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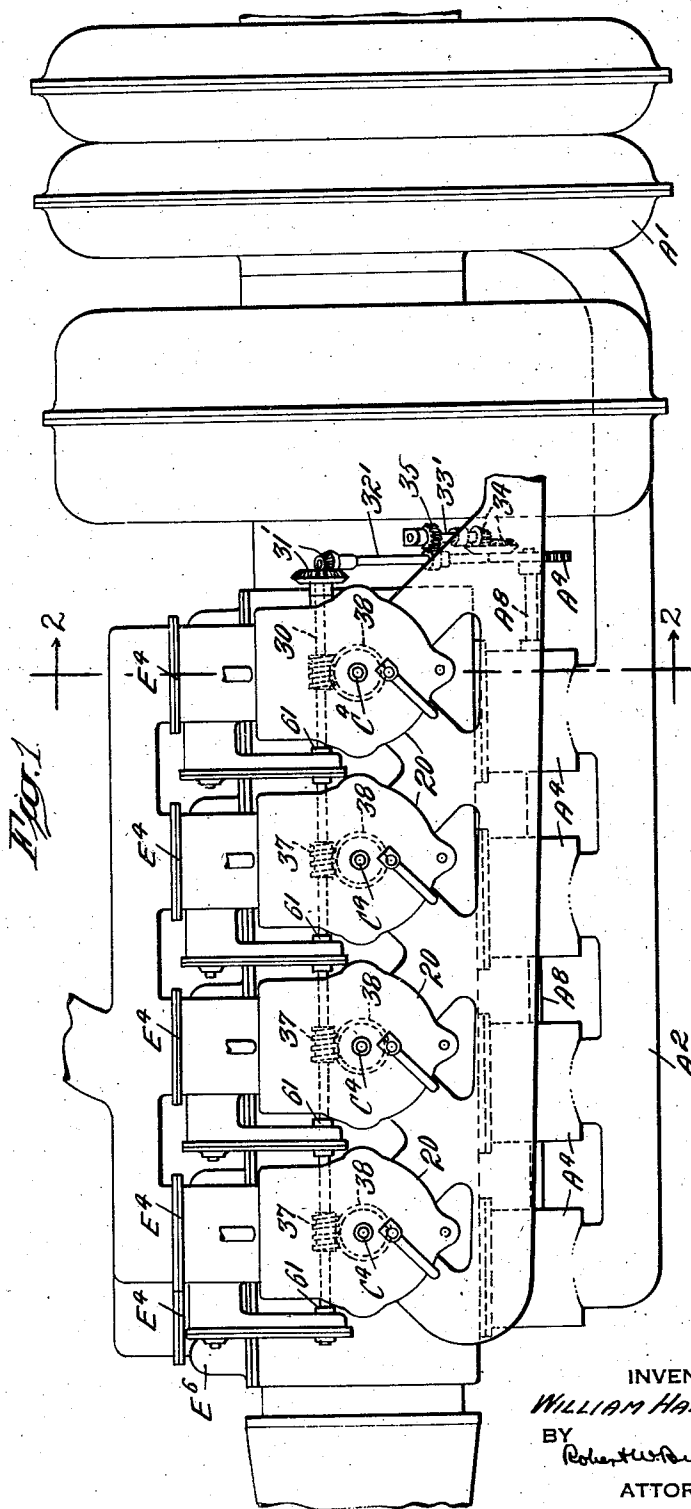
W. HARPER, JR

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INTERNAL COMBUSTION ENGINE

Filed March 27, 1939

6 Sheets-Sheet 1



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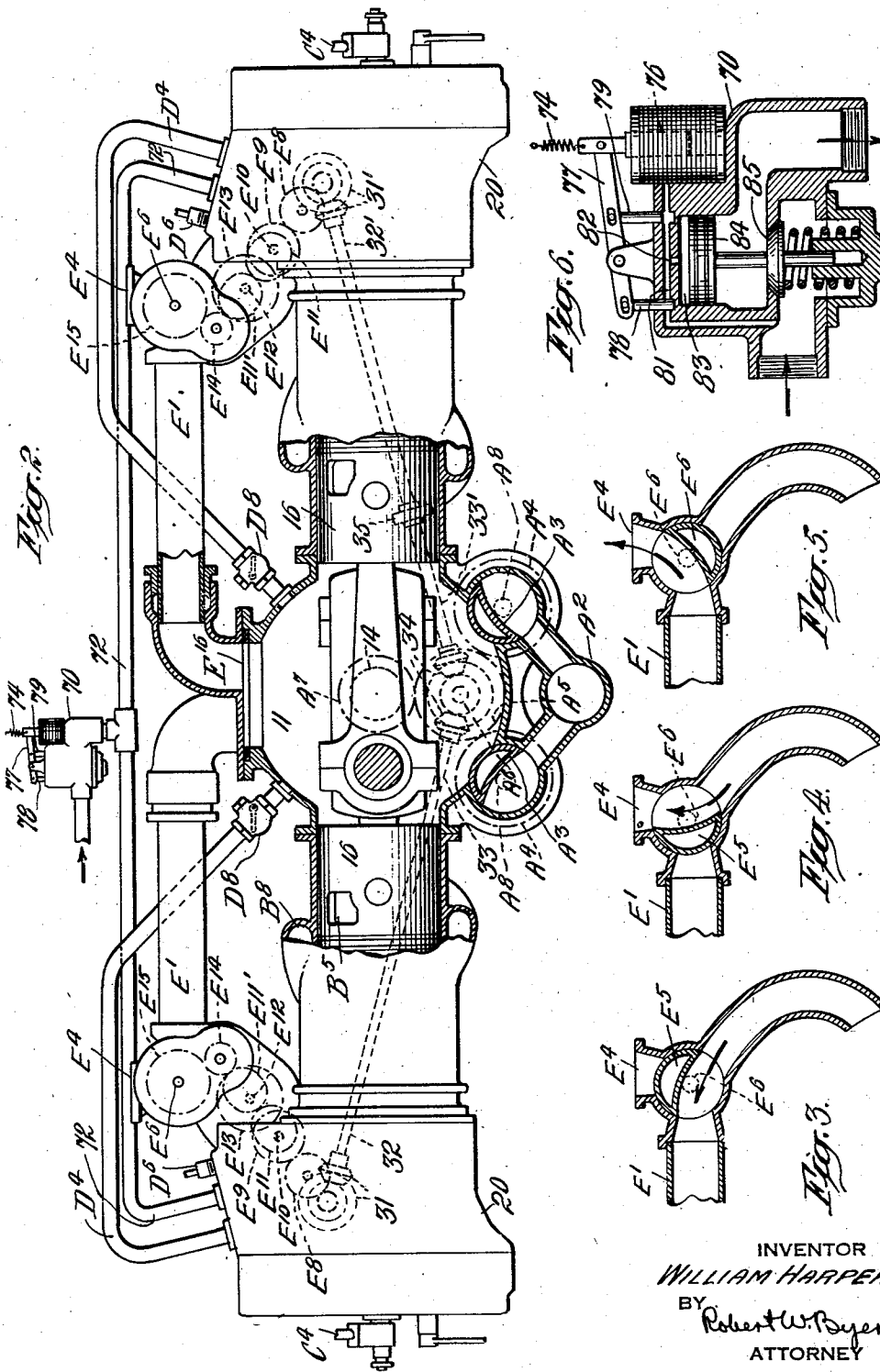
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INTERNAL COMBUSTION ENGINE

