Jan. 5, 1932. G. R. LAWRENCE 1,839,791

COMBUSTIBLE MIXTURE SUPPLY FOR INTERNAL COMBUSTION ENGINES

Filed July 2, 1928 3 Sheets-Sheet 1

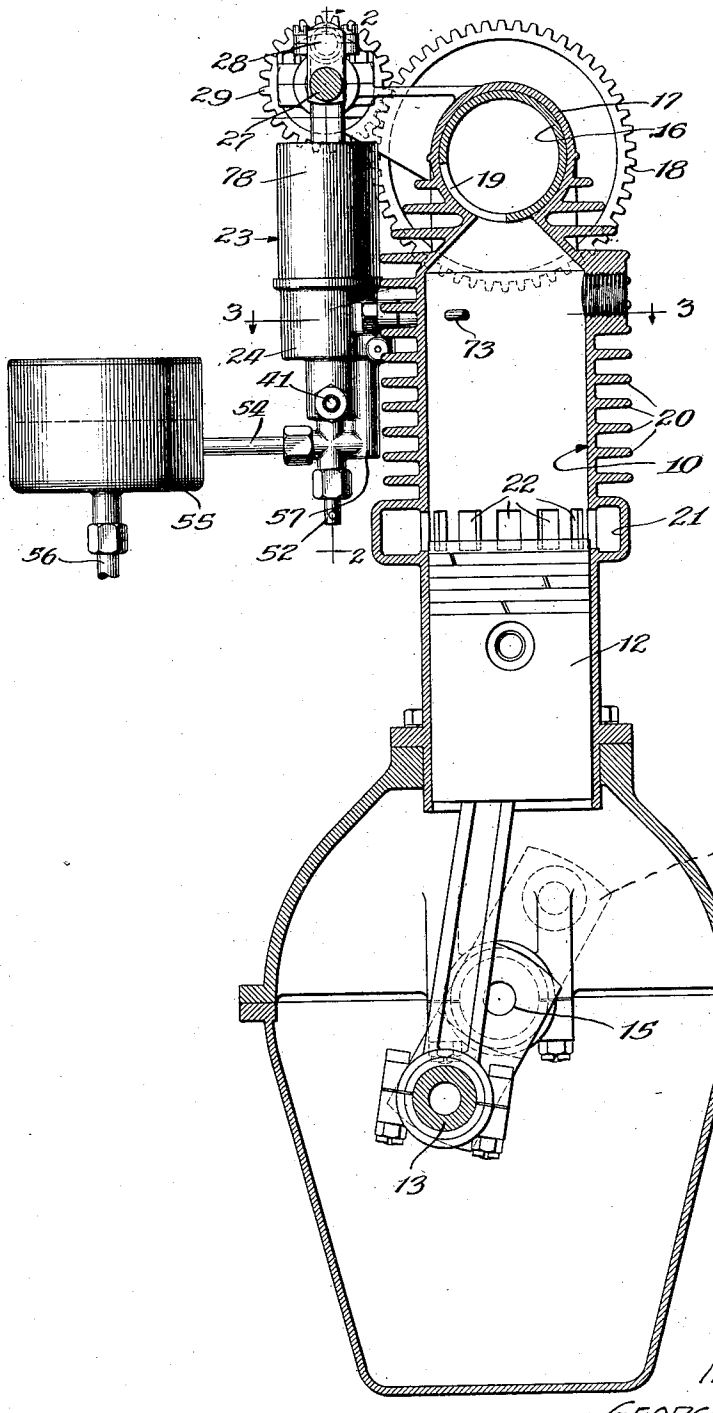


FIG. 1

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Filed July 2, 1928 3 Sheets-Sheet 2

