E. H. BELDEN.

INTERNAL COMBUSTION ENGINE.

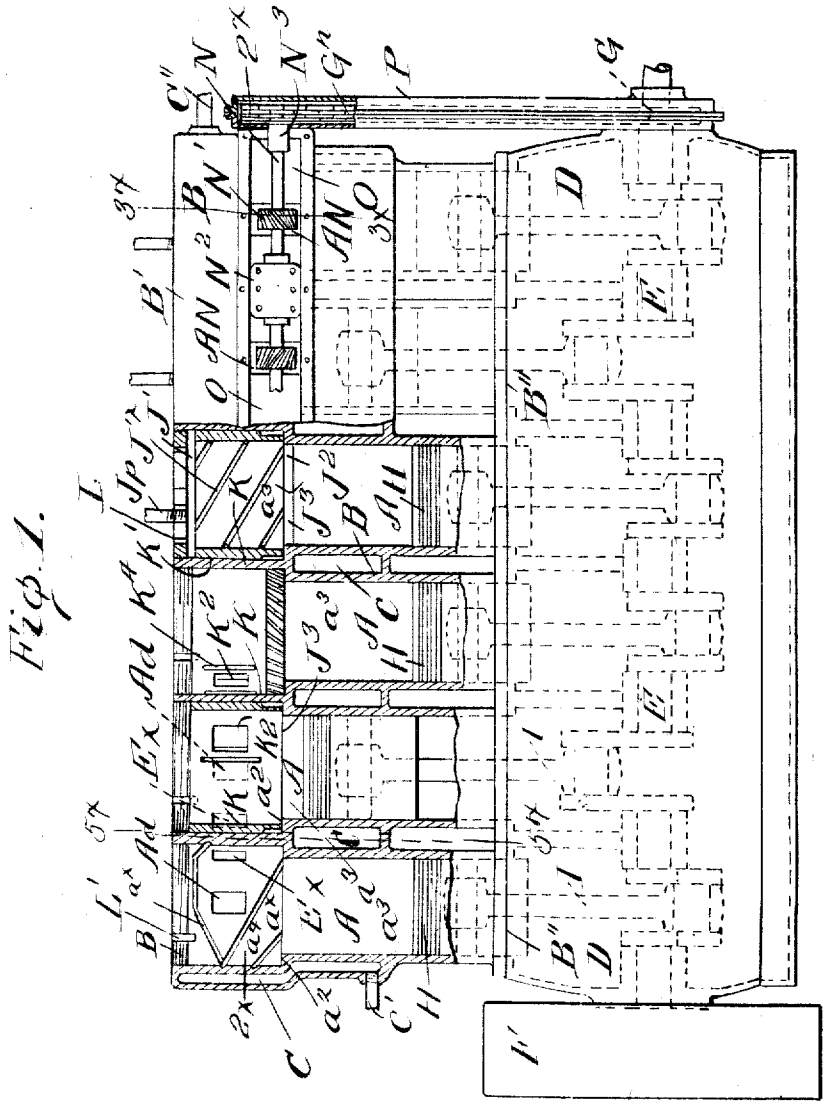
APPLICATION FILED NOV. 8, 1911.

1,017,073.

Patented Feb. 13, 1912.

6 SHEETS--SHEET 1.

Fig. 1.



Witnesses

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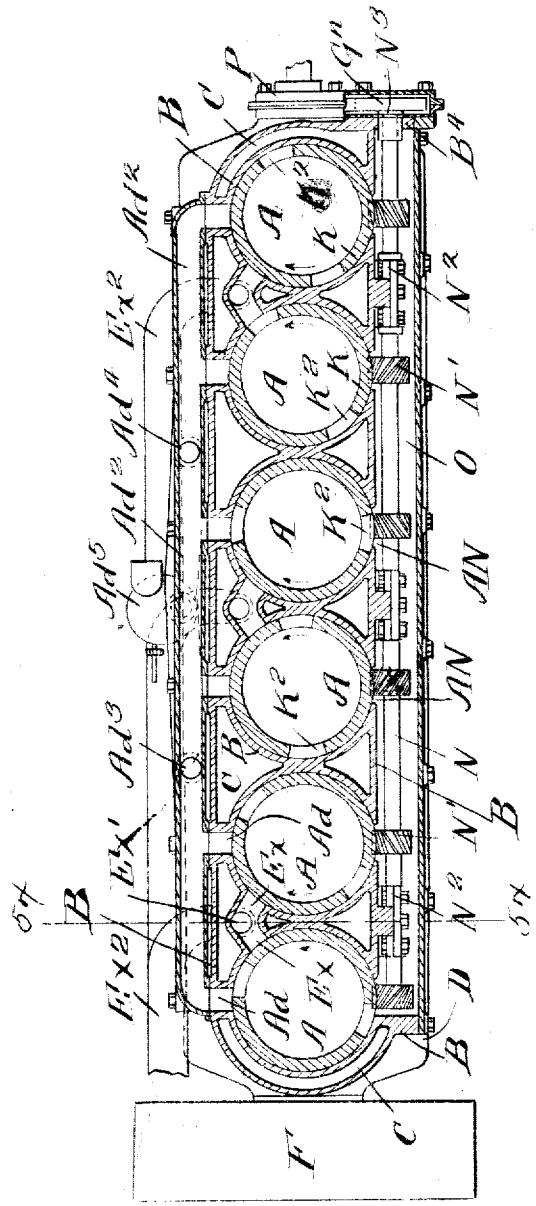
6 SHEETS—SHEET 2.

Fig. 2.



Witnesses

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6 SHEETS—SHEET 3.

Fig. 3.

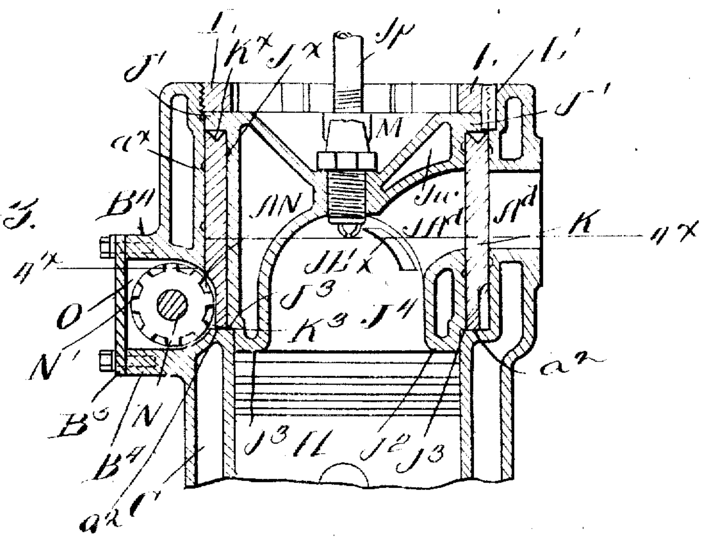
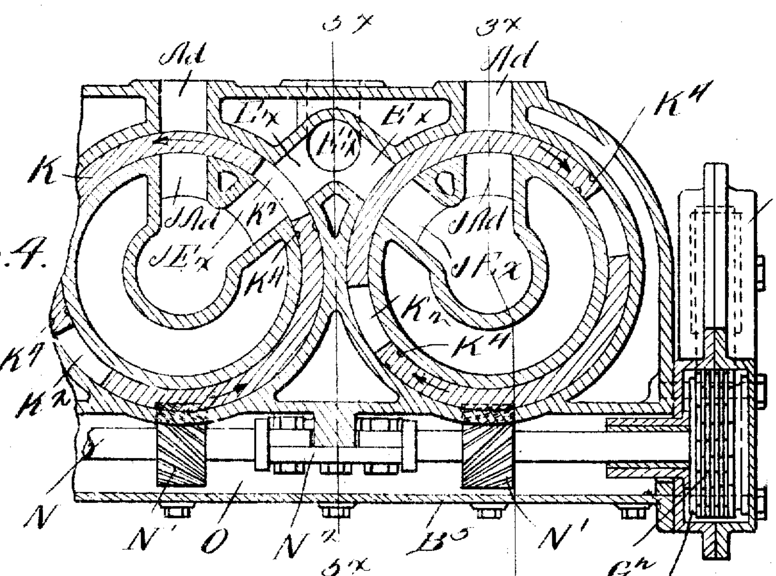


Fig. 4.



