Nov. 19, 1940. E. S. HALL 2,222,294

INTERNAL COMBUSTION ENGINE

Filed Feb. 8, 1938 2 Sheets-Sheet 1

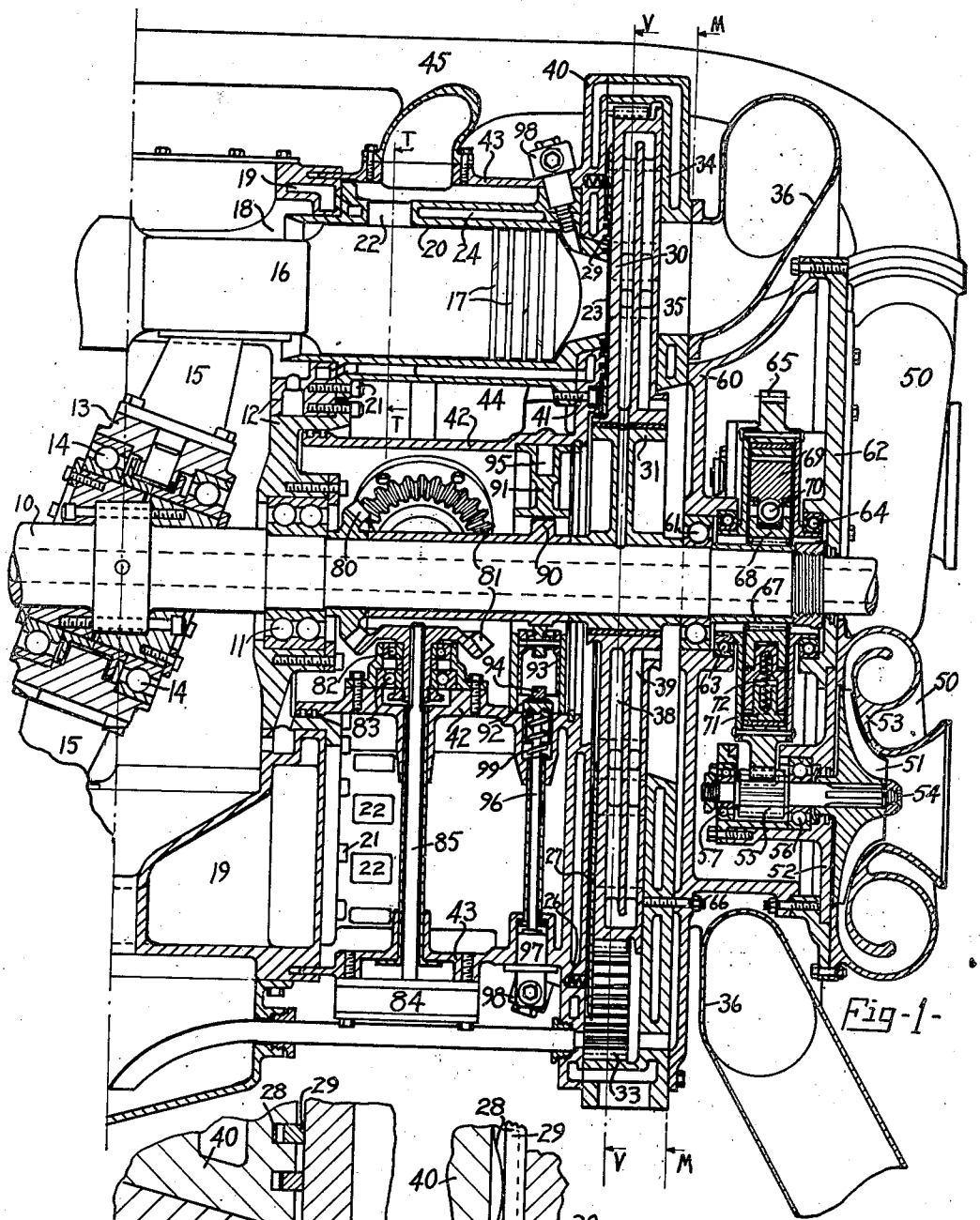


Fig-1-

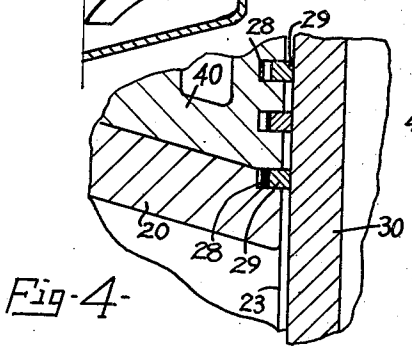


Fig-4-

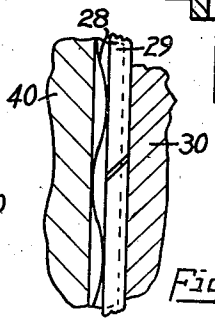


Fig-5-

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INTERNAL COMBUSTION ENGINE

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Fig-3V-

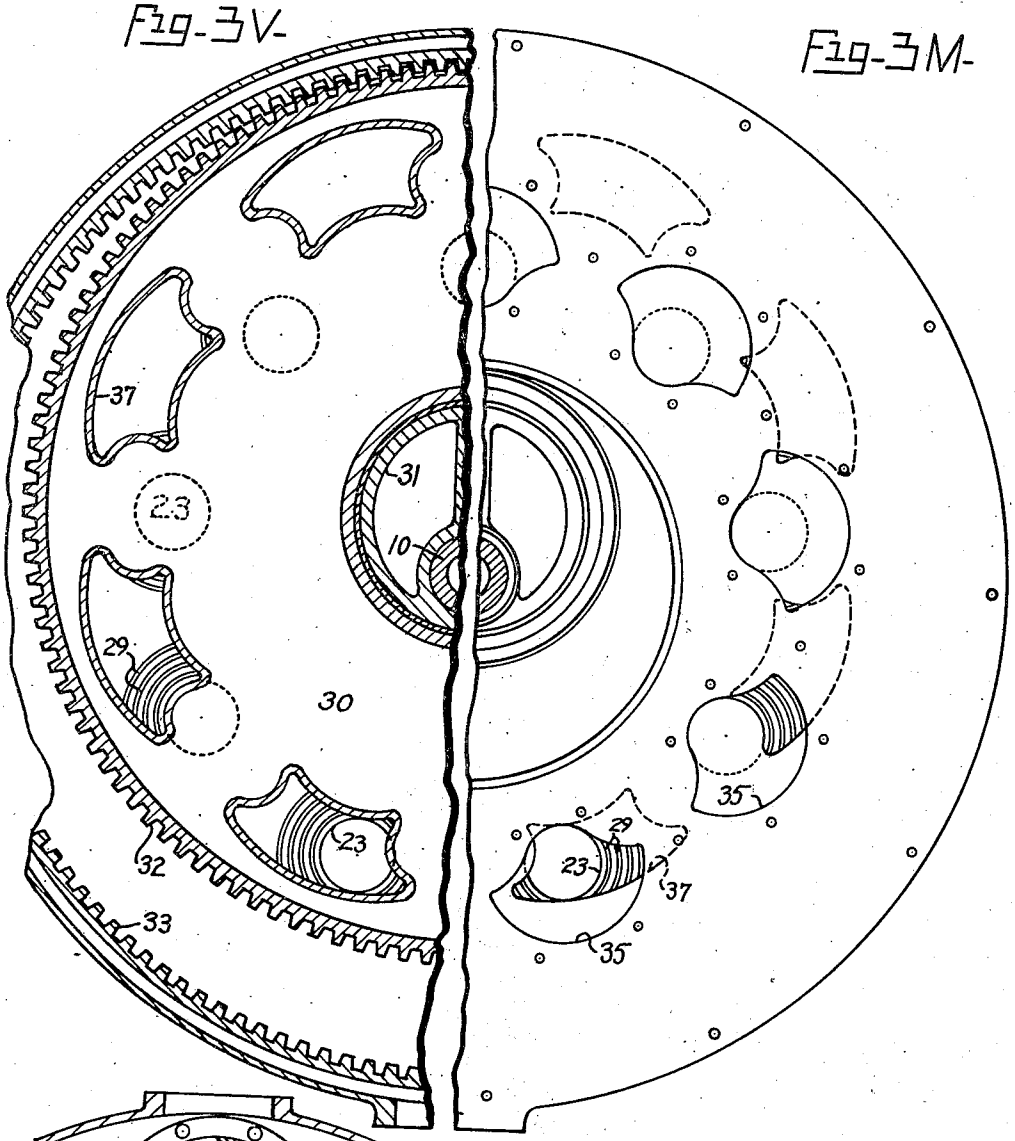


Fig-3M-

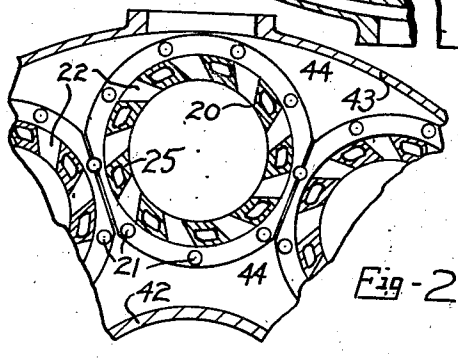


Fig-2-

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UNITED STATES PATENT OFFICE

2,222,294

INTERNAL COMBUSTION ENGINE

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Application February 8, 1938, Serial No. 189,401

2 Claims. (Cl. 123—58)

This invention relates to Internal combustion engines of the type having cylinders parallel to the shaft, commonly called "barrel type" or "round engines", and is particularly concerned with the normal type of round engine, (i. e. that type having double-ended piston members serving two similar groups of working cylinders with the reciprocating-rotary mechanism between them), tho some of the features of the invention are applicable to other types of engines, as will be evident. This application is a continuation in part of my copending application Serial Number 67,017 filed March 4, 1936.

An object of this invention is to provide an efficient and compact engine capable of delivering an unusually large amount of power for its bulk with extremely smooth operation. To this end, the invention consists of a normal round engine with preferably an odd number of double-ended piston members serving two groups of working cylinders, operating on the two-stroke cycle, with air for combustion furnished by separate blower means.

