

May 24, 1927.

1,630,245

J. HALTENBERGER

INTERNAL COMBUSTION ENGINE

Filed Jan. 9, 1926

5 Sheets-Sheet 1

Fig. 1.

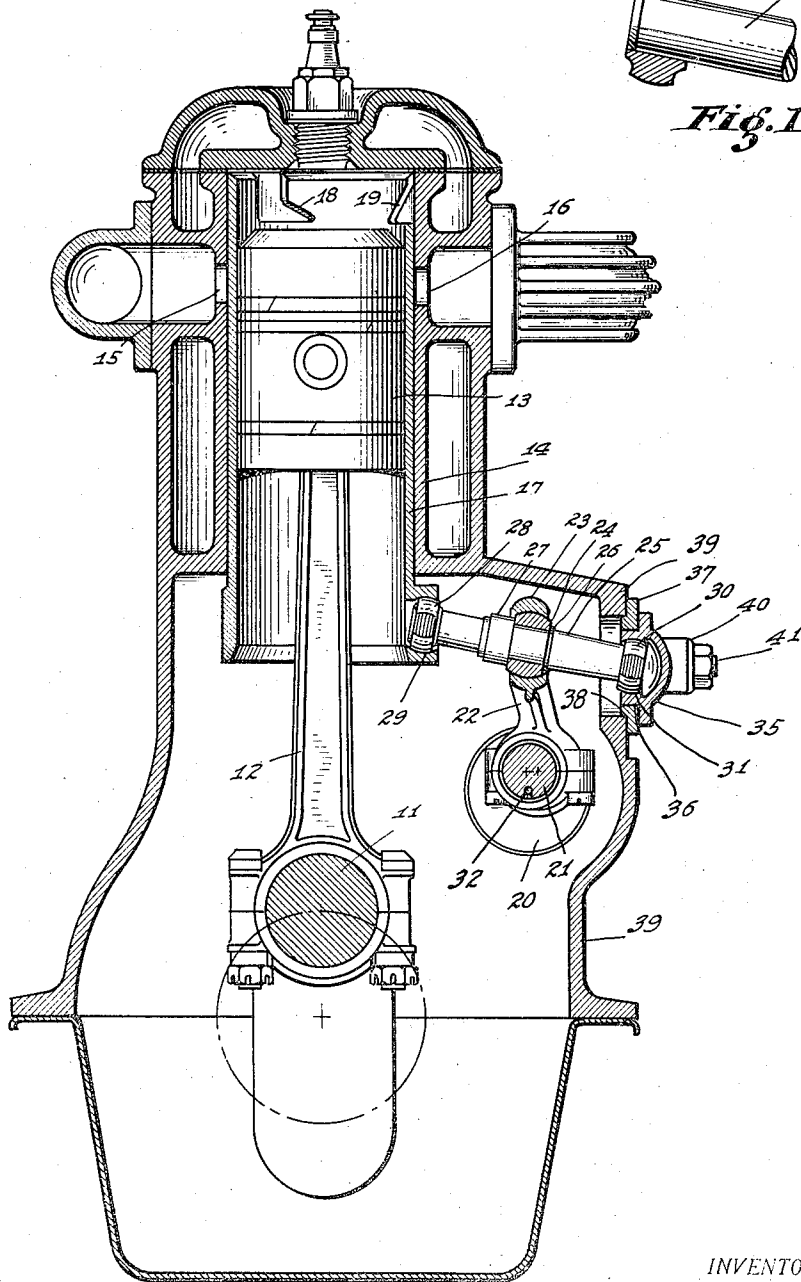


Fig. 1a

INVENTOR.

JULES HALTENBERGER,

BY

G. J. Schley.
ATTORNEY.

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J. HALTENBERGER

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Fig. 2.

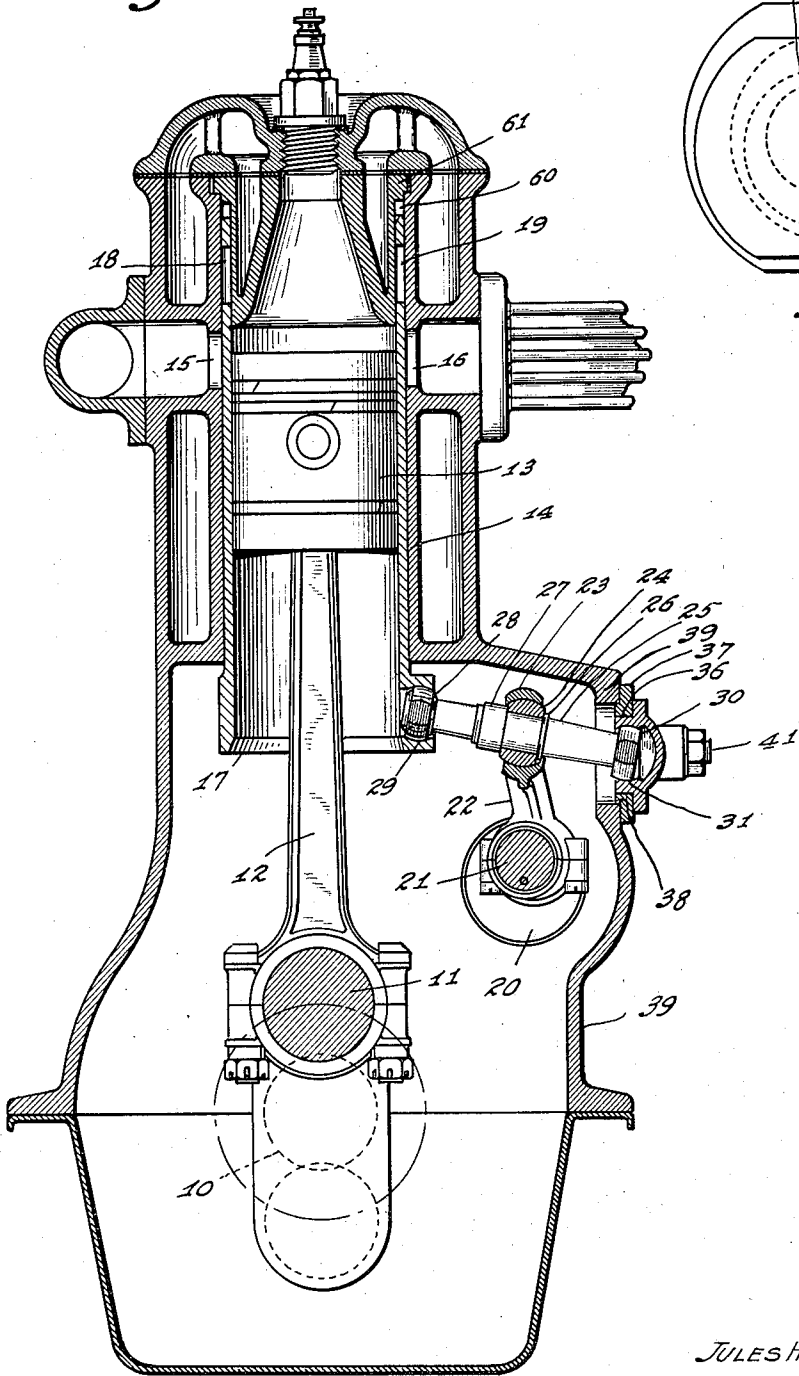
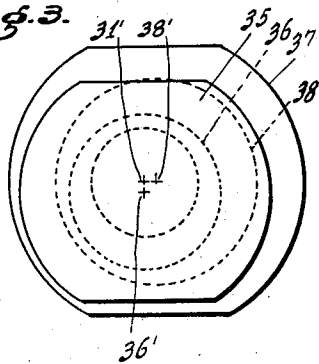


Fig. 3.



