April 16, 1968 V. P. COMBS 3,377,997

TWO-STROKE CYCLE ENGINE

Filed April 21, 1966 4 Sheets-Sheet 1

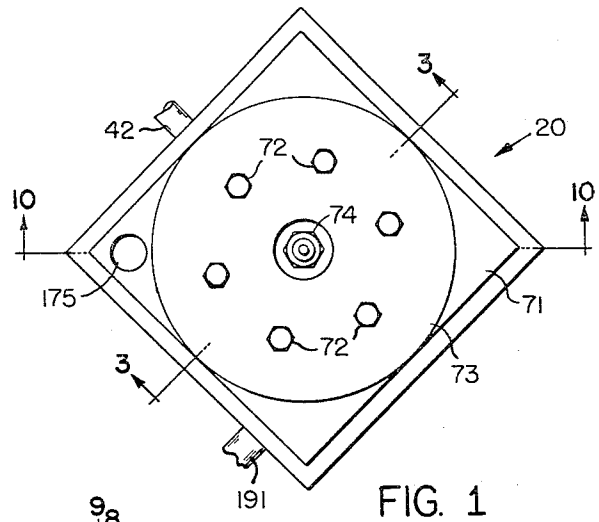


FIG. 1

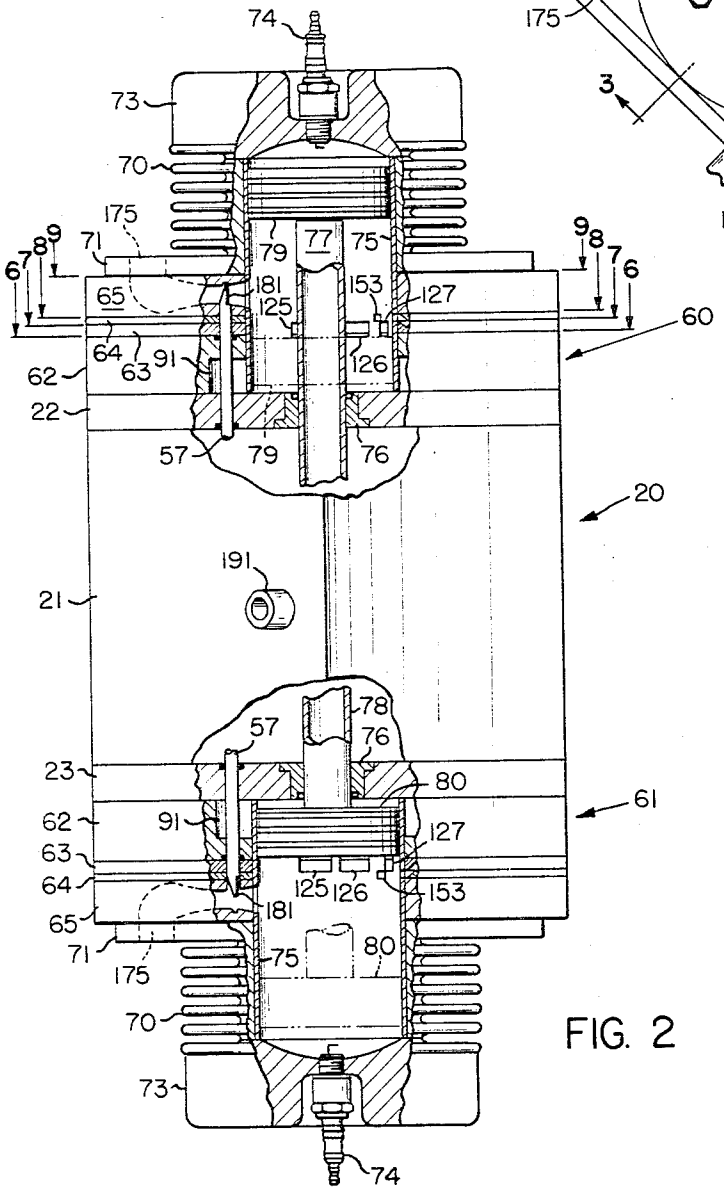


FIG. 2

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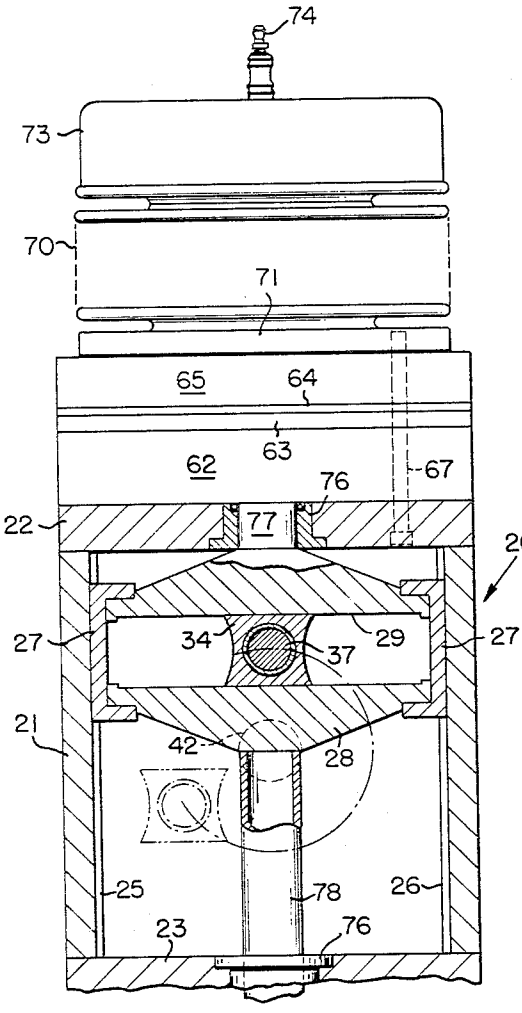


