April 1, 1941. W. VOIT ET AL 2,236,553

FUEL INJECTION APPARATUS FOR INTERNAL COMBUSTION ENGINES

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Fig. 1

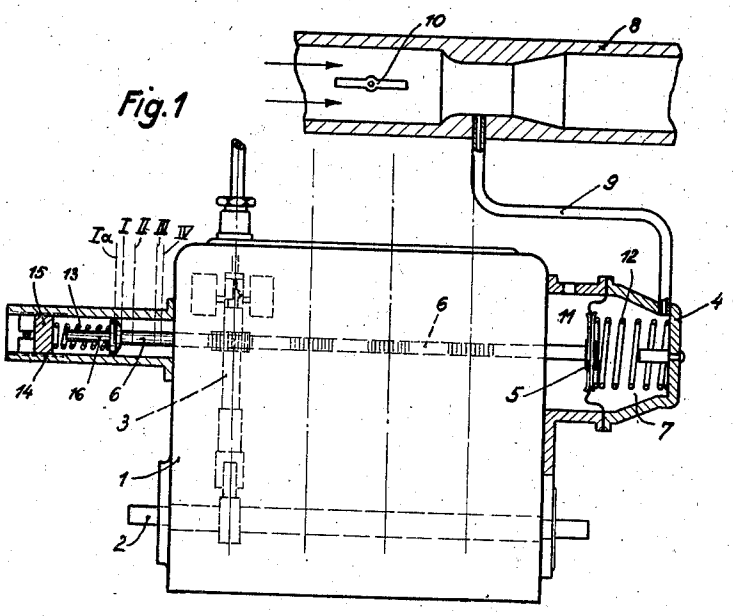


Fig. 2

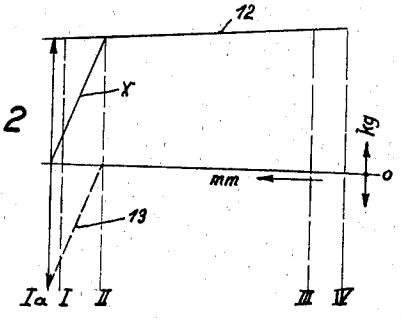
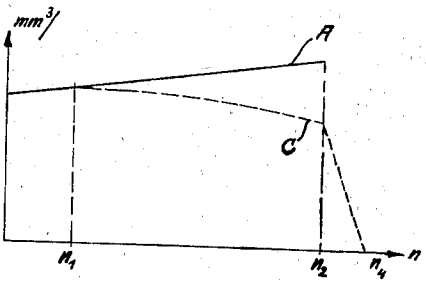


Fig. 3



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Fig. 4

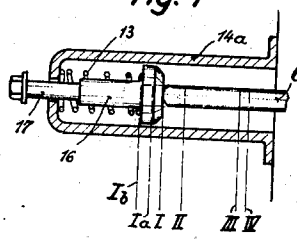


Fig. 5

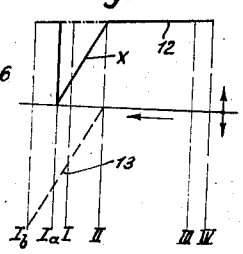


Fig. 6

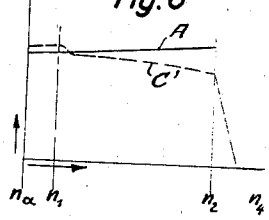


Fig. 7

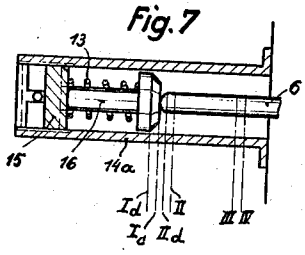


Fig. 8

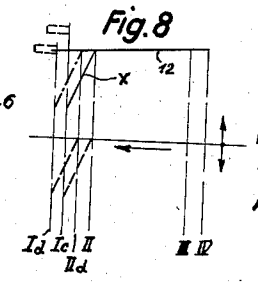


Fig. 9

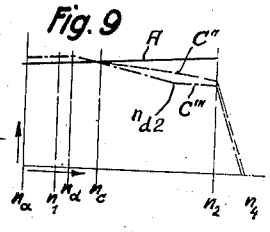


Fig. 10

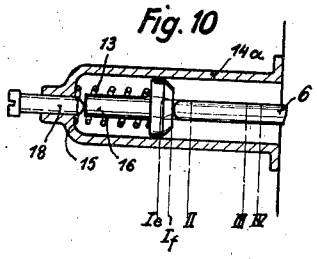


Fig. 11

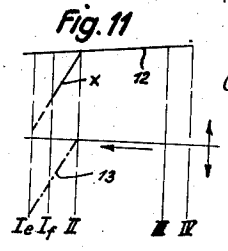


Fig. 12

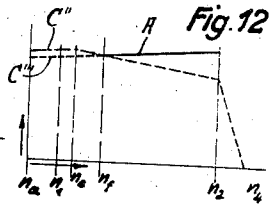


Fig. 13

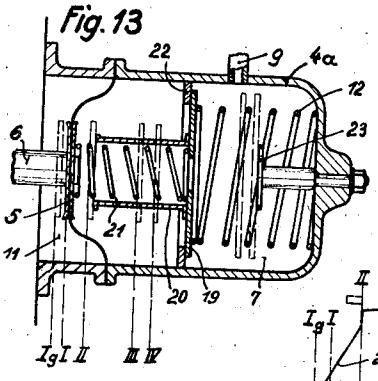
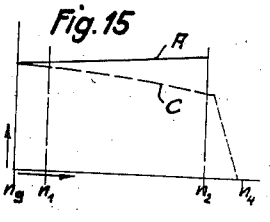