In two-stroke engines, the piston may overrun both intake and exhaust ports at the same time, but uniflow scavenge is preferable with intake at one end of the cylinder and exhaust at the other. In normal round engines, uniflow scavenge can be obtained by using piston-controlled ports for intake and valves for exhaust, or vice versa. An object of this invention is to provide a normal barrel engine operable on the two-stroke cycle with uniflow scavenge, with both ports in the cylinder walls and a valve system. Preferably the intake may be thru piston-controlled ports, the valve system handling exhaust, but the direction of scavenge might be reversed if desired, with the valve system handling intake and the pistons uncovering exhaust ports.

Relative to the valve system, an object of the invention is to provide a very simple system comprising two disc valves, each serving an entire group of cylinders, and mounted on eccentrics on the shaft so as to contribute to the dynamic balance of the engine, and so driven that the speed of the valve relative to the port sealing means is relatively slow during high pressure portions of the cycle, but very much faster during opening and closing of the ports, to provide rapid opening and closing of the ports and to permit very large port openings for free flow of the gases. Further objects are to provide improved driving, sealing, cooling, and oil control means for disc valves.

Good scavenge and favorable combustion conditions can be obtained with the intake ports long enough radially to have a nozzle effect and tangentially inclined to give an orderly swirl to the scavenge air as it enters the cylinders. It is also desirable to be able to machine all ports. Objects of this invention are to provide