FIG. 3

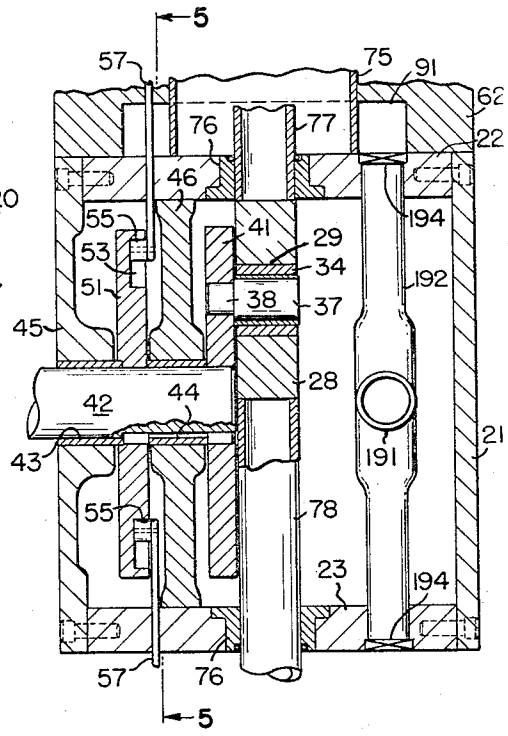


FIG. 4

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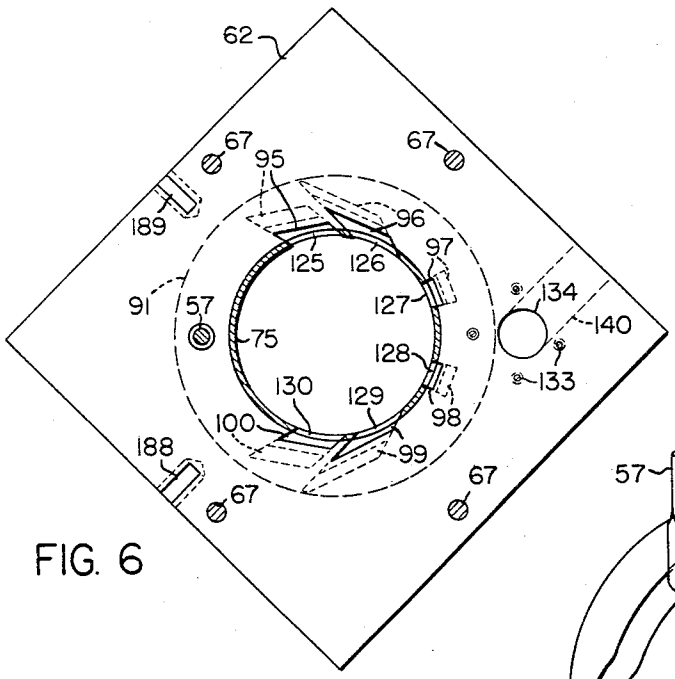


FIG. 6

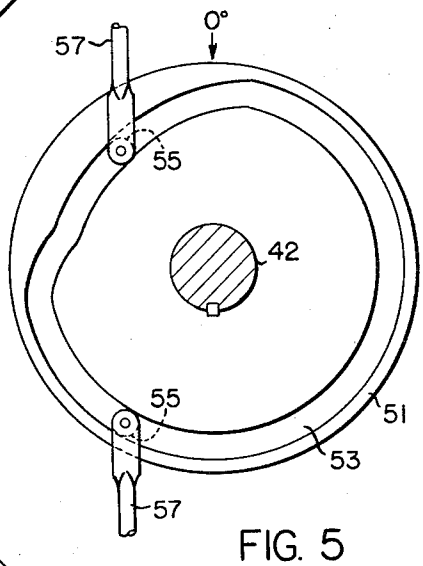


FIG. 5

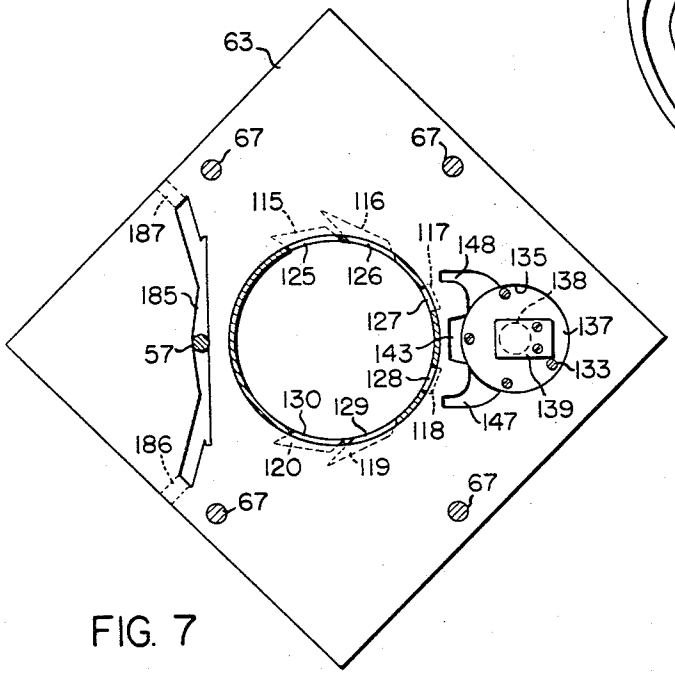


FIG. 7

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TWO-STROKE CYCLE ENGINE

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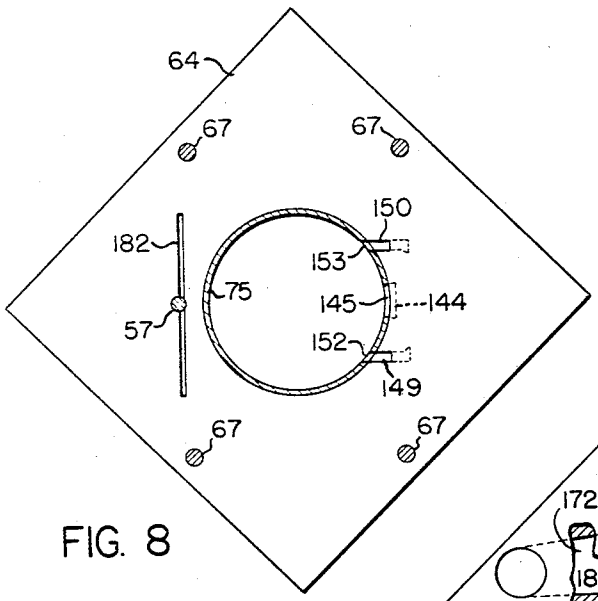