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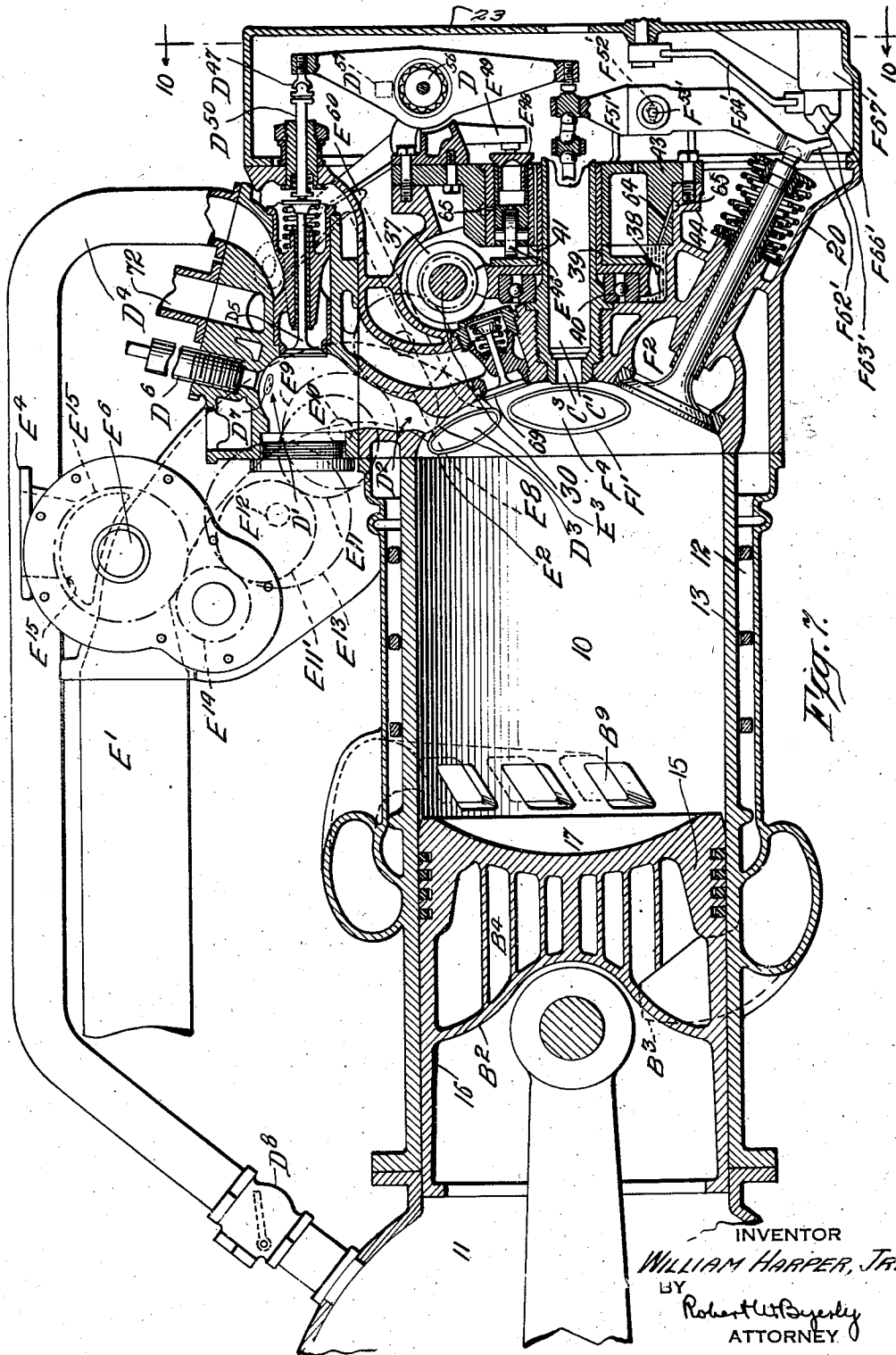
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INTERNAL COMBUSTION ENGINE

