Oct. 21, 1930. R. F. ENSIGN 1,779,374

FUEL SUPPLY SYSTEM FOR INTERNAL COMBUSTION ENGINES

Filed Nov. 13, 1928 2 Sheets-Sheet 1

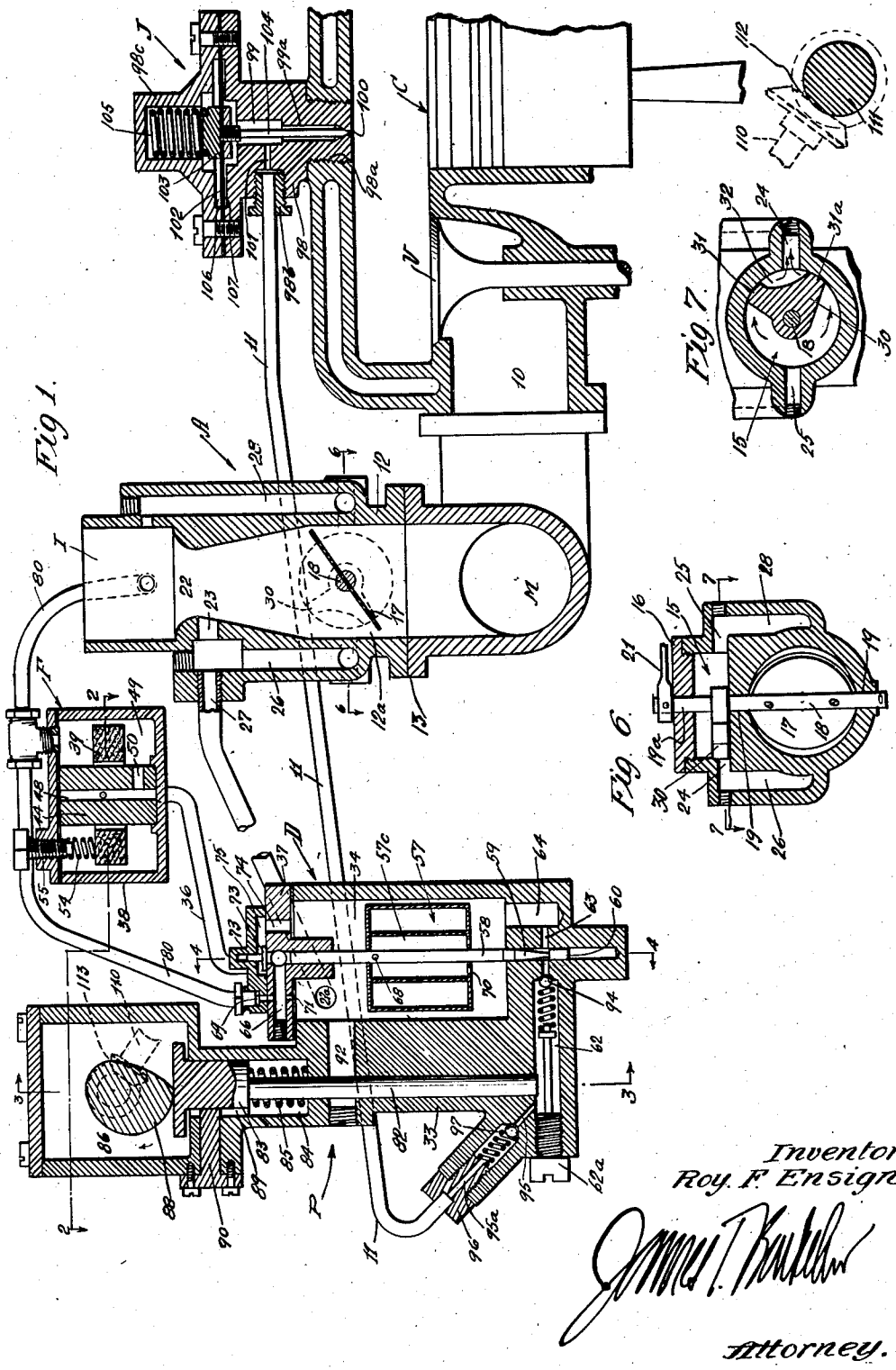


Fig. 1.

Fig. 7.

Fig. 6.

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Filed Nov. 13, 1928 2 Sheets-Sheet 2

Fig. 2.

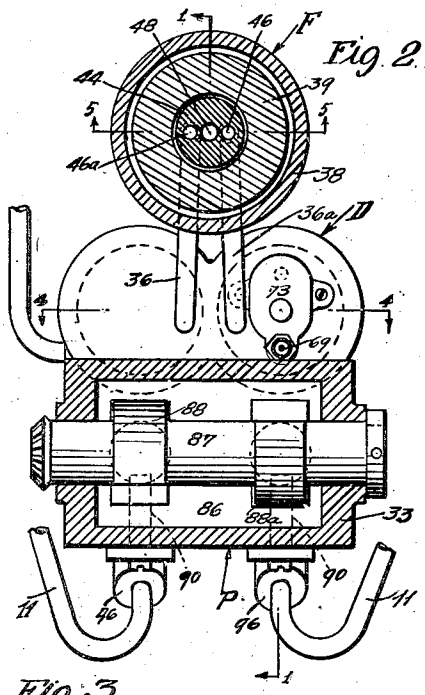


Fig. 5.

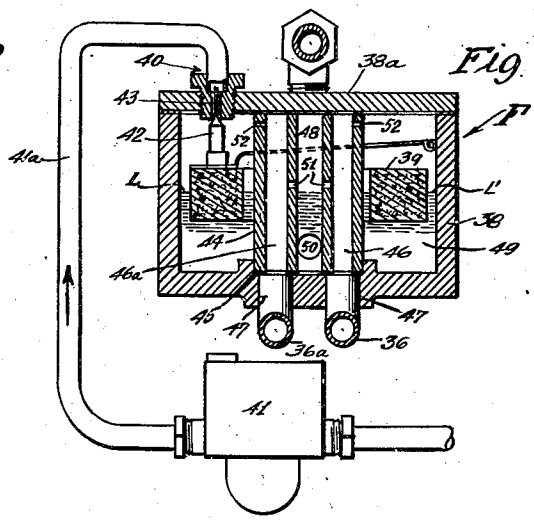


Fig. 3.