Fig. 15



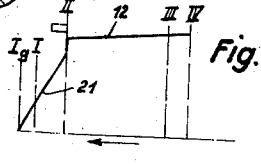


Fig. 14

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2,236,553

FUEL INJECTION APPARATUS FOR INTERNAL COMBUSTION ENGINES

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Application December 16, 1936, Serial No. 116,226
In Germany December 23, 1935

9 Claims. (Cl. 123—140)

This invention relates to fuel injection apparatus for internal combustion engines, comprising a fuel injection pump, control means in said pump for adjusting the fuel delivery of the pump, and a pneumatic governor operating said means. Such a pneumatic governor has two chambers, one of which is connected with the atmosphere and the other with the induction pipe of the engine. The two chambers are separated from one another by a movable governor member, e. g. a piston or a membrane, and said member is under the influence of a spring means which tends to move said member in the direction of increasing fuel delivery whereas the negative pressure or vacuum in the induction pipe causes the member to move, in opposition to said spring means, in the direction of decreasing fuel delivery.

When employing fuel injection apparatus of this kind, the different loads on the engine are adjusted for by a movable throttle which is arranged in the induction pipe of the engine. By closing or partially closing the throttle, the air flow in the pipe can be restricted so that the vacuum in the governor chamber connected therewith increases. With the increase of this vacuum the movable governor member is moved in such a way as to decrease the fuel delivery. In this case the movement of the governor member takes place in opposition to the spring means. By fully opening the throttle the vacuum will decrease and adjust the control means so that the injection pump delivers large amounts of fuel and the engine runs with full power.

With the throttle in its open or full power position, many different engine speeds occur, especially in vehicle engines, and it depends on the engine load whether the engine speed is high or low. A high load reduces and conversely a small load increases the engine speed.

It is well known to those skilled in the art that a pneumatic governor of the type described can be used to avoid an undesired increase of the engine speed beyond an admissible maximum. When the engine has exceeded the maximum speed at which it gives its full output, the vacuum in the governor chamber connected with the induction pipe will increase to such a degree that it displaces the movable governor member, against the opposing spring means, and with it the control means, into its no delivery position, thus fully cutting off the fuel delivery to the engine. With the throttle in its fully open position, the fuel supply can be cut off only when the maximum engine speed has been exceeded. This type of governor can also be used for adjusting the fuel supply at loads less than full engine load by closing the throttle sufficiently to decrease the supply of fuel accordingly.

In internal combustion engines in which full load occurs over a great range of speeds, as principally in vehicle engines, it is important to take steps to enable the greatest possible torque to be obtained from the engine at any speed. A very important preliminary condition for this is that, at each speed, the maximum amount of fuel which the engine can burn without producing smoke, should be supplied to it. This amount varies with the speed in most types of engines. It may increase as the speed increases, in some cases however it remains the same over the whole range of speeds but usually the amount of fuel for running under full load that can be burnt without smoke will decrease as the speed rises.

For any engine the maximum amount of fuel that can be consumed without smoke when running under full load can be experimentally determined for each speed. If the ascertained values are inserted in a system of co-ordinates, a curve is obtained, which may be termed the "consumption curve." According to whether this curve rises, remains the same, or falls, as the speed increases, the engine can be spoken of as having a rising, uniform or falling consumption curve.

The course of the consumption curve of an engine depends on various circumstances. The falling consumption curve will be frequently met with, more especially in the case of engines having a high maximum speed, because the air charge in the engine cylinders decreases considerably for known reasons in the higher speed range, so that the maximum amount of fuel which can be consumed without producing smoke also correspondingly decreases.

In injection internal combustion engines, the injection pump measures the amount of fuel. Every injection pump has a definite delivery amount curve which is produced on a definite, unvarying adjustment of the delivery amount adjusting member depending on the different speeds. Pumps having inlets controlled by sliding valves have for example a delivery curve that rises with the speed. Other pumps, for instance those having the usual suction valve, have a delivery curve which remains fairly uniform over the range of speeds that occur.

If now it is desired to introduce the maximum amount of fuel consumable without smoke into

an injection engine in the whole speed range, in order to enable the highest possible torque to be obtained from the engine at all speeds, attention must be given primarily to making the delivery curve of the injection pump apparatus assimilate or conform as far as possible to the course of the consumption curve of the engine. The best conditions result, of course, when the two curves coincide.

This invention provides a new way in which in a simple manner, in spite of the comparatively great pressure or high pretension and small stiffness of the return spring necessary for cutting off of the fuel supply when maximum speed is exceeded in injection apparatus having pneumatic governing, the amount of fuel delivered to the engine can be regulated in such a way that the delivery curve of the injection apparatus can be adapted or coordinated to the consumption curve of engines having a strongly falling consumption curve so that at each speed at full load the engine operates with maximum power and with smokeless combustion.

