July 30, 1968 F. H. STARK 3,394,684

MEANS FOR DRIVING COMBUSTION ENGINE POPPET VALVES

Filed June 17, 1966 5 Sheets-Sheet 1

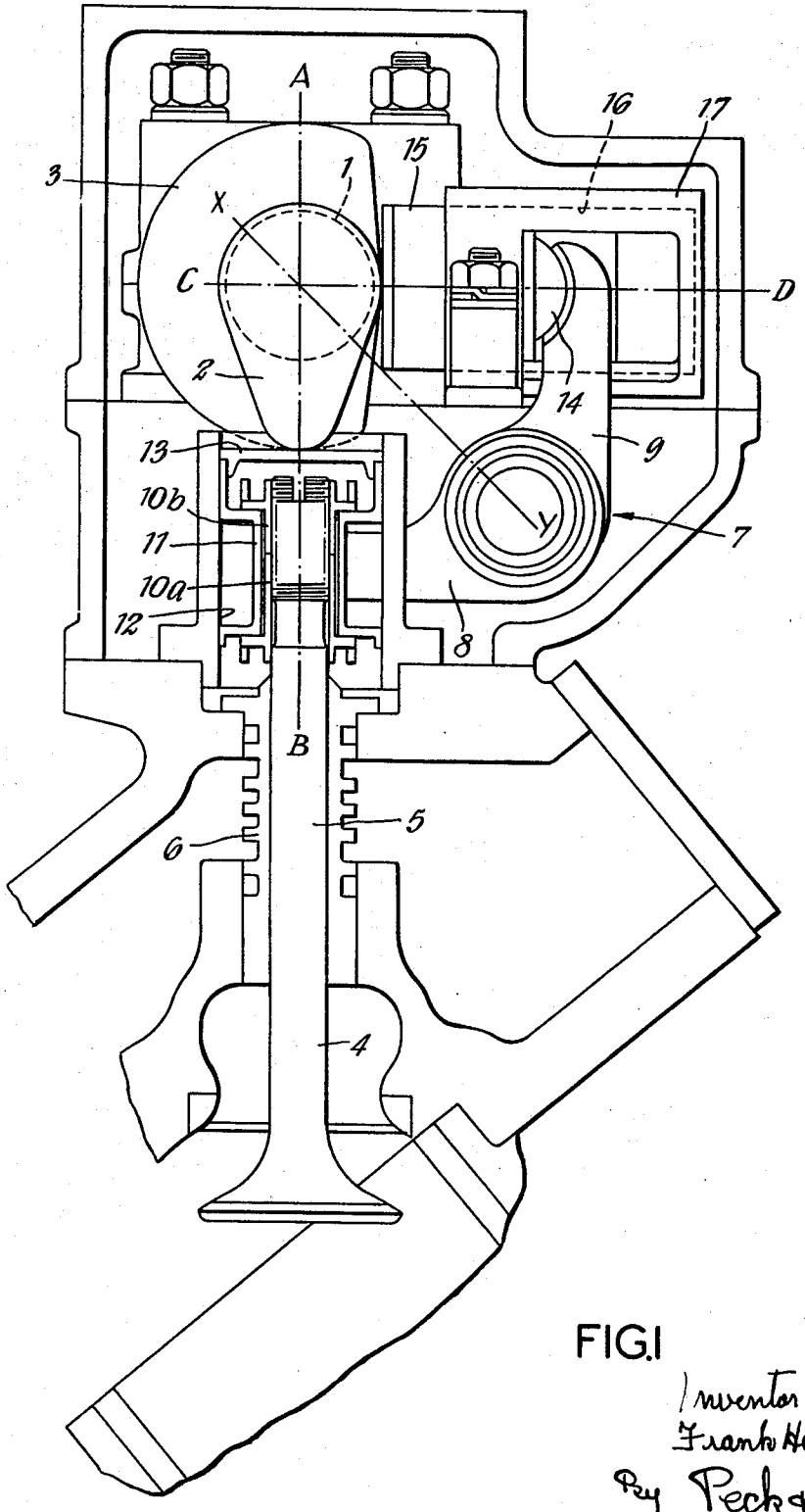


FIG.1

