March 15, 1932. H. JUNKERS 1,849,490

FUEL FEED PUMP AND METHOD OF OPERATING SAME

Filed Nov. 25, 1927

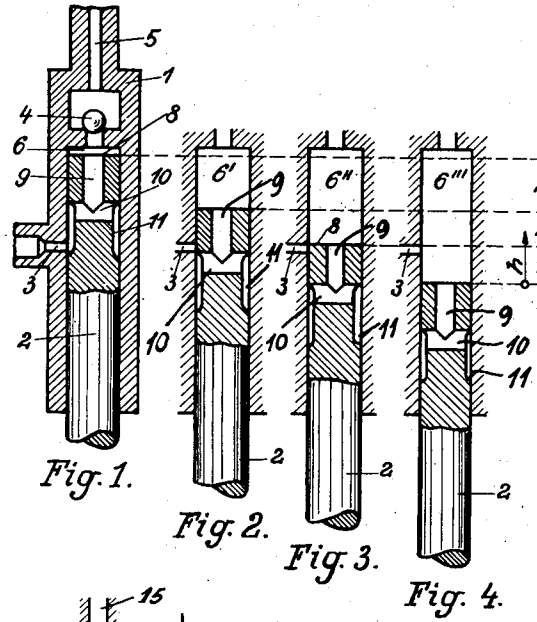

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

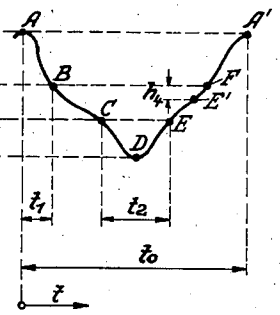

Fig. 5.

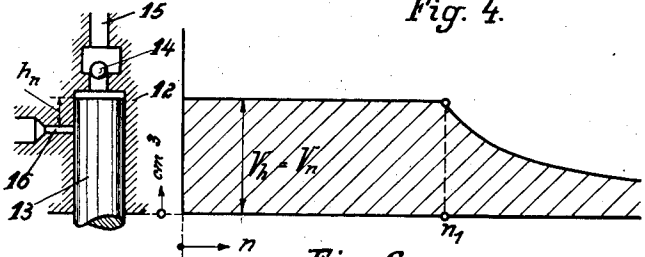

Fig. 6.

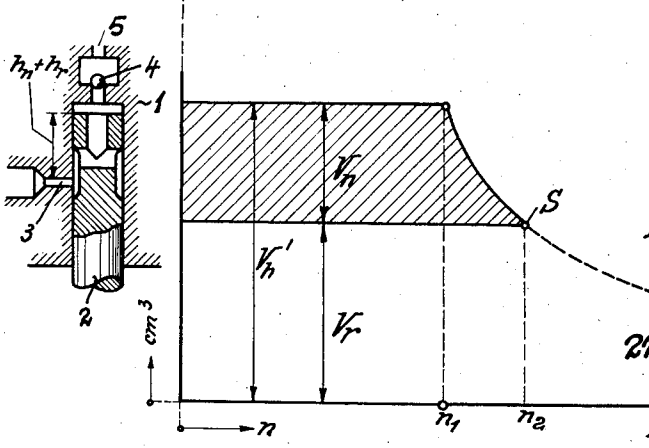

Fig. 7.

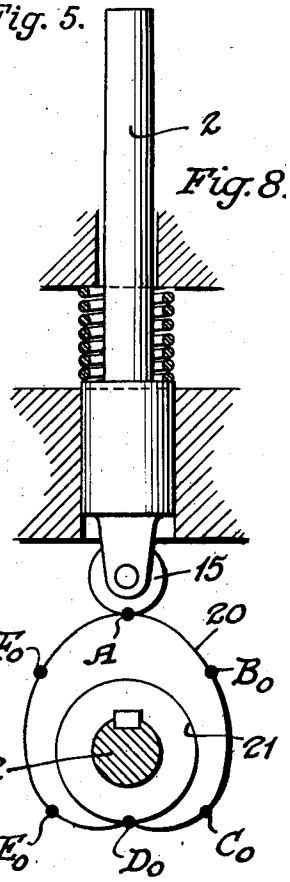

Fig. 8.