INVENTOR.
JULES HALTENBERGER,

BY

G. Zschluy.

ATTORNEY.

May 24, 1927.

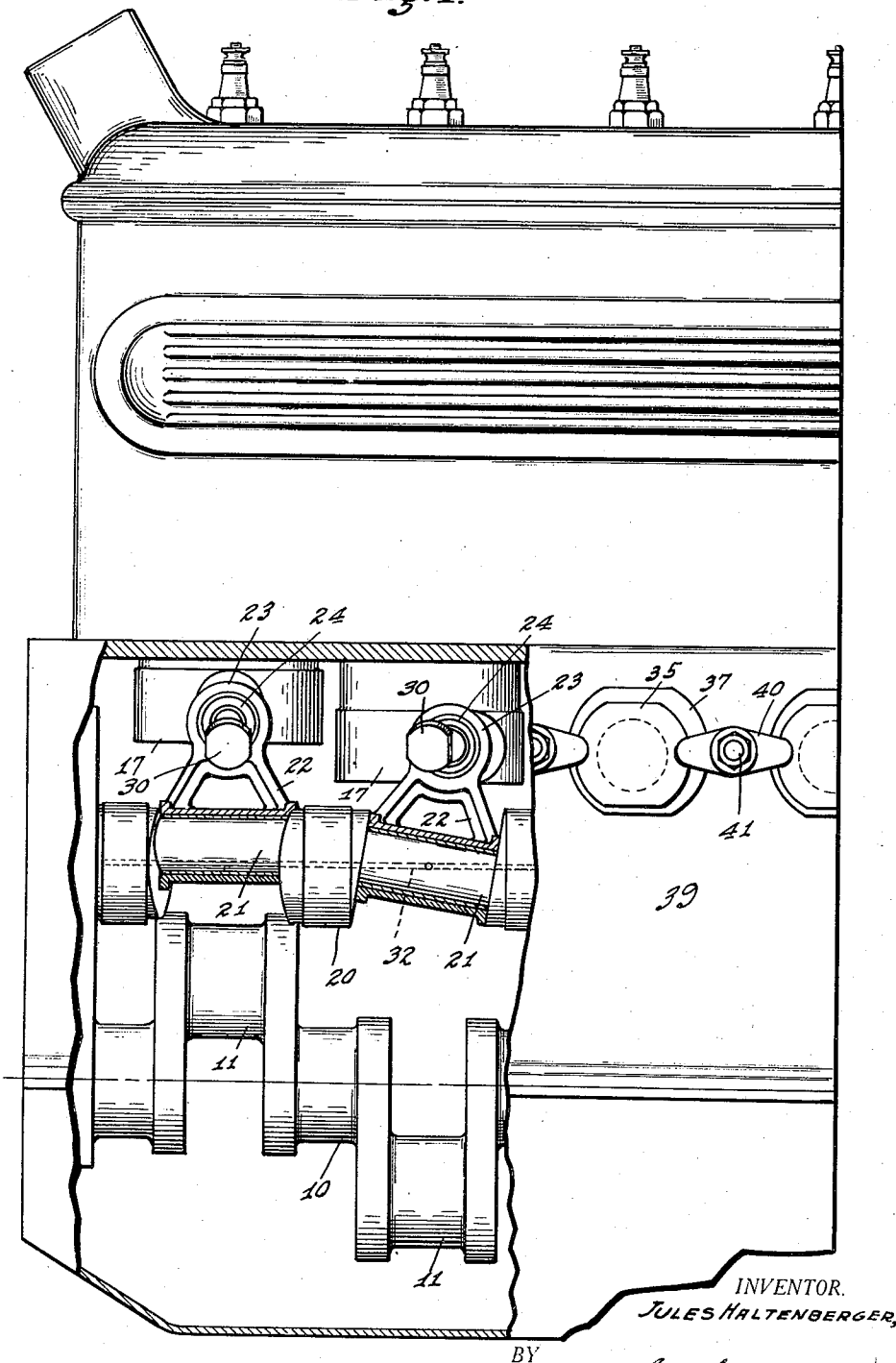
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Fig. 4.



INVENTOR.
JULES HALTENBERGER,

BY

G. B. Schley.
ATTORNEY.

May 24, 1927.

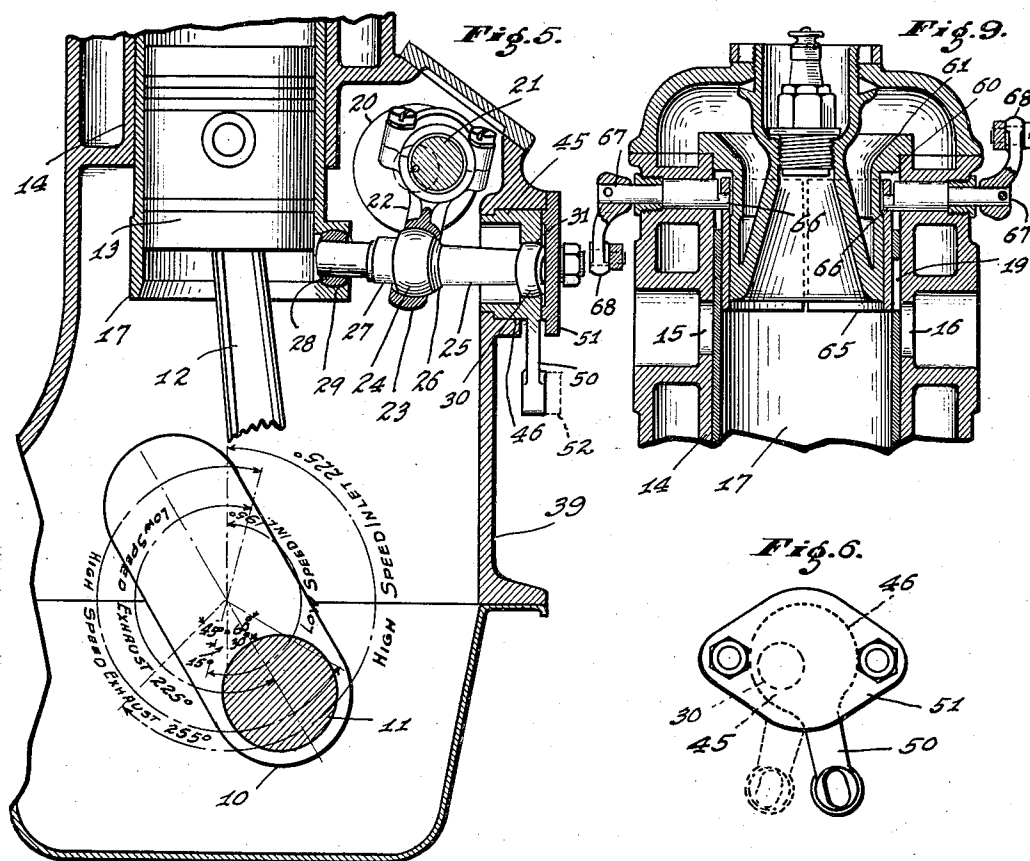
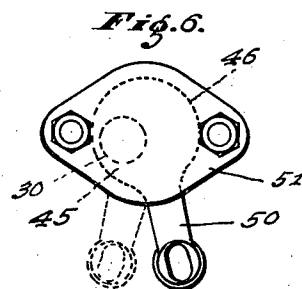
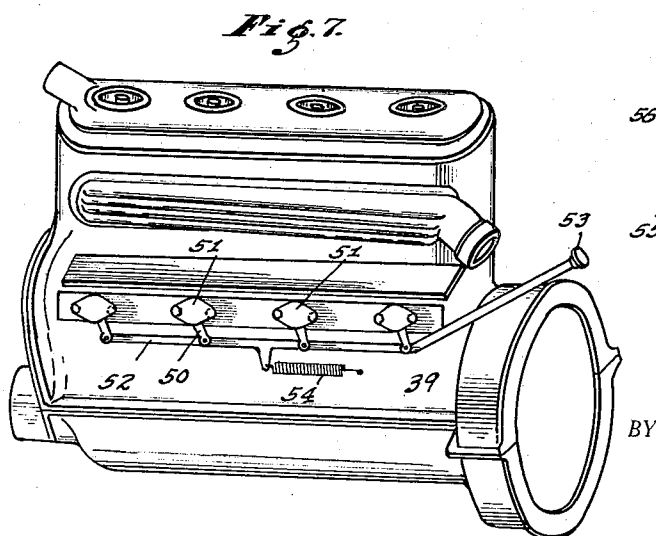
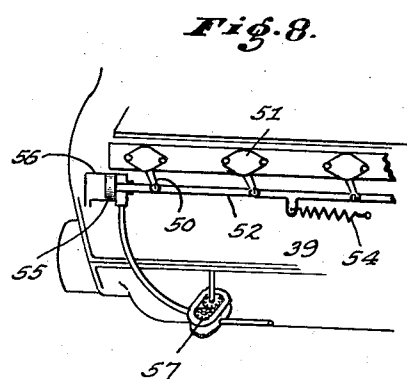
J. HALTENBERGER

