

Oct. 21, 1952

A. SCHWARZ

2,614,546

INTERNAL-COMBUSTION ENGINE

Filed Jan. 22, 1948

8 Sheets-Sheet 1

Fig. 1,

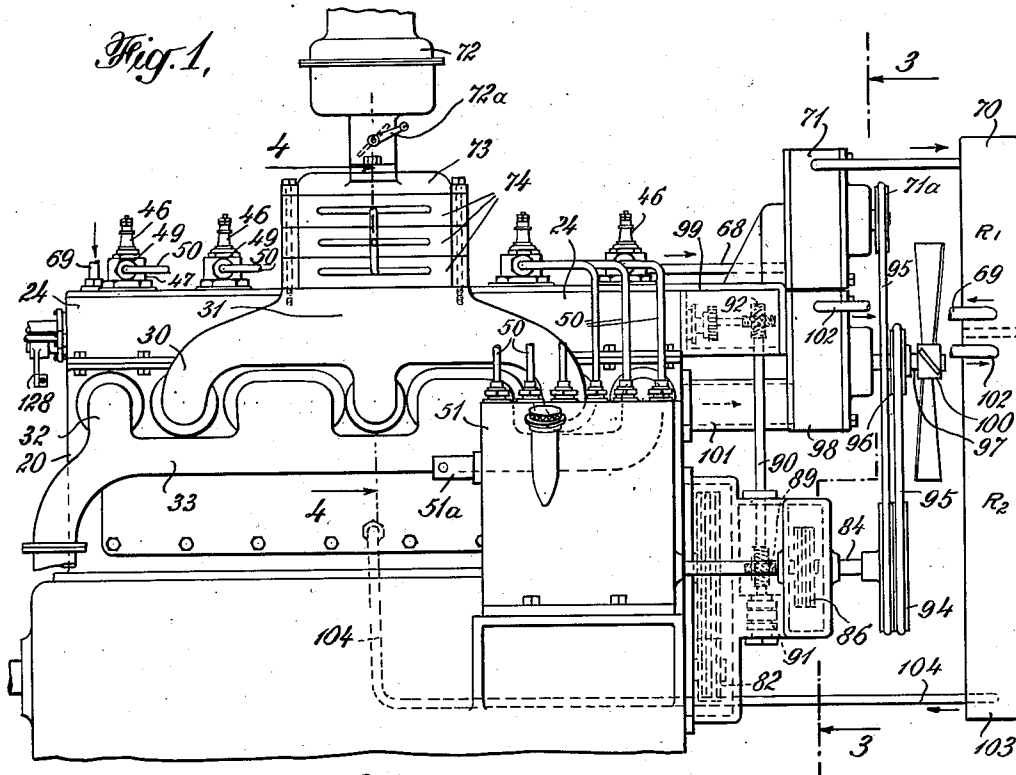
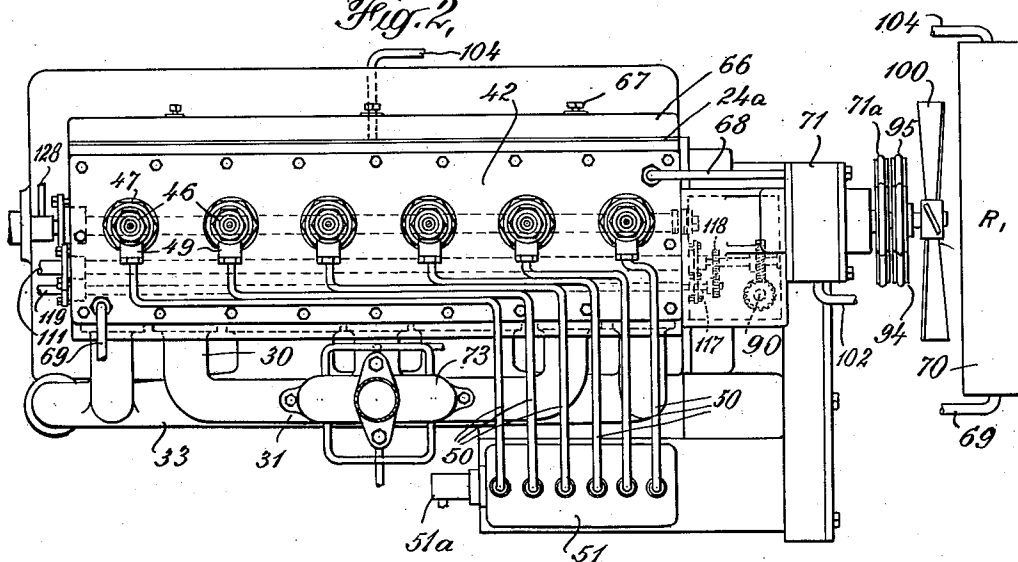


Fig. 2,



INVENTOR
Alfred Schwarz
BY
Percie Edwards Morton & Barrons
ATTORNEYS

Oct. 21, 1952

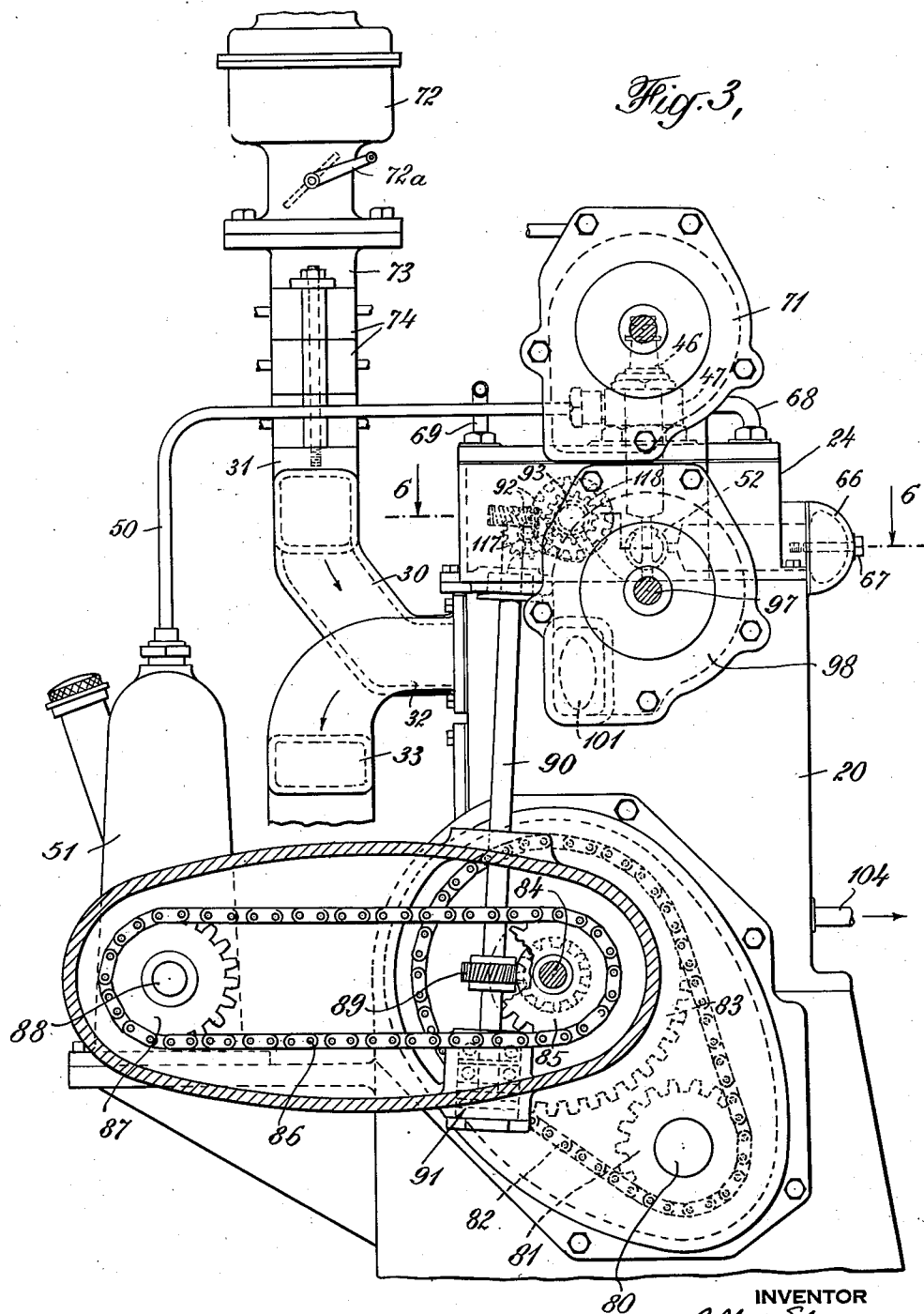
A. SCHWARZ

2,614,546

INTERNAL-COMBUSTION ENGINE

Filed Jan. 22, 1948

8 Sheets-Sheet 2

**INVENTOR**

Alfred Schwarz

B'