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UNITED STATES PATENT OFFICE

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FUEL FEED PUMP AND METHOD OF OPERATING SAME

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My invention relates to fuel feed pumps for internal combustion engines, more particularly engines operated with solid injection. It is an object of my invention to provide means for preventing racing in the case of failure of the regulation without necessitating a separate or safety regulator.

To this end I provide a space in the cylinder of the pump which is connected during part of the inward stroke of the piston with a space under reduced pressure by means of controlled passages so that the delivery stroke or effective stroke (the stroke during which fuel is injected into the engine) is followed by a stroke during which part of the fuel flows back from the cylinder to the space under reduced pressure. In the following specification this stroke will be termed the return flow stroke.

In internal combustion engines operated with positive fuel injection by means of a pump racing can occur when the fuel feed pump supplies a quantity of fuel which is in excess of the quantity required for the power demand of the engine. The energy inherent in the excess of fuel speeds up the engine until finally some important part of the engine breaks down.

In order to obviate this, it has been proposed to provide a separate or safety regulator in addition to the normal regulator which, as a rule, maintains the speed of the engine at a predetermined constant value. The safety regulator becomes operative only when the normal speed is exceeded for a predetermined amount in which case as a rule it cuts off the fuel supply altogether, thereby stopping the engine. However the provision of such safety regulator involves complication and additional cost and yet does not warrant absolute safety as it becomes operative only in exceptional cases, so that its supervision is likely to be neglected. Therefore a safety device of this kind cannot be relied upon to function properly in an emergency.

According to my invention the safety regulator is eliminated by the provision of a fuel feed pump in which the fuel supply is considerably reduced when the normal number of revolutions of the engine is overstepped, a slight increase of the number of revolutions beyond normal being allowed but no racing, even if the engine should be running under no-load conditions and the pump is set for full delivery.

As a rule the total stroke of a fuel feed pump will be made as short as practicable, particularly in high speed engines, because the control of the pump operation, more particularly in cam-operated pumps, is greatly facilitated. Therefore in pumps for intermittent feed interruption of feed is not resorted to unless in cases where the output is only small or, if the feed is interrupted at full load it will be performed with the least possible stroke so that when the pump is set for full power the return passages will be only just opened.

In the fuel pump according to the present invention I have departed from this principle. I make the return flow stroke excessively large, i. e. much larger than would be required under normal conditions. It may be made equal to or even larger than the useful stroke for full power. By these means the pump is made to act as a safety device, as explained above.

In the drawings affixed to this specification and forming part thereof a pump embodying my invention is illustrated diagrammatically by way of example, its function being also illustrated as compared with that of a pump of normal type.

In the drawings:

Figs. 1, 2, 3, and 4 are axial sections of the pump showing various positions of its piston,

Fig. 5 is a diagram illustrating the movements of the piston during a complete cycle of the pump,

Figs. 6 and 7 are axial sections of a normal pump and of the new pump, respectively, with diagrams illustrating the function of each, and

Fig. 8 is a detail view of one form of actuating means for the fuel pump piston.

Referring first to Figs. 1 to 4, 1 is the pump casing, and 2 is the piston arranged in the casing for reciprocation. 3 is the fuel intake port which is controlled by the piston itself, 4 is the delivery valve, and 5 is the

pressure conduit leading to the engine. 11 is a recess in the piston 2, 10 is a transverse bore, and 9 is an axial bore in the piston, both being connected with the recess 11. The axial bore opens into the end face of the piston 3. In certain positions of the piston the system of conduits 9, 10, 11 connects the space 6 of the cylinder 1 with the intake port 3, so that the delivery is interrupted. The conduits constituting the system have large diameters so that their resistance to flow is smaller than that of the intake port 3, and the resistance of this port, in turn, is small as compared with the resistance of the injection member (nozzle) associated with the combustion space of the engine. In this manner the return flow is timed properly and all lagging of the injection will be eliminated.