Witnesses

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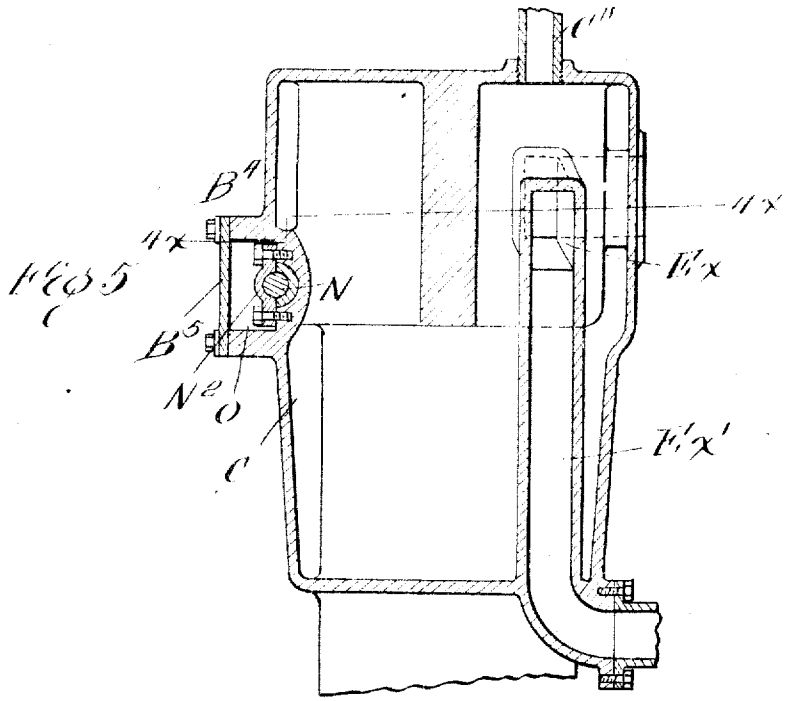
3 SHEETS—SHEET 4.



Witnesses

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6 SHEETS—SHEET 5.

Fig. 6.

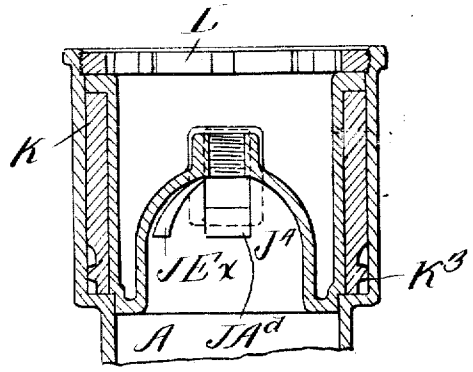


Fig. 7.

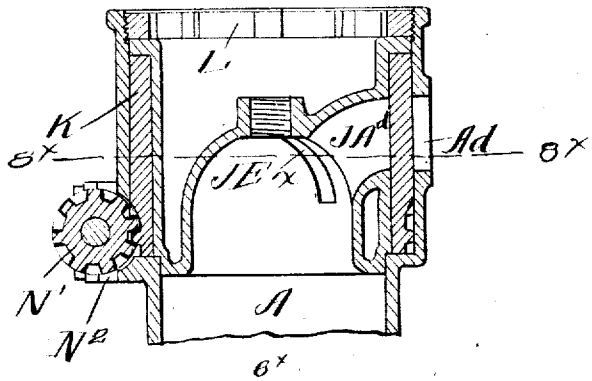
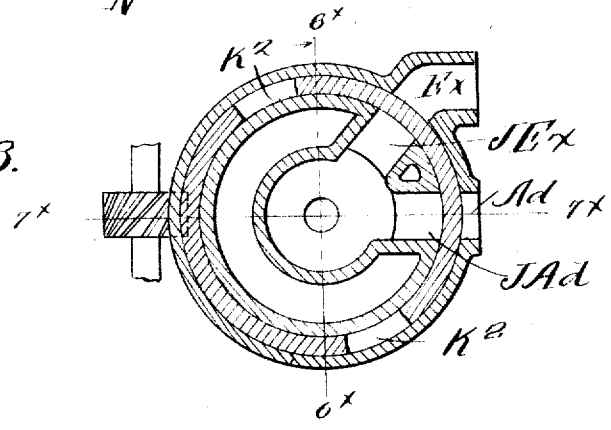


Fig. 8.



Witnesses

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6 SHEETS—SHEET 6.

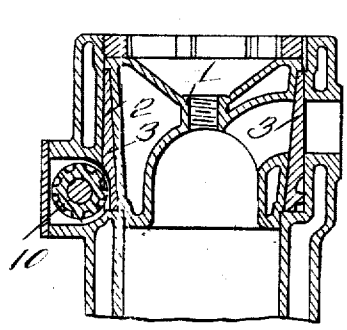

Fig. 9.

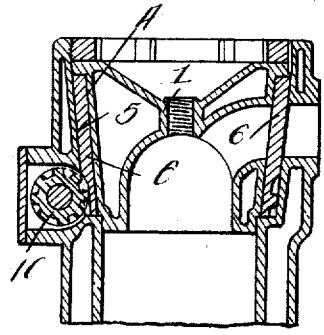

Fig. 10.

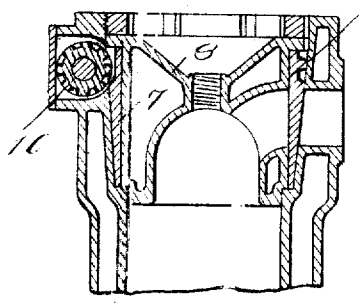

Fig. 11.

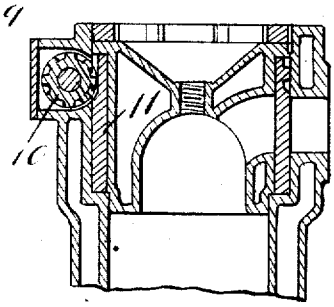

Fig. 12.

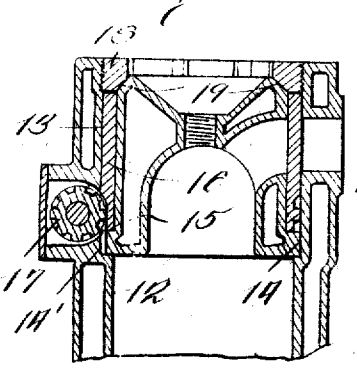

Fig. 13.