these conditions by using individual cylinders each with a ring of tangentially inclined intake ports opening into the cylinder, and to provide uniform distribution of the scavenge air by serving all the ports of the several cylinders of each group from a common windchest thru which the cylinders extend.

The two windchests must be supplied with air at pressure somewhat greater than atmospheric, from the blower system. Positive displacement blowers could be used, but centrifugal blowers have less bulk for the amount of air delivered, and are therefore preferred. The most serious problem involved in the use of centrifugal blowers is to provide a sufficiently sturdy drive, and it is an object of this invention to provide an improved method of driving and mounting centrifugal blowers. To deliver enough air at the required pressure to scavenge a 1000 H. P. engine may require more than 200 H. P., and the step-up gearing must deliver that power continuously with the blower speed ten times engine speed or more. Gear tooth loads are very severe and impeller inertia forces are terrific; the gearing must be protected from shock resulting from irregular operation of the engine shaft. An object of this invention is to reduce the gear tooth loading to a fraction of what it would be ordinarily by providing a system of multiple blowers, instead of the usual single blower. Further objects are to provide a simple and symmetrical system of gearing in which each gear can be maintained in alignment by being mounted on a pair of adequate bearings, cantilever loading being avoided; and to provide cushion and clutch means to avoid shock on the gears; and to provide means for assembling and mounting each blower in a manner insuring correct meshing of its drive pinion.