The piston 2 may be reciprocated by cams, cranks, eccentrics or the like. In Fig. 8 is shown a cam mechanism for operating the piston, the cam 20 being carried by the shaft 22 and having a key inserted between the shaft and hub 21 for fixing the cam to the shaft. Fixed to the end of the piston 2 is a follower 15 which is held against the cam surface by means of a spring or the like. The points A_0, B_0, C_0, D_0, E_0 and F_0 located about the cam surface correspond to the points A, B, C, D, E, F and A′ on the curve shown in Fig. 5.

A complete cycle of the pump (suction and pressure stroke) is illustrated in Fig. 5, the piston strokes h being plotted against times t. Fig. 1 shows the piston in its inner dead center position corresponding to points A and A′ (Fig. 5), Fig. 2 shows the piston with the upper edge of the recess 11 registering with the lower edge of the intake port 3 (points B and F in Fig. 5), Fig. 3 shows the piston with its top 8 registering with the upper edge of the intake port (points C and E in Fig. 5), and Fig. 4 shows the piston in its outer dead center position (point D in Fig. 5).

Assuming first that piston 2 is moving at low speed at which the resistance offered by the intake port 3 does not influence the volumetric efficiency of the pump, the effect will be as follows:

The suction stroke of the pump extends from A to D and is subdivided as follows:

First charging stroke A, B: Fuel is drawn into the pump chamber 6′ from the passage 3 through the conduits 11, 10 and 9.

Vacuum stroke B, C: The passage 3 is closed and the piston generates a vacuum in the chamber 6″ which has been partly filled with fuel during the first charging stroke.

Second charging stroke C, D: The passage 3 is exposed by the piston and fuel is drawn into the space 6‴ under the action of the vacuum.

The delivery stroke of the pump extends from D to A′ and is subdivided as follows:

First return flow stroke, D, E: The piston moves through the stroke h_3 and forces back a portion of the fuel into the passage 3.

Effective delivery stroke, E, F: The piston moves through the stroke h_2, the passage 3 is closed and the fuel is discharged through the check valve 4 and the delivery pipe 5.

Second return flow stroke, F. A′: The piston moves through the stroke h_1, passage 3 is exposed again and the fuel which has not been delivered during the effective stroke h_2 is returned to the passage 3.

It follows that only the effective stroke h_2 is available for the delivery of the fuel, while there is no delivery during the first and second return flow strokes h_3 and h_1.

Assuming now that the pump is operated at a higher speed than normal, the time t_1 available for the first charging stroke is now so short and the head of the suction passage 3 is so small that the chamber 6′ is not completely filled with fuel during the stroke A, B, but a vacuum forms in this chamber, which is increased during the vacuum stroke B, C. During the second charging stroke C, D, the fuel is not able to fill the rapidly increasing volume which the piston exposes and therefore during the first return flow stroke D, E no fuel is returned but on the contrary fresh fuel is drawn into the cylinder under the vacuum which still exists. Delivery obviously can only begin when there is no longer any vacuum in the pump chamber. At normal speed this will occur at E, but under abnormal speed conditions the point E will move into a position intermediate the points E and F, for instance E′ in Fig. 5, corresponding to effective delivery stroke h_4. On the other hand, the point F is fixed as its position is not influenced by the speed but only by the invariable setting of the pump-operating mechanism.

Therefore the quantity of fuel which is actually delivered to the engine is a function of the position of point E′ with respect to point F, and not a function of the quantity of fuel which has been admitted during the charging stroke A, B. This quantity is also a function of the speed, but it is not necessary that the total quantity of fuel which has been drawn into the pump during the charging stroke A, B should be delivered during the stroke E′, F, or h_4, the effective delivery stroke. In theory it is even possible to reduce h_4 to zero, so that none of the fuel drawn into the pump during the charging stroke A, B is delivered to the engine, but in practice this must not be as a certain amount of fuel is required for keeping the engine running under no-load conditions.