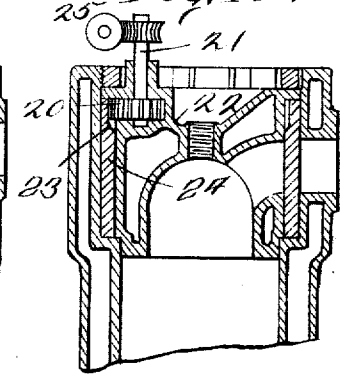

Fig. 14.

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INTERNAL-COMBUSTION ENGINE.

1,017,073. Specification of Letters Patent. Patented Feb. 13, 1912.

Application filed November 8, 1911. Serial No. 659,204.

To all whom it may concern:

Be it known that I, EDWARD H. BELDEN, a citizen of the United States, and a resident of Pittsburgh, county of Allegheny, and State of Pennsylvania, have invented certain new and useful Improvements in Internal-Combustion Engines, of which the following is a specification.

My invention relates to internal combustion engines and has particular reference to improvements in the valves and valve gearing of internal combustion engines of the four-cycle type.

The objects of my invention are to simplify the construction and to lessen the cost of such engines; to eliminate the vibration and the noise incident to their operation; and to increase the power, efficiency and durability thereof.

My further purpose is to do away with the short-lived and noisy reciprocating valves and valve gearing now in common use and to substitute therefor a minimum number of large substantial parts that can not easily be broken, that will offer the least possible resistance to the operation of the engine, and which will wear indefinitely without being reground or refitted.

A special object of my invention is to provide an engine of the class named with a non-vibratory, constantly lubricated admission and exhaust valve and to maintain it at a low temperature protected from the hot gases of the cylinder.

Still other objects of the invention are to provide an internal combustion engine having a cylinder which contains both the cylinder head and the necessary port-controlling means and from which both the head and the piston may be removed without disturbing the cylinder or said port controlling means or gearing, and from which the valve may be removed without disturbing the cylinder or the valve gearing; and to provide an engine having valves and valve seats which shall be freely accessible upon removal of the cylinder head.

Another object of my invention is to provide a four-cycle engine that may be made and assembled, dismembered and reassembled by ordinary mechanics and in less time than other four-cycle engines.

A further object is to provide valves and valve gearing of such form and arrangement that the several cylinders of a multiple engine may be economically formed in one block or casting.

Still further objects of my invention will appear hereinafter.

My invention resides in an internal combustion engine which, in its simplest form, has a single-piece ported cylinder, a single-piece cylinder head, a single-piece valve which is incased by the cylinder and the head, a single valve operating member and a single actuating and timing device which connects the valve operating member with the crank shaft. The simple structure here outlined is somewhat amplified in the higher developments of my invention but even in its multiple cylinder forms I prefer to use only one valve operating member and one driving device.

The invention will be readily understood upon reference to the accompanying drawings, which form part of this specification and in which I have depicted a preferred embodiment of my invention in a six cylinder internal combustion engine.

In the drawings, Figure 1 is a side elevation of my novel engine, four of the cylinders being shown in vertical longitudinal section;—Fig. 2 is a horizontal section, substantially on the line 2^x—2^x of Fig. 1, all of the cylinder heads being removed;—Fig. 3 is an enlarged vertical section on the line 3^x—3^x of Figs. 1 and 4;—Fig. 4 is a similarly enlarged horizontal section on the line 4^x—4^x of Figs. 3 and 5;—Fig. 5 is a vertical transverse section on the line 5^x—5^x of Figs. 1 and 4;—Figs. 6, 7 and 8 are diagrammatic sectional views of the upper portion of a complete engine divested of cooling means, Fig. 6 being a section on the line 6^x—6^x of Fig. 8, and Fig. 7 a section on the line 7^x—7^x of Fig. 8 and Fig. 8 a horizontal section on line 8^x—8^x of Fig. 7;—Figs. 9, 10, 11 and 12 illustrate four modifications suggested by Fig. 3, differing therefrom in the cross sectional shapes of the annular valves;—Fig.

13 shows another modification of my invention in which the head and the valve are removable together; and Fig. 14 discloses a valve operating member which acts on the inner periphery of the valve.

I have here illustrated my invention as embodied in a water cooled multiple cylinder engine of a vertical type particularly adapted for use in automobiles. Its cylinders A, six in number, are arranged side by side in a single casting B. Various means may be employed for cooling the cylinder and valve seats. For example the casting B may contain a water space or jacket C which is common to all the cylinders. The water space extends from the top B′ of the casting to a point near the lower ends of the cylinders. The bottom B″ of the cylinder casting is secured upon the top of the base D. The base contains the crank shaft E shown in dotted lines in Fig. 1. On one end of the shaft E is a fly wheel F. The other end of the crank shaft carries a sprocket wheel G, (see dotted lines Fig. 1) the use of which will be explained hereinafter. Each cylinder A contains a piston H, joined to the crank shaft E by a connecting rod I, shown in dotted lines in Fig. 1. The cylinders open through both the top and the bottom of the casting B. They have separate heads J. The head J of each cylinder is preferably wholly contained within the upper or outer end of the cylinder. I make these ends of the cylinders large enough to receive the pistons so that the latter may be inserted and removed through the tops of the cylinders after the cylinder casting B has been fastened to the base D. The heads are larger than the pistons and each head rests upon an annular shoulder a^2, which distinguishes the piston containing portion a^3 of the cylinder from its head containing portion a^4. Both cylinder portions a^3 and a^4 are cylindrical. They are preferably concentric. The portion a^4 is large enough to contain not only the head but also the valve K, about to be described. Each head has an annular flange J′ that fits the upper part of the cylindrical bore a^4. The lower end J^3 of each head J snugly fits the piston bore a^3 of the cylinder and the annular shoulder J^3 of the head rests upon the cylinder shoulder a^2 as before explained. The upper end of the bore a^4 of each cylinder is threaded to receive a locking ring L, which is screwed firmly upon the flanged top of the head, completing an oil and pressure tight joint between the head and the cylinder at that point. If desired a key L′ or a set screw may be added to lock the head against rotation. Such device however is not essential to the fastening of the head in the cylinder. The shoulder a^2 of the cylinder and the shoulder J^3 of the head are ground together and when the head is thus secured the shoulders form an oil and pressure tight joint between the lower end of the head and the cylinder. It will be observed that the concentricity of the cylinder and the head is insured by the close fitting of the upper end and the lower end of the head within the larger and the smaller bores a^4 and a^3 of the cylinder. The intermediate portion of each head J, between the flange J′ and the shoulder J^3, is cylindrical and concentric with the containing bore a^4. While this portion, as herein shown, is larger than the piston bore a^3, it is somewhat smaller than the bore a^4 and an annular cavity K′ having parallel cylindrical walls is therefore formed between the cylinder and the head. The top of the cavity K′ is formed by the underside of the head flange J′. The bottom of the annular cavity is formed by the cylinder shoulder a^2 on which the head rests. All of the walls of the cavity are finely ground and serve as seats for the valve K before referred to. The valves K are simple one-piece sleeves or rings that exactly fit their respective cavities K′. They are interchangeable. The inner and outer surfaces of each valve K are finely ground and are cylindrical and parallel. The top and bottom edges are also finely ground or finished and are parallel and perpendicular to the cylindrical surfaces. In practice, the cross sectional dimensions of the valve K are approximately two thousandths of an inch smaller than the corresponding dimensions of the cavity K′, leaving space for thin films of oil between all the opposed surfaces of the valve, cylinder and head. Obviously the space is increased at the groove K^x and between the gear teeth on the valve. Each valve K contains at least one opening or port K^2, the same being of sufficient size to quickly admit and to quickly free the gases and being positioned about midway of the height of the valve. As shown in the drawings I prefer to provide each valve with two diametrically opposite ports K^2, so that one revolution of the valve shall serve for eight successive strokes, two complete power operations, of the piston, as hereinafter explained. Each cylinder is provided with an admission port and passage A^4 and an exhaust port and passage E^x, these being formed in the casting B. The ports A^4 and E^x open into respective valve cavities K′ in position to register with the ports K^2 in the valve K. The width of the space between the inlet and exhaust ports approximately equals the width of the port K^2 in the valve K. These dimensions may be considerably varied without departing from the invention but I prefer to maintain the described proportions and relation for the particular reason that after the valve has opened to permit the heated gases to ex-

