(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
19 December 2013 (19.12.2013)

WIPO | PCT

(10) International Publication Number
WO 2013/185802 A1

(51) International Patent Classification:
*F01L 3/20* (2006.01) *F02F 3/16* (2006.01)
*F01L 5/06* (2006.01) *F01L 1/08* (2006.01)

(21) International Application Number:
PCT/EP2012/061025

(22) International Filing Date:
11 June 2012 (11.06.2012)

(25) Filing Language: English

(26) Publication Language: English

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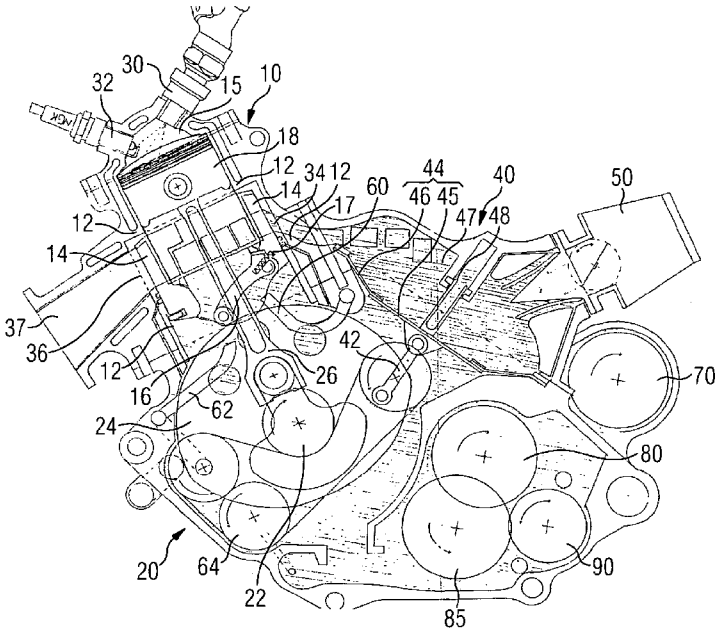
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

**Published**:
— *with international search report (Art. 21(3))*

(54) **Title**: INTERNAL COMBUSTION ENGINE

FIG 1




(57) **Abstract**: The application relates to an internal combustion engine (1), comprising a cylinder (10) having a cylinder wall (12) form¬ ing a main part of a combustion chamber (15), a number of air inlet openings (34) and a number of exhaust openings (36) in the cylinder wall (12), a piston (18) movably arranged in the cylinder (10), a crankcase (20), a crankshaft (22), and a piston rod (26) connecting the crankshaft (22) with the pis¬ ton (18), wherein the cylinder (10) comprises a movable cyl¬ inder wall segment (14) for opening and closing the air inlet openings (34) and/or the exhaust openings (36), and an actu¬ ating member (16) for actuating the movable cylinder wall segment (14) directly or indirectly by the crankshaft (22). Additionally, the application relates to a cooling air and/or oil cooling system (60), an air intake system (40) and a damping method for such an engine.

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# INTERNAL COMBUSTION ENGINE

The present application relates to an internal combustion engine with a cylinder having a cylinder wall forming a main part of a combustion chamber, having a number of air inlet openings and a number of exhaust openings in the cylinder wall, a piston movably arranged in the cylinder, a crankcase, a crankshaft arranged in the crankcase, and a piston rod connecting the crankshaft with the piston. Additionally, the application relates to a cooling air and/or oil cooling system, an air intake system and a damping method for an internal combustion engine.

Conventional two stroke engines usually employ the crankcase and the cylinder to carry out any of the steps of an internal combustion engine, especially one having a so called "Otto cycle", in only two strokes of the piston. Thereby, the two stroke engines mostly are more powerful, lighter or simpler in their construction than four stroke engines of the same size.

Generally, a two stroke cycle includes the step of sucking an air/fuel mixture into the crankcase by vacuum that is generated in the crankcase during the upward stroke of the piston. During the subsequent downward stroke of the piston, the air intake is closed by a valve and the air/fuel mixture is compressed to a certain degree inside the crankcase. Toward the end of the downward stroke of the piston, an air inlet opening in the cylinder wall is opened by the piston in order to allow the compressed air/fuel mixture to flow into the combustion chamber, which is arranged in the cylinder above the piston. At the same time, aided by the pressurized air/fuel mixture, exhaust gases are transferred to the exhaust opening, which usually is arranged in the top of the combustion chamber (especially in case of the use of a valve) or is ar-

ranged at the side of the cylinder wall opposing the air inlet opening.

During the upward stroke of the piston, which is at this time mostly driven by the flywheel moment (or "torque") of the crank, the air inlet opening and the exhaust opening are closed by the moving piston or optionally by a valve. Thereby, the air/fuel mixture is compressed or pressurized in the combustion chamber. At the top end position of the upward stroke of the piston, i.e. at the "top dead centre", the highest compression of the air/fuel mixture has been reached and the compressed air/fuel mixture is ignited by a spark plug or a glow plug. The exploding fuel/air mixture expands, i.e. its volume is significantly increased by the burning gases. Thereby the piston is forced downwards to complete the cycle and to start anew.

The piston moving up and down in the cylinder rotates the crankshaft by means of a piston rod mounted on the crankshaft in an asymmetric manner, i.e. eccentrically to the main axis of the crankshaft, to generate power.

In a conventional two-stroke engine, the fuel/air mixture usually comprises specific oil additives for lubricating any moving and/or rotating elements in the cylinder or in the crankcase, especially the moving piston, the crankshaft, and the connections there between. However, due to the oil content present in the air/fuel mixture, the conventional two stroke combustion engines have a high ratio of oil contents in the exhaust gases. In addition, they are often inefficient and disadvantageous due to the high amount of fuel that escapes through the exhaust port during the step of forcing the exhaust gases out of the exhaust opening of the combustion chamber by the fresh air/fuel mixture.

To avoid problems caused by the use of the air/fuel mixture in the crankcase for lubricating the crankshaft and the pis-

ton, a sleeve valve system was developed for large two stroke diesel engines having a long cylinder casing and mechanical valves at the top of the cylinder. An example of such a large diesel engine is described in EP 0 851 101 A1. However, those diesel engines having a long piston stroke are generally not constructed for revolution speeds of the piston higher than about 600 to 700 revolutions per minute (rev./min). Hence, the engines of the state of the art are desired and restricted to some specific applications such as for large aircrafts, ships, or railroad engines where the weight of the engine and the revolution speed are not critical parameters.

It is an object of the invention to provide an alternative internal combustion engine, especially one using any of the advantages of a two stroke combustion engine and for example being capable to run with high revolutions. More particularly, it is an object to provide an internal combustion engine providing a "green combustion technology", which means having no substantial contents of oil or fuel in the exhaust gases. In addition, it is an object to provide a cooling air and/or oil cooling system as well as an air intake system adapted to such an internal combustion engine. Moreover, it is another object of the invention to provide an improved damping method for the piston for the use in such an internal combustion engine, especially a two stroke internal combustion engine.

The object of the invention is achieved by the internal combustion engine according to claim 1, the cooling air and/or oil cooling system according to claim 13, the air intake system according to claim 14 or the damping method according to claim 15. Any of these aspects individually solve the above mentioned problems, in particular to provide an internal combustion engine having the advantages of a two stroke combustion engine such as, for example, being powerful, lightweight, simple in its construction, and capable of running with high revolutions.

The internal combustion engine according to a first aspect of the invention comprises a cylinder having a cylinder wall forming a main part of a combustion chamber, that means the cylinder wall forms a substantial part of the combustion chamber and the other part is formed by the piston moving up and down in the cylinder bore. Up means in this regard the motion to the top dead point where the combustion chamber has its lowest volume, and down or to the bottom side means the motion in the direction of the bottom dead centre, where the combustion chamber has its highest volume. Up and down or top and bottom are used herein with regard to this direction irrespective how the cylinder is arranged in the engine and can characterize a horizontal direction as well. The cylinder has a number of air inlet openings and a number of exhaust openings in the cylinder wall. The internal combustion engine further comprises a piston movably arranged in the cylinder, a crankcase, a crankshaft arranged in the crankcase, and a piston rod connecting the crankshaft with the piston. According to the invention, the cylinder comprises a movable cylinder wall segment, also called "sleeve valve", for opening and closing the air inlet openings and the exhaust openings. The movable cylinder wall segment moves up and down between a bottom dead centre and a seating area inside the fixed cylinder wall arranged stationary in the engine.

The internal combustion engine further comprises an actuating member for actuating the movable cylinder wall segment directly or indirectly by the crankshaft. More particularly, the movable cylinder wall segment is in driving connection with the crankshaft and can be driven independently from the motion of the piston. Being in driving connection includes either to be directly connected to and driven by a cam or to be connected by means of a cam/rod-arrangement arranged between the cam and the movable cylinder wall segment. The use of such a cam-driven or cam/rod-driven movable cylinder wall segment allows high speed revolution engines up to about

12.000 rev./min or even more. Preferred ranges of the practical maximal piston revolution speeds are about 6.000 to 10.000 rev./min, more preferably between about 6.000 to 8.000 rev./min. Therefore, this engine is particularly suitable for being used in, for example, motorcycles, cars, especially smaller cars, snowmobiles, jet-skis, motor-driven hand apparatuses such as chainsaws, outboard engines and others.

The pressurizing of the air or air/fuel mixture can optionally be realized via a separate air intake system or air intake portion. The air intake portion comprises a compression chamber which is substantially sealed with regard to the crankcase. Hence, the general concept of the air intake portion is different to the above mentioned conventional air compression process of a conventional two stroke engine using the crankcase for compressing the air/fuel.

The new air intake portion or the new air intake system which can optionally be used together with or in the internal combustion engine permits that any lubricants necessary for lubricating the moveable parts of an internal combustion engine can remain below the head of the moving piston, i.e. being in the crankcase and thus sealed from the fuel in the combustion chamber. Hence, in contrast to conventional two stroke engines, lubricants cannot enter into the combustion chamber or reach the exhaust system. Therefore, the pollution with burned lubricants such as oils can be reduced or omitted in the internal combustion engine according to the invention and the environmental acceptability of the exhausted gases is in the range of standard four stroke engines. A green technology engine is thus possible with the new general concept of the invention. The total weight of the system can be kept comparable or in the range of the weight of a conventional two-stroke engine and, thus, this improves the efficiency of internal combustion engines also in view of economic aspects.

In order to guide the piston in the bore of the movable cylinder wall segment and/or the cylinder, piston rings (in conventional engines also called oil rings) are favourably arranged in the circumference of the upper part of the piston. Via the piston rings the combustion chamber is sealed off the crankcase. In conventional engines they pass the air inlet and/or exhaust openings during every stroke of the piston. Especially due to the movable cylinder wall segment, the possibility arises to arrange a number of piston rings (i.e. one, two, three or even more) in such a manner that they do not pass the air inlet and/or exhaust openings. Although they are arranged at the circumference of the upper part of the piston like in a conventional engine, they are preferably moved into the movable cylinder wall segment before the air inlet openings and/or the exhaust openings are opened and, thus, are not in direct contact with the openings during the downwards stroke of the piston. During the upwards motion of the piston, the piston rings can preferably be moved within the movable cylinder wall segment and pass the transition between the fixed cylinder wall segment and the movable cylinder wall segment after the air inlet and/or exhaust openings have been closed. This possibility arises due to the specific constitution or design of the movable cylinder wall segment of the internal combustion engine according to the invention. Thus, the stress level or wear will be significantly lower than the stress level to which the piston rings of conventional two stroke engines are usually exposed. Hence, the advantageous constitution of the movable cylinder wall segment and its specific actuation by the crankshaft, preferably in relation to the motion of the piston moving therein, improves the wear and the durability of the combustion engine and, particularly, of the piston rings used. At the same time, the internal combustion engine can be adjusted to high revolutions of the piston in the combustion chamber.

Moreover, the movable cylinder wall segment can move inside a part of the fixed cylinder wall, more particularly mainly in

its lower part where the air inlet openings and the exhaust openings are arranged. The movable cylinder wall segment preferably provides a bore which is substantially identical to the bore of the upper part of the fixed cylinder wall segment in which the combustion chamber is arranged. Therefore, the bores of the two members are designed in a manner that the piston can be moved up and down in the upper part of the fixed cylinder wall segment and in the movable cylinder wall segment. In other words, the fixed cylinder wall advantageously has a stepwise configuration (indentation) wherein the step or indentation is complementary to the configuration of the movable cylinder wall segment. According to a preferred embodiment of the movable cylinder wall segment, it substitutes a part of the fixed cylinder wall in its top end position respectively, while the cylinder volume (i.e. the volume of the combustion chamber) is enlarged or expanded at the time of the downward movement of the movable cylinder wall segment. This temporary change of volume of the combustion chamber improves the scavenging process. Therefore, it is also possible to operate the engine with a higher compression ratio, especially in combination with an expansion pipe for the exhaust gases.

The optional stepped configuration of the fixed cylinder wall preferably provides an extra swirl of the fresh air/fuel mixture in the combustion chamber during the closure of the air inlet and exhaust openings. Gases in the gap between the upper part of the movable cylinder wall segment and the lower part of the fixed cylinder wall (i.e. the landing site of the movable cylinder wall segment at the fixed cylinder wall) are pressed or forced out of the gap towards the combustion chamber providing the extra swirl shortly before the movable cylinder wall lands in its landing site during its upward motion. The extra swirl is advantageous for the subsequent combustion step in the combustion chamber due to the improved mixing of the air/fuel mixture. This additionally fosters an economic use of fuel in the combustion step.

According to a second aspect of the invention, a cooling air and/or oil cooling system is provided for an internal combustion engine, especially for those as described in the first aspect. The cooling air and/or oil cooling system according to the invention comprises means for cooling and recycling cooling air and/or cooling oil collected in a crankcase in a separate cooling system (e.g. one or more radiators) and for recirculating or transferring the cooling air and the oil into the crankcase. Advantageously the cooling air can, thus, be used for cooling the piston and the movable cylinder wall segment several times advantageously in a closed circulation system. For this purpose, it is preferable that the cooled air is provided to the piston from its bottom, i.e. opposing the combustion chamber, for example by means of a cooling air nozzle. Thereby, an improved air cooling can be applied to cool the internal parts of the engine, and advantageously the high revolving piston.

The use of a cooling air and/or oil cooling system can support high speed revolution engines up to about 12.000 rev./min or even more. Preferred ranges of the practical maximum piston revolution speeds are about 6.000 to 10.000 rev./min, more preferably between about 6.000 to 8.000 rev./min.

In addition, after the cooling and, optionally the separation from the air, regenerated and cooled oil is transferred back into the crankcase for lubrication and cooling purposes. Preferably, such a system may comprise a separator for separating air and oil, a cooling section (e.g. a radiator or cooling surfaces) for air and/or oil and a respective pipe assembly. In the crankcase, the heated air and the heated oil is preferably collected near the bottom of the cylinder or the movable cylinder wall segment because these locations are subjected to the highest temperatures. In order to collect the hot air and oil, the cooling air and/or oil cooling sys-

tem preferably comprises a collector element. This can, for example, be a suction device for actively sucking air and/or oil, especially in the form of oil steam or oil spray, into the collector element and for transporting it to the means for cooling air and/or oil. In order to facilitate the cooling efficiency, the means for cooling are preferably arranged outside the crankshaft. Advantageously, the air cooling and/or oil cooling system comprises expedient heat exchanging members, for example one which effectively transports the heat to the surrounding atmosphere, i.e. is an air cooled heat exchanger such as a radiator. For transporting the heat to the atmosphere, the surface of the heat exchanger is preferably increased by using cooling ribs or the like, realizing one example embodiment of cooling means.

According to a third aspect of the invention, an air intake system is provided, which can preferably be used in an internal combustion engine according to the first aspect. The air intake system according to the invention comprises an air pump, preferably with a bellow member, which is directly or indirectly actuated by the crankshaft for compressing air or an air/fuel mixture in a compression chamber of the air intake system and transporting it to an air inlet opening of an internal combustion engine. The air pump includes preferably a bellow member comprising a plate segment and a bellow segment and preferably is arranged next to the crankcase. The air intake system may also be integrally provided at the crankcase. The plate segment, preferably a metal plate, is preferably driven by a cam and connected via a rod in order to synchronize the movement with the main cam and the crankshaft driving the piston and the movable cylinder wall segment. The bellow member allows an expedient separation of the compression chamber from the crankcase. Advantageously, the bellow is made of a flexible material so that the plate can be moved without any restriction in a wide range. The plate segment is preferably guided by guiding means or a guiding member. Suitable actuating means can be for example a cam

follower, pusher, pile or rod guided in guiding means within a respective running socket or bushing. Other preferred embodiments of actuating means and guiding means are for example a lever rod mounted at the crankcase and allowing a movement up and down to change the volume of the compression chamber like a bellow.

Accordingly the air intake portion can be advantageously implemented in high speed revolution engines allowing up to about 12.000 rev./min or even more. Preferred ranges of the practical maximum piston revolution speeds are about 6.000 to 10.000 rev./min, more preferably between about 6.000 to 8.000 rev./min.