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MEANS FOR DRIVING COMBUSTION ENGINE POPPET VALVES

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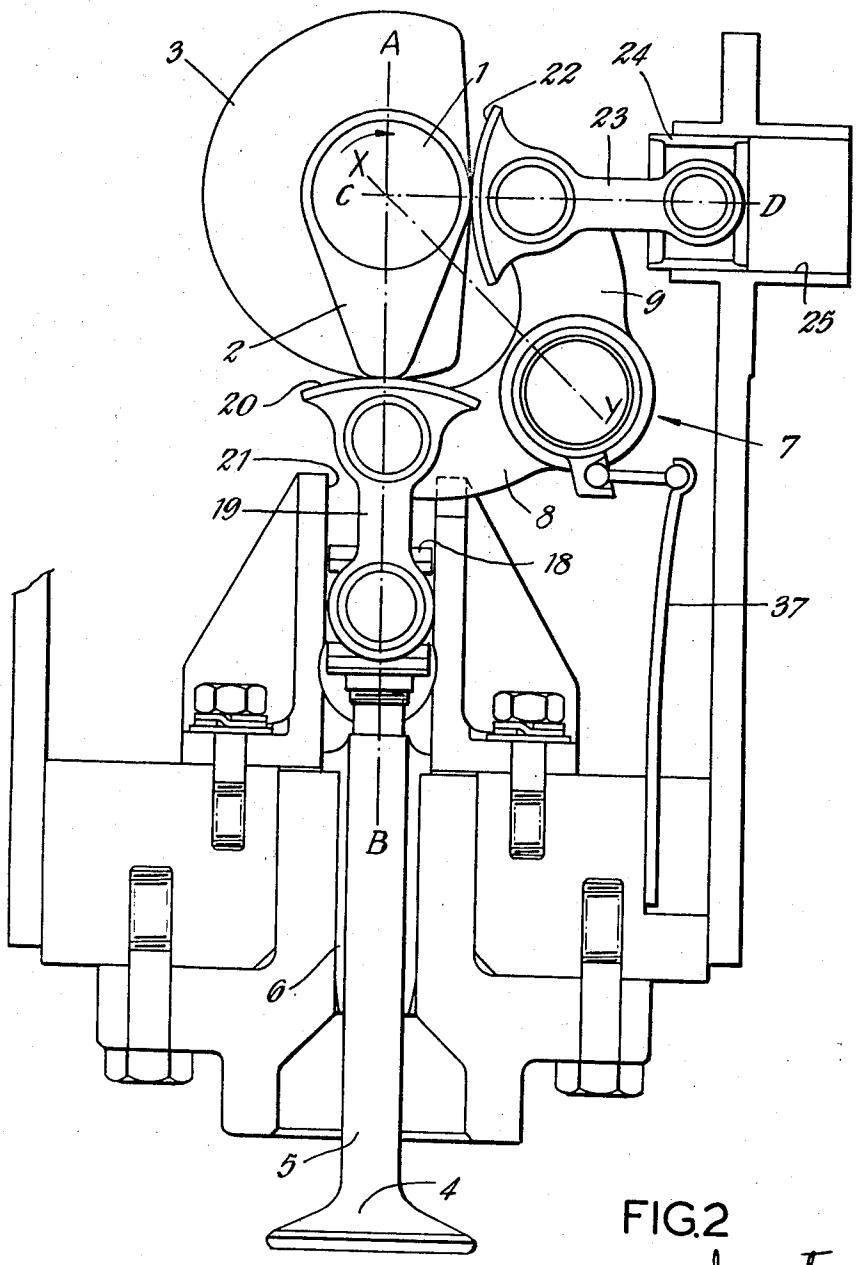