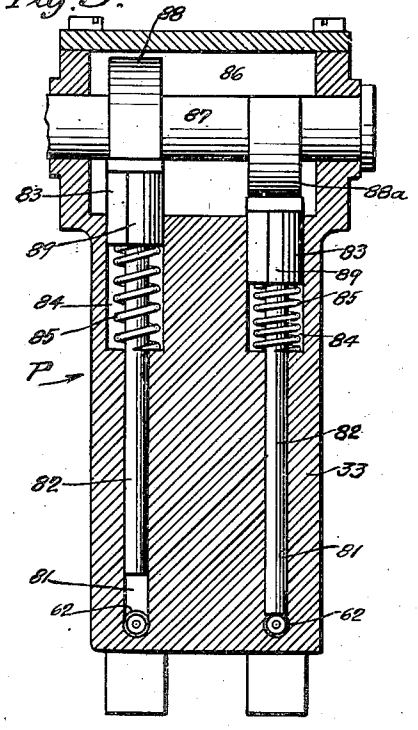
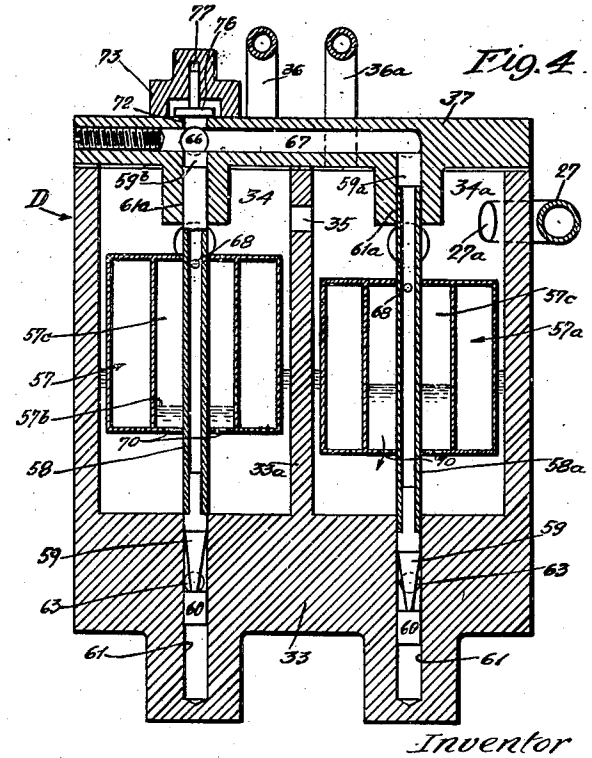


Fig. 4.



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UNITED STATES PATENT OFFICE

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FUEL-SUPPLY SYSTEM FOR INTERNAL-COMBUSTION ENGINES

Application filed November 13, 1928. Serial No. 319,135.

This invention relates generally to systems for supplying fuel to internal combustion engines, and is more particularly concerned with liquid fuel injection systems for use in engines of this general type.

A primary purpose of the invention is to provide a fuel injection system adaptable for use in various types of internal combustion engines, and one which enables an equipped engine to operate with maximum power and efficiency. Superior engine performance is brought about by use of the present system mainly because of the particular method of metering fuel to be delivered to the engine in accordance with its varying requirements, and also the particular means employed for pumping the metered fuel to the engine.

Although fuel injection systems are at present employed for supplying liquid fuel direct to the cylinders of internal combustion engines, these systems usually depend upon some form of fuel pumping device actuated by the engine, and often governor-controlled, and delivering fuel from a suitable supply source in quantity according to the speed of the engine. Because of the inherent mechanical characteristics of such pumping devices it is practically impossible to deliver the exact or nearly exact amount of fuel to the engine for all conditions of operation, since it is impractical to attempt to operate a pumping device in a manner such as to compensate for the various factors which enter into the determination of the ideal fuel composition under all operating conditions.

Proper metering of fuel for delivery to the engine has been accomplished most satisfactorily perhaps by carbureter systems, whereby said metering is controlled in accordance with the quantities of air taken into the engine. Also greater refinements in regulating the amount of feed are possible by controlling the fuel delivery by differential air pressures which, in turn, may be controlled in accordance with the main air intake to the engine, the position of the fuel or air throttle, or numerous other ways known to those familiar with the art. However, the usual carbureter systems are not adapted for use in engines operating under unusually high compression due to the fact that provision is lacking for properly introducing the metered fuel into the engine.

More specifically, in order for an engine to operate under high compression, the fuel generally is introduced during the piston compression stroke of the engine, and during a portion of the firing stroke. Obviously, in carbureter systems intake of fuel to the engine can take place only during the piston suction stroke.

By means of the present invention I have provided an injection system whereby the fuel may be properly metered in accordance with the main air supply taken into the engine, and in a manner comparable in its advantages with carbureter systems. In addition the liquid fuel so metered is discharged under pressure into the engine separately from the main feed of air thereto and in a manner such as to permit the engine to operate under exceedingly high compression.

The present system has certain features of similarity to that system comprising the subject matter of my copending application entitled Fuel injection system, Ser. No. 311,512, filed Oct. 10, 1928, in which both fuel and air are metered in accordance with the main feed of air to the engine and delivered thereto separate from said main feed. The present system, however, differs from the referred system in numerous respects, and mainly in that it is adapted to inject the fuel into the engine unmixed with air, and to effect the metering and delivery of liquid fuel to the pump in a manner different from that followed in the system for supplying both fuel and air.

The various features of the invention as well as its method of operation will be most clearly and readily understood from the following detailed description, reference being had throughout the description to the annexed drawings, in which:

Fig. 1 is a detailed view of the fuel injection system applied to an internal combustion engine, the various portions of the system being shown in section; the section through the pump and fuel chambers being taken on line 1—1 of Fig. 2;

Fig. 2 is a plan view of certain parts of the system taken on line 2—2 of Fig. 1; a portion of the pump being shown in section;

Fig. 3 is a vertical section through the pump taken on line 3—3 of Fig. 1;

Fig. 4 is a vertical section on line 4—4 of Fig. 1;

Fig. 5 is a section on line 5—5 of Fig. 2;

Fig. 6 is a horizontal section on line 6—6 of Fig. 1; and

Fig. 7 is a section on line 7—7 of Fig. 6.

The general arrangement and purposes of the various elements of the present system may be seen most readily by inspection of Fig. 1. An air regulating or throttling device, generally indicated at A, is provided for controlling the flow of air through the intake passage I into the engine manifold M, the flow of air from the manifold to the engine cylinder C taking place through passages 10, one passage each being provided for each cylinder. Intermittent flow of air from passage 10 into the engine cylinder is effected by means of engine valve V. As will later be seen, the air throttling device A serves, in addition to controlling the supply of air to engine, to create depression in the float controlled depression chamber, generally indicated at D, in accordance with the flow of intake air through the air control device.

