Dec. 21, 1943. H. M. JACKLIN 2,337,245

INTERNAL COMBUSTION ENGINE

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Fig. 1.

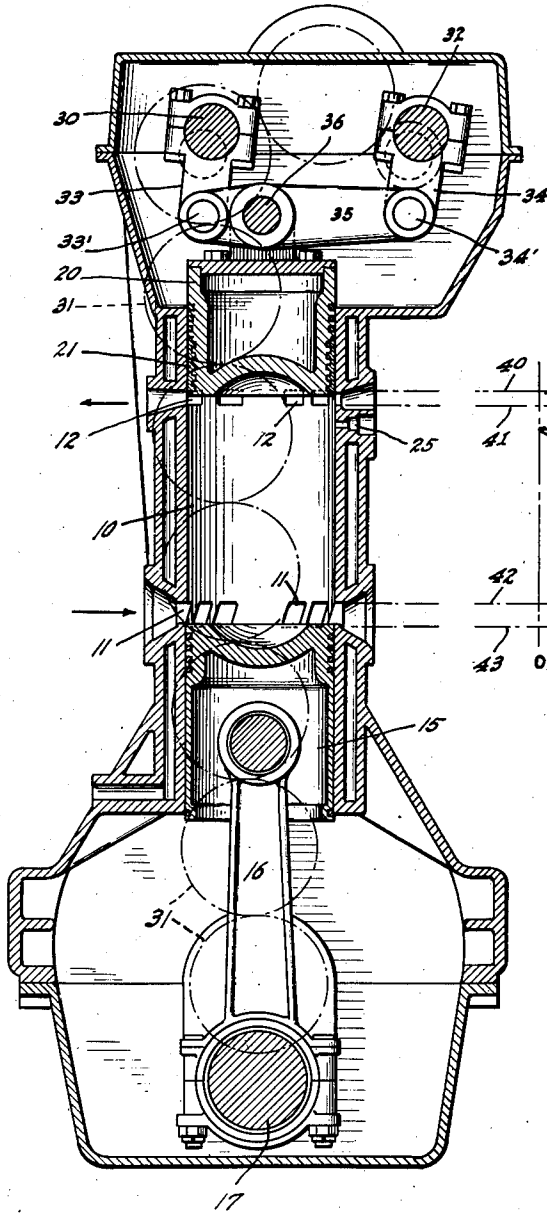


Fig. 3.

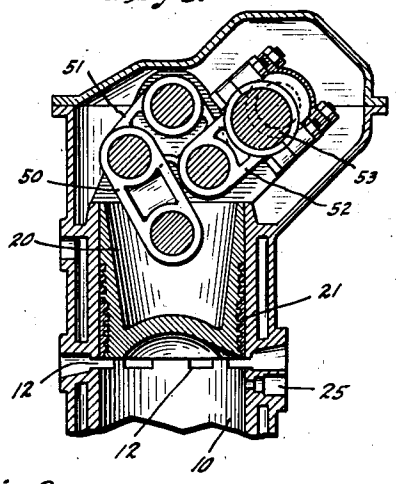


Fig. 2.

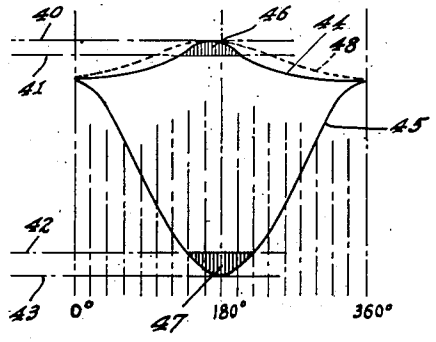
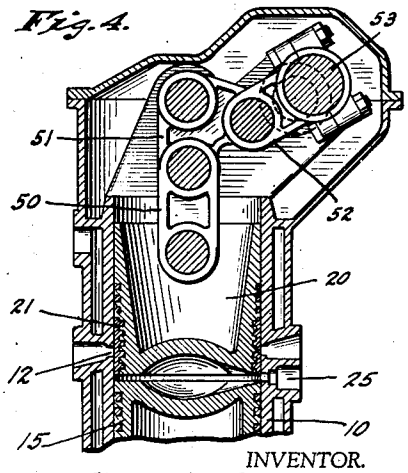


Fig. 4.