1,630,245

INTERNAL COMBUSTION ENGINE

Filed Jan. 9, 1926

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INVENTOR.
JULES HALTENBERGER,

BY
G. S. Kelly
ATTORNEY.

May 24, 1927.

J. HALTENBERGER

1,630,245

INTERNAL COMBUSTION ENGINE

Filed Jan. 9, 1926

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Fig. 10.

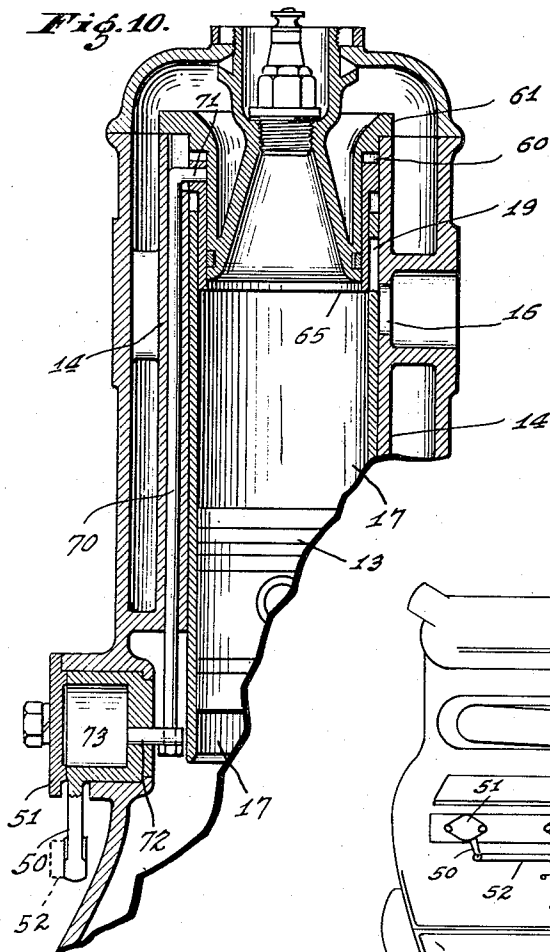


Fig. 11.

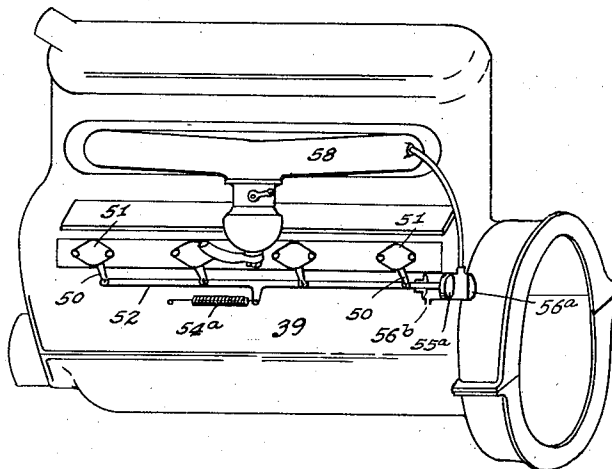
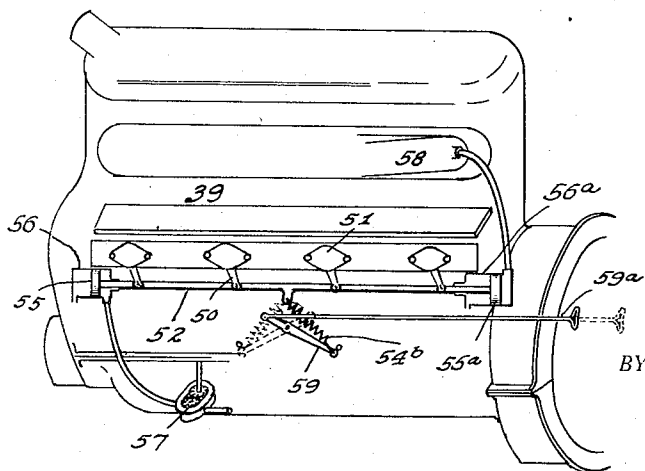


Fig. 12.



INVENTOR.
JULES HALTENBERGER,

BY *H. Gehlby.*
ATTORNEY.

UNITED STATES PATENT OFFICE.

JULES HALTENBERGER, OF INDIANAPOLIS, INDIANA, ASSIGNOR TO JULES HALTENBERGER, INCORPORATED, OF INDIANAPOLIS, INDIANA, A CORPORATION OF INDIANA.

INTERNAL-COMBUSTION ENGINE.

Application filed January 9, 1926. Serial No. 80,268.

My invention relates to internal combustion engines of the sleeve-valve type, and more especially one in which a port or ports are controlled by a single sleeve which is both reciprocable axially of the cylinder and oscillatable about the axis of the cylinder.

It is the object of my invention to decrease the size and weight of the valve-shaft; to decrease the valve-shaft throw required for a given movement of the sleeve-valve; to decrease the length of sleeve-valve movement required for a given valve opening; to increase the strength of the shaft in proportion to its size and throw required to produce a given sleeve motion; to obtain both components of movement of the sleeve-valve by a single connection, and a gearless connection, between the sleeve-valve and the valve-shaft; to reduce the momentum of the complete oscillating system of the sleeve-valve and its actuating parts; to provide a ready adjustment and control of the valve timing, either manual or automatic and with either one or a plurality of controls, operable either when the engine is at rest or in motion; to provide a ready adjustment of the sleeve-valve for a given position of the valve-shaft, either for the purpose of controlling such valve timing or for correcting inaccuracies and variances in design or manufacture, or for both; and to provide ready accessibility to the actuating mechanism of the sleeve-valve.