FIG.2

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MEANS FOR DRIVING COMBUSTION ENGINE POPPET VALVES

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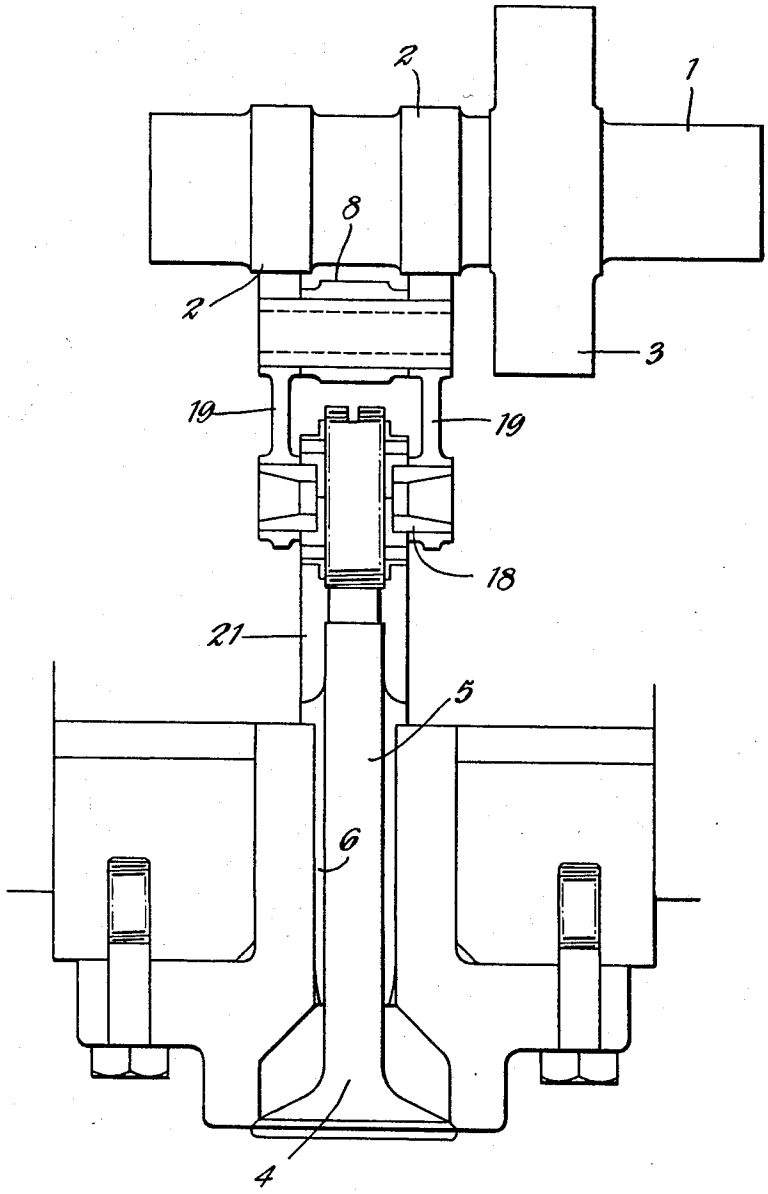