haust, those portions of the valve which are heated by the exhaust gases are almost immediately cooled by the inrush of cool combustible mixture at the port A^d. The time between the exhaust and the admission of mixture is proportionate to the distance that the valve has to travel between the ports E^x and A^d. In a multiple cylinder engine I prefer to pair the cylinders and connect the exhaust passages E^x of each pair as shown in Figs. 2 and 4. From the points of juncture the exhaust passages extend downward and open through the lower part of the casting B as shown in Fig. 5, wherein $E^{x'}$ represents the vertical extension of the united exhaust ports of two cylinders.

E^{x2} represents the exhaust manifold of the engine.

As indicated in Fig. 2 I prefer that the admission passages A^d of the several cylinders shall be independent and shall open through the outer face of the casting above the exhaust manifold. The passages A^d are connected by an admission manifold A^{d2} having two connections A^{d3} and A^{d4} with a suitable carbureter A^{d5}.

As best shown in Figs. 3 and 4, each head J contains a central cavity J^4 hemispherical at the top and opening through the bottom of the head. This cavity which obviously communicates with the piston containing portion a^3 of the cylinder constitutes the compression and combustion chamber of the engine. A central hole is provided in the top of the head and in this hole is the device M for igniting the gases, preferably an electric spark plug. Two passages J—A^d and J—E^x are formed in the head. These open through the valve seat surface of the head at points directly and respectively opposite the ports A^d and E^x in the valve seat surface of the cylinder, hence these passages or ports of the head are in position to register with the ports K^2 in the valve K.

The valve operating mechanism is most clearly shown in Figs. 1, 2, 3 and 4. Each member K is a combined valve and gear wheel; that is, the lower outer edge of each valve K is provided with gear teeth K^3 constituting an integral gear wheel whereby the valve may be rotated in its valve chamber or cavity. The valve operating member is arranged on the side of the engine opposite the side which contains the several admission and exhaust ports. This valve operating member comprises a single shaft N having as many integral gear wheel portions N′ as there are valves. Each cylinder is provided with an opening AN, at a point opposite the gear teeth on the valve and considerably below the level of the ports K^2 in the valve. This opening admits the operating gear N′ into mesh with the gear teeth upon the valve. Obviously all of the openings AN are arranged in a horizontal line. The shaft N is held in suitable bearings N^2 provided on the side of the cylinder casting B as shown in Figs. 2 and 4. The gear teeth on the valves and on the shaft N are preferably 45° spiral teeth. Such gears operate readily in either direction and are noiseless. At its end the shaft N is provided with a sprocket wheel N^3 and this is connected with the sprocket wheel G on the crank shaft by a suitable sprocket chain G^n. The sprockets G and N^3. and the sprocket belt G^n constitute the driver for the valve operating member or shaft N. The rotation of the crank shaft is thereby communicated to the several valves, and the latter are rotated constantly during the operation of the crank shaft. The sprockets G and N^3 and the gears N′ and K^3 are so proportioned that the valves are caused to turn one-half of a revolution during each two revolutions of the crank shaft; *i. e.*, in the time consumed by eight piston strokes. It will be clear that the rotative speed of the valves is relatively low and that nothing short of the breakage of one of these heavy substantial parts can interfere with the proper action of the valve. The valve operating shaft and gears are contained by a horizontal duct O formed in the side of the cylinder casting. B^4, B^4 are the edges of the duct O. These edges are integral with the cylinder casting B. The opening between them is closed by a horizontal plate B^6 tightly bolted thereto and making the duct oil tight. The duct O and the several valve cavities K′ are in communication through the openings AN. The sprockets G and N^3 and sprocket belt G^n are inclosed by a casing P, the upper end of which communicates with the duct O and the lower end of which communicates with the interior of the engine base D. An oil pump (not shown) forces oil into the duct O. The oil is distributed therefrom to the several valves by the gear teeth on the valves K and shaft N; *i. e.*, by the gear wheels N′ and K^3. In the case of each valve, its rotation causes the oil to spread upon the outer surface of the valve, whence it will work above and below the valve and spread upon the inner surface thereof. As before explained the differences of diameter, between the valve, the cylinder and the head, are so slight that only minute films of oil may occupy the spaces. These are in fact capillary spaces and while the oil will freely work into and occupy the spaces, due to the rotation of the valve within the inclosing walls, the oil cannot easily be discharged from the spaces by either internal or external pressure. The films of oil constitute fluid packings for the joints. This fact makes it possible to adequately lubricate the valves and inclosing walls without danger

of gas leakage from or to the cylinders at moments of compression, combustion and vacuum therein. It is clear also that it is practically impossible for any surface of the valve to engage any opposed surface upon the head or cylinder except through the medium of this minute film of oil which envelops the valve. In consequence the valve and valve seats will operate indefinitely without perceptible wear. Shallow vertical collecting grooves K^4 may be formed in the valves K at the "following" side of respective ports K^2, as shown in Figs. 1 and 4 and to expedite the distribution of oil within the valve chambers or cavities, I preferably provide the walls thereof with shallow oil grooves. The grooves d^x in the cylinder walls are so inclined that they tend to elevate the oil from the gear openings AN, whereas the grooves J^x in the surfaces of the heads may tend to force the oil downward. As shown in Fig. 3 the upper edge of each valve K is preferably provided with an annular oil groove K^x for an accumulation of oil, to better distribute the oil upon the inner surface of the valve. Very little of the oil thus supplied to the valve is wiped off at the ports, the greater part returning to the trough through the openings AN. It will thus be seen that the valves, the valve cavities and the valve gears constitute an oil circulating system which insures the positive lubrication of these parts at all times. The tight joint before alluded to, between the lower end of the head J and the cylinder prevents leakage of valve oil into the cylinder, a feature which is of distinct advantage.

As before explained the water space C within the cylinder casting extends to the top of the cylinders and cooling water is therefore supplied to all of the upper parts of the cylinders except those portions or areas which are occupied by the admission and exhaust passages A^d E^x, and the gear openings AN. The cooling of the outer walls of the valve cavities and the outer portions of the valves is thus insured. Each head J contains a water space J^w. The water is supplied and discharged through pipes J^p, two of which are provided for each head. The top of the head contains a depression to admit, and to afford easy access to, the firing plug M. The space J^w occupies nearly the whole of the head, only thin walls remaining; the exceptions being the spaces occupied by the ports JA^d and JE^x. As before described, the head is deeper than the valve K, extending both above and below the same. The water space is likewise deep, its bottom being preferably below the level of the valve K and the water rising therein to a level above the top edge of the valve. In other words, the cooling surface of the valve wall of the head is practically co-extensive with the valve and the maintenance of the valve at a low temperature is positively insured. The extent of the cooled portions of the cylinder and head, in comparison to the size and bulk of the valve, is clearly disclosed by Figs. 6, 7 and 8 of the drawings. It is not material whether these walls which inclose or envelop the valve are cooled by water or by air, or by some other medium; the important point is that the valves and the inclosing walls are so formed and related that they are quite separate from the hotter portions of the cylinder and head and are fully exposed to the cooling medium.

