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|-----------|--------|----------------------|-----------|
| 3,745,768 | 7/1973 | Zechnall et al. | 60/276 |
| 3,747,575 | 7/1973 | Eisele et al. | 123/32 EA |
| 3,750,632 | 8/1973 | Zechnall | 123/32 EA |
| 3,759,232 | 9/1973 | Wahl et al. | 123/32 EA |
| 3,782,347 | 1/1974 | Schmidt et al. | 123/119 R |

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- [57]
- ABSTRACT**

- The exhaust gas composition is sensed by a sensor which provides an electrical output signal which is applied to an integral controller which controls the mixing device (fuel injection system or carburetor) which mixes air and fuel to provide the air-fuel mixture for the engine, in proper proportion for minimum noxious exhaust emission. In accordance with the invention, the integral controller integrates at a rate which is controlled by the speed of the engine. A speed-dependent pulse signal is derived, applied to a monostable multivibrator (MMV) which samples the signal applied to the integral controller, so that the integral controller will integrate only when it receives the sample signal, and hold the then obtained integrated signal until the next sampled signal is applied thereto.

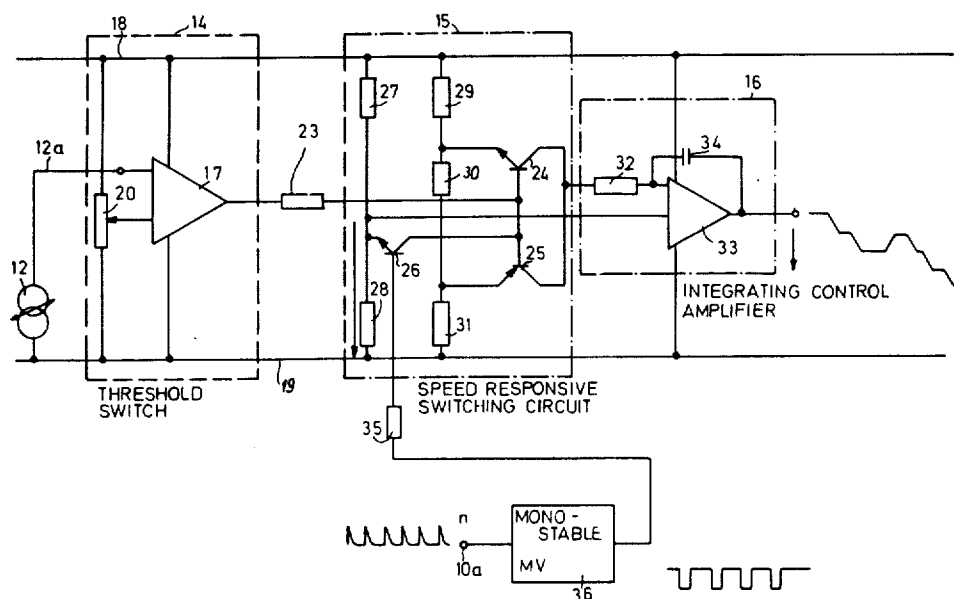
- 14 Claims, 3 Drawing Figures**

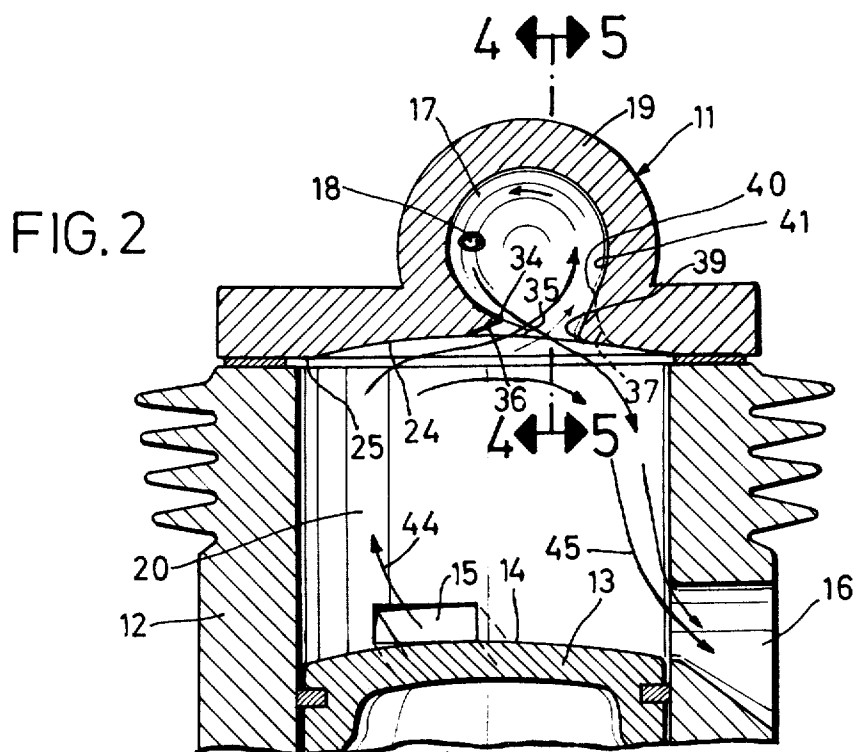
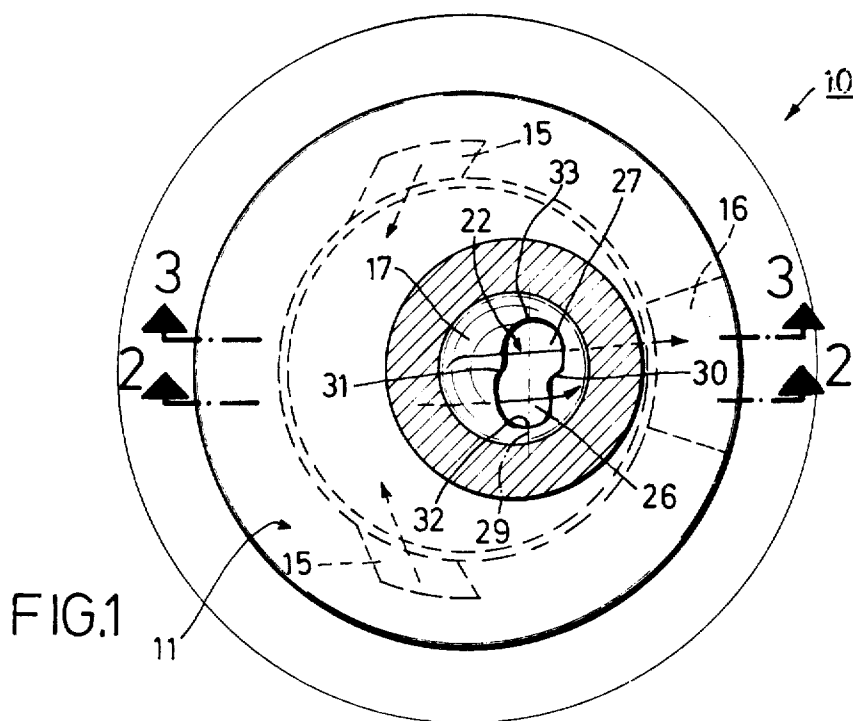
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- [52] **U.S. Cl.**..... 123/32 EA; 123/117 A; 60/276
[51] **Int. Cl.**..... F02b 3/00; F02n 37/00
[58] **Field of Search**..... 123/32 EA, 148 E, 119 R;
60/276