According to the present invention, in a fuel injection apparatus for internal combustion engines comprising an injection pump having a full load delivery curve which rises relatively to the consumption curve of the engine as the speed increases, and a pneumatic governor which controls the fuel amount delivered by the injection pump to the nozzles and adjusts the delivery amount controlling member of the injection pump in dependence on a return force and on a pneumatic drop in pressure acting in opposition to said return force, which drop in pressure varies with the engine speed as well as with the position of a voluntarily operable throttle, a novel return force is provided whereby under full load conditions, that is to say, in a range between full load at low speed and full load at maximum speed, the effective resultant value of the said return force is such that the difference in depression occurring within this full load range due to differences in speed of the engine can cause by a corresponding displacement of the control member, an assimilation of the fuel delivery curve of the pump to that consumption curve of the engine which gives smokeless combustion at each speed at full load to enable the engine to operate at maximum efficiency, said return force also coacting, however, with the opposing depression or increase, to regulate the fuel amounts when maximum speed is exceeded and at all speeds less than maximum under partial load.

The return force acting on the governor member of the pneumatic governor comprises a 2-stage spring means, one stage of which has a high pretension corresponding to the vacuum existing at maximum speed in the governor chamber but of such weakness that it is overcome by a further increase of vacuum when the maximum speed is exceeded, the other stage of said spring means having a low pretension, if any, corresponding to the slight vacuum existing below maximum speed with wide open throttle, but of such a strength that below maximum speed and with wide open throttle it adjusts the control means to the slight vacuum and small variations of vacuum in the induction pipe of the engine so that the control means causes the pump to deliver the maximum quantity of fuel which can be burned smokelessly.

Various examples of construction of the invention are shown in the accompanying drawings in which:

Figure 1 shows, partly in longitudinal section a fuel injection pump provided with a vacuum or pneumatic governor embodying this invention.

Figure 2 is a diagram of the curve of the spring forces of the injection pump governor.

Figure 3 is a diagram of the delivery curve of the pump and the consumption curve of the engine.

Figures 4, 7, 10 and 13 are enlarged sections of different examples of construction of spring stops for the delivery amount adjusting member of the pump, while the curves of the spring forces and the maximum delivery amount of the pump appertaining to each example are indicated in the diagrams (Figs. 5, 6, 8, 9, 11, 12, 14, 15) adjoining said figures.

1 indicates the injection pump, the cam-shaft 2 of which drives the pistons 3 of several separate pumps. On this injection pump a pneumatic governor 4 is built, in which a diaphragm 5 moves a toothed controlling rod 6 of the injection pump. By the movement of the controlling rod all the pump pistons are uniformly angularly turned or rotated, whereby an oblique helix controlling edge arranged on the end of each piston is adjusted in relation to a return flow opening, so that a variable amount of the fuel forced by the pistons can flow back. An externally closed governor chamber 7 of the pneumatic governor 4 is connected by a pipe 9 to the induction pipe 8 of the engine, the other governor chamber 11 being open to the atmosphere. A throttle member 10 is rotatably mounted in the induction pipe 8 of the engine and by closing or partially closing the throttle 10, a vacuum is produced in the chamber 7. The vacuum will displace the diaphragm 5 and this in turn displaces the control rod 6 in the direction which decreases the amount of fuel injected. The opposite movement of the control rod 6 takes place when the vacuum in the chamber 7 decreases, e. g. by adjusting the throttle into the open position as seen in Fig. 1. With the throttle in its open position, a smaller vacuum arises than when it is in its closed or partially closed position. The opening and closing movement of the throttle and the speed of the engine are made use of to adjust both large or small injection amounts at full or part engine loads. The throttle in the present case is used primarily to control the vacuum in the governor chamber and for this reason it is only necessary to partially close the throttle to obtain sufficient vacuum to adjust the fuel delivery for part load and idling speeds. Within the chamber 7, there is arranged a spring 12 which presses the diaphragm 5 and the control rod 6 towards the left hand side in Fig. 1. The force of the return spring 12 tends to adjust the diaphragm and the controlling rod in the direction which increases the amount of fuel injected.

An injection pump of the type shown has per se a rising delivery curve according to the line A and the curve of the maximum fuel amount consumable by the engine, without producing smoke, may have a course indicated by the broken line C in Fig. 3. In order to assimilate the delivery curve of the injection pump fitted with a pneumatic governor to this consumption curve, which falls as the speed increases, an opposing spring 13 is so arranged on the left hand end of the pump casing 1 as shown in Fig. 1, that it bears with one of its ends against an adjustable

bottom or stop member 15 in a sleeve 14, while the other end of the spring 13 bears on a movable stop 16 for the left end of the controlling rod 6. The springs 12 and 13 prevent the pump from delivering amounts of fuel over and above those shown by curve C, provided the throttle is fully open.

When the engine is not running there is no vacuum either in the induction pipe 8 or in the governor chamber 7. The springs 12 and 13 are now the only forces which have influence on the control rod 6 and keep it in a certain position of equilibrium.