In carrying out my invention, I provide a sleeve-valve between the piston and the cylinder wall of an internal combustion engine, for controlling inlet and outlet ports through the cylinder wall. The specific embodiment of my invention illustrated in the present application has a single sleeve-valve, and the more specific claims in this application are limited to that type of engine. The upper end of this sleeve-valve may be exposed to the pressure of the gases within the cylinder, so that the sleeve-valve itself in its piston movement or reciprocating movement becomes a power-producing element supplementing the piston proper; or may be shielded from the pressure of the gases in the cylinder, as by projecting into a suitable pocket. In either case, the sleeve-valve, preferably at its lower end, is connected through a lever to an eccentric on the valve

shaft; which eccentric is oblique in a single-sleeve engine. This lever is desirably a movement-multiplying lever, and most desirably a lever of the third class; and has its power-point connected to a sleeve-connecting rod which is mounted on such eccentric. The fulcrum point, the power point, and the load point of the lever, in the single sleeve engine, are provided with ball-and-socket connections to their respectively associated parts; and suitable provision is made for accommodating the variation in length of the load-arm of the lever, as by having at least one of the balls at the fulcrum and load points made slidable. I prefer to have the ball at the load-point of the lever slidable along the lever. Because of the oblique eccentric, or wobble-crank, the power-point of the lever is moved in a closed curve as the valve-shaft rotates, with components of reciprocation both along the cylinder and transverse to the cylinder; and these components are transmitted to the sleeve-valve, with a multiplied movement because of the lever, so that the sleeve-valve has a greater length both of reciprocation and oscillation than has either the power-point of the lever or the sleeve-connecting rod connecting such power-point to the wobble-crank.

By using a lever of the third class, the fulcrum point of the lever is at the opposite end thereof from the load-point at which the lever is connected to the sleeve-valve. This fulcrum point may be provided in the casing, in a suitably adjustable supporting member. This adjustment is desirably in the form of an eccentric or a plurality of superposed eccentrics. By the use of two eccentrics, suitably arranged, the fulcrum point may be adjusted either up or down or transversely with each movement nearly independent of the other; and this is desirable to compensate for and correct inaccuracies and variances in designing and machining the engine parts to get the proper timing of the valve ports. However, this adjustment of the fulcrum-point of the lever may be used for controlling the timing of the engine, by shifting the fulcrum point in accordance with conditions, either manually or automatically and with either one or a plurality of controls.

I also provide a variable timing of the

valves; by which I can get increased torque at low speeds and increased power at high speeds, and then obtain a wider speed-range of effective performance. I may do this by the adjustment of the lever fulcrum; but I prefer to do it by a shifting of the effective working edges of the ports which co-operate with the sleeve-port, as by a supplemental sleeve or liner which is shiftable in the upper end of the cylinder for that purpose. In either way it is possible to advance the exhaust opening and retard the inlet closing, and vice versa, by substantially equal cycle-angles if desired, without affecting at all, or only slightly varying if preferred, the timing of the exhaust closing or of the inlet opening.

The valve-shaft may be located in various positions with respect to the lever. There is an advantage in so locating the valve-shaft that the axis thereof is substantially between each crank and the power-point of the associated lever when the associated sleeve-valve is at its highest point; as thereby it becomes possible to obtain a given port opening with a smaller movement of the sleeve-valve. It is very desirable to have the valve-shaft and levers within the crank-case of the engine, and the levers connected to the lower ends of the respective sleeve-valves; as that makes for simplicity of design, and gives the benefit of the crank-case oil sprays for lubrication.

The accompanying drawings illustrate my invention: Fig. 1 is a vertical central section through a single-sleeve internal combustion engine embodying one form of my invention, with the upper end of the sleeve-valve exposed to the pressure within the cylinder; Fig. 1^a is a sectional detail showing the sliding mounting of the ball-and-socket joint at the loading point of the movement-multiplying lever; Fig. 2 is a view similar to Fig. 1, with the upper end of the sleeve-valve shielded from the pressure within the cylinder; Fig. 3 is a side elevation of the double eccentric support for the fulcrum point of the actuating lever of a sleeve-valve being drawn on a slightly larger scale than Figs. 1 and 2; Fig. 4 is a partial side elevation, with some parts broken away or in section, of either of the engines shown in Figs. 1 and 2, to show the wobble-cranks and levers, and the mountings of the latter; Fig. 5 is a view similar to the lower part of Figs. 1 and 2, but with the valve-shaft above the levers instead of below them, and with a shifting lever for the fulcrum-support for obtaining variable timing; Fig. 6 is a side view of the fulcrum mounting of Fig. 5; Fig. 7 is a perspective view of a complete engine, on a somewhat smaller scale, embodying the construction shown in Fig. 5, with a foot control of the

supports for the fulcrum points of the levers; Fig. 8 is a partial view similar to Fig. 7, but with such fulcrum-point supports adjustable to control the valve-timing automatically in response to the oil-pressure developed by an engine-driven pump, for speed control; Fig. 9 is a sectional view of the upper part of the engine of Fig. 2, showing a preferred construction for controlling the timing of the exhaust-port opening and the inlet-port closing by a supplemental or special valve-timing sleeve; Fig. 10 is a view generally similar to Fig. 9, but showing a modified construction for operating the supplemental or valve-timing sleeve; Fig. 11 is a perspective view generally similar to Fig. 7, but with the automatic control of the valve-timing responsive to the vacuum in the intake manifold, for economy control; and Fig. 12 is another view generally similar to Fig. 7, but with both oil-pressure and intake-manifold-vacuum control of the valve-timing.

The internal combustion engine embodying my invention may have any suitable crank-shaft 10, the cranks 11 of which are connected by suitable connecting rods 12 to pistons 13 which are reciprocable within cylinders 14, in the usual manner. There may be any number of cylinders. These are shown as water-jacketed cylinders, but that is a mere detail. In the side walls of each cylinder 14 are inlet and exhaust ports 15 and 16. These ports are here controlled by a single sleeve-valve 17, which is interposed between the piston 13 and the cylinder 14 so that the piston 13 actually reciprocates inside of and directly in contact with the sleeve-valve 17. The sleeve-valve 17 is provided at or near its upper end with ports 18 and 19 which co-operate with the ports 15 and 16 respectively to control the inlet and exhaust of that cylinder. The ports 15, 16, 18, and 19 are properly located for the effective opening and closing of the ports by the movement of the sleeve-valve 17; and this movement of the sleeve-valve is in a closed curve having components both along the cylinder axis and around the cylinder axis, so that the sleeve-valve both reciprocates longitudinally and oscillates circumferentially.

The movement of the sleeve-valve is obtained from a valve-shaft 20, which is suitably driven from the crank-shaft 10, in any usual manner (not shown), so that as usual the valve-shaft 20 makes one revolution for each two revolutions of the crank-shaft. The valve-shaft 20 has a fixed phase relationship with the crank-shaft 10, and also with each piston 13. The valve shaft 20 has a series of eccentrics or cranks 21, one for each engine cylinder; and each crank 21 is oblique to the axis of the valve-shaft, or is a wobble crank, as is perhaps most clear

from Fig. 4. There is a sleeve-connecting wobble-rod 22 for each wobble-crank 21. Each wobble-rod has one end journaled on the associated wobble-crank, and at the other end is provided with a socket 23 which co-operates with a ball 24 to form a ball-and-socket joint permitting relative universal movement between its two parts. The socket member 23 and the ball 24 are of any suitable construction which permits them to be put together; as by having opposite flattened portions on the ball, and making both the ball and the socket as segments which are sufficiently small to permit the ball to be removed from the socket upon sufficient relative tilting from their working position. The ball member 24 is an annulus which is mounted on a lever 25 between a shoulder 26 and a clamping nut 27. This lever is desirably a movement-multiplying lever, most desirably of the third class. In that case, the load point is provided by a ball 28 slidable on the inner end of the lever 25 and located in a socket 29 provided in the lower end of the sleeve-valve 17. This ball-and-socket may also readily be put together or separated upon sufficient tilting. The outer end of the lever 25 is provided with a third ball 30, which is mounted within a socket 31. Thus the lever has three ball-and-socket joints, comprising the joint 30—31 at the fulcrum point, the joint 23—24 at the power point, and the joint 28—29 at the load point. The particular arrangement of the fulcrum-point joint will be described hereinafter.