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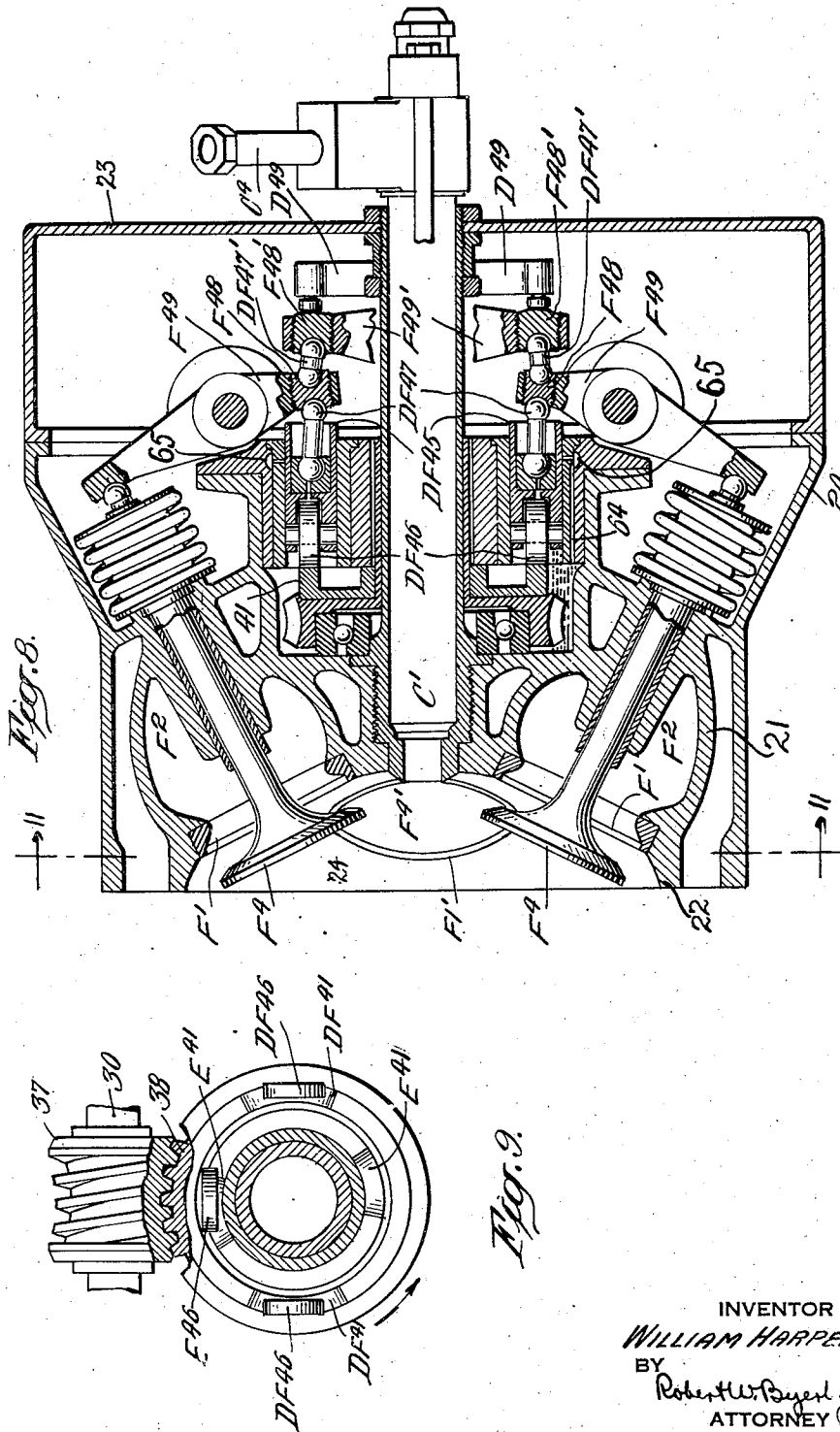
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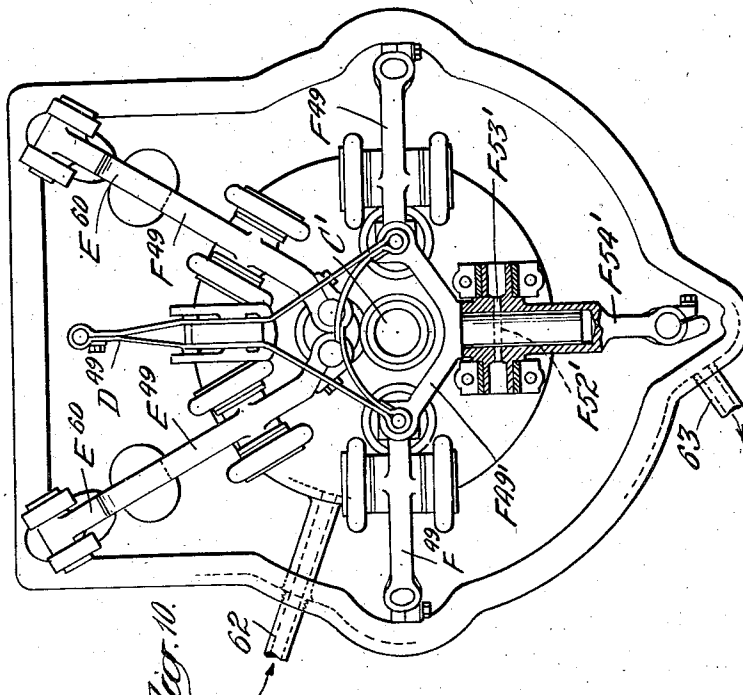


Fig. 10.