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Fig. 5.

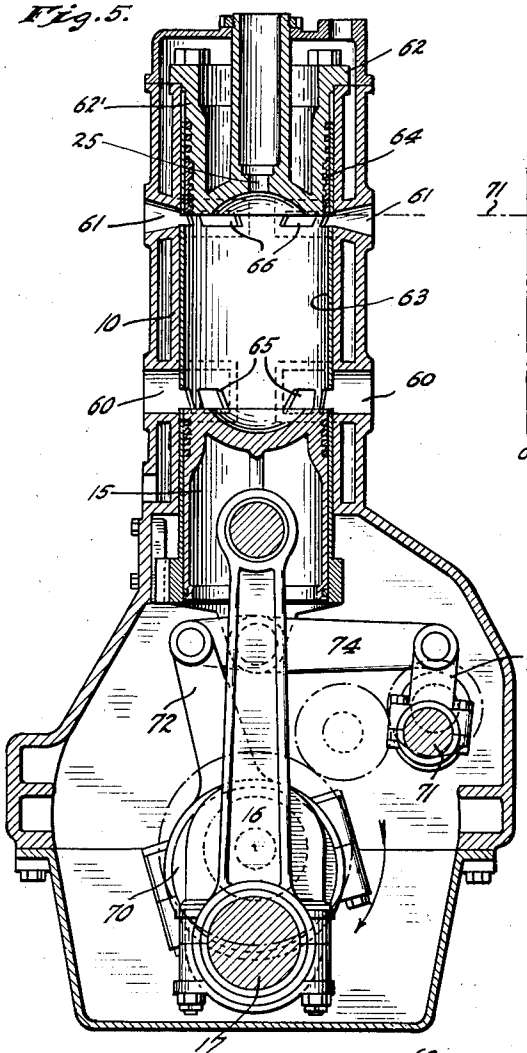


Fig. 6.

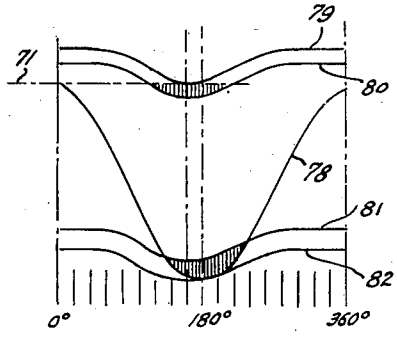


Fig. 7.

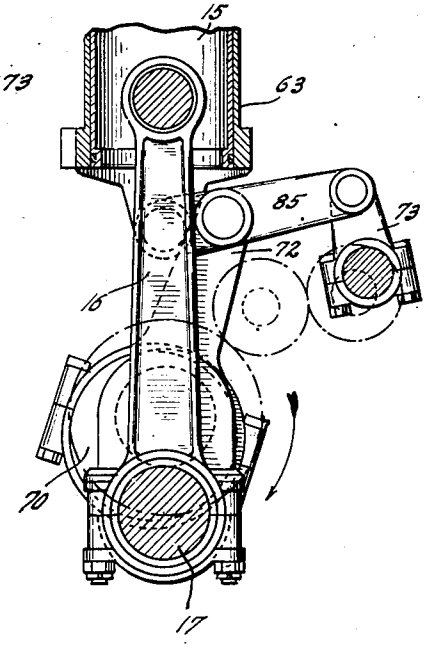
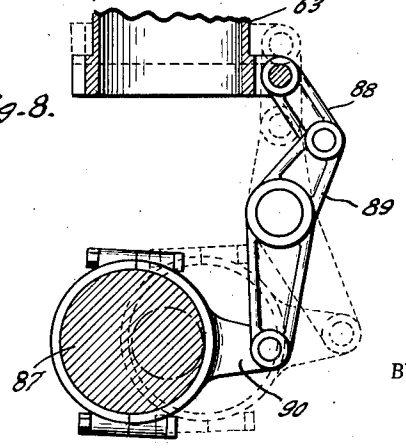


Fig. 8.