By virtue of the depression existing in chamber D, fuel from the float-controlled supply reservoir F is drawn into the depression chamber in accordance with the amount of depression existing therein, this depression being modified as will later be described. The delivery of fuel to the pump P is made by way of the depression chambers D, the discharge of fuel from the pump to the engine cylinders taking place through the supply lines 11, there being one supply line for each cylinder. Mounted immediately above each cylinder and in the feed supply line is an injector valve generally indicated at J, the purpose of this valve being, generally speaking, to spray fuel into the cylinders during the intervals of delivery by the pump. It may be noted at this point, that the flow of air to the engine is regulated in accordance with its varying requirements, delivery of fuel to the pump being metered, as mentioned, in accordance with the flow of intake air, and liquid fuel thus metered is delivered to the engine entirely separate from the air feed thereto.

It is to be understood that the invention is applicable for use with an engine of any number of cylinders, and that the present showing of the application of the system to an engine having two cylinders is in no way to be considered limitative on the invention, for adapting the system to use with a larger engine involves essentially mere duplication of parts; and the manner in which said duplication may be effected will be made apparent to those familiar with the art, during the following description.

Referring particularly to the air throttle device A; a tube-shaped body portion 12 is joined to the engine manifold M as at 13, and is open at its upper end to provide an air inlet I. As illustrated in Fig. 6, the body portion 12 is shaped at its side to provide a separate auxiliary circular valve chamber 15, closed at its outer end by means of plug 16. The body has a cylindrical bore 12^a within which is a throttle valve 17 mounted upon a horizontally extending shaft 18, the latter being journaled in the body at 19, and in plug 16 at 19^a as shown. The throttle valve 17 is actuated to control the flow of air through bore 12^a by suitable connection (not shown) with arm 21, mounted on the end of shaft 18. Intermediate the upper and lower ends of bore 12^a is a comparatively restricted portion or venturi 22, into the throat of which a passage 23 opens, the venturi serving in the usual manner to create depression through said passage.

Opening into the sides of the auxiliary valve chamber 15 is a pair of oppositely disposed ports 24 and 25, the former communicating through passage or conduit 26, with the Venturi passage 23 and depression passage 27 leading to chamber D, and port 25 communicating with the air inlet I through passage 28 extending outside the venturi. An auxiliary valve 30 is mounted on shaft 18 in chamber 15, and is adapted, upon rotation of the shaft to control the flow of air from passage 28 through the auxiliary valve chamber and into passage 26. It is seen that the auxiliary valve is shaped to provide arms 31 and 31^a, the ends of which slidably engage the cylindrical wall of chamber, that portion of the valve between the arms being cut away as at 32 to permit the flow of air, as indicated by the arrows in Fig. 7, from port 25 to port 24 in the valve position shown.

It may be noted at this time that the illustrated position of valve 30 corresponds to an intermediate position of adjustment of throttle valve 17, and that by moving the throttle valve either to its open or closed position, port 24 is caused to be closed by the auxiliary valve ends 31 and 31^a respectively. Thus, during intermediate adjustments of the throttle valve, by-pass of air from the inlet I to the depression line 27 is effected through passages 28 and 26 and the auxiliary valve chamber. However, at wide open and closed positions of the throttle valve, the by-pass is closed and the full depression occurring at the throat of the venturi 22 is transmitted directly through line 27 to the depression float chamber D. As will later be seen, the purpose of the auxiliary valve arrangement is to modify the fuel metering, and it may be stated that other devices having simi-

lar operating characteristics and purposes may be used in the invention.

Although a single depression chamber may be provided for supplying fuel to the pump, that is, a single depression chamber for supplying fuel for all of the engine cylinders and having suitable communication with the pump chambers, I have found it preferable to provide, as shown in Fig. 4, a depression float chamber D for each engine cylinder, these chambers preferably being formed in the pump body 33. The depression line 27 opens at 27ª into space 34ª above the liquid level in one of the chambers, communication being established between said space and space 34 above the liquid level in the second depression chamber by way of opening 35 in wall 33ª separating the chambers. A pair of fuel delivery lines 36 and 36ª extend through the depression chamber cover 37 to open into spaces 34 and 34ª respectively, and extend upward to communicate with the fuel supply reservoir F.

As shown in Fig. 5, the supply reservoir has a body 38 containing a float 39, the intake of fuel delivered by the fuel pump 41 through line 41ª into the chamber being regulated by the float controlled valve 40 mounted on the body cover 38ª. The feed pump 41 is adapted to be operated by suitable driving connection (not shown) with the engine. Although any suitable form of float controlled inlet valve may be employed, I have shown as typical a float-actuated needle valve 42 adapted to regulate the flow of fuel into the reservoir through the valve opening 43.

A fluid passage block 44 is confined centrally within the body 38 between cover 38ª and the bottom of the body as at 45. Block 44 is drilled vertically to provide oppositely disposed bores 46 and 46ª communicating respectively with fuel conduits 36 and 36ª which extend through the reservoir bottom as at 47. Between bores 46 and 46ª is a third vertical bore 48 communicating near its lower end with the reservoir fuel chamber 49 by way of passage 50, and thus liquid in the fuel chamber is permitted to rise in bore 48 to its normal level L—L′ in the fuel chamber. Bores 46 and 46ª communicate with bore 48 by way of orifices 51 located slightly above the normal liquid level L—L′. Suitable bleeder openings 52 may be provided between bores 46 and 46ª and the fuel chamber 49.

It will be apparent that depression in line 27, brought about by the action of the venturi, is transmitted to lines 36 and 36ª and bores 46 and 46ª by way of spacers 34 and 34ª above the liquid levels in the depression chambers, the depression thus brought about in bores 46 and 46ª being transmitted to the inner bore 48 by way of orifices 51, and fuel therein is caused to rise by virtue of said depression and to discharge through the orifices into lines 36 and 36ª. It will be understood, of course, that the amount of fuel thus delivered to the depression chambers by way of orifices 51 is dependent upon the amount of depression in said chambers which depression is brought about in accordance with the flow of air through the venturi.