Many modifications of my invention will readily suggest themselves to one who is skilled in the art, and I do not confine or limit the invention to the specific details of construction herein shown and described. As examples of such modifications I refer to Figs. 9 to 14 inclusive. In Fig. 9 I have shown a head 1 which is a truncated cone, the inner end of the valve seating portion of the head being smaller than the upper portion. The valve seating wall 2 of the cylinder is cylindrical and the annular valve 3 is tapered on the inside to fit the head. A head and valve so formed are substantially cylindrical but the head may be withdrawn more easily without disturbing the valve. The same advantage as to the head may be secured by constructing the parts as shown in Fig. 10, wherein the valve seating walls 4 and 5 of the head and cylinder and the valve 6 itself are all conical. Furthermore such formations facilitate the removal of the valve from the cylinder after the head is taken out. This latter advantage may be preserved in the valve by forming the parts as shown in Fig. 11. The interior of valve 7 is cylindrical while the exterior is conical, with the large end uppermost. The head 8 and the cylinder 9 are made to fit the tapered valve 7. It should be understood that the drawings exaggerate the taper of all these parts. The operating gear 10 may be placed at either the top or the bottom of the valve as will be seen upon comparison of the Figs. 9, 10, 11 and 12. Fig. 12 shows the structure of Fig. 3 modified in this respect, the valve 11 being of uniform cylindrical section from end to end. When the operator is placed at the top, the ports should be lower than in other forms to retain adequate lap of the valve, adjacent to the several openings in the walls of the valve cavity. Fig. 13 discloses a structure in which the piston containing portion 12 of the cylinder and the valve and head containing portion 13 are more nearly of the same diameter. In this case the lower end 14 of the head fits the bore 13 and is provided with a smaller upper or intermediate portion and a top shoulder 15 which car-

ries the ring valve 16. The valve is toothed as before and the head is notched at 14′ to permit the insertion and withdrawal of the valve and head together without disturbing the operating gear 17. The means for fastening the head concentrically within the cylinder comprises a locking ring 18 of modified form. It screws down over the valve and bears upon a conical seat 19 provided on the head. While a valve operating shaft which is common to all the valves of the multiple cylinder engine shown in preceding figures is to be preferred because of its simplicity and because it is not disturbed by the withdrawal of the cylinder heads and valves, it is not absolutely necessary to use such an operating mechanism. In support of this statement I have in Fig. 14 shown a modified operating mechanism, which comprises a gear pinion 20 and shaft 21 set in the head 22 and acting upon internal gear teeth 23 formed on the inner periphery of the ring valve 24. With this construction the head may be withdrawn without disturbing the valve. Any suitable means such as the worm gears 25, 25 may be employed for driving the pinion from the crank shaft of the engine.

The operation of the engine is according to the well known four cycle principle and will be clearly understood from the foregoing detailed description of the operation of its several related parts. As explained the valves K of the several engines derive motion from the crank shaft. The directions of rotation of the valves are indicated by arrows in Figs. 1 and 4. The rotation of each valve is, obviously, timed to suit the movements of the piston in its respective cylinder, and the moments of opening and closing the ports are determined by the relative positioning of the ports in the cylinder and by the relative width of the ports in the valve and the cylinder. The drawings clearly disclose these several relative positions and proportional dimensions. Starting with a valve port K^2 in register with the exhaust port, the action may be traced as follows:—The cylinder is cleared or scavenged while the exhaust port E^x is open. As the valve rotates the port K^2 is moved away from the exhaust port and soon registers with the admission port A^d. At such time the piston is moving down and the explosive mixture will be drawn into the cylinder. Further rotation of the valve removes the port K^2 from the port A^d and closes the latter at about the time the piston begins to move up again. This upward stroke compresses the charge; which is exploded at about the time the piston reaches the upper end of its stroke. Then follows the downward power stroke of the piston. During these last two up and down strokes of the piston, the ports A^d and E^x are closed by the blank portion of the rotating valve but at about the end of the power stroke of the piston the valve will have rotated to the point of presenting its other port K^2 to the exhaust port E^x of the cylinder, thus completing the last of the four cycles and beginning the next series of operations or cycles.

The words top, bottom, upper, lower, above, below, height and depth as used in this specification and appended claims are relative terms. It is obvious that the relations of the parts so described would not be changed by inverting the engine or by placing it in a horizontal position.

The combination of parts, including the gear shaft N, for actuating the valves, comprises the subject matter of my co-pending application Serial No. 667,764, and is not herein specifically claimed.

Having thus described my invention I claim as new and desire to secure by Letters Patent:—

1. In an internal combustion engine, a cylinder in combination with a piston operable therein, a head wholly within the end of the cylinder and having both its inner end and its outer end circumferentially engaged with and guided by said cylinder, means securing said head against movement in said cylinder and effecting oil and pressure tight circumferential joints between the cylinder walls and head at said ends of the head, said cylinder and head having admission and exhaust ports intermediately situated therein, between said ends of the head and between the planes of said joints, and means situated between the ports in the cylinder and the ports in the head for effecting the opening and closing of said ports in time with the movement of said piston.

2. In an internal combustion engine, a cylinder in combination with a piston operable therein, a head within the end of the cylinder and having both its inner end and its outer end circumferentially engaged with and guided by the walls of said cylinder, means also within the cylinder securing the head therein and effecting complete oil and pressure tight circumferential joints between the cylinder walls and head at said ends of the head, and admission and exhaust controlling means operated by said piston and situated between the cylinder and head and between the planes of said joints.

3. In an internal combustion engine, a cylinder in combination with a piston therein, a head within the end of the cylinder and having both its inner end and its outer end circumferentially engaged with and guided by the walls of said cylinder, means securing said head against movement in said cylinder and effecting oil and pressure tight joints between the cylinder and head at said ends of the head, corresponding admission and

exhaust ports in the cylinder and head between said ends of the head, a ported valve confined between the cylinder and head and between the planes of said joints, controlling said ports and actuated by said piston.

4. In an internal combustion engine, a cylinder in combination with a piston therein, a head within the end of the cylinder and having both its inner end and its outer end circumferentially engaged with and guided by the walls of said cylinder, means securing said head against movement in said cylinder and effecting oil and pressure tight circumferential joints between the ends of the head and the walls of said cylinder, admission and exhaust ports situated in said cylinder and head between the planes of said joints, a port controlling valve also situated between said joints and movable rotatively between the cylinder and head, and means through the medium of which said valve is timed and is operated by said piston.

5. In an internal combustion engine, a cylinder in combination with a piston therein, a head within the end of the cylinder and having both its inner end and its outer end circumferentially engaged with and guided by the walls of said cylinder, means securing said head against movement in said cylinder, and effecting oil and pressure tight annular joints between the cylinder and the head at said inner and outer ends of the head, admission and exhaust ports being provided in said cylinder and head intermediate said ends of the head, an annular port-controlling valve concentric with, confined between and operable upon those surfaces of said cylinder and head, which are between said joints, and means through the medium of which said valve is actuated by said piston.