According to a fourth aspect, the invention relates to a damping method for an internal combustion engine comprising at least the step of damping the motion of the movable cylinder wall segment in direction to the cylinder wall at its top dead centre by adjusting the speed of the movable cylinder wall segment in relation to the speed of the piston. This damping method is especially suitable for engines with high-speed revolutions of the piston and a sleeve valve and, therefore, especially for the internal combustion engine according to the first aspect. Due to the damping method the speed of the movable cylinder wall segment is lowered by means of disengaging the combined movement of the movable cylinder wall segment and the piston at a predetermined position shortly before the movable cylinder wall segment engages, i.e. lands, at its seating in the fixed cylinder wall. More particularly, the movable cylinder wall segment is preferably damped by means of an air cushion, which is generated by enclosing air in a gap between the fixed cylinder wall, the upper side or the top of the movable cylinder wall segment (also called the “crown”) and the circumferential surface of the piston. This air cushion significantly lowers the speed of the motion of the movable cylinder wall segment shortly before the movable cylinder wall engages at its seat

in the fixed cylinder wall. Therefore, high revolution speeds up to 12.000 rev./min, preferably about 6.000 to 10.000 rev./min, more preferably about 6.000 to 8.000 rev./min, can be achieved by the use of such a damping mechanism as described in the fourth aspect.

Particularly advantageous embodiments and features of the invention are given by the dependent claims, as revealed in the following description. Further embodiments may be derived by combining the features of the various embodiments described below. Of course, it is intended that the invention is not restricted to the specifically exemplified combinations of features and a skilled person can easily gather from the following description that any combination of features of the several aspects according to the invention falls within the general disclosure, even though they are not explicitly mentioned in the following.

In a preferred embodiment of the internal combustion engine according to the invention, the actuating member comprises an asymmetric cam arranged on the crankshaft, i.e. a cam with an asymmetric circumference or surface when looking onto the cam in the direction of the crankshaft. The asymmetric cam provides a number, that means a plurality like e.g. three four or five, of different control positions for actuating the movable cylinder wall segment. Each control position can be responsible for a specific position and/or function of the movable cylinder wall segment during the operating cycle and will be explained at a specific embodiment by reference to the figures. In a preferred example, the asymmetric cam has an asymmetric circumference or surface and permits the guidance of a connection member connecting the cam with the movable cylinder wall segment. The connection member is actuated by the rotation of the cam and is moved along the asymmetric circumference of the cam in a sliding arrangement. Following the asymmetric circumference of the cam, the connection member is moved up and down and, thus, the position of the mov-

able cylinder wall segment in the cylinder is adjusted in the longitudinal axis of the cylinder respectively. Up and down means the direction with regard to the longitudinal axis of the cylinder in which the piston and the movable cylinder wall are moved upwards and downwards. If the cylinder is mounted in a substantial horizontal position, up indicates the direction as to the top dead centre position of the piston stroke in the combustion chamber and down indicates the direction as to the bottom dead centre of the piston stroke.

The connection member may be a crank arm or a lever rod having a lower end connected to the crankshaft and an upper end connected to the movable cylinder wall segment. The crank arm or the lever rod guides the movable cylinder wall segment within the upper end of the fixed cylinder wall in an upward and downward direction following the circumference of the cam arranged rotating around the main axis of the crankshaft. The cam provides several control positions at its circumference. At the circumference means at its outer rotating surface of the cam. The cam provides one and, preferably two, three or more different control positions, which can be used for accurately actuating the movable cylinder wall segment. Depending on the shape of the cam and the actuation of the piston, the moveable cylinder wall segment and the piston can be controlled separately, preferably by the use of a single cam. Thus an improved control of the opening of the inlet openings and the exhaust openings by means of the movable cylinder wall segment and of the damping mechanisms are possible by this actuation control using an asymmetric cam on the crankshaft.

According to another embodiment of the internal combustion engine of the invention, the actuating member comprises a compensation arm as actuating member for damping the movement of the movable cylinder wall segment at its bottom dead centre. The compensation arm can be a longitudinal extendable arm, for example an arm made of a flexible material or com-

prising a spring or elastomeric member. The flexibility enables the compensation arm to improve the guidance of the movable cylinder wall segment during its longitudinal movement along the longitudinal axis of the fixed cylinder wall. Moreover, shortly before reaching the bottom dead centre during the downwards stroke, the compensation arm is biased, for example by increasing the spring pressure by a respective shape of the cam (e.g. a specific control position), in order to facilitate the lowering of the speed of the movable cylinder wall segment. Therefore, the spring pressure works in opposite direction to the motion of the movable cylinder wall segment and permits a damping during the landing of the movable cylinder wall segment in its seating at the bottom dead centre.

In addition, the flexibility of the compensation arm permits some compensation due to installation errors or minor differences in material thicknesses, for example of the gaskets used. Moreover, the compensation arm can absorb changes in material thickness caused by heat expansion of the cylinder wall, the piston or the movable cylinder wall segment during the use of the engine. Changes of the material thickness may also be caused by the wear. Hence, the compensation arm improves the lifetime of the movable cylinder wall segment and the surrounding members.

Exemplified materials for the piston are preferably those having a low heat expansion coefficient such as metal alloys, preferably based on titanium or aluminium, titanium, aluminium, but also carbon materials if lightweight materials are preferred. Suitable materials for the cylinder wall are preferably metal alloys such as titanium or aluminium alloys. Other materials having similar heat expansion coefficients can be used as well.

In order to improve the damping of the piston at its landing site, i.e. its seating, at the fixed cylinder wall, the in-

ternal combustion engine according to another embodiment of the invention comprises a movable cylinder wall segment with an inner bore which is substantially identical to the bore of the cylinder and having a piston damping segment with a smaller bore at its lower end. The piston can be moved along the longitudinal axis of the movable cylinder wall segment and can be oil damped at the bottom thereof in the piston damping segment. In an exemplifying embodiment, the piston damping segment comprises a groove at the bottom of the movable cylinder wall segment which is filled with cooling oil. During its downward stroke, the piston advantageously lands in a circular groove of the movable cylinder wall segment, forming an oil bath or oil pan. At this moment, oil and, thus, pressure will preferably be released through vent holes provided in the bottom of the groove in order to slowly reduce the speed of the piston and/or allowing the movement of the piston and the movable cylinder wall segment in an assembled manner to the bottom dead centre. When the assembly made of the movable cylinder wall segment and the piston approaches the bottom dead centre, the compensation arm is responsible for the damping action of the assembly as has been described before. Therefore, the piston damping segment improves the landing of the piston in the movable cylinder wall segment. Advantageously, the motion of the moveable cylinder wall segment in its downward direction can be stopped and returned by this improved damping mechanism. In addition, the oil damping advantageously facilitates the motion of the movable cylinder wall segment in upwards direction after the assembly has reached the bottom dead centre and is pushed upwards again by the motion of the cam rod member or the actuating member. The reason is that the piston sticks to the movable cylinder wall segment because of the oil placed in the small gap between the two elements. Thus, during the upwards stroke of the piston, the movable cylinder wall segment follows due to the actuating force of the actuating member and, at least in the first part of the upwards movement, the sticking at the piston.

Another embodiment of the internal combustion engine according to the invention comprises a damping system, preferably an air damping system, for damping the motion of the movable cylinder wall segment in direction to the fixed cylinder wall at its top seating position or top dead centre. In an exemplified embodiment, the damping system works by closing the gap between the upper end of the movable cylinder wall segment (also called the "crown") and the lower end of the fixed cylinder wall) while the piston closes the gap in order to provide an air cushion. This can be achieved by disengaging the movable cylinder wall segment and the piston at a position shortly before the crown will reach the seating in the fixed cylinder wall. The piston is not always accelerating, it might even have negative acceleration, i.e. be decelerating, depending on the way the engine is built (for instance it depends on the length of the piston rod, i.e. realizing a so called short or alternatively long-stroke type engine as known in the art, or on the duration of the exhaust timing, i.e. on the duration of time intervals reflecting an open exhaust port or ports or a closed exhaust port or ports, preferably defined by the height of the respective exhaust-port). The movable cylinder wall segment will however always be slowed down, i.e. be decelerated with respect to the piston by the damping system. This can, for example, be achieved by means of lowering the spring force in the compensation arm or by a respective control position at the cam actuating the actuating member for the motion of the movable cylinder wall segment. Thereby the air in the gap between the upper end of the movable cylinder wall segment and the lower end of the fixed cylinder wall, the seating, will be enclosed and more and more compressed by the upwards directed motion of the movable cylinder wall segment. Thereby, the pressure on top of the movable cylinder wall segment increases. This permits an air cushioned, i.e. a gentle, landing of the moveable cylinder wall segment in the seating area of the fixed cylinder wall at the position of the movable cylinder wall segment.

The improved damping mechanism permits higher revolutions as the conventional engines without such a special damping system, preferably up to 12.000 rev./min and more preferably about 6.000 to 8.000 rev./min.

The internal combustion engine according to another embodiment of the invention comprises a crankcase which is at least partially filled with oil. The crankcase is substantially closed and separated from the air/fuel intake and the combustion chamber to avoid any oil content in the exhaust gases. The oil level in the crankcase is at least high enough for lubricating the crankshaft and allows pumping of some oil via an oil pump to the upper cylinder part below the piston for lubrication. In an exemplified embodiment, the oil can be pumped to the cylinder wall parts which are passed over by the piston during the up- and downward strokes. Alternatively or together with the embodiment before, the oil can be collected in or pumped into a circular groove into which the piston is inserted at each stroke.

It is preferred that the oil is not only used for lubrication of the moving and rotating parts in the crankcase, but is also used for cooling the movable cylinder wall segment and the piston. As those parts usually are heated up to high temperatures, a lot of oil spray will be generated inside the crankcase, for example up to one third, preferably from 1 to 20 percent, more preferably from 1 to 10 percent, of the available volume of oil in the crankcase will be present in the form of oil spray. The oil spray is separated in the air cooling and/or oil cooling system by means of a separator. Otherwise droplets can damage the cooling fan or the centrifugal air pump. In case a part of the oil is heated to such a high temperature that it vaporizes, which is favourably kept at a minimal amount or is avoided, the vaporized oil can be condensed at a part of the crankcase having a lower temperature or in a special oil cooling system.

In order to cool the movable cylinder wall segment and/or the piston running with high revolutions in the cylinder, the internal combustion engine according to another embodiment of the invention preferably comprises a cooling air nozzle in the crankcase which is driven by a centrifugal air pump or any other expedient air pumping device. For an effective cooling action, it is preferable that the cooling air is provided to the piston and/or the movable cylinder wall segment from its bottom.

As has been described before as to the second aspect of the invention, the internal combustion engine according to a preferred embodiment may comprise a cooling air and/or oil cooling system for cooling and permitting recirculation of the cooling air and/or the oil into the crankcase. Thereby the air and the oil, advantageously the oil spray, are preferably collected shortly below the piston and movable cylinder wall segment, for example by a number of suction nozzles. The collected air/oil mixture can preferably be transferred to an external cooling system for optionally condensing the oil and separating the oil and the air by means of a separator, for example a deflector plate. The oil can be collected at the bottom of the cooling system and can be pumped back to the crankcase, e.g. pumped to the cylinder wall for cooling and lubricating the piston. The air is preferably collected at the upper part of the cooling system and can also be pumped back to the cooling air nozzle for cooling the piston and the movable cylinder wall segment again. The cooling air and/or oil cooling system preferably has an heat exchanger with a high surface to the surrounding atmosphere for cooling. The high surface can be achieved with a high number of cooling rips made of a material allowing a good heat transfer, such as a metal like iron, titanium or aluminium.

In another embodiment, the internal combustion engine according to the invention comprises an air pump in an air intake portion of the internal combustion engine for transporting

air and/or fuel to the air inlet opening. As the crankcase is encapsulated and is not used for compressing the air/fuel mixture, the inventive concept permits a separate compression of air or an air/fuel mixture. The advantage of such a separate air intake system or air intake portion is that the air/fuel mixture does not need to contain any lubricants such as oil. Therefore, an environmentally improved burning process can be used for generating the power of the engine.

The internal combustion engine according to this embodiment further can have an air pump comprising a bellow member which is directly or indirectly actuated by the rotation of the crankshaft for compressing the air/fuel mixture in the air intake portion. In an exemplified embodiment, the bellow member may be supported by a plate linked to the crankshaft and working in a substantially inverted movement opposed to the piston direction. Substantially inverted movement means that the bellow member is moved up and down by a cam nearly with the same revolutions as the piston, but might be timely asymmetrically synchronized with the movement of the piston. The asymmetrical synchronization can improve the so called scavenging phenomenon. This is a further advantage of the present invention, because the synchronization could be controlled separately from the movement of the piston or at least varied in a specific time frame.

Alternatively, the air intake portion comprises a guided intake-membrane. In a guided intake-membrane, the membrane plates which are preferably made from or comprise a fibre enhanced or reinforced material, are forced open mechanically at the moment the exhaust-pipe works at its optimal range in terms of RPMs (rev./mins), i.e. the RPMs are in the range of a resonance frequency of the exhaust pipe. At that moment the exhaust sucks the air more efficiently than a crankcase-pump or the bellow member described in one of the above embodiments. The membrane is preferably completely opened during the sucking of air into the combustion chamber, avoiding un-

necessary drag, i.e. air resistance. Hence, the use of a guided air intake-membrane is an advantageous way for gaining extra power for an internal combustion engine as described.

Balancing counter shafts can be attached to the crankshaft in order to permit an improved and smooth revolution of the crankshaft. The shape and the size of such balancing counter shafts generally are adjusted by the skilled person dependent on the imbalance of the crankshaft which is caused by any of the cams or rods mounted thereon.

Another preferred embodiment of an internal combustion engine may be equipped with a cylinder having a variable combustion chamber. The cylinder preferably comprises a cylinder head with a movable core element. Movable means that the core element can be moved in order to enlarge the volume of the combustion chamber or to make its volume smaller. Advantageously, the movable core element is movable in the same direction as the piston in the cylinder. By varying the volume of the combustion chamber, the efficiency of the engine can be advantageously adjusted. The volume of the combustion chamber may be adjusted by means of a hydraulically driven movable inner core which can be controlled electronically and/or mechanically.

Another embodiment of the internal combustion engine according to the invention comprises a fuel injection pump for injecting fuel into the combustion chamber. This direct injection of the fuel into the combustion chamber by a fuel injection pump in a cold or supercritical state is possible due to the general construction of the internal combustion engine as described before. Advantageously the separation between the crankcase and the combustion chamber permits the direct injection of the fuel into the combustion chamber. The reason is that the crankcase is separately lubricated and the air/fuel mixture does not need any lubricants anymore. Thus, it is preferred that the air intake only passes fresh air to

the combustion chamber and the fuel is injected directly into the combustion chamber. The injection of the fuel may be carried out from the top of the cylinder or from a number of nozzles at the upper part of the cylinder wall. Preferably the injection may be assisted by air in order to improve the air/fuel content of the mixture. This would permit the adjustment of an improved burning condition, for example adjusting the engine as a lean burn system.

In a further embodiment, the internal combustion engine may comprise a power valve at its exhaust opening. This power valve includes an adjustable valve section in order to adjust the height of the exhaust opening (exhaust port). The valve is preferably a sliding member which protrudes into the exhaust port and is adapted to adjust the height of the exhaust port in a predefined amount, depending on the setting or adjustment of the power valve. The sliding member is preferably in a sliding engagement parallel to the fixed cylinder wall and the movable cylinder wall segment. Thus, the clearance between the movable cylinder wall segment and the sliding member is similar or substantially identical at all positions, preferably in a range of a view millimetres, more preferably between about 0,5 mm and 3 mm, especially between about 0,5 mm and 1,5 mm. The power valve can close the exhaust port up to about 40 percent, more preferably up to about 30 percent and is especially adjustable within a closing range of about 1 percent to 40 percent, more preferably of about 1 percent to 30 percent, especially about 1 percent to 20 percent.

Exceeding the design of conventional power valves, the parallel sliding arrangement improves the power valve according the present invention inter alia in minimizing the clearance provided between the movable cylinder wall segment and the power valve sliding member.

In addition, the specific design of the sliding members enables the use of such power valves at the air intake ports as well. Hence the invention enables the power valve to be designed sufficiently compact to be used at the air intake ports which was prohibited in conventional two stroke engines because of the lack of enough room for providing a power valve at this position. The conventional power valves are diagonally oriented with regard to the piston, so that a big clearance is present if the power valve is opened to some extent.

In a preferred embodiment of the internal combustion engine according to the invention, the power valves can be provided substantially parallel to the movable cylinder wall segment, i.e. outside the fixed cylinder wall and in parallel direction thereto. Thus, it is preferred that the internal combustion engine according to the invention has an adjustable air intake port as well. In this case, it is possible to raise the exhaust port height and the air intake port height simultaneously in an identical manner (linear adjustment of both power valves) or at least in a substantially similar manner. For Example, it is possible to close the exhaust port height by about 30 percent while the air intake port height may be reduced by about 10 percent only.

If a power valve is provided at the exhaust port and the air intake port, the handling will be improved, especially with regard to a wider power-band adjustment or a better efficiency.

The internal combustion engine is preferably equipped with at least one, preferably two, three or more of the air inlet openings which are adjustable in its/their heights. Adjustable in their heights means that the size of each of the openings, i.e. the opening area in its height or width or diameter, is variable such as in the power valves explained before. The height adjustable air inlet openings are advanta-

geous because they can be used to improve the scavenging phenomenon by adjusting the size of the opening.

The above preferred embodiments described with regard to the internal combustion engine according to the first aspect of the invention can suitably adapted to or used in combination with the cooling air and/or oil cooling system according to the second aspect or the air intake system according to the third aspect or the damping method for an internal combustion engine according to the fourth aspect of the invention.