When the engine is in operation, a vacuum will arise in both the induction pipe 8 and the chamber 7, which vacuum will have the tendency to draw the diaphragm 5 towards the right for decreasing the fuel delivery amount, which movement is opposed by the resultant force of the springs.

The left end of the controlling rod stands, when the engine is stopped or not running, in the position I*a*, as in this case no drop in pressure acts on the diaphragm, so that the pressure of the return spring 12 and that of the opposing spring 13 are equal. If now the engine is running under full load (i. e. the throttle valve fully open) at a slow speed, for example when the car is traveling uphill, the left end of the controlling rod is in the position denoted by I.

At a high full load speed the current in the air induction pipe is stronger, so that the vacuum in the governor chamber increases somewhat and pulls the diaphragm more to the right, until the left end of the controlling rod in the region of maximum speed reaches the position II. In this position of the governor parts the force exerted by the opposing spring 13 on the controlling rod has been expended, and upon a further increase in speed and in vacuum, the control rod is moved further to the right so that the left end of the controlling rod comes out of the range of action of the opposing spring. In position III of the end of the controlling rod, only the amount of fuel necessary to maintaining idle running is still delivered. The controlling rod moves into this position III when the throttle valve is fully open when maximum speed is exceeded. With the throttle valve partially closed (idle running adjustment), the vacuum then existing in the induction pipe 8 and in the governor chamber 7 is also able to pull the controlling rod into position III. The stop position of the controlling rod is indicated at IV.

The spring 12 has the characteristic indicated by 12 in Fig. 2, a diagram in which the ordinates show the force exerted by the springs and the abscissas the stroke of the movable end of each of the springs. The positions of the left end of the controlling rod in Fig. 1 correspond to the spring path I*a*—IV in Fig. 2. The spring 13 has the characteristic indicated by numeral 13 in Fig. 2 and shown by a dotted line below the axis of abscissas to illustrate that spring 13 works in the opposite direction to spring 12. In position I*a* both springs have the same tension in opposite directions and are in equilibrium. From I*a* to II the tension of spring 13 decreases until at II the spring 13 has fully expanded. Between I*a* and II the springs 12 and 13 work together like a spring with the resultant characteristic X in Fig. 2 and as if such a resultant spring were opposed to the vacuum in the chamber 7.

As previously pointed out, the vacuum in the chamber 7 increases with increasing engine speed because with increase in speed the velocity of the air-flow also increases. With the throttle in its open position the vacuum in the pipe 9 leading into the induction pipe and in the chamber 7 is relatively small as long as the engine is running at slow speed under full engine load because the velocity of the air-flow in the induction pipe is also small. The vacuum increases with increasing engine speed and becomes at the maximum speed so great that it overcomes the relatively high pretension of spring 12.

Fig. 1 shows the control rod 6 with its left end in the position I, but it will stand in the position I*a* when the engine is stationary and the pressure is the same on both sides of the diaphragm 5. From the I*a* position in which equilibrium exists between the springs 12 and 13, the control rod moves towards the right as soon as the vacuum in chamber 7 overcomes the resultant spring force X. In order to achieve this a small vacuum will be sufficient as the strength of X near I*a* in Fig. 2 is small. In fact, even the small vacuum will suffice which occurs in chamber 7 when, with the throttle in the open position and with high engine load (e. g. driving uphill), the engine speed has very much decreased, for instance down to the lowest speed at which the engine is still able to operate under full load. In the following, this lowest speed will be referred to as "lowest full load speed." The position of the control rod 6 corresponding to the "lowest full speed" is that indicated by I in Fig. 1. Now, if with decreasing torque the engine speed and the vacuum increases—while the throttle remains in its open position—the increasing vacuum will further shift the control rod 6 towards the right against the resistance of the spring the strength of which increases corresponding to the rising course of X. Between I and II in Figs. 1 and 2 the shifting movement of the control rod 6 will terminate in those positions in which the vacuum and the strength of the resultant X are in equilibrium. The springs 12 and 13 are so dimensioned and the resultant X so chosen that with increasing speed—the throttle, be it remembered, always being open—the left hand end of the control rod 6 has reached the position II at the maximum engine speed. That is the highest possible engine speed which is admissible for the engine under full load. In this position II the spring 13 has fully expanded and the stop 16 touches only lightly the left hand end of the control rod 6. If because of further decreasing engine torque (for instance when driving downhill) the engine speed exceeds the maximum speed, the vacuum would further increase; but as the expanded spring 13 no longer operates at the right hand side of II—in which position only spring 12 works—at II another range of governing will begin. Here, only the spring 12 will resist the increasing vacuum. As according to Fig. 2 the stiffness of the spring 12 is very small, only a small increase of vacuum, corresponding to a small increase of speed over maximum speed, is necessary to shift the control rod 6 towards IV and so fully cut-of the fuel delivery at a speed which is not very much higher than maximum speed. Thus by exceeding the maximum speed only slightly the fuel delivery is fully cut-off, while below maximum speed the stiffer characteristic X will cause an even alteration in the amount of fuel delivered in dependence on variations of engine speed as Fig. 3 is intended to show.