In order to facilitate the delivery of fuel from the fuel supply reservoir to the depression chambers during idling speed operation of the engine, I have provided adjustable means for controlling the position of the float with respect to the liquid level, with the result that the location of the liquid level with respect to orifices 51 simultaneously becomes regulated. This means of adjustment consists in a comparatively weak spring 54 (see Fig. 1) confined between the float 39 and screw 55 threaded in the cover of the chamber. Spring 54 is of such strength that when the float is in its normal or uppermost position, it becomes submerged within the liquid slightly below its normal floating depth, with the result that fuel in bore 48 is caused to rise to a point near the orifices 51, and at such point that the slightest depression acting through the orifices will cause the discharge of fuel therefrom into the depression float chamber. Should it be desired to provide for a still greater supply of fuel under conditions of idling speed operation the float may be submerged to an extent such that the fuel may be caused to cover the orifices, and thereby provide a liquid head for effecting delivery in addition to the depression. It will be understood, of course, that a quantity of fuel in the reservoir sufficient to cover the orifices would be had only during operation of the feed pump 41, and therefore during operation of the engine, and thus no continuous overflow through the orifices would be had when the engine is idle. When float 39 becomes substantially lowered from its normal position, the action thereupon by spring 54 becomes relatively ineffective, and the float assumes its normal position relative to the liquid level. In other words the spring may be capable of but limited expansion from its compressed condition when the float is in its upper position, so that it will exert relatively little or no downward thrust on the float as the latter becomes lowered, or the spring may be such that it is capable of submerging the float abnormally only when it is in compressed condition, and that as the liquid level lowers, the buoyancy of the float will overcome the thrust of the spring and the float will assume its normal submergence. Therefore, the effect of the spring is to cause the float to become submerged below its normal floating level during idling speed operation, thereby causing the liquid level in the chamber to become abnormally raised during this period, and to permit the float to assume its normal po-

sition, and therefore the liquid to resume its normal level, during higher speed operations.

Within the depression chamber is a pair of valve actuating floats 57 and 57ª which are mounted upon valve stems 58 and 58ª, respectively, these stems being confined at their upper ends in bore 61ª in the chamber cover. On the lower ends of the stems are liquid control valves 59 adapted to move vertically with the floats and in bores 61 formed in the body 33. Communication is established between each pump chamber 62 and the interior of each depression chamber, by means of bore 63, intersecting the valve bore 61 as shown in Fig. 1, and vertical wells or bores 64 into which bore 63 opens. Thus, by virtue of its vertical movement brought about by changes in the buoyancy in the float or by changes in the liquid level in the chamber, the liquid control valve serves to regulate the feed of fuel from the depression chamber through bores 64 and 63 into the pump chamber. An extension 60 is provided on the lower end of each valve and is proportioned so as to fit the bore wall of bore 61 more or less closely, the purpose of this extension being to eliminate vibration of the float and valves due to engine vibration or other causes.

The tubular valve stems 58 and 58ª open at their upper ends into bores 59ª and 59ᵇ, the former communicating with a horizontal bore 66 formed in the cover and plugged at its outer end. A second horizontal bore 67 extends between bores 59ª and 59ᵇ and serves to establish communication between bores 66 and the valve stem bores. An air inlet 69 opens into bore 66, and although this opening may communicate directly with the atmosphere, I prefer that it communicate with air inlet I through line 80 as will later be described. Openings 68 are formed one each in each of the valve stems to establish communication between the stem bores and the inner chambers 57ᶜ of the float 57 and 57ª. Thus air is taken into the float chamber by way of opening 69, bore 66, (and 67 for float 57ª) the tubular valve stems and openings 68.

Openings 70 are provided in the bottom of the float in order to permit liquid from the depression chamber to flow into and out of the interior float chambers 57ᶜ according to the relative pressure conditions therein. Bore 66 communicates with chamber 34 through a restricted passage 71 the effect of this passage being to cause more or less depression in bore 66 according to the size of opening 71, this size being determined, in turn, by the particular operating conditions it is desired to maintain. Thus it is seen that with a comparatively greater amount of pressure existing on top the liquid contained within the float, due to the admission of air thereto as described, and comparatively less pressure existing in the depression chamber due to depression being created within the chamber, liquid within the float is caused to flow therefrom through openings 70 by virtue of the pressure differential. As a result each float is caused to rise in the liquid fuel and to carry with it the liquid control valve on the lower end of the stem.

It is desirable that means be provided for preventing all the fuel contained within the float from draining through opening 70 into the depression chamber in the event high depression is suddenly applied to that chamber. I have therefore, provided a cap 73, mounted on the chamber cover and covering bore 72 and a second bore 74 opening into space 34 (see Fig. 1) the cap being shaped to provide a space 75 for establishing communication between the bores mentioned. A valve 76 having its stem confined within the cap bores 77 normally rests upon cover 37 and closes bore 72 to the space 75. Upon sudden application of depression to chamber 34 causing float 57 to rise to its uppermost position, the pressure differential on the top and bottom faces of the air valve becomes sufficient to cause the valve to raise from its seat, and to permit air taken into bore 66 through opening 69, to flow into space 75 and thence into chamber 34. The depression then is limited to an extent such that the discharge of liquid out of the float by way of opening 70 is discontinued before the float becomes entirely depleted of its liquid content. It is unnecessary to provide a cap and valve arrangement as described for depression chamber 34ª, since both chambers are interconnected by way of opening 35, and whatever modification in depression is applied to chamber 34 will instantly become effective in chamber 34ª.

The purpose of the described operation of floats 57 and 57ª will be apparent from consideration of the operation of those parts of the system described in detail. It may be noted at this point that normally, the positions of the floats are substantially the same, their positions being altered as in Fig. 4 for purposes of illustration only. Assuming first that the position of the air throttle valve 17 is regulated for idling speed operation of the motor, the depression occurring at the throat of the venturi is transmitted through line 27 to the depression chambers and then through conduits 36 and 36ª to the fuel supply reservoir F from which fuel is taken into said conduits as previously described. The amount of fuel in the depression chambers, delivered from the supply reservoir, normally determines the position of the floats, and therefore the position of valve 59 with respect to fluid passage 63 leading into the pump chamber.

Increasing depression at the throat of the venturi, occasioned by additional intake of

air to the engine, results in increased delivery of fuel from reservoir F to the depression chambers, with the resultant raising of the floats therein with valves 59 to permit the increased amounts of fuel delivered to be taken into the pump chambers. However, it is readily apparent that should it be desired to accelerate the engine from idling speed to full speed, the fuel to provide for such increased speed must instantly be available for pumping into the engine cylinders, and also that valves 59 must instantly be positioned to permit the flow of that amount of fuel to the pump. The procedure of drawing fuel from the reservoir F into the depression chamber and thereby causing valve 59 to rise to permit greater intake of fuel to the pump, normally would be too slow to effect immediate fuel delivery to the pump as soon as the throttle valve 17 is swung to its wide open position.