Other objects and features of the present invention will become apparent from the following detailed descriptions considered in conjunction with the accompanying drawings. It is to be understood, however, that the drawings are designed solely for the purposes of illustration and not as a definition of the limits of the invention.

Fig. 1 shows a cross-sectional view of an internal combustion engine according to an embodiment of the invention during a working cycle at the top dead centre of the piston;

Figs. 2A, 2B, and 2C show a cross-sectional view of an internal combustion engine according to Fig. 1 during the same working cycle at the moment of starting the movement of the movable cylinder wall segment;

Fig. 3 shows a cross-sectional view of an internal combustion engine according to Fig. 1 during the same working cycle at the bottom dead centre of the piston;

Fig. 4 shows a cross-sectional view of an internal combustion engine according to Fig. 1 during the same working cycle at the moment of closing the air inlet openings;

Figs. 5A and 5B show a cross-sectional view of an internal combustion engine according to Fig. 1 during the same working

cycle at the moment of closing the gap between the movable cylinder wall segment and the fixed cylinder wall;

Fig. 6 shows a cross-sectional view of the movable cylinder wall segment with the actuating member according to the embodiment shown in Fig. 1;

Figs. 7A to 7H show cross-sectional views of an internal combustion engine according to a second embodiment of the invention during one operating cycle at eight different positions of the piston;

Fig. 8 shows a schematic cross-sectional view of an internal combustion engine according to a third embodiment of the invention with a cooling air and/or oil cooling system arranged thereto;

Fig. 9 shows a schematic sectional plan view of an internal combustion engine according to a fourth embodiment of the invention with an air intake portion for an internal combustion engine;

Fig. 10 shows a cross-sectional view of an air intake portion of an internal combustion engine according to a fifth embodiment of the invention;

Fig. 11 shows a cross sectional view of a cylinder of a conventional two stroke engine comprising a power valve;

Fig. 12 shows a cross sectional view of a cylinder of an internal combustion engine with power valves according to a further embodiment of the invention;

Fig. 13 shows a cylinder with a variable combustion chamber for the use in an internal combustion engine according to a further embodiment of the invention.

In the drawings, like reference numbers refer to like objects throughout. Objects in the diagrams are not necessarily drawn to scale.

Fig. 1 shows a cross-sectional view of an internal combustion engine according to an embodiment of the invention during a working cycle at the top dead centre of the piston. The internal combustion engine is based on a two stroke Otto cycle. It comprises a cylinder 10 having a fixed cylinder wall 12, a movable cylinder wall segment 14, a combustion chamber 15, an actuating member 16 including a spring 17, a piston 18, a crankcase 20, a crankshaft 22, an asymmetric cam 24, a piston rod 26, a fuel injection pump 30, a spark 32, air inlet openings 34, exhaust openings 36 and exhaust ports 37. The internal combustion engine further comprises an air intake portion 40 with a plate actuating rod 42, a bellow member 44 including a plate 45 and a bellow 46, a compression chamber 47, a guiding means 48, and an air inlet nozzle 50. In the crankcase 20, a cooling air nozzle 61, a cooling air and/or oil collecting member 62, and an oil pump 64 are provided. In addition, Fig. 1 shows the position of a kick starter 70, a primary gear shaft 80, a secondary gear shaft 85, and a gear-selector drum 90.

The piston 18 is at its top dead centre so that the piston rod 26 is in upright position. The piston is fully disengaged from the movable cylinder wall segment. The air inlet openings 34 and the exhaust openings 36 are closed by the movable cylinder wall segment 14. At this time, the air/fuel mixture in the combustion chamber 15 is ignited by the spark 32 and the burning fuel suddenly expands its volume. Thereby the piston 18 is pushed downwards and rotates the crankshaft via the piston rod 26.

The air intake portion 40 is in a status of sucking air into the compression chamber 47 via the air inlet nozzle 50. The plate 45 of the bellow member 44 is in a position of its low-

er dead centre. That means that the compression chamber 47 has a volume at its maximum level. Thus, the driving force for sucking air is the low pressure, preferably vacuum, in the compression chamber 47.

The Fig. 2A shows the same internal combustion engine as shown in Fig. 1 during the moment of opening the moveable cylinder wall segment 14. At this moment, the upper surface of the piston 18 reaches the upper end of the movable cylinder wall segment 14. At the same time, the piston 18 lands in the piston damping segment 119 provided at the bottom end of the movable cylinder wall segment 14. Before the piston 18 lands therein, the movable cylinder wall segment is slightly moved by an air pressure wave produced by the circular shaped bottom of the skirt of the piston 18, which substantially corresponds to the shaped circular damping segment 119 of the movable cylinder wall segment 14. The bottom of the circular damping segment 119 is shaped in such a manner that the pressure will increase slowly. The movement of the movable cylinder wall segment 14 caused by the air wave of the piston 18 sliding in a downwards direction results in a slight move of the upper segment (i.e. of the crown) of the movable cylinder wall 14 away from its seat at the fixed cylinder wall 12. Thereby a small gap 130 in the range of a few millimetres will be generated between the movable cylinder wall segment 14 and the fixed cylinder wall 12 as it is shown in the enlarged view "b" (cf. Fig. 2C).

As the gap 130 allows the combustion gas to flow into the gap, the pressure in the gap will increase substantially to the pressure of the combustion gas present in the combustion chamber 15. Thereby, the combustion gas pressure brings the movable cylinder wall segment 14 to a speed which is substantially the same as the speed of the piston. This permits a gentle engagement of the piston 18 in the movable cylinder wall segment 14 and also an improved adjustment or matching of the speed of both parts.

At the same time, the piston 18 lands in an oil bath for damping the motion of the piston 18. This is shown in Fig. 2B which is an enlarged view of the part "a" of Fig. 2A, the piston damping segment 119 essentially consist of the circular groove which has the same shape as the bottom of the piston 18 with the circular protrusion 118. The groove is filled with cooling oil which is also used for lubricating the motion of the piston 18 in the movable cylinder wall segment 14 having an inner wall 114 made from a material having a low heat expansion coefficient such as titanium. At the bottom of the groove 119, vent holes are provided for permitting the flow of oil there trough. The flow of oil through the vent holes reduces the pressure build up by the landing piston 18 in the groove 119. Thus, the speed of the piston 18 is slowly reduced to provide an oil damped landing of the piston 18 at the piston damping segment 119.

Accordingly, the piston 18 moves together with the movable cylinder wall segment 14 in an assembled manner downwards in the direction to the bottom dead centre after its landing in the piston damping segment 119.

The piston has a number of piston rings 125 to avoid that oil can escape into the combustion chamber. Three piston rings 125 are shown in Fig. 2C. In addition, small circular grooves 135 are provided in the wall of the fixed cylinder in the segment of the small gap 130 opened by means of the air wave of the skirt of the piston 18 generated by the downwards motion of the piston 18. The small circular grooves 135 are connected with the exhaust opening and permit an improved transport of the hot combustion gases to the exhaust opening. Especially, the groves 135 lead hot combustion gasses which have leaked past the movable cylinder wall segment 14 without upper rings to the exhaust side. Thereby, the combustion gases are prevented from being mixed with the fresh air/fuel mixture in the intake ports.

Fig. 3 shows a cross-sectional view of an internal combustion engine according to Fig. 1 during the same working cycle, but at the bottom dead centre of the piston 18. The movable cylinder wall segment 14 is at its lowest point as well. Thereby, the air inlet opening 34 and the exhaust opening are fully opened. The fresh air/fuel mixture (arrow "A") which has been compressed by the bellow member 44 in the air intake portion 40 is automatically pressed into the combustion chamber 15. This scavenging process is in the internal combustion engine of the invention improved, because of the large volume in the cylinder created by the movement of the movable cylinder wall segment 14.

At the same time the exhaust gases (arrow "E") are forced to the exhaust pipe in order to fill the combustion chamber 15 with a fresh air or air/fuel mixture, respectively. As can be seen in the open position of the air inlet openings 34 and the exhaust openings 36, it can be gathered from Fig. 3 that the cylinder volume and, therefore, its capacity is locally larger than in a conventional two stroke engine without a movable cylinder wall segment 14. The reason is that the movable cylinder wall segment 14 moves downwards and widens the bore of the cylinder 10 at the same time of opening the air inlet openings 34 and exhaust openings 36. This results in an improvement of the scavenging process.

Fig. 4 shows a cross-sectional view of an internal combustion engine according to Fig. 1 during the same working cycle at the moment of closing the air inlet openings 34 in the cylinder 10 by the movable cylinder wall segment 14. At this moment, the exhaust openings 36 are still open to a reasonable amount and some of the gases in the exhaust pipe are forced back into the combustion chamber 15 of the cylinder due to the pressure wave created by the design of the expansion pipe. This further improves the next ignition process, because it is known that small amount of exhaust gases can

serve as a catalyst for the next combustion step. The enlarged view in Fig. 4 shows an extra clearance C1 between the movable cylinder wall segment 14 and the upper part of the lower fixed cylinder wall. This clearance is advantageous because of the possibility of tilting of the movable cylinder wall segment 14 in some extent. Thus, the movable cylinder wall segment 14 can slide inside the fixed cylinder wall 12 without touching it. As there is no lubrication in this area, the clearance C1 avoids wear and tear in the cylinder wall segment 14 as well as in the fixed cylinder wall 12.

Fig. 5A shows a cross-sectional view of an internal combustion engine according to Fig. 1 during the same working cycle at the moment of closing the gap between the movable cylinder wall segment 14 and the fixed cylinder wall 12.

As can be seen from Fig. 5A, the exhaust opening has already been closed at the time of landing the movable cylinder wall segment 14 in its seat at the fixed cylinder wall 12. A small gap 150 is still open between the crown of the movable cylinder wall segment 14 and the bottom section of the fixed cylinder wall 12, while the speed of the movable cylinder wall segment 14 is lowered in relation to the speed of the piston 18. This results in a situation in which the gap 150 is nearly closed and the pressure of the remaining air in the gap is raised due to the compression of the air enclosed therein. The remaining air is pressed out of the gap 150 into the combustion chamber 15 in order to result in an improved swirling action towards the centre of the combustion chamber. This state is shown in Fig. 5B in an enlarged view. Thereby an improved mixing result and an extinguishing of hot gases in the gap 150 can be achieved.

In addition to the extra swirl of the remaining air, the increased pressure inside the gap 150 permits a gentle landing of the movable cylinder wall segment 14 in its seat at the fixed cylinder wall 12. The number of revolutions can be in-

creased compared to conventional internal combustion engines when using this air damping process together with a movable cylinder wall segment 14.

Fig. 6 shows a cross-sectional view of the movable cylinder wall segment 14 with the actuating member 16 according to the embodiment shown in Fig. 1. The movable cylinder wall 14 comprises at its bottom section a piston damping segment with grooves 119 and vent holes 120 for oil damping during the downwards stroke of the piston (not shown). The movable cylinder wall 14 comprises an actuating member 16 with a spring 17 as a compensation arm mounted between the cam (not shown) and the movable cylinder wall segment 14. The arm is connected by a wheel 200 or a sliding device like a rocker arm to the cam in order to follow the circumference of the cam. It is further connected to the movable cylinder wall segment 14 by a connecting member 210 in a non-rigid or slightly flexible manner in order to allow some compensation motions of the actuating member 16.

The compensation motions are limited by the buffers 220 and 230 in order to restrict the movement of the movable cylinder wall segment 14 during the damping of the piston (not shown) in the piston damping segment 119. The buffers 220 and 230 allow a maximal movement MAX of the actuating member 16 in a range of few millimetres, preferably about 3 to 5 mm in the exemplified internal combustion engine. Thereby, it can be secured that the piston (not shown) rises too much about the upper side of the movable cylinder wall segment 14 during the upwards stroke. In Fig. 6, the angle MIN identifies the minimum angle which can be used for compensation activity. If the actuating member is in this position, the movable cylinder wall segment 14 is moved in an upwards direction.

In addition, the movable cylinder wall 14 comprises skirts 250 to prevent it from fluttering within the cylinder bore. The skirts 250 are provided at both sides of the actuating

member in this embodiment, but can also be provided at one side only. Moreover, the retainer 240 is a rotation preventing member in order to hinder the movable cylinder wall segment 14 to start rotating within the fixed cylinder wall (not shown). The retainer can be moved in a respective guiding rail (not shown).

In Figs. 7A to 7H an internal combustion engine according to a second embodiment of the invention is shown during one operating cycle. The Figures show a cylinder 12 with an air inlet opening (not shown) and an exhaust port 37, an asymmetric cam 24, the piston rod 26, the actuating member 16, the piston 18, and the movable cylinder wall segment 14 at eight different positions of the piston 18. The sequence of eight views explains the operation of the asymmetric cam and the actuating member during the operation cycle in greater detail.

In Fig. 7A, the piston is moved downwards, i.e. in the direction of the bottom dead centre. The situation 3 mm before opening the exhaust port 37 is shown. The detail $A_1$ shows the complete sealing of the movable cylinder wall segment 14 and the cylinder wall 12 because of the high spring pressure generated by the spring 17 of the actuating member 16 which is held in position 1 by the asymmetric cam 24. The detail $B_1$ shows the circular groove of the piston damping segment 119. At this moment, some pressure is being build up in the groove, though there is still some space for air to escape at points $C_1$ and $D_1$.

In Fig. 7B, the piston is moved downwards by 1 mm, whereby the sealing at detail $A_1$ is still present, while the air pressure at the piston damping segment 119 is being build up due to the smaller gap at points $C_1$ and $D_1$. As the circumference of the asymmetric cam 24 at the contact position of the actuating member 16 to the asymmetric cam 24 drops faster than the piston moves downwards (see detail $E_1$), the spring

pressure of the spring 17 is reduced to some extent. Thus, the actuating member changes into position 2, that means in a position, in which the tension of the movable cylinder wall segment is reduced.

The Fig. 7C shows the situation 1 mm before opening the exhaust port 37. Due to the asymmetric circumference of the cam 24 (see detail $D_2$), the actuating member 16 is almost completely loose from the asymmetric cam 24 because of the contact with buffer 220 (see detail $C_2$). This position of the actuating member 16 is called position 3. In addition, the piston 18 is almost landed in the groove of the piston damping segment 119. Thus, the air is fully compressed in the circular groove. Due to the compression at the piston damping segment 119 (see detail $B_2$) and the loosened spring pressure, the movable cylinder wall segment 14 moves downwards as well so that its sealing position at the fixed cylinder wall 12 is slightly opened (see detail $A_2$).

In Fig. 7D, the piston has now full contact with the movable cylinder wall segment 14, i.e. the piston has hit the oil bath provided at the ground of the grooves in the piston damping section 119. The oil is squeezed out through the vent holes 120, thus enhancing the damping effect of the piston 18. As the piston is now engaged with the movable cylinder wall segment 14, the gap (see detail $A_3$) opens. Thus, the compressed air/combustion gases penetrate into the gap and push the movable cylinder wall segment downwards. This action is damped to some extent by the force of the spring 17 of the actuating member 16 which is now in position 2 (that means contacted with the circumference of the cam 24) again. After this point in the operating cycle, the piston 18 drags along the movable cylinder wall segment 14 while the actuating member is in position 2.

The Fig. 7E shows the situation in the operating cycle in which the exhaust port 37 is fully opened and the piston 18

is at its bottom dead centre. The actuating member 16 is again in position 1 by means of the raised pressure of the cam 24 against the actuating member 16. The force of the spring 17 increases at the same time and helps the movable cylinder wall segment 14 getting upwards after having passed the bottom dead centre.

In Fig. 7F, the piston has moved about 5 mm upwards and the shape of the cam 24 lowers the position of the actuating member 16 again to position 2, that means lowering the spring force acting on the movable cylinder wall segment 14.

Fig. 7G shows the point at which the exhaust port is closed (please see detail $A_4$) by means of the movable cylinder wall segment 14. From this point of the operating circle, the movable cylinder wall segment 14 will start to slow down due to the air compression build up above the crown of the movable cylinder wall segment 14.

In Fig. 7H the situation approximately 1 mm before closing the gap between the crown of the movable cylinder wall segment 14 and the fixed cylinder wall 12 is shown ($A_4$). The spring pressure is completely loosened by changing the shape of the circumference of the cam 24 at this time so that the actuating member is in position 3 again. The actuating member 16 is preferably some tenth of a millimeter (detail $B_4$) away from the circumference of the cam 24 at this point of the operating circle. Due to the lowering of the force acting on the movable cylinder wall segment 14, the piston 18 can escape the movable cylinder wall segment 14 so that the piston 18 is moved faster compared to the movable cylinder wall segment 14. Thus the air in the gap between the crown of the movable cylinder wall segment 14 and the fixed cylinder wall 12 (see detail $A_4$) is blocked from escaping. The remaining air acts as an air damping system. During the closing of the gap by means of bringing the actuating member in position 1 by means of increasing the cam height of the cam 24, the

closing movable cylinder wall segment, the air acts as an air cushioning system improving the long-life of the engine.

Now the gap is closed again and the piston can go to its top dead centre and start a new operating cycle. The actuating member as well as the air damping and air cushioning systems used during the downwards and upwards strokes of the piston allow high revolutions and a long life of the engine.

Fig. 8 shows a schematic cross-sectional view of an internal combustion engine 1 according to a third embodiment of the invention with a cooling air and/or oil cooling system 60 arranged thereto. The cooling air and/or oil cooling system 60 comprises a cooling air nozzle 61, a cooling air and/or oil collecting member 62, a centrifugal air pump 63 (or optional an air pumping device with another constructional design), an oil pump 64, a hot air pipe 65, a cool air pipe 66, a cool oil pipe 67, an oil cooler connecting pipe 68, and a lubricating pipe 69.