It will be seen from this diagram that the coaction of the spring 12 and 13 only takes place

between stop position (Ia) and the maximum speed at full load position (II). When the speed exceeds the predetermined maximum speed at full load the final regulation or cutting off of the fuel supply starts, and the return spring 12 is increasingly compressed by the increasing vacuum until the idling amount adjustment (III) and finally the stop position (IV) of the controlling rod is reached.

In Fig. 3 the maximum speed is indicated by n_2 and the lowest full load speed by n_1. It has already been mentioned that between these two limits of speeds one stage X of the spring means comes into operation, i. e. the stage in which both springs 12 and 13 operate, while above n_2 in the other stage only spring 12 is opposed by the vacuum.

According to the present invention the strength of the resultant spring means X is such that the delivery curve A of the pump is assimilated as much as possible to the fuel requirements of the engine corresponding to the smokeless consumption curve C. Further, the new governor has a second control stage above n_2, the operation of which is practically the same as that of the commonly known maximum speed regulator cutting-off fuel supply at maximum speed.

It will be seen, therefore, that according to this invention, the control of the fuel amount takes place in the full load speed range by the coaction of the forces in a different way than if only the fall in pressure and the main return spring 12 were operative.

Fig. 4 relates to another embodiment of the invention. If differs from Fig. 1 by the fact, that the stop 16 has a prolongation 17 which extends through the bottom of the sleeve 14a and can at will be drawn manually further to the left, beyond the position Ia in which it would stand when the engine is not running, into a position Ib in which the stop 16 bears on the bottom of the sleeve. When the engine is out of operation and the stop 16 has been drawn manually to the left, the control rod will follow the stop under the pressure of spring 12 until the end of the control rod 6 has reached the Ib position. In this condition, the injection pump is so adjusted that the pump delivers an excess amount of fuel which in many cases is desirable for starting the engine. During the excess fuel adjustment period the spring 13 is kept inoperative and the fuel delivery is adjusted by spring 12 alone according to the upper straight line in Fig. 5. If, for starting purposes, the stop 16, 17 has been drawn to the left, excess fuel amounts can be adjusted which according to the left hand part of curve C' between n_a and n_1 in Fig. 6 are shown to be larger than the full load delivery amounts between n_1 and n_2, adjusted by the springs 12, 13 after the stop has been released so that the springs can operate in the manner described in Fig. 1.

In Figure 5, as in Figure 2, the strength of the springs 12 and 13 are plotted as ordinates over the length of spring travel, the positions of the left hand end of the control rod in Fig. 4 corresponding to the spring travel Ib to IV of Fig. 5. The combined action of the springs 12 and 13 is shown by the line X (Fig. 5) disposed between the position n_1 and the maximum speed position n_2 (Fig. 6). The left hand end of the control rod moves in this speed range from the position Ia to the position II (Fig. 5).

If prior to starting the engine, the driver manually displaces the excess fuel stop 16 to the left, then the tension of the spring 13 is overcome by him in the position Ia of the control rod so that spring 13 no longer acts in opposition to the spring 12, which latter spring is then free to expand so that the control rod moves until its left hand end comes into position Ib in which this control rod, when the engine throttle is wide open and the engine is revolving at low speed sets the pump to give an increased quantity of fuel, which is often desirable at starting of the engine. This condition is shown in Fig. 6 in which the quantity of fuel injected per stroke is plotted against revolutions per minute.

Should the excess fuel device be pulled back, the fuel delivery curve would rise throughout the range, above the curve A and parallel thereto but as the governor comes into operation at or about the point n_1 this curve will take the form shown at C'—where only the first part of the curve lies above the curve A but the latter part of the curve falls below it.

Further according to this invention, the strength of the opposing spring can be adjusted. An example of such an arrangement is shown in Fig. 7. One end of the opposing spring 13 bears on the adjustable bottom or stop 15 of the sleeve 14a, and the other end bears on the movable controlling rod stop 16. At a low full load speed (position Ic) the stop 16 impinges on the bottom 15 of the sleeve 14a, while the spring 13 is compressed. As the stop 16 impinges on the bottom 15 before the left end of the controlling rod has reached a position Id equivalent to the position Ia, of the above examples, in which it would stand on non-running of the engine, if the stop was not present, a condition of equilibrium of the springs 12 and 13 cannot occur as in the arrangements shown in Figs. 1 and 4. The adjustable bottom is moved, furthermore, according to Fig. 7 beyond the non-running position Id (Ia as indicated in Figs. 1 to 4) somewhat further to the right into position Ic, so that the end of the controlling rod approaches still nearer the position II that corresponds to the maximum speed at full load. In this initial position the pressure of the return spring preponderates over the opposing spring in the region of low full load speeds (Fig. 8) so that thereby the controlling rod is pressed against the stop. With the throttle valve fully open and low full load speeds, no assimilatory action of the opposing spring takes place, because the controlling rod does not move, and the delivery amount of the pump increases as shown by the line A (Fig. 9). It is only when a higher full load speed is reached (as indicated at point n_c Fig. 9) that the drop in pressure can overcome the pressure of the return spring against the stop, and then the opposing spring can act to cause assimilation by reducing the delivery amount of the pump. The resultant of the two spring forces increases owing to the increase in the drop in pneumatic pressure as shown in Fig. 8 only from a definite speed n_c which corresponds to the stop-position Ic of the left end of the controlling rod, until the maximum speed at full load n_2 is attained, when the cutting off of the fuel feed begins. The delivery amount of the pump, increasing at first with the curve A, is this assimilated to the consumption curve of the engine, as shown in Fig. 9, from the full load speed n_c onward according to the curve C''.