FIG.3

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MEANS FOR DRIVING COMBUSTION ENGINE POPPET VALVES

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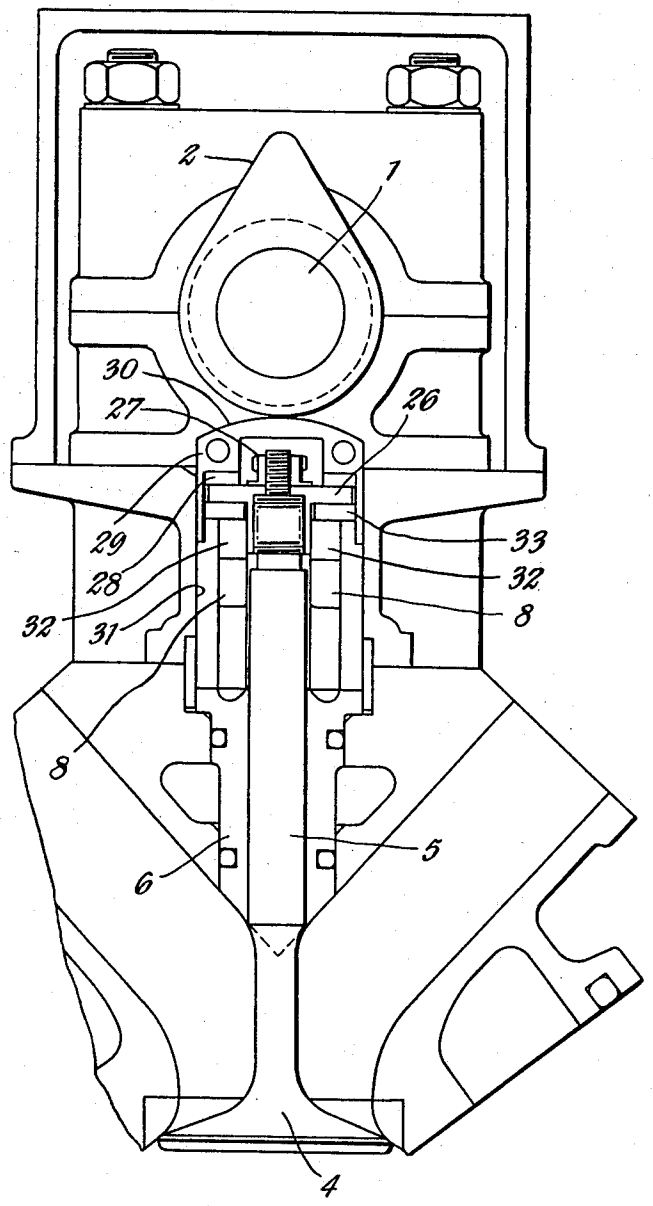


