March 13, 1945. E. G. HUBER 2,371,297

INTERNAL-COMBUSTION ENGINE

Filed July 10, 1943 3 Sheets-Sheet 1

Fig. 1

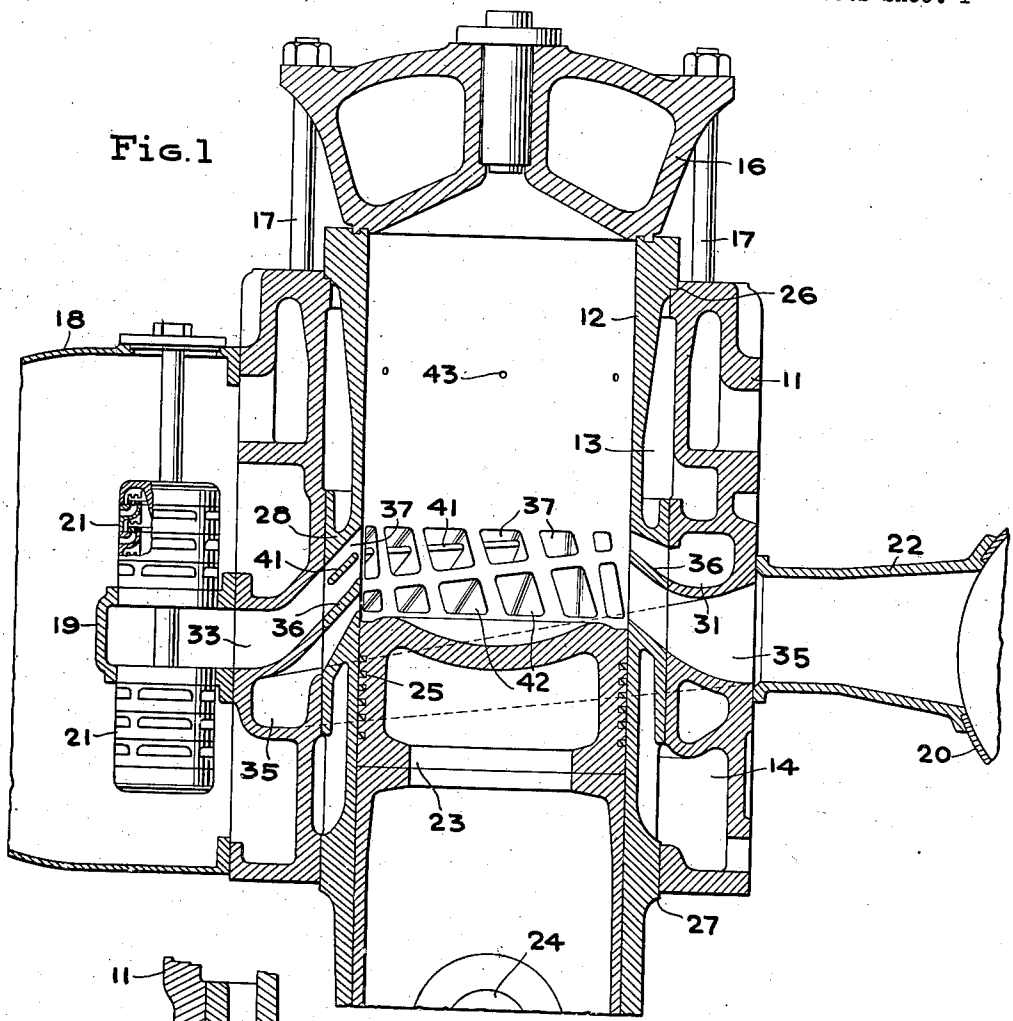


Fig. 3

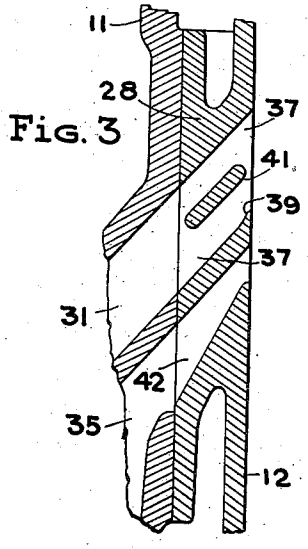
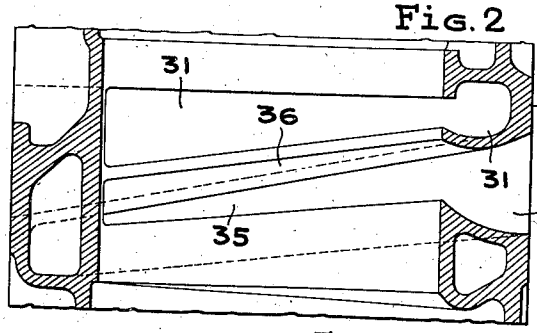