6. In an internal combustion engine, a cylinder in combination with a piston therein, a head within the end of the cylinder and having both its inner end and its outer end circumferentially engaged with and guided by the walls of said cylinder, means securing said head against movement in said cylinder and effecting oil and pressure tight circumferential joints between the cylinder and the head at said inner and outer ends of the head, admission and exhaust ports in said cylinder and head substantially midway between said ends of the head, an annular port-controlling valve confined between said cylinder and head and between said joints, and means through the medium of which said valve is actuated by said piston.

7. In an internal combustion engine, a cylinder in combination with a piston therein, a head wholly within the end of the cylinder, means also within said cylinder securing said head against movement therein and effecting oil and pressure tight circumferential joints between the cylinder walls and the head at the inner and outer ends of the head, admission and exhaust ports in said cylinder and head substantially midway between said circumferential joints, and a ported annular port-controlling valve concentric with, confined by, and revoluble between, said cylinder and head, and means through the medium of which said valve is rotated by said piston to open and close said ports in time with the movements of said piston.

8. In an internal combustion engine, a cylinder in combination with a piston therein, a head having annular upper and lower portions within the end of the cylinder, means securing said head against movement in said cylinder and effecting oil and pressure tight annular joints between the cylinder and said annular portions of the head, admission and exhaust ports in said cylinder and head between said annular portions of the head, an annular port-controlling valve revoluble between and concentric with said cylinder and head, said valve being wholly situated between said joints, and means actuated by the movement of said piston and adapted to rotate said valve in step with the movements of the piston.

9. In an internal combustion engine, a cylinder and a piston therein, in combination with a cylinder head within said cylinder and having its ends engaged with and longitudinally guided by the walls of the cylinder throughout their respective circumferences, means securing the head against movement in said cylinder and effecting circumferentially complete tight joints between the cylinder and head at said ends of said head, admission and exhaust ports in the cylinder and head between said joints, a rotary port-controlling valve situated between the cylinder and head and actuated by and in time with the relative movements of said cylinder and piston.

10. In an internal combustion engine, a cylinder and a piston therein, in combination with a cylinder head fixed within said cylinder and having inner and outer ends which make oil and pressure tight joints with the cylinder, the portions of the head and cylinder between said joints containing admission and exhaust ports, an annular port-controlling valve of greater diameter than said head and of less diameter than the cylinder and seating upon the head both above and below the ports therein, and positioned between said joints, and means for actuating said valve to open and close said ports in proper time with the movements of said piston.

11. In an internal combustion engine, a cylinder and a piston therein, in combination with a cylinder head fixed within said cylinder and having inner and outer ends

which make oil and pressure tight joints with the cylinder, the portions of the head and cylinder between said joints containing admission and exhaust ports intermediately positioned therein, an annular port-controlling valve of greater diameter than said head, of less diameter than the cylinder, of greater height than said ports and circumferentially seated against the said portions between said joints, means for constantly packing the spaces between said valve, cylinder and head with lubricant to maintain pressure tight joints therebetween, and means for actuating said valve to open and close said ports in proper time with the movements of said piston.

12. In an internal combustion engine, a cylinder and a piston therein, in combination with a cylinder head fixed in said cylinder and having inner and outer ends which make oil and pressure tight joints with the cylinder, the cylinder and head having admission and exhaust passages and ports intermediate said joints, an annular valve of greater diameter than said head and of less diameter than the cylinder, longitudinally fixed therein between said joints and having a port to register with the ports in the head and cylinder, the differences of diameter providing capillary spaces between the cylinder, valve and head, means for supplying oil to said valve, and means for rotating said valve to open and close said ports in proper time with the movements of said piston.

13. In an internal combustion engine, a cylinder and a piston therein, in combination with a cylinder head concentric with the cylinder and fixed therein and having inner and outer ends which make tight joints with the cylinder, the portion of said cylinder between said joints containing admission and exhaust ports and said head having a passage for communication therewith, an annular port-controlling valve of slightly greater diameter than said head and of slightly less diameter than the cylinder wholly situated between said joints, means for lubricating said valve, and means through the medium of which said piston rotatively actuates said valve to open and close said ports in proper time with the movements of said piston.

14. In an internal combustion engine, a cylinder and a piston therein, in combination with a cylinder head concentric with and fixed in the end of said cylinder and having inner and outer ends which make oil and pressure tight joints with the cylinder, the portions of the cylinder and head which lie between said joints containing admission and exhaust passages and ports positioned for communication, an annular valve of greater diameter than said head and of less diameter than the cylinder longitudinally fixed therein wholly between said joints and having a port to register with aforesaid ports, the differences of diameter providing capillary spaces between the cylinder, valve and head, means for constantly supplying oil to said spaces, gear teeth on said valve, and an actuating means meshing therewith and driven by the movement of said piston.

15. In an internal combustion engine, a cylinder and a piston therein, in combination with a cylinder head concentric with and fixed in the end of said cylinder and having inner and outer ends which make oil and pressure tight joints with the cylinder, the portions of the cylinder and head which lie between said joints containing admission and exhaust passages and ports positioned for communication, an annular valve of greater diameter than said head and of less diameter than the cylinder, longitudinally fixed therein wholly between said joints and having one or more ports to register with aforesaid ports, the differences of diameter providing capilliary spaces between the cylinder, valve, and head, means for constantly supplying oil to said spaces, gear teeth on said valve, a means movably mounted on said cylinder and meshing with the teeth on said valve and a driving connection whereby said means is driven in time with the movement of said piston.

16. In an internal combustion engine, a cylinder and a piston therein, in combination with a head concentric with and fixed in the end of said cylinder, said head having inner and outer ends which make tight joints with the cylinder, the cylinder and head having corresponding admission and exhaust ports in one side thereof between said joints, an annular valve of slightly greater diameter than said head and of slightly less diameter than the cylinder longitudinally fixed therein wholly between said joints and having two diametrically opposite ports adapted to register with the aforesaid ports, the distance between the ports in the cylinder approximating the width of each port in said valve, means for supplying oil to said valve, and means for rotating said valve once during every eight strokes of said piston.

17. In an internal combustion engine, a cylinder and a piston therein, in combination with a cylinder head fixed in the end of said cylinder, the inner and outer ends of said head being annular and jointed to said cylinder throughout their respective circumferences, the intermediate portion of said head, between its annular ends, being of less diameter than the adjacent portion of the cylinder and concentric therewith an annular valve cavity being thereby formed between said annular ends of the head, one side of said head and cylinder containing admission and exhaust ports which open

into said cavity between said ends of the head, an annular valve of slightly greater diameter than the head and of slightly less diameter than said adjacent portion of the cylinder and occupying said cavity, said valve containing one or more ports positioned to register with aforesaid ports, means for supplying oil to said cavity, and means for rotating said valve in time with the movement of said piston.

18. In an internal combustion engine, a cylinder and a piston therein, in combination with a cylinder head fixed in the end of said cylinder, the inner and outer ends of said head being annular and tightly jointed to said cylinder throughout their respective circumferences, the intermediate portion of said head being of less diameter than the adjacent portion of the cylinder and concentric therewith an annular valve cavity being provided between the cylinder and said intermediate portion of the head, one side of said intermediate portion and cylinder containing admission and exhaust ports which open into said cavity, an annular valve of slightly greater diameter than said intermediate portion of the head and of slightly less diameter than said adjacent portion of the cylinder occupying said cavity, said valve containing one or more ports positioned to register with aforesaid ports, the distance between the ports in the cylinder approximately equaling the width of the port in the valve, a gear formed at the end of said valve, and valve operating gearing deriving rotation from said piston.