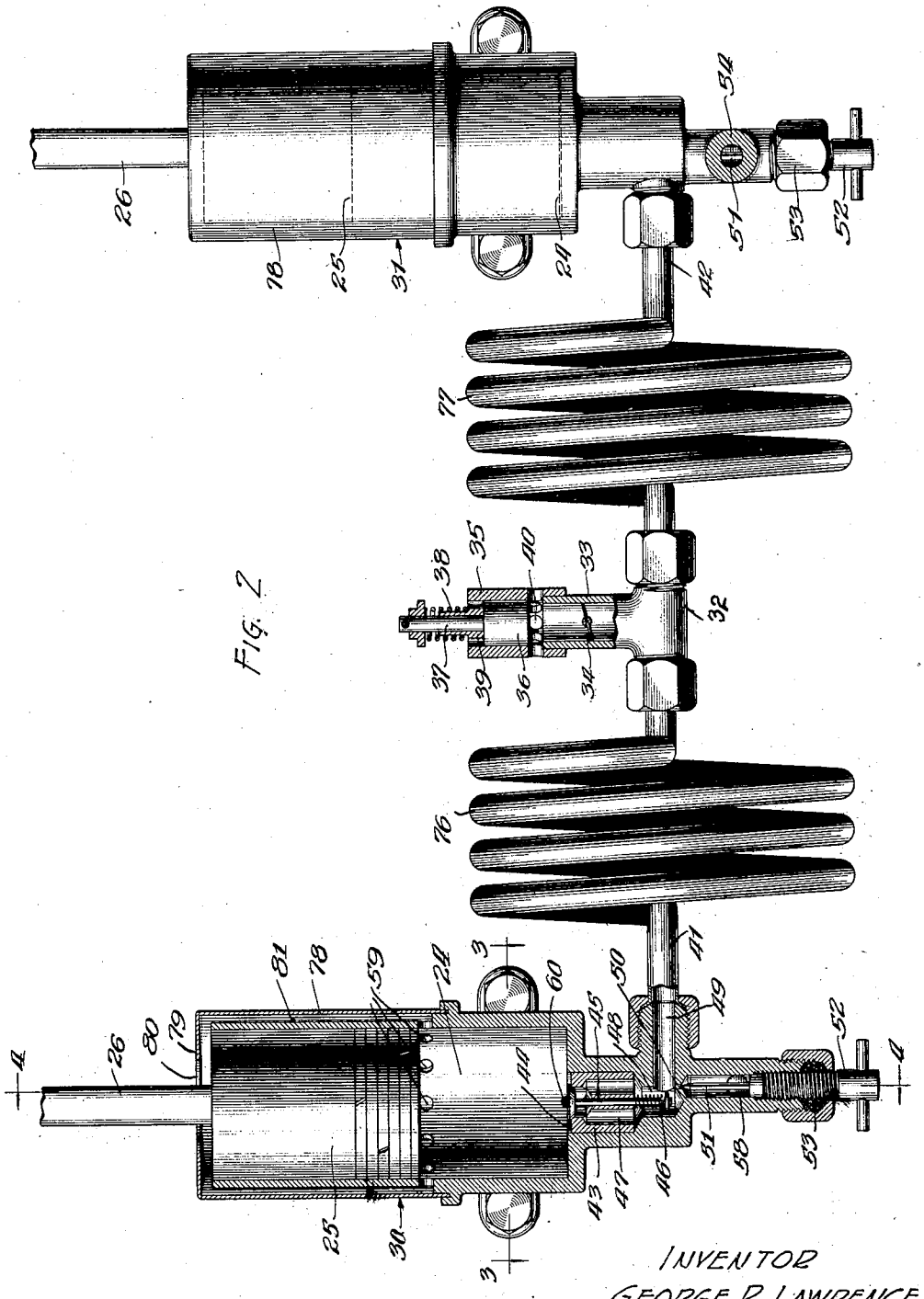


Fig. 2

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FIG. 3

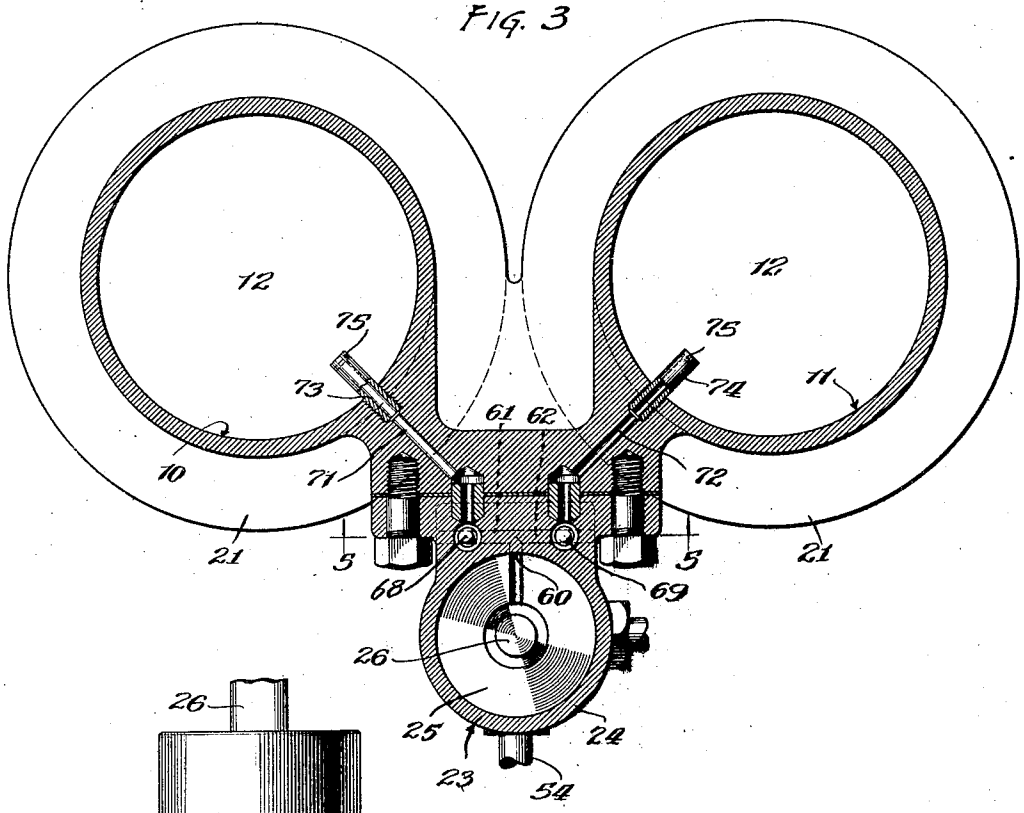


FIG. 4

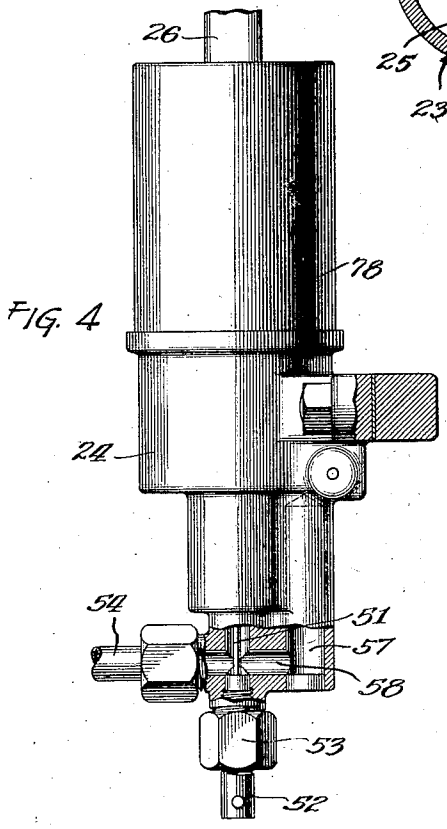
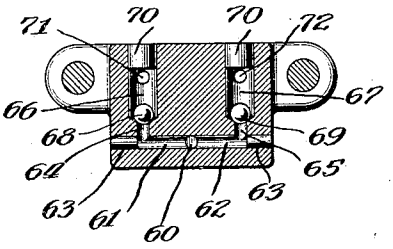


FIG. 5.



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UNITED STATES PATENT OFFICE

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COMBUSTIBLE MIXTURE SUPPLY FOR INTERNAL COMBUSTION ENGINES

Application filed July 2, 1928. Serial No. 289,958.