Fig. 2



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Fig. 4

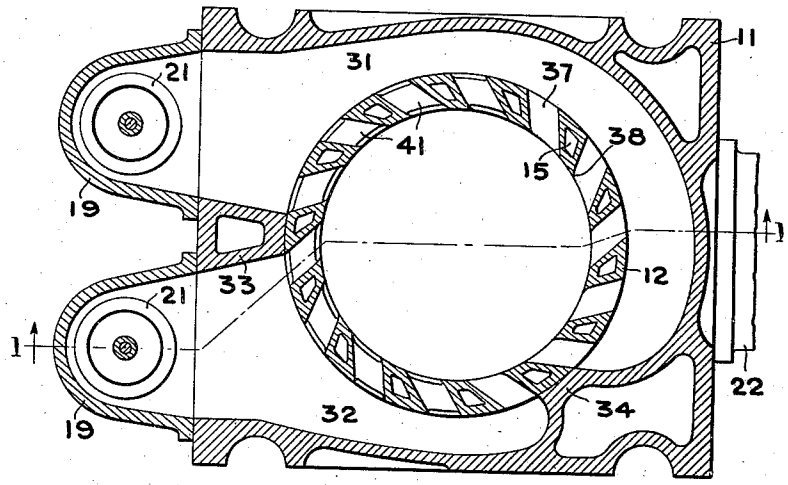
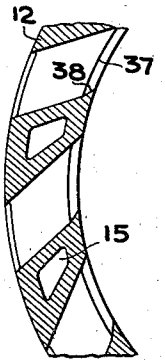


Fig. 6



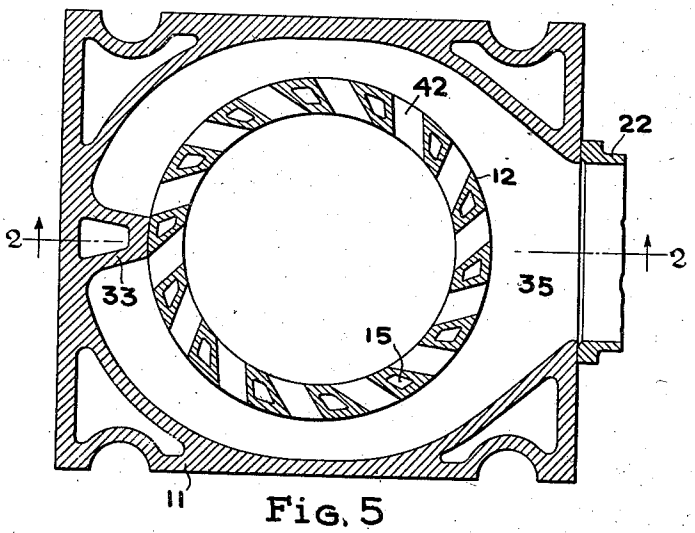
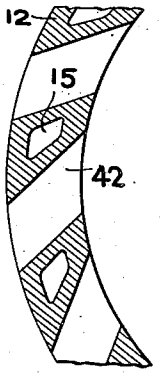