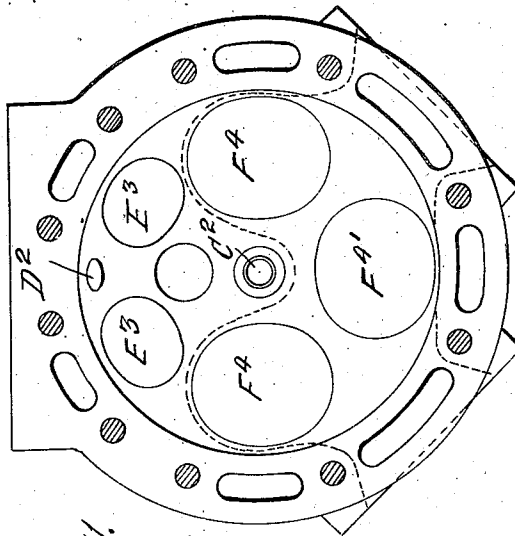
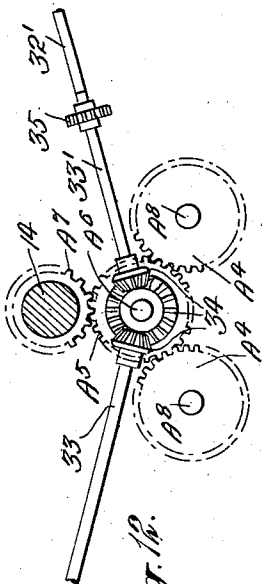


Fig. 11.



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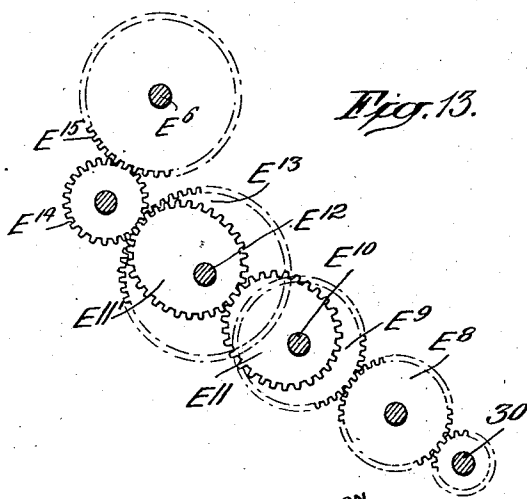
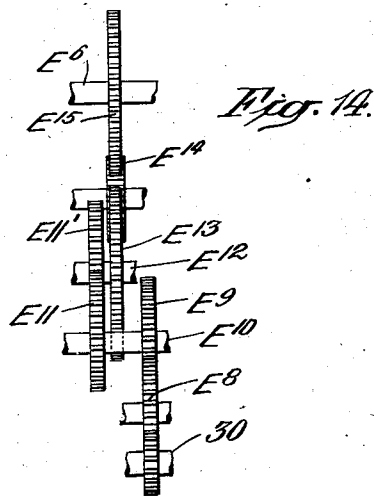
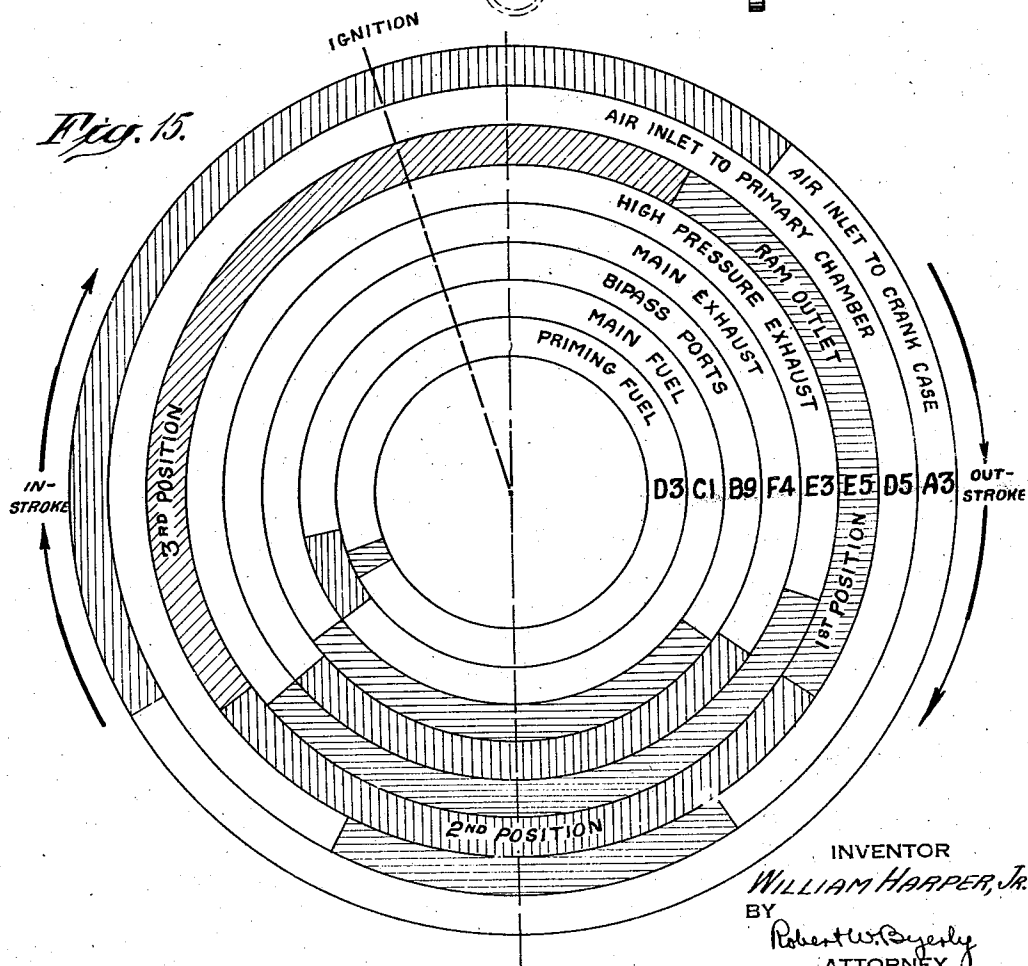
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UNITED STATES PATENT OFFICE

2,272,171

INTERNAL COMBUSTION ENGINE

William Harper, Jr., Montreal, Quebec, Canada

Application March 27, 1939, Serial No. 264,462

16 Claims. (Cl. 123—65)

This invention relates to internal combustion engines and aims to provide improvements in the valve mechanism for internal combustion engines.

This application is a continuation in part of my co-pending application filed March 27, 1936, Serial No. 71,117, now Patent Number 2,151,698, dated March 28, 1939.