BY *Pennie Edmonds Norton & Barrows*
ATTORNEYS

ATTORNEYS

Oct. 21, 1952

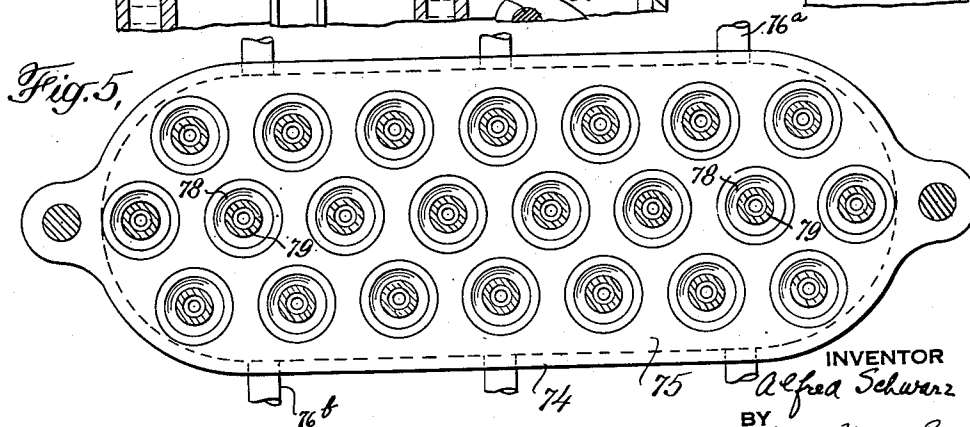
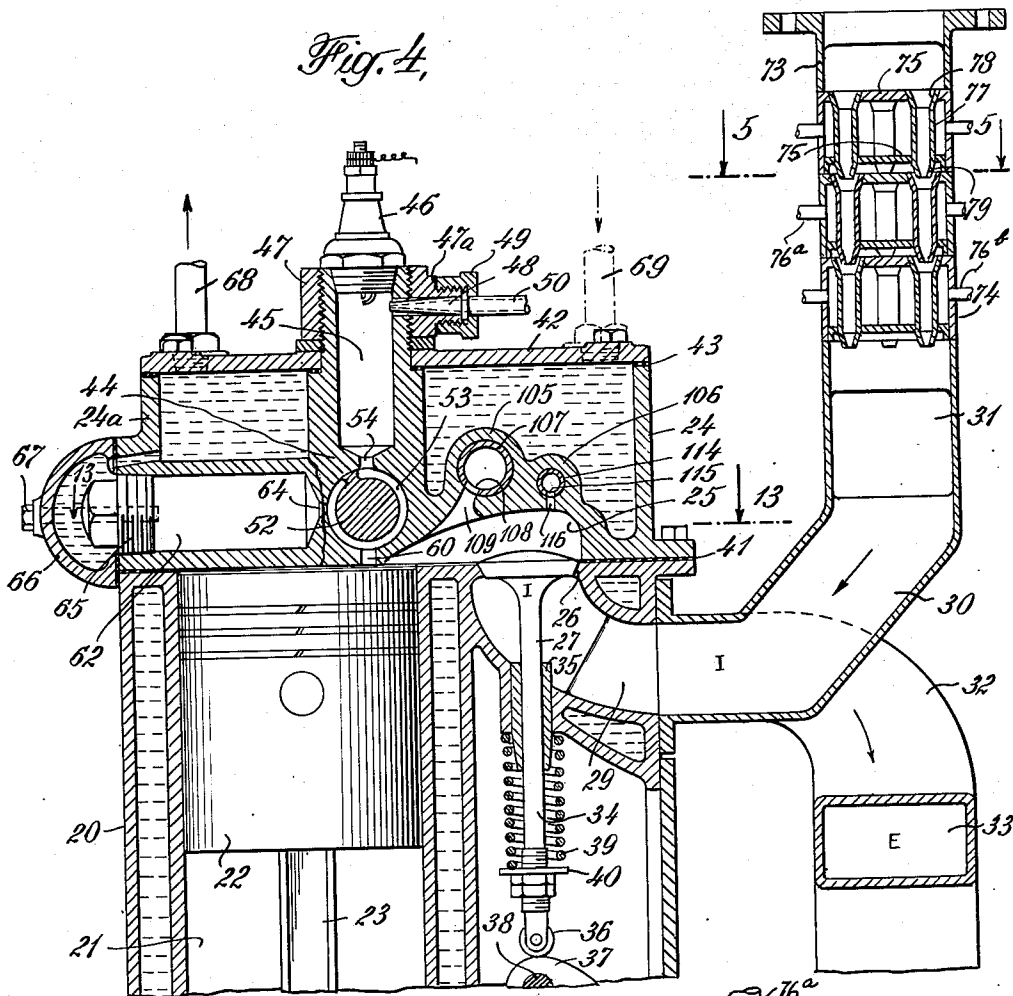
A. SCHWARZ

2,614,546

INTERNAL-COMBUSTION ENGINE

Filed Jan. 22, 1948

8 Sheets-Sheet 3



INVENTOR
Alfred Schwarz
BY
Benjamin Edmonds Morton Carrross
ATTORNEYS

Oct. 21, 1952

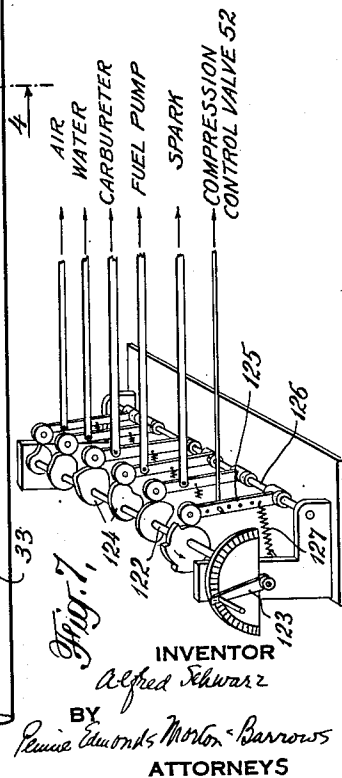
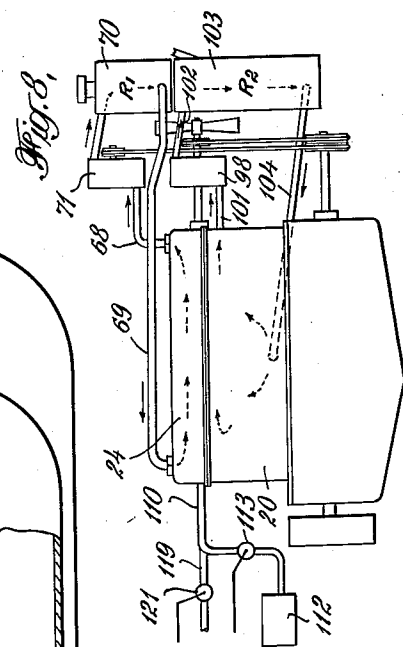
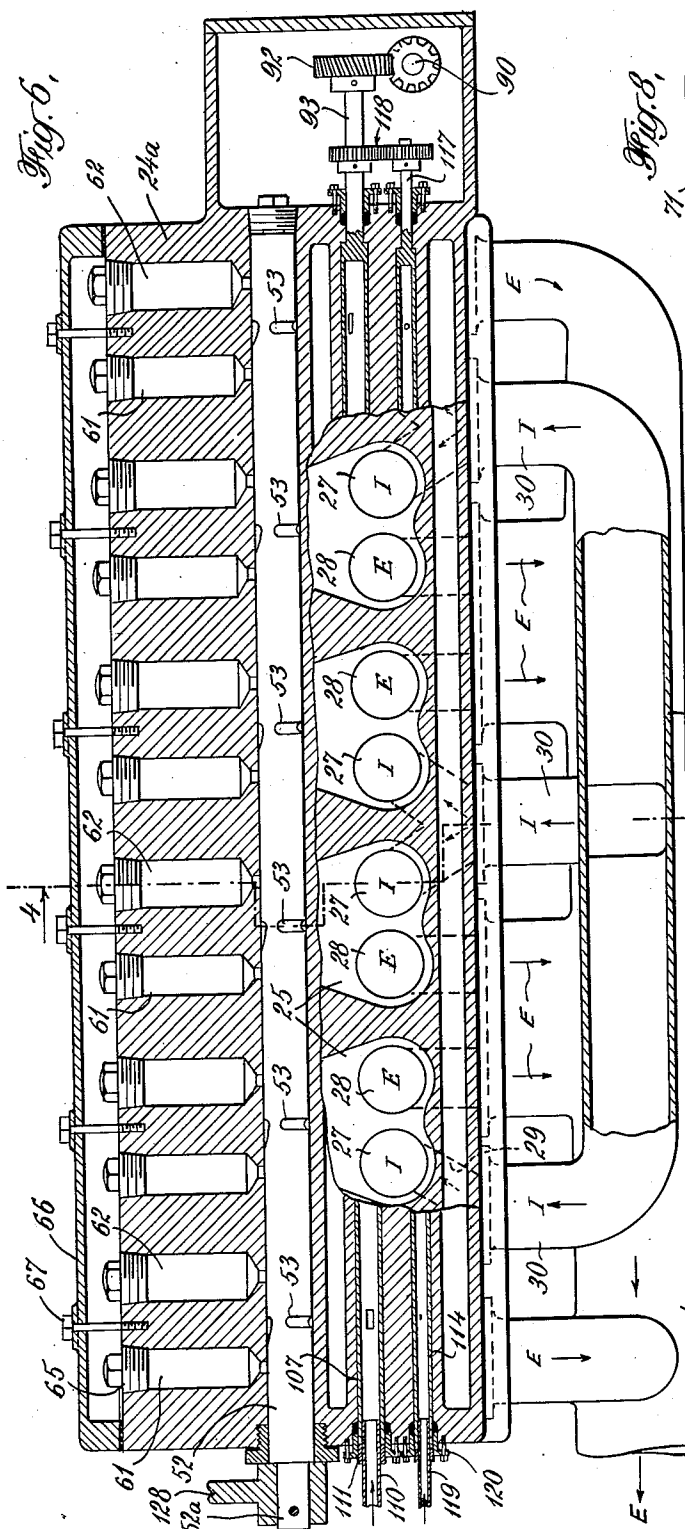
A. SCHWARZ