Fig. 5

Fig. 7



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Fig. 8

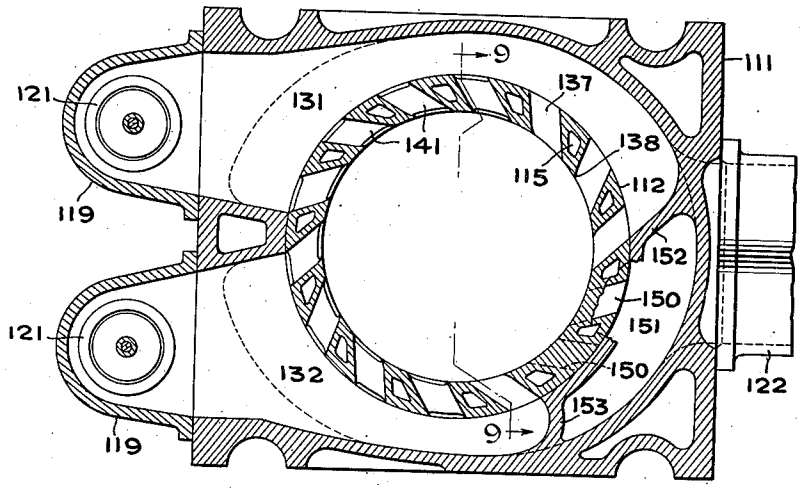


Fig. 9

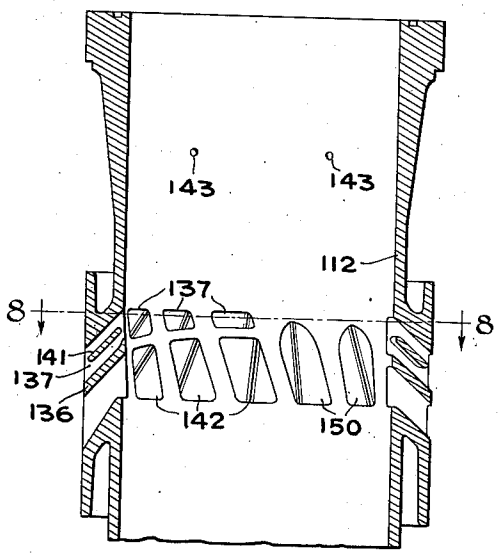
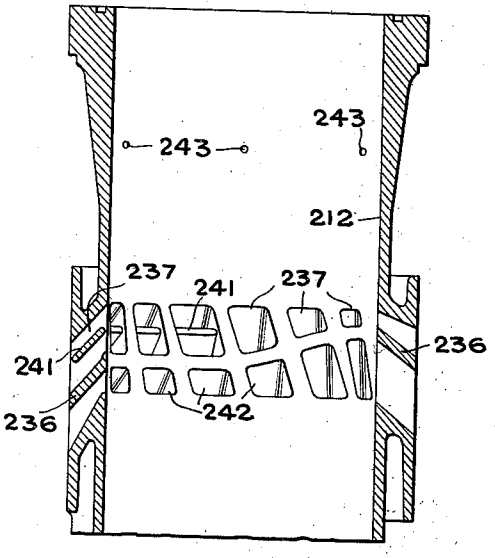


Fig. 10



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Patented Mar. 13, 1945 2,371,297

UNITED STATES PATENT OFFICE

2,371,297

INTERNAL-COMBUSTION ENGINE

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Application July 10, 1943, Serial No. 494,233

17 Claims. (Cl. 123—65)

This invention relates to internal combustion engines and particularly to the arrangement of the exhaust and scavenging ports in a two cycle port-scavenged engine. The invention is particularly suited for use in large engines of the fuel injection type including Diesel engines.

The invention contemplates location of a circular series or belt of scavenging ports above a similar series or belt of exhaust ports. Both series may completely encircle the cylinder, the ports of the two series being separated by an interval so formed or inclined that the encircling passages with which the ports communicate can be tapered and thus favorably proportioned. Alternatively a few of the exhaust ports may extend nearly to the upper limit of the scavenging ports.

The effect in either case is to ensure gradual opening of the exhaust path, the attainment of large exhaust port area while scavenging flow occurs, and thereafter gradual closure of the exhaust ports followed by a brief continuing flow of scavenging air. This gives a moderate supercharging effect.

Gradual opening and closing of the exhaust ports reduces the initial blast effect of the exhaust and suppresses more or less completely the wave action heretofore encountered in the exhaust connections. There is also a beneficial relationship between port area and the tapered form of the branch passages with which the ports communicate directly, in that gradual development of flow velocity in the passages is favored by serial opening of ports.

The arrangement may if desired be used with the scavenging ports skewed, so as to induce rotary upward flow of an envelope of dense scavenging air along the cylinder walls. This arrangement can be used to give better segregation of scavenging air and combustion products, and is included in all the illustrated embodiments of the invention.