FIG. 8

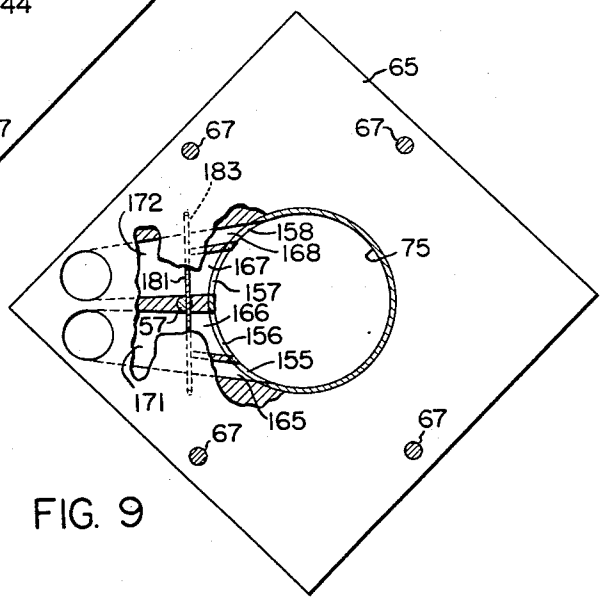


FIG. 9

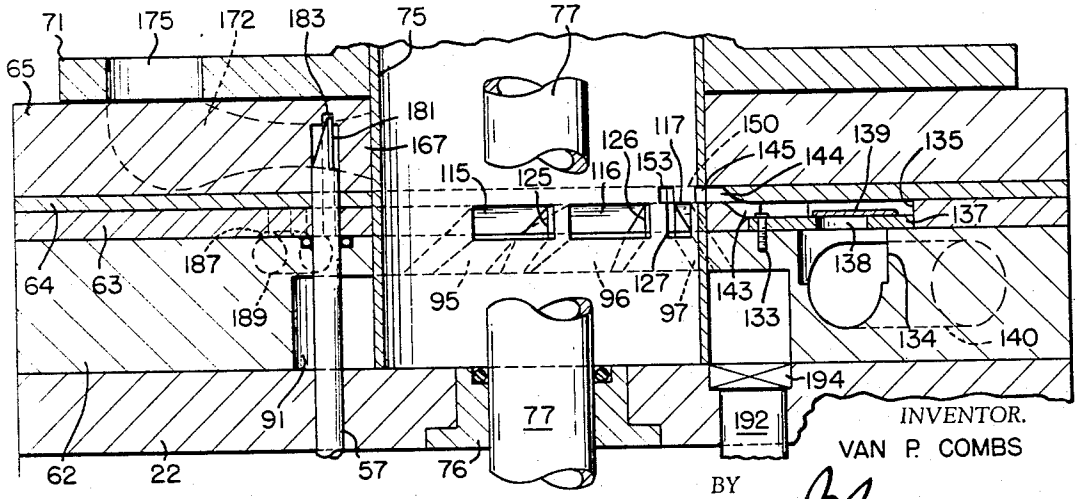


FIG. 10

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United States Patent Office 3,377,997 Patented Apr. 16, 1968

3,377,997

TWO-STROKE CYCLE ENGINE

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Filed Apr. 21, 1966, Ser. No. 544,277
17 Claims. (Cl. 123—74)

ABSTRACT OF THE DISCLOSURE

Each cylinder block comprises a plurality of metal laminates having registering openings defining a bore in which a piston reciprocates. Fuel is fed to a plenum, which is connected by inlet ducts with the bore adjacent one end thereof. Exhaust ducts open on the bore adjacent its opposite end; and scavenging ducts lead from the bore between the inlet and exhaust ducts, and opposite the latter. The ducts extend through several of the laminates; and the inlet ducts are inclined to the bore axis to direct fuel into the bore and away from the exhaust ducts, and toward the scavenging ducts. The piston in its movement controls the opening of the several ducts.

This invention relates to a two-stroke cycle engine, and particularly to a two-cyclinder, internal combustion piston engine suitable for driving air compressors, generators, pumps, etc.

The typical or customary method of constructing engine cyclinder walls is by molding or casting the entire cylinder wall as one piece, whether the engine be air cooled or liquid cooled. Moreover, it has been the practice heretofore to manufacture the cylinder heads or walls for such engines from a casting provided with inlet and outlet ports for the fuel and exhaust gases, respectively. The shapes of such ports are thus restricted to relatively simple forms; and the ports are limited in number to prevent undue weakening of the cylinder wall, which might inturn lead to warping of the wall.

Heretofore, two-stroke cycle engines have had specifically the disadvantages of low volumetirc efficiency, a cylinder height exceptionally large in relation to the strokes of the pistons, a tendency to overheat the pistons, imperfect mixing of the fuel-air mixture, loss of fuel-air mixture out of the engine exhaust ports, warping of the cylinder wall, and poor scavenging of exhaust gases from the cylinder.

One object of this invention is to provide an improved engine construction of laminated form.

Another object of this invention is to provide an improved two-stroke cycle engine which obviates the disadvantages inherent in prior engines of this type.

Another object of this invention is to provide a two-stroke cycle engine which has an external configuration different from prior engines of this type.

Another object of this invention is to provide a two-stroke cycle engine having improved means for compressing and then injecting a fuel-air mixture into each combustion chamber of the engine.

An additional object of this invention is to provide an improved two-cycle engine in which maximum porting characteristics can be achieved.

A further object of this invention is to provide improved means for cooling the pistons in an engine of the type described during the power strokes of the pistons.

It is an object also to provide an engine of the type described which has an improved power/weight ratio as compared to prior, like engines.

Still another object of the invention is to provide a two-cycle engine with which some of the advantages of

supercharging can be obtained without actually providing a supercharger.

In addition it is an object to provide an improved internal combustion engine, which as compared to prior, like engines will: weigh less per horsepower; have less vibration; occupy less space; have fewer total parts; be more economical to operate per horsepower hour; be easier to dismantle; have no piston slap or side thrust of piston against cylinder wall; and be more easily adjusted to accept various types of fuel.

A still further object of the invention is to provide an engine to the type described having multipiece cylinder heads, which may be ported by machining the individual pieces of each head prior to their assembly, and which minumizes the likelihood of cylinder wall warpage during use.

Other objects of the invention will be apparent hereinafter from the specification and from the recital of the appended claims, particularly when read in conjunction with the accompanying drawings.

In the drawings:

FIG. 1 is a plan view of an engine made in accordance with one embodiment of this invention;

FIG. 2 is a fragmentary elevational view of this engine, parts thereof being cut away and shown in section;

FIG. 3 is an enlarged, fragmentary part side elevational, part sectional view of the engine, the sectional view being taken along the line 3—3 in FIG. 1 looking in the direction of the arrows, and showing how the engine may be used to drive a crank;

FIG. 4 is a fragmentary sectional view taken at right angles to FIG. 3 and illustrating further details of the crank mechanism,

FIG. 5 is a fragmentary sectional view taken along the line 5—5 in FIG. 4, and on a scale slightly larger than that of FIG. 4;

FIGS. 6, 7, 8 and 9 are slightly enlarged sectional views taken along the lines 6–6, 7–7, 8–8 and 9–9, respectively, in FIG. 2 looking in the direction of the arrows; and

FIG. 10 is an enlarged, fragmentary sectional view taken along the line 10—10 in FIG. 1 looking in the direction of the arrows.