- UNITED STATES PATENTS

- | | | | |
|-----------|---------|-------------------|-----------|
| 3,616,274 | 10/1971 | Eddy | 204/1 T |
| 3,621,826 | 11/1971 | Chrestensen | 123/148 E |
| 3,738,341 | 6/1973 | Loos | 123/119 R |





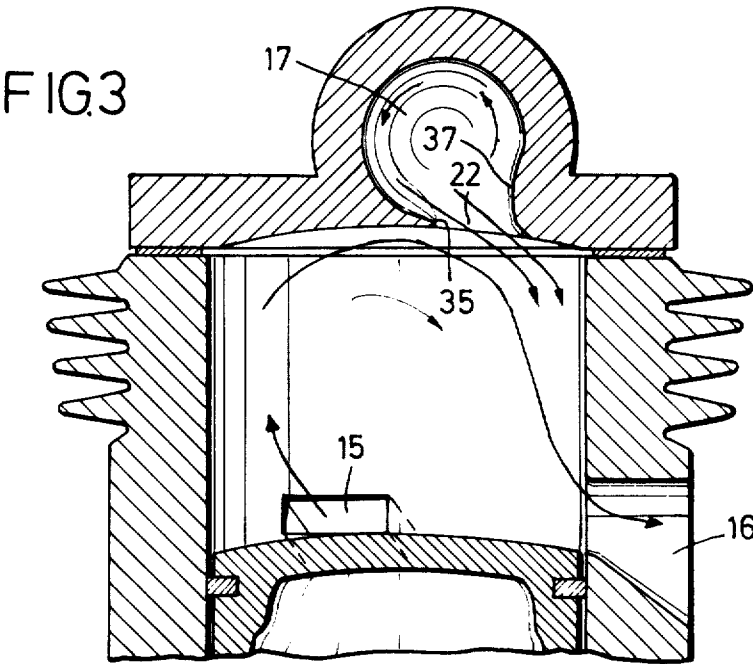


FIG.4

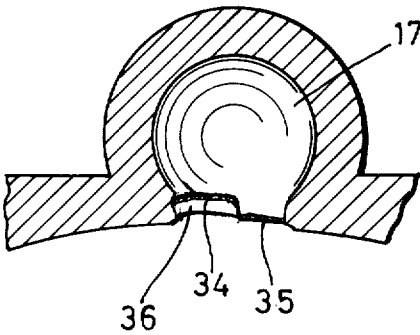
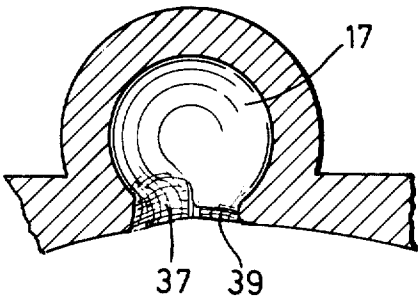
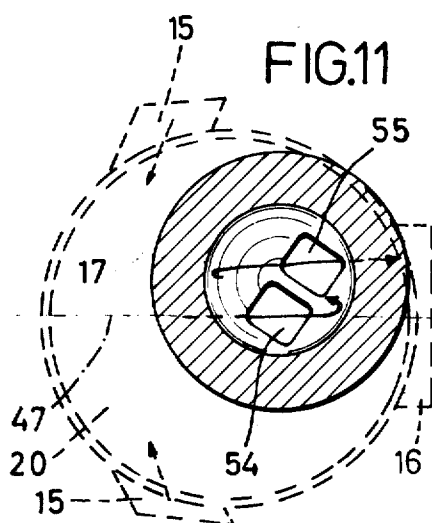
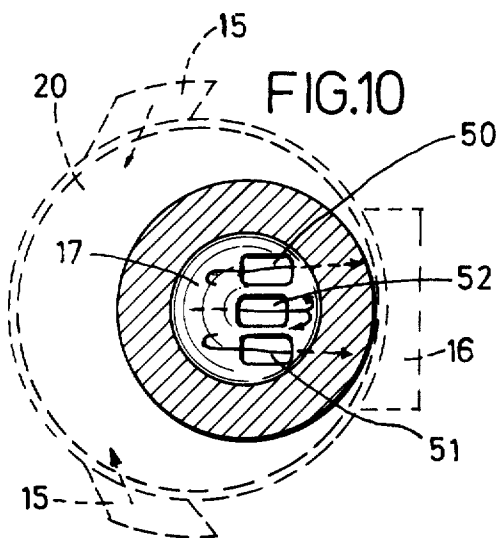
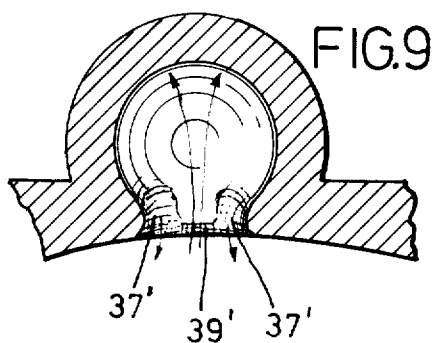
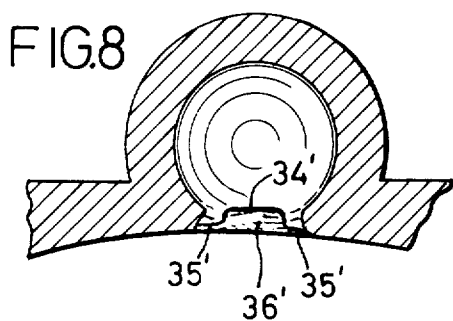
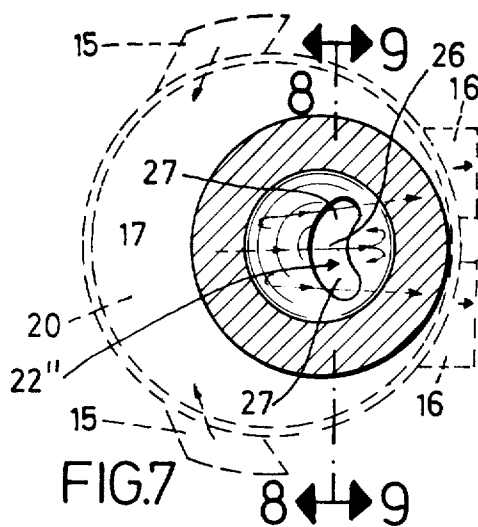
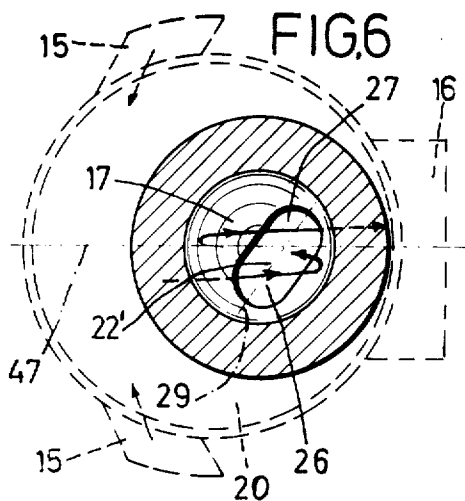


FIG.5





PROCESS AND APPARATUS FOR SCAVENGING THE SWIRL COMBUSTION CHAMBER OF TWO-STROKE CYCLE INTERNAL COMBUSTION ENGINES

BACKGROUND, OBJECTS AND SUMMARY OF THE INVENTION

The present invention relates to a process or method of purging or scavenging the swirl combustion chamber of a two-stroke cycle (hereinafter, two-cycle) internal combustion engine; and to an engine having at least one cylinder which has such a swirl combustion chamber, a working chamber with at least one gas inlet and at least one gas outlet, and a swirl combustion chamber which establishes a communication between the flow aperture and the working chamber, for carrying out the process.