This invention has to do with certain improvements in means for supplying combustible mixture to internal combustion engines, and also has reference to the mode of operation thereof. Briefly stated the invention relates to the foregoing features as applied to internal combustion engines generally. The structure and mode of operation herein disclosed are particularly intended for use with two stroke cycle engines; and more particularly the features of the invention have been devised for use in connection with that type of engine illustrated and described in Letters Patent of the United States No. 1,160,419 which was issued to me on November 16, 1915. Inasmuch as, however, the features of the present invention may be advantageously used in connection with many other forms of engines, both two and four stroke cycle, I wish it understood that I do not intend to limit the usefulness or scope of my invention to engines of the type particularly illustrated and described in the said earlier patent, except as I may do so in the claims.

The present invention relates primarily to improvements in the means for introducing the individualized charges of fuel into the different cylinders together with the relationship which such means bears to the general construction and operation of the engine as a whole, as well as to the construction and mode of operation of the fuel pumping device per se, and if considered as an independent element.

The main feature of the present invention relates to the provision of an improved construction and arrangement of fuel pump for delivering the fuel charges to the working cylinders of the engine under the most advantageous conditions. More particularly the invention has to do with improvements in fuel pumps for engines of the general type already referred to herein; but it will presently appear that numerous features of the invention may also be advantageously used in connection with fuel pumps for other purposes.

One of the features of the invention relates to a provision of a fuel charge forming pump of a construction such that the same delivers to the working cylinders of the engines charges composed of the fuel, together with a volume of air which is generally smaller than the air contained within the working cylinder of the engine. The air charges delivered by the fuel pump are of constant volume, being uniform throughout the range of load conditions; but the individual charges of fuel taken into the constant volume charges of air are varied accordingly to the load requirements of the engine.

The charges of liquid fuel taken up by these air charges are drawn into the fuel pump itself by an aspirating or suction action which is dependent upon the amount of throttle opening of the air line through which the air is admitted to the fuel pump. As this air line is closed the flow of air through it decreases and the suction increases with a consequent increase of the amount of fuel drawn into the pump cylinder at each stroke; and a contrary action will take place with an increased amount of throttle opening. The fuel pump itself is so constructed that just before the completion of its intake stroke, an air port or ports are uncovered by the pump piston allowing a sudden inrush of additional air which joins the air charge previously drawn into the pump cylinder and insures a full charge of combustible mixture at atmospheric pressure. This charge is then introduced into the working cylinder of the engine as already explained.

It is very difficult to meter minute quantities of liquid fuel such as gasoline with a high degree of accuracy; and a relatively small variation in the amount of liquid so metered will produce a very appreciable percentage of error in the metering action. On the contrary it is possible to meter the relatively larger charges of air and vapor with the desired degree of accuracy; and the same amount of variation in the metering of this relatively large body of air will produce only a very small fraction of the error in percentage which is represented by a similar variation of amount when applied to the relatively small charge of liquid fuel itself.

I have therefore provided an arrangement such that the metering is a metering of a relatively large body of air and vapor and not a metering of a small quantity of liquid; thus making it possible to secure a very accurate control of the fuel charge forming operations.

More particularly, I have provided a fuel charge forming device comprising a pump driven in synchronism with the movements of the working pistons whose cylinders it supplies. This fuel pump is in effect an air pump, the primary source of air supply thereto being through a passage which can be controlled by a suitable valve such as a throttle valve. The primary supply of air flowing through this passage to the fuel pump will aspirate and carry with it into said fuel pump the charges of liquid fuel. These charges are then taken into the fuel pump together with the primary air therefor, so that this fuel pump handles a rich mixture of air and fuel. This mixture, together with a certain amount of secondary air, is then delivered by the fuel pump to the working cylinders of the engine.

The fuel pump itself is so arranged that the primary charges of air and fuel are drawn into the pump cylinder on the suction stroke of the pump piston, and necessarily under a degree of vacuum dependent on numerous factors. One of these factors is the amount of closure of the throttle valve which controls the primary air. As this valve is opened and closed to control the engine, greater or lesser quantities of primary air are allowed to be drawn into the pump cylinder during its suction stroke.

The aspirating effect of the charges of air drawn into the pump cylinder will depend upon the amount of such air drawn in at each suction stroke of the pump; and I have provided an arrangement whereby the fuel is drawn into this primary air by reason of its aspirating effect and therefore approximately inverse in proportion to the amount of primary air being used.