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UNITED STATES PATENT OFFICE

2,337,245

INTERNAL COMBUSTION ENGINE

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Application August 22, 1941, Serial No. 408,006

6 Claims. (Cl. 123—65)

This invention relates to two-stroke cycle engines of the uniflow type. In such engines, ports located at opposite ends of the cylinder are uncovered at or near the end of the working stroke of the piston, the burnt gases are exhausted through the ports at one end of the cylinder, while air or a mixture of fuel and air is admitted through the ports at the opposite end of the cylinder.

Heretofore, engines of this general kind have been of either of two types. In the first type, called the opposed piston type, two reciprocating pistons move oppositely in a single cylinder and respectively uncover the inlet and exhaust ports as they near the ends of the working strokes. In the other type, there is a single working piston which uncovers cylinder ports at one end of the cylinder as it nears the end of its working stroke, while the ports at the opposite end of the cylinder are controlled by a poppet valve. The opposed piston-type of engine has certain disadvantages because of the problems encountered in interconnecting the two working pistons. The poppet valve type of engine is open to the objection that relatively large forces must be used in order to obtain the necessary quick opening and quick closing of the valves, and such large forces entail high unit bearing-pressures and necessitate the use of heavy springs.

It is the object of my invention to produce a two-stroke cycle engine of the uniflow type which will be free from the above noted disadvantages possessed by prior engines of this kind. More specifically, it is my object to provide an engine which may have a single working piston controlling or aiding in the control of one set of ports and in which the other set of ports will be controlled by valve-operating mechanism which will provide a quick opening and quick closing of the ports and do so without the imposition of relatively large forces.

In carrying out my invention, I employ a cylinder having inlet ports at one end and outlet ports at the other. One set of these ports is controlled by a reciprocable valving element which may be either a piston or a sleeve, while the other set of ports may be controlled at least in part by the working piston. The valving element is reciprocated in the cylinder by an eccentric operating at the same speed as the crank shaft of the engine; but instead of connecting the valving element directly to such eccentric, which would cause the valving element to operate with an approximately harmonic motion, I interpose between the valving element and the eccentric movement-modifying mechanism which operates to effect a relative retardation of the valving element when its associated ports are closed and a relative acceleration of the valving element during its movement to open and close the ports. This movement-modifying mechanism may take various forms, as will be more fully brought out hereinafter.

The accompanying drawings illustrate my invention: Fig. 1 is an axial section through a cylinder of an engine embodying a piston valve which is under the joint control of two eccentrics; Fig. 2 is a diagram showing movements of the working piston and piston valve during the two-stroke cycle of the engine; Fig. 3 is a fragmental view similar to Fig. 1 illustrating the upper end of a piston-valve engine with a movement-modifying means embodying a single eccentric, the valve being shown as open; Fig. 4 is a view similar to Fig. 3 showing the valve closed; Fig. 5 is a sectional view similar to Fig. 1, but showing a valving element in the form of a sleeve operated by two eccentrics; Fig. 6 is a diagram illustrating movements of the piston and sleeve in the construction of Fig. 5; Fig. 7 is a fragmental view similar to Fig. 5 showing a modified form of double-eccentric sleeve-operating mechanism; and Fig. 8 is a view similar to Fig. 7 illustrating a sleeve-operating mechanism embodying a single eccentric.