A particular object of the present invention is the provision of valve mechanism adapted for use in a heavy-oil-burning engine whose ratio of weight to power is sufficiently low, and whose speed of operation is sufficiently high, to make it available for airplane use.

It is essential in heavy-oil-burning internal combustion engines, particularly those of the two-cycle type in which the exhaust valve ports are located in the cylinder head, that the area of those ports be as large as the diameter of the cylinder will permit. Past attempts to supply such exhaust ports of the necessary area have entailed the use of expensive valve mechanism which was so heavy and cumbersome that it has been impossible to attain the rapidity of operation of the valve mechanism which is essential to high-speed operation of the engine.

Further difficulties have arisen from inability to attain the required speed of operation and acceleration of the valves without such very steep cams that the violence of their action has caused the valves to chatter and from inability to provide for the adequate lubrication of the valve mechanism.

The valve mechanism which I have invented avoids the foregoing difficulties and provides an inexpensive, light, compact, symmetrical assembly which provides high volumetric efficiency and permits excellent combustion chamber design and in which the lines of stress are straight and there is no wide variation in the temperature gradients of the assembly during operation. Other objects and advantages of my invention will be apparent from the following description of a specific embodiment thereof.

In accordance with my invention, the cylinder head of an internal combustion engine is provided with a plurality of ports, each of which is provided with a valve. The valves are operated by mechanism which is actuated by a cam member mounted in the cylinder head casing for rotation about the axis of the cylinder.

The nature of my invention may best be understood from a detailed description of the construction and operation of a practical internal combustion engine embodying the invention and

illustrated in the accompanying drawings. The drawings show, for the sake of illustration, an eight-cylinder heavy-oil-burning engine of the opposed cylinder, two-cycle type embodying the invention:

Fig. 1 is a side elevation of the engine;

Fig. 2 is a vertical section on the axis of one of the pairs of opposed cylinders taken on the line 2—2 of Fig. 1;

Figs. 3, 4 and 5 are diagrammatic illustrations of the different positions assumed by the rotary ram outlet valve;

Fig. 6 is an enlarged section of the solenoid valve shown in Fig. 2;

Fig. 7 is an enlarged section of one of the cylinders taken on the same plane as Fig. 2;

Fig. 8 is an enlarged section of one of the cylinders taken on the opposite plane from Fig. 7;

Fig. 9 is a fragmentary view showing a valve cam and means for operating it;

Fig. 10 is a section on the line 10—10 of Fig. 7 showing the valve-operating mechanism;

Fig. 11 is a section on the line 11—11 of Fig. 8;

Fig. 12 is a fragmentary view of the mechanism for transmitting rotation from the drive shaft to the shaft actuating the exhaust valves;

Figs. 13 and 14 are fragmentary views showing the gear train which operates the ram outlet valve; and

Fig. 15 is a timing diagram of the engine.

The engine illustrated has four pairs of opposed cylinders 10. The inner ends of each pair of cylinders 10 open into a crank case 11 which connects the cylinders. The cylinders are provided with water jackets 12 whose efficiency is increased by the spiral baffles 13 contained in them. With each pair of cylinders and its crank case are associated A means for supplying air to the crank case, B means for by-passing air around the pistons from the crank case to the cylinders, C a main fuel supply, D means for firing the fuel and air mixture, E means for utilizing a part of the exhaust fumes to increase the pressure of the air in the crank case, and F means for exhausting the main body of burnt gases from the cylinders.

The means for supplying air to each crank case 11 includes a blower A1, which may be directly connected to the main shaft of the engine and which forces air, under a pressure of approximately three pounds per square inch through an inlet manifold A2 to rotary inlet valves A3 which control the admission, at the proper time, of air to the crank case. Inlet valve A3 is fixed to shaft A8 which is rotated from

drive shaft 14. A spur gear, A4, fixed to the shaft A8 meshes with spur gear A5 attached to shaft A6 and the spur gear A5 also meshes with gear A7 fixed to drive shaft 14.

The air is by-passed from the crank case to the cylinders 10 when piston 15 is at the inner end of its stroke. Each piston 15 is provided with a skirt 16 which has a transverse partition B2 containing two apertures B3 which form the entrance of two passages B4 leading from the rear end of the piston to ports B5 in the skirt 16 of the piston. When the piston is at the inner end of its stroke, as illustrated in Fig. 2, the ports B5 in the skirt of the piston register with ports in the cylinder wall which are connected by spiral external conduits B8 to diametrically opposite sets of air entrance ports B9 in the wall of the cylinder. The entrance ports B9 are positioned so that they are uncovered by the front end of the piston when the piston is at the inner end of its stroke. The front end of the piston is preferably provided with a concave surface 17 which causes air admitted from the crank case through the ports B9 to advance through cylinder 10 in a flat-topped column during the compression stroke of the piston 15.

The fuel supply means, the firing means and the valve mechanism for each cylinder is located in a casing 20 at the head of the cylinder. This casing consists of a casting 21, which may be made integral with the cylinder head 22 as shown, and a cover 23 closing the outer end of the casting 21. The inner surface 24 of the cylinder head is preferably concave like the front surface 17 of the piston.

The main fuel supply means includes an injector C1 located in the casing 20, with its inner end secured in a central opening C2 in the cylinder head 22, so that its nozzle C3 is directed axially into the cylinder. The injector C1 is of the conventional type used for the injection of heavy fuels into the cylinders of Diesel engines, and is, therefore, not described in detail. Fuel is supplied to it through a pipe C4 from a pump, not shown, which is driven from the main shaft of the engine and timed by the means customarily used with such fuel injectors in Diesel engines.