The cooling air and/or oil collecting system comprises an air cooling section X, an air/oil separation section Y, and an oil cooling section Z for separating and cooling the air and/or oil components present in the circulation system of the internal combustion engine 1 according to the invention.

Cooling and lubricating oil O is cooled in the oil cooling section Z and delivered through the cool oil pipe 67 to the crank case 20 which is partly filled with oil O. The oil is usually collected at the bottom of the crankcase and pumped by the oil pump 64 optionally provided with an oil filter (not shown) via the oil cooler connecting pipe 68 back to the hot oil inlet W at the oil cooling section Z for cooling the oil and via the lubricating pipe 69 to the ports and bearings for lubrication of the piston and movable parts of the engine.

The centrifugal air pump 63 pumps cooling air via the cooling air nozzle 61 to the bottom of the piston 18 and movable cylinder wall segment 14 in order to cool the hottest parts of the moving elements in the engine. This additional air cooling allows higher revolution speeds than in conventional engines without additional air cooling. The cooling air is collected in the cooling air and/or oil collecting member 62 which is directly placed in the upper part of the crankcase 20 and below the movable cylinder wall segment. The collecting member sucks hot air and oil spray in order to transport them via the hot air pipe 65 into the air/oil separation section Y. In this section, the air and the oil are separated by means of a number of deflecting plates so that the oil in form of droplets is collected at its bottom and passed to the oil cooling section Z and the hot air is collected at the upper part of the separation section Y and transferred to the air cooling section X. After cooling the air, the cooled air is transported via the cool air pipe 66 to the centrifugal air pump 61 to start a new cooling cycle.

Fig. 9 shows a schematic sectional plan view of an internal combustion engine according to a fourth embodiment of the invention with an air intake portion 40 for an internal combustion engine. The air intake portion 40 comprises a bellow member consisting of a metal plate 45 and a rubber bellow 46, two plate guidance rods 48 for guiding the motion of the plate, and an air inlet nozzle 50 (usually called “carb”) with membrane members 51 as a check-valve with an air inlet choke.

The metal plate 45 and the rubber bellow 46 can be moved down and up, that means out of the plane of the sheet in order to compress the air in the compression chamber (above the sheet plane) and forcing the compressed air into the transfer ports A1, A2, A3 and the boost ports B (one is shown in this embodiment). The end of the port A1, A2, A3 and B are the air inlet openings into the cylinder 10 which are opened and

closed by the movable cylinder wall segment 14. The air is sucked into the air inlet nozzle 50 by means of an under-pressure in the compression chamber of the air intake portion 40 and transferred via the membrane members 51 and the transfer ports A1, A2, A3 and the boost port B to the combustion chamber (not shown) arranged above the piston 18.

After the ignition of the air/fuel mixture in the combustion chamber (not shown), the exhaust gases are transferred to the exhaust ports 37 into the exhaust pipe (not shown) and a new cycle will be started.

Fig. 10 shows a cross-sectional view of an air intake portion 40 of an internal combustion engine according to a fifth embodiment of the invention. The air intake portion 40 comprises a bellow member 44 consisting of a metal plate 45 and a rubber bellow 46, a plate guidance member 48 for guiding the motion of the plate, an plate actuating rod 42, a bellow cam 43 and an air inlet nozzle 50 (usually called "carb") with membrane members 51 as a check-valve with an air inlet choke. The air intake portion 40 is arranged next to the cylinder 10 with a fixed cylinder wall 12 and air inlet openings 34. The bellow cam 43 is driven by means of the main cam 24 or the crankshaft (not shown), for example by means of a driving belt or chain (not shown). Alternatively, it can also be driven by means of other mechanical and electrical solutions.

The metal plate 45 and the rubber bellow 46 can be moved down and up like a bellow in order to compress the air in the compression chamber (47) and pushing the compressed air to the air inlet openings 34. The motion is in this embodiment guided by means of the plate guidance member 48 which holds the metal plate 45 via a lever arm.

The highest compression is achieved in the position "C" of the metal plate while the position "S" means that a vacuum is

provided in the compression chamber to suck fresh air via the air inlet nozzle 50 and the membrane 51 into the compression chamber (as shown in Fig. 10).

The embodiment of Fig. 10 allows an advantageous compact construction of the air intake portion. Especially, a short distance between intake ports and inlet nozzle 50 can be provided. Moreover, compared to the embodiment shown in Fig. 9, no lubrication is necessary as guidance rods are not provided in this embodiment. This embodiment is additionally advantageous in providing a shorter distance between the intake ports and the carburator or air intake nozzle.

Fig. 11 shows a cross sectional view of a cylinder 312 of a conventional two stroke engine comprising a power valve 338 at its exhaust opening 336. The engine has a cylinder 312, an air inlet opening 334 with a fixed height B' at its air intake port 335, an exhaust pipe 333, an exhaust opening 336, and a power valve 338 at its exhaust opening 336.

The power valve 338 with a sliding member can be diagonally slide into the upper part of the exhaust opening 336 to replace the free upper part of the opening with a side wall element 339 in a specific amount. If the sliding member is engaged at its lowest position (position A'), the exhaust port has its minimum port height. The port height can be freely adjusted by pulling the sliding member backwards so that the port opening is opened to some extent (position D') or totally. As the sliding member slides in a diagonal direction, there remains a clearance C' from the piston (not shown) in this conventional two stroke engine.

Fig. 12 shows a cross sectional view of a cylinder 12 of an internal combustion engine according to a further embodiment of the invention. In this embodiment, the engine comprises a cylinder 12 with a fixed cylinder head 122 and a movable cylinder wall 14, an air intake port 35 with an air inlet open-

ing 34, an exhaust opening 36, an intake power valve 38 at the air intake port 35 and a power valve 39 at the exhaust opening 36.

The intake power valve 38 and the power valve 39 include an adjustable valve section in order to adjust the height of the air inlet opening 34 at the air intake port 35 and the exhaust opening (exhaust port) 36 by a specific adjusting height A'' and B'', respectively. The intake power valve 38 and the power valve 39 are preferably sliding members which protrude into the exhaust port and intake port, respectively. The sliding members are in a sliding engagement parallel to the fixed cylinder wall 12 and the movable cylinder wall segment 14. Thus, the clearance C'' between the movable cylinder wall segment 14 and the intake power valve 38 and the power valve 39 is similar or substantially identical at all positions.

Compared to the conventional power valve shown in Fig. 11, the parallel sliding arrangement improves the power valve as used according the present invention especially in the less clearance provided between the movable cylinder wall segment and the power valve sliding member. In addition, the specific design of the sliding members enables the use of such power valves at the air inlet ports as well. Thereby, the handling is improved, especially with regard to a wider power-band adjustment or a better efficiency.

Fig. 13 shows a cylinder 12 with a variable combustion chamber 18 for the use in an internal combustion engine according to a further embodiment of the invention. The cylinder 12 comprises a cylinder head 122 with a movable core element 412 including a spark 32. The movable core is movable in the same direction as the piston 18 moves in the cylinder 12, thereby changing the volume of the combustion chamber 15. If the movable core element 412 is moved out of the cylinder head 122, the volume will be bigger, while the volume will be smaller

if the movable core element 412 is pushed into the cylinder 12. Thereby the efficiency of the engine can be advantageously adjusted by varying the volume of the combustion chamber.

The movable core element 412 is sealed against the cylinder head 122 by means of a number of seals 420. As the variable combustion chamber is driven hydraulically, the cylinder head 122 comprises an upper hydraulic oil chamber 430 including the oil channel 435 and a bottom hydraulic oil chamber 440 including the oil channel 445. The upper hydraulic oil chamber 430 is arranged as a groove around the movable core member 412. The bottom hydraulic oil chamber 440 is arranged in the same manner around the core member 412. Between both chambers 430 and 440, the movable inner core member has one or more protrusions 450 including a seal 420 to avoid any leakage from the upper oil chamber 430 to the bottom oil chamber 440. By means of pumping hydraulic oil via the oil channels 435 and 445 from the upper oil chamber into the bottom oil chamber and vice versa, the position of the movable core element 412 can be adjusted. If more hydraulic oil is pumped into the upper oil chamber 430, the combustion chamber volume will be decreased and it will be increased by means of pumping oil from the upper oil chamber 430 into the bottom oil chamber 440.

Although the present invention has been disclosed in the form of preferred embodiments and variations thereon, it will be understood that numerous additional modifications and variations could be made thereto without departing from the scope of the invention. While the internal combustion engine is described with regard to a two-stroke engine, it is also possible to apply the present constitution or at least parts of it to a four-stroke internal combustion engine. For example, the air intake portion or the cooling air or oil recovering system can be used in such an engine as well. Moreover, the general concept of the present invention has been described with

regard to one cylinder only, but the skilled person knows how this concept can be used with a engine having two or more cylinders, for example three, four, six, eight or twelve cylinders. Moreover, the air intake portion can be a compressor or a 24/7-intake system instead of the herein described below system. For the sake of clarity, it is to be understood that the use of "a" or "an" throughout this application does not exclude a plurality, and "comprising" does not exclude other steps or elements. A "member" or "means" can comprise a number of members or means, unless otherwise stated.

List of Reference Signs

| | |
|---|---|
| 1 | internal combustion engine |
| 10 | cylinder |
| 12 | fixed cylinder wall |
| 14 | movable cylinder wall segment |
| 15 | combustion chamber |
| 16 | actuating member |
| 17 | spring |
| 18 | piston |
| 20 | crankcase |
| 22 | crankshaft |
| 24 | asymmetric cam |
| 26 | piston rod |
| 30 | fuel injection pump |
| 32 | spark |
| 34 | air inlet opening |
| 35 | air intake port |
| 36 | exhaust opening |
| 37 | exhaust ports |
| 38 | intake power valve |
| 39 | power valve |
| 40 | air intake portion |
| 42 | plate actuating rod |
| 43 | bellow cam |
| 44 | bellow member |
| 45 | plate |
| 46 | bellow |
| 47 | compression chamber |
| 48 | guiding means |
| 50 | air inlet nozzle |
| 51 | membrane member |
| 60 | cooling air and/or oil cooling system |
| 61 | cooling air nozzle |
| 62 | cooling air and/or oil collecting member |
| 63 | air pump |
| 64 | oil pump |

65 hot air pipe
66 cool air pipe
67 cool oil pipe
68 oil cooler connecting pipe
69 lubricating pipe
70 kick starter
80 primary gear shaft
85 secondary gear shaft
90 gear-selector drum
114 inner wall
118 protrusion
119 piston damping segment
120 vent holes
122 cylinder head
125 piston ring
130 gap
135 grooves
150 gap
200 wheel
210 connecting member
220 buffer
230 buffer
240 retainer
250 skirt
312 cylinder
333 exhaust pipe
334 air inlet opening
335 air intake port
336 exhaust opening
338 power valve
339 power valve
412 movable core element
420 seal
430 upper hydraulic oil chamber
435 oil channel
440 bottom hydraulic oil chamber
445 oil channel

450 protrusion

A arrow
A1 transfer port
A2 transfer port
A3 transfer port
B boost port
C position
C1 clearance
E arrow
$A_{1-4}$ detail
$B_{1-4}$ detail
$C_1$ point
$C_2$ detail
$D_1$ point
$D_2$ detail
$E_1$ detail
A′ position
A′′ adjusted height
B′ fixed height
B′′ adjusted height
C′ clearance
C′′ clearance
D′ position
MAX maximal movement
MIN angle
O oil
S position
W oil inlet
X air cooling section
Y air/oil separation section
Z oil cooling section

Claims

1. An internal combustion engine (1) comprising a cylinder having a cylinder wall (12) forming a main part of a combustion chamber (15) and having a number of air inlet openings (34) and a number of exhaust openings (36) in the cylinder wall (12), a piston (18) movably arranged in the cylinder (10), a crankcase (20), a crankshaft (22) arranged in the crankcase (20), and a piston rod (26) connecting the crankshaft (22) with the piston (18), wherein the cylinder (10) comprises a movable cylinder wall segment (14) for opening and closing the air inlet openings (34) and/or the exhaust openings (36), and an actuating member (16) for actuating the movable cylinder wall segment (14) directly or indirectly by the crankshaft (22).

2. The internal combustion engine according to claim 1, wherein the actuating member (16) comprises an asymmetric cam (24) arranged on the crankshaft (22) providing a number of control positions for actuating the movable cylinder wall segment (14).

3. The internal combustion engine according to claim 1 or 2, wherein the actuating member (16) comprises a compensation arm as actuating member (16) for damping the movement of the movable cylinder wall segment (14) at its bottom dead centre.

4. The internal combustion engine according to one of the preceding claims, wherein the movable cylinder wall segment (14) has an inner bore which is substantially identical to the bore of the cylinder (10) and a piston damping segment (119) with a smaller bore at its lower end.

5. The internal combustion engine according to one of the preceding claims, comprising a damping system for damping the motion of the movable cylinder wall segment (14) in direction to the cylinder wall (12) at its top dead centre.

6. The internal combustion engine according to one of the preceding claims, wherein the crankcase (20) is partially filled with oil.

7. The internal combustion engine according to one of the preceding claims, further comprising a cooling air nozzle 61 in the crankcase (20) for cooling the piston 18 and/or the movable cylinder wall segment (14).

8. The internal combustion engine according to claim 6 or 7, comprising a cooling air and/or oil cooling system (60).

9. The internal combustion engine according to one of the preceding claims, comprising an air pump (44) in an air intake portion (40) of the internal combustion engine for transporting air and/or fuel to the air inlet opening (34).

10. The internal combustion engine according to claim 10, wherein the air pump comprises a bellow member (44) actuated by the rotation of the crankshaft (22) for compressing the air/fuel mixture in the air intake portion (40).

11. The internal combustion engine according to one of the preceding claims, comprising a fuel injection pump (30) for injecting fuel into the combustion chamber (15).

12. The internal combustion engine according to one of the preceding claims, wherein at least one of the air inlet openings (34) is adjustable in its height.

13. A cooling air and/or oil cooling system (60) for an internal combustion engine, comprising means for cooling and recycling cooling air and/or cooling oil collected in a crankcase (20) in a separate cooling system and for recirculating them into the crankcase (20).

14. An air intake system (40) for an internal combustion engine, comprising a bellow member (44) directly or indirectly actuated by a crankshaft (22) for compressing air or air/fuel mixture in the air intake system (40) and transporting it to an air inlet opening (34) of an internal combustion engine.

15. A damping method for an internal combustion engine (1) having a movable cylinder wall segment (14) and a piston (18) revolving therein, comprising the step of damping the motion of a movable cylinder wall segment (14) in direction to a cylinder wall (12) at its top dead centre by adjusting the speed of the movable cylinder wall segment (14) in relation to the speed of the piston (18).