The engine illustrated in Fig. 1 has a working cylinder 10 provided at one end with an annular series of ports 11 and at the opposite end with a second annular series of ports 12. Either set of these ports may serve as inlet ports and the other as exhaust ports; but it is preferable in most instances that the upper ports be used as exhaust ports and the lower ports as inlet ports, and this arrangement is assumed in Fig. 1. Working in the cylinder 10 there is a conventional piston 15 connected by a connecting rod 16 to the usual crank shaft 17, the arrangement being such that the piston 15, as it nears outer (crank-end) dead-center position, will uncover the inlet ports 11.

For the purpose of controlling the exhaust ports 12, a piston valve 20 provided at its lower end with a junk ring 21 is mounted for reciprocation in the cylinder 10 in such a manner that the lower edge of the junk ring will pass across the ports 12 and open and close them as the valve 20 reciprocates. Between the valve 20 and piston 15, the cylinder is provided with an opening 25 for the reception of a spark plug or other ignition device, if the engine is of a type requiring igni-

tion, or for the reception of a fuel-injection nozzle, if the engine is of the compression-ignition type.

For the purpose of controlling movements of the valve 20, there is mounted above the head end of the cylinder a rotatable main eccentric 30 adapted to be driven at crankshaft speed as by means of a train of gears 31. Also mounted above the head end of the cylinder is a second or auxiliary eccentric 32 arranged to be driven at twice crank-shaft speed. Connecting rods 33 and 34 serve to connect the eccentrics 30 and 32 respectively with pins 33' and 34' in the opposite ends of a lever 35 pivotally connected at an intermediate point to the valve 20, as through a pivot pin 36.

The exact movement imparted to the valve 20 by the two eccentrics 30 and 32 will depend upon a number of factors among which are the respective throws of the two eccentrics, their phase-relationship, and the relation between the distances of the pins 33' and 34' from the pin 36. Ordinarily, the eccentric 30, which rotates at the same speed as does the crank shaft, will lead the crank 17 by an angle between 8° and 15°, while the eccentric 32 will lead the crank 17 by an angle between 16° and 30°, so that the valve 20 will reach its lower dead-center 8° to 15° before the working piston 15 reaches its outer (upper) dead-center position. The relative spacing of the pins 33' and 34' from the pin 36 may vary considerably, but I prefer to make the distance from the pin 33' to the pin 36 between 15% and 50% of the distance between the pins 33' and 34'.

The diagram shown in Fig. 2 represents the disposition of the valving events within a complete cycle. In this diagram, the line 40 represents the upper edge and the line 41 the lower edge of the ports 12, while the line 42 represents the upper edge and the line 43 the lower edge of the ports 11. The curved line 44 represents the displacement of the lower edge of the junk ring 21 during a complete cycle (360° of crankshaft rotation) beginning with the working piston 15 at head-end dead center; while the curved line 45 represents displacement of the upper end of the working piston 15 during the same interval. Whenever the curved line 44 lies above the horizontal line 41, the ports 12 will be open, as represented by the shaded area 46; and whenever the line 45 is located below the line 42, the ports 11 will be open, as indicated by the shaded area 47. The dotted line 48 shown at the top of Fig. 2 represents approximately what displacement of the lower edge of the junk ring 21 would be if the valve 20 were directly connected to a single eccentric operating at crank-shaft speed.

From a comparison of the full-line 44 and the dotted-line 48, it will be apparent that during the time in which the lower edge of the junk ring 21 is moving across the port 12 its speed is relatively rapid. In order to obtain a port-opening of the same duration with the valve 20 directly connected to a single eccentric it would be necessary to reduce greatly the height, and therefore the area, of the exhaust ports 12. It will be further apparent from Fig. 2 that when the main piston 15 is near the upper limit of its movement in the cylinder the speed of the valve 20 is relatively slow. It is when the working piston is near the upper end of its stroke that working pressures within the cylinder are at their highest; and it is advantageous for the piston valve 20 and its associated junk ring 21 to undergo as little movement as possible while subjected to those high pressures.