The invention also permits better lubrication by permitting a better distribution of oil ports and by reducing if not eliminating the tendency heretofore encountered for the scavenging air to blow part of the oil into the exhaust ports.

Preferred embodiments of the invention will be described by reference to the accompanying drawings, in which:

Fig. 1 is an axial section through a cylinder ported according to the invention, the section being taken on a plane generally transverse to the crank shaft as is indicated by the line 1—1 of Fig. 4;

Fig. 2 is a fragmentary section of the cylinder casting as it would appear with the liner removed. The plane of section is indicated by the line 2—2 of Fig. 5, and the view shows the form and reversely tapering characteristics of the passages which supply scavenging air to the scavenging ports in the liner, and of the passages which receive exhaust gases from the exhaust ports of the liner;

Fig. 3 is an enlarged fragment of the liner as illustrated in Fig. 1, intended to show in greater detail the form of a scavenging port;

Fig. 4 is a section transverse to the cylinder axis and through the scavenging ports;

Fig. 5 is a similar section through the exhaust ports;

Figs. 6 and 7 are enlarged sectional views of the ports shown in Figs. 4 and 5 respectively;

Fig. 8 is a view similar to Fig. 4 but showing a modification in which two exhaust ports in the liner extend nearly to the upper limit of the scavenging ports. The plane of section is indicated by line 8—8 of Fig. 9;

Fig. 9 is a section on the line 9—9 of Fig. 8; and

Fig. 10 is a sectional view similar to a portion of Fig. 1 but showing another modification of the port arrangement in the liner.

Referring first to Fig. 1, the cylinder casting is indicated generally by the numeral 11 and receives the cylinder liner 12, the two being so formed as to preserve jacket spaces 13 and 14 which encircle the liner and communicate with each other through the passages 15 in the webs which lie between the ports described hereinafter (see Figs. 4 to 7).

The cylinder head 16 seats in the upper end of the liner and is held by tension rods 17 which pass through the cylinder casting 11 and connect with the engine frame structure (not shown).

The scavenging air manifold 18 extends along the engine (which would usually be of the multi-cylinder type) and supplies scavenging air from a suitable blower or compressor of known type (not shown) to all the cylinders. There are two inlet bonnets 19 for each cylinder and these communicate with scavenging ports to be described. The bonnets are housed within the manifold and each bonnet has an upper and a lower set of check valves each indicated as a group by the numeral 21. Each check valve unit 21 comprises a plurality of ring-like plate valves each coacting with a corresponding ported seat so that the aggregate port area is large, the valves are light, and their lift is small. The valves thus open rapidly and

with slight resistance to permit flow in large volume from the manifold toward the scavenging ports. They close almost instantly against reverse flow.

The exhaust connection appears at 22 and leads to an exhaust line 20 which may or may not be a manifold. For example, where Buchi turbo charges are used special connections are provided. The invention imposes no limitations in the form of the exhaust connections.

The piston 23 can be of any type but a trunk type piston with wrist pin 24 is shown. The piston has the usual rings 25. It may be cooled by any of the usual means, but this detail is not illustrated.

The mounting of the liner in the cylinder casting follows known practice. At its upper end it engages a shouldered seat 26 and at the lower end of the cylinder casting has a collar 27 which fits the bore of the cylinder casting. In the zone of the scavenging and exhaust ports the liner has an encircling flanged collar 28 which also fits the bore of the cylinder casting. Obviously the liner must closely fit the cylinder casting at the three contact areas mentioned and watertight joints are necessary, but the details by which this result is attained are not involved in the present invention.

Indeed, as so far described, the construction follows principles heretofore standard with applicant's assignee, and the novelty here disclosed and claimed resides chiefly in features of port arrangement about to be described.

Each of the bonnets 19 communicates with a corresponding one of the two scavenging air passages 31, 32. These are similar in that their upper and lower walls are inclined upward and radially inward and in that their cross sectional areas diminish in directions away from their respective bonnets. They differ only in that passage 31 extends in an arc of some 225° while passage 32 occupies the remaining portion of the circumference, except for the bridges 33, 34.

As will appear from an examination of Fig. 4 the inclination of ports 37 (hereinafter described) is more favorable to flow from passage 31 inward through the communicating ports 37, than it is to flow from passage 32 inward through the remaining ports. Hence it is appropriate to make port 31 somewhat longer, so that the overall flow losses will be about equalized and all the ports 37 will deliver scavenging air at nearly equal rates. Since flow occurs at comparatively low pressures, the advantage secured in this way is significant.