The invention is illustrated in connection with an alternately firing free piston engine, that is, a two-cylinder engine in which one cylinder is displaced in an axial plane exactly 180° from the other cylinder. A piston reciprocates in each cylinder, and the pistons are rigidly connected to one another. The combustion principle is the two-stroke cycle. Therefore, within one cylinder the piston is moving away from combustion position while the piston in the other cylinder is compressing or moving toward a subsequent combustion position. Therefore, energy of combustion is added to the engine at each half cycle.

In the engine illustrated, each cylinder wall is laminated and comprises a plurality of stacked, rectangular plates having registering openings that define a bore closed at its outer end by a conventional cooling jacket. The plates of each cylinder having registering openings and recesses which define fuel-air inlet ports, exhaust ports, and fresh air inlet ports, all of which communicate with the associated bore at angularly spaced points thereabout. A conventional sparkplug, or the like, is mounted in the outer end of each head to ignite the fuel-air mixture therein, when the latter has been compressed into the outer end of the head upon the compression stroke of the associated piston. The laminated construction enables the ports to be provided readily at the desired locations and inclined at the desired angles to the cylinder wall, prevents warpage, etc., as will appear hereinafter.

In operation, when ignition causes one of the pistons to be driven on its expansion stroke from its outermost position inwardly, at such time the opposite piston will be driven on its compression stroke, or from the inner end toward the outer end of its cylinder. A plenum chamber communicates with each cylinder. On the inward stroke of each piston, the associated cylinder is first sealed, so that an air-fuel mixture therein is forced by the piston into the associated plenum chamber. As the piston moves on inwardly, it uncovers tthe associated exhaust ports, which are now open, and the burned gases are thus exhausted. This outward rush of burned gases creates a slight vacuum in the outer end of the cylinder. As the piston advances inwardly, it also uncovers fresh-air inlet ports, which allow flow of air into the outer end of the cylinder. These ports are in the cylinder wall opposite the exhaust ports, and direct incoming air onto the outer end of the piston to cool the latter, and simultaneously to purge burned exhaust gases from the cylinder. When this is done, a cam operated valve closes the exhaust ports, and a check valve closes the fresh air inlet ports.

As the piston continues to advance inwardly, it next uncovers the fuel-air inlet ports, and the compressed fuel-air mixture flows from the plenum chamber into the cylinder between the piston and the associated sparkplug.

After one piston has reached the limit of its expansion stroke, it commences to return driven partly by the other piston which is now on its own expansion stroke, toward the outer end of the cylinder, during which movement it compresses the blended fresh air and fuel-air mixture previously admitted to the outer end of the cylinder. During this return movement, the piston first covers and then uncovers the ports opening on the cylinder bore. The plenum chamber is connected by a check valve to a carburetor, so that after the piston uncovers the fuel-air inlet ports on its advance toward the outer end of the cylinder, the vacuum created in the inner end of the cylinder behind the piston causes a fresh fuel-air mixture to be drawn into the inner end of the cylinder subsequently to be compressed into the plenum chamber, when the piston is again driven inwardly as above described.

Referring now to the drawings by numerals of reference, and first to FIGS. 1 to 5, the two-cycle engine **20** shown comprises a hollow crankcase or housing **21** which is rectangular in cross section and opposite ends of which are closed by spaced, parallel, rectangular plates **22** and **23** (FIGS. 2 and 3). Formed in opposite sides of the housing **21** are confronting way grooves **25** and **26** (FIG. 3). Guided in ways **25** and **26** for reciprocation vertically in housing **21** are shoes **27** supporting the crosshead **28** of a conventional Scotch yoke. The crosshead **28** has a slot **29** extending transversely between its sides. Mounted to reciprocate in the slot **29** is shoe **34**. Mounted to rotate in a bushing in shoe **34** is a crank pin **37**, which has a projection **38** (FIG 4) extending therefrom that engages in a hole in the crankplate or fly wheel **41**. This hole is eccentric of the axis of rotation of the crank plate; and the crank plate is keyed to the inner end of a shaft **42**, which is journaled by bushings **43** and **44** in spaced trusses **45** and **46**, which are secured in housing **21** at one side of crosshead **28**. The axis of pin **37** is radially spaced from and parallel to the axis of rotation of shaft **42**, so that as the crosshead **28** reciprocates, the reciprocating shoe **34** causes the crank pin **37** to rotate crankplate **41** and shaft **42**.

Keyed to shaft **42** between the trusses **45** and **46** is a further flywheel **51** (FIGS. 4 and 5), the inner face of which is provided with a cam groove **53**. Mounted in cam groove **53** are two cam roller followers **55**, each of which is rotatably mounted on the inner end of one of two, oppositely disposed valve stems **57**. The valve stems **57** extend slidably through openings in the base plates **22** and **23**, respectively, and into a pair of laminated cylinder heads **60** and **61** (FIG. 2). These heads are secured to

the outer faces of plates **22** and **23**, respectively, and are substantially identical in construction.

Each head **60**, **61** comprises four axially bored, rectangular plates **62**, **63**, **64** and **65**, which are secured in registry with one another and the adjacent plate **22** or **23** by a plurality of bolts **67**, only one of which is illustrated in FIG. 3. Secured also by the bolts **67** over the outer face of each plate **65** coaxially of its bore is a conventional, radial-fin cooling jacket **70**, which has at its inner end a flange **71** into which the associated bolts **67** thread. Secured by bolts **72** (FIG. 1) over the outer ends of each jacket **70** is a cap **73**, which carries a spark plug **74**.

Secured in the registering bores in each set of plates **62**, **63**, **64** and **65**, coaxially thereof and of the bore of the adjacent jacket **70**, is a cylinder liner **75** (FIG. 2). Secured to opposite ends of the crosshead **28** (FIG. 3), and projecting slidably through bearings **76** (FIG. 2) in the plates **22** and **23**, are two hollow piston rods **77** and **78**, each of which has a conventional piston **79**, **80**, respectively, secured to it for reciprocation in one of the sleeves **75**.