It is desirable in an engine of the type with which this invention is concerned for the exhaust ports to open, and thus relieve pressure in the cylinder 10, before the inlet ports are open. If the engine is to be supercharged, it is preferable for the exhaust ports to close while the inlet ports are still open. It is for this reason that a lead is imparted to the eccentrics 30 and 32; and because of the existence of this lead the shaded area 46 in Fig. 2 is displaced to the left from the center of the diagram. From the diagram which constitutes Fig. 2, it will be apparent that the opening of the exhaust ports 12 would occur about 10° to 15° (of crankshaft rotation) earlier than does opening of the inlet ports 11, while closing of the exhaust ports 12 would occur from 15° to 20° earlier than closing of the inlet ports.

The engine illustrated in Figs. 3 and 4 embodies the same ported cylinder 10, piston 15, and piston-valve 20 as does the engine shown in Fig. 1. In this instance, however, the piston-valve 20 is connected through a link 50 to one arm of a bell-crank lever 51 whose other arm is connected by a connecting rod 52 to an eccentric 53 rotating at crank-shaft speed. As the eccentric 53 rotates, the bell crank 51 oscillates about its axis and causes reciprocation of the valve 20 in the cylinder to open and close the exhaust ports 12.

The parts of the mechanism operating the piston-valve 20 of Figs. 3 and 4 are so arranged that when that valve is at lower dead center, or in the position illustrated in Fig. 4, the points of interconnection of the link 50 with the valve 20 and bell crank 51 will be in approximate alinement with the axis of the bell crank. This arrangement results in imparting to the valve 20 a movement having the same characteristics as is imparted to the valve by the mechanism illustrated in Fig. 1—namely, the valve moves relatively rapidly while its lower edge is crossing the exhaust ports 12 and relatively slowly after it has covered the ports 12. Moreover, in the arrangement shown in Figs. 3 and 4, when the valve 20 is at lower dead center, the heavy cylinder-pressures existing at that time are transmitted substantially directly through the link 50 and bell crank 51 to the bell-crank pivot and are not reflected to any great extent as forces imposed on the connecting rod 52 and eccentric 53.

The engine illustrated in Fig. 5 is of the sleeve-valve type. The cylinder 10 is provided at its opposite ends with two sets of ports 60 and 61 the former of which, located at the lower end of the cylinder, are assumed as before to be intake ports, while the latter are exhaust ports. The upper end of the cylinder 10 is closed by a head 62 having a downwardly extending, centrally located, cylindrical boss 62' somewhat smaller than the bore of the cylinder 10 in order to provide an annular space for the reception of the upper end of a sleeve valve 63 within which the working piston 15 reciprocates. The head 62 is provided with one or more sealing rings preferably including at its lower end a relatively wide junk ring 64. The sleeve 63 extends downwardly through the cylinder 10 and is provided in the region of the cylinder ports 60 with a circumferential series of intake ports 65 and in the region of the cylinder ports 61 with a circumferential series of exhaust ports 66. The opening 25, for the reception of an ignition or fuel-injection device, is in this engine disposed in the head 62.

For the purpose of reciprocating the sleeve 63 to control the opening and closing of the intake and exhaust ports I employ, as in the engine shown in Fig. 1, a main eccentric 70 operating at crank-shaft speed and an auxiliary eccentric 71 operating at twice crank-shaft speed. The main eccentric 70 may be carried by the crank shaft of the engine, and is so illustrated; while the auxiliary eccentric 71 is disposed at one side of the cylinder axis. Connecting rods 72 and 73 associated with the two eccentrics 70 and 71 have their upper ends connected respectively to the opposite ends of a lever 74 which, at an intermediate point, is pivotally connected to the lower end of the sleeve 63.

The diagram constituting Fig. 6 illustrates the effect of movement of the sleeve and piston upon the opening and closing of the inlet and exhaust ports. In this diagram, the line 77 indicates the elevation of the lower edge of the junk ring 64, and the curved line 78 represents vertical displacements of the piston 15. The two equidistant curved lines 79 and 80 represent respectively the displacements of the upper and lower edges of the exhaust ports 66 in the sleeve; while the two equidistant lines 81 and 82 represent displacements of the upper and lower edges of the inlet ports 65 in the sleeve. As will be readily apparent, whenever the line 80 lies below the line 77 the exhaust ports 66 will be open, and whenever the line 78 lies below the line 81 the inlet ports will be open.