FIG 1

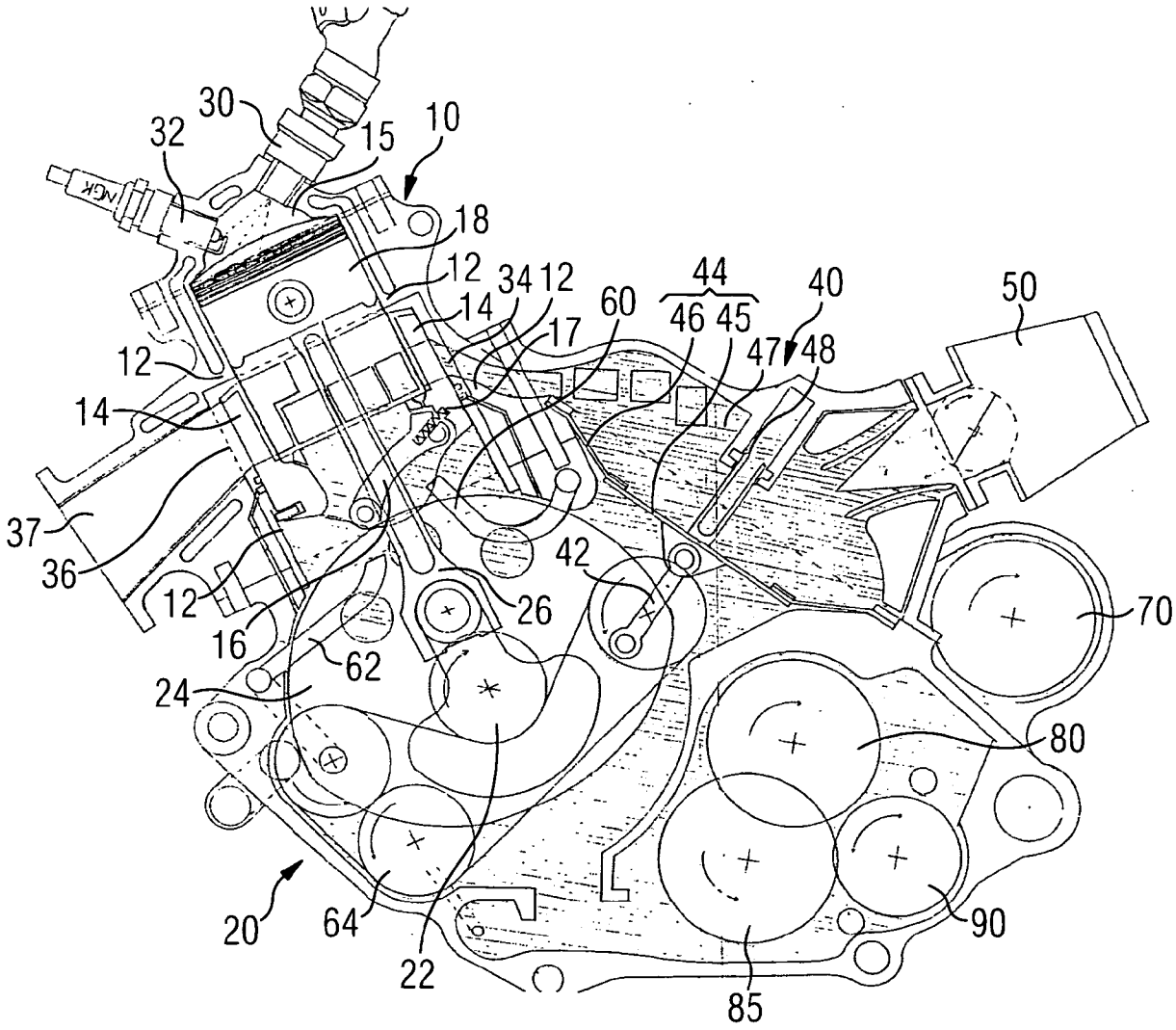

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FIG 2A

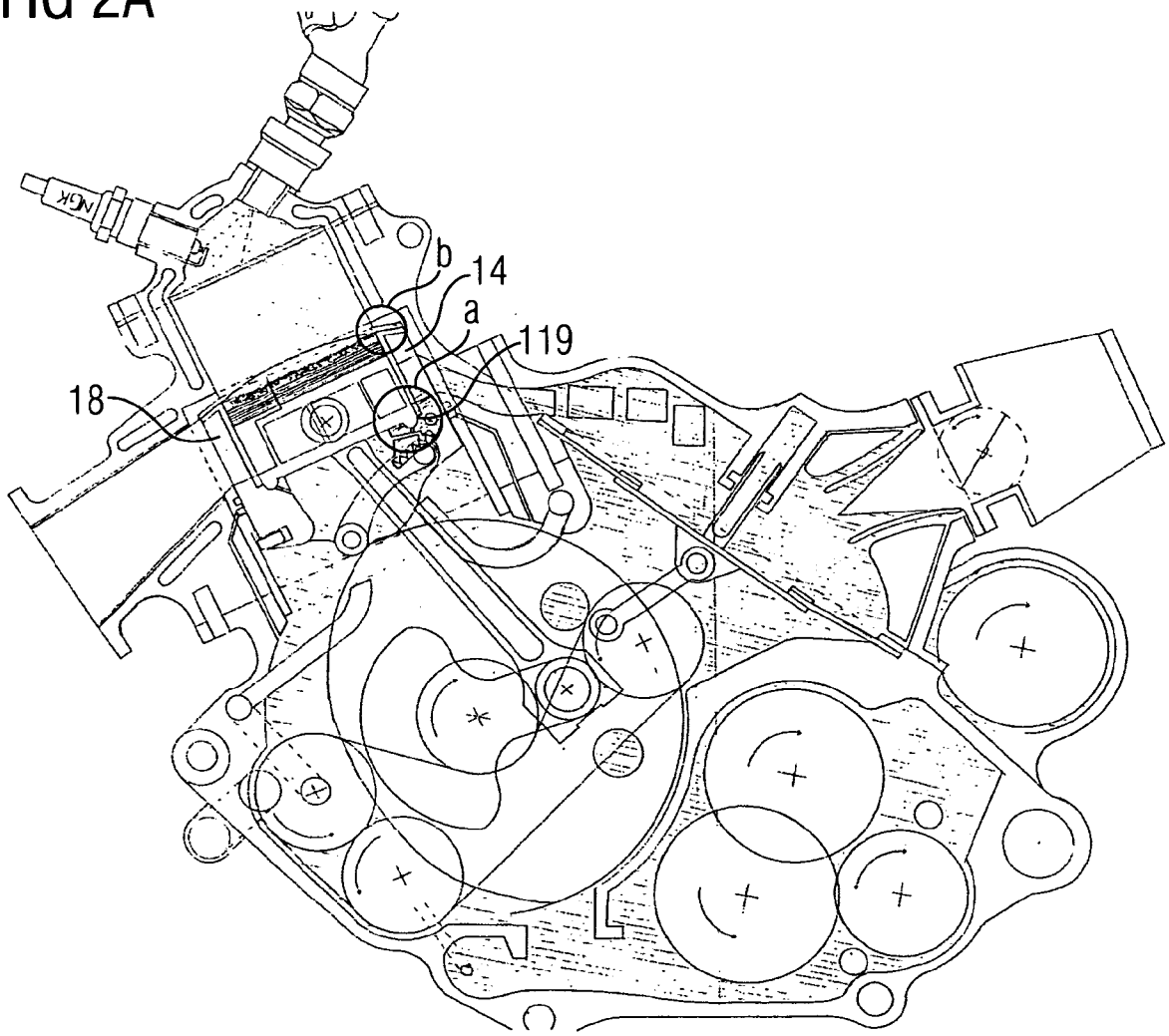



FIG 2B

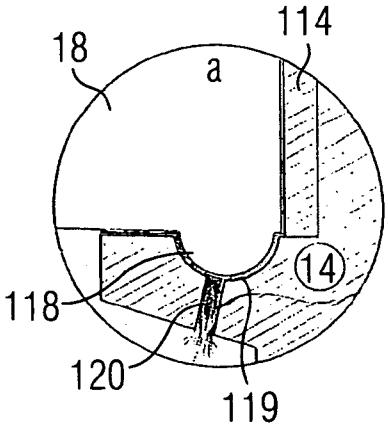



FIG 2C

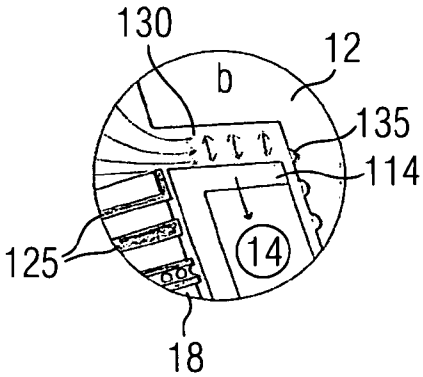


FIG 3

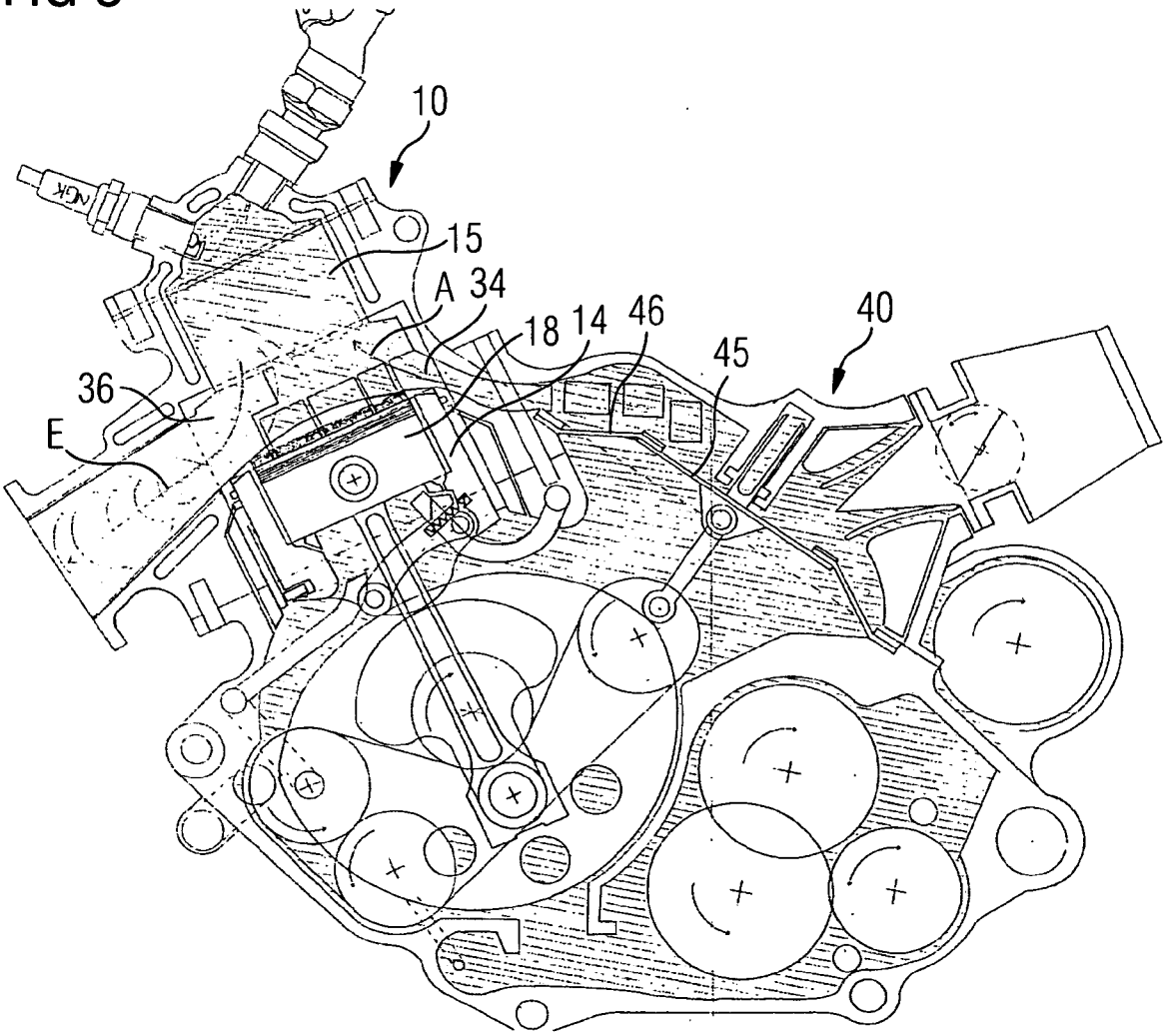


FIG 4

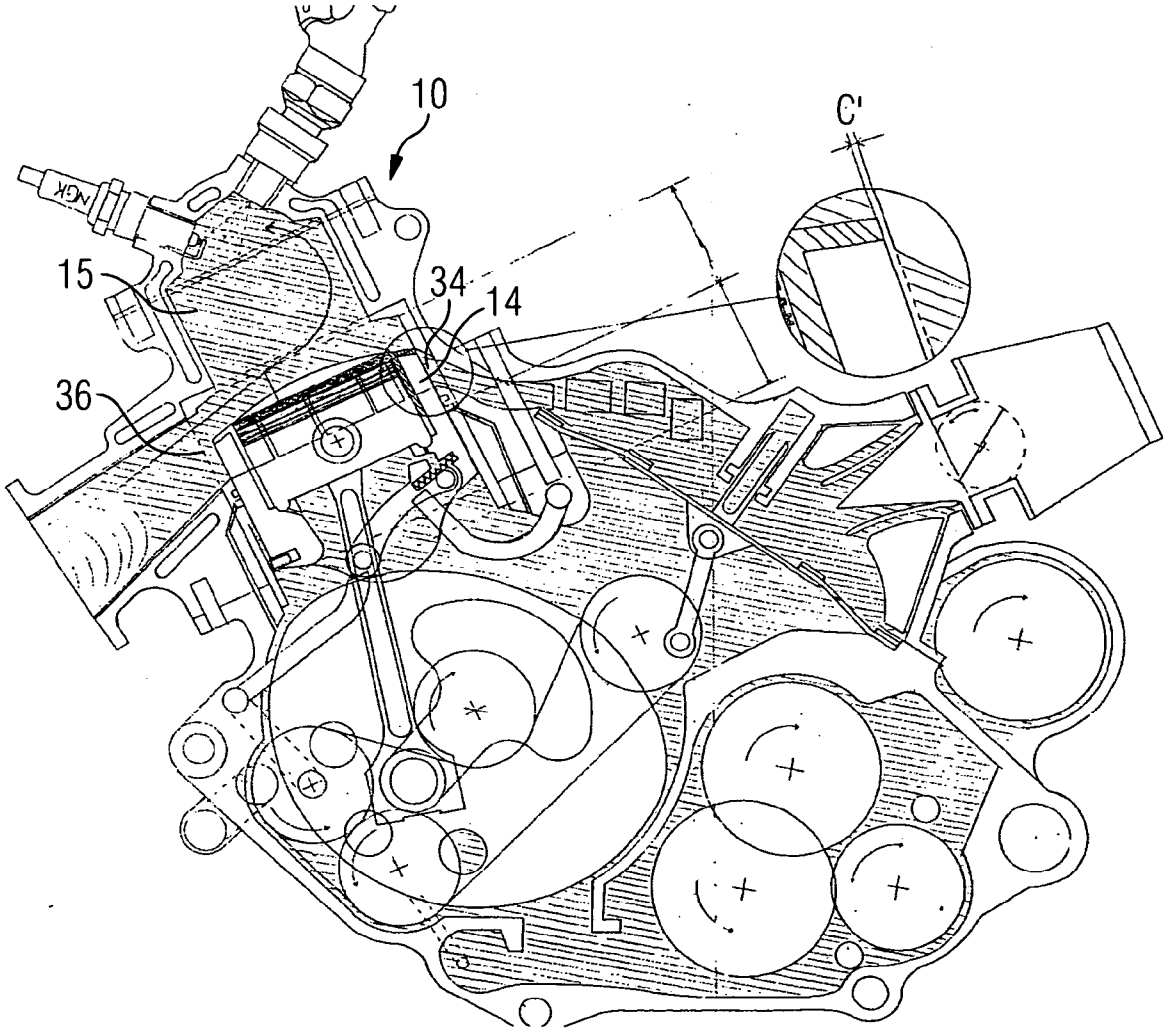


FIG 5A

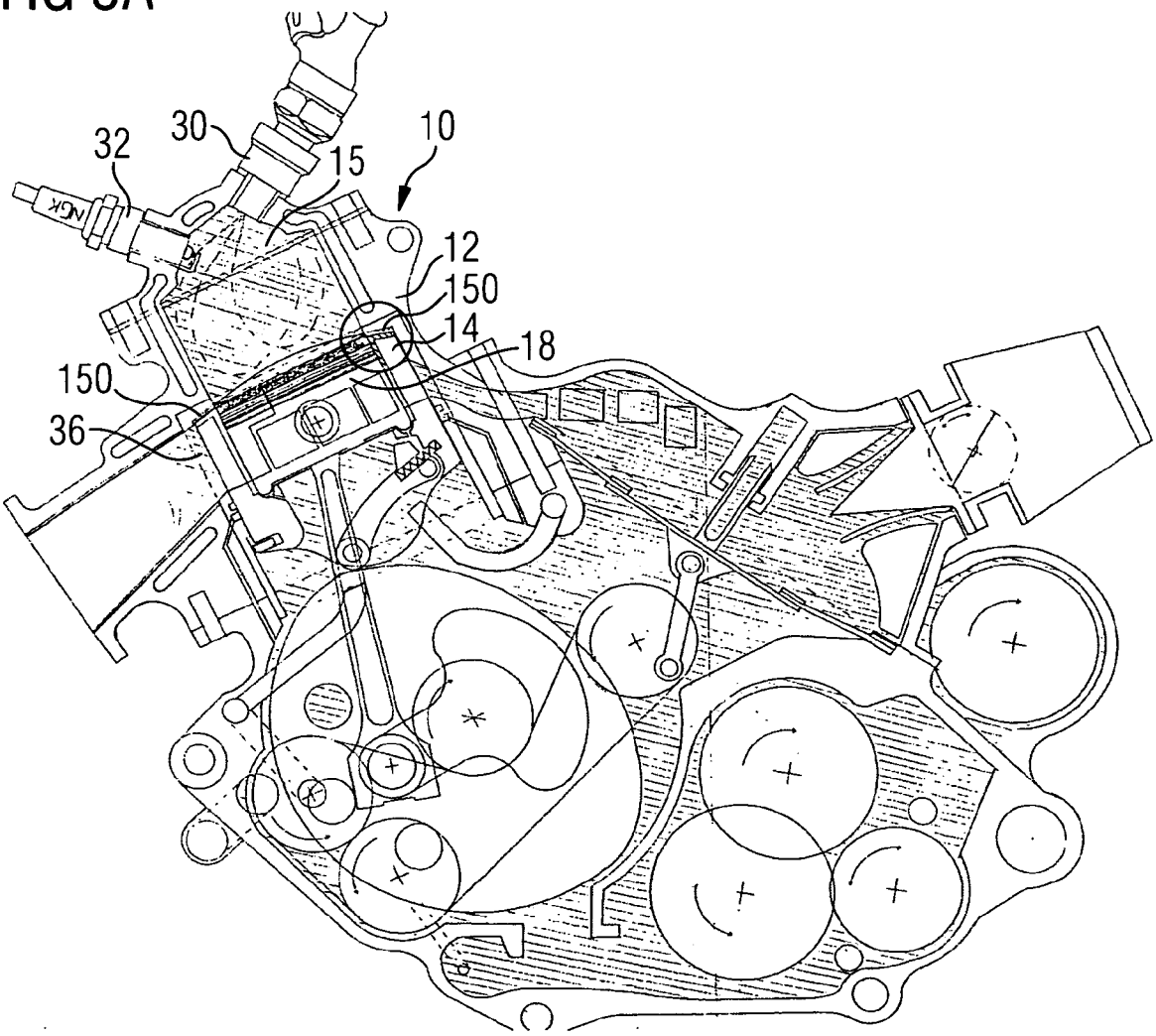



FIG 5B

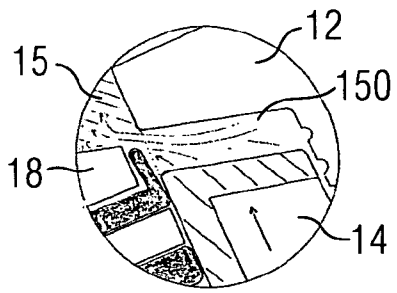


FIG 6

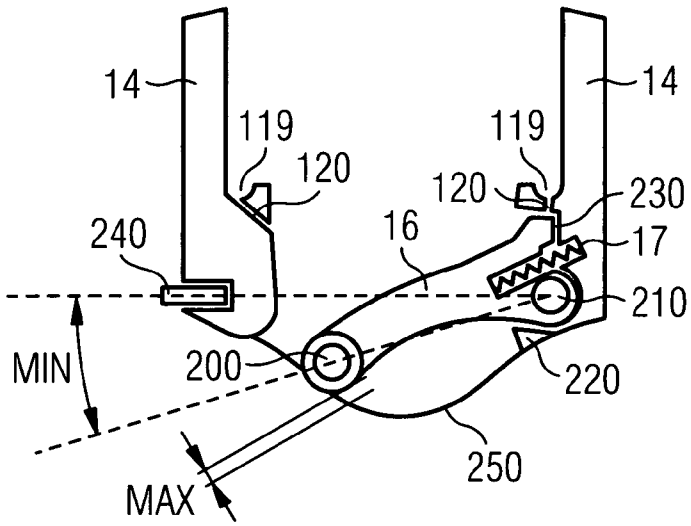


FIG 7A

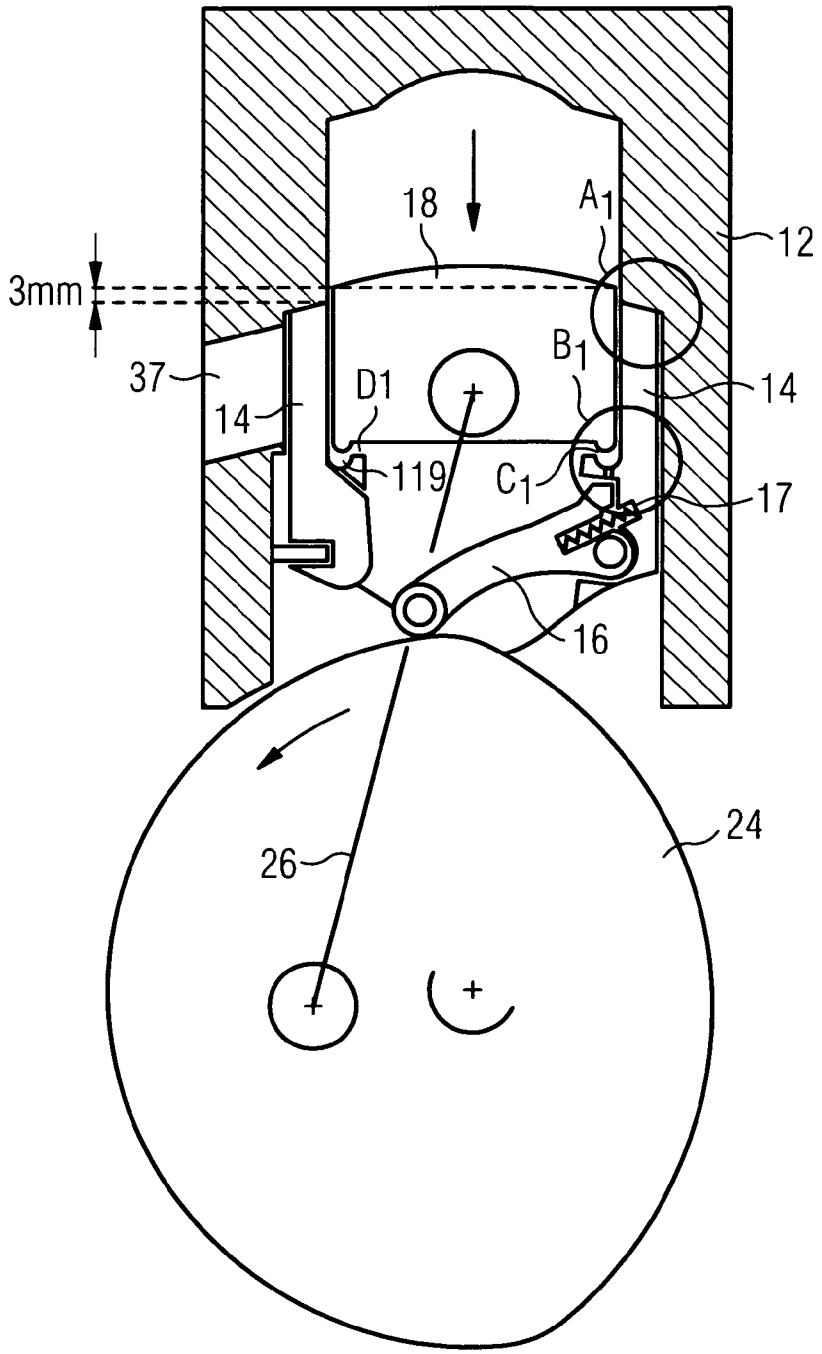


FIG 7B

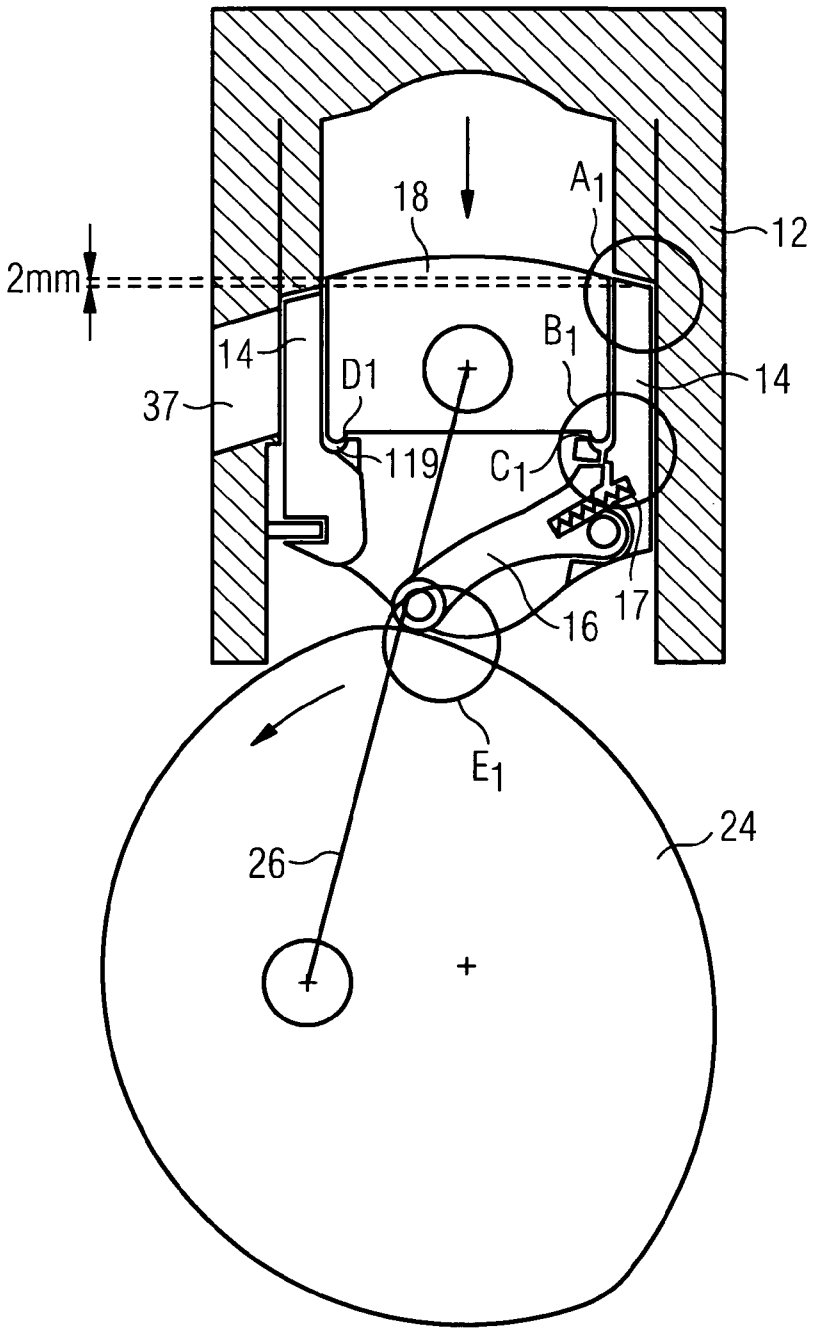


FIG 7C

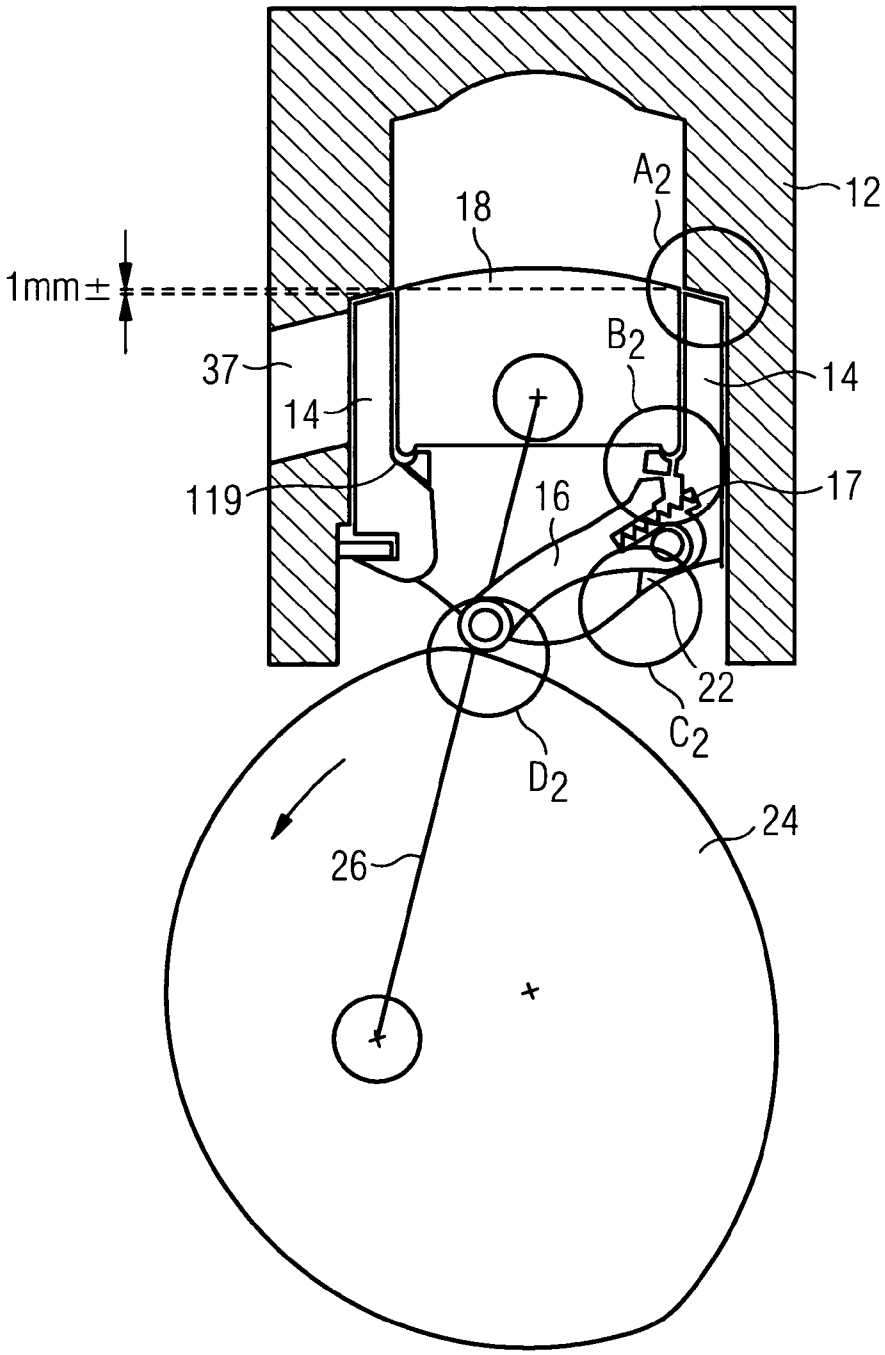


FIG 7D

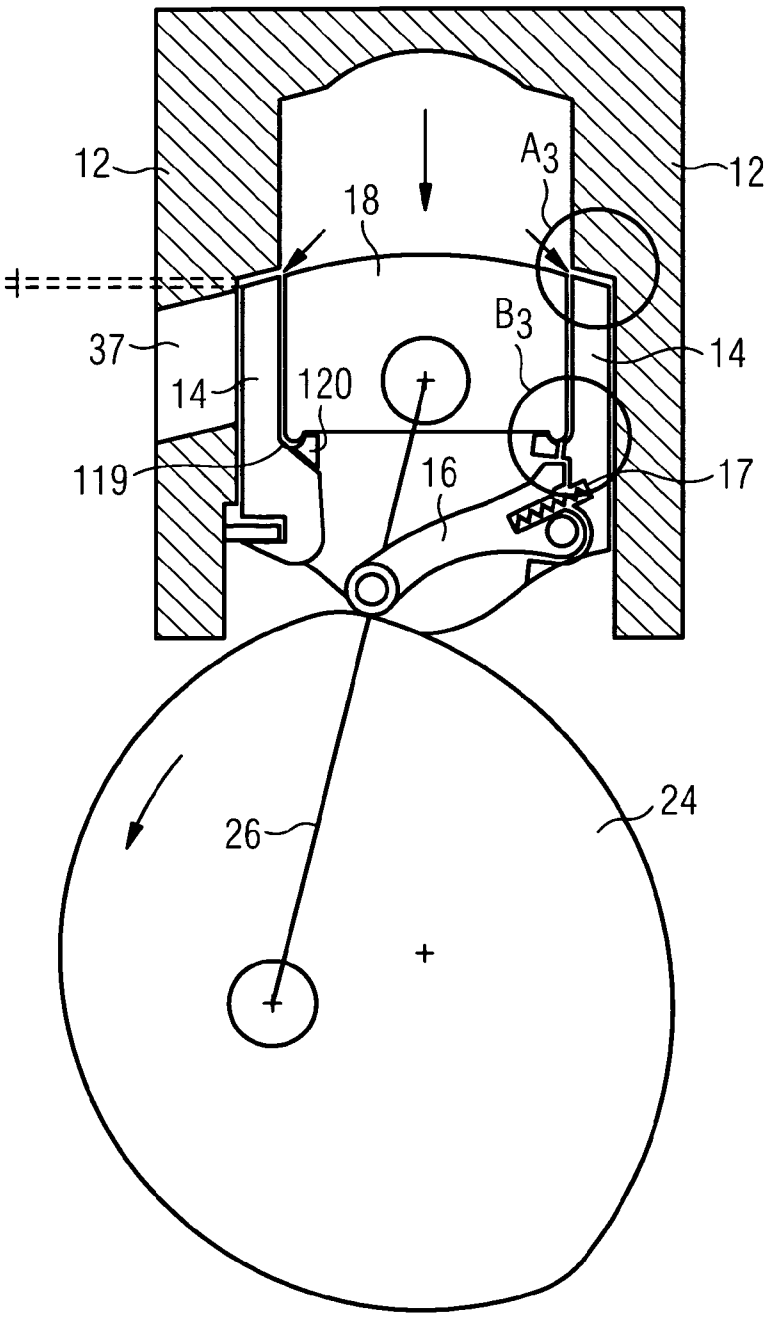


FIG 7E

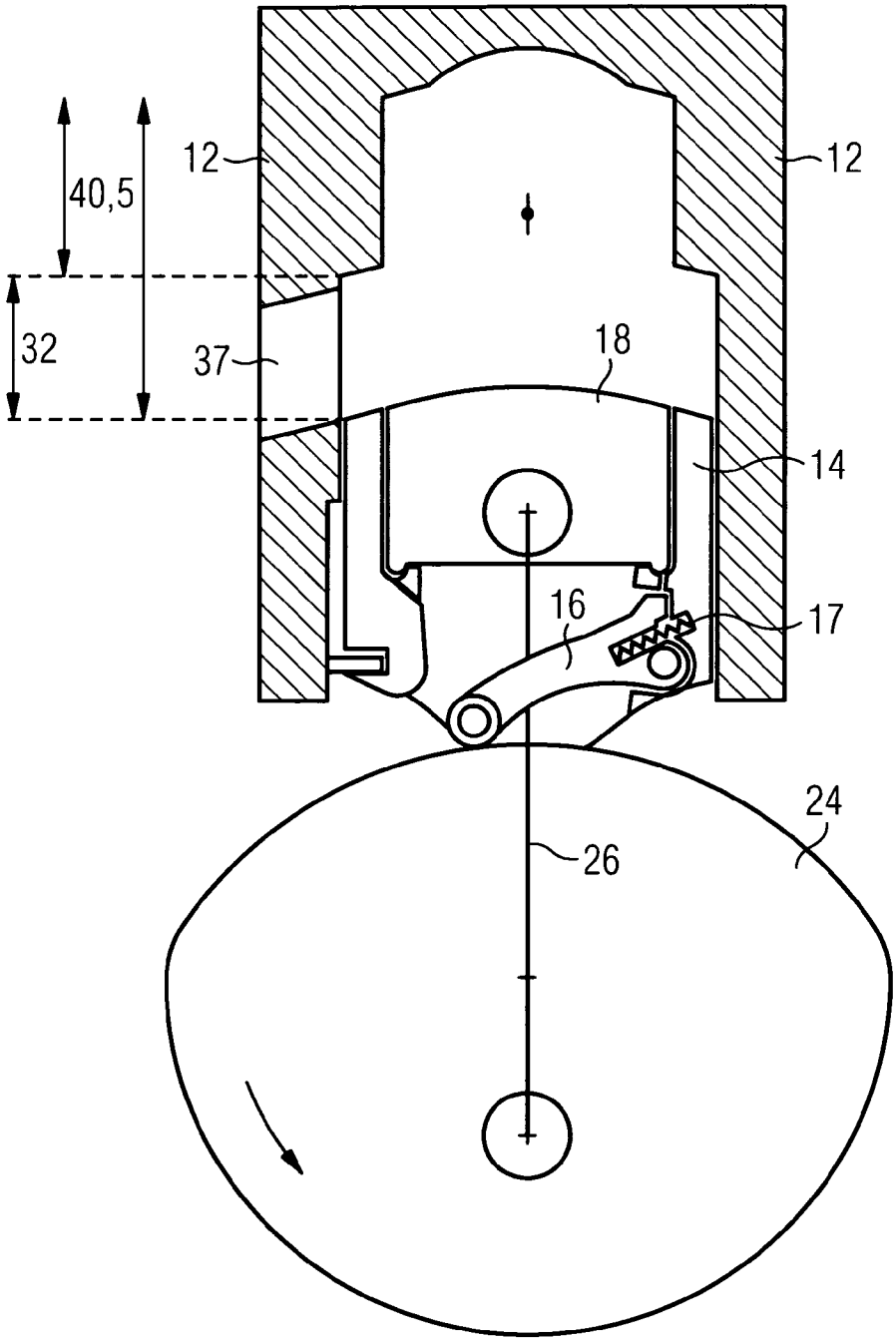