Referring now to FIGS. 6 to 10, each plate **62** has in its underside a counterbore or chamber **91** (FIGS. 2 and 10), which surrounds the associated liner **75**, and which is closed at its lower end by the upper face of the adjacent plate **22** or **23**. Each chamber **91** communicates with the bore of the associated liner **75** through a plurality of ducts **95**, **96**, **97**, **98**, **99** and **100**, which are formed in each plate **62** to open at their lower ends on the recess **91**, and at their upper ends onto the lower ends of registering ducts or recesses **115**, **116**, **117**, **118**, **119** and **120**, respectively, which are formed in each plate **63** at angularly spaced points thereabout, and which are inclined downwardly from the upper to the lower face of each plate **63** as shown in FIGS. 7 and 10. Upper portions of the ducts **95**, **96**, **97**, **98**, **99** and **100** in each plate **62**, and lower portions of the ducts **115**, **116**, **117**, **118**, **119**, **120**, in each plate **63**, register with ports **125**, **126**, **127**, **128**, **129**, and **130** (FIG. 7), respectively, which are formed in each cylinder liner **75**.

Secured by screws **133** (FIG. 7) over an opening **134** (FIGS. 6 and 10) formed in the upper face of each plate **62** radially outwardly of its recess **91**, and seated in the lower end of a further opening **135** (FIGS 7 and 10) formed through each plate **63** to register with the adjacent opening **134**, is a disc-shaped valve block **137**. In its center each block **137** has an opening **138** that is normally closed by a reed **139**, which is riveted at one end to the upper face of the associated block **137** so that its free end overlies the opening **138**. A duct **140** (FIGS. 6 and 10) extends from one side of each plate **62** to the lower end of each opening **134**. Each plate **63** has in its upper face a first, inclined recess **143** (FIGS. 7 and 10), which communicates at its lower end with the adjacent opening **135** above its valve **139**, and at its upper end with the lower end of a registering, inclined recess **144**, which is formed in each plate **64** adjacent its central bore. At its upper end each recess **144** opens on the central bore in the associated plate **64**, and registers with a port **145**, which is formed in each cylinder liner **75** between, and axially outwardly from, its ports **127** and **128**. Two further, spaced, inclined recesses **147** and **148** (FIG. 7) are formed in the upper face of each plate **63** adjacent opposite sides, respectively, of its recess **143**, and communicate at their lower ends with the upper end of the adjacent opening **135** above its valve **139**, and at their upper ends register with the rear ends of a pair of spaced, parallel slots **149** and **150** (FIGS. 8 and 10), respectively, which are formed in each plate **64** to open on its central bore. At their lower ends these slots are inclined downwardly to register with the recesses **147** and **148** in the associated plate **63**, and at their upper ends they register with ports **152** and **153**, respectively, which are formed in each cylinder liner **75** at points angularly spaced on opposite sides, respectively, of its port **145**.

Opposite and slightly above its ports 145, 152 and 153, each cylinder liner 75 has four ports 155, 156, 157 and 158 (FIG. 9), which register with the inner ends of four, generally rectangular ducts 165, 166, 167 and 168, respectively, which are formed in each plate 65 to open on its central bore. The ducts 165 and 166 of each plate 65 converge toward one another and communicate at their outer ends with a further duct 171, which is formed in each plate 65, and which opens at its outer or upper end on the upper face of the plate. The ducts 167 and 168 in each plate 65 also converge at their inner ends toward one another, and communicate with a further duct 172, which is formed in each plate 65, and which opens at its upper end on the upper face of each plate adjacent duct 171.

The upper ends of the ducts 171 and 172 register with one or more exhaust ports 175 (FIGS. 1, 2 and 10) formed in the flange 71 of the associated cooling jacket 70. As shown more clearly in FIGS. 2 and 10, the ducts 171 and 172 in each plate 65 are throttled adjacent their inner ends, and are adapted to be closed by a valve 181. Each valve 181 is of generally rectangular shape, and is secured to the upper end of a valve stem 57 to reciprocate in a slot 182 (FIG. 8) formed in the associated plate 64, and a registering recess 183 (FIGS. 9 and 10) formed in the associated plate 65. A valve 181 is shown in closed position in FIG. 10 and in the upper part of FIG. 2 When open, as illustrated by the lower valve 181 in FIG. 2, each valve 181 places the exhaust ducts 171 and 172 in each plate 65 in communication with the registering ducts 165, 166, 167 and 168, and hence with the bore of the associated liner 75.

Each plate 63 (FIG. 7) is provided with an enlarged slot 185 beneath slot 182 in the adjacent plate 64. Opposite ends of each slot 185 communicate with recesses 186 and 187 (FIG. 7) that are formed in the underside of each plate 63 adjacent each of two sides thereof. The recesses 186 and 187 in each plate 63 communicate with two further recesses 188 and 189 (FIG. 6), respectively, which are formed on the upper face of the associated plate 62, and the outer ends of which open upon, respectively, two different sides of the plate.

In operation, a fuel-air mixture is fed from a conventional carburetor (not illustrated) to a conduit 191 (FIGS. 1, 2 and 4), which extends through one side of housing 21. At its inner end conduit 191 is connected to a manifold 192 (FIGS. 4 and 10), opposite ends of which are mounted in the plates 22 and 23 to communicate with the chambers 91 (FIG. 2). Mounted in each of the plates 22 and 23 over opposite ends, respectively, of the manifold 192 is a conventional reed valve 194 (illustrated schematically in FIGS. 4 and 10), which is generally similar to the above-described valves 139. Valves 194 permit unidirectional flow of a fuel-air mixture from the carburetor into the chambers 91.

In FIG. 2, the piston 79 in head 60 has just moved to uppermost position and the fuel-air mixture has been compressed between the piston and the upper end of the head. A spark across the gap of the adjacent plug 74 will ignite the compressed mixture so that the piston 79 will then be driven downwardly toward its lowermost or broken line position. During the initial downward movement of piston 79, the associated valve 181 (upper valve in FIG. 2) is closed, as are the normally-closed reed valves 139 (FIG. 7) and 194 (FIG. 10) in head 60. As a result, a fuel-air mixture, which, as will be described below, had been previously introduced into the bore of the liner 75 beneath the piston 79, is now compressed or forced through the liner ports 125 to 130, and the registering ducts 115 to 120, and 95 to 100, into the associated chamber 91.

But, just after the lower surface of the downwardly moving piston 79 passes approximately the midpoint of the associated liner exhaust ports 155, 156, 157 and 158, the associated valve 181 commences to open, and is completely open at approximately the time that the upper surface of the piston 79 has reached approximately the midpoint of the last-named ports. At this moment the pressure of the burned gases in the liner 75 above the upper surface of the piston 79 is greater than atmospheric pressure, so that these gases are exhausted out of head 60 through the liner exhaust ports 155 to 158, the ducts 165 to 68, the ducts 171 and 172, and the port or ports 175 formed in the adjacent flange 71. This outward rush of the exhaust gases causes air to be drawn into the slot 185 to cool the valve stem in the head 60, and also creates a vacuum in the bore of its liner 75 above the upper surface of the piston 79.