It is, therefore, an object of the present invention to effect scavenging of the swirl combustion chamber in all performance conditions and with the lowest possible stream losses, in order to achieve a high performance of the internal combustion engine while holding the emission of noxious materials within low levels.

This as well as other objects are accomplished according to the present invention by causing the scavenging of the swirl combustion chamber by means of a fresh gas stream which is split-off during the scavenging process from the main scavenging stream prevailing within the working chamber of the cylinder. The gas stream enters the swirl combustion chamber through one or several primary partial regions of the flow aperture after having been separated by one or several upstream edge sections of the edge of the flow aperture. The gas stream crosses itself laterally in a transposed fashion within the flow aperture to effect thereby a reverse scavenging during which the old or exhaust gas streams out of the swirl combustion chamber through at least a secondary partial region of the flow aperture. The exhaust gas stream is situated alongside the gas which enters the swirl combustion chamber, and, thereafter, combines with the main gas stream, that is, the gas stream swirling within the working chamber, toward the gas outlet or exhaust port.

It has been found that by the process and structure according to the present invention, a particularly effective scavenging of the swirl combustion chamber is achieved during all engine load regimes, including idling, as a result of which the old exhaust gas is completely or nearly completely scavenged from the swirl combustion chamber by the inwardly streaming gas. It is also possible according to the present invention to achieve extremely low values of emission of noxious matter in the exhaust gases especially during partial loading and during idle. The exhaust gas is preferably guided out of the swirl combustion chamber through the flow aperture and into the working chamber in such a direction, that it undergoes small deviation or essentially no deviation during the scavenging process and in addition attaches itself to the main gas stream swirling in the working chamber so that both streams flow directly together in the direction of the outlet or exhaust port of the engine cylinder. Thus, only minimum streaming losses occur during scavenging of the swirl combustion chamber and the working chamber, thereby avoiding power losses, and, moreover, guaranteeing as a result a high specific power of the internal combustion engine.

According to a further preferred embodiment of the present invention, it is intended that the gas be introduced through a partial region located on one side of the flow aperture and that it then travels a loop-like path which has a single axial component in the direction of the axis of curvature of the path.

According to another preferred further embodiment of the process and structure according to the present invention it is provided that the fresh gas streams into the swirl combustion chamber through a middle region of the flow aperture, and that as a result, the fresh gas displaces the old or exhaust gas from the swirl chamber and through the regions of the flow aperture situated on either side of the middle region. In this embodiment, the fresh gas follows a loop-like path in the swirl combustion chamber such that it has two mutually opposite axial components.

The gas inlet ports which lead into the working chamber of the engine cylinder may be constructed and arranged in the usual way such that the fresh gas scavenging stream, which is created within the working chamber during the scavenging process, has a stream component which is directed toward the cylinder head. The gas stream component so directed then flows along the cylinder head in the direction of the edge region of the cylinder, which is adjacent to the outlet port or ports. The flow aperture is located above the path traversed by this gas stream component. It lies along the cylinder head so that the fresh gas streams into the swirl combustion chamber through a primary partial region or regions provided therefore in the flow aperture. The fresh gas then laterally displaces the old or exhaust gas which circulates within the swirl combustion chamber and causes this exhaust gas to consequently flow out of the swirl chamber and into the working chamber through one or several secondary regions of the flow aperture while suffering only minimum streaming losses. In consequence of the chosen stream directions of the fresh gases and the old or exhaust gases and of the gas stream prevailing within the working chamber, the exhaust gas streaming out of the combustion chamber combines with the main gas stream prevailing within the working chamber and together they stream toward the outlet port or ports with minimum losses. Preferably it is intended that the fresh gas stream which is formed within the swirl combustion chamber during the scavenging process defines a loop-like path. It is suitable that during scavenging of the exhaust gas the fresh gas streams within the swirl combustion chamber in a single loop. In this way it is possible to achieve a result according to which the exhaust gas is quickly and nearly completely scavenged from the swirl combustion chamber.

Conditions may expediently be chosen so that the exhaust gas has been scavenged from the swirl combustion chamber before the outlet port or ports of the engine cylinder are closed so that while the scavenging process is taking place, some of the fresh gas follows the exhaust gas out of the swirl combustion chamber through the secondary partial region or regions of the flow aperture which have been previously passed by the preceding exhaust gas. In this way an optimum scavenging of the interior of the engine cylinder is achieved.

The two-cycle internal combustion engine which serves for the application of the process and structure according to the present invention is characterized by the fact that the flow aperture of the swirl combustion

chamber of the engine cylinder is constructed and arranged in such a way that the fresh gas which reaches the flow aperture during the scavenging process streams into the swirl combustion chamber through one or several primary partial regions of the flow aperture but preferably through a single partial region of the flow aperture after having been separated or split-off from the main gas stream flowing within the work chamber towards the outlet port or ports. The angle of separation or deviation is an acute angle. The secondary partial regions of the flow aperture, on the other hand, which are located on the side of the primary partial region or regions, are constructed and arranged in such a manner that they offer a smaller resistance to the gas streaming from the swirl combustion chamber than to the gas streaming into the swirl combustion chamber. The secondary partial regions are also constructed and arranged to guide the gas streaming from the swirl combustion chamber in such a manner that it can directionally attach itself to the main gas stream flowing towards the gas outlet port or ports without difficulty, and preferably without or with only very little deviation.

According to the preferred further embodiment of the present invention it can be advantageously provided that the upstream and downstream (with respect to the direction of the fresh gas streaming through the flow aperture during the scavenging process) edge sections of the flow aperture in the primary partial region or regions are constructed differently than the edge sections in the secondary partial region or regions. In this preferred embodiment the primary partial region or regions of the flow aperture, which are limited by the differently constructed edge sections of the edge forming the flow aperture, are so constructed that they offer substantially less resistance to the influx of gas into the swirl combustion chamber than do the secondary partial region or regions. Moreover, the secondary partial region or regions of the flow aperture present a substantially lesser resistance to the efflux of gas from the swirl combustion chamber than do the primary partial region or regions of the flow aperture, so that during the scavenging process the fresh gas flows completely or substantially completely only through the primary region or regions into the swirl combustion chamber and the gas which flows out of the swirl combustion chamber, which consists at least in the beginning of the scavenging process of exhaust gas, flows completely or substantially completely only through the secondary partial region or regions of the flow aperture. This effect may be enhanced by the suitable inclination of the flow aperture.

In some cases it may be sufficient if the primary and the secondary partial regions of the flow aperture are constructed identically but are arranged in such a way that the fresh gas stream formed in the working chamber during the scavenging process has the tendency to flow into the swirl combustion chamber more intensively through the primary partial region or regions than through the secondary partial region or regions. This has the effect that the exhaust gas flows out of the swirl combustion chamber during the scavenging process through the secondary partial region or regions. In order to achieve this effect one can also provide that the primary partial region is located at a part of the engine cylinder head which is very intensively swept by the fresh gas stream, while the secondary partial region

or regions are located at a portion of the engine cylinder head which is less intensively swept or not swept at all by the fresh gas stream; taking care, however, that the pressures prevailing in the working chamber near the flow aperture during the scavenging process are such that the described scavenging process of the swirl combustion chamber is enhanced.

It can be preferably provided that the flow aperture has only a single primary partial region. Similarly it may be advantageously provided that the flow aperture has only a single secondary partial region. However, in many cases it may be suitably provided that the flow aperture has several secondary partial regions, preferably two secondary partial regions and/or several primary partial regions, preferably two primary partial regions.