By reason of the actuating mechanism just described, the sleeve-valve 17 is given the desired movement. As the valve shaft 20 rotates, it moves the socket 23 up and down, and also reciprocates it lengthwise of such valve-shaft, on account of the obliqueness of the associated wobble-crank 21. In consequence, the ball 24 is given a corresponding movement in both of these directions; and because of the lever 25, this movement is multiplied into a movement of generally corresponding shape but greater magnitude at the ball 28. The movement of the ball 28 does not exactly correspond to that of the ball 24, because the ball 28 has a slight sliding movement along the lever 25 as the associated socket 29 moves around the axis of the sleeve-valve 17. The various ball-and-socket joints provide the necessary universal movements at all three working points of the lever.

Because of this multiplication of movement, by the lever 25, a given movement of the sleeve-valve 17 both along and about its axis may be obtained with a smaller throw of the crank 21. This makes it possible to make the valve-shaft materially smaller than would otherwise be the case, with a resultant saving in both weight and cost, and with a gain in strength because of the smaller

eccentricity required for the cranks. This even makes it possible to have a straight axial oil-hole 32 extending the whole length of the valve shaft and through all of the eccentrics thereof, because all such eccentrics can be made to overlap the valve-shaft axis and one another.

The valve-shaft 20 may be located either below the series of levers 25, as is indicated in Figs. 1, 2, and 4, or above such series of levers, as is indicated in Fig. 5. There is an advantage in having the valve-shaft located above such series of levers, when they are of the class shown, and above the plane at which the driving connection from the valve-shaft to the sleeve-valves is made to the sleeve-valves; in that it affords a greater opening of the ports for a given total axial reciprocation of the sleeve-valve, or makes it possible to decrease the length of such reciprocation necessary to obtain a given opening of the valve ports.

This is because the sleeve-valve is moved idly, so far as valve-opening or valve-closing is concerned, during the compression and explosion periods of the engine, during which periods the valve ports are closed; while it serves to open and close the ports during the exhaust and inlet periods. The sleeve-valve is at about the highest point of its movement at the instant of firing, at the end of the compression period and beginning of the explosion period. That is, the wobble-rod 22 (in the arrangements shown) projects substantially vertically from its associated wobble-crank to the joint 23—24 at such firing instant, projecting upward from such crank if the valve-shaft is below the levers 25 and downward from such crank if the valve-shaft is above such levers; and the wobble-crank is then substantially at its high point. Because of the shortness of the wobble-rod 22—for this situation would not apply if this wobble-rod were of infinite length—when the wobble-crank has traveled half-way, or 90°, from its high point toward its low point, the sleeve-valve will have moved either more or less than half-way from its high point. Such movement of the sleeve will be more than half if the valve-shaft is below the levers 25, as indicated in Figs. 1 and 2; but will be less than half if the valve-shaft is above such levers, as is indicated in Fig. 5. That is, the travel which the sleeve-valve must have during that part of the cycle when the ports are wholly closed may be less if the valve-shaft is above the levers 25 than if it is below such levers; so that the ratio of the sleeve-valve movement in which the ports are wholly closed to the remaining part in which the ports are at least partly open may be less with the valve-shaft above the levers than below them, and the total movement of the sleeve-valve may be less for a given port

opening or the port opening may be greater for a given total sleeve-valve movement if the shaft is above the levers.

For simplicity this situation has been specifically described in connection with levers of the third class, because they are the ones shown. It applies generically, however, to levers of other kinds, and even to leverless sleeve-drives. Put generically, the valve-shaft is so located that its connecting rod extends substantially across the axis of the valve-shaft when the associated cylinder is at the firing point.

The fulcrum points of the levers 25, furnished by the ball-and-socket joints 30—31 are desirably made adjustable. This adjustment may be merely for the purpose of compensating for inaccuracies and variances in design and machining, to get the desired correlation of the ports in the sleeve-valve and in the cylinder; or it may be for controlling and varying the timing of the port-opening and port-closing.

If for the purpose of compensating for inaccuracies and variances in the design machining, I prefer the arrangement shown in Figs. 1 to 4 inclusive. In this arrangement, the socket 31 is provided in an angularly adjustable member 35 which has an outer cylindrical bearing surface 36 which fits in a cylindrical hole in a second angularly adjustable member 37, which in turn has an outer cylindrical bearing surface 38 which fits in a cylindrical hole in the casing 39 of the engine. The surfaces 36 and 38 are eccentric to each other, and both of them are eccentric to the engaging surfaces of the ball-and-socket joint 30—31. As perhaps best shown in Fig. 3, the axis 36' of the surface 36 is slightly displaced generally vertically from the axis 31' of the ball-and-socket joint 30—31; while the axis 38' of the surface 38 is displaced generally horizontally from such axis 31'. In consequence, by rotating the member 35, without rotating the member 37, the axis 31' of the ball-and-socket joint 30—31 is shifted substantially horizontally, with only a negligible vertical component if the angle of such rotation is small; while by rotating the member 37, without rotating the member 35, the axis 31' of such ball-and-socket joint is shifted substantially vertically, with only a negligible horizontal component if the angle of such rotation is small.

To facilitate this shifting, and the clamping of the parts 35 and 37 in adjusted position, those parts have flanges which overlie the respectively subjacent parts, and are provided with flattened portions for receiving a wrench. The parts are clamped in adjusted position by clamping plates 40 which bear on the flanges of the members 35, each intermediate clamping plate 40 co-operating with two members 35. The clamp-

ing plates 40 are mounted on clamping screws 41 mounted in the engine casing 39, and each clamping plate projects in opposite directions from its supporting clamping screw. By the tightening of the nuts on clamping screws 41, the members 35 and 37 are clamped together and against the engine casing 39.

By the adjustment just described, a member 35 may be adjusted angularly to move the associated sleeve-valve 17 slightly about its axis to get the desired circumferential correlation between the ports of the sleeve-valve and of the cylinder; while by adjusting the member 37, the sleeve-valve is adjusted vertically within the cylinder to get the desired vertical correlation between such ports.

While this double adjustment of the socket 31 is desirable, especially to compensate for inaccuracies and variances in manufacture, yet when the shifting of the socket 31 is used for controlling the timing of the valves it is ordinarily necessary to provide only a single adjustment for such socket. Such an arrangement is shown in Figs. 5, 6, 7, 8, 11, and 12. In that arrangement, the socket 31 is provided in an angularly adjustable member 45, having an outer cylindrical bearing surface 46 fitting in a cylindrical hole in the engine casing 39. The axis of the ball-and-socket joint 30—31 is offset substantially horizontally from the axis of the surface 46, as is clear from Fig. 6; so that by turning the member 45, the ball-and-socket joint 30—31 is shifted substantially vertically with only a negligible component of horizontal shifting. This shifting varies the time at which the exhaust ports start their opening and the inlet ports complete their closing, with substantially little change in the time of completion of the closing of the exhaust ports and in the beginning of the opening of the inlet ports if it is so desired; and thus an effective timing of the valve action may be obtained to suit conditions. This timing by the turning of the members 45 is obtained by providing them with operating arms 50 which extend from them between the engine casing 39 and clamping plates 51 by which the various members 45 are held in place. The arms 50 of all the members 45 may be interconnected by a rod 52, as is indicated in Figs. 7, 8, 11, and 12; so that by the shifting of the rod 52 all the members 45 may be adjusted simultaneously and correspondingly.

This movement of the rod 52 may be either by hand (or foot) or automatically. In the arrangement shown in Fig. 7, the rod 52 is shiftable by a foot pedal 53 toward high-speed position from a normal low-speed position toward which it is pulled by a spring 54. Instead of having the hand (or foot) shifting, such shifting may be auto-

matic, in response to any desired condition or conditions. Three forms of automatic control are shown in Figs. 8, 11, and 12.