The firing means includes a primary combustion chamber D1, formed in the casting 21, outside the cylinder and a nozzle D2 extending from the primary combustion chamber D1, and entering the cylinder head at D3. Air under compression is supplied to the primary combustion chamber D1 from the crank case 11, through a conduit D4, controlled by an inlet valve D5, located in the casing 20. A light fuel is supplied to the primary combustion chamber D1 through an injector D6 of conventional construction, to which the fuel is supplied by a conventional pump and timing device. Spark plugs D7 are provided to ignite the mixture in the primary combustion chamber D1. Conventional means for supplying electricity and timing the spark are connected with these spark plugs.

The means for utilizing a part of the exhaust for increasing the pressure in the crank case includes ram conduits E1, connecting the crank case 11 with two small high-pressure exhaust ports E2 in the cylinder head (Figs. 9 and 10). The ports E2 are controlled by valves E3. Exhaust or scavenging ports E4 are provided in the ram conduits E1 near the ends of these conduits which enter the cylinder head and are controlled by rotary valves E5, each of which is operated by its individual shaft E6, driven

from transverse shaft 30, so that it makes one complete revolution with each revolution of the engine shaft 14, but at varying speeds:

Transverse shaft 30, extending across casing 20 and journaled in its side walls, is driven from the drive shaft 14 at speeds which correspond with those of the drive shaft. The shaft 30 for one bank of cylinders is connected through miter gears 31' with the upper end 32 of a cross-shaft whose lower end 33 is connected through miter gears 34 with spur gear A5 driven from the engine shaft 14 as aforesaid. The cross-shaft 30 for the other bank of cylinders is connected through miter gears 31' with the upper end 32' of a cross-shaft whose lower end 33' is likewise connected with spur gear A5. In order that the upper ends 32, 32' of the cross-shafts will rotate in the same direction, the upper end 32' is connected with the lower end 33' through a pair of spur gears 35.

The rotation of transverse shaft 30 is transmitted to spur gear E8 which is in mesh with spur gear E9 fixed to shaft E10. Elliptic gear E11 keyed to shaft E10 meshes with elliptic gear E11' keyed to shaft E12. The varying speeds of rotation of shaft E12 occasioned by elliptic gears E11 and E11' are transmitted through spur gears E13, E14 and E15 to the shaft E6 upon which rotary valve E5 is mounted.

The ram conduits E1 may be closed, if desired, by a manually operated grid valve E16 which is provided at the ends of those conduits which enter crank case 11.

The main exhaust from the cylinder is through three large ports F1, F1, F1' in the cylinder head, connected through passages F2 in the casting 21, with the exhaust manifold F3. The ports F1, F1, F1' are controlled respectively by the main exhaust valves F4, F4, F4'.

Valve control mechanism for operating the high pressure exhaust valves E3, the main exhaust valves F4, F4, F4' and the inlet valve D5 of the primary combustion chamber D1 is contained in the casing 20 and is also driven by the transverse shaft 30. The shaft 30 carries a worm 37 which meshes with gear 38 journaled on a sleeve 39 surrounding the fuel injector C1 and supported by anti-friction bearings 40. The cam member 41 is mounted upon gear 38 for rotation therewith, and the gearing is such that the cam member is rotated at one-half the speed of rotation of the engine shaft. On the upper surface of the cam member 41 are two concentric pairs of cams with the cams of each pair spaced 180° apart. The cams DF41 of the outer series control the inlet valve D5 and the main exhaust valves F4, F4, F4'. The cams E41 of the inner series control the high-pressure exhaust valves E3.

A fulcrum-bearing disc 43 with a central opening surrounds the sleeve 39 and the injector C1, and is secured in an opening at the top of an inner wall 44 in the casting 21. This disc contains vertical bores in which are mounted plungers DF45, each of which bears rollers DF46 in position to be engaged by cams DF41. The plungers DF45 are connected through knuckles DF47 with adjustable bearings F48 screwed in the inner ends of rocker arms F49, whose outer ends engage the stems of the main exhaust valves F4, F4.

The stem of the main exhaust valve F4' is engaged by the outer end of a forked telescoping lever F49', whose inner ends are connected through the knuckles DF47' and adjustable bearings F48' with the inner ends of the rocker arms

F49. The inlet valve **D5** is actuated by forked rocker arm **D49**, whose inner ends rest upon the adjustable bearings **F48'**, and whose outer end is provided with an adjustable member **D47** adapted to engage and depress plunger **D50**, which rests upon the stem of inlet valve **D5**.

The inlet valve **D3** and the main exhaust valves **F4**, **F4'** are thus actuated by a balanced set of rocker arms and, as illustrated in Figs. 10 and 11, the valve mechanism is symmetrically arranged about the axis of the cylinder.

A limited tipping movement is permitted the inner, forked ends of the rocker arms **F49'** and **D49** to compensate automatically for any inequalities in the adjustments of the members **F48**, **F48'** and **D48**. This is accomplished in the telescoping rocker arm **F49'** by providing the inner forked portion **F51'** with slot **F52'** through which the pin **F53'** extends so that the forked portion **F51'** is permitted a limited amount of rotary movement with respect to the outer portion **F54'**. A like result is obtained in the forked arm **D49** by mounting it upon a self-aligning ball bearing **D56**. Rubbing blocks **D57** maintain the member **D47** above the member **D50** and the swivel mounting for the lower portion of the member **D47** preserves the proper alignment of its face with the upper face of plunger **D50**.

The fulcrum-bearing disc **43** also contains a vertical bore in which is mounted plunger **E45** which bears a roller **E46** in position to be engaged by either of the cams **E41**. The plungers **E45** are connected by adjustable member **E48** with the inner ends of rocker arms **E49**. The outer ends of rocker arms **E49** rest upon the inner ends of levers **E60** which bear upon the stems of the high-pressure exhaust valves **E3** and whose outer ends are pivoted to the inner wall **44** of casting **21**. The high-pressure exhaust valves **E3** are thus actuated by compound levers which cause the opening of those valves to be accelerated very rapidly when plunger **E45** is raised by one of the cams **E41**.