2,614,546

INTERNAL-COMBUSTION ENGINE

Filed Jan. 22, 1948

8 Sheets-Sheet 4



INVENTOR
Alfred Schwarz
BY *Reuben Edwards Morton & Barrows*
ATTORNEYS

Oct. 21, 1952

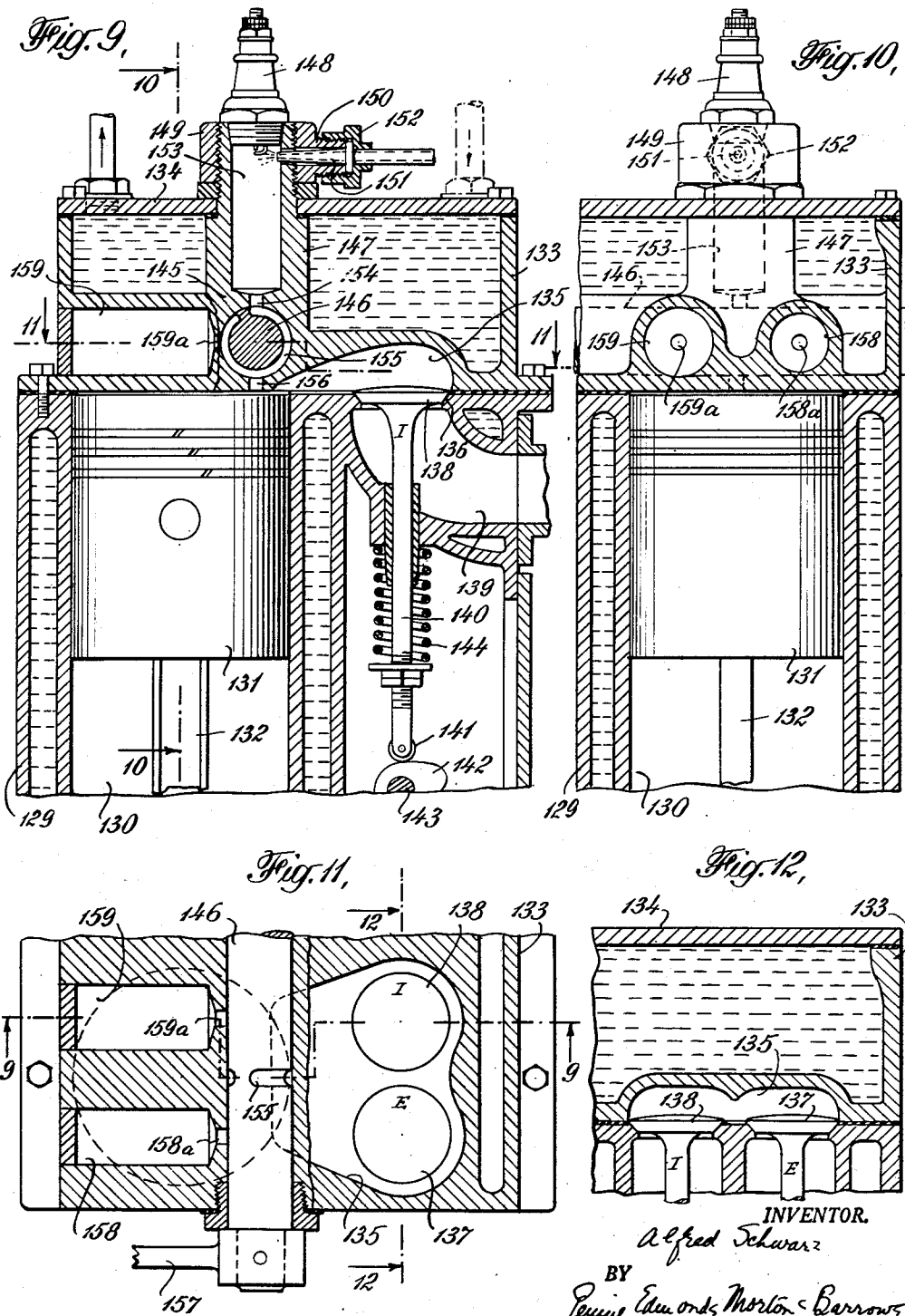
A. SCHWARZ

2,614,546

INTERNAL-COMBUSTION ENGINE

Filed Jan. 22, 1948

8 Sheets-Sheet 5



Oct. 21, 1952

A. SCHWARZ

2,614,546

INTERNAL-COMBUSTION ENGINE

Filed Jan. 22, 1948

8 Sheets-Sheet 6

Fig. 13,

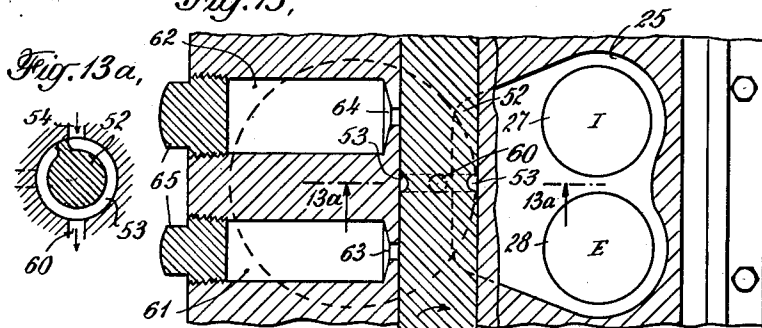


Fig. 14,

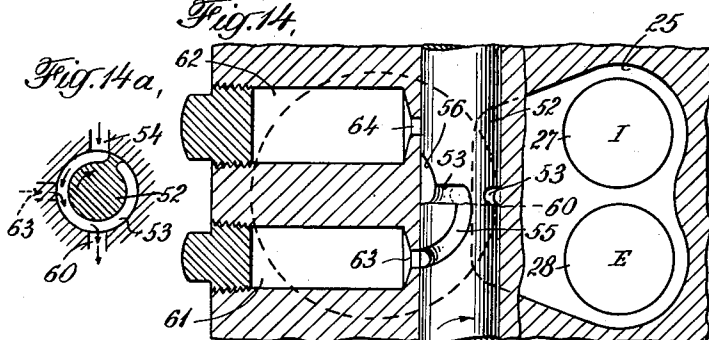


Fig. 15,

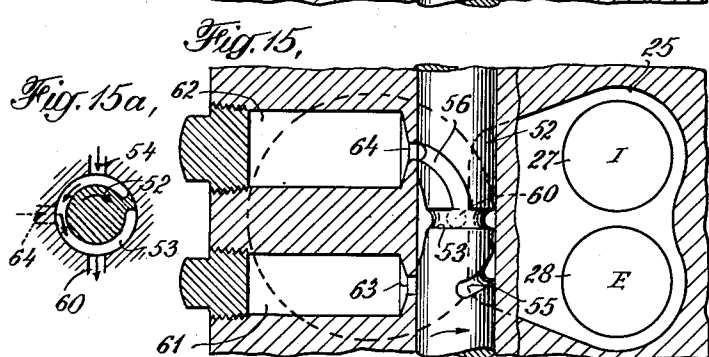
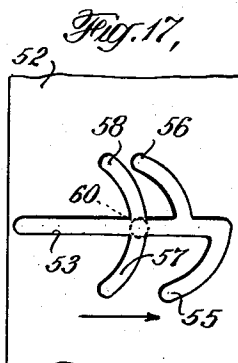
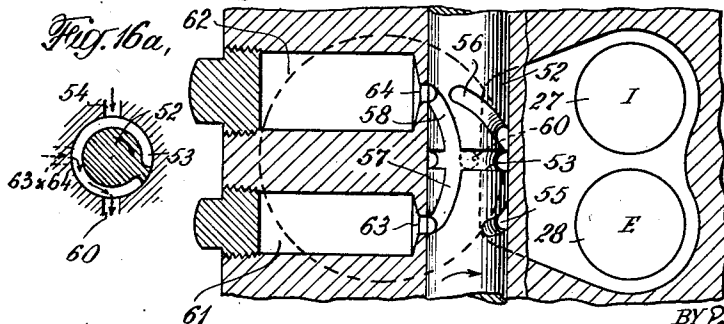


Fig. 16,



INVENTOR.