In the arrangement shown in Fig. 8, the control of the valve-timer is in response to engine speed. This is obtained in a simple manner, by mounting a piston 55 on the rod 52, which piston is located within a cylinder 56 so connected to the discharge of the lubricating-oil pump 57 that the piston 55 will be moved against the spring 54 as the oil pressure rises upon increase in speed, but will be moved in the other direction by such spring 54 when the oil pressure falls upon decrease in speed. By this control, the point at which the exhaust ports begin to open is advanced in the cycle, and the point at which the inlet ports complete their closing is retarded in the cycle, automatically, as the engine speed rises; and vice versa.

In the arrangement shown in Fig. 11, I mount on the rod 52 a piston 55^a, located within a cylinder 56^a which is so connected to the intake manifold 58 that the vacuum produced in such manifold and transmitted therefrom to the cylinder 56^a tends to draw the piston 55^a and rod 52 toward the right, or toward low-speed position, against a spring 54^a; which, contrary to the spring 54 of Figs. 7 and 8, tends to move the rod 52 toward a high-speed position. This control makes for economy of operation, for the rod 52 is shifted toward low-speed position as the vacuum in the intake manifold rises, and toward high-speed position as such vacuum falls.

To prevent the movement of the rod 52 from being too rapid, I desirably arrange the cylinder 56^a so that it also acts as a dash-pot cylinder. That is, I close the other end of such cylinder from that which is connected to the intake manifold 58, save for a slight leakage outlet 56^b, the size of which determines the maximum speed at which the rod 52 may be shifted.

It is possible to combine both the control for speed and the control for economy, and I have shown this in Fig. 12. Here the rod 52 is provided with both pistons 55 and 55^a, operating in cylinders 56 and 56^a connected respectively to the discharge of the oil pump 57 and to the intake manifold 58. The oil pressure from the pump 57 varies with the engine speed, and tends to shift the rod 52 toward the left, or toward high-speed position. The vacuum from the intake manifold 58 tends to draw the rod 52 toward the right, or toward low-speed position. A spring 54^b is provided to act in either direction on the rod 52, as desired; for which purpose one end of such spring 54^b is connected to the rod 52 and the other end connected to a lever 59 which may be swung by an operating handle 59^a to either the full-line position or to the dotted-line position shown in Fig. 12.

When the lever is in the full-line position, the spring 54^b tends to draw the rod 52 to the right, or to low-speed position, and the control is then substantially wholly in response to speed, as the oil-pressure varies, with perhaps some slight modification by variations in the vacuum in the intake manifold. When the lever 59 is swung to the dotted-line position, the spring 54^b tends to draw the rod 52 toward the left, or toward high-speed position; and then the control is fundamentally in response to the variations in the vacuum in the intake manifold. With the lever 59 in this latter position, or dotted-line position, the economy control by the vacuum in the intake manifold is somewhat modified by variations in the pressure of the oil in the oil pump 57. Thus there is a joint control of the position of the rod 52 in response to speed and in response to economy; with a manual supervision by the shifting of the lever 59.

The upper end of the sleeve-valve 17 may be exposed to the pressure within the explosion chamber of the engine, as is indicated in Fig. 1; so that the sleeve-valve itself in its piston movement will be pushed downward by the explosion pressure within the cylinder during the explosion period and will thus act as a power-member helping to drive the engine, by its connection through the lever 25 and wobble-rod 22 to the valve-shaft 20. On the other hand, as shown in Figs. 2, 9, and 10, if it is preferred, the upper end of the sleeve-valve may work in an annular pocket 60 provided between the upper end of the cylinder 14 and a head 61 which depends into the upper end of the cylinder in proper spaced relation to the cylinder to provide such pocket. The details of this head, when the head is used, are not part of the invention covered by the present application.

Whether or not the engine is arranged to shift the socket 31 to control the valve timing, I may provide a valve-timing means directly in connection with the ports in the sleeve-valve and cylinder. This is conveniently by a supplemental slidable sleeve 65, which co-operates with the inner face of the sleeve-valve 17 at and near the upper end of the latter. This supplemental sleeve 65, as shown, bears directly against the inner face of the sleeve-valve; and is located between such sleeve-valve and the head 61 when such head is used, by being received within the pocket 60, which is enlarged for that purpose. The supplemental sleeve 65 is desirably split, either partly so that the sleeve remains a unit, or wholly into halves so that one half controls the inlet ports and the other the outlet ports and the two halves are movable independently; and if split only partly, it may have a slight outward spring so that it tends to seat against the inner

surface of the sleeve-valve. The lower edge of the supplemental sleeve 65 may overlap the ports 15 and 16 to a greater or less extent, by an amount depending upon the vertical position of such supplemental sleeve; so that by shifting the supplemental sleeve 65 vertically, the points in the cycle when the exhaust ports start to open and the inlet ports completely close may be varied.

10 The supplemental sleeve 65 may be shifted vertically in any desired manner. I show two types of shifting means, in Figs. 9 and 10 respectively; both of which show simple forms of such shifting means.

15 In the arrangement shown in Fig. 9, eccentric pins 66 are provided on the inner ends of a pair of rock-shafts 67 which may be rocked by arms 68 operable in any convenient way. The two rock-shafts are provided for the two halves of the sleeve if it is split into two separate halves, for the separate operation of such halves and the separate control of the inlet and the exhaust. But two arms are desirable even if the supplemental sleeve is a unit, to avoid binding, because of the shortness of the supplementary sleeve 65; and in that case, since the eccentric pins 66 if they fit merely in holes in the sleeve 65 instead of in horizontal slots therein will in their movement tend to turn the sleeve 65 about its axis, one of the arms 68 desirably projects upward and one downward, so that even though such arms are operated by a single operating mechanism they will turn the two rock-shafts 67 in opposite directions and thus will avoid interference between the actions of the two eccentric pins 66 on the sleeve 65 by making them both tend to turn the sleeve in the same circumferential direction about its axis as they move it in the same linear direction along its axis. The arms 68 may be operated, manually or automatically, under any desired control; such, for instance, as any of those shown in Figs. 7, 8, 11, and 12 for operating the rod 52.

20 In the arrangement shown in Fig. 10, I have shown the supplementary sleeve 65 as a unit; and have shown it operable by a shift-rod 70 which extends vertically along the engine cylinder outside of the sleeve-valve 17 and is vertically slidable in a suitable guide-hole. The upper end of the shift-rod 70 is turned inward to project into a hole 71 in the supplementary sleeve 65; while from the lower end of such shift-rod a transverse pin 72 projects outward into an eccentric hole in a rotatably mounted member 73 which may be rocked to different positions in the same way that the member 45 of the arrangement shown in Figs. 5, 6, 7, 8, 11 and 12 is so rocked. The member 73 may correspond in location, as it does in general function, to the member 45; and may be pro-

vided with the same operating arms 50 connected to the rod 52. The rod 52 in the arrangement shown in Fig. 10 is the same rod which has already been described in connection with Figs. 7, 8, 11, and 12; so that it may be operated in any of the ways already described in connection with those figures, to produce the desired control of the valve-timing, though such control in this instance is by the shifting of the supplemental sleeve 65.