If now the bottom 15 of the sleeve 14 is moved to the left, the return spring can displace the left end of the controlling rod into the position Id against the opposing spring, while the return spring further expands. Accordingly at first, a

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somewhat larger injection amount is adjusted. As the speed increases, however, the vacuum can now put the diaphragm and controlling rod somewhat earlier into movement and pull them to the right, during which the opposing spring acts in an assimilatory manner. The opposing spring will now also be earlier expanded (IId), as its abutment (bottom 15) has also been displaced. Its assimilatory action thus ceases even before the maximum speed at full load is reached. The curve C''' will thus at first lie above the line A and parallel thereto, then fall, and finally again rise somewhat up to the full load maximum speed. The assimilation can thus be limited, according to the invention, to a portion of the full load speed region.

Figs. 3 and 6, previously discussed, are based on the fact that the engine would have a fuel consumption curve C, C' respectively with a falling tendency for the whole full load speed range between n_1 and n_2. In Fig. 9, the consumption curve C'' is that of a combustion engine which can combust without smoke increasing fuel amounts up to n_c, (this curve coincides from n_a to n_c with the delivery curve A of the pump), but from n_c to n_2 the consumption curve C'' falls. In this case, an alteration of the fuel delivery of the injection pump below n_c is not necessary, but only above n_c. In order to obtain an alteration between n_c and n_2 the bottom 15 of the sleeve 14a is to be adjusted as previously described so that the stop 16 does not permit movements of the control rod to the left beyond Ic. The control rod 6 will then remain in this position as long as the speeds remain below n_c, the throttle being in the open position. Thus, below n_c the injection pump delivers according to its delivery characteristic A, while from n_c up to n_2 the resultant strength X (see Fig. 8) of the springs 12, 13 is in operation and from n_2 to n_4 the strength of spring 12 alone.

In the case where the engine has a consumption characteristic shown by the dash and dotted line C''' in Fig. 9 with deviations at n_d and n_{d2}, with the same means as shown by Fig. 7, it will be possible to influence the injection pump according to curve C'''. In order to achieve this result it is only necessary to slacken the bottom 15 of the sleeve 14a so far that the control rod 6 would be stopped at Id, while in the first-mentioned adjustment the lefthand movement of the control rod was limited at Ic. In the same manner as during the previous adjustment Ic the injection pump delivered below n_c according to its delivery curve A—because the control rod does not move below n_c with the open throttle—the small vacuum below n_d—in the open position of the throttle—will not move the control rod. Therefore, below n_d the injection pump will deliver with the control rod in position Id (which corresponds to a larger fuel delivery amount) according to a deliver, curve the course of which is similar to the curve A but higher because the position Id of the control rod corresponds to a larger delivery amount than Ic. Above n_d the vacuum increases and the resultant force X in Fig. 8 determines the delivery amounts. While with the stop in the Ic position the control rod will be adjusted by the resultant force X between n_c and n_2 from Ic to II; the adjustment of the stop 16 into position Id will cause X to operate between Id and IId when the speed increases from n_d to n_{d2}, a speed lower than n_2. From the said speed n_{d2} onwards the spring 13 has fully expanded and cannot operate any longer. Only the spring 12 will still remain in operation. But the strength of spring 12 at IId (Fig. 8) is not much different from the strength at II and can, therefore, not be contracted by a vacuum which is not essentially smaller than that at n_2. For this reason, the control rod 6 keeps its position IId until the speed n_2 has been approximately reached. In position IId of the control rod the pump will deliver according to a curve which is parallel to A (between n_{d2} and n_2). Above n_2 the vacuum in the induction pipe will contract spring 12 and cut-off the fuel delivery in order to prevent the maximum speed n_2 being exceeded.

Fig. 10 represents another example of construction, in which the left hand end of the stop 16 is adjustable by a screw 18, but the bottom of sleeve 14a, which forms an abutment for one end of the spring 13, is immovable. While the screw 15 in Fig. 7 was the abutment for both the stop 16 and the spring 13 and so shifted when displaced the whole operating range of X in Fig. 8, in the present case only the left hand range of the operation of the control rod 6 is adjustable and the range which operates when the control rod 6 and the stop 16 are out of contact with one another cannot be altered. This will be seen from the following explanation.

By adjusting the screw 18 in such a manner that the right hand end of the stop 16 and the left hand end of the control rod 6 are in position If (see Figs. 10 and 11), the resultant force X of the springs 12, 13 can only be operable between n_f and n_2 (Fig. 12). Below n_f the injection pump will operate, without the position of the control rod 6 being altered, according to the curve C''' which has the same course as the delivery curve A of the pump. Above n_f the pump will deliver fuel amounts according to the dotted line in Fig. 12 between n_f and n_2. If by a different adjustment of screw 18 the control rod is permitted to reach position Ie, the control rod can follow the stop 16 until at n_e (beyond n_f) a higher fuel delivery amount is obtained. From If to Ie a further decrease of X occurs as can be seen from the dotted part of the line X in Fig. 11. At the same time the fuel delivery amount increases between n_f and n_e as can be seen from curve C'' in Fig. 12 which rises from n_f to n_e while below n_e the fuel delivery curve C'' is parallel to the injection pump delivery curve A as the vacuum in the open position of the throttle at the low engine speeds below n_e cannot displace the control rod. According to this arrangement, it is possible to adapt the delivery curve of the pump to the consumption curve of the engine to the fullest possible extent.