In round engines of both the normal and opposed-piston types, the driving and disposition of such accessories as oil and water pumps, generator, tachometer, etc., have been something of a problem. An object of this invention is to provide a workmanlike system of driving the accessories of a barrel engine in a manner permitting their convenient and accessible location. Within each group of cylinders, a plurality of

bevel gears are mounted on their own bearings and driven by a single gear on the engine shaft, and radial drive shafts each associated with its accessory or group of accessories are inserted between the cylinders to connect with the bevel gears, the accessory or group thereof being mounted on a flange on the outside of the engine in a convenient and accessible position.

In any two-stroke engine, it is desirable to use fuel injection to avoid loss of unused fuel thru the exhaust. An object of this invention is to provide a fuel injection system for a barrel engine with radially arranged pump units driven from a cam on the engine shaft, each pump unit being associated with its own nozzle, both pump and injection nozzle being easily accessible. Long high-pressure pipes are avoided and uniform action is assured. A further object is to provide means for controlling the timing of the operation of the fuel pumps.

Another object is to provide improved accessibility to various parts and accessories of a barrel engine, and a further object is to provide an improved general arrangement for a barrel engine comprising a series of unit sub-assemblies so constructed that they may be assembled in order as follows: the engine mechanism proper including the pistons as an operable mechanism; the cylinders in two groups, one at each end of the engine casing; a valve and accessory assembly at each end; and the blower unit at one end and the power offtake gearing or coupling at the other.

Another object is to provide for axial flow of the cooling medium thru the jackets of the individual cylinder units to insure their uniform cooling and to insure especially the cooling of the port bridges. The wabbler case is jacketed to assist in cooling the oil and to form a water manifold connecting the inner ends of all cylinder water jackets, while the valve housings, also water-jacketed to assist in cooling the valve, form the water manifolds connecting the outer ends of the cylinder water jackets. Circulation of the cooling medium by pumps may be from the wabbler casing jackets outwardly thru the cylinder jackets to the valve housings, or vice versa, as desired, suitable radiators being included in the circuit as usual.

These and other objects and features of the invention will be more apparent from the following description in connection with the drawings, in which: Fig. 1 is a longitudinal sectional view of the rear portion of the engine, it being understood that the forward end is similar and the various parts symmetrically arranged to those shown excepting only the blower unit which serves both rear and forward groups of cylinders. As usual, in longitudinal sectional drawings of barrel engines, projections of some of the parts behind the plane of the drawing are omitted to avoid unnecessary confusion. Fig. 2 is a transverse section on the line T—T of Fig. 1, showing the cylinder intake port arrangement. Figs. 3V and 3M are sectional views of the disc valve system, taken on the lines V—V and M—M of Fig. 1. Fig. 4 is an enlarged view of a portion of Fig. 1 showing the particular type of port sealing means used in connection with the disc valve. Fig. 5 is a development of a portion of one of the sealing rings and its spring ring.

Referring to the drawings, engine shaft **10** is operable in ball bearings **11** mounted in casing **12**. Wabbler **13** is mounted on bearings **14** on shaft **10**, the axis of the wabbler and its bearings being inclined to that of the shaft. Wabbler arms **15** have suitable operable connections with piston members **16** which are reciprocable in guide surfaces **18** in casing **12** while piston rings **17** slide in cylinders **20**.