Figure 2 gives a clear illustration of passage 31 and indicates its formation as a groove within the cylinder casting 11.

The exhaust connection 22 communicates with a passage 35 which surrounds the liner completely except for the bridge 33 which is diametrically opposite to the exhaust connections. There are thus two branches, each formed as a groove in the casting 11. The form of one branch is clearly shown in Fig. 2, from which the tapering and inclined configuration of the passage will be readily understood.

The lower wall of the passage 35 is inclined upward and inward but at a varying angle. The upper wall is defined by the web 36 which separates passage 35 from the overlying passage 31 or 32 as the case may be.

The liner 12 has a circular series of scavenging ports 37 (see Figs. 1 and 4) which communicate with passage 31 or 32. Their upper margins are in a plane normal to the cylinder axis, but their "length" (a term used in this specification and in the claims to define a measurement taken in the direction of the cylinder axis) varies. The ports are "long" on the scavenging inlet side and "short" on the exhaust side of the cylinder varying progressively between. The ports are not radial but are secant and indeed nearly tangential to the periphery of the cylinder. The ports have lips 38 to induce circumferential flow of the entering air. Further the ports are inclined upward and have lips 39 to divert inflowing air toward the cylinder head so far as reasonably practicable. Perhaps the best description of the angular relationship of the ports is offered by the word "skewed."

The longer of the scavenging ports have intermediate vanes or bridges 41 and all flow-directing surfaces are designed to give to the discharging scavenging air such directions as will induce whirling flow with a pronounced component of motion toward the cylinder head.

The liner 12 has also a circular series of exhaust ports 42 (see Figs. 1 and 5) which communicate with passage 35. Their lower margins are in a plane normal to the cylinder axis but their lengths vary inversely with respect to the lengths of the ports 37, the "long" exhaust ports being in the exhaust side beneath the "short" scavenging ports, while the short exhaust ports are beneath the long scavenging ports. The exhaust ports are also inclined upward and inward. The ports have the same secant arrangement described for the scavenging ports, but have no lips such as 38 and 39 (compare Figs. 6 and 7).

The sides of all ports are desirably inclined to elements of the cylinder wall as shown, to distribute wear on the piston rings.

When the piston moves downward it commences to open all the scavenging ports at the same time, but the exhaust ports start to open serially and somewhat later. The check valve units 21 prevent outflow into the scavenging manifold. The gradual opening of the exhaust gives gradual development of exhaust flow, and by suppressing initial surges, reduces the tendency for pressure waves to develop in the outflowing exhaust gases.

On the return excursion of the piston the serial final closure of the exhaust ports is similarly favorable. The closure of the scavenging ports after a short interval permits some supercharging by scavenging air to occur.

In Fig. 1 three oil ports 43 are visible. There are six such ports at 60° intervals around the cylinder. They are fed from a lubricating pump by conventional pipe connections (not shown) which lead from collar 27 upward through the jacket spaces and through certain of the passages 15. The connections are not themselves novel. The ability to lubricate the cylinder even at the side above the exhaust connection without serious loss of oil is a valuable feature made possible by the port arrangement.

The scavenging air picks up any oil flowing down the cylinder walls to the scavenging ports, and carries it to the cylinder walls. Oil cannot flow along the cylinder walls directly to the exhaust ports, nor is it blown from scavenging ports toward or into the exhaust ports. These wasteful possibilities are present in most prior art engines and have led to asymmetric location of oil ports and to similar undesirable expedients.

Modification Figs. 8 and 9

The modification shown in Figs. 8 and 9 provides two exhaust ports so "long" that they interrupt the circular series of scavenging ports.

In these figures parts corresponding to parts in Figs. 1 to 7 have reference numerals used in Figs. 1 to 7 but increased by 100.

The difference is that there are exhaust ports 150 (two such being shown) which are tapered at their tops as shown and which extend upward, nearly but not quite to the plane of the upper margin of the scavenging ports 137 (see Fig. 9).