As the upper surface of the piston 79 passes below the upper face of the plate 64, it commences to uncover the associated liner ports 145, 152 and 153, which are in communication with the opening 135 above the associated reed valve 139. Since the pressure above this valve 139 is below atmospheric pressure, the valve opens and permits fresh, cool air from the associated inlet duct 140 to enter head 60 through the opening 138 in its valve block 137, the ducts defined by the cooperating recesses 143, 147, 148 in associated plate 63 and 144, 149, 150 in adjacent plate 64, respectively, to the now-opened ports 145, 152 and 153 in its liner 75. This incoming fresh air is directed onto the upper surface of the piston 79 to cool the latter, and to assist in purging the exhaust gases from the cylinder.

As soon as the upper surface of the piston 79 passes beneath the lower surface of the associated plate 64, it commences to open the adjacent cylinder liner ports 125 to 130, which communicate through the inclined ducts 115 to 120 in the adjacent plate 63, and the ducts 95 to 100 in the adjacent plate 62, with the chamber 91 in head 60 which contains the compressed fuel-air mixture. As a result, the compressed fuel-air mixture flows upwardly from this chamber 91 into the bore in the associated liner 75 above the upper surface of the piston 79, where is blends with the fresh air previously admitted through the ports 145, 152 and 153. This immediately increases the pressure above the piston 79 to a valve above atmospheric pressure, so that the associated reed or check valve 139 closes. Although at this moment the associated valve 181 has commenced to close, it will be noted that the compressed fuel-air mixture from this chamber 91 is directed through the associated liner ports 125, 126, 129 and 130 toward the side of the liner diametrally opposite to that containing the exhaust ports 155 to 158, so that this valve 181 can close completely before any of the incoming fuel-air mixture can leak out to the atmosphere through the exhaust ports. By the time the piston 79 reach its lowermost position, as illustrated by the broken lines in FIG. 1 it will have completely uncovered the ports 125 to 130, and its associated valve 181 will have reached its fully closed position.

As the piston 79 moves downwardly, the piston 80 is forced downwardly because the piston rods 77, 78 and the Scotch yoke crosshead 28 connect the two pistons rigidly together.

After reaching its lowermost position, piston 79 commences to move upwardly in the cylinder liner 74, both as the result of the rotational inertia imparted to the crank shaft 42 by the fly wheels 41 and 46, and also as the result of the force then being applied to the other piston 80 as the result of the ignition that is then taking place in head 61. During this upward movement the associated valves 139 and 181 are closed, so that the fuel-air mixture above the piston 79 is compressed. Also during this upward movement, and after the piston 79 has passed above the associated liner ports 125 to 130, a vacuum is created in the bore of the associated liner 75 beneath the piston 79, so that the associated reed or check valve 194 opens to admit fuel-air mixture from the manifold 192 to the chamber 91 in head 60, and through the adjacent ducts 95–100 to the bore of this liner. After the piston 79

passes above the ports **145**, **152** and **153** in the surrounding liner **75**, the vacuum beneath the piston **79** causes the associated valve **139** to open and admit fresh air into the bore of this liner along with the fuel-air mixture. It is this blend of fuel and air that is subsequently compressed into chamber **91**, as above described, when piston **79** is thereafter once again driven downwardly.

After the piston **79** reaches its uppermost position, the compressed fuel-air mixture above its upper surface is ignited by the adjacent spark plug **74** as above described, and the piston **79** once again commences its downward stroke.

During the described operations of piston **79**, similar operations are effected by piston **80**. Thus, as piston **80** moves downwardly from the full line position shown in FIG. 2 to the dotted line position shown therein, its associated valves **181**, **139** and **194** in head **61** are at first closed, so that a previously admitted fuel-air mixture is compressed between the piston **80** and its associated plug **74** at the same time that a new fuel-air mixture is being drawn into the head behind or above piston **80** as illustrated in FIG. 2. This new fuel-air mixture will subsequently be compressed into the plenum **91** in head **62** during the initial return of piston **80** from its broken to its solid line position in FIG. 2.

From the foregoing it will be apparent that applicant has devised a relatively simple and inexpensive two-cycle engine having cylinder heads, that are manufactured from a plurality of flat plates, rather than from a single casting, whereby the fuel and exhaust ports, or ducts, in each head can be made to direct incoming fuel and/or air in predetermined directions within the bore of the combustion cylinder. This aids in blending the fuel-air mixture, and helps purge exhaust gases from the cylinder. Moreover, applicant's novel engine permits each of its pistons to compress, and then to inject, a fuel-air mixture into the associated combustion cylinder during the firing or power stroke of the piston. This gives the injected fuel-air mixture more time for vaporization before it is fired. Also, since the piston itself is utilized to draw a fuel-air mixture into the lower end of the cylinder during the compression stroke of the piston, conventional fuel pump requirements are minimized, if not eliminated. Moreover, the novel heads permit fresh air to be drawn into the cylinder to cool the piston after ignition, thereby to minimize preignition, hence undesirable "knocking." Furthermore, because each head is made in sections or laminates, undesirable warping of the cylinder can be minimized or eliminated, and the height of the inlet and outlet ports can be reduced by increasing the widths (peripheral dimensions) thereof around the cylinder wall. This permits corresponding reduction in the height and hence weight of the cylinder and its piston. The structure, however, provides sufficient structural strength for attachment of the outer portion of the split cylinder, and provides sufficient space for the plenum chamber **91** for air-fuel mixtures can readily be provided at one end of the cylinder. Horeover, it permits use of slide valves for exhaust valves.

With the supercharging effect achieved by each piston, when operating as a power piston, pumping (compressing) air/gas mixture into the plenum, the volume of air/gas compressed on the compression stroke will be upwards of 100%.

My engine will weigh less per horsepower, have less vibration, occupy less space, have fewer total parts, be more economical to operate per horsepower/hour, be easier to dismantle, and be more easily adjusted to accept various types of fuel than conventional two-cycle engines. It has no piston slap or thrust of a piston against the cylinder wall. It eliminates wastage of fuel since no fuel/air mixture escapes out of the exhaust ports before the exhaust ports are closed. It avoids the nuisance of mixing the proper kind and amount of lubricating oil with the fuel for lubrication purposes, which is a necessity with conventional two-cycle engines. It largely obviates maintenance problems due to carbon deposits or accumulations bridging the sparking electrodes, which may cause misfire or failure to operate. It renders it unnecessary to attach or build into an engine an auxiliary pump or blower to provide pressures for proper scavenging; it uses the reduction in cylinder pressure created by the exhaust gases reeling out of a cylinder after the exhaust port opens, to allow atmospheric pressure to introduce a precise amount of air (without fuel) into the cylinder above the piston to aid in scavenging the cylinder, to cool the exhaust port areas, and to provide an air lock near the ports to block escape of the air/fuel mixture subsequently admitted through the regular air/fuel intake ports under greater than atmospheric pressure.