It will be noted in Fig. 6 that the valve-operating mechanism imparts to the sleeve 63 a movement similar in character to that imparted to the piston-valve 20 by the double-eccentric valve-operating mechanism shown in Fig. 1. That is, during the time the working piston 15 is near the upper limit of its stroke with all ports closed movement of the sleeve 63 is relatively slow; whereas when the sleeve is moving to open or close the ports its movement is relatively rapid.

In the case of the inlet ports 65 which are opened and closed by relative movement of the sleeve and piston, the relative rapidity of sleeve movement tends to retard the speed of port-opening and port-closing; for during each of these events the sleeve and piston are moving in the same direction with the latter moving the more rapidly. However, the speed of the piston is so much greater than the speed of the sleeve, that the increase of sleeve-speed which results from the incorporation of my invention does not objectionably increase the duration of port-opening and port-closing. Moreover, it would be possible if desired to lower the upper edges of the ports 60 in the cylinder to a point such that closing of the intake ports 65 in the sleeve would occur as the result of coincidence between their lower edges and the upper edges of the ports 60, thus making closing of the inlet ports 65 independent of the position of the piston 15.

The eccentrics 70 and 71, like the eccentrics 30 and 32 in the engine shown in Fig. 1, can be given leads over the crank shaft so as to throw the period in which the exhaust ports 66 are open ahead of the midpoint of the cycle.

It is not essential in either of the valve-operating mechanisms illustrated in Figs. 1 and 5 that the valve be connected to an intermediate point on the lever (35 or 74) actuated by the two eccentrics; as movement of the same general character can be imparted to the valve by connecting it to one end of the lever. Thus, in Fig. 7 I have shown a construction in which a lever 85 has one end connected to the sleeve 63 and its other end pivotally connected to the connecting rod 73, while the connecting rod 72 is pivotally connected to an intermediate point of the lever.

In the arrangement illustrated in Fig. 8, the sleeve 63 is operated by a single eccentric 87 rotating at crank-shaft speed and conveniently mounted directly on the crank shaft. Here, the lower end of the sleeve is connected through a link 88 with one end of a lever 89, whose opposite end is connected through a connecting rod 90 with the eccentric 87. The arrangement of the parts is such that as the sleeve approaches the upper end of its movement, where the ports are all closed, the points of pivotal connection of the link 88 with the sleeve 63 and lever 89 approach alinement with the axis about which the lever swings. The position of the parts when the sleeve is at the upper limit of its movement is indicated in dotted lines in Fig. 8. This arrangement imparts to the sleeve 63 a comparatively rapid movement while the ports are being opened and closed and a comparatively slow movement after the ports have been closed, and also reduces the forces to which the eccentric 87 and connecting rod 90 are subjected when the piston 15 is near the head end of the cylinder and cylinder pressures are high.

In all the modifications illustrated in the drawing, the movement of the valving element, whether it be a piston or a sleeve, has essentially the same general character. That is, the movement of the valving element is more rapid than a harmonic motion would be during valve-opening and valve-closing, but is materially slower than a harmonic motion after the ports have once been closed. Since the highest cylinder pressures exist when the ports are closed, the valving element will move only slightly while subjected to high pressures, which feature results in a material reduction in wear. This characteristic of the movement of the valving element results from modifying the action of an eccentric operating at crank-shaft speed.