As shown in Fig. 9, the cam member **41** rotates in a counterclockwise direction and the leading edges of the cams **E41** are spaced respectively from the leading edges of the following cams **DF41** by an angle greater than 90° so that the roller **E46**, which is symmetrically spaced by angles of 90° from the rollers **DF46**, will open the high-pressure exhaust valves **E3** in advance of the opening of the main exhaust valves **F4**, **F4'**. A clearance is provided between the member **D47** and the top of plunger **D50** when the main exhaust valves are closed so that the inlet valve **D5** is not opened until after the main exhaust valves **F4**, **F4'** have been opened.

The transverse shaft **30** of the valve mechanism terminates a short distance outside of the walls of the cylinder head casing **20** of each cylinder. The shafts **30** of the adjoining cylinders in the respective banks are joined by removable couplings **61** and the miter gears **31**, **31'** are readily separated. The valve-actuating mechanism for each cylinder is thus a complete unit which may be removed with the head of that cylinder and without disturbing the adjustments of the various valves by merely removing the couplings **61** or separating the miter gears **31** or **31'** at the ends of the cross-shaft **30** of that cylinder.

The valve mechanism is lubricated by oil which is supplied from a conventional pump (not shown) which is driven from the drive shaft. The oil enters the casing **20** through an inlet conduit **62** connected with the oil pump and then flows

through an annular channel **65** formed in the inner wall **44** of casting **21**. From the channel **65** the oil flows through passages **64**, some of which are shown in the drawings, to all of the bearings of the valve mechanism. After the oil has passed through the bearings, it flows to the bottom of the lowest part of the casing **20** and is then withdrawn through an outlet conduit **63**.

Manually operated means are provided for relieving the compression in each cylinder when desired: Rocker arm **F49'** is provided at its outer end **F54'** with a finger **F62'**. A plunger **F63'** is connected by a link **F64'** with a lever **F65'** projecting outside the casing **23**. Manual operation of the lever **F65'** occasions rotation of the plunger **F63'** causing the cam **F66'** to be forced out of the dwell in sleeve **F67'**, thus forcing plunger **F63'** and the outer end of rocker arm **F49'** downward and opening valve **F4'**.

To start the engine, compressed air is forced through check valves **69** into those cylinders **10** whose pistons **15** are in position to make a power stroke. In order that the proper pistons may be supplied with compressed air at appropriate times, the flow of air to each pair of pistons is controlled by a solenoid valve **70** connected by T fitting **71** with a conduit **72** which communicates with the inlet port of check valves **69** of opposed cylinders.

Normally the solenoid valve **70** is held in closed position as illustrated in Fig. 6 by the spring **74**. When current is supplied to the coil **76** the core is pulled inwardly pivoting lever **77** to raise plunger **78** and depress plunger **79**. Air is forced by a conventional compressor (not shown), connected with solenoid valve **70** by pipe **80**, through passageway **81**, which is then open, and passageway **82** to the interior of cylinder **83**, depressing piston **84** and opening port **85**. The compressed air then flows through port **85** and check valve **69** to the cylinder **10** where it forces piston **15** inwardly. As piston **15** ends its instroke, the supply of current to coil **76** is cut off and spring **75** causes lever **77** to be pivoted so that plunger **78** closes passageway **81** and plunger **79** opens passageway **87** through which the compressed air in cylinder **83** escapes. Conventional timing means for supplying electricity to coils **76** at appropriate times are connected with those coils.

The operation of the engine which has been described may best be understood from the timing diagram Fig. 15, which indicates by shading the approximate periods during each revolution of drive shaft **14** at which the various ports and valves are open. The right-hand side of the diagram represents the outstroke of the piston, that is, the stroke in which the piston moves away from the cylinder head, while the left-hand side represents the instroke.

During the latter part of the instroke and the first part of the out or power stroke of piston **15**, air is supplied from the compressor **A1** to crank case **11** through inlet valve **A3** until a pressure of approximately 3 pounds per square inch is attained in the crank case. This pressure is increased as the pistons approach each other during the balance of the outstroke, and it is built up to a very considerable pressure, for example, 15 pounds per square inch as follows: During the power stroke of the piston **15**, the ram conduit inlet valves **E5** are in the position illustrated in Fig. 3. At the end of the power stroke, the high-pressure exhaust valves **E3** are opened, thus forcing exhaust gases under very high pressure into the ram conduits **E1**. In order that these ex-

haust gases shall not reach the crank case, the rotary movement of valve E5 is suddenly accelerated by the action of elliptical gears E11, E11', so that the valve E5 assumes the position illustrated in Fig. 2, in which exhaust gases from the high-pressure exhaust port pass out through the exhaust outlet E4, thus providing super-charging through the high-pressure exhaust gas without contaminating the air in the crank case or reducing the effective exhaust area of the valves. At the same time that ram conduit E1 is closed, the main exhaust valves F4, F4', F4' are opened.

Shortly after ram conduit E1 is closed by rotary valve E5 and the main exhaust valves F4, F4', F4' are opened, the pistons uncover ports B9. The exhaust valves and the ports B9 remain open during the latter part of the outstroke and the first part of the instroke of piston 15 until fresh air from the crank case displaces the burnt gases in cylinder 10 when the exhaust valves are closed. Shortly thereafter, the ports B9 are closed and the valve E5 rotates to the position illustrated in Fig. 5 when burnt gases from conduit E1 are forced through exhaust E4 by compressed air from the crank case. Heavy fuel is injected into the cylinder after the ports B9 are closed, and the continuance of the instroke of the piston causes the fuel mixture in the cylinder 10 to be compressed until it is ignited by burning gas from the primary combustion chamber.

At the end of the outstroke of piston 15, when the air in crank case 11 is under maximum pressure, air enters the conduit D4 through check valve D8 which prevents that air from returning to the crank case when the pressure therein is reduced. After the main exhaust valves F4, F4', F4' are opened, the primary combustion chamber inlet valve D5 is opened long enough to admit the fresh compressed air in conduit D4 to primary combustion chamber D1 whence it expels the burnt gases which pass from the cylinder through the exhaust valves. A light fuel is then admitted through injector D6 to primary combustion chamber D1 where it is ignited by spark plugs D7, and the burning gases from primary combustion chamber enter cylinder 10 through opening D3 and ignite the fuel and air contained in cylinder 10 shortly before the piston 15 ends its instroke.