Instead, therefore, of depending upon the increase in fuel delivery to the depression chamber to position the float and valve when acceleration is required, I have, by virtue of the particular float and air valve structure described, enabled the float to be positioned in accordance with the depression brought about within the depression chambers, said depression in turn, being in proportion to the amount of fuel required by the pump. When depression is applied to chambers 34 and 34ª by way of line 27, it is clear that the pressure upon the liquid body 57ᵇ in each of the floats is comparatively greater due to the connection of the interior of the floats with bore 66 and opening 69 as described. Thereupon liquid from within the float interior chamber 57ᶜ flows through opening 70 into the depression chamber as indicated by arrow A in Fig. 4, with the result that the float is caused to raise and carry with it the liquid control valve 59. The amount of liquid displaced from the float is, of course, dependent upon the amount of the depression, and in addition, the extent to which the comparatively greater pressure in bore 66 and above the liquid level in the float is modified by taking air from bore 66 through opening 71 into the depression chamber as previously described.

Now in order to prevent a great amount of depression suddenly applied to the chamber, from causing the complete removal of fuel from the float, I have provided the air valve arrangement described in order that at a predetermined pressure differential on the upper and under faces of the air valve, and therefore corresponding to a predetermined point in the raising of the float, the depression is modified to such an extent that further displacement of fuel from the float is prevented. Thus, assuming that such depression is suddenly applied to chamber 34, the air valve 76 raises to permit the passage of air from bore 66 into space 75 and thence from bore 74 into the depression chamber. At this point, there is comparatively free access of air from bore 66 through the valve port 72 into the depression chamber and as a result, the difference in depression between chamber 34 and the float chamber 57ᶜ becomes limited to such an extent that further discharge of liquid from the float chamber is prevented. Thus while the air throttle valve is in open position and the engine is running at high speed, the air valve 76 may be continuously open to permit the required amount of air to flow into the chambers to limit the depression therein. Inasmuch as the interiors of both floats 57 and 57ª are in communication at all times, as well as the depression chamber 34 and 34ª by way of opening 35, it is readily seen that movement of floats 57ª is accompanied by simultaneous and corresponding movement of the other float and therefore it is unnecessary to provide a second by-pass air valve arrangement for chamber 34ª.

Further modifications of the depression existing within the depression float chambers may be effected by use of the auxiliary air control valve 30 operating in conjunction with the throttle valve 17. In numerous instances it is desirable that the combustible mixture supplied to the engine be relatively rich at idling and slow speed, and that the mixture be relatively lean at intermediate speed. Thus at closed and opened positions of the throttle valve 17, the arms 31ª and 31, respectively, of the auxiliary valve serve to close the opening 24 (see Fig. 7) to the end that the full depression at the front of the venturi is transmitted to the depression chamber to effect the delivery of fuel from these chambers to the pump as described. At intermediate speeds, conditions prevail according to the illustrated positions of the auxiliary valve, that is, air is by-passed from the inlet I to the depression chamber by way of passages 28 and 26 causing modification of the depression, and corresponding modification of the fuel delivered to the pump in proportion to the main supply of air to the engine.

From the described portions of the system for supplying fuel to the pump for delivery to the engine, it will be seen that the metering of fuel in accordance with the requirements of the engines takes place initially in the fuel supply chamber F, it being considered that the amount of fuel delivered from the supply chamber to the depression chamber is at all times the amount required by the engine. The float control valve in the depression chamber then may be considered as secondary means for metering fuel from the depression chamber to the pump. Obviously the delivery of fuel from the depression chamber to the pump must be in accordance with the delivery from the supply chamber

to the depression chamber. The float and valve arrangement tends automatically to bring about the proper delivery to the pump in that, for instance, should the engine speed decrease and the amount of fuel delivered to the depression chamber correspondingly decrease, the float controlled valves would gradually lower in a closing direction due to the lowering of the fuel level in the chambers. And the resultant liquid level in the chambers would be that at which the amount of fuel being delivered to the pump would equal that being put into the chambers from the supply reservoir. The converse of this operation would take place should the engine speed increase instead of decrease.

It may be stated at this point, that I do not restrict the invention to the use of the particular type of fuel supply reservoir illustrated. In the operation of certain types of engines, for instance Diesel engines, wherein constant intake of air to the engine is maintained at all times, it may be desired to effect the delivery of fuel to the depression chamber by means other than the present supply chamber, as in such operation where it is found advantageous to meter the fuel independently of the air intake by direct delivery from an engine controlled fuel pump, or by similar means.

Communication is established between the air inlet I and the space above the liquid level in the fuel reservoir F and also the air inlet opening 69 by means of a compensating line 80. By the provision of this line it will be seen that an air filter or any other attachment be applied to inlet I which would attempt to cause a depression in the inlet below atmospheric pressure, that depression is compensated in that constant relative pressure conditions are maintained between the reservoir, opening 69, and the air inlet I regardless of obstructions to flow of the air before it enters the inlet. It is an additional advantage that vapors from the fuel reservoir are vented to the air inlet instead of to the atmosphere.

A pair of vertical plunger bores 81 are provided in the pump body 33, these bores containing the pump plungers 82. The plungers have enlarged heads 83 within correspondingly enlarged bores 84, coaxial with the plunger bores 81, the plungers being constantly urged upwardly by springs 85 confined between the plunger heads and the lower end of bores 84. The upper portion of the pump body is shaped to provide a box 86 in the ends of which a horizontally extending cam shaft 87 is journaled. This shaft carries cams 88 and 88ª, the relative positions of the cams being determined in accordance with the timing given the plungers for their compression strokes.

The plunger heads 83 each are provided with vertical groove 89 in which a pin 90 terminates, the purpose of the pin and groove arrangement being to prevent turning of the plunger during operation. Horizontally extending bores 92, communicating with the plunger bores and the depression chambers, are provided in order that fuel leaking upward around the plungers during their downward compression strokes, may drain through bores 92 back into the depression chambers.