75 Whether by shifting the socket 31 or by shifting the supplemental sleeve 65, I obtain an effective control of the valve timing. This variable timing is important, to increase the torque of the engine at low speeds and the power of the engine at high speeds. The diagram in the lower part of Fig. 5 shows the effect of this variable timing, whether obtained by the shifting of the socket 31 or by the shifting of the supplementary sleeve 65. When either the socket 31 or the sleeve 65 is in its lowest position, the opening of the exhaust ports is at its latest point in the cycle and the closing of the inlet ports is at its earliest point in the cycle; which gives high torque at low speeds. As the socket 31 or the supplementary sleeve 65 is raised, the starting of the exhaust opening becomes earlier in the cycle and the completion of the inlet closing becomes later; until, at the high point of either the socket 31 or the supplementary sleeve 65, the opening of the exhaust is at its earliest and the closing of the inlet is at its latest, which gives high power at high speeds. The angular shift of the exhaust-opening start and the inlet-opening completion, in opposite directions in the cycle, may be made equal if desired; as is indicated in Fig. 5.

I claim as my invention:—

1. In an internal combustion engine, the combination of a cylinder, a piston, a sleeve-valve, a single valve-shaft, and a movement-multiplying operating connection between said valve-shaft and said sleeve-valve and operated wholly by said single valve-shaft for producing an increased axial throw of said sleeve-valve.

2. In an internal combustion engine, the combination of a cylinder, a piston, a sleeve-valve, a single valve-shaft, a lever having a normally stationary fulcrum and having its load point connected to said sleeve-valve, and an actuating connection from said valve shaft to the power-point of said lever.

3. In an internal combustion engine, the combination of a cylinder, a piston, a sleeve-valve, a single valve-shaft, a lever having a normally stationary fulcrum and having its load point connected to said sleeve-valve, and an actuating connection from said valve shaft to the power-point of said lever, said

power-point being closer to the fulcrum of the lever than is said load point so that the lever serves to multiply movement.

4. In an internal combustion engine, the combination of a cylinder, a piston, a sleeve-valve, a single valve-shaft, a lever having a normally stationary fulcrum and having its load point connected to said sleeve-valve, an actuating connection from said valve-shaft to the power-point of said lever, and an adjustable fulcrum for said lever.

5. In an internal combustion engine, the combination of a cylinder, a piston, a sleeve-valve, a valve-shaft, said valve-shaft having a wobble-crank thereon, a wobble-rod mounted on said wobble-crank, and a movement-multiplying lever connecting said wobble-rod to said sleeve-valve for obtaining multiplied movements of the sleeve-valve both axially and circumferentially.

6. In an internal combustion engine, the combination of a cylinder, a piston, a sleeve-valve, a valve-shaft, said valve-shaft having a wobble-crank thereon, a wobble-rod mounted on said wobble-crank, and a movement-multiplying lever connecting said wobble-rod to said sleeve-valve, said lever having ball-and-socket joints at its three working points.

7. In an internal combustion engine, the combination of a cylinder, a piston, a sleeve-valve, a valve-shaft, said valve-shaft having a wobble-crank thereon, a wobble-rod mounted on said wobble-crank, a movement-multiplying lever connecting said wobble-rod to said sleeve-valve, and an adjustable fulcrum for said lever.

8. In an internal combustion engine, the combination of a cylinder, a piston, a sleeve-valve, a valve-shaft, said valve-shaft having a wobble-crank thereon, a wobble-rod mounted on said wobble-crank, a movement-multiplying lever connecting said wobble-rod to said sleeve-valve, and a fulcrum for said lever, said fulcrum having two adjustable devices for adjusting it substantially vertically and substantially horizontally respectively.

9. In an internal combustion engine, the combination of a cylinder having inlet and exhaust ports, a piston, a sleeve-valve having a cyclic axial movement, a single valve-operating shaft for operating said sleeve-valve, said valve-operating shaft having a fixed phase relationship with the piston, and means for varying the point in the engine cycle where the exhaust ports start their opening and the point in the engine cycle where the inlet ports complete their closing.

10. In an internal combustion engine, the combination of a cylinder having inlet and exhaust ports, a piston, a sleeve-valve having a cyclic axial movement, a single valve-operating shaft for operating said sleeve-valve, said valve-operating shaft having a

fixed phase relationship with the piston, and means for varying the point in the engine cycle where the inlet ports complete their closing.

11. In an internal combustion engine, the combination of a cylinder having inlet and exhaust ports, a piston, a sleeve-valve having a cyclic axial movement, a single valve-operating shaft for operating said sleeve-valve, said valve-operating shaft having a fixed phase relationship with the piston, and means for varying the point in the engine cycle where the exhaust ports start their opening.

12. In an internal combustion engine, the combination of a cylinder having inlet and exhaust ports, a piston, a sleeve-valve having a cyclic axial movement, a single valve-operating shaft for operating said sleeve-valve, said valve-operating shaft having a fixed phase relationship with the piston, and automatic means for varying the point in the engine cycle where the inlet ports complete their closing.

13. In an internal combustion engine, the combination of a cylinder having inlet and exhaust ports, a piston, a sleeve-valve having a cyclic axial movement, a single valve-operating shaft for operating said sleeve-valve, said valve-operating shaft having a fixed phase relationship with the piston, and automatic means for varying the point in the engine cycle where the exhaust ports start their opening.

14. In an internal combustion engine, the combination of a cylinder having inlet and exhaust ports, a piston, a sleeve-valve having a cyclic axial movement, a single valve-operating shaft for operating said sleeve-valve, said valve-operating shaft having a fixed phase relationship with the piston, and means for varying simultaneously the point in the engine cycle where the exhaust ports start their opening and the point in the engine cycle where the inlet ports complete their closing.

15. In an internal combustion engine, the combination of a cylinder having inlet and exhaust ports, a piston, a sleeve-valve having a cyclic axial movement, a single valve-operating shaft for operating said sleeve-valve, said valve-operating shaft having a fixed phase relationship with the piston, and means for varying oppositely the point in the engine cycle where the exhaust ports start their opening and the point in the engine cycle where the inlet ports complete their closing.

16. In an internal combustion engine, the combination of a cylinder having inlet and exhaust ports, a piston, a sleeve-valve having a cyclic axial movement, a single valve-operating shaft for operating said sleeve-valve, said valve-operating shaft having a fixed phase relationship with the piston, and

means for varying oppositely and substantially equally the point in the engine cycle where the exhaust ports start their opening and the point in the engine cycle where the inlet ports complete their closing.

17. In an internal combustion engine, the combination of a cylinder having inlet and exhaust ports, a piston, a sleeve-valve having a cyclic axial movement, a single valve-operating shaft for operating said sleeve-valve, said valve-operating shaft having a fixed phase relationship with the piston, and means for varying the point in the engine cycle where the exhaust ports start their opening and the point in the engine cycle where the inlet ports complete their closing without affecting as greatly the points in the engine cycle where the inlet ports open and the exhaust ports close.

18. In an internal combustion engine, the combination of a cylinder having inlet and exhaust ports, a piston, a sleeve-valve having a cyclic axial movement, a single valve-operating shaft for operating said sleeve-valve, said valve-operating shaft having a fixed phase relationship with the piston, and means for varying the point in the engine cycle where the inlet ports complete their closing without affecting as greatly the point in the engine cycle where the inlet ports open.

19. In an internal combustion engine, the combination of a cylinder having inlet and exhaust ports, a piston, a sleeve-valve having a cyclic axial movement, a single valve-operating shaft for operating said sleeve-valve, said valve-operating shaft having a fixed phase relationship with the piston, and means for varying the point in the engine cycle where the exhaust ports start their opening without affecting as greatly the point in the engine cycle where the exhaust ports close.

20. In an internal combustion engine, the combination of a cylinder having inlet and exhaust ports, a piston, a sleeve-valve having a cyclic axial movement, a single valve-operating shaft for operating said sleeve-valve, said valve-operating shaft having a fixed phase relationship with the piston, and means for automatically varying the valve-timing.