In all embodiments shown, the action of the eccentric is modified through the employment of a lever which forms part of the mechanism by which the valving element is connected to the eccentric operating at crank-shaft speed. In the arrangement illustrated in Fig. 1, the element 35 may be regarded as a lever of the second class fulcrumed at 34', receiving the operating effort at 33', and having the load applied to it at 36. The element 74 in Fig. 5 may also be regarded as a lever of the second class fulcrumed at its point of connection with the connecting rod 73, receiving the operating effort through the connecting rod 72, and having the load applied to it at its point of pivotal connection with the sleeve 63. On the same basis, the element 85 in Fig. 7 would be a lever of the third class, fulcrumed at its point of interconnection with the connecting rod 73, receiving the operating effort at an intermediate point through the connecting rod 72, and having the load applied at its outer end where it is connected to the sleeve. In all three of these arrangements, the points at which the operating effort and the load are respectively applied to the lever move back and forth in lines which are generally parallel to the cylinder axis; and the lever-fulcrum is reciprocated also along a line generally parallel to the cylinder axis and at twice crank-shaft speed to produce relatively rapid valve movement during port-opening and

port-closing and relatively slow valve movement when all ports are closed.

In the modification of my invention shown in Figs. 3 and 4 the lever which modifies the action of the eccentric is the bell-crank **51**. In this case the fulcrum of the lever—i. e., the axis of the bell-crank—is fixed, and modification of the action of the eccentric is obtained by so arranging the parts that the path of the point at which the operating effort is applied to the lever is in general alinement with such operating effort throughout the entire range of swinging movement of the lever **51**, while the path of the point at which the load is applied to the lever is generally perpendicular to the path of valve movement after the ports have been closed. In the respect just noted, the construction shown in Fig. 8, which also employs a fixed fulcrum or pivot, is the same as that shown in Figs. 3 and 4. The fact that the loaded end of the lever (**51** or **89**) is moving in a direction generally perpendicular to the path of valve movement during most of the interval in which the ports are closed makes it possible for movement of the valve to be relatively slight in comparison with movement of the lever.

As previously noted, the exact shape of the curve **44** (Fig. 2) representing axial displacement of the valve **20** will depend upon several factors. Because the eccentric **32** rotates at twice the speed of the eccentric **30**, the right-hand end of the lever **35** will reciprocate vertically twice while the left-hand end of such lever is reciprocating once. If, as the result of the relation between the throws of the eccentrics and of the spacing of the pins **33'**, **34'**, and **36**, the effect of the eccentric **32** upon movement of the valve **20** is great enough, the valve may change its direction of movement four times instead of twice during each cycle. That is, after moving upwardly for a distance from its lowermost position, the valve may reverse itself and move downwardly for an interval and then resume an upward movement which continues until the valve has reached the upper limit of movement at the mid-point of its cycle. If such a reversal of valve movement occurs during the first half of the cycle, a symmetrically placed reversal will also occur during the second half of the cycle. However, and especially if the proportions of the valve-operating mechanism are kept within the limits above defined, any such temporary reversal of valve movement can be made to occur when the lower edge of the junk ring **21** is well below the ports **12** so that the desired valve timing will not be interfered with.

The same possibility of an intermediate and temporary reversal of valve movement in each half of the cycle exists in the case of the sleeve-valve engines illustrated in Figs. 5 and 7 and can in similar manner be prevented from affecting the valve-events.

I claim as my invention:

1. In a two-stroke cycle internal combustion engine, a working cylinder having inlet ports at one end and exhaust ports at the other end, a working piston reciprocable in said cylinder and arranged to uncover one set of such ports when at the adjacent end of the cylinder, a crankshaft operatively connected to said piston, a valve axially reciprocable in said cylinder for controlling the other set of ports, and means for reciprocating said valve in timed relation with said piston, said means including a lever extending generally perpendicularly to the cylinder axis and a pair of lever-operating devices, said devices and said valve being connected to said lever at three points spaced along the lever, said devices operating to reciprocate the lever-points to which they are respectively connected, one point at a rate corresponding to the rate at which the piston reciprocates and the other point at twice such rate, said lever and operating devices being proportioned to cause said valve to produce a complete opening of its associated ports in less than 60° of crank-shaft rotation.