Cylinders **20** are individual units, each bolted to casing **12** by bolts **21** and having an annular water jacket **24** and integral combustion chamber opening axially with port **23**. Each cylinder **20** also has intake ports **22** tangentially inclined and having enough radial length in passing thru the water jacket to direct the air as it enters cylinder **20**. Ports **22** are piston-controlled and ports **23** are controlled by disc valve **30** which is rotatable on eccentric **31** fixed on shaft **10**. Disc valve **30** has peripheral gear **32** engaging internal gear **33** carried by valve casing member **34** which member also has ports **35** opposite to and larger than combustion chamber ports **23**. Ports **35** discharge into manifold **36** which is fastened to casing member **34**. Ports **37** thru valve disc **30** successively connect each of ports **23** with its corresponding port **35**. Chambers **38** and **39** within valve disc **30** may be filled with cooling liquid. Combustion chamber ports **23** are sealed relative to the face of valve **30** by rings **29**, identical in construction with ordinary "piston rings", and urged against the face of valve **30** by springs **38** augmented by the gaseous pressure being confined. Valve ports **37** when not in alignment with ports **23** are kept closed relative to the interior of the valve housing by sealing plate **27** which is resiliently held against the face of valve **30** by springs **26** seated in casing member **40**.

Casing member **40** is part of the housing for valve **30** and is bolted to cylinders **20** by bolts **41**. Casing member **40** has concentric cylindrical walls **42** and **43** engaging casing **12** and forming an annular chamber **44** enclosing cylinders **20** and forming a common windchest to supply ports **22** in all cylinders **20** of the group. Casing member **40** also carried various engine accessories and their driving arrangements, and the fuel injection system, as will be presently described.

Windchests **44** are supplied from a plurality of blower units **50** thru conduits **45**. Each blower unit **50** is a self-contained unit having an impeller **51** enclosed in casing members **52** and **53**, the latter having formed therein the diffuser by which the kinetic energy of the air delivered by the impeller is converted into pressure. Impeller **51** is fixed on shaft **54** having an integral drive pinion **55**. Bearings **56** and **57**, mounted in casing member **52**, are fixed on shaft **54** on either side of pinion **55** and are thus favorably situated to maintain pinion **55** in correct alignment without undue deflection under load, and concentric with casing member **52**.

Casing members **52** of the blower units **50** pilot into holes in the blower drive housing whose two members **60** and **62** carry bearings **63** and **64** on which blower drive gear **65** runs. Thus accurate meshing of pinions **55** with gear **65** is assured. Drive housing member **60** is piloted onto bearing **61** of shaft **10**, locating the blower drive assembly concentric with shaft **10**. Housing member **60** is fastened to valve casing member **34** by bolts **66**.

Splines **67** fixed on shaft **10** engage internal splines on inner torque cushion member **68** which is surrounded by outer cushion member **69**. Cushion members **68** and **69** have interlocking teeth between which springs **70** are tangentially arranged so as to provide a torsionally yielding coupling. In radial cylinders in member **69**, segmental shoe members **71** are slidable and urged

outwardly by light springs 72 to engage their shoe portions with the inside of gear 65, forming a friction clutch by which gear 65 is driven.

Accessory drive gear 80 is fixed on shaft 10 and engages a plurality of accessory driven gears 81 each of which is mounted in ball bearings 82 and 83 secured to inner wall 42 of valve casing member 40. Various accessories such as the oil pump 84 indicated in Fig. 1, are mounted on bosses formed on outer wall 43 of casing member 40. Each accessory has its own drive shaft 85 extending between adjacent cylinders 20 thru a suitable oil-tight housing across windchest 44 and engaging a driven gear 81 with a splined connection.

Fuel pump cam 90 is fixed on shaft 10. Surrounding fuel pump 90 is a cage member 91 fitted into inner wall 42 of casing member 40 in a manner permitting angular adjustment of cage member 91 by any convenient means. Cage member 91 has radial cylinders 92 one for each cylinder 20 of the group. In each cylinder 92, cam follower 93 is reciprocable with its roller engaging cam 90. Each cam follower 93 is provided with segmental shoe 94 whose ends are a free fit in peripheral groove 95 in cage member 91. Each shoe 94 engages a pushrod 96 which extends radially outward thru a suitable oil-tight housing across windchest 44 between adjacent cylinders 20, to operate fuel pump 97 which is associated with an injection nozzle 98 for each combustion chamber of the several cylinders 20. Push rod spring 99 is provided to return push rod 96 and cam follower 93.