It is to be understood that, while the specific embodiment of my invention which I have described is a heavy-oil-burning internal combustion engine of the two-cycle type, the valve mechanism which I have invented is not limited in use to such an engine but may be applied to other types of engines.

What I claim is:

1. In an internal combustion engine, a cylinder having three ports in its head, a valve for each of said ports, a pair of opposed cams mounted in the cylinder head casing for rotation about the axis of the cylinder, and mechanism actuated by said cams for operating said valves simultaneously.

2. In an internal combustion engine, a cylinder having three ports in its head, a valve for each of said ports, a pair of opposed cams mounted in the cylinder head casing for rotation about the axis of the cylinder, and radial rocker arms actuated by said cams for operating said valves simultaneously.

3. In an internal combustion engine, a cylinder having three ports in its head, a valve for each of said ports, a cam disc mounted in the cylinder head casing and having a pair of op-

posed cams, rocker arms actuated by said cams and adapted to open said valves simultaneously, and an adjustable connection between said rocker arms and said cams.

4. In an internal combustion engine, a cylinder having a plurality of ports in its head, a valve for each of said ports, a cam member mounted in the cylinder head casing, and mechanism actuated by said cam member for operating said valves, including a forked rocker arm mounted for pivotal movement in the cylinder head casing and extending outwardly from the axis of the cylinder along a fixed radial line, and means for permitting limited tipping movement of said rocker arm.

5. In an internal combustion engine, a cylinder having a plurality of ports in its head, a valve for each of said ports, a casing enclosing the head of the cylinder and having oil channels on its inner surface, a disc mounted in said casing, a cam member mounted in said disc, mechanism supported by said disc and actuated by said cam member for operating said valves, and means for forcing oil through the channels in said casing and said disc to said valve-operating mechanism.

6. In an internal combustion engine, a cylinder having an inlet port and a plurality of exhaust ports in its head, an inlet valve, an exhaust valve for each of said exhaust ports, a pair of opposed cams, means actuated by said pair of cams for opening all of said valves, and means for delaying the opening of the inlet valve until after the exhaust valves have been opened.

7. In an internal combustion engine, a cylinder having a set of high-pressure exhaust ports and a set of low-pressure exhaust ports in its head, a valve for each of said exhaust ports, a cam member, and means actuated by said cam member for opening the high-pressure exhaust valves in advance of the low-pressure exhaust valves.

8. In an internal combustion engine, a cylinder having an inlet port, a set of high-pressure exhaust ports and a set of low-pressure exhaust ports in its head, an inlet valve, an exhaust valve for each of said exhaust ports, a cam member, means actuated by said cam member for opening each of said valves, means for opening the high-pressure exhaust valves before the low-pressure exhaust valves, and means for delaying the opening of the inlet valve until after the low-pressure exhaust valves have been opened.

9. In an internal combustion engine, a cylinder provided with an exhaust valve, a conduit communicating with the crank case, an exhaust outlet, a valve chamber having one port communicating with the exhaust valve, another port communicating with the conduit and a third port communicating with the exhaust outlet, and means for closing any one of said ports.

10. In an internal combustion engine, a cylinder provided with an exhaust valve, a conduit communicating with the crank case, an exhaust outlet, a valve chamber having one port communicating with the exhaust valve, another port communicating with the conduit, and a third port communicating with the exhaust outlet, a rotary valve adapted to close any one of said ports, and means driven from the drive shaft for revolving the rotary valve at varying speeds during each revolution of the drive shaft.

11. In an internal combustion engine, a cylinder having a high-pressure exhaust valve, a conduit communicating with said high-pressure exhaust valve and with the crank case, a rotary valve between the conduit and the exhaust valve,

means for revolving the rotary valve, means for opening the high-pressure exhaust valve when the rotary valve is opened, and means for accelerating the rotation of the rotary valve to close it shortly after the high-pressure exhaust valve is opened.

12. In a two-cycle internal combustion engine, a cylinder head containing a plurality of valve ports whose combined area is equal to a large proportion of the area of the cylinder head, valves controlling said ports, means for opening some of said valves in advance of the others, and means for directing the exhaust from the first opened valves into a super-charging device until the other valves are opened and then directing it to the atmosphere.

13. In an internal combustion engine, a cylinder having an exhaust valve, a conduit communicating with the crank case, an exhaust outlet, means connecting the conduit with the exhaust valve for the admission of high-pressure exhaust fumes into said conduit, and means for connecting the conduit with the exhaust outlet so that air in the crank case may expel the fumes from said conduit through the exhaust outlet.

14. In an internal combustion engine, a cylinder constituting the main combustion chamber of the engine and having an exhaust valve and a fire inlet opening, a primary combustion chamber communicating with said fire inlet opening,

a conduit connecting the primary combustion chamber with the crank case, means for forcing compressed air into said conduit, means for opening the exhaust valve, and means for admitting compressed air from the conduit to the primary combustion chamber after said exhaust valve is opened.

15. In a multi-cylinder engine having cylinders containing valves in their heads, a casing secured to the head of each cylinder, aligned shafts each of which extends transversely through one of the casings with its ends projecting short distances outside the casing, a valve-controlling mechanism in each casing actuated by the transverse shaft of that casing, and detachable couplings connecting the ends of the aligned transverse shafts of the casings of the different cylinders.

16. In an internal combustion engine, a cylinder provided with an exhaust valve, a conduit communicating with the crank case, an exhaust outlet, a valve chamber having one port communicating with the exhaust valve, another port communicating with the conduit, a third port communicating with the exhaust outlet, and a rotary valve adapted to close said ports singly and in sequence so that the intervals during which the respective ports are closed are of unequal duration.

WILLIAM HARPER, JR.