Alfred Schwarz

BY *Pennie Edwards Morton Barrows*
ATTORNEYS

Oct. 21, 1952

A. SCHWARZ
INTERNAL-COMBUSTION ENGINE

2,614,546

Filed Jan. 22, 1948

8 Sheets-Sheet 7

Fig. 18,

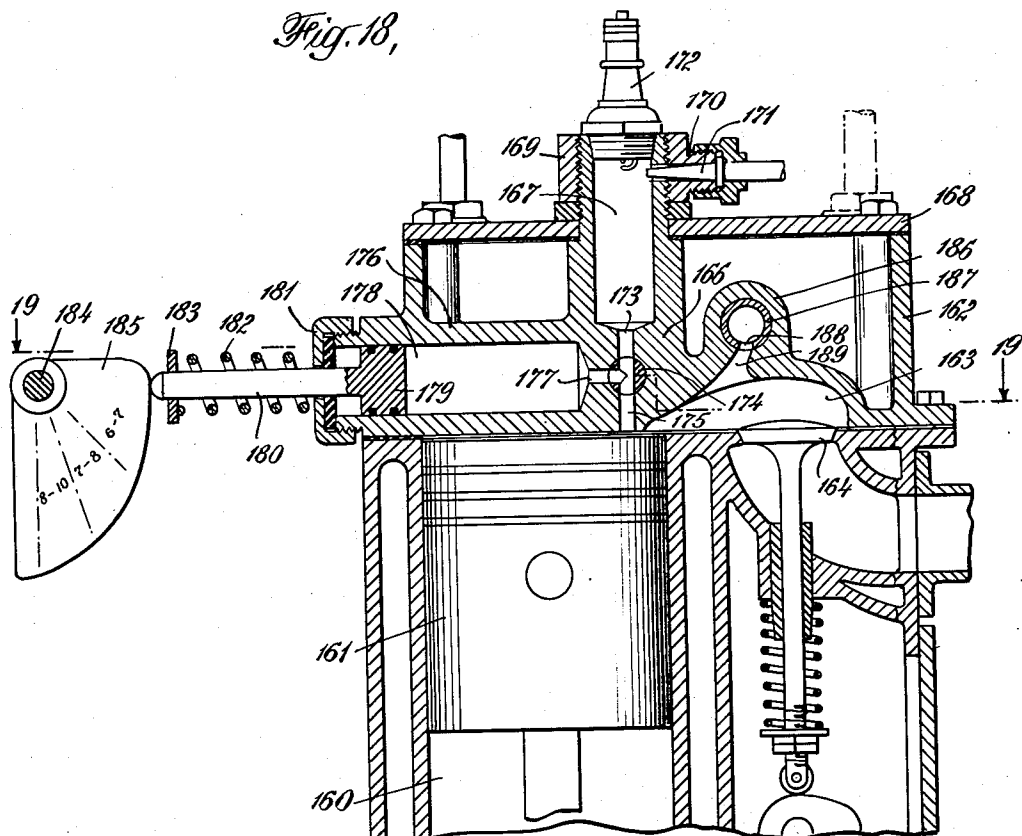
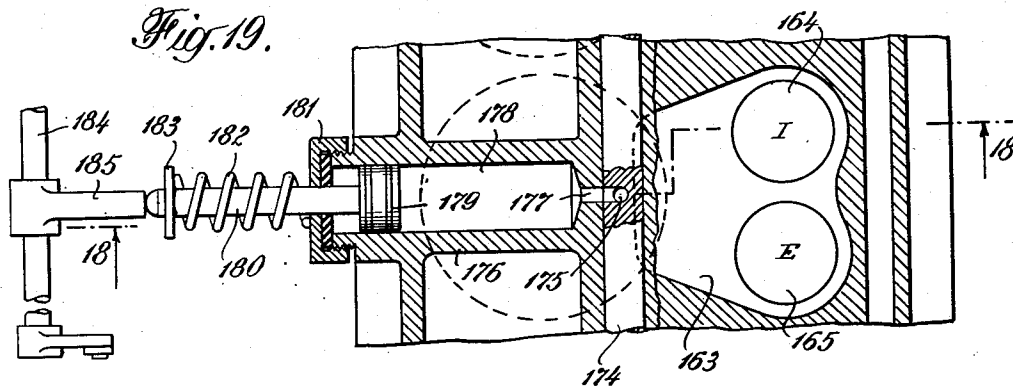


Fig. 19.



INVENTOR
Alfred Schwarz
BY *Levine Edwards Norton Barrows*
ATTORNEYS

Oct. 21, 1952

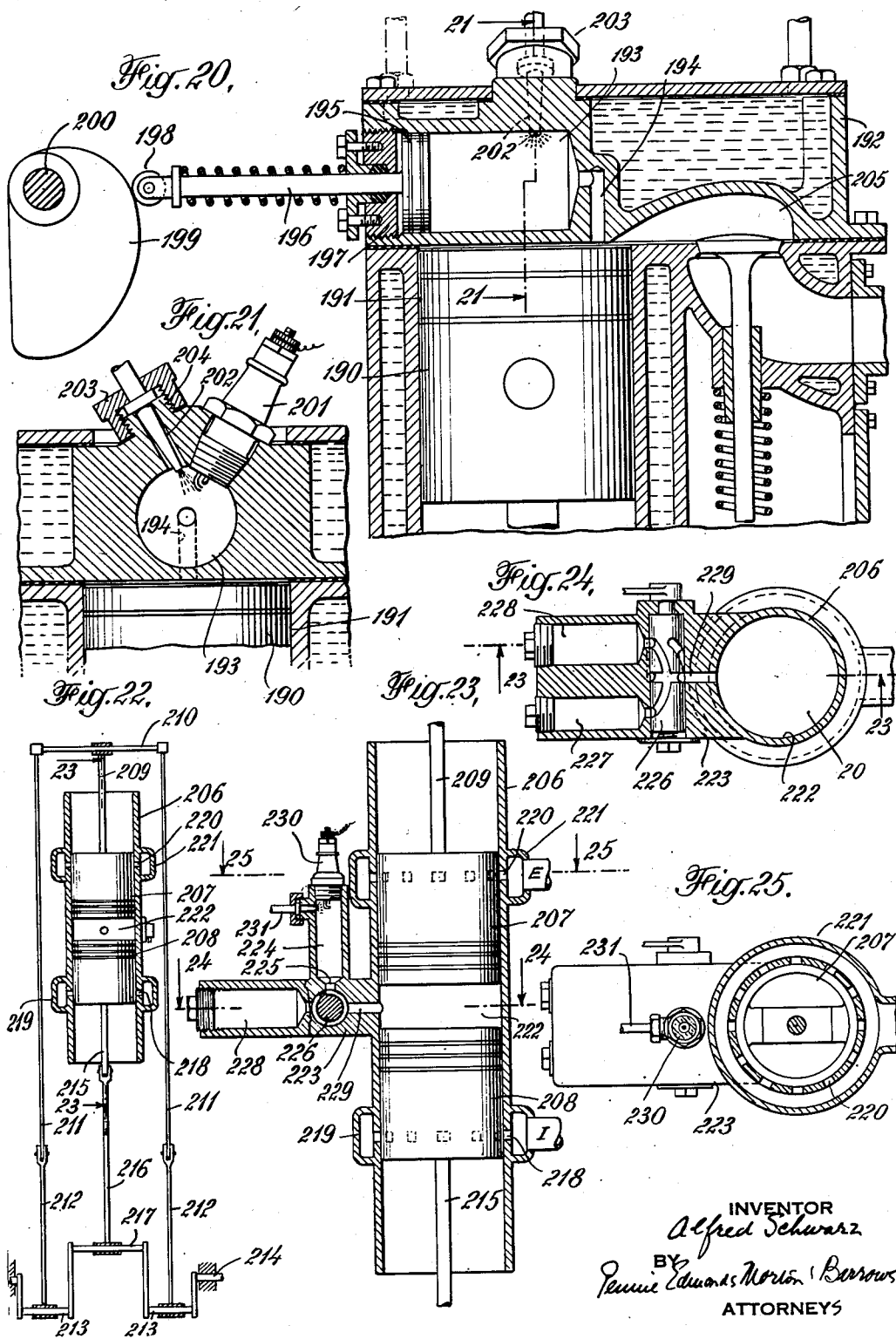
A. SCHWARZ

2,614,546

INTERNAL-COMBUSTION ENGINE

Filed Jan. 22, 1948

8 Sheets-Sheet 8



UNITED STATES PATENT OFFICE

2,614,546

INTERNAL-COMBUSTION ENGINE

Alfred Schwarz, New York, N. Y., assignor, by
mesne assignments, of sixty per cent to Sinclair
Research Laboratories, Inc., Harvey, Ill., a cor-
poration of Delaware

Application January 22, 1948, Serial No. 3,725

3 Claims. (Cl. 123-48)

1

This invention relates to internal combustion engines and is concerned more particularly with a novel internal combustion engine, which operates with greater fuel economy and is capable of producing more power than comparable prior engines. The increased power output of the new engine is obtained without special fuels and the engine can be run at low loads without severe fuel loss and at full load without detonation on fuels which contain no expensive anti-knock agents or else only small amounts thereof.

The new engine may be constructed to operate on either the Otto or diesel cycles or on either a two stroke or a four stroke cycle, and it may have a single piston, which may be either single or double acting, or opposed pistons operating within the cylinder. The engine can be operated with all the fuel introduced into the combustion chamber or cylinder by solid injection, with the major part of the fuel introduced by injection and a minor part introduced with air by induction, or with all the fuel introduced in the form of a fuel-air mixture by induction. The air may be supplied by induction at sub-atmospheric or atmospheric pressures through the usual throttling range and, when high power output is required, the cylinder may be supercharged by the introduction of cold compressed air. As a further means of increasing the power output, a fluid that is inert and does not take part in the combustion, may be introduced into the cylinder in small quantities after combustion has been completed and the burned gases have begun to expand. Such a fluid absorbs heat and is expanded and its expansion adds to the power.

The superior performance of the engine of the invention is obtained in part by the provision of means, by which the compression ratio may be varied under the control of the operator and while the engine is running and this makes it possible to keep the compression pressure within desirable limits at all times. Thus, during idling, the compression ratio may be relatively high but the compression pressure is not excessive because of the sub-atmospheric charging produced by throttling. At full throttle and on supercharge, the compression ratio is correspondingly lower, so that the compression pressure is kept below a value that would promote detonation. To achieve the desired result, the engine is so constructed that the end clearance, that is, the space occupied by the charge when it is under maximum compression, has a variable effective volume, which is controllable and may be altered during operation.

2

The end clearance of a conventional engine is of constant volume and is defined in part by the walls of the combustion chamber and a surface of the displacement member, when the latter is in a particular position. Thus, in a simple reciprocating piston engine, the end clearance is the space above the piston at the top of its stroke and, in an opposed piston engine, the end clearance is the space between the faces of the pistons when they most nearly approach each other. In the new engine, the end clearance is divided into a plurality of spaces, one of which is a space of fixed volume, as defined above, which will be termed the "basic end clearance." The remainder of the end clearance is made up of one or more chambers, which can be connected as desired to the basic end clearance to vary the total end clearance volume effective at any time. Preferably, one of the chambers is continuously connected to the basic end clearance and fuel is injected into and ignited in this chamber, which will, accordingly, be designated the "primary combustion chamber." When the engine operates at low load and with the supply of air throttled, the total effective end clearance may consist of the basic end clearance plus the primary combustion chamber and, as the weight of the charge is increased, additional chambers or chambers of larger size are connected to the basic end clearance to increase the total effective end clearance, until maximum charge is reached. With an increase in the total effective end clearance, the compression ratio decreases and thus may be varied inversely with the charge. The cutting in and out of the chambers is under the control of the operator through engine control means, such as the accelerator pedal, and, in a preferred construction, the control means is constructed to coordinate the compression ratio, and thus the compression pressure, with the weight of the charge.