Engine casing 12 is provided with water jackets 19 which assist in cooling the oil and also serve as a manifold communicating with the individual water jackets 24 of cylinders 20. The valve housing is also water-jacketed and the casing member 40 serves as a manifold to connect the outer ends of the individual water jackets 24 of cylinders 20. The bridges 25 between intake ports 23 are also water-jacketed.

In assembling the mechanism, wabbler 13 is assembled on bearings 14 on shaft 10, and the shaft 10 in bearings 11 in casing 12. Then piston members 16, followed by wabbler arms 15 and their operable connections, may be assembled thru handholes in casing 12. The engine mechanism proper is now assembled as an operable unit. Then cylinders 20 may be bolted to casing 12.

An accessory drive gear 80 and fuel pump cam 90 are assembled on each end of shaft 10. Driven gears 81 and their bearings 82 and 83, and then push rods 96, springs 99, and cage member 91 with cam followers 93, are assembled in casing member 40, two such assemblies being bolted to cylinders 20. Accessories with their drive shafts 85, and fuel pumps 97 and nozzles 98 may then be added.

Eccentrics 31 are added to shaft 10, with valves 30 on them, and the valves are timed, and casings 34 assembled and bolted to casings 40. Then bearing 61 and splined member 67 may be added to shaft 10 and drawn up with the lock nut.

The blower drive unit assembled in casing members 60 and 62 may then be piloted onto bearing 61, splines 67 mating with those of member 68, and the unit bolted to casing 34. Blower units 50 may be assembled to casing member 62 either before or after assembly of the drive unit to casing 34. To assemble a blower unit 50 in casing 62, insert the pinion-containing end of the unit and hook it over gear 65, then move inwardly until casing 52 can pilot into the hole in casing 62, and press the pilot into place. Then bolt casing 53 to casing 62. With accurate machining of the parts, pinions 55 will be precisely located and held in the designed position relative to gear 65.

Manifold 36, in two parts, may then be assembled, and conduits 45 connected, after which the various controls and the exterior oil, fuel, and cooling system plumbing may be attended to.

Operation.—Rotation of shaft 10 will be accompanied by reciprocation of piston members 16 by the operable action of the wabbler mechanism in a known manner, details of which are not included in the present invention. Rotation of shaft 10 will also drive blower units 50 in a manner hereinafter described, to deliver air thru conduits 45 to windchests 44, and whenever the pistons uncover ports 22, the air is directed into cylinders 20 by ports 22 in a manner causing a high-speed swirling action. Somewhat before ports 22 of a given cylinder are opened, its port 23 is opened by the motion of valve 30, permitting discharge of the exhaust thru ports 37 and 35 to manifold 36, so that when ports 22 open, the swirling scavenge can effectively clear the cylinder. Valve 30 is timed to close port 23 somewhat before ports 22 are closed by the piston, permitting the cylinder to be supercharged approximately to blower pressure. The operation of valve 30 is described in greater detail hereinafter.

With cylinder 20 scavenged and charged with air, the piston next compresses the air, and when near "top center", cam 90 operates one of the radiating members of the fuel system as hereinafter described, to cause the corresponding nozzle 98 to inject a shot of fuel into the combustion chamber. The piston is driven "downward" again by the ensuing combustion and expansion of the gases, to repeat the cycle.

Since both groups of cylinders are working cylinders operating on the two-stroke cycle, an outside source of air for combustion must be provided. Splines 67 drive inner cushion member 69 which drives outer cushion member 69 thru springs 70, these members comprising a spring coupling. The action of springs 72 augmented by centrifugal force acting on segmental shoe members 71 frictionally engages shoe members 71 with the interior of gear 65 to drive it, and drive gear 65 drives pinions 55 and impellers 51 at high speed.