Since the pump operations are of a pulsating nature, the primary air charges are also of a pulsating nature and this is also true of the fuel charges. Since both the air and fuel are delivered to the pump or the intake thereof through passages it follows that the inertia effect of the flow through said passage will be aggravated as the rate of the pulsations increases. I have provided an arrangement whereby the effect of this pulsating condition will be minimized.

Furthermore since the fuel is a liquid and therefore substantially non-compressible, whereas the air is highly compressible and expansible, it follows that the effect of the pulsations on the column of liquid flowing through the supply passage will be very different from its effect on the column of air flowing through the primary air supply passage.

I have provided an arrangement whereby the proper ratio of primary air and fuel will be substantially maintained notwithstanding the foregoing condition. I have also provided an arrangement whereby the pressure of the mixture of air and fuel will be substantially atmospheric at the instant the same is ready for delivery to the working cylinder. This result I accomplish by allowing the introduction into the fuel pump cylinder, of a sufficient amount of air just before the completion of the suction stroke to restore the pressure to atmospheric. This insures the presence of a full charge of air within the pump cylinder, together with the metered amount of fuel drawn in with the primary air. This full volume of mixture is then delivered to the working cylinder of the engine.

In connection with the foregoing, this supplemental or secondary air for the fuel pump is drawn into the cylinder thereof from a space around the top side of the pump piston. Consequently any seepage which may have previously taken place past the pump piston is restored to the working side of the pump and delivered into the working cylinder on the next succeeding pump delivery stroke. As a consequence the loss and error so occasioned by seepage, is practically eliminated and the accuracy of operation correspondingly improved.

Another feature of the invention relates to the provision of an arrangement whereby the fuel nozzles can be adjusted by the operator to the desired conditions so as to insure correct operation with fixed nozzle adjustments, the control of the fuel supply operation being proportioned to regulation of the flow of primary air.

A further feature of the invention relates to the provision of an arangement whereby any leakage of burnt gases from the working cylinder backwardly cannot have any appreciable effect upon the operation of the system, and cannot seriously impair either its operation or its efficiency.

A further feature of the invention relates to the provision of an arrangement whereby any leak in the intake valve of the fuel pump will simply result in a leakage of mixture back to atmospheric and will not effect the amount of fuel taken into the pump on the next succeeding cycle.

A further feature of the invention relates to the provision of a fuel pumping device which also serves largely the function of a supercharger, that is, it delivers the fuel together with a portion of the air into the cylinders under a certain amount of compression, thereby increasing the quantity of combustible introduced into each working cylinder per working stroke.

A further feature of the invention relates to the provision of a fuel pump in conjunction with a plurality of individual working

cylinders of the engine, said pump being so timed in its operations with respect to the working piston movements that it delivers charges of fuel to the different working cylinders in sequence and takes care of the requirements of all of the working cylinders for which it is intended. More particularly it is an object in this connection to combine each fuel pump with two of the working cylinders of a two stroke cycle engine, timing the operations of said pump at double engine speed so that the fuel pump may serve to deliver to the two cylinders in alternation. This result is further accomplished by combining the fuel pump with two working cylinders whose crank throws are set in opposion or 180° apart.

A further object accomplished by the foregoing is that the speed of operation of the fuel pump is doubled so that the duration of the injection cycles is correspondingly reduced and the operation improved.

A further feature in conjunction with the foregoing is a provision of a valve arrangement of very simple form for insuring the delivery of fuel to the two cylinders in alternation this result being made possible by reason of the fact that during the injection movement of the pump one working cylinder of the pair is under pressure and the other working cylinder of the pair is under exhaust so that the pressure in one of the working cylinders is very high while the other is practically at atmospheric pressure. The fuel pump will automatically select its delivery of combustible into the working cylinder of low pressure, which is of course the one which should receive the charge.