The advantage of so constructing the engine that it has a variable effective end clearance may be made clear as follows. In a conventional engine operating on the Otto cycle and supplied with a fuel-air mixture by the carburetor, the compression ratio is constant, because of the fixed end clearance, and the compression pressure then depends on the weight of the charge, which in turn depends on the setting of the butterfly valve of the carburetor. Such an engine is designed to have a compression ratio appropriate for the fuel, on which the engine is to operate, and, if, for example, the desired compression ratio is 6:1 and the piston displacement is about 500

cc., the end clearance will be about 100 cc. Assuming that the engine operates at perfect volumetric efficiency, then, when the engine is on full throttle, the charge taken into the cylinder on each suction stroke will be 600 cc. at atmospheric pressure, and the pressure of the charge compressed into the end clearance on each compression stroke will be 6 atmospheres, disregarding the increase in pressure that results from the heating of the gas. When the throttle is partially closed for a reduced power output, the charge enters the cylinder at sub-atmospheric pressure and may be only such as to fill only one-quarter of the cylinder at atmospheric pressure. It is obvious that, when such a charge is compressed into the end clearance, the compression pressure will be much less than in the first instance, when the charge was supplied at full throttle. It is well known that an internal combustion engine operating with a low compression pressure requires a high fuel-air ratio and the fuel consumption of such an engine, which may be 0.5 to 0.6 pound per horse power hour under normal full throttle operation, may rise to as much as 4 pounds per horse power hour, when the engine is operating with the low compression pressure resulting from throttled operation. Since the end clearance and compression ratio of such a conventional engine are fixed, and the compression pressure depends on the throttle setting, it will be evident that such an engine must operate with poor economy under partial load, since any attempt to improve that economy will result in the development of compression pressures at higher loads, which will produce detonation.

In the engine of the invention, in which the compression ratio may be changed during operation by changing the effective volume of the end clearance, the compression ratio may be varied inversely with the weight of the charge and the compression pressure may thus be kept substantially constant throughout the range of operation. As a result, it is not necessary during idling at part throttle, as in conventional engines, to use excessively rich mixtures because of the low compression pressure, and, at the same time, the compression pressure is not so high as to cause detonation, when the engine is operating at full load.

The subdivision of the total end clearance in the new engine into a plurality of separate spaces or chambers serves another useful purpose, in that the walls of the chambers provide additional surface area, through which heat may be dissipated. The amount of heat that must be removed from the combustion zone of an internal combustion engine is in proportion to the weight of the charge and, since, in the new engine, the total effective end clearance is varied directly with the weight of the charge, the total heat dissipating surface is also varied directly with the weight of the charge. The compression temperature may, accordingly, be kept within desirable limits and better economy and power output obtained. The desired results are further promoted by the provision of separate cooling systems for the combustion and expansion zones of the engine, in order that the circulation of the coolants to remove heat from the two zones may be at different rates selected to provide sufficient cooling of the combustion zone to prevent detonation and to avoid over-cooling of the expansion zone with subsequent loss of power. In the combustion zone in an internal combustion engine, the tempera-

ture is likely to exceed 4,000° F. immediately after the fuel is burned, while the temperature in the expansion zone, that is, the cylinder barrel, may be about 2,000° F. It is obvious, therefore, that the expansion zone does not require and should not have as much cooling as the combustion zone and, in the new engine, proper cooling of the two zones is achieved.

The provision of the primary combustion chamber, into which the major part of the fuel is injected, contributes greatly to the fuel economy of the engine, particularly at low loads, in that a fuel mixture sufficiently rich to be readily ignited may be produced in this chamber, the air for complete combustion of the fuel then being contained within the basic end clearance and in the other chambers, when they are used. In a conventional engine, in which the fuel-air mixture is drawn into the cylinder and compressed into a fixed end clearance, it is necessary, when operating on throttle and at low power output, to employ an over-rich mixture to insure ignition at the low compression pressure and much of the fuel is unconsumed, because sufficient air for complete combustion is not available. In the new engine operating with the major part of the fuel supplied by injection, the injection preferably takes place during the compression stroke so that the richest mixture fills the primary combustion chamber only, instead of the total end clearance volume, and the mixture in the basic end clearance is very lean. The total amount of air available is then such as to insure that little, if any, of the fuel will leave the cylinder unburned.

A further feature of the new engine, which contributes to its performance, is the provision of control means, by which the operation of the different parts of the engine may be coordinated to produce optimum results. During operation, the total effective end clearance should be varied in accordance with the weight of the charge, and that weight depends on the amount of fuel injected, on the throttle setting, which determines the amount of air induced into the cylinder, and on the amount of supercharge, when the latter is used. The weight of fuel supplied should be correlated with the weight of air charge, whether by induction alone or by induction plus supercharge. Similarly, the amount of inert fluid injected should be correlated to the weight of the fuel being burned. In order to coordinate these various factors, the engine is provided with a single control means, which may conveniently take the form of a shaft carrying a plurality of cams. The cams operate devices for controlling, for example, the interconnection of the basic end clearance with the additional chambers to vary the total effective end clearance, the weight of fuel injected, the weight of air supplied to the cylinder by induction, the weight of supercharged air, the amount of inert fluid injected, and the advance of the spark. The cams are formed on the basis of dynamometer tests to adjust the control devices to give best results throughout the range of operation and the operator may thus control the engine merely by rotation of the control cam shaft.

The new engine includes various other features of novelty, which will be apparent from the following detailed description, when considered in connection with the accompanying drawings. In the drawings

Fig. 1 is a view in side elevation of a six cylinder engine embodying the invention;

5

Fig. 2 is a plan view of the engine shown in Fig. 1;

Figs. 3 and 4 are sectional views on the lines 3—3 and 4—4 of Fig. 1, respectively;

Fig. 5 is a plan view on the line 5—5 of Fig. 4;

Fig. 6 is a sectional view on the line 6—6 of Fig. 3;

Fig. 7 is a view in perspective of a control mechanism for operating the engine of Fig. 1;

Fig. 8 is a diagrammatic view similar to Fig. 1, showing circulation through the cooling systems;

Fig. 9 is a view in vertical section on the line 9—9 of Fig. 11, of a modified form of engine constructed in accordance with the invention;

Figs. 10 and 11 are sectional views on the lines 10—10 and 11—11, respectively, of Fig. 9;

Fig. 12 is a sectional view on the line 12—12 of Fig. 11;

Fig. 13 is a sectional view on the line 13—13 of Fig. 4;

Fig. 13a is a transverse sectional view through a rotary valve in the position that the valve occupies in Fig. 13;

Figs. 14, 15, and 16 are views similar to Fig. 13, showing the rotary valve in different operative positions;

Figs. 14a, 15a, and 16a are sectional views similar to Fig. 13a, showing the rotary valve in the positions, in which it is shown in Figs. 14, 15, and 16, respectively;

Fig. 17 is a developed view of the rotary valve showing the ports therein;

Fig. 18 is a vertical sectional view of a modified form of the new engine;

Fig. 19 is a sectional view on the line 19—19 of Fig. 18;

Fig. 20 is a vertical sectional view of a modified form of the new engine;

Fig. 21 is a sectional view on the line 21—21 of Fig. 20;

Fig. 22 is a diagrammatic vertical sectional view of a form of the new engine provided with opposed pistons;

Fig. 23 is a sectional view, on an enlarged scale, on the line 23—23 of Fig. 22; and

Figs. 24 and 25 are sectional views on the lines 24—24 and 25—25, respectively, of Fig. 23.

The new engine may be of any of the standard constructions but, for the purpose of simplifying the explanation, two main forms of the engine are illustrated, one being of the simple reciprocating piston type and the other including opposed pistons. The engine illustrated in Figs. 1 to 6 is of the first type and it includes a jacketed cylinder block 20 containing cylinders 21, in each of which there is a movable piston 22 connected by a connecting rod 23, to the usual crank on the main crank shaft of the engine. The cylinder block is closed at its upper end by a cylinder head 24, which contains a valve cavity 25 for each cylinder, the major portion of the cavity lying offset from the cylinder at one side thereof. The block is formed with a pair of valve seats 26 at the bottom of each cavity for an inlet valve 27 and an exhaust valve 28, respectively. A passage 29 in the block leads to each inlet valve and the inlet passages are connected to branches 30 of an inlet manifold 31, the ends of the branches being connected to the block in the usual manner. Similar passages lead from the exhaust valves to branches 32 of an exhaust manifold 33. In successive cavities along the block, the positions of the inlet and exhaust valves are reversed, so that branches 30 of the inlet manifold lead to passages for a pair of cylinders and certain of the branches 32

6

of the exhaust manifold are also connected to passages leading from a pair of cylinders. Each inlet and exhaust valve has a stem 34 passing through a guide 35 in the wall of its passage and, at its lower end, the valve stem has a cam follower 36 acted on by a cam 37 on the engine cam shaft 38. A spring 39 encircling the valve stem acts at one end against the outer wall of the passage and, at the other, against a collar 40 on the valve stem to hold the valve on its seat, until it is raised by the cam.

The head 24 is secured to the top of the block by bolts with the usual gasket 41 between the head and the block. The head is hollow and it is closed at its top by a cover 42 bolted to the head with a gasket 43 between. The head is formed with a boss 44 extending along the upper surface of the lower wall of the head from end to end thereof and, above each cylinder, there is a vertical extension from the boss containing a chamber 45. The end of the extension projects through the cover 42 and has a threaded top opening, in which is inserted a spark plug 46. A collar 47 is threaded on the outside of the portion of the extension exposed above cover 42 and the collar has a hollow lateral projection 47a, in which is inserted an atomizing nozzle 48. The nozzle extends through an opening in the wall of chamber 45 and is held in place by a collar 49 threaded on the outside of extension 47a. The nozzle is connected by a line 50 to one cylinder of a fuel pump 51 provided with a control rod 51a.