To permit this the exhaust passage in cylinder casting 111 which is essentially similar to the passage 35 of Fig. 5 has an upward extension 151 (see Fig. 8) separated from the passages 131 and 132 by the webs 152 and 153. It is considered important that extension 151 is closely adjacent exhaust connection 122 so that here again the "long" ports which open first are among those nearest exhaust connection 122.

The only difference is a slightly earlier start of exhaust flow.

Modification of Fig. 10

In this figure parts similar to parts in Figs. 1 to 7 are given the same numerals increased by 200.

The only difference is a change of contour of the separating bridge 236 between the scavenging and exhaust ports, and Fig. 10 is significant chiefly as indicating that this feature may be varied to change the opening and closing rates of the exhaust ports while still retaining the operating characteristics of the invention.

Operation

This is the same in principle for all three embodiments and can best be traced by reference to Figs. 1 to 7.

When the piston moves downward it first starts to uncover the scavenging ports, but no significant flow through the port occurs, since the check valves 21 close against out flow.

Then the exhaust ports begin serially to open, and ultimately all are wide open. When cylinder pressure falls below scavenging air pressure the flow of scavenging air into the cylinder starts. Relatively cool dense air enters, and because of the port arrangement flows in a rotating layer upward along the cylinder walls. The centrifugal effect causes the dense scavenging air to hug the cylinder walls. This air recurves toward the center at the cylinder head and then flows downwardly in a central core which forces residual exhaust gases downward so that they are deflected outward by the piston into the exhaust ports.

Consequently the cooling effect on the cylinder walls is uniform, the tendency of scavenging air to mix with exhaust gases is minimized, and for reasons above set forth the loss of oil is resisted.

The exhaust gases have little or no rotary motion. They start to flow out of the cylinder and are largely exhausted before the whirling scavenging air flow starts. Hence they are not materially affected by the whirling flow of the scavenging air.

Rotary flow of exhaust gases is not desired and does not occur to any material extent. The secant arrangement of ports in Fig. 5 does not imply that exhaust gases approach the ports with a rotary motion. Consideration of Figs. 4 and 5 will make it clear that the secant direction of the ports 42 is opposite to that which would be needed if any such action were sought.

The secant arrangement of ports 42 is dictated by structural and manufacturing considerations. Greater strength, freedom from heat stresses, and easier manufacture are attained by making the ports 42 conform approximately to ports 41. Except for this they could desirably be radial.

On the upward excursion of the piston the exhaust ports close gradually, final closure occurring serially. The scavenging ports remain open for a brief period.

Gradual opening and closing of the exhaust ports tends to suppress wave action in the exhaust line or manifold and this improves scavenging. It also favors a tendency toward supercharging by the final scavenging air flow.

Another detail of considerable significance which has been alluded to briefly is the fact that the exhaust ports which are the longest and which consequently are the first to open, are located close to the exhaust connection 22. This is true of all embodiments herein illustrated.

As the exhaust ports open successively, the exhaust products enter the exhaust passage, for example passage 35 in Figure 5, at points more and more remote from the connection 22. This and the fact that the passage 35 increases in cross section from the bridge 33 toward the connection 22 assists in producing a relatively smooth discharging flow of the exhaust products.

Thus the concept involves something more than a mere serial opening of the ports or a mere tapering of the upper ends of the ports such as is indicated in Figure 9 with reference to the ports 150.

It is well known that where the exhaust starts with a sudden blast, wave action in the exhaust stream actually causes back flow through the exhaust ports into the cylinder. This action can readily be detected by examination of indicator cards taken from conventional engines. This impairs the exhaust flow and the scavenging action and its suppression results in decidedly improved performance.

The best arrangement of the ports depends to some extent on the speed at which the engine operates, the size of the engine, the nature of the exhaust connections and other factors which will readily suggest themselves.

The arrangements shown in the present application have the advantage that they permit the longest practicable effective stroke. The effective stroke ends when the exhaust ports start to open. The attainment of a long effective stroke with suppression of wave action in the exhaust involves two factors which contribute very decidedly to performance.

The operative characteristics of the embodiments illustrated in Figures 8 and 9 and in Figure 10 are similar to those already described and are believed to be advantageous in particular cases.

In all of the embodiments the scavenging ports are exposed first and consequently closed last. This permits some supercharging.

The skewing of the ports to secure upward rotary flow of the scavenging air is considered to be desirable but is an optional feature which can be dispensed with in some instances.