Each plunger bore opens at its bottom into a horizontally extending pump chamber 62, closed at its outer end by means of plugs 62ª and communicating at its inner end with the fuel passage bore 63. The size of chamber 62 preferably is such that it will contain a volume of fuel greater than is required to be delivered at any time by the pump. Reverse flow of fuel from chamber 62 into the intake passage 63 is prevented by check valve 94 in the inner end of the chamber. Discharge from chamber 62 into the fuel line 11 is effected by way of passages 95 and 95ª in the pump body and in bushing 96, respectively, the fuel line terminating in the latter. A second check valve 97 serves to prevent the flow of fuel from line 11 back into the pump chamber.

In the operation of the pump, it is seen that as a plunger 82 is urged upwardly on its suction stroke by means of spring 85, fuel is drawn from the depression chamber into pump chamber 62 during this operation in amount according to the position of valve 59. The plunger being urged downwardly on its compression stroke by cam 88, valve 94 closes and check valve 97 opens to permit fuel to discharge into line 11.

The injector valve J is mounted upon the engine head above cylinder C and, as will later be seen, serves to discharge fuel under pressure from line 11 into the cylinder. It will be understood that the illustrated type of injector valve is merely typical of numerous devices of this general nature that may be used for injecting the liquid fuel into the cylinders, and therefore the invention is not to be considered as limited to the use of this particular form of injector valve. The valve is provided with a body 98 threaded into the engine head at 98ª, there being formed in the body a pair of vertically extending coaxial bores 99 and 99ª, the latter terminating at its lower end in an orifice 100. The injector valve body has a horizontally extending bore 101 communicating at its inner end with bore 99 and at its outer end with the fuel supply line 11 which terminates within bushing 98ᵇ. A flexible diaphragm 102 is confined between the cover 98ᶜ of the injector valve and its body 98, a head 103 being centrally mounted on the diaphragm. Needle valve 104 is threaded into the lower end of head 103 and depends therefrom through bores 99 and 99ª to seat in the orifice 100. The head and therefore the needle valve are urged downward by

means of springs 105 confined between the head and body cover 98c. It will be noted that the diaphragm is spaced from the body and cover at 106 and 107 respectively, and therefore is adapted to yield upwardly when the fuel pressure is applied to its lower face, to permit needle valve 104 to rise and similarly to yield against the downward thrust of spring 105 when said fuel pressure is released to permit the needle valve to seat.

In considering the operation of the pump in conjunction with the injector valve it will be noted that upon downward movement of the plunger upon its compression stroke, the charge in chamber 62 is compressed causing check valve 97 to open, and fuel to be discharged under pressure into line 11. Since this line is filled with liquid fuel, practically simultaneous with the opening of check valve 97, the pressure developed in line 11 acting upon diaphragm 102 is sufficient to raise the needle valve 104 from its seat and to permit fuel to be discharged through orifice 100 into the engine cylinder. When the pump plunger has reached the end of its compression stroke, the pressure on the under side of the diaphragm becomes insufficient to counteract the thrust of spring 105, and the needle valve 99 therefore is returned to its seating position to close the intake of fuel to the cylinder.

The cam shaft 87 may be driven by suitable connection with the engine, the drive being typically illustrated by shaft 110 geared to the engine crank shaft 111 at 112, and to the cam shaft at 113. The ratio of the speed of the cam shaft to that of the engine crank shaft is predetermined in accordance with the particular type of engine used. That is, injection of fuel into the engine may be brought about during practically any predetermined interval of the piston strokes by timing the rotation of the cam shaft relative to the engine crank shaft to cause the pump plungers to deliver during the proper intervals.

Because of the fact that the fuel may be discharged into the engine cylinders under practically any desired pressure, and since the period of discharge may be predetermined to take place during any interval of the engine piston stroke, the engine may be operated under extremely high compression. More specifically, fuel may be injected into the cylinder during any interval of the piston suction and/or compression stroke, and in addition, the injection may be continued into a portion of the firing stroke.

Reviewing generally the operation of the system, it will be noted first that the fuel delivered to the pump or discharged to the engine at any one time is determined in quantity by the air requirements of the engine as determined by the flow through the air regulating device A. The metering of fuel in direct proportion to the amount of intake air is, of course, modified by the action of the auxiliary air controlled valve which, in turn, is dependent upon the position of the throttle, as described. Then, in accordance with the flow through the air controlled device, fuel is delivered from the reservoir F to the depression chamber wherein it is held, along with an auxiliary supply, for immediate delivery to the pump and thence to the engine in direct accordance with the requirements of the engine. Finally, by accordingly timing the pump and injector valve with the engine, the latter may be permitted to operate under practically any compression.

I claim:

1. In a charge feeding system for internal combustion engines, means for delivering fuel to a pump supply chamber in amounts according to varying requirements of the engine, means for pumping fuel from said chamber to the engine independently of the air intake, and means for controlling the amount of fuel supplied to the pump from the chamber in accordance with the amount of fuel delivered to said chamber.

2. In a charge feeding system for internal combustion engines, means for metering and delivering fuel to a pump supply chamber in accordance with the air intake of the engine, means for pumping fuel from said chamber to the engine independently of the air intake, and means for controlling the amount of fuel supplied to the pump from the chamber in accordance with the amount of fuel delivered to said chamber.

3. In a charge feeding system for internal combustion engines, a pump supply chamber, a pump for delivering fuel from said chamber to the engine, means for metering and delivering fuel to the chamber in accordance with the varying requirements of the engine, and means for controlling the amount of fuel supplied to the pump from said chamber in accordance with the amount of fuel delivered to said chamber.

4. In a charge feeding system for internal combustion engines, a pump supply chamber, a pump for delivering fuel from said chamber to the engine, means for metering and delivering fuel to the chamber in accordance with the varying requirements of the engine, and a float controlled valve for regulating the amount of fuel pumped from said chamber to the engine.

5. In a charge feeding system for internal combustion engines, a pump supply float chamber, a pump for delivering fuel from said chamber to the engine, means for supplying fuel to the chamber in accordance with the amount of air taken into the engine, and a float controlled valve for regulating the flow of fuel from the chamber to said pump.

6. In a charge feeding system for internal combustion engines, a pump supply depres-

sion chamber, a pump for delivering fuel from said chamber to the engine, means for supplying fuel to the chamber in accordance with the amount of air taken into the engine, and a float and depression controlled valve for regulating the flow of fuel from the chamber to said pump.

7. In a charge feeding system for internal combustion engines, a fuel pump for each engine cylinder, a fuel supply chamber for each pump, a float controlled valve in each chamber for regulating the flow of fuel from said chambers to the pumps, and means for feeding fuel to the chambers in accordance with the requirements of the engine.