Shock loading on the gear teeth is avoided by the yielding nature of torque cushion springs 70, by the yieldable overload slip ability of clutch shoes 71, and by the flywheel effect of gear 65 which resists sudden changes in velocity. However, even these comprehensive and effective means of protecting the gear teeth would not save them if the gears were severely overloaded as they would be if a single blower were used for so large an engine. Attempts to design a drive with reasonable gear tooth loads for such an engine have been unsatisfactory. A system of several smaller blowers in accordance with the present invention seems a much better way. Tooth loadings are reasonable, the symmetry of the drive system in helpful, and the method of mounting each gear on a pair of adequate bearings accurately located and rigidly supported, also contributes to success. Centrifugal clutch action, increasing the torque capacity about as the square of the speed, is provided because it

more nearly suits the requirements than any fixed capacity clutch can.

Any breathing system suitable for a two-stroke engine could be used in the normal two-stroke round engine, but uniflow scavenge with ported intake and exhaust controlled by valves is preferred. Any suitable valve system could be used including poppet valves, but the disc valve system illustrated has numerous advantages. As shaft 10 rotates, valve 30 is carried around bodily on eccentric 31 while engagement of gears 32 and 33 rotates valve 30 on eccentric 31 at a speed slower than that of shaft 10 and in the opposite direction, as can be understood from a study of Fig. 3. The number and proportions of ports 37 in valve 30 are arranged to cooperate with the trochoidal movement of the valve to produce the desired port timing. The peculiar advantages of the eccentrically driven valve as applied to two-stroke engines will be appreciated from a consideration of the speed of the valve surface relative to a given port during various parts of the cycle of operation.

With internal gear 33 fixed and spur gear 32 on the valve as shown, the speed of the valve face relative to the center of port 23 when the piston is at "top center" is proportional to:

$$-\frac{(\text{radial distance of port 23 from shaft 10})-(\text{radius of gear 33})}{(\text{number of cylinders in the group})-1}$$

The speed of the valve face relative to the center of port 23 when the piston is at "bottom center" is proportional to:

$$-\frac{(\text{radial distance of port 23 from shaft 10})+(\text{radius of gear 33})}{(\text{number of cylinders in the group})-1}$$

From the former ratio it is obvious that if gear 33 had the same radius as the cylinder pitch circle, the value of the first ratio would be zero, signifying that the instantaneous axis of valve disc 30 would be the axis of port 23 when the piston is at "top center". Practically speaking, the valve would stop when the pressure is at peak, a desirable condition from the standpoint of the sealing rings and their wear. This condition could be provided by constructing gear 33 on a separate disc axially spaced and beyond manifold 36 from the valve proper. With gear 33 larger than the pitch circle of ports 23 as shown, the velocity of valve 30 relative to port 23 when the piston is at "top center" is still quite slow, but reversed in direction from that during most of the cycle. From the second ratio it is obvious that the larger gear 33 is made, the faster the ports in a two-stroke engine will open and close and the larger the ports in the valve can be made. With proportions such as those of Figs. 1 and 3 the speed of the valve when the ports open and close, relative to the ports 23, is about four times that when pressures are at peak. Port action is twice as fast, and the ports can be twice as big, as if the valve were an ordinary rotary valve running concentric with the shaft at the same speed, (i. e. one-eighth shaft speed for nine cylinders with the proportions shown). The breathing ability can thus be about four times more free.

Thus the application of the eccentrically driven disc valve to the two-stroke engine gains new and important ends, and the advantages would hold just the same if the valve were used for intake instead of for exhaust, or for both. The peculiar motion of the valve is in every way advantageous for two-stroke cycle operation, and the advantages are greater by the use of relatively large diameter gears. The speed of the valve relative to the port sealing means and the casing against which the valve is pressed by cylinder pressure, is relatively slow during the high pressure portions of the cycle, while the speed during port opening and closing is several times faster, providing quick port opening and closing and permitting very large ports.

The action of sealing rings 29 relative to their concentric grooves in casing member 40 and relative to the face of valve 30, is similar to that of ordinary piston rings, except that initial contact of rings 29 with valve 30 is insured by spring rings 28. Contact having been made, the pressure trying to leak past rings 29 presses them outward against the outer walls of their grooves, and gets under them to press them against the face of valve 30, precisely as the pressure gets behind a piston ring to press it against the cylinder wall and the lower face of its ring groove. The rotary and orbital movement of valve 30 induces rings 29 to rotate slowly in their grooves, preventing scoring, insuring even wear and perfect seal.