Although the illustrated embodiment of this engine is intended to be powered by gasoline and conventional spark ignition, it is to be understood that the novel engine may be powered by other fuels, if desired. Also, instead of operating a crank shaft the piston rods may be utilized to drive a pump, a compressor, a generator, or like mechanisms.

While the invention has been described in connection with a specific embodiment thereof, it will be understood that it is capable of further modification, and this application is intended to cover any variations, uses, or adaptations of the invention following, in general, the principles of the invention and including such departures from the present disclosure as come within known or customary practice in the art to which the invention pertains and as may be applied to the essential features hereinbefore set forth, and as fall within the scope of the invention or the limits of the appended claims.

Having thus described my invention, what I claim is:

1. An internal combustion engine
   (a) a cylinder block,
   (b) a piston reciprocable in a bore in said block intermediate the ends thereof,
   (c) said cylinder block comprising a plurality of laminates having therethrough registering openings which define said bore,
   (d) a second cylinder block disposed in tandem with the first-named block,
   (e) a second piston reciprocable in a bore in said second block coaxially of the bore in said first-named block,
   (f) said second cylinder block comprising a plurality of laminates having therethrough registering openings which define the second-named bore,
   (g) means connecting said pistons for movement together in unison,
   (h) means for supplying a mixture of fuel and air to one end of each bore during the movement of its associated piston toward the opposite end of the bore,
   (i) a plenum in each block through which said mixture is drawn on its way to said one end of the associated bore, and into which said mixture is compressed during the movement of the associated piston from said opposite end of each bore toward said one end thereof, and
   (j) each block having at least one duct opening at one end on its associated plenum, and at its opposite end on the bore in its block for conveying the compressed mixture of fuel and air from the associated plenum to the bore in its block between its piston and said opposite end of its bore before the return of the associated piston from said one end to said opposite end of each bore,
   (k) each of said ducts disposed to open on its associated bore between its associated piston and said one end of its bore, when said piston is moved to said opposite end of its bore, thereby first to convey said mixture from said plenum to said one end

of the associated bore, and thereafter to convey said mixture back into said plenum to be compressed therein during movement of said piston back toward said one end of said bore.

2. An internal combustion engine

(a) a cylinder block,

(b) a piston reciprocable in a bore in said block intermediate the ends thereof,

(c) said cylinder block comprising a plurality of laminates having therethrough registering openings which define said bore,

(d) a second cylinder block disposed in tandem with the first-named block,

(e) a second piston reciprocable in a bore in said second block coaxially of the bore in said first-named block,

(f) said second cylinder block comprising a plurality of laminates having therethrough registering openings which define the second-named bore,

(g) means connecting said pistons for movement together in unison,

(h) each of said blocks having therein a chamber and a first duct connecting said chamber with one end of its bore,

(i) means for feeding combustible fuel into said one end of said bore in each block through said chamber and said first duct during the movement of its piston from said one end toward the opposite end of its bore, whereby upon the subsequent movement of its piston toward said one end of its bore the piston compresses said fuel through said first duct into said chamber,

(j) each of said first ducts opening at one end of its chamber and at its opposite end on its associated bore to direct compressed fuel from its chamber into its bore between its piston and said opposite end of its bore after its piston has moved a first distance toward said one end of its bore,

(k) means in each block for igniting the fuel in its bore between its piston and said opposite end of its bore, when its piston has moved to one of its limit positions adjacent said opposite end of its bore, and

(l) exhaust means for exhausting burned fuel from the bore in each block between its piston and said opposite end of its bore after its piston has moved a second distance toward said one end of its bore, and before it has travelled said first distance.

3. An engine as defined in claim 2, including means for feeding air from the exterior of each block into its bore between its piston and said opposite end of its bore, when its piston has moved toward said one end of its bore a third distance, which is greater than said second distance and less than said first distance.

4. An engine as defined in claim 3, wherein

(a) each block has therein a second duct which opens at one end on the exterior of the block, and at its opposite end on the bore in said block between said opposite end of its first duct and said opposite end of its bore, and

(b) said exhaust means comprises a first valve movably mounted in each block to open its second duct after its piston has moved toward said one end of its bore said second distance, and to close its second duct after its piston has moved said first distance.

5. An engine as defined in claim 4, wherein

(a) each block has therein a third duct which opens at one end on the exterior of the block, and at its opposite end on the bore in said block between said opposite ends of its first and second ducts, and

(b) said air feeding means comprises a second valve movably mounted in each block to open its third duct after its piston has moved said third distance, and to close its third duct after its piston has moved said first distance.

6. An engine as defined in claim 5, wherein in each block

(a) said opposite ends of its second and third ducts are disposed in approximately diametrally opposite sides, respectively, of its bore, and

(b) its first duct being inclined to the axis of its bore to direct said compressed fuel toward said opposite end of its third duct and away from said opposite end of its second duct.

7. An engine as defined in claim 6, wherein

(a) each block has therein a fourth duct opening at one end on its chamber and at its opposite end on its bore approximately diametrally opposite to, and in registry with, said opposite end of its first duct, and

(b) in each block said fourth duct is angled to direct at least a portion of said compressed fuel toward said opposite end of its third duct and away from said opposite end of its second duct.

8. An engine as defined in claim 6, wherein in each block said second valve comprises a pressure-operated check valve positioned in its third duct and operative to permit the unidirectional flow of air into its bore.

9. An engine as defined in claim 6, including

(a) a pair of piston rods each of which is secured at one end thereof to one of said pistons and extends at its opposite end slidably through an opening in the associated block at said one end of its bore,

(b) a rotatable shaft mounted adjacent said blocks,

(c) means connecting said rods to said shaft for rotating the latter in response to the reciprocation of said pistons, and

(d) cam means connecting said first valves to said shaft and operative to move said first valves to open and close said second ducts.