It has been found that in order to obtain the desired effect the return flow stroke h_1 should be about equal to or even larger than the effective stroke corresponding to full charge (h_2).

The desired action can be expedited by reducing the periods t_1 and t_2 during which the inlet passage 3 is connected with the cylinder. However, the cross-sectional area of the intake port 3 must not be reduced below a certain limit in view of the precise timing of the injection, and therefore the so-called time-area factor can only be kept small by selecting the times t_1, t_2 as short as practicable in relation to the total period t_0 for the complete cycle. In other words, the piston speed must be increased at the beginning and at the end of the suction strokes h_1, h_3 and at the beginning of the effective strokes h_2 or h_4.

The volumetric efficiency of a pump is known to decrease with increasing number of strokes. One might imagine that this phenomenon, which might be assisted by reducing the cross-sectional area of the intake port in pumps in which the passage is controlled by the piston, could be utilized for the present invention, but this would not lead to success because the fuel feed will not decrease rapidly enough to prevent excessive speed under no-load conditions.

This will appear from a comparison of Figs. 5, 6 and 7, Fig. 6 illustrating the delivery of a pump lacking the system of conduits according to the present invention, plotted (in cubic centimeters) against the number of revolutions n. 12 is the cylinder, 13 is the piston, 14 is the pressure valve, 15 is the pressure conduit, and 16 is the intake port of the pump.

Up to a given speed n_1 the fuel is not throttled in the intake port 16 and therefore delivery is constant, that is, the effective volume Vn is equal to the cylinder volume Vh, corresponding to the stroke h_n from the closed intake port 16 to the inner dead center. When the speed is increased beyond n_1, delivery decreases but becomes nil only in the infinite so that an excessive speed will be attained under no-load conditions.

Referring now to Fig. 7 in the pump here shown according to the present invention the stroke from the intake port 3 to the inner dead center may be said to be artificially increased to $h_n + h_r$, the corresponding volume being V'_h. In this pump delivery per stroke will be constant until a given number of revoluoion n_1 is attained and from this point on it will decrease until it becomes nil in the infinite. However only a fraction V_n of this total delivery is utilized and the residual volume V_r is forced back so that the curve indicating the decrease of total delivery will very soon intersect with the line representing Vr, the intersection being marked S. At this point the fuel feed ceases altogether and the speed n_2 at which this occurs is the maximum speed the engine may attain but, as mentioned above, this speed is not attained in practice as a certain fuel feed is required even under no-load conditions.

I wish it to be understood that I do not desire to be limited to the exact details of construction shown and described for obvious modifications will occur to a person skilled in the art.

I claim:—

1. The method of operating fuel pumps for internal combustion engines which comprises connecting the cylinder space of the pump during the delivery stroke with a space under comparatively low pressure so as to interrupt the delivery, so controlling the operation of the pump as to obtain an excessive return flow stroke following the delivery stroke, and providing for particularly high piston speeds at the beginning and at the end of the suction stroke and at the beginning of the delivery stroke so that the period during which the cylinder is connected with the supply of fuel is short as compared with the total period of a cycle, and the delivery of the pump is reduced to the demand under no-load conditions at a comparatively small increase of speed.

2. A fuel feed pump for internal combustion engines comprising a cylinder, a piston therein defining a passage which connects the cylinder with a space under comparatively low pressure, and means for actuating the piston at increased speed at the beginning and the end of its suction stroke and at the beginning of its delivery stroke, said piston being adapted to perform an excessively large return flow stroke following the effective delivery stroke.

3. The method of operating fuel pumps for internal combustion engines which comprises supplying fuel to the pump through a restricted supply passage, and increasing the speed of travel of the pump piston during communication with the supply through said passage so as to effect a throttling of the supply incident to any increase of speed of the engine above normal.

In testimony whereof I affix my signature.

HUGO JUNKERS.