The boss 44 has a lengthwise cavity occupied by a rotary valve 52 of rod form. The valve has a plurality of main channels 53 in its surface extending nearly completely circumferentially of the valve, and a passage 54 leads from the bottom of each chamber 45 to register with a channel. Branch channels 55, 56, 57, and 58 are also formed in the surface of the valve to connect with each main channel 53. A passage 60 leads through the boss to the top of each cylinder, each passage 60 being aligned with a channel 53.

The boss 44 is formed with a pair of auxiliary end clearance chambers 61, 62 for each cylinder, and passages 63, 64 lead from the inner ends of the respective chambers to the surface of the rotary valve 52. The channels 55, 56, 57, and 58 in the surface of the valve are formed to connect passages 63, 64 for each of chambers 61, 62 to a passage 60 in different arrangements, depending on the angular position of the rotary valve. Thus, when the valve is in the position shown in Figs. 13 and 13a, the main channels 53 in the surface of the valve connect all the passages 54 to their respective passages 60, so that each chamber 45 is in communication with its cylinder. At the same time, all passages 63, 64 are closed. When valve 52 is turned angularly to the position shown in Figs. 14 and 14a, each chamber 45 remains connected through its passage 54, its main channel 53, and its passage 60 to its cylinder. Also, the chamber 61 for each cylinder is connected through its passage 63, its branch channel 55, its main channel 53, and its passage 60 to the cylinder, so that both chambers 45 and 61 are effective. When the valve is in the position shown in Figs. 15 and 15a, each chamber 45 is connected, as previously described, to the interior of its cylinder and the associated chamber 62 is connected through its passage 64, its branch channel 56, its main channel 53, and its passage 60 to the interior of the cylinder, so that both chambers 45 and 62 are effective. When the valve has the position shown in Figs. 16 and 16a,

chamber 45 is connected to its cylinder as above described and both chambers 61 and 62 for each cylinder are connected through their branch channels 57 and 58 and their main channel 53 to the interior of the cylinder.

The wall 24a of the head lies inwardly from the outer ends of chambers 61, 62 and has an outwardly extending flange spaced from the top of that part of the boss 44, in which the chambers are formed. Each chamber 61, 62 is closed at its outer end by a threaded plug 65, which can be moved into or out of the chamber to vary the volume thereof. The plug used may be solid or hollow, the substitution of one type for the other making possible a further variation in the volume of the chamber. A cap plate 66 is secured by bolts 67 to the head to overlie the ends of the plugs, and the plate bears along its lower edge against the head and block and along its upper edge against the edge of the flange extending from wall 24a of the head. The interior of the cap plate is open to the interior of the head through the space between the lower end of wall 24a and the top of that part of the boss 44a containing chambers 61, 62.

The space between the face of each piston at the top of its stroke and the lower surface of the head 24, plus the space within the cavity 25 in the head for the cylinder constitute the basic end clearance, which is ordinarily supplemented by the volume of chamber 25 and may also be supplemented by the volume of chamber 61 or chamber 62 or the combined volumes of the two chambers, by adjustment of the rotary valve 52. The total effective end clearance of the engine may, accordingly, be varied in accordance with the requirements of different conditions of operation and the range of variation may be increased by changing the positions of plugs 65 or by replacing solid plugs with hollow ones. The interior of the head 24 is connected by lines 68, 69 to a radiator 70, and a coolant is circulated through the interior of the head and the radiator by a pump 71. When chambers 61 and 62 are cut off from the cylinder, there is less transmission of heat through their walls to the coolant than when they are connected to the interior of the cylinder. Accordingly, when either or both chambers are connected to the cylinder, the effect is both to increase the total end clearance of the engine and also to increase the surface, through which heat may be conducted to the coolant flowing through the head.

The inlet manifold 31 may be provided with a throttle valve (not shown) and be open beyond the throttle valve to the air, so that only air is drawn into the cylinder by the downward movement of the piston on the suction stroke, but preferably, the intake manifold is connected to a carburetor 72 through a vaporizer 73. The vaporizer includes a plurality of sections 74, each having upper and lower walls 75 and hot exhaust gases are supplied to the interior of the sections by inlet pipes 76a and led away through outlet pipes 76b. A plurality of tubes 77 extend through each vaporizer section, each tube having an enlarged end 78 terminating flush with the top wall 75 of its section and a lower end 79 of diminished size, which projects into the enlarged upper end of a tube 77 in the next lower section. With this arrangement, as the fuel-air mixture leaving the carburetor passes into the vaporizer section, it is drawn through tubes 77, slightly compressed, as it passes through the small end 79 of each tube, and then expanded. Any droplets of fuel that

leave the carburetor are broken up by passage through the vaporizer, and complete vaporization of the fuel is effected by the hot gases by the time the fuel leaves the vaporizer.

The crank shaft 80 of the engine carries a gear 81 connected by a chain 82 to a gear 83 on the shaft 84 carrying the valve cams. A second gear 85 on the cam shaft is connected by a chain 86 to a gear 87 on the shaft 88 of the fuel pump 51. Between gears 83 and 85, the cam shaft is connected through skewed gearing 89 to a shaft 90 running at its lower end in a thrust bearing 91 and connected at its upper end through gearing 92 to a shaft 93, the purpose of which will later be described. The chain drives are enclosed within casings and the cam shaft 84 extends forwardly and, on its exposed end, carries a pulley 94 connected by a belt 95 to a pulley 96 on the shaft 97 of a pump 98, attached to a housing 99 secured to the front end of the head 24. Pump 71 may be mounted on top of pump 98 with belt 95 driving a pulley 71a on the shaft of pump 71. Shaft 97 carries a fan 100 on its forward end. The intake of pump 98 is connected by a duct 101 to the interior of the jacket of the cylinder block 20, and the pump outlet is connected by a line 102 to the top of a radiator 103 beneath radiator 70. The bottom of radiator 103 is connected by a line 104 to the lower part of the jacket of the cylinder block.

The lower wall of the head 24 is provided with a pair of bosses 105, 106 extending lengthwise thereof and lying above the cavities 25 for the cylinders. Boss 105 is hollow and contains a rotary valve 107 in the form of a tube having an opening 108 for each cylinder, the openings being offset angularly about the valve in the order in which the cylinders are fired. A passage 109 leads through the lower wall of the boss from the surface of valve 107 to the interior of each cavity 25 above a cylinder. The shaft 93 extends through the front wall of the head 24 into the forward end of valve 107 and is connected thereto, and the driving connections, through which valve 107 is rotated from the engine crank shaft, are such that each cylinder is connected through its cavity 25, passage 109, and opening 108 to the interior of valve 107 once per cycle. At the rear end of the engine, the end of a line 110 extends through a gland 111 into the interior of valve 107. The line may be connected to a source of air under pressure, which may be contained in a tank 112 at relatively high pressure, the tank being connected through a reducing valve 113 to line 110, so that the air entering the valve 107 is at a pressure of twenty pounds, for example. If desired, the pressure within the tank 112 may be maintained by a pump driven by the engine, the output of the pump passing through a cooler to the tank, so that the latter contains cold compressed air.

The boss 106 is hollow and it contains a rotary valve 114 in the form of a tube having an opening 115 for each cylinder. Passages 116 lead through the wall of boss 106 from the several cavities 25 to the surface of valve 114 in registry with the respective openings 115. The openings 115 are offset circumferentially about the valve 114, and the arrangement is such that, as the valve is rotated, the cavities 25 of the cylinders are connected once per cycle through passages 116 and openings 115 to the interior of the valve 114. At the forward end of the engine, a shaft 117 extends through the wall of the head into the end of valve 114 and is connected thereto.

Shaft 117 is connected to shaft 93 by gearing 118. At the rear end of the head, the end of a line 119 extends through a gland 120 into the interior of valve 114. Line 119 may be connected through a control valve 121 to a supply of inert fluid under pressure. The construction and operation of valve 114 is such that a small quantity of the inert fluid is supplied by the valve to the interior of each cylinder on each firing stroke after combustion is complete.

The engine may be controlled by a control cam shaft 122 mounted for rotation in suitable bearings and operable by a crank 123, a pedal, or other suitable means. The shaft carries a plurality of cams 124, and levers 125, provided with cam follower rollers engaging the respective cams, are mounted for swinging movement on a rod 126 extending parallel to shaft 122. Each lever 125 is acted on by a spring 127 to hold its roller in contact with its cam. The levers 125 are connected to the various control devices on the engine, as, for example, one of the levers may be connected to air control valve 113, the second to the inert fluid control valve 121, the third to the lever 72a controlling the butterfly valve of carburetor 72, and the fourth to the control rod 51a of the fuel pump 51. The lever 125 associated with the fifth cam may be employed to control the advance of the spark and the sixth lever may be utilized to vary the angular position of the rotary valve 52. For the latter purpose, the lever may be connected to arm 128 fixed on a short shaft 52a extending into one end of valve 52 and secured thereto. The forms of cams 124 are determined by dynamometer tests, so that as cam shaft 122 is swung to different positions, the cams will cause the several control devices to be adjusted for optimum performance of the engine under varying conditions.