In general it is particularly suitable to provide that the flow aperture is formed by a single penetration through the cylinder head connecting the working chamber of the engine cylinder with the interior of the swirl combustion chamber. However, in many cases it can be suitably provided that the flow aperture is formed by at least two penetrations, in effect two apertures, located side by side at a distance from one another. In the latter case it is particularly advantageous if each aperture forms a primary partial region or a secondary partial region. In this way one or several of the available apertures serve for the influx of fresh gases into the swirl combustion chamber, while the other aperture or apertures serve for the efflux of gases from the swirl combustion chamber during the scavenging process thereof.

The two-cycle internal combustion engine may be preferentially a spark ignition engine. However, the invention may be used to advantage even with two-cycle compression ignition engines, preferably two-cycle diesel engines.

In general it has been shown to be particularly advantageous if the volume of the swirl combustion chamber is equal to approximately 40 to 90% of the compression volume defined when the piston is at the top-dead-center. Within these extremes, however, the range of 60 to 90% is preferred and in particular the range of 80 to 90%. Further, it is generally suitably provided that the smallest open cross-sectional area of the flow aperture is equal to approximately 20 to 95% of the maximum cross section of the swirl combustion chamber. Within these extremes, however, the range of 40 to 90% is preferred and in particular the range of 60 to 80%, and at most 35% of the cross section of the bore of the cylinder, i.e., of the volume swept by the piston. It is preferably provided that the swirl combustion chamber be at least essentially located above the piston head of the piston, i.e., that it lie at least essentially within an imaginary continuation of the cylinder volume whose diameter is determined by the diameter of the piston.

In a preferred embodiment of the present invention it is provided that the middle of the flow aperture has a different and preferably larger radial distance from the longitudinal axis of the engine cylinder than does the middle of the swirl combustion chamber.

It has been shown to be particularly advantageous if those edge sections of the flow aperture at which the fresh gas which streams into the swirl combustion chamber during the scavenging process and the gas which streams out of the swirl combustion chamber are

staggered and have radii of curvature as small as is permissible by the thermodynamic loading in the cylinder.

In many cases it is suitable to provide that those staggered sections of the edge of the flow aperture have an average smaller distance from the longitudinal axis of the engine cylinder than the respectively oppositely located edge regions of the primary or secondary partial openings of the flow aperture and that in any case the mentioned edge regions can advantageously have other dispositions with regard to the cylinder axis.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a top plan view partly in cross section of a cylinder of a two-cycle internal combustion engine according to one embodiment of the present invention;

FIG. 2 illustrates a partial elevational view in cross section through the cylinder of FIG. 1 taken along the section line 2—2 thereof;

FIG. 3 illustrates a partial elevational view in cross section through the cylinder of FIG. 1 taken along the section line 3—3 thereof;

FIG. 4 illustrates a cross-sectional view through the swirl combustion chamber of the cylinder of FIG. 2 taken along the sectional line 4—4 thereof;

FIG. 5 illustrates a cross-sectional view through the swirl combustion chamber of the cylinder of FIG. 2 taken along the sectional line 5—5 thereof;

FIG. 6 illustrates a top plan view partly in cross section of a cylinder of a two-cycle internal combustion engine according to another embodiment of the present invention;

FIG. 7 illustrates a top plan view partly in cross section of a cylinder of a two-cycle internal combustion engine according to yet another embodiment of the present invention;

FIG. 8 illustrates a partial elevational view in cross section through the swirl combustion chamber of the cylinder of FIG. 7 taken along the sectional line 8—8 thereof;

FIG. 9 illustrates a partial elevational view in cross section through the swirl combustion chamber of the cylinder of FIG. 7 taken along the sectional line 9—9 thereof;

FIG. 10 illustrates a top plan view in cross section of a cylinder of a two-cycle internal combustion engine according to still another embodiment of the present invention; and

FIG. 11 illustrates a top plan view in cross section of a cylinder of a two-cycle internal combustion engine according to yet another embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In discussing the various embodiments of the present invention, like parts are identified by like reference numerals for simplicity of discussion.

Turning first to the embodiment illustrated in FIGS. 1—5, a cylinder 10 is identified, which may be the only cylinder of a two-cycle internal combustion engine, which, in turn, is not shown in further detail. Although only a single cylinder is shown, it should be understood that on occasion this engine may have further similar or identical cylinders. Except for the novel construction of the cylinder head 11, the two-cycle fuel burning engine in question has the usual construction which in-

cludes a working chamber 20 which is scavenged in an especially advantageous manner according to the principle of reverse scavenging. However, under other circumstances, different scavenging systems of the working chamber 20 could be provided. In this embodiment, the reverse scavenging of the working chamber 20 is a so-called "Schnurle" reverse scavenging, named according to the inventor, Mr. Schnurle.

The cylinder 10 includes: a cylinder block 12, equipped with cooling fins, a cylinder head 11; a piston 13 with a slightly convexly curved upper outer surface or crown 14; a pair of gas inlet ports 15 which are symmetrical and are symmetrically arranged with respect to a plane which extends through the center of the interior of the cylinder; and a single exhaust port 16 whose mid plane is the symmetry plane common to both inlet ports 15. The cylinder block 12, the cylinder head 11 and the piston 13 in assembly form the working chamber 20. The maximum volume which can be achieved by the working chamber 20 occurs when the piston 13 is at bottom-dead-center.

According to the invention, the cylinder head 11 is equipped with a vortex or swirl combustion chamber 17, in whose wall 19, a spark plug 18 is mounted. The swirl chamber 17 communicates with the working chamber 20 through a flow aperture 22. The flow aperture 22 has a slight height and is preferably formed as a single penetration or opening. The swirl chamber 17 has an essentially spherical shape, although it should be understood that it can have other shapes. In many cases it can advantageously have another shape, such as, for example, an oval or ellipsoidal shape.

The spark plug 18 is situated at approximately the mid-height of the swirl chamber 17 above the broken or staggered edges 34, 35, which has been demonstrated in many cases as particularly appropriate. However, it should be noted that occasionally one can also place the spark plug 18 at other locations in the wall of the swirl combustion chamber 17, for example, diametrically opposite the flow aperture 22 is also a preferred location.

In spite of the fact that the swirl chamber 17 has been designated as the combustion chamber, it is clear that combustion can also take place in the working chamber 20. It is expedient not to cool the swirl combustion chamber 17 with cooling ribs, rather, in many cases, it is preferably thermally insulated. Nevertheless, it should be understood that the swirl chamber 17 may also be cooled.

The cylinder head 11 includes an inner wall 24, which lies opposite the upper outer surface 14 of the piston 13. The inner wall 24 has a slightly concave curvature which has nevertheless a greater degree of curvature than the degree of curvature of the upper outer surface 14. For this reason, at the edge of the inner wall 24 there is defined a so-called squeezing zone 25 when the piston 13 is in its top-dead-center position. In this position there exists the least possible distance between the cylinder head inner wall 24 and the upper outer surface 14 of the head of the piston 13, while the open distance between the piston head surface 14 and the inner wall 24 in directions which lead from the squeezing zone 25 toward the flow aperture 22, increases steadily to a maximum value which occurs at the beginning of the edge of the flow aperture 22 where a guiding zone is formed in the vicinity of the top-dead-center of the piston for the gas streaming into the swirl combustion

chamber 17. The guiding zone facilitates the streaming of gas into the swirl combustion chamber 17 during compression. Actually the guiding zone is effective on the gas stream, somewhat before the scavenging process in the swirl combustion chamber begins, and has an advantageous effect on the flow during the scavenging process in the swirl combustion chamber.