FIG.4

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MEANS FOR DRIVING COMBUSTION ENGINE POPPET VALVES

Filed June 17, 1966 5 Sheets-Sheet 5

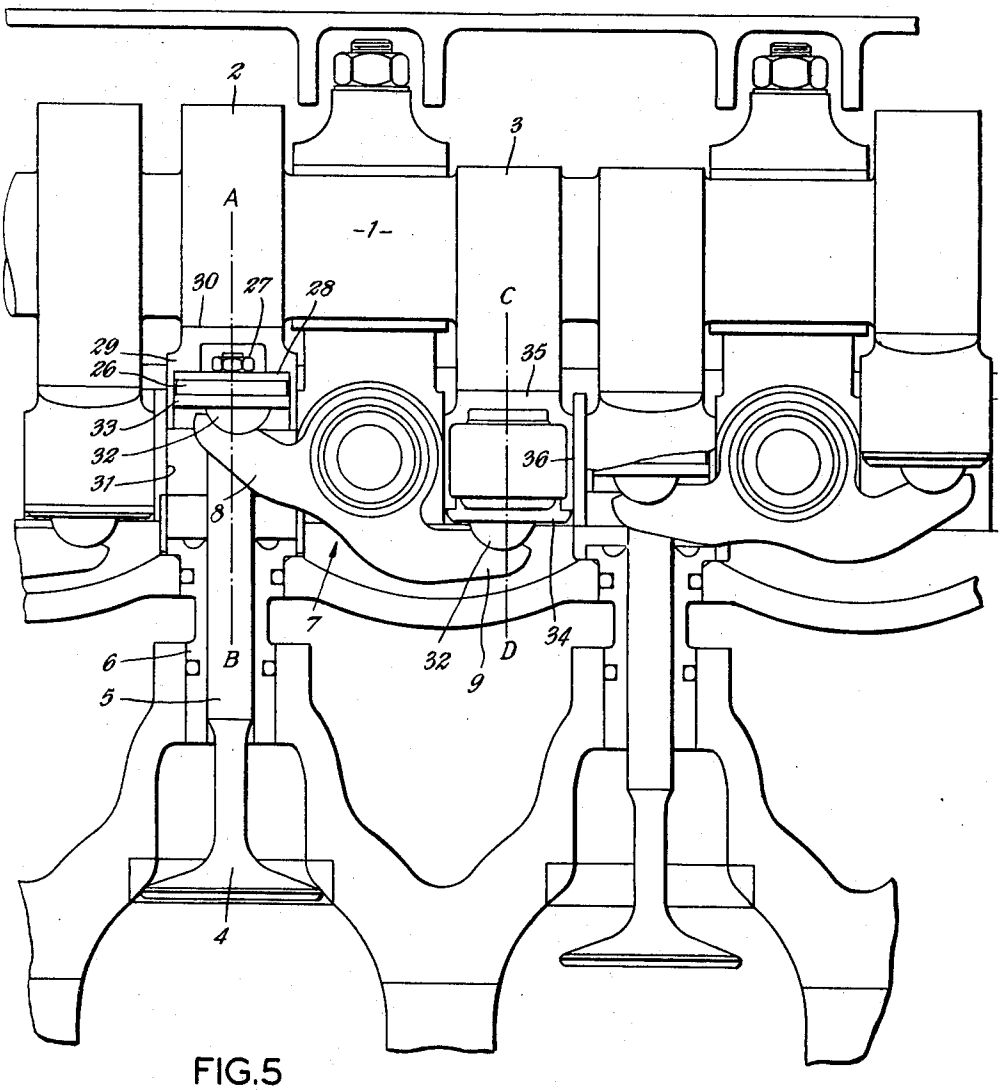


FIG.5

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3,394,684

MEANS FOR DRIVING COMBUSTION ENGINE POPPET VALVES

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8 Claims. (Cl. 123—90)

ABSTRACT OF THE DISCLOSURE

Means for driving internal combustion engine poppet valves comprising cam followers reciprocable along axes radially of the cam shaft, a rocker having two arms, the coupling between the valve, rocker and followers comprising a driving member carried by the valve stem having flat opposed surfaces, an element having a first end constituting the first follower and the second end defining a cavity accommodating with lateral clearance the driving member, washers mounted around the stem with lateral clearance, engaging the opposed surfaces of the driving member, and with a close fit in the cavity, one engaging the base of the cavity while the other is pivotally coupled to one of the rocker arms.

This invention relates to means for driving internal combustion engine poppet valves.

According to the present invention, means for driving an internal combustion engine poppet valve comprises a first cam and a second cam carried on a common rotatable camshaft and having associated first and second followers respectively each of which is operatively connected to a different one of two arms of a rocker pivotable about an axis, one of the said followers or its associated rocker arm also being operatively connected to the poppet valve which is to be driven, and the arrangement being such that each follower is reciprocable along a different one of two rectilinear axes both of which axes are disposed radially of the camshaft.

Preferably the said first cam is a positive acceleration cam, the said second cam is a negative acceleration cam, and it is the said first follower or its associated rocker arm which is operatively connected to the poppet valve.

The pivotal axis of the rocker may extend parallel with the axis of the camshaft, in which case the said two rectilinear follower axes are disposed symmetrically about a plane which contains both the axis of the camshaft and the pivotal axis of the rocker. Alternatively, the rocker arms themselves may be arranged parallel with a radial plane passing through the axis of the camshaft, in which case the said two rectilinear follower axes may be disposed substantially parallel with each other.

Three embodiments of the present invention will now be described by way of example with reference to the accompanying drawings, in which:

FIG. 1 illustrates a first embodiment,

FIGS. 2 and 3 are front and side views of a second embodiment in test rig form, respectively showing the valve in its open and closed position, and

FIGS. 4 and 5 are front and side views of a third embodiment.

In all three embodiments a rotatable camshaft **1** carries a first cam **2** and a second cam **3** which respectively provide the positive acceleration and the negative acceleration for an internal combustion engine poppet valve **4** having a stem **5** slidable in a valve guide **6**. A rocker **7** adjacent the camshaft **1** and the valve stem **5** is pivotable about an axis and has two rocker arms **8** and **9**.

In the first two embodiments (FIGS. 1 to 3) the pivotal axis of the rocker **7** extends parallel with the axis of the camshaft **1**, but in the third embodiment (FIGS. 4 and 5) the two axes are perpendicular to each other.

Referring now more specifically to the first embodiment as shown in FIG. 1, the valve stem **5** is screw-threaded at its outer end and at that point carries nuts **10***a* and **10***b* which are mounted with some lateral clearance within a tubular crosshead **11** arranged to slide between guide surfaces **12**. The arm **8** of the rocker **7** is bifurcated at its outer end to engage the crosshead **11**, and the latter carries a follower **13** for the cam **2**, the follower being spigoted to the crosshead. This arrangement is such that axial loads imparted by the cam **2** to the follower **13** are transmitted by way of the nut **10***a* to the valve stem **5**, but the lateral clearance between the nuts **10***a*, **10***b* and the crosshead **11** serves substantially to isolate the valve stem from side-thrust caused by lateral loads which may occur during operation of the valve.