19. In an internal combustion engine, a cylinder and a piston therein, in combination with a cylinder head fixed in the end of said cylinder, the inner and outer ends of said head being annular and tightly jointed to said cylinder throughout their respective circumferences, the intermediate portion of said head being of less diameter than the adjacent portion of the cylinder and concentric therewith an annular valve cavity being provided between the cylinder and said intermediate portion of the head, one side of said intermediate portion and cylinder containing admission and exhaust ports which open into said cavity, an annular valve of slightly greater diameter than said intermediate portion of the head and of slightly less diameter than said adjacent portion of the cylinder, occupying said cavity, and adapted to rotate therein, said valve containing two diametrically opposite ports positioned to register with aforesaid ports, the distance between the ports in the cylinder approximately equaling the width of each port in the valve, a gear formed on the end of said valve, an operating gear meshing therewith and deriving rotation from said piston, and means for constantly supplying oil to said gears and cavity.

20. In an internal combustion engine, a cylinder in combination with a piston therein, a head within the end of the cylinder, said head having its inner end in complete circumferential and endwise engagement with the walls of said cylinder and having its outer end circumferentially engaged and guided by the walls of said cylinder, means also within the cylinder engaging the outer end of said head and securing said head against movement in said cylinder and effecting oil and pressure tight joints between the said cylinder and head at said ends of the head, an annular valve positioned between the cylinder and head and between the ends of said head, said cylinder and head having ports controlled by said valve and means for actuating said valve in time with said piston.

21. In an internal combustion engine, a cylinder in combination with a piston therein, a head within the end of said cylinder, said head having its inner end in complete circumferential and endwise engagement with the walls of the cylinder and having its outer end circumferentially engaged with and guided by the walls of the cylinder, the cylinder being threaded at the end, a threaded ring fitting the threads of the cylinder and fastening said head against movement in the cylinder and effecting tight joints between the head and cylinder at said ends of the heads, an annular cavity being provided between said cylinder and head between said joints, an annular valve in said cavity, said head and cylinder containing admission and exhaust ports controlled by said valve and means for rotating said valve.

22. In an internal combustion engine, a cylinder in combination with a piston therein, a head within the end of the cylinder, means securing said head against movement in said cylinder and effecting circumferentially complete oil and pressure tight joints between the cylinder and head at the ends of the head, said cylinder and head having corresponding admission and exhaust ports substantially midway of the height of the head, a valve enveloped by the portions of said cylinder and head between said joints, and gearing through the medium of which the piston operates said valve to open and close said ports in time with the piston movements.

23. In an internal combustion engine, a cylinder in combination with a piston therein, a head within the end of the cylinder, means securing said head against movement in said cylinder and effecting oil and pressure tight complete annular joints between the cylinder and head at the ends of the head, said cylinder and head having corresponding admission and exhaust ports, an annular valve concentric with and wholly enveloped by the portions of the cylinder

and head between the planes of said joints and means operated by said piston and rotating said valve to open and close said ports in time with the piston movements.

24. In an internal combustion engine, a cylinder having a piston containing portion and a head containing portion, in combination with a head having its inner end in complete circumferential and endwise engagement with the walls of said piston containing portion and having its outer end circumferentially jointed to said head containing portion of the cylinder, means securing the head against movement in the cylinder and effecting tight joints between said ends of the head and the cylinder, the intermediate portion of said head being concentric with said head containing portion of the cylinder, ports in said cylinder and the intermediate portion of the head, an annular valve cavity being provided between the head and cylinder and between said joints, an annular ported valve fitting said cavity, an opening in the side of the cylinder and cavity and a valve operator positioned in said opening.

25. In an internal combustion engine, a cylinder having a cylindrical piston containing portion and a head containing portion, in combination with a head having an intermediate valve seating portion of less diameter than the head containing portion of said cylinder, said head having its inner end and its outer end engaged with the walls of said piston containing portion and said head containing portion respectively, means fastening said head against movement in the cylinder and effecting tight joints between the cylinder walls and said ends of the head, an annular cavity which is closed at its ends being formed by and between said cylinder and said head and situated wholly between the outer end of the cylinder and the inner end of the head, admission and exhaust ports provided in the cylinder and the head and opening into said cavity, an annular valve occupying substantially the whole of said cavity and provided with a port to register with said admission and exhaust ports and means engaged with a periphery of said valve and adapted to rotatively move said valve in said cavity, substantially as described.

26. In an internal combustion engine, a cylinder in combination with a head the ends of which make circumferentially complete annular oil tight joints with the cylinder, an annular valve space or cavity being provided between the cylinder and the head, a valve revolubly movable in said cavity, said valve having a port and said cylinder and said head being ported for the admission and exhaust of gases, the ports therein being situated between said annular ends of the head and opening into said cavity, and means entering said cavity for operating said valve.

27. In an internal combustion engine, a cylinder having a piston containing portion or bore and a valve-and-head-containing portion or bore distinguished by a valve-and-head-seating shoulder, in combination with an annular sleeve valve containing port, fitting said valve-and-head bore of the cylinder and seated on said shoulder of the cylinder, a head fitting within the valve and having its inner end seated upon said shoulder at the end of said valve, means securing the head against movement in the cylinder and effecting tight joints between the head and cylinder at the ends of the head, a suitable valve actuator and a driver therefor.

28. In a four-cycle internal combustion engine, a single cylinder block or casting containing a plurality of cylinder bores in combination with cylinder heads, one within each said bore, an annular sleeve valve between each head and cylinder bore and enveloped thereby, each said head and cylinder being jointed together at the ends of their respective valves, said heads, valves and cylinders having suitable registering ports, a single valve actuating member for simultaneously rotating said valves thereby causing the periodic registry of said ports, and said heads being removable from said block without disturbing respective valves therein.

29. In a four-cycle internal combustion engine, a single cylinder block or casting containing a plurality of cylinder bores in combination with cylinder heads, one within each said bore, an annular sleeve valve between each head and cylinder bore and enveloped thereby, each said head and cylinder being jointed together at the ends of their respective valves, said heads, valves and cylinders having suitable registering ports, a single valve actuating member for simultaneously rotating said valves and thereby causing the periodic registry of said ports and said heads being removable from said block without disturbing respective valves therein or said actuating mechanism.

30. In a four-cycle internal combustion engine, a one piece casting containing a cylinder bore comprising a piston containing portion and a head containing portion, in combination with an annular valve located within said head containing portion of the cylinder bore, a single piece head also located in the head containing portion of the cylinder bore and within said valve, said head having its ends jointed to the cylinder bore above and below said valve, means for actuating the valve so held and said head, valve and cylinder having suitable admission and exhaust ports.

31. In an internal combustion engine, a single block containing a plurality of suit-

ably cooled cylinder bores, in combination with a single piece suitably cooled head in each said bore, a single piece annular sleeve valve concentric with and interposed between each head and its bore, each said head being jointed to the cylinder bore above and below its respective valve, said cylinders, valves and heads each having a complement of ports, an opening in the side of each cylinder bore, a single valve operating member acting upon all said valves through said openings, pistons in said bores and a single driving device for said member, operated by the movement of said pistons.

32. In an internal combustion engine, a one piece cylinder containing a cylinder bore comprising a piston containing portion and a head containing portion, in combination with a one-piece ported sleeve valve concentric with and fitting the head containing portion of said bore, a one-piece head concentric with and fitting said valve, the ends of said head being jointed to the cylinder above and below respective ends of said valve, said cylinder and head containing admission and exhaust ports to register with the port in the valve, and means for rotating said valve.