A further feature of the invention is the provision of a multiple cylinder engine with its cylinders working in pairs in opposition to each other, together with a fuel pump for each of said pairs working in opposition, so that any particular pair of cylinders and the corresponding fuel pump may be thrown out of commission as a pair or unit and without throwing the engine as a whole out of balance except so far as torque impulses are concerned. Furthermore, the throwing of certain cylinders of the engine out of commission will not impair the operation of the remaining cylinders and fuel pump. It is further a feature of the invention to provide a needle valve in conjunction with each fuel pump, for controlling the supply of liquid fuel thereto, together with a single control valve for the air supply for the fuel pumps of the engine, so that the operation of the engine as a whole can be controlled by the use of a single air valve or throttle valve. Under such circumstances the needle valve for each fuel pump serves to fix the adjustment thereof, and the needle valves of the different fuel pumps may be so related to each other as to balance the various pumps in respect to each other.

Other objects of the invention are to provide devices for the foregoing purposes which are extremely simple and rugged in construction, built up from relatively few parts of simple form and which can be readily manufactured in quantities according to standard factory operations and at low cost.

Other objects and uses of the invention will appear from a detailed description of the same which consists in the features of construction and combinations of parts hereinafter described and claimed.

In the drawings:

Fig. 1 shows a vertical section through one of the working cylinders together with the main air valve thereof, of a two stroke cycle engine of the general type described in my aforesaid Patent No. 1,160,419, having applied thereto a fuel supply pump construction embodying the features of the present invention;

Fig. 2 shows a vertical elevation of the fuel pumping mechanism, partially in section, and may be considered as being taken substantially on the line 2—2 of Fig. 1, looking in the direction of the arrows but on enlarged scale;

Fig. 3 shows a horizontal section on the line 3—3 of Fig. 1 looking in the direction of the arrows but on enlarged scale; and may also be considered as being a section on the line 3—3 of Fig. 2 looking in the direction of the arrows on same scale;

Fig. 4 shows a side elevation of one of the fuel pumps, partly in section; and

Fig. 5 shows a fragmentary vertical section on the line 5—5 of Fig. 3 looking in the direction of the arrows.

In the drawings I have shown a single element or unit comprising two cylinders numbered 10 and 11 respectively the same comprising a single two cylinder unit. This unit may be individually considered or it may be considered as one unit of a multiple cylinder engine of more than two cylinders.

Each of the cylinders is provided with the usual piston 12 and the two pistons of each unit are connected to the opposing throws 13 and 14 of the crank shaft 15. These throws being in opposition, insure movements of the two pistons in opposition.

Along the upper portion of the cylinder structure there is placed a rotary air inlet valve 16, the same being rotatably mounted within a cylindrical casing 17 on the upper end of the structure. This valve 16 is driven at crank shaft speed and is connected to a gear 18 and the valve is drivingly connected to the crank shaft 15 on a 1 to 1 ratio. Consequently the valve 16 makes one revolution for each crank shaft revolution.

The valve 16 is provided with an air inlet port 19 in line with the upper end of each cylinder; and air under a suitable pressure supply is delivered to the interior of the valve 16 by any suitable source of compressed air

supply in accordance with certain of the principles disclosed in my aforesaid Patent No. 1,160,419. The valve 16 is so timed that it closes after the piston commences its upward or compression stroke; and this timing is varied so as to trap in the cylinder an amount of air to be compressed, the amount of such air being in proportion to the power to be developed. For a full power stroke the valve closes just after the exhaust ports have closed to seal the cylinder, thus trapping a full charge of air; for a less than full power stroke the valve 16 does not close until somewhat later, allowing some air to be expelled back from the cylinder so that less than a full charge of air is trapped and compressed.

The cylinders illustrated are for convenience shown as being air cooled for which purpose they are provided with fins 20, but, manifestly, as far as the present invention is concerned, the cylinders might be jacketed and cooled by a selected circulating medium.

Around the belt of each cylinder at a point adjacent to the lower-most piston movement there is located an exhaust or scavenging passage 21, which communicates with the interior of the cylinder by a series of ports 22. These ports are so placed that they are uncovered as the piston approaches its lower limit of movement to thereby insure proper scavenging and discharge of the spent gases.

The rotation of the air inlet valve 16 is so timed that the uncovering of the port 19 takes place shortly after the exhaust ports 22 are uncovered by the piston movement, and the port 19 is of sufficient angular length for the varying requirements of the operations. As a consequence the inrushing fresh charge of air materially assists the scavenging operation by positively displacing the spent gases downwardly through the ports 22.