The engine illustrated in Figs. 9 to 12, inclusive, is similar to that above described, except that it contains no rotary valves similar to valves 105 and 114. The water jacketed cylinder block 129 contains a plurality of cylinders 130, each containing a piston 131 connected by a connecting rod 132 of a crank on the main crank shaft. Block 129 is provided with a head 133, the top of which is closed by a cover 134. The bottom wall of the head is formed with a plurality of valve cavities 135, one for each cylinder, each cavity partially overlying the cylinder at one side thereof. The block is formed with a pair of valve seats 136 beneath each cavity and an exhaust valve 137 cooperates with one seat and an inlet valve 138 cooperates with the other. A passage 139 leads from each valve, the inlet and the exhaust passages being connected to branches of an inlet manifold and an exhaust manifold, respectively. Each valve has a stem 140 extending through a guide in the wall of its passage and having a roller 141 at its lower end, which engages a cam 142 on a cam shaft 143. A spring 144 encircling the stem acts to hold the valve on its seat, until it is raised therefrom by its cam.

The lower wall of the head is formed with a boss 145 extending lengthwise thereof, and the boss is hollow and contains a rotary valve 146. The boss is formed with a hollow vertical extension 147 above each cylinder, the extension projecting out of the top of the head and being closed at its upper end by a spark plug 148. A collar 149 is threaded on the projecting end of the extension, the collar having a lateral neck 150, in which is mounted an atomizing nozzle 151 held in place by a nut 152 on the end of the neck.

The nozzle extends through an opening in the wall of the extension 147 and into the interior of the chamber 153 within the extension. The nozzle is connected to one cylinder of a fuel pump by a line 151a.

A passage 154 leads through the wall of the boss 145 from the bottom of each chamber 153 to the surface of a rotary valve 146. The rotary valve has a plurality of circumferential channels 155 registering with the passages 154 and with respective passages 156 leading through the boss to the tops of the cylinders. The rotary valve is provided with channels corresponding to channels 53 and 55-58, inc., of valve 52 (Fig. 17) and it projects beyond one end of head 133 and carries an arm 157 by which it may be placed in different angular positions.

Boss 145 is provided with a pair of hollow lateral extensions defining chambers 158, 159 above each cylinder, chamber 158 being somewhat smaller than chamber 159. The chambers have passages 158a, 159a leading therefrom to the surface of rotary valve 146. The formation of the channels on the surface of the rotary valve is such that, in all angular positions of adjustment of valve 146, each chamber 153 is connected through a channel in the surface of the valve to its cylinder. In one position of valve 146, chambers 158, 159 are both cut off from their cylinder, while, in other positions of valve 146, chamber 158 or chamber 159 or both chambers are connected to their cylinder.

The engine illustrated in Figs. 18 and 19 includes a water jacketed cylinder 160 containing a piston 161 and closed at its top by a head 162 formed with a cavity 163 above the seats for valves 164, 165. The head is formed with a longitudinal hollow boss 166 containing a chamber 167 above each cylinder. The top of the head is closed by a cover 168 and the wall of the chamber projects through the cover. A collar 169 is threaded on the projecting end of the chamber and the collar has a lateral extension 170, in which is mounted a fuel atomizing nozzle 171, the nozzle extending through an opening in the wall of the chamber. At its upper end, the chamber is closed by a spark plug 172 threaded in place.

A passage 173 leads through boss 166 from the bottom of chamber 167 to the surface of a rotary valve 174 within the hollow interior of the boss. Beyond the valve, there is a passage 175 leading into the top of the cylinder. The boss 166 has a lateral extension 176 defining a chamber 178, and a passage 177 leads from the inner end of the chamber to the surface of valve 174. The valve is so constructed that, in one position, both chambers 167 and 178 are connected to the interior of the cylinder, while, in a second position, chamber 167 alone is connected to the cylinder.

A piston 179 is mounted in chamber 178 and has a rod 180 which projects through a cap 181 closing the outer end of the chamber. A spring 182 encircling the rod bears at one end against the cap and, at the other end, against a disc 183 fast on the rod, the spring tending to move the piston toward the outer end of chamber 178. A shaft 184 is mounted beyond the outer end of rod 180 and the shaft carries a cam 185 bearing against the outer end of the rod. By angular adjustment of the shaft and cam, the piston 179 may be moved inwardly of the cylinder against the resistance of spring 182.

The bottom wall of the head 162 is formed with

a longitudinal boss 186, which is hollow and contains a hollow rotary valve 187. The valve has a port 188 for each cylinder, the port lying in position to be brought into registry with a passage 189 leading through the boss into the top of the cavity 163 of the cylinder. Cold compressed air or other fluid may be supplied to the interior of valve 187 and the ports 188 in the valve are so positioned and the valve is rotated in such timed relation to the crank shaft of the engine that, once per cycle and at the desired time in the cycle, the fluid contained within the valve is supplied to each cylinder.

The operation of a single cylinder of the engine shown in Figs. 1-6, inclusive, may be as follows. Under a light load, the primary combustion chamber 45 is connected through valve 52 to the cylinder, and the auxiliary end clearance chambers 61 and 62 are cut off. The carburetor supplies a very lean mixture to the cylinder and, if desired, the fuel supply to the carburetor may be cut off, so that only air is supplied. The charge of air or lean mixture drawn into the cylinder on the suction stroke is compressed on the compression stroke and a part of the charge enters the primary combustion chamber 45. During the compression stroke, the injection of fuel through nozzle 48 and chamber 45 starts at about 35° ABC and continues to about 90° ABC. The fuel is vaporized in chamber 45 and the fuel-air mixture in the chamber is ignited by spark plug 46 a few degrees before TDC. The mixture in the primary combustion chamber is sufficiently rich to be readily ignited, but the chamber contains insufficient air for complete combustion of the fuel. Sufficient additional air for complete combustion of the fuel is, however, contained in the basic end clearance made up of the space above the top of the piston at the upper end of its stroke, such space including the cavity 25 for the cylinder. The burning mixture, accordingly, travels through passage 54, channel 53 in valve 52, and passage 60 into the cylinder, where its combustion is completed. At this stage of operation, the engine is operating at a compression ratio depending on the relative volumes of the piston displacement and the total end clearance, which consists of the basic end clearance plus the volume of chamber 45.

As the load on the engine increases, control cam shaft 122 is moved angularly so that the fuel pump cam thereon causes additional fuel to be supplied to the primary combustion chamber by the pump. Additional air is required to effect complete combustion of such fuel and the air is supplied through the carburetor by adjustment of the butterfly valve thereof by its cam on shaft 122. With the charging of additional fuel and air, the compression pressure increases and, if no change were made in the setting of the rotary valve 52, the compression pressure might, in time, reach such a value that detonation would occur. The cam on shaft 122 controlling valve 52 is so formed, however, that, when the compression reaches a selected value, valve 51 is shifted to connect chamber 61 to the cylinder. The total effective end clearance is thereby increased by the volume of chamber 61 and the compression ratio is decreased accordingly. As the charge is further increased to meet the requirements of the engine, valve 52 is adjusted by its cam so that at the proper time, chamber 61 is cut out and chamber 62, which is larger than chamber 61, is connected to the cylinder.

The adjustments of valve 52 as described make

it possible to operate the engine with four different compression ratios and to maintain the compression pressure under different conditions of operation within such limits as to prevent detonation. The sizes of the chambers relative to one another and to the combined volumes of the basic end clearance and chamber 45 will depend upon the detonation characteristics of the fuel, with which the engine is to be operated. While it is desirable, in order to obtain the best power output, to use a relatively high compression ratio, a ratio appropriate for use with a high octane fuel would be too high for a low octane fuel. When conditions demand, the volumes of chambers 61, 62 may be increased or decreased by adjustment of the plugs 65 in the ends thereof or use of plugs of different types.

When the engine is running at full throttle, an increase in power may be obtained by supplying cold compressed air to the cylinder during early part of each compression stroke. For this purpose, valve 113 is opened at the proper time by its cam on the control cam shaft 122 and the air enters the rotary valve 107. The valve 107 rotates at cam shaft speed, so that the port 108 therein is open to passage 109 leading to cavity 25 once per cycle and at the desired point in the compression stroke. The cold compressed air may be introduced into the cylinder through any part of the operating range of the engine, but will ordinarily not be used except at full throttle.

At any time in the operation of the engine, valve 121 may be opened so that inert fluid, such as water, is supplied under pressure to rotary valve 114. Like valve 107, valve 114 rotates at cam shaft speed, so that once per cycle, the port 115 is open to passage 116 and a small quantity of inert fluid is supplied to the cylinder through cavity 25. The fluid is injected on the power stroke after combustion is completed. The fluid absorbs heat and its expansion so adds to the power output.

The inert fluids that may be injected through rotary valve 114 may be water or gaseous knock suppressors, such as cold exhaust gas, but the valve may also be employed for the introduction of secondary fuels, such as alcohol and alcohol-water mixtures.

In the foregoing, the new engine has been described as being supplied with fuel injected into the primary combustion chamber and air, either alone or in the form of a thin fuel-air mixture, supplied to the cylinder by induction. So operated, the engine provides the best economy, particularly when idling, since, under such conditions, only the primary combustion chamber is supplied with a fuel-air mixture sufficiently rich to be easily ignited. Some of the advantages of the new engine, however, are made available, when it is operated with all the fuel supplied by the carburetor and no fuel supplied by injection. The provision of the auxiliary end clearance chambers 61, 62 makes it possible to operate the engine during idling with a compression ratio, which would be undesirably high at full throttle operation. The high compression ratio improves the efficiency of the engine but does not produce excessive compression pressures, because the fuel-air mixture is supplied at subatmospheric pressure in the lower part of the throttle range. As the operation of the engine approaches full throttle operation, the total effective end clearance is increased by means of the auxiliary end clearance chambers, so that the compression ratio does not produce a compression pressure at

13

full throttle, which would be likely to produce detonation.