The masses of eccentrics 31 and valves 30 are designed of right amount so that the couple produced by their rotation with shaft 10 will offset the couple arising from piston reciprocation, to produce practically perfect mechanical balance, in a known manner.

In the fuel system, cam 90 operates successively the cam followers 93, and each drives its pushrod 96 outward to operate the corresponding pump 97, and a shot of fuel is injected thereby into the appropriate combustion chamber thru nozzle 98. Spring 99 returns cam follower 93 and pushrod 96 after the injection stroke. Pump 97 has its own return spring, as is known.

To adjust the timing of the fuel injection, cage member 91 is adjusted angularly by any suitable control means, shoes 94 still riding on their respective push rods 96. When the axes of cam followers 93 are somewhat out of line with the axes of pushrods 96, the length of stroke of fuel pumps 97 is slightly shorter, but the discrepancy is very small and of no significance in view of the fact that the pump is so constructed that only a small central portion of its piston stroke is effective anyway.

The various accessories are driven by gears 80 and 81 thru their several radiating shafts 85. Of these accessories, the water pumps may circulate cooling fluid thru radiators of well-known types, pumping the fluid into jackets 19 in casing 12, from whence it flows axially outward thru the several jackets 24 of individual cylinder units 20 to jackets in casing members 40 and 34, when it may be returned to the pumps and radiators. Alternately, the flow could be reversed. One of the most constricted parts of the circuit is where the water goes thru the intake port bridges; the velocity at these points will therefore be high, and the bridges effectively cooled. All water system gaskets are clamped between plane surfaces so that leakage can be prevented. The combustion chamber proper of each cylinder 20 is not directly water-jacketed; it is desirable in a Diesel engine for the combustion chamber to run rather hot. This condition could be avoided if the engine were to be run on the Otto cycle.

Other accessories may include the oil pumps, one of which is indicated at 84. Oil is circulated thru shaft 10 as an oil main, which can be tapped wherever necessary. Oil is fed out thru eccentric 31 to fill chambers 38 and 39 in valve 30 by centrifugal action, to assist in cooling the valve, the

overflow from the inner lip of chamber 39 being returned to the sump from which it can be sent thru oil coolers by the scavenge pump in a known manner.

Having thus described the invention, its construction, assembly, and operation, it is obvious that all the objects as stated herein have been attained. The invention has been described as a normal round engine substantially complete with its various accessories as a uniquely compact source of smooth and efficient power. Certain features of the invention are applicable to other types of engines and it is understood that they may be so applied, and that other changes in the construction and in the arrangement of the various parts of the invention may be made, without departing from the spirit or scope of the invention as expressed in the following claims.

I claim:

1. A two-stroke normal barrel engine comprising a shaft, cylinders parallel to said shaft, piston members operable in said cylinders, a wabbler mechanism operably connecting said piston members to the central portion of said shaft, a pair of eccentrics fixed on said shaft toward the ends thereof, plate valves rotatable on said eccentrics, said eccentrics and valves being so constructed and arranged that the centrifugal couple thereof during operation will be opposite to and substantially equal to the inertia couple produced by operation of said piston members with said wabbler mechanism, means for driving said valves comprising gears on said valves and gears fixed relative to said cylinders and meshing therewith, and means for providing uniflow scavenging thru said cylinders, said uniflow scavenging means comprising inlet ports tangentially inclined in the walls of said cylinders and controlled by said pistons, and exhaust ports in the heads of said cylinders and controlled by said plate valves.

2. A two-stroke engine comprising a shaft, cylinders parallel to said shaft, piston members operable in said cylinders, a wabbler mechanism operably connecting said piston members to the central portion of said shaft, ports in the heads of said cylinders and spaced about said shaft in a plane normal thereto, a pair of plate valve members controlling said ports, ports thru said plate valve members, and means for driving said valves uniformly and at constant rate relative to said shaft so as to cause said valve ports to register successively with said cylinder ports and in such a manner that the speed of said valve relative to said cylinder ports will be relatively slow when the pressures in said cylinders are high, and several times faster whenever said valve ports are registering with said cylinder ports, said valves and their drive means being so constructed and arranged as to produce a centrifugal couple during operation opposed to the couple resulting from the inertia of said piston members.

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