The two gas inlet ports 15 are obliquely inclined upward in a direction away from the exhaust port 16 so that the main streaming, which takes place in this embodiment in the working chamber 20 during scavenging, assumes the directions shown approximately by the arrows. In the directions shown, the process of the main streaming follows along the cylinder head and past the flow aperture 22.

The flow aperture 22 is constructed according to the present invention to contain a primary partial region 26 and a secondary partial region 27 located side by side, which are limited by the differently formed edge sections of the edge of the flow aperture 22. Each of the two partial regions 26 and 27 extends for approximately half the length of the flow aperture 22 in the direction of its longitudinal axis indicated by the reference numeral 29 in FIG. 1. The edge section of the flow aperture 22 assigned to the primary partial region 26 and which belongs to what will in the following be described as the edge, meaning thereby the circumferential wall of the streaming aperture, extends from approximately the location 30 in a clockwise direction to approximately the location 31. The remaining edge section of the flow aperture 22 is assigned to the secondary partial region 27.

As can be seen most clearly in FIGS. 2-5, the edge section of the flow aperture 22 which is assigned to the primary partial region 26 is constructed differently than the edge section of the flow aperture 22 which is assigned to the secondary partial region 27. In this way a fresh gas from the working chamber 20 streams into the swirl combustion chamber 17 during the scavenging process essentially only via the primary partial region 26 of the flow aperture 22 in the direction of the arrows shown. The fresh gas is thereby forced into a loop-like stream within the swirl combustion chamber 17. The loop-like stream has an axial component which is parallel to the longitudinal axis 29. In this manner, the old exhaust gas which is present at the beginning of the scavenging process within the swirl combustion chamber 17 and which has the same rotational direction in the swirl combustion chamber as the fresh gas, which is introduced into the swirl combustion chamber, is completely or at least nearly completely displaced by the gas now introduced in the region of the swirl chamber which is located above the primary partial region 26 of the flow aperture 22. It is displaced laterally and streams completely or essentially completely only through the secondary partial region 27 of the flow aperture 22 in the direction of the arrows shown in FIGS. 2 and 3, where the direction of the exhaust gas stream is approximately tangential with respect to the rotational stream within the swirl combustion chamber 17. The exhaust gas streaming out of the swirl combustion chamber 17 attaches itself without deviation or without substantial deviation to the main gas stream which is streaming in the working chamber 20 to the outlet port 16. As soon as the old exhaust gas has been completely or substantially removed from the swirl combustion 17 through the secondary partial region 27, the fresh gas

which follows the old exhaust gas can also stream through the secondary partial region 27 of the flow aperture 22 into the working chamber 20.

Conditions have been selected so that the gas traverses substantially only a single loop, exhibiting the above-mentioned axial component during the scavenging process, as it streams into and then out of the swirl combustion chamber 17, i.e., the fresh gas follows a somewhat helical stream with substantially only one loop. Of course, this does not exclude the possibility that portions of the gas perform more than one loop during the scavenging process within the swirl combustion chamber 17. However, it is particularly advantageous, because of the lower streaming losses, to construct the flow aperture 22 in such a manner that, if possible, the gas performs only one loop with an axial component during the scavenging process. Of course, even after the scavenging process is completed, and during the compression stroke, gas enters the swirl combustion chamber 17 from the working chamber 20 so that the gas circulates within the swirl combustion chamber 17. It has been shown that the described embodiment of the flow aperture 22 creates particularly advantageous streaming conditions even during the combustion stroke within the swirl combustion chamber 17 and these conditions have advantageous effects on the combustion process after ignition.

In order to achieve the described streaming in the swirl combustion chamber, it is advantageous to equip that half of the edge of the flow aperture 22 which extends in a counterclockwise direction (FIG. 1) approximately from location 32 to approximately location 33, with the smallest radii of curvature as is permitted by the thermal and technical production conditions, so that this half of the edge forms a first upstream broken or staggered edge 34 for the gas which streams obliquely through the primary partial region 26 of the flow aperture 22; that is, for the gas which streams approximately tangentially into the swirl combustion chamber 17, and a secondary upstream broken or staggered edge 35 for the gas leaving the swirl combustion chamber 17 obliquely through the secondary partial region 27 of the flow aperture 22.

The staggered edge 34, which is assigned to the primary partial region 26 and which extends approximately from location 32 to location 31, is located higher than the staggered edge 35, which is assigned to the secondary partial region 27, in the upstream direction, as seen in FIG. 2. The latter extends approximately from location 31 to location 33. The staggered edge 35 borders, in this preferred embodiment, more immediately the working chamber 20 than does the staggered edge 34, i.e. the curvature of the staggered edge 35 begins immediately at that opening of the flow aperture 22 which is lowest (as seen in FIG. 3). By contrast, a guide surface region 36 leads to the staggered edge 34, which is assigned to the primary partial region 26 of the flow aperture 22. The guide surface region 36 forms an acute angle with a plane perpendicular to the longitudinal axis of the cylinder 10, as seen most clearly in FIG. 2. This has the effect that the staggered edge 34, which connects to the guide surface region 36, is located at some distance above the working chamber 20.

The half of the edge of the flow aperture 22 which lies downstream and which extends in the clockwise direction approximately from location 33 to location 32

in FIG. 1 is constructed in a manner which is particularly evident from FIGS. 2, 3 and 5. There is included, a downstream edge section 37 of the flow aperture 22 which is assigned to the secondary partial region 27 and which extends approximately from location 33 to location 30. The section 37 has a convex curvature with relatively large radii of curvature. A downstream edge section 39 is also included. The section 39 extends approximately from location 30 to location 32, and is assigned to the primary partial region 26. The section 39 has a convex curvature with radii of curvature which are as small as the thermal and production technical conditions will permit. A plane section 40 is connected to the convexly curved edge section 39. The plane section 40 is straight and lies within the plane of the section of FIG. 2 and up to a location 41 where it leads into the spherical curvature of the swirl combustion chamber 17.

The embodiment of the edge of the flow aperture 22 which is described above, has the effect that the scavenging of the swirl combustion chamber 17 is produced by a reverse scavenging which crosses in the flow aperture and whose two directions are displaced laterally. The gas leaving the swirl combustion chamber 17 during the scavenging process is displaced from the gas which streams into the swirl combustion chamber 17 in such a manner that these two gas streams are laterally displaced and cross one another within the flow aperture 22. As may be seen especially clearly from FIGS. 1 and 2, the flow aperture 22 lies in that half of the cylinder 10 which also contains the outlet port 16. The inlet ports 15, however, are located in the other half of the cylinder 10. Furthermore, that half of the edge of the flow aperture 22 which is upstream, referring to the gas streaming through the flow aperture 22 during the scavenging process, has a greater distance from the outlet 16 than the downstream half of the edge. If one further views the main stream present in the working chamber 20 during the scavenging process, then it is clear, that with reference to the plane of FIG. 2 it experiences a deviation of approximately 180° from location 44 to location 45, and when one considers the direction of rotation of this 180° stream, then it is obvious from FIG. 2 that the direction of rotation of the gas stream prevailing in the swirl chamber 17 during the scavenging process is oppositely directed.