8. In a charge feeding system for internal combustion engines, a fuel pump for each engine cylinder, a plurality of fuel supply chambers, one for each pump, float controlled valves for regulating the flow of fuel from said chambers to the pump, and means for feeding fuel to the chambers in accordance with the requirements of the engine.

9. In a charge feeding system for internal combustion engines, a fuel pump for each engine cylinder, a plurality of fuel supply depression chambers, one for each pump, float and depression controlled valves for regulating the flow of fuel from said chambers to the pumps, and means for feeding fuel to the chambers in accordance with the requirements of the engine.

10. In a charge feeding system for internal combustion engines, a fuel pump for each engine cylinder, a fuel supply chamber for each pump, a float controlled valve in each chamber for regulating the flow of fuel from said chambers to the pumps, and means for feeding fuel to the chambers in accordance with the amount of air taken into the engine.

11. In a charge feeding system for internal combustion engines, an air inlet having a restriction, a constant level fuel reservoir, a fuel injection pump, a pump supply chamber, means actuated by the depression at the air passage restriction for delivering fuel from said reservoir to the supply chamber, and a float valve for controlling the amount of fuel supplied to the injection pump from said chamber.

12. In a fuel injection system for internal combustion engines, an air intake passage having a restriction, a constant level fuel supply reservoir, a depression float chamber communicating with the supply reservoir and with the air intake passage at said restricted portion, means for delivering fuel from the supply reservoir to the depression chamber, a fuel pump adapted to take fuel from the depression chamber and to introduce such fuel to the engine, and a float controlled valve for regulating the delivery of fuel from the depression chamber to the pump in accordance with the amount of fuel delivered to the depression chamber from the supply chamber.

13. In a fuel injection system for internal combustion engines, an air intake passage having a restriction, a constant level fuel supply reservoir, a depression chamber communicating with the supply reservoir and with the air intake passage at said restricted portion, a fuel pump adapted to take fuel from the depression chamber and to introduce such fuel to the engine, a valve for regulating the delivery of fuel from the depression chamber to the pump, and means for controlling the position of said valve in accordance with the depression at said restriction in the air passage.

14. In a fuel injection system for internal combustion engines, an air intake passage having a restriction, a constant level fuel supply reservoir, a depression float chamber communicating with the supply reservoir and with the air intake passage at said restricted portion, a fuel pump adapted to take fuel from the depression chamber and to introduce such fuel to the engine, a float in the depression chamber, a valve controlled by said float for regulating the delivery of fuel from the depression chamber to the pump, and means for controlling the position of said float relative to the fuel level in accordance with the depression at said restriction in the air passage.

15. In a fuel injection system for internal combustion engines, an air intake passage having a restriction, a constant level fuel supply reservoir, means for feeding and isolating fuel from the supply reservoir in accordance with the depression at the air passage restriction, a depression float chamber communicating with the supply reservoir and with the air intake passage at said restricted portion, the fuel isolated from the supply reservoir, being delivered to the depression chamber, a fuel pump adapted to take fuel from the depression chamber and to introduce such fuel to the engine, and a float controlled valve for regulating the delivery of fuel from the depression chamber to the pump.

16. In a fuel injection system for internal combustion engines, an air intake passage having a restriction, a constant level fuel supply reservoir, means for feeding and isolating fuel from the supply reservoir in accordance with the depression at the air passage restriction, a depression float chamber communicating with the supply reservoir and with the air intake passage at said restricted portion, the fuel isolated from the supply reservoir being delivered to the depression chamber, a fuel pump adapted to take fuel from the depression chamber and to deliver such fuel to the engine, a float controlled valve for regulating the delivery of fuel from the depression chamber to the pump, and an injector valve for introducing fuel from the pump into the engine.

17. In a fuel injection system for internal

combustion engines, an air intake passage having a restriction, a constant level fuel supply reservoir, a plurality of depression float chambers, one each for each engine cylinder, said depression chambers communicating with the supply reservoir and with the air intake passage at said restricted portion, a fuel pump having a plurality of pumping chambers, each communicating with one each of the depression chambers, the pump being adapted to discharge fuel from said pumping chambers to the engine cylinder, and a plurality of float controlled valves for regulating the delivery of fuel from the depression chambers to said pumping chambers.

18. In a fuel injection system for internal combustion engines, an air intake passage having a restriction, a constant level fuel supply reservoir, a plurality of depression float chambers, one each for each engine cylinder, said depression chambers communicating with the supply reservoir and with the air intake passage at said restricted portion, a fuel pump having a plurality of pumping chambers, each communicating with one each of the depression chambers, the pump being adapted to discharge fuel from said pumping chambers to the engine cylinders, a plurality of valves each controlled by one each of the floats in said depression chambers for regulating the delivery of fuel from the depression chambers to the pumping chambers, means for controlling the position of one of said floats relative to the fuel level in accordance with the depression at said restriction in the air passage, and means for automatically adjusting the remaining floats in accordance with the first positioned float.

19. In a fuel injection system for internal combustion engines, an air intake passage having a restriction, a constant level fuel supply reservoir, a vertically extending block within the reservoir, said block having a pair of vertical passages, one of said passages communicating with the reservoir at a point below the normal liquid level and with the other passage at a point above the normal liquid level, a depression chamber communicating with the last mentioned passage and with the air intake passage at said restricted portion, and a fuel pump adapted to take fuel from the depression chamber and to introduce such fuel to the engine independent of the air feed thereto.

20. In a fuel injection system for internal combustion engines, an air intake passage having a restriction, a constant level fuel supply reservoir, a vertically extending block within the reservoir, said block having a pair of vertical passages, one of said passages communicating with the reservoir at a point below the normal liquid level and with the other passage by way of an opening above the normal liquid level, means for abnormally raising the liquid level, in the reservoir to a point above said opening during substantially idling speed operation of the engine, a depression chamber communicating with the last mentioned passage and with the air intake passage at said restricted portion, and a fuel pump adapted to take fuel from the depression chamber and to introduce such fuel to the engine independent of the air feed thereto.

21. In a system of the character described, a constant level fuel supply reservoir containing a float, a fuel inlet to the reservoir, a pair of vertically extending fuel passages in said reservoir, one of said passages communicating with the reservoir at a point below the normal liquid level and with the other passage by way of an opening above the normal liquid level, means for applying depression to the last mentioned passage to draw fuel from the reservoir through said opening, and yielding means adapted to submerge said float in the fuel abnormally during comparatively slow delivery of fuel from the reservoir to cause the liquid level to rise above said opening, said means becoming substantially ineffective during comparatively rapid delivery of fuel from the reservoir.