The other arm **9** of the rocker **7** carries a driving pad **14** which engages a cylindrical follower **15** for the second cam **3**. The follower **15** is slidable on guide surfaces **16** in a carrier **17**.

It will be seen that as the camshaft **1** rotates and brings the cams **2** and **3** into contact with their respective followers **13** and **15**, the poppet valve **4** is driven alternately out of and into sealing engagement with its cylinder port. It will be seen further that the axes of the paths along which the followers **13** and **15** reciprocate are both disposed radially of the camshaft **1**; and that these axes (shown as A–B and C–D respectively) are in this embodiment disposed symmetrically about a plane X–Y which contains both the axis of the camshaft **1** and the pivotal axis of the rocker **7**.

In the second embodiment (FIGS. 2 and 3) the valve stem **5** carries at its outer end a crosshead **18** within which a pair of links **19** are pivotally mounted at their inner ends on opposed sides of the valve stem. At their outer ends the links **19** are formed with arcuate portions **20** constituting followers for a pair of first (positive acceleration) cams **2** which are carried by the camshaft **1**: the centre of curvature of each of the arcuate followers **20** lies on the axis about which the associated link **19** can pivot within the crosshead **18**. Adjacent its outer end, each link **19** is pivotally attached to the outer end of the rocker arm **8**.

The crosshead **18** is slidably mounted between guide surfaces **21**, so that the paths along which the twin followers **20** reciprocate during operation are both contained in a plane A–B.

The follower for the second (negative acceleration) cam **3** is similarly constituted by an arcuate surface **22** at the outer end of a link **23**, the inner end of the latter being pivotally mounted in a crosshead **24** slidable between guide surfaces **25**. The centre of curvature of the follower **22** lies at the point where the link **23** is pivotally attached to the crosshead **24**. Adjacent its outer end the link **23** is pivotally attached to the rocker arm **9** at a point near the free end of the latter. During operation of the valve, the follower **22** reciprocates along a path whereof the axis is shown at C–D in FIG. 2. It will be seen, then, that as in the first embodiment the axes of reciprocation of the cam followers **20** and **22** are disposed radially of the camshaft **1**, and lie symmetrically on either side of a plane X–Y which contains the axis of the camshaft and the pivotal axis of the rocker **7**.

In both the embodiments described hitherto the reciprocation axes A–B and C–D lie at substantially 90° to each other, but this is not necessary; for example there is envisaged an arrangement in which these axes are inclined at an angle of 82° to each other. A special case arises when it is wished to reduce the angle between the follower reciprocation axes to 0° i.e. when it is wished to

make both followers reciprocate along paths parallel with the axis of the valve stem **5**. Such an arrangement is shown in FIGS. 4 and 5, from which it will be seen that in this embodiment the pivotal axis of the rocker **7** does not extend parallel with the axis of the camshaft **1**, as was the case in the first two embodiments.

In this third embodiment the valve stem **5** is screw-threaded at its outer end to receive an internally screw-threaded driving member **26** which is held in position by a lock nut **27**. A washer **28** rests on the driving member **26** and is a tight fit within a counter-bored part of an element **29** having a convexly curved surface **30** which constitutes a follower for the first (positive acceleration) cam **2**. The follower element **29** is mounted to slide on guide surfaces **31** and it will be seen that some lateral clearance is allowed between the driving member **26** and the counterbored part of the follower element **29** in order to reduce lateral loads on the valve stem **5**.

The rocker arm **8** is bifurcated to extend on opposed sides of the valve stem, and carries a pair of driving pads **32** which are operatively connected with the driving member **26** through the intermediary of a contact washer **33**, the latter being a tight fit within the counterbored part of the follower element **29**.