The provision of the means in the new engine for varying the compression ratio also adapts the engine for operation by means of producer gas. Operation of an engine with that fuel requires a compression ratio between 10 and 15 to 1 as compared with the usual compression ratios of 6 or 7 to 1 for operation with ordinary fuels. By proper formation and control of the auxiliary end clearance chambers, the engine may be started on gasoline with a suitable compression ratio and then switched over to operation on producer gas at the necessarily higher compression ratios. This shift may be readily accomplished by proper formation of the rotary valve controlling the chambers so that, in one position of the valve, both chambers are effective and, in another position, both chambers are cut out. The operation of the rotary valve as described may be accomplished by means of a cam of proper form on the control cam shaft.

The engine shown in Figs. 9 and 10 is similar in its mode of operation to that shown in Figs. 1 to 6, inclusive, but includes no means for introducing fluids, such as cold compressed air, water, a gaseous anti-knock agent, etc., into the cylinder during operation. The engine, however, includes the chambers 158, 159, which may be used for varying the compression ratio and maintaining the compression pressure within a desirable range. These chambers are utilized for this purpose in the same manner as chambers 61, 62 in the engine of Figs. 1 to 6, inclusive.

The engine shown in Figs. 18, 19 includes a primary combustion chamber 167 for each cylinder and also a single auxiliary chamber 178 for each cylinder, which may be used to increase the total effective end clearance volume for the purposes above described. The chamber 178 is of variable effective volume as determined by the position of the piston 179 therein and shaft 184 with its cam 185 may be used to move the piston within the chamber, as desired. With the piston in the position illustrated, the volume of chamber 178 may be such that, when it is used, the engine has a compression ratio of approximately 6 to 1. This ratio may be increased by moving the piston farther into the chamber by means of the shaft and cam and, depending upon the shape of the cam, the piston in its innermost position may so reduce the effective volume of chamber 178 that the compression ratio of the engine may reach 10 or more.

An engine of the type shown in Fig. 13 may be advantageously employed for operation with both ordinary fuels and with producer gas. The engine may be started on an ordinary fuel such as gasoline, and with the piston near the outer end of the chamber 178, so that the compression ratio is appropriate for gasoline operation and lies between 6 and 7 to 1, for example. When the changeover to producer gas operation is to be made, a much higher compression ratio of 10 or more to 1 is necessary and, accordingly, shaft 184 is moved angularly, so that cam 185 moves the piston to its innermost position. In an engine, which is to be operated alternately with gasoline and producer gas, the cam 185 may be mounted on a control shaft, such as shaft 122, or shaft 184 may be actuated from the control cam shaft. The cams on the control cam shaft for such an engine will then be shaped so that, on movement of the cam shaft as described, the various control devices on the engine will be actuated ap-

14

propriately for producer gas operation. Thus, for example, the control cam shaft may carry a cam, which will be effective, when the changeover from liquid to gaseous fuel is made, to put the fuel pump out of operation. The new engine may, accordingly, be operated either on ordinary fuels or producer gas with the changeover effected by a single simple adjustment of the main control means.

The engine shown in Figs. 20, 21 includes a water jacketed cylinder 190 containing a piston 191, the cylinder being closed at its top by a head 192. The head is formed with a chamber 193 connected to the cylinder through a passage 194 and containing a piston 195 having a rod 196, which extends through the removable end wall 197 of the chamber. The rod carries a roller 198 at its outer end, which bears against a cam 199 on a control cam shaft 200, so that, by rotation of the shaft, the piston can be moved to different positions within chamber 193. The wall of the chamber has a tapped opening, in which is inserted a spark plug 201 and the wall is provided with another opening, in which is inserted a fuel nozzle 202, the nozzle being held in place by a collar 203 threaded on a boss 205, through which the nozzle extends.

In the engine shown in Figs. 20, 21, the total effective end clearance consists of the space above the face of the piston at the top of its stroke, including the valve cavity 205, plus the volume of passage 194 and the space in chamber 193. The volume of chamber 193 available for end clearance purposes varies with the position of piston 195 in the chamber, so that the total effective end clearance volume is variable and the compression ratio of the engine may be correspondingly changed.

The engine shown in Figs. 22 to 25, inclusive, is of the opposed piston type and it includes a cylinder 206, in which reciprocate pistons 207, 208. Piston 207 has a rod 209 connected to a shaft 210, which is, in turn, connected by side rods 211 to rods 212 connected to cranks 213 of a crank shaft 214. Piston 208 has a rod 215 connected by a rod 216 to a crank 217 on shaft 214 lying between cranks 213. The cylinder wall is formed with a row of inlet ports 218 leading into the cylinder from an inlet manifold 219 and a row of exhaust ports 220 leading from the cylinder into an exhaust manifold 221.

The engine of Figs. 22, 23 is of the two cycle type and, as the pistons move apart on the back stroke, piston 207 uncovers the exhaust ports 220, so that the exhaust gases may pass into manifold 221, after which piston 208 uncovers inlet ports 218 to permit a fresh charge to be introduced. As the pistons approach each other, the exhaust ports and the inlet ports are closed in that order and the charge is compressed in the space 222 within the cylinder between the faces of the pistons when they approach each other most closely. The space 222 is, therefore, the end clearance and, whereas, in a simple single piston engine, the end clearance is defined in part by the face of the piston and in part by a stationary wall, namely, the cylinder head, in an opposed piston engine, the end clearance may be considered as defined in part by the face of a piston and the surface of a movable wall, which is the face of the other piston. In a conventional opposed piston engine, the space 222 constitutes the total end clearance and it is of constant volume.

The cylinder of the new engine, in the form shown in Figs. 22-25, inclusive, is provided with

15

an outward extension 223 from its wall opposite the space 222 and the extension has a vertical portion containing a chamber 224. The chamber has an outlet passage 225 at its lower end leading to a surface of a valve 226 mounted for rotary movement in a passage in the extension. Outwardly from the cylinder beyond valve 226, the extension 223 is formed with a pair of chambers 227, 228 of different size and having outlets leading to the surface of valve 226. Valve 226 is formed with channels in its surface, so that it is of the same general construction as valve 52, and can be moved to different positions to connect chambers 224, 227, and 228 to a passage 229 in the extension leading to space 222 within the cylinder. A spark plug 230 is mounted in the outer end of chamber 224 and a fuel nozzle 231 connected to a fuel pump is mounted in the wall of chamber 224 near its outer end in position to inject fuel into the chamber.

In the engine described, the space 222 is the basic end clearance, and, in the operation of the engine, chamber 224 is at all times connected to the basic end clearance through valve 226. At the proper time in the cycle, fuel is injected into chamber 224 and ignited and the burning fuel issuing from chamber 224 is completely consumed because of the air available in the basic end clearance and in chambers 227 and 228, when they are used. When the engine is idling, or operating under low load, the primary combustion chamber 224 is the only one of the chambers connected to the basic end clearance but, as the weight of the charge is increased because of an increase in the load, it is desirable to reduce the compression ratio. For this purpose, valve 226 is rotated to a position, in which it connects both chambers 224 and 227 to the basic end clearance. When a further reduction in compression ratio is desired, valve 226 is moved to another position, in which chambers 224 and 228, which are larger than chamber 227, are connected to the basic end clearance and chamber 227 is cut off. For the final reduction in compression ratio, valve 226 is moved to a position, in which all three chambers 224, 227, and 228 are connected to the basic end clearance. The engine thus functions in the same manner as the engines previously described and, if desired, may be constructed to include means for supercharging and for the injection of an inert fluid.

The engine illustrated and described operates on the Otto cycle with the charge ignited by a spark plug. It will be apparent that the new engine may be of the diesel type, in which case auto-ignition of the charge occurs because of the compression pressure developed.

I claim:

1. In an internal combustion engine having a cylinder block containing a cylinder, a piston movably mounted in said cylinder and a throttle control means, the improvement which comprises a cylinder head mounted on said block over said cylinder, said cylinder head having a first boss positioned over said cylinder, a rotary valve positioned within said first boss, said cyl-

16

inder head having a first passage connecting said rotary valve with said cylinder, an extension member integral with and extending upwardly from said boss and defining a primary combustion chamber connected to said cylinder through said rotary valve and said first passage, charge igniting means positioned in said extension member, fuel injection means positioned in said extension member, said cylinder head having auxiliary end clearance chambers communicating with said rotary valve, means responsive to throttle setting operably connected to said rotary valve for additively connecting said auxiliary end clearance chambers to said cylinder as the throttle setting is increased thereby reducing the compression ratio, a second boss formed in the cylinder head, a first rotary tube positioned within said second boss and having an opening therein, said cylinder head having a second passage therein connecting said tube with said cylinder, tube rotating means for rotating said tube, and means for supplying fluid medium to said tube for delivery to said cylinder during the combustion phase.

2. In an internal combustion engine as defined in claim 1 and including a third boss formed in said cylinder head, a second rotary tube positioned within said third boss and having an opening therein, said cylinder having a third passage connecting said second tube with said cylinder, means for rotating said second tube, and means for supplying fluid medium to said second tube for delivery to said cylinder during the combustion phase.

3. In an internal combustion engine as defined in claim 1 wherein the throttle control means is operably connected to said tube rotating means for coordinating the operation of said tube rotating means and said throttle control means in a predetermined manner in accordance with throttle setting.

ALFRED SCHWARZ.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
741,824	Pehrsson	Oct. 20, 1903
1,094,329	Henderson	Apr. 21, 1914
1,139,106	Cutler	May 11, 1915
1,334,031	Ingram	July 5, 1921
1,751,231	Leonard	Mar. 18, 1930
1,787,326	Sanders	Dec. 30, 1930
1,821,396	Nardin	Sept. 1, 1931
1,962,134	Brubaker	June 12, 1934
2,001,535	Lang	May 14, 1935
2,114,924	Kahlenberger	Apr. 19, 1938
2,142,466	Wagner	Jan. 3, 1939
2,163,015	Wagner	June 20, 1939

FOREIGN PATENTS

Number	Country	Date
5,947	Great Britain	Mar. 9, 1911
6,508	Great Britain	Mar. 15, 1911