FIG 7F

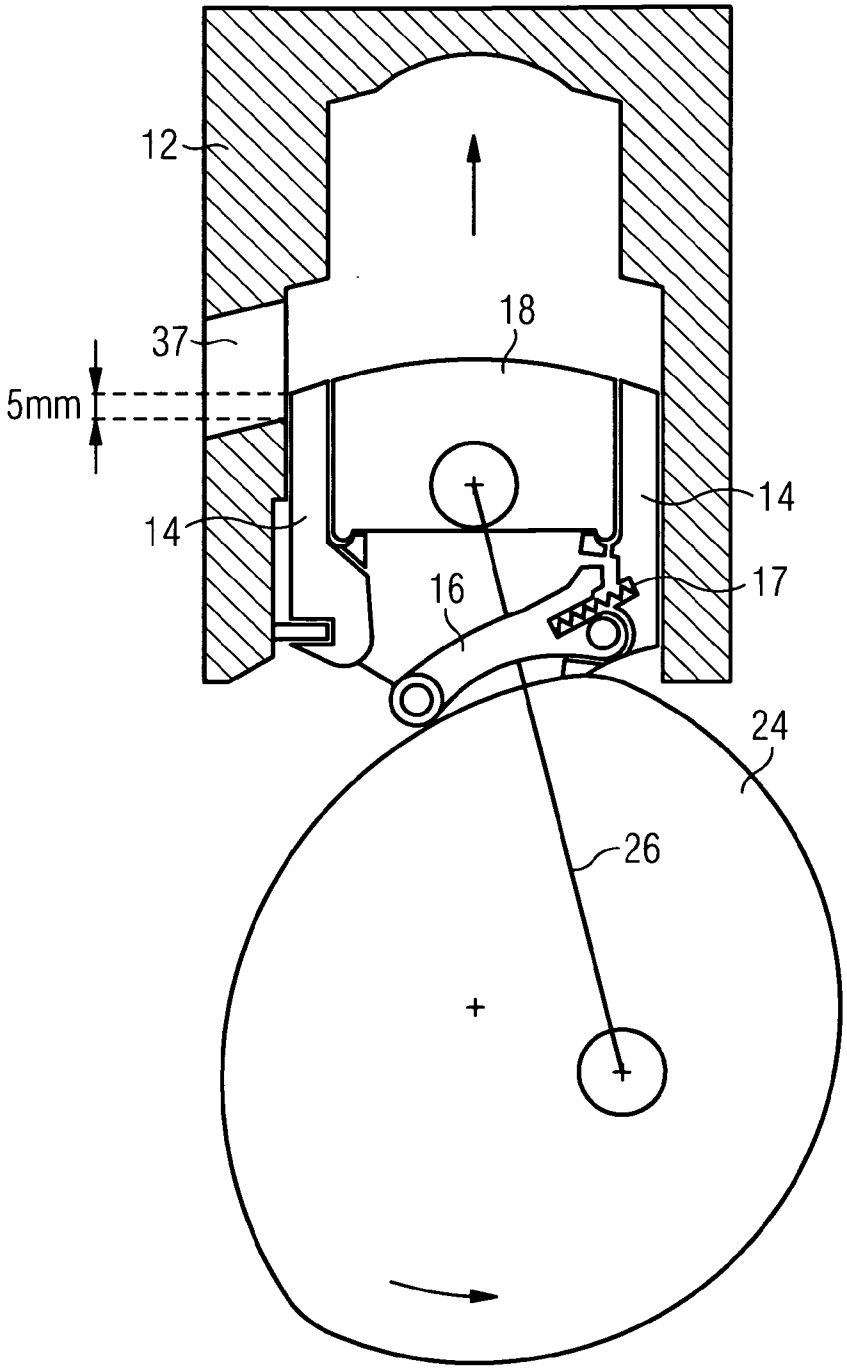


FIG 7G

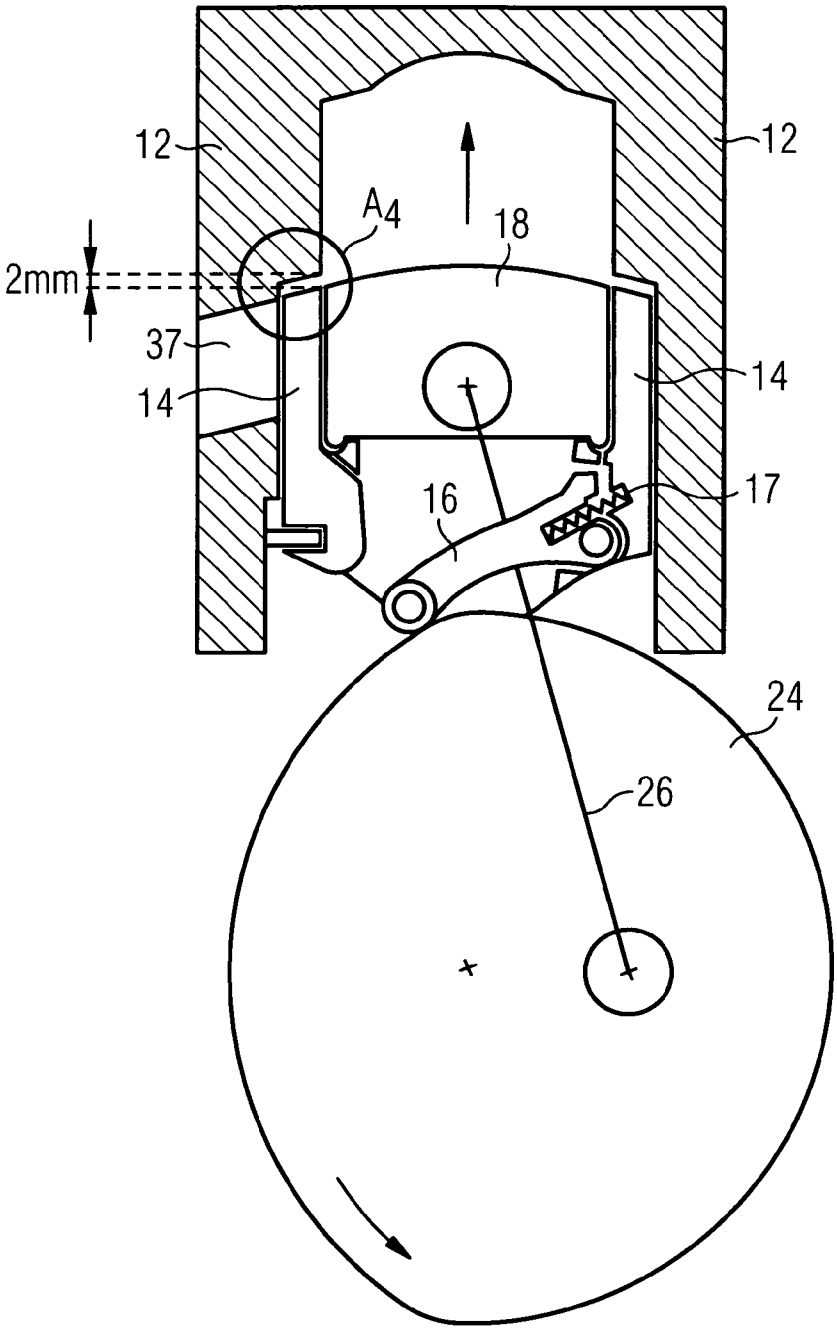


FIG 7H

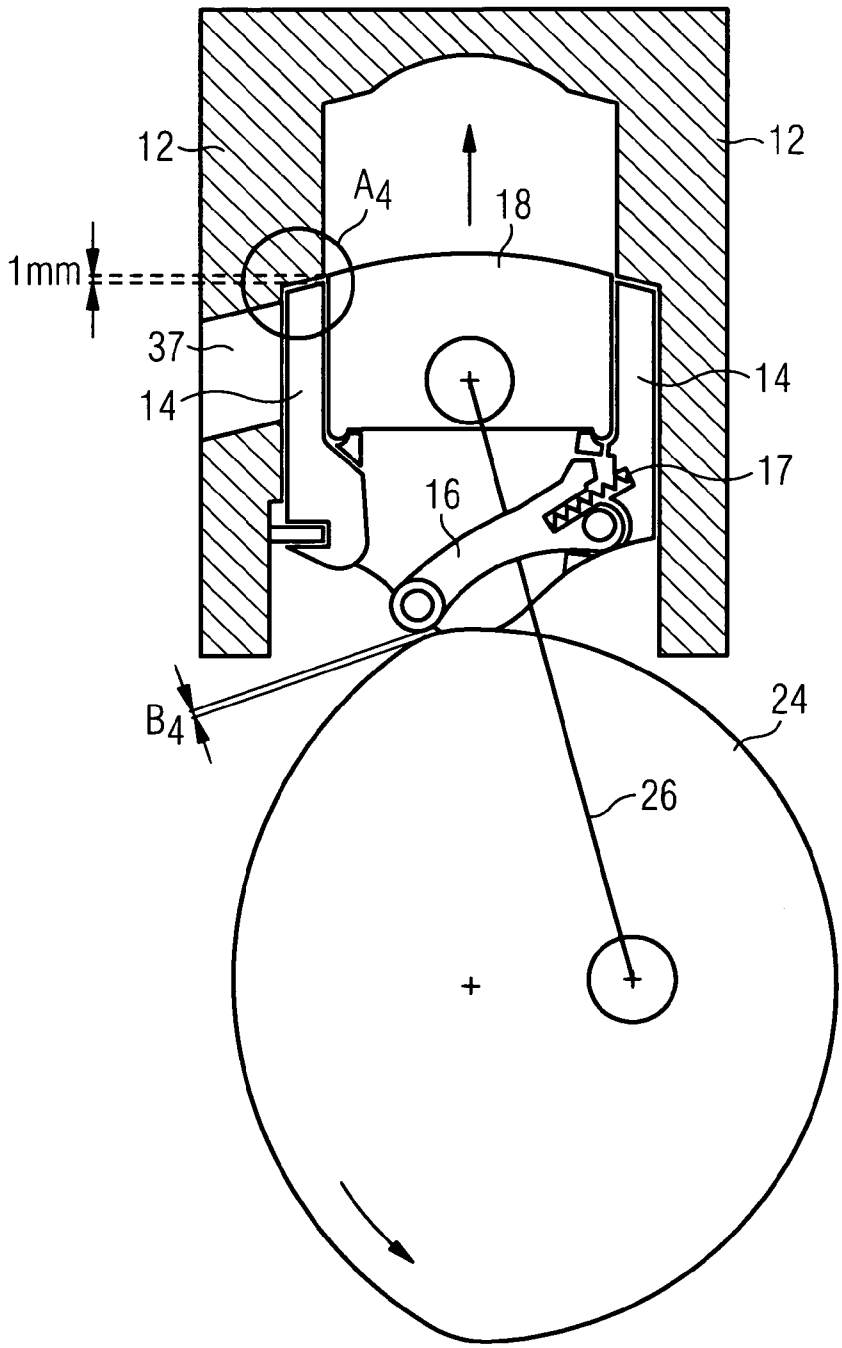


FIG 8

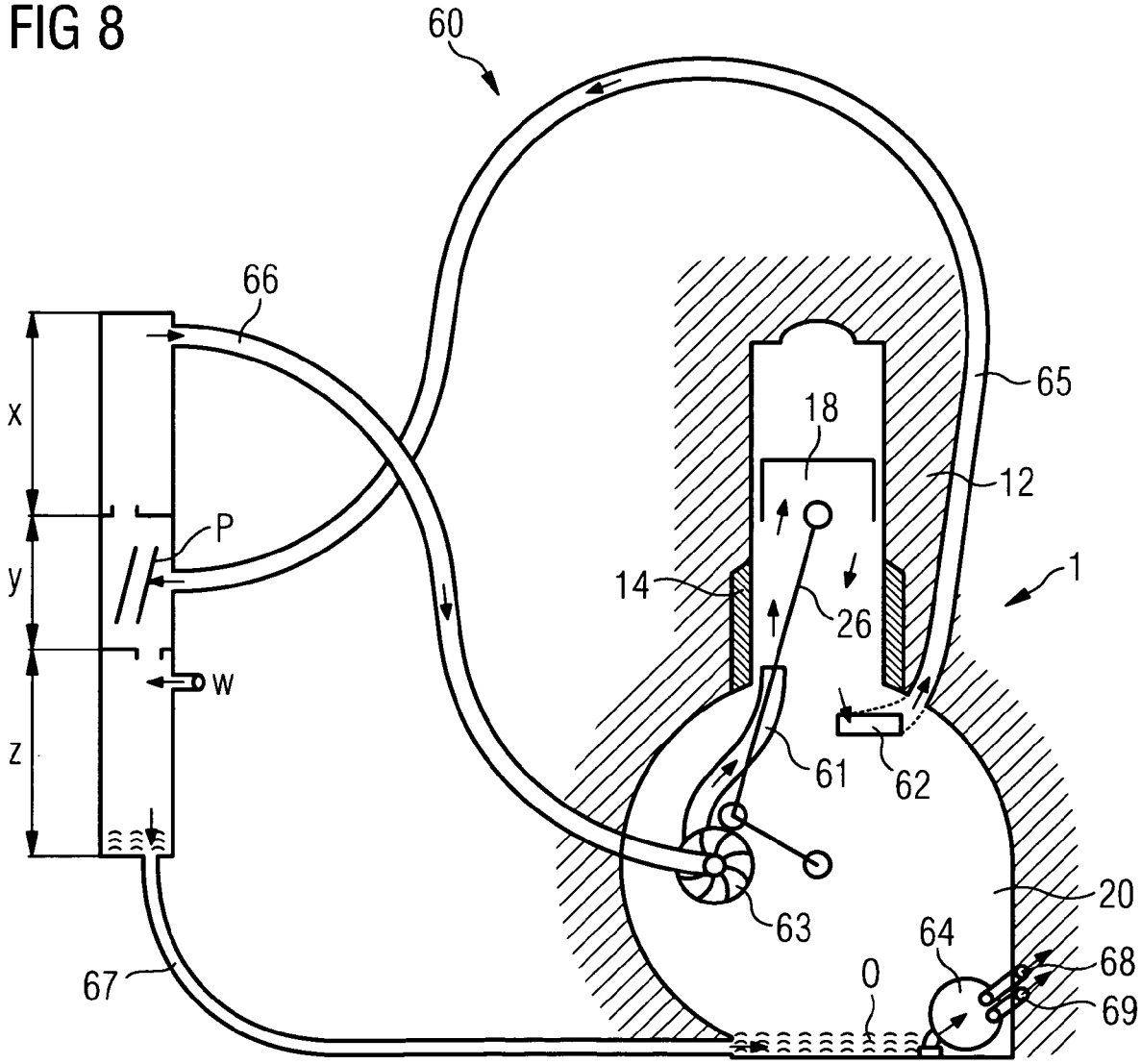


FIG 9

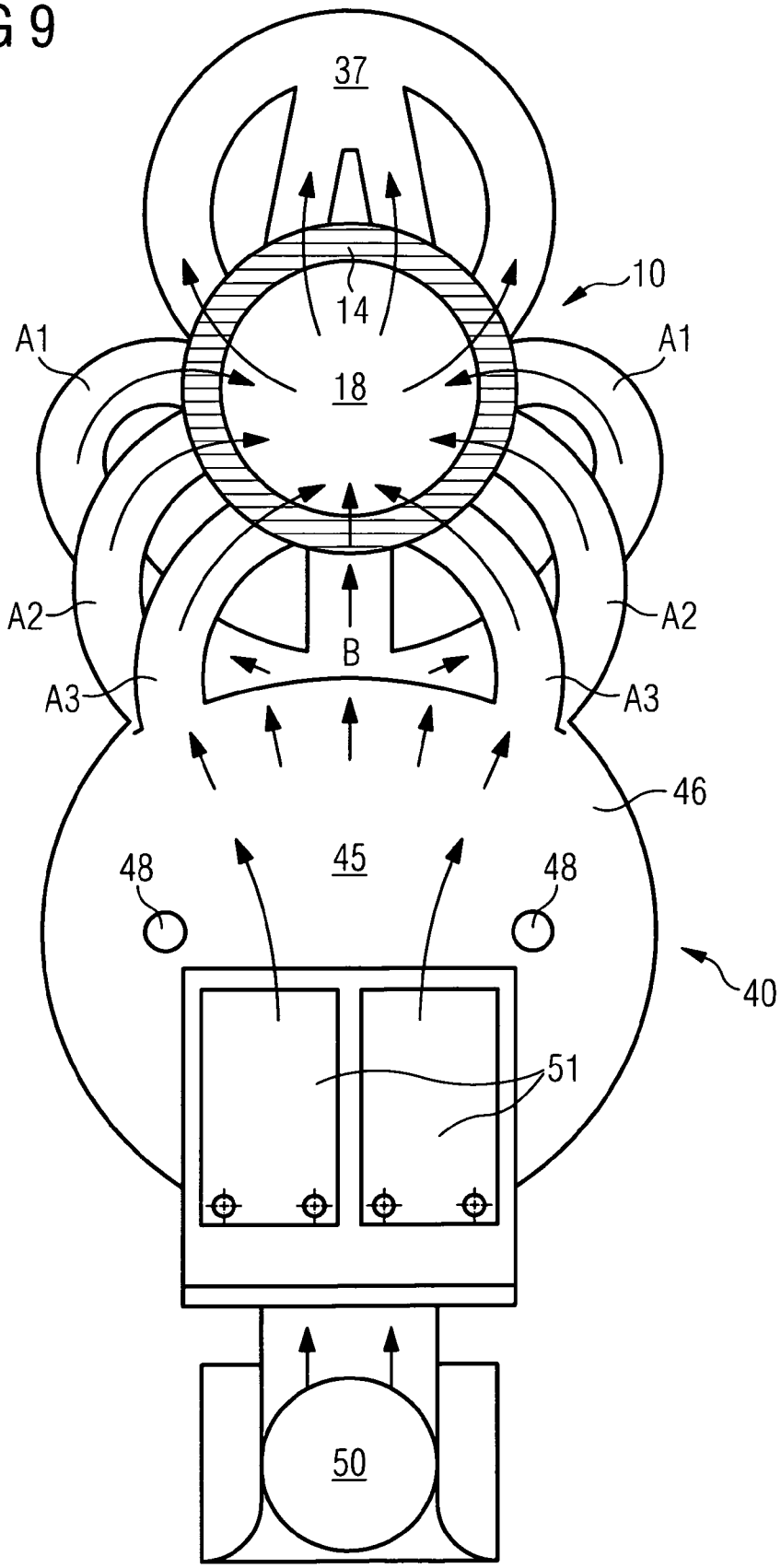


FIG 10

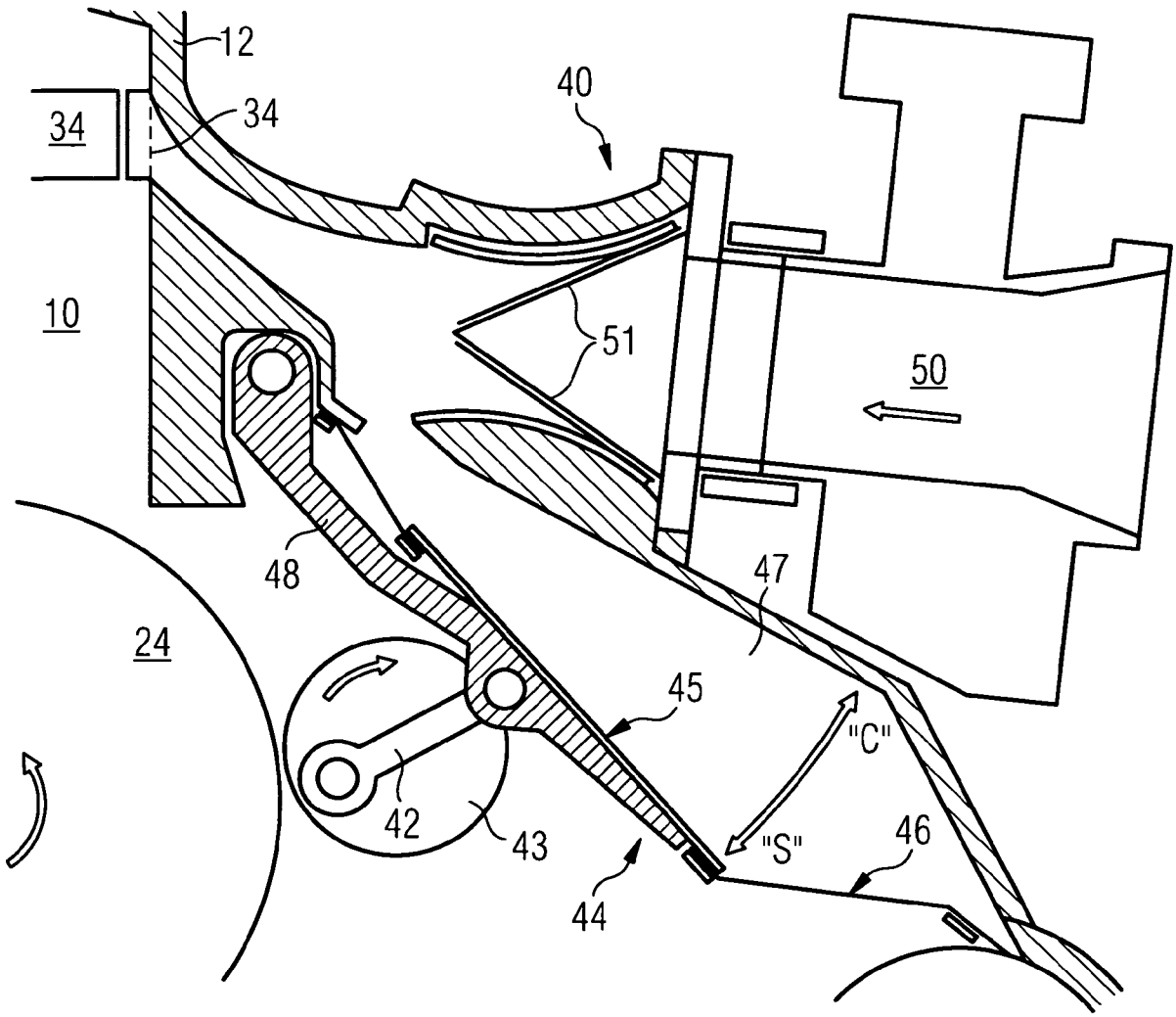


FIG 11

(PRIOR ART)

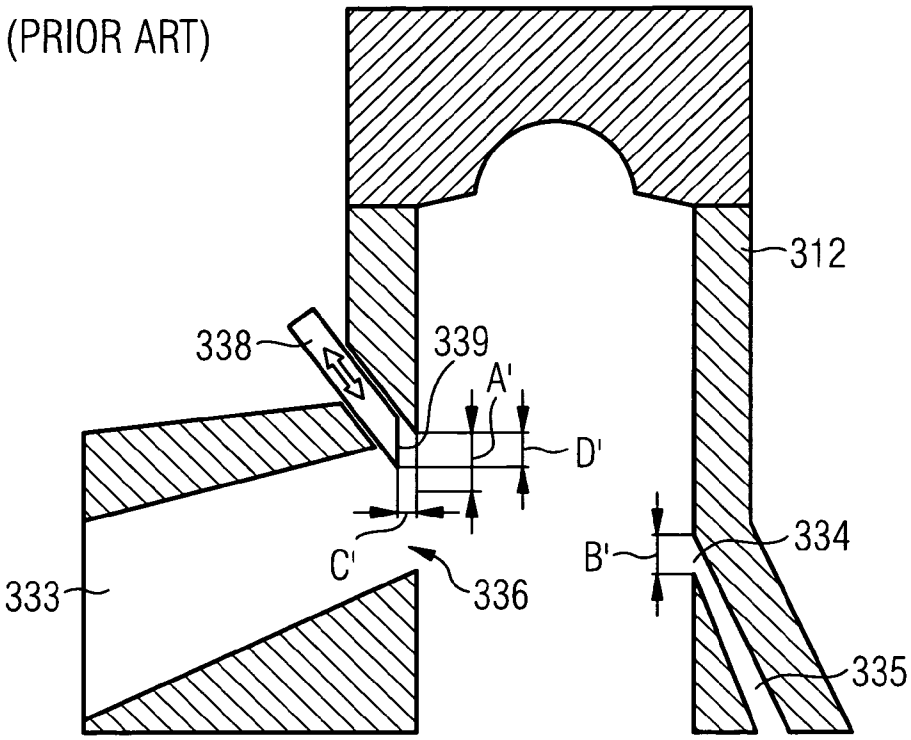



FIG 12

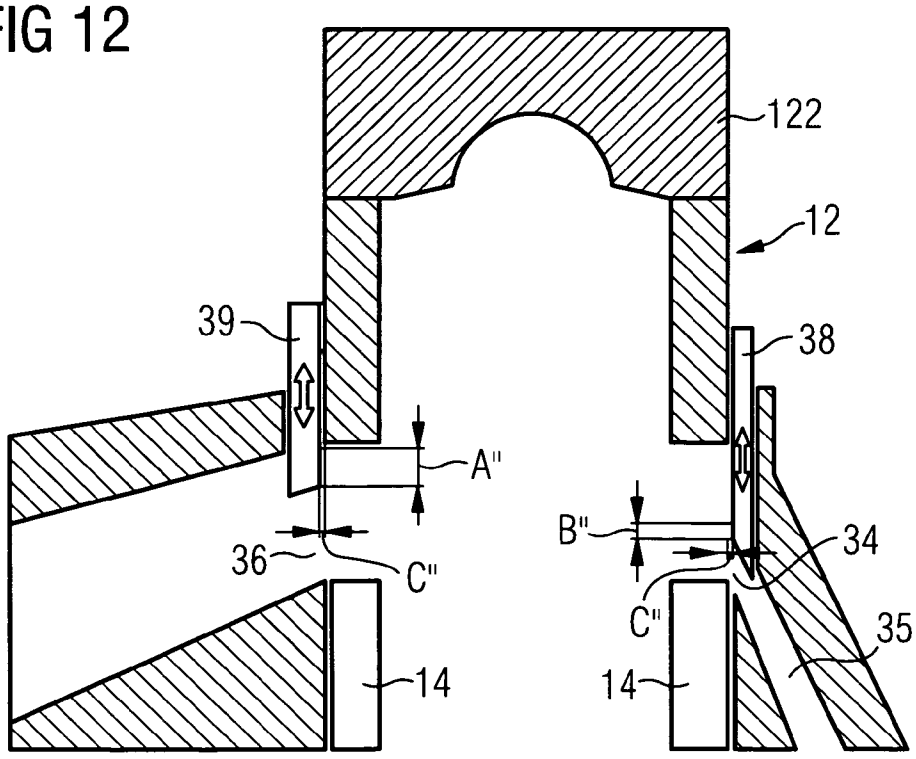
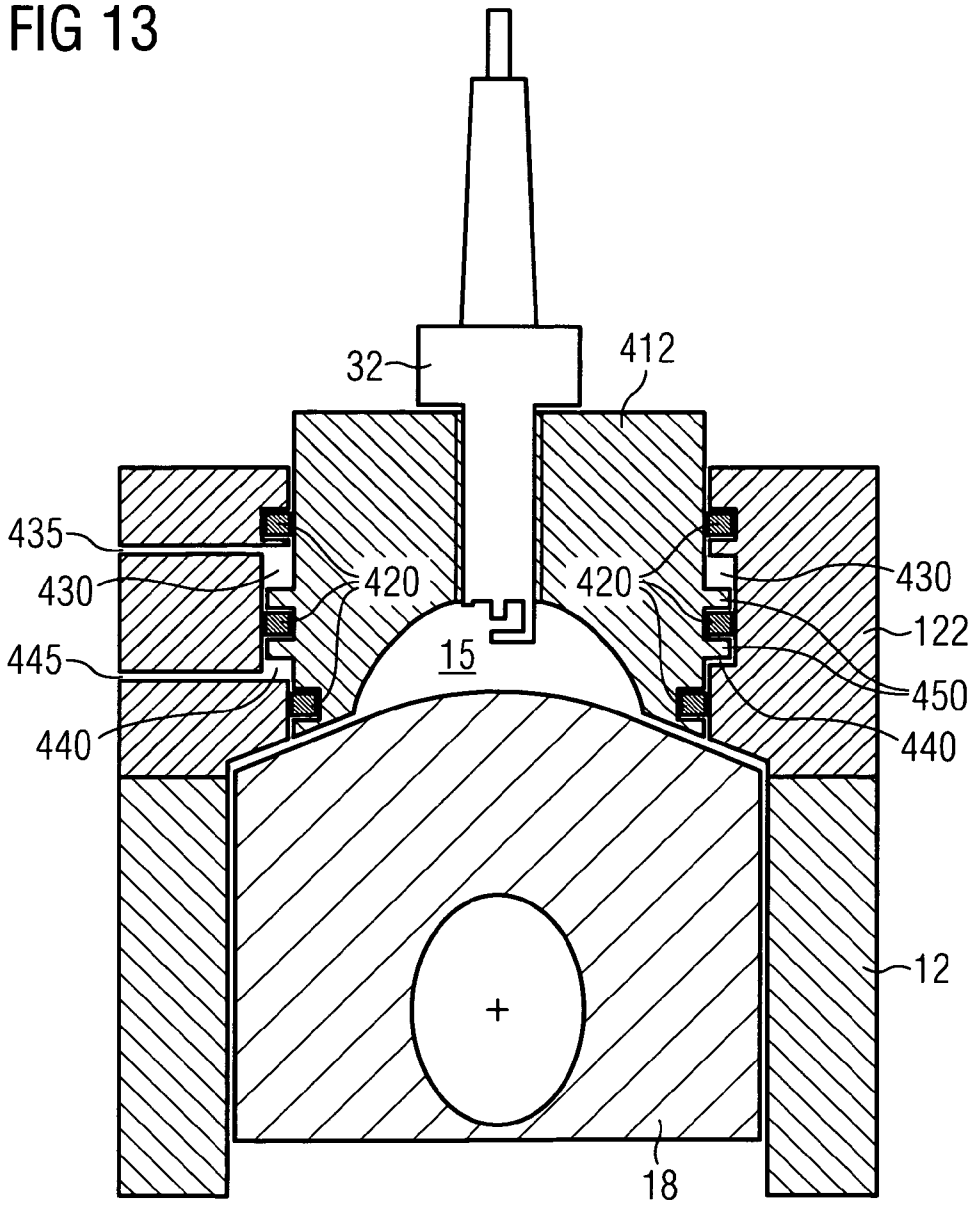


FIG 13



# INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2012/061025

A. CLASSIFICATION OF SUBJECT MATTER
INV. F01L3/20 F01L5/06 F02F3/16 F01L1/08
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F01L F02F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X<br>Y | GB 133 232 A (STOKES)<br>9 October 1919 (1919-10-09)<br>the whole document | 1,2,6,8,<br>9,11,12<br>7 |