Fig. 13 shows another embodiment of the invention and Figs. 14 and 15 are diagrams for illustrating the operation thereof. 7 is the governor chamber, which is formed by the governor casing 4a and the membrane 5. It is connected by the pipe 9 with the induction pipe of the engine. Within the casing there is arranged a spring 12, which at one end rests upon the bottom of the casing 4a and at the other end presses a disc 19 against a stop ring 22 fixed to the casing. Stop ring 22 limits movement to the left of disc 19, movement thereof to the right being limited by stop 23. Under the pressure of the spring 12, the disc 19 forms a support for one end of a second spring 21 which at its other end bears on the diaphragm 5. In the position shown in the drawings, the spring 12 cannot direct its whole pretension on the membrane, but only with the smaller tension of the spring 21. The char-

acteristics of the springs 12 and 21 can be seen from Fig. 14. As the pretension of spring 21 is very small compared with the pretension with which the spring 12 is pressed against the disc 19, the spring 21 alone will be contracted as long as small vacuums arise in chamber 7. In this case the parts 5, 21 and 6 will move without contracting the spring 12. During such movements of the control rod 6 under the small vacuum at open throttle below maximum speed n_2, the delivery amounts of the pump—according to curve A in Fig. 15—will be reduced to amounts C in Fig. 15 which can be burned in the engine cylinders without smoke.

The spring 21 has been dimensioned so that by the small vacuum at maximum speed n_2 it will be contracted so far that the membrane 5 abuts against a tubular part 20 connected with the disc 19. The membrane will abut against the tubular member at II in Figs. 13 and 14. When the vacuum further increases upon an increase of speed above maximum speed n_2, the membrane 5 will be drawn so much towards the right that now the pretension of spring 12 will be overcome, taking with it the control rod 6 and cutting-off the fuel delivery. From the foregoing it will be seen that, as in the previous examples, the example of construction according to Figs. 13, 14, 15 also has two stages of operation, one low vacuum stage in which a relatively stiff spring 21 of small pretension is opposed to the small vacuum occurring at open throttle below maximum speed and adjusts the fuel delivery of the pump in such a manner that the engine produces at each full load speed the maximum possible power without smoke, and another high vacuum stage in which a spring 12 of high pretension but of relatively weak chaacteristic (small alteration of strength in the large stroke between II to III) is operable to cut-off the fuel delivery above maximum speed.

We declare that what we claim is:

1. In an internal combustion engine of the injection type having an air intake manifold and a throttle valve therein, the combination comprising adjustable fuel injection means, a displaceable control member connected to said fuel injection means for controlling the quantity of fuel supplied to said engine, means housing said control member and defining with the two sides thereof two chambers, one on each side of said control member, resilient means for applying a force to one side of said control member, means connecting one of said chambers to the atmosphere, means connecting the other of said chambers to the intake manifold on the engine side of the throttle valve whereby the pressure variations in the intake manifold will function to displace said control member by differential pressure acting thereon in opposition to said resilient force to adjust the fuel injection means, and resilient means operative only when said control member reaches a position for adjustment of fuel supply within the full load range of said engine and at speeds below maximum and then automatically operating to apply a resisting force to said control member in opposition to the force applied by said first-mentioned force-applying means, the resultant force exerted on said control member by said opposed force-applying means being so weak that said control member is sensitive to and movable by the small pressure differences which occur in said chambers when the engine runs with wide open throttle under full load at speeds lower than maximum speed.

2. In an internal combustion engine of the liquid fuel injection type having an air intake pipe and a throttle valve therein manually operable at will, a fuel supply system and control means therefor adapted to control the speed of the engine, said fuel supply system and control means therefor comprising a fuel injection pump driven by said engine, a displaceable fuel quantity control member, means mounting said control member for movement in opposite directions, said control member being movable in one of said directions by difference in fluid pressures on its opposite faces, means exposing one face of said control member to atmosphere and its opposite face to the pressure in said intake pipe on the engine side of said throttle valve, means operated by said control member to reduce the fuel delivery of said pump in accordance with the displacement of said control member in said one direction, resilient means operable to apply a resisting force to said control member in opposition to the effect of said differential pressure, and auxiliary resilient means inoperative until said control member reaches a position for adjustment of the fuel delivery of said pump within the full load range of said engine at speeds below maximum and with wide open throttle and then automatically operating to apply a resisting force to yieldingly resist movement of said control member in the fuel-increasing direction, the resultant force exerted on said control member by the two resilient means being so weak that said control member is sensitive to and movable by the small fluid pressure differences to which said control member is subjected when the engine runs with wide open throttle under full load at speeds lower than maximum speed.