Three embodiments of the inventive concept have been described in an effort to develop fully the possibilities of the invention, and they have been described in considerable detail in compliance with the provisions of the patent statutes. These described embodiments, however, are intended to be illustrative and not limiting. Other

modifications within the scope of the claims are possible and are contemplated.

What is claimed is:

1. A port scavenged engine having a cylinder with means closing one end thereof and scavenging and exhaust ports spaced from the closed end of the cylinder; and a reciprocating piston arranged to expose said ports at its limit of motion away from said closed end, the scavenging ports and the exhaust ports being arranged in two series each of which substantially completely encircles the cylinder, the scavenging series being nearer the closed end of the cylinder, the ports being of progressively varying length in each series whereby the exhaust ports open and close gradually, and the scavenging ports close after the exhaust ports have closed.

2. The combination defined in claim 1 in which the longest exhaust ports are tapered at the ends first exposed by the piston.

3. The combination with the structure defined in claim 1, of means for delivering lubricant to the cylinder walls between the closed end of the cylinder and the scavenging ports, at points approximately uniformly spaced around the circumference of the cylinder.

4. A port scavenged engine having a cylinder with means closing one end thereof and scavenging and exhaust ports spaced from the closed end of the cylinder; and a reciprocating piston arranged to expose said ports at its limit of motion away from said closed end, the scavenging port and the exhaust ports being arranged in two series each of which substantially completely encircles the cylinder, the scavenging series being nearer the closed end of the cylinder, the interval between ports of the two series being oblique to the axis of the cylinder so that the ports are graduated in length, the longest port in the scavenging series being approximately alined with the shortest of the exhaust series and vice versa, whereby the exhaust ports start to open serially and are closed serially.

5. A port scavenged engine having a cylinder with means closing one end thereof and scavenging and exhaust ports spaced from the closed end of the cylinder; and a reciprocating piston arranged to expose said ports at its limit of motion away from said closed end, the scavenging ports and the exhaust ports being arranged in two series each of which substantially completely encircles the cylinder, the scavenging series being nearer the closed end of the cylinder, the interval between ports of the two series being oblique to the axis of the cylinder so that the ports are graduated in length, the longest port in the scavenging series being approximately alined with the shortest of the exhaust series and vice versa, whereby the exhaust ports start to open serially and are closed serially, the scavenging ports being skewed so as to discharge scavenging air with motion components in directions to induce flow toward the closed end and to induce rotary flow about the axis of the cylinder.

6. The combination defined in claim 5 in which the scavenging ports have discharge directing lips serving to intensify at least one of the directional flows therein defined.

7. The combination defined in claim 5 in which the longer ones of the scavenging ports are subdivided by flow directing vanes.

8. The combination with the structure defined in claim 5 of means for delivering lubricant to the cylinder walls between the closed end of the cylinder and the scavenging ports and at points approximately uniformly spaced around the circumference of the cylinder.

9. A port scavenged engine having a cylinder with means closing one end thereof and scavenging and exhaust ports spaced from the closed end of the cylinder; and a reciprocating piston arranged to expose said ports at its limit of motion away from said closed end, the scavenging ports and the exhaust ports being arranged in two series each of which substantially completely encircles the cylinder, the scavenging series being nearer the closed end of the cylinder, the interval between ports of the two series being oblique to the axis of the cylinder so that the ports are graduated in length, the longest port in the scavenging series being approximately alined with the shortest of the exhaust series and vice versa, whereby the exhaust ports start to open serially and are closed serially, the scavenging ports being skewed so as to discharge scavenging air with motion components in directions to induce flow toward the closed end and to induce rotary flow about the axis of the cylinder and the exhaust ports being skewed in similar directions.

10. A port scavenged engine having a cylinder with means closing one end thereof and scavenging and exhaust ports spaced from the closed end of the cylinder; and a reciprocating piston arranged to expose said ports at its limit of motion away from said closed end, the scavenging ports and the exhaust ports being arranged in two series, each of which substantially completely encircles the cylinder, the scavenging series being nearer the closed end of the cylinder, said scavenging ports being fed by tapering passages each of which leads from one side of the cylinder approximately half way around the cylinder; and said exhaust ports communicating with tapering exhaust passages each of which leads around approximately one-half of the periphery of the cylinder to an exhaust outlet on the other side of the cylinder, the ports of each series being graduated in length in consonance with the taper of the communicating passage, the longest exhaust port being adjacent the shortest scavenging port and vice versa, whereby the initial opening and final closing of exhaust ports is gradual, the cross section of the flow passages is consonant with effective port areas, and wave action, particularly in the exhaust stream, is minimized.