The other rocker arm **9** carries a similar driving pad **32** which engages a driving element **34**, the latter in turn engaging a hollow follower **35** for the second (negative acceleration) cam **3**. The follower **35** is reciprocable along an axis C–D between guide surfaces **36** and it will be seen that the latter axis is parallel with the axis of reciprocation (A–B) of the cam follower element **29**. It will also be seen that both axes of reciprocation are disposed radially of the camshaft **1**.

In all three of these embodiments, the positive and negative accelerations of the valve are induced by the operation of the respective cams and the interconnecting rocker so that the valve is driven both into and out of sealing engagement with its associated cylinder port. Nevertheless a light spring may be provided (such as at **37** in FIG. 2) to hold the valve on its port seating and so facilitate the starting of the engine. It will be appreciated, however, that this spring will not provide the force necessary for the negative acceleration of the valve at anything but low operating speeds.

With the elimination of the conventional valve spring as the source of the negative acceleration of the valve, instead of the negative acceleration being a fraction of the positive acceleration its value can now be greatly increased and the optimum design balance can be achieved if the two accelerations have the same or similar values. Moreover, since the cam follower which provides the positive acceleration no longer has also to provide the force necessary to compress the valve spring, a higher rate of acceleration can be used without increasing the load at the point of contact between the cam and the follower.

With the different acceleration conditions that can profitably be used, the valve lift curve for positive, or desmodromic, operation may differ considerably from the type of curve that is obtained with spring operation, and can enclose a significantly greater area, with corresponding benefit to the engine performance. With the improved valve opening curve it is possible to reduce the duration of the period for which the valve remains open and so improve the engine performance at the middle and lower portions of the speed range without unduly detracting from its high speed power output.

Manufacture of the valve operating mechanism is facilitated and uniformity of stressing is obtained if with positive or desmodromic operation the period for which the valve remains open is divided into four equal parts, with the maximum lift occurring at the junction of the second and third parts. Each of the four component parts of the complete valve opening period consists of two phases. During one phase the valve velocity is changing, or, in other words, positive or negative acceleration is taking place. During the other phase the valve velocity is

maintained at a constant value. The initial opening and the final closing of the valve may be accomplished by the employment of the "ramp" commonly used, and such a ramp may be superimposed on the constant velocity phase of the valve opening period, for the purpose of taking up working clearances without shock or noise.

Thus the valve lift period, comprising four equal parts, takes the following form. The first part, which may or may not be preceded by an opening ramp, consists of an initial phase, during which the valve is accelerated in accordance with any required pattern or curve, followed by the second phase during which the valve continues at constant velocity, the velocity being that which has resulted from the preceding acceleration, with or without a superimposed ramp to take up the working clearances in preparation for the later negative acceleration.

The second part of the valve opening period is the reverse of the first part. The first phase of the second part is a continuation of the second phase of the first part, the valve movement being continued at the constant velocity with or without the "ramp." The second phase of the second part duplicates the first phase of the first part except that the acceleration is opposite in direction, i.e. negative instead of positive. At the end of this second period the valve velocity is nil, the valve being stationary at maximum lift.

The third part of the valve lift period is similar to the second part except that the two phases occur in the reverse order; the acceleration phase, identical to that of the second part, is a continuation of it, and is followed by a constant velocity phase. Again the constant velocity phase continues into the first phase of the following fourth part, the second phase of which provides positive acceleration, identical with that of the first phase of the first part, to complete the closing of the valve. At this point again the conventional ramp may or may not be provided according to the requirement of the design.

Utilising a cam form of the type described, it is possible (especially if most of the acceleration is at the constant value which at the maximum speed of the engine corresponds to the maximum permissible values of bearing load or induced stress in the valve operating mechanism components) to achieve a valve maximum lift that is much greater than is commonly used with a spring operated gear. This is especially desirable if the associated valve port, in combination with the valve, has a high flow coefficient, because the flow coefficient can continue to increase with valve lifts greater than the nominally correct maximum value of one quarter of the valve minimum seat diameter.

The acceleration phases, positive or negative, of the valve opening period, have been described as being largely occupied by acceleration at constant value, but building up to this value at a constant rate from the commencement of each phase and reducing at a constant rate to zero acceleration (constant velocity) at the end of the phase. This trapezoidal acceleration curve pattern may be replaced by any other acceleration pattern according to the requirements of the valve in question.