22. In a fuel injection system for internal combustion engines, an air intake passage having a restriction, fuel supply means, a depression chamber communicating with said supply means and with the intake passage at said restricted portion, a vertical valve stem in the depression chamber and having on its lower end a valve vertically reciprocable in a bore in the bottom of said chamber, a float mounted on said valve stem, a transverse passage in the bottom of said chamber intersecting said bore and communicating with the chamber interior, and a pump adapted to take fuel from said passage for delivery to the engine.

23. In a fuel injection system for internal combustion engines, an air intake passage having a restriction, fuel supply means, a depression chamber communicating with said supply means and with the intake passage at said restricted portion, a vertical valve stem in the depression chamber and having on its lower end a valve vertically reciprocable in a bore in the bottom of said chamber, a float mounted on said valve stem, a transverse passage in the bottom of said chamber intersecting said bore and communicating with the chamber interior, and a pump adapted to take fuel from said passage for delivery to the engine and means for controlling the position of said float with respect to the liquid level in the depression chamber in accordance with the amount of depression existing therein.

24. In a fuel injection system for internal combustion engines, an air intake passage having a restriction, fuel supply means, a de-

pression chamber communicating with said supply means and with the intake passage at said restricted portion, a vertical valve stem in the depression chamber and having on its lower end a valve, vertically reciprocable in a bore in the bottom of said chamber, a float mounted on said valve stem, said float having a liquid displacement chamber communicating with the liquid body in the depression chamber, means for admitting air from outside the depression chamber to said float displacement chamber; a transverse passage in the bottom of the depression chamber and intersecting said bore and communicating with said liquid body, and a pump adapted to take fuel from said passage for delivery to the engine.

25. In a fuel injection system for internal combustion engines, an air intake passage having a restriction, fuel supply means, a depression chamber communicating with said supply means and with the intake passage at said restricted portion, a vertical tubular valve stem in the depression chamber and having on its lower end valve means for controlling the flow of fuel from the depression chamber for delivery to the engine, the upper end of said stem extending within a guide bore in the depression chamber top, a float mounted on said valve stem and having a liquid displacement chamber communicating with the stem bore and with the liquid body in the depression chamber, a transverse bore in the depression chamber top and communicating with said guide bore above the upper end of the stem and with the valve stem interior, an air inlet for admitting air to the transverse bore, and a comparatively restricted opening between said transverse bore and the depression chamber.

26. In a fuel injection system for internal combustion engines, an air intake passage having a restriction, fuel supply means, a depression chamber communicating with said supply means and with the intake passage at said restricted portion, a vertical tubular valve stem in the depression chamber and having on its lower end valve means for controlling the flow of fuel from the depression chamber for delivery to the engine, the upper end of said stem extending within a guide bore in the depression chamber top, a float mounted on said valve stem and having a liquid displacement chamber communicating with the stem bore and with the liquid body in the depression chamber, a transverse bore in the depression chamber top and communicating with said guide bore above the upper end of the stem and with the valve stem interior, an air inlet for admitting air to the transverse bore, a comparatively restricted opening between said transverse bore and the depression chamber, a passage communicating with said transverse bore and the depression chamber, and valve means in said passage adapted to permit air to flow from said air inlet into the depression chamber only, when the amount of depression therein reaches a predetermined value.

27. In a fuel injection system for internal combustion engines, a pump supply float chamber, means for delivering fuel to said chamber, a pump having a compression chamber adapted to receive fuel from said float chamber, a float controlled valve for regulating the flow of fuel from the float chamber to the pump chamber, a fuel delivery line from said pump chamber to the engine, valve means preventing reverse liquid flow between said chambers, and valve means preventing liquid flow from said line to the pump chamber.

28. In a fuel injection system for internal combustion engines, a pump supply float chamber, means for delivering fuel to said chamber, a pump having a compression chamber adapted to receive fuel from said float chamber, a float controlled valve for regulating the flow of fuel from the float chamber to the pump chamber, a fuel delivery line from said pump chamber to the engine, valve means preventing reverse liquid flow between said chambers, valve means preventing liquid flow from said line to the pump chamber, and an injector valve in said line for injecting fuel into the engine at predetermined pressure.

29. In a fuel injection system for internal combustion engines, an air intake passage having a restriction, a constant level fuel supply reservoir, a depression float chamber communicating with the supply reservoir and with the air intake at said restricted portion, a pump having a compression chamber adapted to receive fuel from said float chamber, a float controlled valve for regulating the flow of fuel from the float chamber to the pump chamber, a fuel delivery line from said pump chamber to the engine, valve means preventing reverse liquid flow between said chambers, valve means preventing liquid flow from said line to the pump chamber.

30. In a fuel injection system for internal combustion engines, a plurality of pump supply float chambers, one each for each engine cylinder, means for delivering fuel to said chambers, a pump having a plurality of compression chambers, one each for each float chamber and adapted to receive fuel from the float chamber, float controlled valve means for regulating the flow of fuel from the float chambers to said pump chambers, a plurality of fuel delivery lines each extending from one each of the pump chambers to one each of the engine cylinders, valve means preventing reverse liquid flow between the chambers, valve means preventing liquid flow from said lines to the pump chambers, pump plungers for compressing fuel in each

of said pump chambers, a pump shaft drivingly connected to the engine, and cam means on said shaft for actuating the pump plungers in timed relation with the engine.

31. In a charge feeding system for internal combustion engines, an air inlet having a restriction, a fuel reservoir, a fuel injection pump, a pump supply chamber, means controlled by the depression at the air passage restriction for delivering fuel from said reservoir to said supply chamber, and means for delivering fuel to said pump in accordance with the amount of fuel delivered to said chamber from the fuel reservoir.

32. In a charge feeding system for internal combustion engines, an air inlet having a restriction, a fuel reservoir, a fuel injection pump, a pump supply chamber, means controlled by the depression at the air passage restriction for delivering fuel from said reservoir to said supply chamber, means for delivering fuel to said pump in accordance with the amount of fuel delivered to said chamber from the fuel reservoir, and means for injecting the pumped fuel into the engine under predetermined pressure and in timed relation with the engine operation.

In witness that I claim the foregoing I have hereunto subscribed my name this 18 day of October, 1928.

ROY F. ENSIGN.