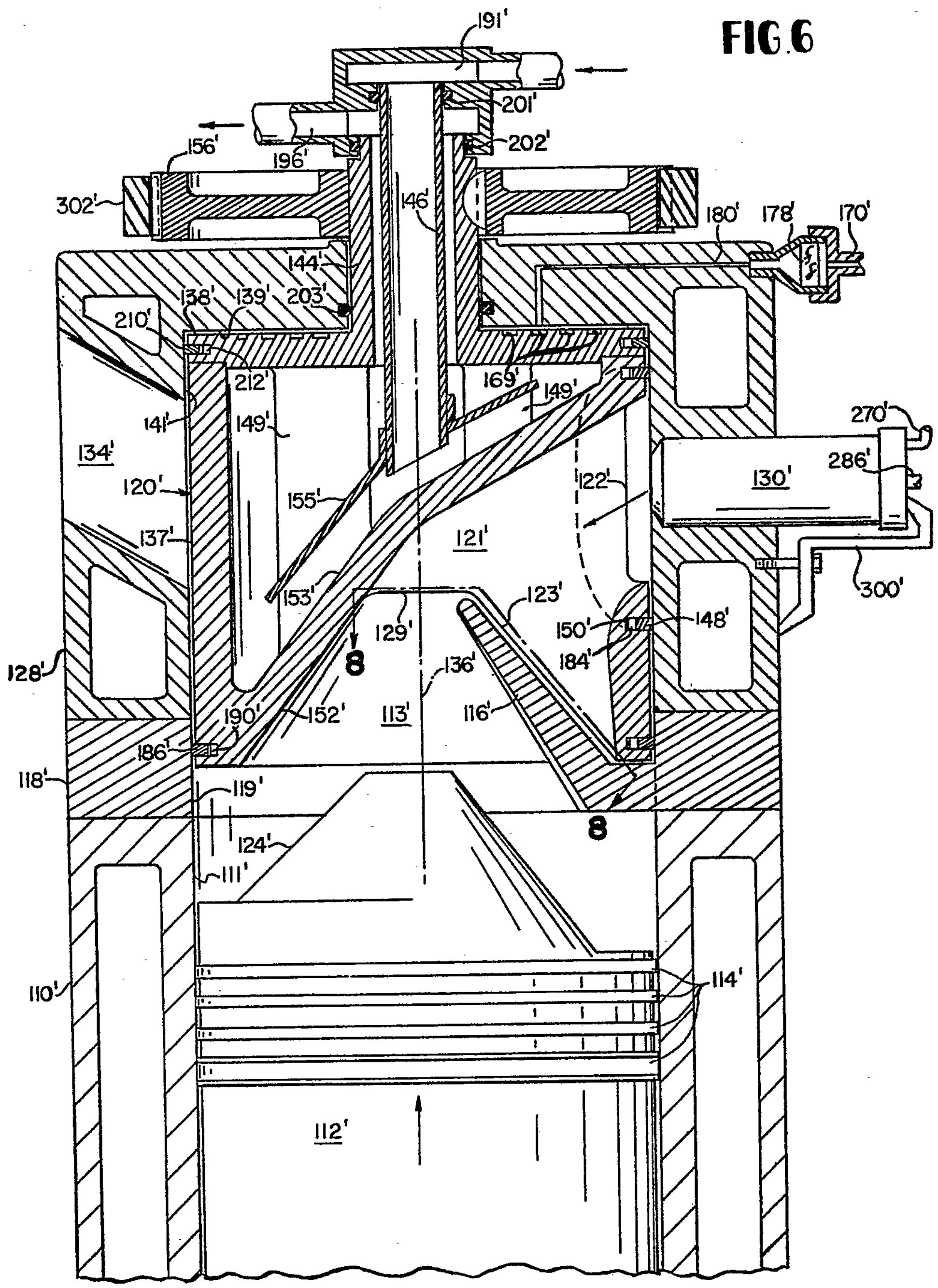
FIG.4

FIG.6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