| X | GB 04333 A A.D. 1910 (ROOTS JAMES DENNIS [GB]) 12 January 1911 (1911-01-12)<br>the whole document | 1,2,6,12 |
| X | GB 10944 A A.D. 1912 (ROBINSON ANGUS MUNRO [AU]) 26 September 1912 (1912-09-26)<br>the whole document | 1,2,6,12 |
| X | GB 580 398 A (CLEMENT TIPTON RHODES)<br>5 September 1946 (1946-09-05)<br>the whole document | 1,6,11 |

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 13 February 2013 | 25/02/2013 |

| Name and mailing address of the ISA/ | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040,<br>Fax: (+31-70) 340-3016 | Klinger, Thierry |

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Form PCT/ISA/210 (second sheet) (April 2005)

# INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2012/061025

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | US 1 639 898 A (REID PERCY H)<br>23 August 1927 (1927-08-23)<br>the whole document<br>----- | 1,6,9 |
| Y | US 2 808 039 A (GATES ALFRED C)<br>1 October 1957 (1957-10-01)<br>the whole document<br>----- | 7 |

1

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2012/061025

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
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| GB 191004333 A | 12-01-1911 | NONE | |
| GB 191210944 A | 26-09-1912 | NONE | |
| GB 580398 A | 05-09-1946 | NONE | |
| US 1639898 A | 23-08-1927 | NONE | |
| US 2808039 A | 01-10-1957 | NONE | |