2. In a two-stroke cycle internal combustion engine, a working cylinder having inlet ports at one end and exhaust ports at the other end, a working piston reciprocable in said cylinder and arranged to uncover one set of such ports when at the adjacent end of the cylinder, a valve axially reciprocable in said cylinder for controlling the other set of ports, and means for reciprocating said valve in timed relation with said piston, said means including a lever extending generally perpendicularly to the cylinder axis and a pair of lever-operating devices, said devices and said valve being connected to said lever at three points spaced along the lever, one of said devices operating to reciprocate the lever-point to which it is connected at a rate equal to that at which the piston reciprocates and the other of said devices operating to reciprocate the lever-point to which it is connected at twice such rate, the distance between the points of connection of said lever to said valve and the former of such devices being less than the distance between the points of connection of the lever to the valve and the latter of such devices.

3. In a two-stroke cycle internal combustion engine, a working cylinder having inlet ports at one end and exhaust ports at the other end, a working piston reciprocable in said cylinder and arranged to uncover one set of such ports when at the adjacent end of the cylinder, a valve axially reciprocable in said cylinder for controlling the other set of ports, and means for reciprocating said valve in timed relation with said piston, said means including a lever extending generally perpendicularly to the cylinder axis and a pair of eccentrics one of which rotates at a speed corresponding to that of reciprocation of said piston and the other of which operates at twice such speed, said eccentrics and said valve being operatively connected to said lever at three points spaced along the lever, the distance between the points at which said lever is connected to the valve and the slower eccentric being less than the distance between the points at which the lever is connected to the valve and the faster eccentric.

4. In a two-stroke cycle internal combustion engine, a working cylinder having inlet ports at one end and exhaust ports at the other end, a working piston reciprocable in said cylinder and arranged to uncover one set of such ports when at the adjacent end of the cylinder, a valve axially reciprocable in said cylinder for controlling the other set of ports, and means for reciprocating said valve in timed relation with said piston, said means including a lever extending generally perpendicularly to the cylinder axis and a pair of eccentrics one of which rotates at a speed corresponding to that of reciprocation of said piston and the other of which operates at twice such speed, said eccentrics and said valve being operatively connected to said lever at three points spaced along the lever, said eccentric and lever being so proportioned to cause

said valve to produce a complete opening of its associated ports in less than 60° of crank-shaft rotation.

5. In a two-stroke internal combustion engine, a working cylinder having inlet ports at one end and exhaust ports at the other end, a working piston reciprocable in said cylinder and arranged to uncover one set of such ports when at the adjacent end of the cylinder, a crank-shaft operatively connected to said piston, a valve axially reciprocable in said cylinder for controlling the other set of ports, and means for reciprocating said valve in timed relation with said piston, said means comprising a valve-operating eccentric rotating at a speed equal to that at which the piston reciprocates and mechanism including a lever operatively interposed between said eccentric and valve for effecting a relative reduction in the effect of eccentric-movement upon valve-movement when the ports controlled by said valve are closed and for increasing the effect of eccentric-movement upon valve-movement when such ports are being opened and closed by said valve to an extent sufficient to produce complete opening of such ports in less than 60° of crank-shaft rotation.

6. In a two-stroke cycle internal combustion engine, a working cylinder having inlet ports at one end and exhaust ports at the other end, a working piston reciprocable in said cylinder and arranged to uncover one set of such ports when at the adjacent end of the cylinder, a crank-shaft operatively connected to said piston, a valve axially reciprocable in said cylinder for controlling the other set of ports, and means for reciprocating said valve in timed relation with said piston, said means comprising a valve-operating eccentric rotating at a speed equal to that at which the piston reciprocates and mechanism operatively interconnecting said eccentric and valve for effecting a relative reduction in the effect of eccentric-movement upon valve-movement when the ports controlled by said valve are closed and for increasing the effect of eccentric-movement upon valve-movement when such ports are being opened and closed by said valve to an extent sufficient to produce complete opening of such ports in less than 60° of crank-shaft rotation.

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