It is found that if the valve lift curve is designed as described, ample valve lift is available with the shortest valve opening period that it is desired to use. However, if it is required to employ a longer valve opening period, the need to evolve a completely new lift curve, and to provide completely new master cams and other manufacturing equipment, may be avoided if, after the conclusion of the second part of the valve opening period when the valve is stationary at maximum lift, a "dwell" of the requisite duration is introduced before the commencement of the third part of the valve opening period. Thus, for the dwell period, the valve remains stationary at the valve maximum lift, and the increase in the area enclosed by the valve lift curve is introduced in the most effective manner. Ramps may be introduced during the dwell period if required.

Zero clearance hydraulic devices may be incorporated

in the cam followers or elsewhere in the mechanism as may be desired.

In all three embodiments of the invention described herein, the arm **9** of the rocker **7** may be bifurcated or not, as is convenient to the design.

In the present invention the rectilinear movements of the positive and negative cam followers along axes radial to the camshaft axis, and the geometry of the follewers' connection to the valve which they operate, ensure that the lift curve determined by the cam forms is applied to the valve without distortion and without the need for modification of the cam profiles to allow for any geometrical aberration of the mechanism.

What is claimed is:

1. Means for driving an internal combustion engine poppet valve, comprising a crosshead carried by the stem of said valve, a rotatable camshaft, a first cam and a second cam both carried by said camshaft, a link having an inner end and an outer end, the outer end of said link constituting a follower for said first cam and being reciprocable along a first rectilinear axis which is disposed radially of said camshaft and the inner end of said link being pivotally attached to said crosshead, a second follower associated with said second cam and reciprocable along a second rectilinear axis which is disposed radially of said camshaft, a rocker having two arms and pivotable about its axis, a pivotal connection between one of said rocker arms and the said link at a point adjacent the outer end of said link, and a further pivotal connection between said second follower and the other of said rocker arms.

2. Means for driving an internal combustion engine poppet valve according to claim **1**, wherein the outer end of said link presents an arcuate surface to said first cam, and the centre of curvature of said arcuate surface lies on the pivotal axis of the pivotal attachment between said link and said crosshead.

3. Means for driving an internal combustion engine poppet valve having a stem, comprising a cam shaft rotatable about its axis, a positive acceleration cam and a negative acceleration cam both carried by said cam shaft, a first follower associated with said positive acceleration cam and reciprocable along a first rectilinear axis which is disposed radially of said cam shaft, a second follower associated with said negative acceleration cam and reciprocable along a second rectilinear axis which is disposed radially of said cam shaft, a rocker having two arms and pivotable about its axis, a driving member carried by the stem and having substantially flat opposed surfaces, an element having a first end and a second end, the first end constituting the first cam follower and the second end defining a cavity having a base, the cavity accommodating with lateral clearance the driving member, first and second washers mounted around the stem with lateral clearance, the washers engaging respectively with the opposed surfaces of the driving member, the washers being a close fit in the cavity, one of the washers engaging the base of the cavity and the other of the washers being pivotally coupled to one of the rocker arms, and said second follower being pivotally connected to the other of the rocker arms.

4. Means for driving an internal combustion engine poppet valve according to claim **3** in which the formation of the cams is such that substantial portions of the opening and closing movement of the valve take place at constant velocity and ramps are superimposed on the constant velocity portions.

5. Means for driving an internal combustion engine poppet valve according to claim **3**, wherein said one rocker arm is bifurcated to extend on opposite sides of said valve stem.

6. Means for driving an internal combustion engine poppet valve according to claim **3** wherein the pivotal axis of said rocker extends transversely of the axis of rotation of said camshaft and said first and second rectilinear follower axes are substantially parallel with each other.

7. Means for driving an internal combustion engine poppet valve according to claim **3**, wherein the formation of said cams is such that the period of time for which said valve is open comprises four equal parts, with maximum valve lift occurring at the junction of the second and third parts.

8. Means for driving an internal combustion engine poppet valve according to claim **7**, wherein said cams are formed to incorporate a ramp between negative acceleration and positive acceleration of said valve.

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