3. Apparatus as set out in claim 2 including means for adjusting the tension of said auxiliary resilient means.

4. In an internal combustion engine of the liquid fuel injection type having an air intake pipe and a throttle valve therein manually operable at will, a fuel supply system and control means therefor adapted to control the speed of the engine, said fuel supply system and control means therefor comprising a fuel injection pump driven by said engine, a displaceable control member, means mounting said control member for movement in opposite directions, said control member being movable in one of said directions by difference in fluid pressures on its opposite faces, means exposing one face of said control member to atmosphere and its opposite face to the pressure in said intake pipe on the engine side of said throttle valve, means operated by said control member to reduce the fuel delivery of said pump in accordance with the displacement of said control member in said one direction, resilient means operable to apply a resisting force to said control member in opposition to the effect of said differential pressure, and a resilient device located in the path of movement of said control member so as to engage said control member as it reaches a position for fuel delivery control for full load running of the engine at speeds below maximum and thereby to yieldingly resist movement of said control member in the fuel-increasing direction, the resultant force exerted on said control member by said resilient means and said resilient device being so weak that said control member is sensitive to and movable by the small fluid pressure differences to which said control member is subjected when the engine runs with wide open throttle under full load at speeds lower than maximum speed.

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5. Apparatus as set out in claim 4 including manual means for temporarily rendering said resilient device inoperative during starting of the engine.

6. Apparatus as set out in claim 4 including means for varying the end position of said resilient device in the direction of increasing the fuel amount.

7. A fuel supply system for internal combustion engines provided with an air intake pipe and a throttle valve therein, comprising a casing connected to said pipe at a point therein on the engine side of said throttle valve, a control member in said casing displaceable in opposite directions through a predetermined range of displacement and in one of said directions under the influence of reduced pressure, transmitted from said intake pipe to said casing, a fuel injection pump having a delivery curve which rises relative to the consumption curve of the engine as the speed increases, means connected to said control member and to said fuel pump operative to reduce the delivery of said pump in accordance with the extent of displacement of said control member in said one direction, resilient means operable to apply a resisting force to said control member in opposition to the effect of said reduced pressure, additional resilient means operable to apply a resisting force opposed to said first mentioned resilient means to said control member, said additional resilient means being ineffective until said control member reaches a position of fuel delivery control for full load running of the engine at speeds below maximum and both resilient means cooperating to apply a resultant resisting force to said control member in opposition to the effect of said reduced pressure which is weaker in the position of said control member for adjustment of the fuel delivery of said pump within the full load range of said engine at speeds below maximum and with wide open throttle than at speeds higher than maximum, the resultant force exerted on said control member by said resilient means being so weak that said control member is sensitive to and movable by the small fluid pressure differences to which said control member is subjected when the engine runs with wide open throttle under full load at speeds lower than maximum speed.

8. A fuel supply system for internal combustion engines provided with an air intake pipe and a throttle valve therein, comprising a casing connected to said pipe at a point therein on the engine side of said throttle valve, a control member in said casing and displaceable in opposite directions through a predetermined range of displacement and in one of said directions under the influence of reduced pressure, transmitted from said intake pipe to said casing, a fuel injection pump having a delivery curve which rises relative to the consumption curve of the engine as the speed increases, means connected to said control member and to said fuel pump operative to reduce the delivery of said pump in accordance with the extent of displacement of said control member in said one direction, resilient means operable to apply a resisting force to said control member in opposition to the effect of said reduced pressure, said resilient means comprising a relatively weak spring and an opposing relatively strong spring, said weak spring operating alone during a portion of the stroke of said control member and both springs cooperating to apply a resultant resisting force to said control member in opposition to the effect of said reduced pressure when the control member reaches a position for adjustment of fuel supply within the full load range of said engine at speeds below maximum, said resultant force being weaker than the force exerted by said weak spring alone and being so weak that said control member is sensitive to and movable by the small fluid pressure differences to which said control member is subjected when the engine runs with wide open throttle under full load at speeds lower than maximum speed.

9. A fuel supply system for internal combustion engines provided with an air intake pipe and a throttle valve therein, comprising a casing connected to said pipe at a point therein on the engine side of said throttle valve, a control member in said casing and displaceable in opposite directions through a predetermined range of displacement and in one of said directions under the influence of reduced pressure, transmitted from said intake pipe to said casing, a fuel injection pump having a delivery curve which rises relative to the consumption curve of the engine as the speed increases, means connected to said control member and to said fuel pump operative to reduce the delivery of said pump in accordance with the extent of displacement of said control member in said one direction, a relatively strong spring of substantially no pretension and a pretensioned but relatively weak spring arranged in series to apply a resisting force to said control member in opposition to the effect of said reduced pressure, and stop means between said springs to limit the extension of said weak spring and hold it under the desired pretension whereby essentially only the force exerted by said relatively strong spring is exerted on said control member when said control member reaches a position for adjustment of fuel supply within the full load range of said engine at speeds below maximum, the force exerted on said control member in opposition to the effect of said reduced pressure in the full load range of said engine being so weak that said control member is sensitive to and movable by the small fluid pressure differences to which said control member is subjected when the engins runs with wide open throttle under full load at speeds less than maximum speed.

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