11. A port scavenged engine having a cylinder with means closing one end thereof and scavenging and exhaust ports spaced from the closed end of the cylinder; and a reciprocating piston arranged to expose said ports at its limit of motion away from said closed end, the scavenging ports and the exhaust ports being arranged in two series, each of which substantially completely encircles the cylinder, the scavenging series being nearer the closed end of the cylinder, said scavenging ports being fed by tapering passages each of which leads from one side of the cylinder approximately half way around the cylinder, and said exhaust ports communicating with tapering exhaust passages each of which leads around approximately one half of the periphery of the cylinder to an exhaust outlet on the other side of the cylinder, the ports of each series being graduated in length in consonance with the taper of the communicating passage, the longest exhaust port being adjacent the shortest scavenging port and vice versa, the scavenging ports being skewed so as to discharge scavenging air with motion components in directions to induce

flow toward the closed end and to induce rotary flow about the axis of the cylinder.

12. The combination defined in claim 11 in which the scavenging ports have discharge directing lips serving to intensify at least one of the directional flow characteristics therein defined.

13. The combination defined in claim 11 in which the scavenging ports have discharge directing lips serving to intensify both of the directional flow characteristics therein defined.

14. The combination defined in claim 11 in which the longer ports are subdivided by flow directing vanes.

15. A port scavenged engine having a cylinder with means closing one end thereof and scavenging and exhaust ports spaced from the closed end of the cylinder; a reciprocating piston arranged to expose said ports at its limit of motion away from said closed end, the scavenging ports and the exhaust ports being arranged in two series each of which approximately completely encircles the cylinder, the scavenging series being nearer the closed end of the cylinder, the interval between ports of the two series being inclined to the axis of the cylinder so that the ports are graduated in length, the longest port in the scavenging series being approximately alined with the shortest of the exhaust series and vice versa; an offtake for the exhaust products located adjacent the longest exhaust ports and having branches which extend around the cylinder and communicate with all the ports of the exhaust series, said branches being reduced in cross section progressively in directions away from said offtake; a scavenging air connection communicating with all of said scavenging ports; and means for resisting outflow through the scavenging ports.

16. A port scavenged engine having a cylinder with means closing one end thereof and scavenging and exhaust ports spaced from the closed end of the cylinder; a reciprocating piston arranged to expose said ports at its limit of motion away from said closed end, the scavenging ports and the exhaust ports being arranged in two series each of which approximately completely encircles the cylinder, the scavenging series being nearer the closed end of the cylinder, and the ports of both series being graduated in length, the longest port in the scavenging series being approximately alined with the shortest of the exhaust series, the arrangement being such that the exhaust ports start to open serially and are closed serially; and means providing flow connections to the scavenging ports and from the exhaust ports, the supply connection comprising an inlet located adjacent the longest scavenging ports and having branches each of which extends approximately halfway around the cylinder and is gradually reduced in cross section in a direction away from the supply connection, and an exhaust connection comprising an offtake approximately diametrically opposite the supply connection and having branches which extend around the cylinder and are reduced in cross section in a direction away from the offtake.

17. A port scavenged engine having a cylinder and means closing one end thereof and scavenging and exhaust ports arranged in two adjacent series in a belt which encircles the cylinder and is spaced from the closed end thereof; a reciprocating piston arranged to expose said ports at its limit of motion away from said closed end, the exhaust ports substantially encircling the cylinder and being graduated in length, the longest thereof extending nearly the entire depth of the belt, and the shortest being approximately diametrically opposite the longest, the scavenging ports being nearer the closed end of the cylinder and also graduated in length to occupy substantially the remainder of the belt; an exhaust offtake adjacent and in communication with the longest exhaust port and having branches which encircle the cylinder and communicate with the shorter exhaust ports; a scavenging air inlet having branches which approximately encircle the cylinder and communicate with all the scavenging ports; and means resisting outflow through the scavenging ports.

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