33. In an internal combustion engine, a one-piece cylinder containing a cylinder bore comprising a piston containing portion and a head containing portion, in combination with a one-piece ported sleeve valve concentric with and fitting the head containing portion of said bore, a one-piece head concentric with and fitting said valve, the ends of said head being jointed to the cylinder above and below respective ends of said valve, said cylinder and head containing admission and exhaust ports to register with the port in the valve, and a one-piece valve operating member for rotating said valve.

34. In an internal combustion engine, a cylinder in combination with a piston therein, a crank shaft connected to said piston, a cylinder head opposed to said piston, said cylinder and head together containing an annular valve cavity concentric therewith and closed at top and bottom, said cylinder and head containing admission and exhaust ports which open into said cavity, an annular ported sleeve valve occupying and substantially filling said cavity for controlling said admission and exhaust ports, the bottom of said valve being above the lower end of said head, and valve rotating means entering said cavity and connected with said crank shaft and adapted to drive said valve one revolution or twice as many revolutions of the crank shaft as there are ports in the valve.

35. In an internal combustion engine, a cylinder and a piston therein, in combination with a cylinder head fixed in said cylinder and having inner and outer ends which make oil and pressure complete circumferential joints with the cylinder, the cylinder and the intermediate portion of said head being of different diameters and forming an annular valve cavity, said head and cylinder containing admission and exhaust passages and ports positioned about midway between the top and bottom of said intermediate portion of the head, an annular valve occupying and of slightly less diameter than said cavity and having a port to register with the ports in the head and cylinder, such differences of diameter providing capillary spaces between the cylinder, valve and head, an opening in the cylinder wall of said cavity, a closed oil pocket at said opening for supplying oil to said valve, and means operating in said opening for rotating said valve to open and close said ports in proper time with the movements of said piston.

36. In a four-cycle internal combustion engine, a single cylinder block or casting containing a plurality of cylinder bores in combination with cylinder heads, one within each said bore, an annular sleeve valve between each head and cylinder bore, said heads and cylinders being tightly jointed above and below respective valves, said heads, valves and cylinders having suitable registering ports, a single valve actuating member for simultaneously rotating said valves thereby causing the periodic registry of said ports and a single duct containing said member and supplying oil to all said valves.

37. In an internal combustion engine, a single block containing a plurality of suitably cooled cylinder bores, in combination with a single piece suitably cooled head in each said bore, a single piece annular sleeve valve concentric with and interposed between each head and its bore, each said head being jointed to the cylinder bore above and below its respective valve, said cylinders, valves and heads each having a complement of ports, an opening in the side of each cylinder bore, a single valve operating member acting upon all said valves through said openings, a single oil duct containing said member and communicating with all said openings, a piston in each bore and a driving device for said member operated by the movement of said pistons.

38. In an internal combustion engine, a cylinder in combination with a piston operable therein, a cylinder head wholly within said cylinder, means also within said cylinder securing said head against movement therein and effecting oil and pressure tight complete circumferential joints between the cylinder walls and the ends of said head, said head and cylinder containing admission and exhaust ports, an annular port controlling valve operable between and circumferentially seated upon the head and cylinder,

and valve gearing connecting the valve and piston.

39. In an internal combustion engine, a cylinder in combination with a piston operable therein, a cylinder head fastened in said cylinder and having annular ends in complete jointure with the cylinder, the intermediate portion of said head and the adjacent portion of said cylinder being concentric and of different diameter providing an annular valve cavity between the cylinder and head, said intermediate and adjacent portions containing admission and exhaust ports positioned in one side thereof intermediate said ends of the head, an annular valve occupying said cavity, the inner periphery of said valve seating upon said intermediate portion of the head and the outer periphery of the valve seating upon said adjacent portion of the cylinder, said valve containing a port positioned to register with the aforesaid ports, and means actuated by said piston for rotatively operating said valve in said cavity.

40. In an internal combustion engine, a cylinder containing a cylinder bore comprising a piston containing portion and a head containing portion in combination with an annular sleeve valve concentric with and fitting the head containing portion of said bore, one side of said cylinder containing admission and exhaust ports which open against the outer side of said valve, said valve having one or more ports to register with said admission and exhaust ports, a head concentric with and fitting within said valve and ported to communicate with aforesaid ports in the cylinder and valve, said head having annular ends in complete jointure with the cylinder respectively above and below said ports, and valve gearing for rotatively actuating said valve.

41. In an internal combustion engine, a one-piece cylinder containing a cylinder bore comprising a piston containing portion and a head containing portion, in combination with a ported annular valve concentric with and fitting the head containing portion of said bore, a one-piece head concentric with and fitting said valve, the ends of said head being jointed to the cylinder above and below respective ends of said valve, said cylinder and head containing admission and exhaust ports to register with the ports in the valve, and means for rotating said valve.

42. In a four-cycle internal combustion engine, a single cylinder block or casting containing a plurality of cylinder bores in combination with cylinder heads, one within each said bore, an annular sleeve valve between each head and cylinder bore and enveloped thereby, each said head and cylinder being jointed together at the ends of their respective valves, said heads, valves and cylinders having suitable registering ports, means for simultaneously rotating said valves thereby causing the periodic registry of said ports, and said heads being removable from said block without disturbing respective valves therein.

43. In a four-cycle internal combustion engine, a single cylinder block or casting containing a plurality of cylinder bores in combination with cylinder heads, one within each said bore, an annular sleeve valve between each head and cylinder bore and enveloped thereby, each said head and cylinder being jointed together at the ends of their respective valves, said heads, valves and cylinders having suitable registering ports, actuating mechanism for simultaneously rotating said valves and thereby causing the periodic registry of said ports and said heads being removable from said block without disturbing respective valves therein or said actuating mechanism.

44. In an internal combustion engine, a cylinder containing an annular shoulder, in combination with a piston in said cylinder below said shoulder, a head within the cylinder and having annular ends in complete circumferential jointure with the cylinder above and below said shoulder, an annular valve cavity being formed between said cylinder and head, said shoulder comprising the bottom of said cavity, an annular valve occupying said cavity and provided with a port, said head and cylinder having exhaust and admission ports positioned to successively register with the port in said valve, and means for rotating said valve in said cavity.

45. In an internal combustion engine, a cylinder containing a circumferential shoulder, in combination with a piston in the cylinder below said shoulder, a head wholly within said cylinder and resting upon said shoulder, a ring also within the cylinder and pressing upon said head to secure it within the cylinder, the lower end of said head being circumferentially jointed to the cylinder below said shoulder, an annular valve cavity being formed between the cylinder and head, an annular valve occupying and substantially filling said cavity, valve gearing connected with the piston for operating said annular valve, and said valve, cylinder and head containing ports for the admission and exhaust of gases.

46. In an internal combustion engine, a cylinder containing an internal circumferential shoulder, in combination with a piston operable in said cylinder below said shoulder, a cylinder head wholly within said cylinder and having its lower end seated upon said shoulder, means within said cylinder above the head securing said head therein and effecting oil and pressure tight complete circumferential joints at the ends of the head, said head and cylinder contain-

ing admission and exhaust ports, an annular port controlling valve operable between and circumferentially seated upon the intermediate portion of said head and the adjacent part of the cylinder, and valve gearing connecting the valve and piston.

In testimony whereof, I have hereunto set my hand, this 7th day of November, 1911, in the presence of two subscribing witnesses.

EDWARD H. BELDEN.

Witnesses:
N. CURTIS LAMMOND,
CHARLES GILBERT HAWLEY.