10. An internal combustion engine comprises

(a) a cylinder block,

(b) a piston reciprocable in a bore in said block intermediate the ends thereof,

(c) said cylinder block comprising a plurality of laminates having therethrough registering openings which define said bore,

(d) a second cylinder block disposed in tandem with the first-named block,

(e) a second piston reciprocable in a bore in said second block coaxially of the bore in said first-named block,

(f) said second cylinder block comprising a plurality of laminates having therethrough registering openings which define the second-named bore,

(g) means connecting said pistons for movement together in unison,

(h) each of said blocks having therein a chamber which communicates with one end of its bore,

(i) means for feeding combustible fuel into said one end of said bore in each block during the movement of its piston from said one end toward the opposite end of its bore, whereby upon the subsequent movement of its piston toward said one end of its bore the piston compresses said fuel into the chamber which communicates with its bore,

(j) each block having a first duct opening at one end on its chamber and at its opposite end on its bore to direct compressed fuel from its chamber into its bore between its piston and said opposite end of its bore after its piston has moved a first distance toward said one end of its bore,

(k) means in each block for igniting the fuel in its bore between its piston and said opposite end of its bore, when its piston has moved to one of its limit positions adjacent said opposite end of its bore,

(l) exhaust means for exhausting burned fuel from the bore in each block between its piston and said opposite end of its bore after its piston has moved a second distance toward said one end of its bore, and before it has travelled said first distance,

(m) means for feeding air from the exterior of each block into its bore between its piston and said opposite end of its bore, when its piston has moved toward said one end of its bore a third distance,

(n) each block having therein a second duct which opens at one end on the exterior of the block, and at its opposite end on the bore in said block between said opposite end of its first duct and said opposite end of its bore,

(o) said exhaust means comprising a first valve movably mounted in each block to open its second duct after its piston has moved toward said one end of its bore said second distance, and to close its second duct after its piston has moved said first distance,

(p) each block having therein a third duct which opens at one end on the exterior of the block, and at its opposite end on the bore in said block between said opposite ends of its first and second ducts,

(q) said air feeding means comprising a second valve movably mounted in each block to open its third duct after its piston has moved said third distance, and to close its third duct after its piston has moved said first distance,

(r) a pair of piston rods each of which is secured at one end thereof to one of said pistons and extending at its opposite end slidably through an opening in the associated block at said one end of its bore,

(s) a rotatable shaft mounted adjacent said blocks,

(t) means connnecting said rods to said shaft for rotating the latter in response to the reciprocation of said pistons,

(u) cam means connecting said first valves to said shaft and operative to move said first valves to open and close said second ducts,

(v) said first valve in each of said blocks having a stem which is reciprocable in the block parallel to its piston axis, and transverse to its second duct,

(w) a fifth duct opening at one end on the exterior of each block and at its opposite end on the stem in the block to provide air for cooling said stem, and

(x) said second duct in each block having a throttled portion intermediate its ends which communicates with said fifth duct in the block to draw air therethrough, when said first valve in the block is opened to exhaust burned fuel from its bore.

11. An engine as defined in claim **9**, wherein

(a) a sleeve is secured in each of said bores and surrounds its piston coaxially thereof, and has in its annular wall a plurality of axially spaced ports,

(b) a pair of end members are releasably secured over and close opposite ends, respectively, of each sleeve, and one of said end members in each block has therethrough an opening for slidably supporting the associated piston rod intermediate the ends thereof, and

(c) the laminates in each block are removably secured between the associated end members, and

(d) each of said first and third ducts in each block extends through more than one of said laminates in the block and registers at said opposite end thereof with one of said ports in the associated sleeve.

12. An engine as defined in claim **11**, wherein

(a) said one end member in each block has therein a duct which communicates at one end with a supply of combustible fuel, and which opens at its opposite end on the chamber in said block, and

(b) a pressure-operated check valve is mounted in each of the last-named ducts and is operative to permit the unidirectional flow of fuel into the associated chamber from said supply.

13. An internal combustion engine, comprising

(a) a cylinder block,

(b) a piston reciprocable in a bore in said block,

(c) a plenum in said block communicating with said bore,

(d) means for feeding combustible fuel to said plenum, to be compressed in said plenum upon movement of said piston toward one end of said bore,

(e) said block having therein a plurality of inlet ducts each of which opens at one end on said plenum and at its opposite end on said bore to convey compressed fuel from said plenum to said bore between said piston and the opposite end of said bore, when said piston has moved a predetermined distance toward said one end of said bore, and to pump said combustible fuel through said plenum and into said bore between said piston and said one end of said bore when said piston has moved a predetermined distance toward said opposite end of said bore, and to convey said fuel from said plenum to said bore between said piston and the opposite end of said bore to charge said cylinder,

(f) means for igniting the fuel between said piston and said opposite end of said bore when said piston has moved to one of its limit positions adjacent said opposite end of said bore,

(g) said block having therein at least one exhaust duct opening at its inner end on said bore between said inlet ducts and said opposite end of said bore, and at its outer end at the exterior of said block, and

(h) at least certain of said inlet ducts being inclined to the axis of said bore between said plenum and said bore so that the fuel conveyed thereby into said bore is directed away from said inner end of said exhaust duct, and toward the side of said bore substantially diametrally opposite to that on which said inner end of said exhaust duct opens.

14. An internal combustion engine as defined in claim **13**, wherein

(a) said block comprises a plurality of laminates having therethrough registering openings defining said bore, and

(b) at least one of said laminates has therein a recess defining said plenum, and a plurality of ports, each of which opens at one end on said recess, and at its opposite end communicates through registering ports in at least one other of said laminates with said bore to define said inlet ducts.

15. An internal combustion engine as defined in claim **14**, wherein

(a) said block has therein at least one scavenging duct opening at its outer end on the exterior of said block, and at its inner end on said bore between said inner end of said exhaust duct and said one ends of said inlet ducts, and on the side of said bore which is substantially diametrally opposite to that on which said inner end of said exhaust duct opens, and

(b) said inlet ducts open on substantially diametrally opposite sides of said bore and are angles so that the compressed fuel is directed thereby toward said inner end of said scavenging duct.

16. An internal combustion engine as defined in claim **15**, wherein

(a) said scavenging duct extends through at least three of said laminates, and

(b) a check valve is mounted in a recess in one of said laminates to permit the unidirectional flow of air through said scavenging duct to said bore, when said piston moves toward said one end of said bore.

17. An internal combustion engine as defined in claim **15**, including

(a) a reciprocable valve stem extending through registering openings in said laminates,

(b) a valve secured to one end of said stem and extending transversely of said exhaust duct to open and close, respectively, said exhaust duct when said stem is moved from one to the other of its limit positions, and

(c) means for conveying cooling air from the exterior of said block to the openings housing said stem there-

by to cool said stem and valve during operation of the engine.

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