As can be seen further from FIG. 1, the plan of symmetry of the two inlet ports 15 extends through the longitudinal axis of the work chamber 20 and approximately through the center of the flow aperture 22. This plane, however, is not a symmetry plane of the flow aperture 22. In many cases the center of the swirl combustion chamber 17 and/or of the flow aperture 22 could lie preferentially at some distance laterally displaced from the above-mentioned symmetry plane as is shown in an exemplary embodiment in FIG. 11.

If the two-cycle internal combustion engine considered here is an engine with fuel injection, then the injection nozzle can be located in the wall of the swirl combustion chamber 17, preferentially in such a manner that the fuel injected during the compression stroke into the swirl combustion chamber 17 remains completely or nearly completely in the swirl combustion chamber until the moment of ignition. For example, the injection nozzle can be located diametrically opposite the spark plug 18.

As can be seen particularly clearly from FIG. 1, the longitudinal axis 29 of the flow aperture 22 is approximately perpendicular to the symmetry plane of the gas inlet ports 15, which plane bisects the outlet port 16 and contains the longitudinal axis of the cylinder 10, so that the described scavenging of the swirl chamber 17 occurs as a consequence of the construction of the edge of the flow aperture 22, where the average height of the flow aperture measured in the axial direction of the flow aperture is relatively small compared to the diameter of the swirl combustion chamber 17. This too has an advantageous effect on the achieved power increase and the decrease of emission of noxious substances. However, it is conceivable, that the height of the flow aperture 22 is chosen larger or smaller than in the shown exemplary embodiment.

The exemplary embodiment of FIG. 6 which illustrates a sectional top view of an alternate embodiment of the swirl combustion chamber 17 of FIG. 1 can be constructed in all essential details similar to the embodiment of FIGS. 1-5, except that the longitudinal axis 29 of the flow aperture 22' of the swirl combustion chamber 17 is inclined at an acute angle of approximately 50° to the longitudinal axis of the outlet port 16 as viewed in the top view. Instead of this angle of approximately 50° , of course, depending upon the requirements, other angles could be used, preferably in the range of $20^\circ - 60^\circ$. Otherwise, the edge of the flow aperture 22' could be constructed similar to the flow aperture 22 of the exemplary embodiment of FIGS. 1-5. In the exemplary embodiment of FIG. 6 (and also in the other exemplary embodiments) it is intended, as shown, that the center of the flow aperture is preferably at a greater distance from the longitudinal axis of the cylinder 10 than is the center of the sphere-like region of the swirl combustion chamber 17. Furthermore, the above-mentioned center of the swirl combustion chamber 17, as well as the center of the flow aperture are preferably located between a plane which contains the longitudinal axis of the cylinder 10 and is perpendicular to the common symmetry plane of the two inlet ports 15 and another plane which perpendicularly intersects the longitudinal axis of the outlet port 16 at the level of the inlet orifice of the outlet port 16.

The fresh gas which streams through the swirl combustion chamber 17 during scavenging in the exemplary embodiment of FIG. 6, also has an approximately loop-like direction with an axial component and preferably only one loop.

In the exemplary embodiment of FIG. 7, the inlet ports 15 of the cylinder 10, are constructed and located according to the exemplary embodiment of FIGS. 1-5, except that there are two separate outlet ports 16 from the working chamber 20. The common symmetry plane of the inlet ports 15 which is now also the common symmetry plane of the outlet ports 16, contains the longitudinal axis of the cylinder 10. This plane is also a symmetry plane of the sphere-like region of the swirl combustion chamber 17 and of the flow aperture 22''. The cross section of the flow aperture 22'' in top view has a kidney-shaped form with the primary partial region 26 in the sense of this invention being formed by a central region thereof and the secondary partial region 27 in the sense of the present invention being formed by the two regions of the aperture 22'' on either side of the central region. During the scavenging process, a fresh gas flows into the swirl combustion

chamber 17 and also experiences a loop-like streaming. However, this fresh gas stream splits symmetrically to both sides having oppositely directed axial components and as a result, the old gas present in the swirl combustion chamber 17 streams from the two sides of the primary partial region 26 and out of the symmetrical two secondary partial regions 27 in such a manner that the exiting gas attaches itself without substantial deviation to the main stream prevalent during scavenging in the working chamber 20. As may be seen from FIG. 8, the upstream half of the edge of the flow aperture 22' is effectively constructed so that a staggered edge 34' of the primary partial region 26 is at a greater distance from the working chamber 20 than the staggered edges 35' of the two secondary partial regions 27. A surface 36' inclined to the plane which is perpendicular to the longitudinal axis of the cylinder 10 leads to the staggered edge 34'. This surface can be constructed similarly to the surface 36 of FIG. 2.

The staggered edges 35' which lie upstream, when referred to the gas streaming through the flow aperture 22' and which are assigned to the secondary partial region 27, also once more border practically on the working chamber 20 and have very small radii of curvature.

As may be seen especially clearly from FIG. 9, the half of the edge of the flow aperture 22' which lies downstream with reference to the gases streaming through the flow aperture 22', is constructed in such a manner that the center section 39' of this half edge, which is assigned to the primary partial region 26, has a convex curvature with a very small radius of curvature and begins immediately at the working chamber 20, whereas the edge sections 37', which lie on both sides of the center section 39' and which are assigned to the secondary partial regions 27, while also convexly curved, have relatively larger radii of curvature.

In some cases it has been found advantageous and useful not to form the flow aperture, as in the above exemplary embodiment, as a single aperture connecting the working chamber 20 with the swirl combustion chamber 17, but rather to form several such apertures which re separate from one another, preferably such that when one or the other of the apertures serves as the inlet of the fresh gas into the swirl combustion chamber, the other aperture or apertures substantially serve as the outlet or outlets of the gases from the swirl combustion chamber during the scavenging process. FIGS. 10 and 11 illustrate two such exemplary embodiments, and it can be seen that they are variants of the embodiments of FIGS. 7 and 6. In the embodiments of FIGS. 10 and 11, the primary and secondary partial regions of the flow aperture are separated by lands which is not the case in the exemplary embodiments of FIGS. 6 and 7. In the embodiments of FIG. 10 the total flow aperture is divided by lands into three separate penetration or apertures 50, 51 and 52, of which the center aperture 52 forms the primary partial region of the flow aperture, i.e., it serves for the influx of fresh gas during the scavenging process and is constructed suitably for this purpose. On the other hand, the two other apertures 50, 51 serve as the gas outlet from the swirl combustion chamber 17 during the scavenging process and are suitably constructed for this purpose. The streaming of fresh gas formed during the scavenging process in the swirl combustion chamber 17 of the embodiment of FIG. 10 conforms in principle to the corresponding streaming of the exemplary embodiment of FIG. 7.

However, the fresh gas exiting from the swirl chamber 17 is laterally displaced from the gas streaming into the swirl chamber by the presence of the two lands.

In some cases it might be desirable to construct the apertures 50 and 51 so that they serve as fresh gas inlets to the swirl combustion chamber 17, while aperture 52 is constructed so that it serves as a gas outlet from the swirl combustion chamber during the scavenging process.

In the exemplary embodiment of FIG. 11, the flow aperture of the swirl combustion chamber 17 is formed by two separate penetrations or apertures 54 and 55, separated from one another by a small land. The aperture 54, which lies closer to the longitudinal axis of the working chamber 20, is constructed for the inlet of fresh gas during the scavenging process, while the aperture 55 is constructed to serve as the gas outlet from the swirl combustion chamber 17 during the scavenging process. The scavenging stream created in the swirl chamber 17 has a loop-like progress, just as it has in principle also in the exemplary embodiment of FIG. 6. A single outlet port 16 is utilized and the symmetry plane 47 of the two inlet ports 15 contains the axis of symmetry of the outlet port 16 as viewed in FIG. 11. The center of the swirl combustion chamber 17 lies laterally displaced at some distance from the symmetry plane 47 in such a manner that the symmetry plane 47 approximately contains the center of the primary partial region of the flow aperture, which is formed by the aperture 54, so that the most intensive streaming region of the main gas stream forming at the cylinder head in the working cylinder 20 during the scavenging process acts upon the aperture 54.