21. In an internal combustion engine, the combination of a cylinder having inlet and exhaust ports, a piston, a sleeve-valve having a cyclic axial movement, a single valve-operating shaft for operating said sleeve-valve, said valve-operating shaft having a fixed phase relationship with the piston, and means for automatically varying the valve-timing in response to variations in the engine speed.

22. In an internal combustion engine, the combination of a cylinder having inlet and exhaust ports, a piston, a sleeve-valve, and

means for automatically varying the valve-timing for economy of operation.

23. In an internal combustion engine, the combination of a cylinder having inlet and exhaust ports, a piston, a sleeve-valve, and means for automatically varying the valve-timing in response to intake vacuum.

24. In an internal combustion engine, the combination of a cylinder having inlet and exhaust ports, a piston, a sleeve-valve, and means for automatically varying the valve-timing in response to the engine speed or in response to intake vacuum as desired.

25. In an internal combustion engine, the combination of a cylinder having inlet and exhaust ports, a piston, a sleeve-valve, and means for automatically varying the valve-timing in response to a plurality of operating conditions.

26. In an internal combustion engine, the combination of a cylinder having inlet and exhaust ports, a piston, a sleeve-valve, means for varying the valve-timing, and a plurality of operating means for operating said means for varying the valve-timing.

27. In an internal combustion engine, the combination of a cylinder having inlet and exhaust ports, a piston, sleeve-valve means for controlling such inlet and exhaust ports and having a cyclic axial movement, a single valve-operating shaft for operating said sleeve-valve means, said valve-operating shaft having a fixed phase relationship with the piston, and means for varying the valve-timing.

28. In an internal combustion engine, the combination of a cylinder having inlet and exhaust ports, a piston, valve means for controlling such inlet and exhaust ports and having a cyclic axial movement, a single valve-operating shaft for operating said valve means, said valve-operating shaft having a fixed phase relationship with the piston, and means for varying oppositely in the cycle the points where the exhaust ports start to open and the inlet ports complete their closing.

29. In an internal combustion engine, the combination of a cylinder having inlet and exhaust ports, a piston, sleeve valve means for controlling such inlet and exhaust ports and having a cyclic axial movement, a single valve-operating shaft for operating said sleeve-valve means, said valve-operating shaft having a fixed phase relationship with the piston, and means for varying the proportionate part of the cycle during which the inlet ports are open.

30. In an internal combustion engine, the combination of a cylinder having inlet and exhaust ports, a piston, sleeve-valve means for controlling such inlet and exhaust ports and having a cyclic axial movement, a single valve-operating shaft for operating said sleeve-valve means, said valve-operating

shaft having a fixed phase relationship with the piston, and means for varying the proportionate part of the cycle during which the exhaust ports are open.

5 31. In an internal combustion engine, the combination of a cylinder having inlet and exhaust ports, a piston, sleeve-valve means for controlling such inlet and exhaust ports and having a cyclic axial movement, a single
10 valve-operating shaft for operating said sleeve-valve means, said valve-operating shaft having a fixed phase relationship with the piston, and means for varying the proportionate parts of the cycle during which
15 the inlet ports and the exhaust ports remain open.

32. In an internal combustion engine, the combination of a cylinder having inlet and exhaust ports, a piston, valve means for controlling such inlet and exhaust ports and having a cyclic axial movement, a single
20 valve-operating shaft for operating said valve means, said valve-operating shaft having a fixed phase relationship with the piston, and means for varying the point in the cycle at which the inlet ports complete their closing without correspondingly affecting the exhaust ports.

33. In an internal-combustion engine, the combination of a cylinder having inlet and exhaust ports, a piston, a cylinder head projecting into said cylinder and radially spaced therefrom to provide an annular space, a sleeve-valve slidable within said cylinder to
35 control said ports and having one end with a sliding fit within said annular space, a valve-shaft having a wobble-crank, and a connecting rod swingingly mounted at one end on said wobble-crank and having its
40 other end operatively connected to said sleeve-valve to give it both a reciprocating motion and an oscillating motion.

34. In an internal-combustion engine, the combination of a cylinder having inlet and exhaust ports, a piston, a cylinder head projecting into said cylinder and radially spaced therefrom to provide an annular space, a sleeve-valve slidable within said cylinder to control said ports and having one end with a
50 sliding fit within said annular space, a valve-shaft having a wobble-crank operatively connected to said sleeve-valve to give it both a reciprocating motion and an oscillating motion, and means for varying the valve
55 timing produced by said sleeve-valve.

35. In an internal combustion engine, the combination of a cylinder having inlet and exhaust ports, a piston, a cylinder head projecting into said cylinder and radially spaced therefrom to provide an annular space, a sleeve-valve slidable within said cylinder to control said ports and having one end with a sliding fit within said annular space, a valve-shaft having a wobble-crank operative-

ly connected to said sleeve-valve to give it
65 both a reciprocating motion and an oscillating motion, and means for oppositely shifting the points in the cycle where said sleeve-valve starts to open said exhaust port and completes the closing of said inlet port.
70

36. In an internal combustion engine, the combination of a cylinder having inlet and exhaust ports, a piston, a cylinder head projecting into said cylinder and radially spaced therefrom to provide an annular
75 space, a sleeve-valve slidable within said cylinder to control said ports and having one end with a sliding fit within said annular space, a valve-shaft having a wobble-crank operatively connected to said sleeve-valve to give it both a reciprocating motion and an oscillating motion, and means for shifting the point in the cycle where said sleeve-valve completes the closing of said inlet port.
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37. In an internal combustion engine, the combination of a cylinder having inlet and exhaust ports, a piston, a cylinder head projecting into said cylinder and radially spaced therefrom to provide an annular
90 space, a sleeve-valve slidable within said cylinder to control said ports and having one end with a sliding fit within said annular space, a valve-shaft having a wobble-crank operatively connected to said sleeve-valve to give it both a reciprocating motion and an oscillating motion, and means for shifting the point in the cycle where said sleeve-valve starts to open said exhaust port.
95

38. In an internal combustion engine, the combination of a cylinder having inlet and exhaust ports, a piston, sleeve-valve means for controlling such inlet and exhaust ports and having a cyclic axial movement, a single
100 valve-operating shaft for operating said sleeve-valve means, said valve-operating shaft having a fixed phase relationship with the piston, and means for varying oppositely in the cycle the points where the exhaust
105 ports start to open and the inlet ports complete their closing.
110

39. In an internal combustion engine, the combination of a cylinder, a piston, a sleeve-valve having a combined axial reciprocation and circumferential oscillation, a single
115 valve-shaft having a crank portion, a fulcrum separate from any valve-shaft, and a lever interconnecting said sleeve-valve and said crank-portion and said fulcrum, and operated wholly by said crank portion to give said sleeve-valve such combined motion.
120

40. In an internal combustion engine, the combination of a cylinder, a piston, a sleeve-valve having a combined axial reciprocation and circumferential oscillation, a single
125 valve-shaft having a crank portion, and adjustable means operatively connecting said sleeve-valve and said crank portion and

operated by said crank portion to give such sleeve-valve such combined motion, and adjustable to correct errors.

41. In an internal combustion engine, the combination of a cylinder having inlet and exhaust ports, a piston, a sleeve-valve, and means for automatically varying the valve-timing in response to variations in a fluid pressure affecting the engine.

42. In an internal combustion engine, the combination of a cylinder having inlet and exhaust ports, a piston, a sleeve-valve having a cyclic axial movement, a single valve-

operating shaft for operating said sleeve-valve, said valve-operating shaft having a fixed phase relationship with the piston, and means for varying the valve-timing, and means accessible to the operator for controlling said means for varying the valve-timing.

In witness whereof, I have hereunto set my hand at Indianapolis, Indiana, this 8th day of January, A. D. one thousand nine hundred and twenty-six.

JULES HALTENBERGER.