The piston 13, shown in FIGS. 1 - 5, is preferably constructed as a piston with a slightly convexly curved top portion. It should be understood, however, that the invention is not limited in any way to this configuration, but that in two-cycle internal combustion engines other piston shapes can and are utilized, for example, the piston may be a deflector piston, a flat piston or the like. The invention can also be used in opposed piston engines. Furthermore, as has already been mentioned, instead of the scavenging process of working chamber 20, which is described in the exemplary embodiment of FIGS. 1-5, some other scavenging process may be used in which a portion of the fresh gas from the main stream of fresh gas is introduced during the scavenging into the swirl combustion chamber for the purpose of scavenging it.

As is obvious from the preceding specification, the purging or scavenging of the swirl combustion chamber is effected during the scavenging of the working chamber by a spit-off portion of the fresh gas main stream prevailing in the working chamber. Therefore the scavenging stream prevailing in the working chamber has been designated as the main scavenging stream and the scavenging stream prevailing in the swirl combustion chamber has been designated as the secondary scavenging stream.

By way of example only, the dimensions, for purposes of the present invention, of a test engine according to FIGS. 1-5, which displayed an extremely small emission of noxious substances while exhibiting very good power output, are as follows:

Engine: Two stroke with loop scavenging (Schnurle type)

Bore: 56 mm

Stroke: 50 mm

Piston according to FIG. 2

Compression ratio: 6.8 : 1

Diameter of chamber 17: 27.5 mm

Flow aperture 22:

Distance between points 32 - 33: 20 mm

Distance between points 30 - 31: 13 mm

Radius of 34 and 35: 0.1 mm (nearly sharp)

Radius of 39: 0.2 mm

Radius of 37: 5 mm

Average height of the flow aperture: 2.5 mm

Angle between plane 36 and a plane perpendicular to the axis of the bore of chamber 20: 20°

Length of the plane 36: 11 mm

In FIG. 2, the vertical distance between edges 34 and 35 is approximately 3.5 mm. In some cases, this distance may be larger or smaller. In a special case, this distance was 0 which means that the plane 36 was extended from point 32 until point 33 and the edges 34 and 35 were in line. The radii of at least one of the edges 34, 35, 39 could be as small as possible, this means, that the temperature of the edges in operation cannot burn the edges.

A single loop of the scavenging stream in the chamber 17 is advantageous regarding the scavenging losses and the short time available for the scavenging.

Finally, it will be understood that according to the present invention, the fresh gas entering the working chamber and forming the main gas scavenging stream can contain fuel or not. In the first case, the fuel is mixed with the fresh air in any known manner before the air enters the working chamber. In the latter case, the fuel can preferably be injected into the swirl combustion chamber.

What is claimed is:

1. A process for scavenging a swirl combustion chamber of a two-stroke cycle internal combustion engine having at least one cylinder including a working chamber, a swirl combustion chamber, a flow aperture through which the swirl combustion chamber communicates with the working chamber, a single reciprocating piston, and at least one gas inlet port and at least one exhaust port in communication with the working chamber which are free of any valve control, the process comprising:

- a. forming the flow aperture to include a plurality of partial regions laterally adjacent each other and at least one upstream edge section;
- b. forming the at least one inlet port and the at least one exhaust port in the cylinder wall in the vicinity of the bottom dead center of the piston so that they are opened only when the piston is in its bottom dead center;
- c. establishing a main scavenging stream within the working chamber from a gas entering the working chamber through the at least one gas inlet port when the piston is at its bottom dead center; and
- d. splitting-off a portion of the main scavenging stream also when the piston is at its bottom dead center and as a result of the main scavenging stream contacting said at least one upstream edge section to thereby effect redirection of said split-off portion of the main scavenging stream through one of said plurality of partial regions and into the swirl combustion chamber, said redirected split-off portion of the main scavenging stream effecting a reverse, cross scavenging according to which said

split-off portion is laterally displaced with the flow aperture so that the exhaust gases stream out of the swirl combustion chamber alongside of said incoming split-off portion and through another one of said plurality of partial regions to thereafter combine with the main scavenging stream flowing within the working chamber toward the at least one exhaust port.

2. A process for scavenging a swirl combustion chamber of a two-stroke cycle internal combustion engine as defined in claim 1, wherein said plurality of partial regions is formed to include at least one lateral region, and wherein said split-off portion is redirected through said lateral partial region so that it traverses a loop-like path within the swirl combustion chamber, said redirected stream having a single axial component in the direction of the axis of curvature of the path.

3. A process for scavenging a swirl combustion chamber of a two-stroke cycle internal combustion engine as defined in claim 1, wherein said plurality of partial regions is formed to include a middle region, and wherein said split-off portion is redirected through said middle region so that it traverses a loop-like path within the swirl combustion chamber, said redirected stream having two opposite axial components thereby displacing the exhaust gases to either side of said middle region and out of the swirl combustion chamber.

4. A process for scavenging a swirl combustion chamber of a two-stroke cycle internal combustion engine as defined in claim 1, wherein the exhaust gases stream out of the swirl combustion chamber separated from the split-off portion.

5. A process for scavenging a swirl combustion chamber of a two-stroke cycle internal combustion engine as defined in claim 1, wherein said plurality of partial regions is formed to include at least one primary partial region and at least one secondary partial region, and wherein said split-off portion is redirected through said at least one primary partial region and the exhaust gases stream out of the swirl combustion chamber through said at least one secondary partial region.

6. In a two-stroke cycle internal combustion engine having at least one cylinder provided with at least one inlet port and at least one exhaust port which are free of any valve control, a cylinder head, a piston, a working chamber defined by the cylinder, the piston and the cylinder head, a swirl combustion chamber, and a flow aperture providing communication between the working chamber and the swirl combustion chamber, the improvement wherein the at least one inlet port and the at least one exhaust port are located in the cylinder so that they are opened when the piston is at its bottom dead center, and wherein said flow aperture is constructed to include at least one primary partial region and at least one secondary partial region, said regions being constructed and disposed relative to each other in such a way that said at least one secondary partial region presents a lesser resistance to the movement of gas out of rather than into the swirl combustion chamber, as a result during scavenging of the cylinder a main gas stream within the cylinder upon reaching said flow aperture has a portion thereof split-off at an acute angle to the direction of said main stream and streams at least substantially into the swirl combustion chamber through said at least one primary partial region, said at least one secondary partial region being disposed, when viewed in the direction of said main gas stream, later-

ally to said at least one primary partial region, said at least one secondary partial region serving to guide the gas leaving the swirl combustion chamber so that it attaches itself to said main gas stream with substantially no deviation and moves therewith in the direction toward the at least one outlet port.

7. A two-stroke cycle internal combustion engine as defined in claim 6, wherein said flow aperture is defined by an edge section having edge sectors which are located both upstream and downstream, with reference to said main stream passing through said flow aperture, said edge section being associated with said primary and secondary partial regions, with those edge sectors associated with said primary partial region having a different construction than those edge sectors associated with said secondary partial region.

8. A two-stroke cycle internal combustion engine as defined in claim 6, wherein said flow aperture is defined by an edge section, the upstream portion of which, with reference to said main stream passing through said flow aperture, is equipped with staggered portions for the gas which streams into the swirl combustion chamber and the gas which streams out of the swirl combustion chamber, and wherein said staggered portions are associated with said primary and secondary partial regions, with those staggered portions associated with said primary partial region being further from the working chamber than those staggered portions associated with said secondary partial region.

9. A two-stroke cycle internal combustion engine as defined in claim 8, wherein those staggered portions associated with said secondary partial region include at least one partial sector which is located at the level of the orifice which lies in the direction of the top of the piston.

10. A two-stroke cycle internal combustion engine as defined in claim 6, wherein said flow aperture contains a single secondary partial region.

11. A two-stroke cycle internal combustion engine as defined in claim 10, wherein approximately one-half of the flow aperture is constructed as a gas inlet for the swirl combustion chamber and the other half is constructed as a gas outlet for the swirl combustion chamber.

12. A two-stroke cycle internal combustion engine as defined in claim 6, wherein said flow aperture is constructed to include a middle region and two further regions with one on each side of said middle region, said middle region being constructed as a primary partial region and said two further regions being constructed as secondary partial regions.

13. A two-stroke cycle internal combustion engine as defined in claim 6, wherein said flow aperture is defined by an edge section including convexly curved sections associated with said primary and secondary partial regions which are located downstream, with reference to said main stream passing through said flow aperture, said convexly curved sections associated with said secondary partial region having a substantially larger radius of curvature than said convexly curved sections associated with said primary partial region.

14. A two-stroke cycle internal combustion engine as defined in claim 6, wherein said flow aperture is defined by an edge section which includes staggered portions associated with said primary and secondary partial regions and has associated therewith a guiding surface leading to said staggered portions, said guiding

surface being inclined at an angle with respect to a plane normal to the longitudinal axis of the cylinder and being located upstream, with reference to said main stream passing through said flow aperture, with respect to said staggered portion associated with said primary partial region.

15. A two-stroke cycle internal combustion engine as defined in claim 6, wherein the cross section of said flow aperture has an elongated form defining a longitudinal axis which is inclined to the longitudinal axis of said outlet port.

16. A two-stroke cycle internal combustion engine as defined in claim 6, wherein the working chamber includes two gas inlet ports and one gas outlet port, and wherein said gas inlet ports and said gas outlet port are symmetrical with respect to a symmetry plane containing the longitudinal axis of the working chamber, said symmetry plane intersecting said flow aperture.

17. A two-stroke cycle internal combustion engine as defined in claim 16, wherein said symmetry plane intersects said flow aperture approximately through the center thereof.

18. A two-stroke cycle internal combustion engine as defined in claim 6, wherein the working chamber includes two gas inlet ports and two gas outlet ports, and wherein said gas inlet ports and outlet ports are symmetrical with respect to a symmetry plane containing the longitudinal axis of the working chamber, said symmetry plane intersecting said flow aperture.

19. A two-stroke cycle internal combustion engine as defined in claim 18, wherein said symmetry plane intersects said flow aperture approximately through the center thereof.

20. A two-stroke cycle internal combustion engine as defined in claim 15, wherein said symmetry plane extends approximately through the center of said at least one primary partial region of said flow aperture.

21. A two-stroke cycle internal combustion engine as defined in claim 6, wherein the middle of said flow aperture is displaced from the longitudinal axis of the working chamber and is located in that half of the cylinder which contains said at least one outlet port of the working chamber.

22. A two-stroke cycle internal combustion engine as defined in claim 6, wherein said flow aperture is formed as a single penetration connecting the working chamber with the inside space of the swirl combustion chamber.

23. A two-stroke cycle internal combustion engine as defined in claim 6, wherein said flow aperture is formed as at least two displaced penetrations.

24. A two-stroke cycle internal combustion engine as defined in claim 6, wherein the height of said flow aperture is substantially less than the height of the swirl combustion chamber.

25. A two-stroke cycle internal combustion engine as defined in claim 6, wherein the entire flow aperture lies above the top of the piston.

26. A two-stroke cycle internal combustion engine as defined in claim 6, wherein the swirl combustion chamber is at least substantially located above the top of the piston.

27. A two-stroke cycle internal combustion engine as defined in claim 6, wherein the volume of the swirl combustion chamber is approximately 40 to 90% of the volume of the cylinder when the piston is at its top-dead-center position.

28. A two-stroke cycle internal combustion engine as defined in claim 6, wherein the volume of the swirl combustion chamber is preferably 60 to 90% of the volume of the cylinder when the piston is at its top-dead-center position.

29. A two-stroke cycle internal combustion engine as defined in claim 6, wherein the volume of the swirl combustion chamber is preferably 80 to 90% of the volume of the cylinder when the piston is at its top-dead-center position.

30. A two-stroke cycle internal combustion engine as defined in claim 6, wherein the smallest open cross section of said flow aperture is approximately 20 to 95% of the maximum cross section of the swirl combustion chamber.

31. A two-stroke cycle internal combustion engine as defined in claim 6, wherein the smallest open cross section of said flow aperture is preferably 40 to 90% of the maximum cross section of the swirl combustion chamber.

32. A two-stroke cycle internal combustion engine as defined in claim 6, wherein the smallest open cross section of said flow aperture is preferably 60 to 80% of the maximum cross section of the swirl combustion chamber.

33. A two-stroke cycle internal combustion engine as defined in claim 6, wherein said flow aperture includes an edge region part of which is assigned to said primary partial region, said assigned edge region, being that region where said split-off portion is generated, having a channel-shaped bay area surface associated therewith, with said channel-shaped bay area surface being formed in the cylinder head and extending to said assigned edge region in such a manner that its depth increases.

34. A two-stroke cycle internal combustion engine as defined in claim 6, wherein the piston at its top-dead-center position defines along with the cylinder head a squeezing zone of the working chamber, said squeezing zone being defined to begin at the circumference of the piston top and extend inwardly towards the longitudinal axis of the cylinder and be connected to a guide

zone leading to said flow aperture and wherein the open height of said guide zone increases from said squeezing zone toward said flow aperture.

35. A two-stroke cycle internal combustion engine as defined in claim 6, wherein the radial distance from the center of said flow aperture to the longitudinal axis of the cylinder is greater than the radial distance from the center of the swirl combustion chamber to the longitudinal axis of the cylinder.

36. A two-stroke cycle internal combustion engine as defined in claim 6, wherein said flow aperture includes an edge section part of which is assigned to said primary partial region and another part of which is assigned to said secondary partial region, said part being assigned to said primary partial region being that region where said split-off portion is generated, both parts of said edge region having radii of curvature which are as small as is permitted by the thermodynamic loading in the cylinder.

37. A two-stroke cycle internal combustion engine as defined in claim 6, wherein said flow aperture includes an edge section part of which is assigned to said primary partial region and another part of which is assigned to said secondary partial region, said edge section assigned to said primary partial region having a first sector where said split-off portion is generated and an opposite sector, and said edge section assigned to said secondary partial region having a first sector and an opposite sector, and wherein said first sectors are located generally at a lesser distance from the longitudinal axis of the cylinder than said opposite sectors.

38. A two-stroke cycle internal combustion engine as defined in claim 6, wherein the internal combustion engine is a spark-ignition engine.

39. A two-stroke cycle internal combustion engine as defined in claim 6, wherein the internal combustion engine is a self-igniting engine.

40. A two-stroke cycle internal combustion engine as defined in claim 6, wherein the internal combustion engine is a diesel engine.

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