Means (not shown) are provided for varying the angular position or timing of the inlet valve 16 with respect to the crank shaft 15, in accordance with the fundamental disclosures of my aforesaid Letters Patent No. 1,160,419 and as already mentioned herein. In this way it is possible to regulate the charge of air which will be trapped in the cylinder, and in accordance with the momentary power requirements of the operation.

I will now describe my improved fuel charge forming and pumping device for delivering the charges of fuel into the cylinder in proper quantity and timing and under proper conditions to insure the most perfect operating results.

For each pair of cylinders 10 and 11 I provide a single fuel pump 23. This pump comprises a cylinder 24, open at its top end, and within which reciprocates the piston 25. This piston is provided with an upwardly reaching connecting rod 26, which is driven by a pump crank shaft 27 through the medium of a crank 28 as illustrated in Fig. 1. The crank shaft 27 is in turn driven by a pinion 29 which meshes with the gear 18, the pinion being of one-half size so as to rotate at double speed as compared with gear 18 and therefore at double the speed of the main crank shaft 15. It thus follows that the pump piston 25 makes a complete up and down reciprocation for each down stroke of the two pistons of the pair of working cylinders which are served by said pump.

In the case of a four cylinder engine two of the pumps 23 are provided, one for each pair of cylinders, these being the pumps 30 and 31 of Fig. 2. In such case both of said pumps may be supplied with air by a common T connection 32, the inlet leg 33 of which is provided with a butterfly valve 34 under the control of the operator. At the inlet side of said butterfly valve the inlet connection 33 is provided with a tubular or cylinder chamber 35 within which is placed a plunger 36 having the stem 37, said plunger being normally raised by a spring 38 into the uppermost position illustrated in Fig. 2. At this point the plunger 36 strikes against a cross piece 39 by means of which its upward movement is limited.

The chamber 35 is provided with a series of inlet ports 40 immediately below the position of the plunger 36, and upon the existence of an unusually heavy suction beneath the plunger it will be drawn down against the spring 38 and thereby partially close the ports 40, thus reducing the rate of air inlet. The ports 40 are, however, never closed completely.

From the T connection 32 the air supply lines 41 and 42 lead to the two pumps 30 and 31 respectively; and the form of these air supply lines will be explained more in detail presently.

In the floor of each of the pump cylinders there is located a fitting 43 having at its upper end a valve seat which receives the poppet valve 44 having the downwardly depending stem 45. A light spring 46 normally draws the valve stem down and thereby seats the valve. The fitting 43 has a series of vertical passages 47 through which the charges of air and fuel are drawn upward past the valve into the cylinder. The passages 47 communicate at their lower ends with a small chamber 48 immediately beneath the fitting 43, and the air drawn through the connection 41 or 42 as the case may be enters the chamber 48 through a passage 49 in a right angle direction.

Immediately adjacent to the point of entry of the passage 49 with the chamber 48 there is a small fuel port 50, the same being on the bottom side of the passage 49, and being controlled by a needle valve 51. This needle valve is in turn provided with a finger piece 52 at its lower end whereby its setting can be

adjusted. The usual packing 53 may be provided around the needle valve or the stem 52.

The fuel is supplied to each of the needle valves 51 by a connection 54, and a float chamber 55 is provided to serve the two connections 54 of the two pumps 30 and 31, said float chamber 55 receiving its supply of fuel from the common connection 56, and maintaining a predetermined level of fuel below the opening 50 of each needle valve.

Due to the fact that the liquid fuel is drawn into the pump in an intermittent manner there will necessarily be a certain amount of resistance to the delivery of the individual impulses of fuel due to inertia. In order to reduce the effect of this inertia in the fuel supply line as much as possible I have provided a small chamber 57 (see Fig. 4) in close proximity to each of the needle valves and connected to the needle valve by a short passage 58, the upper end of each of the said chambers being sealed. As a consequence the momentary demands for liquid fuel will be supplied from the chamber 57 corresponding to the impulses, and there will be a more or less continuous and uninterrupted supply of fuel through the connection 54. Thus the inertia effect on the liquid fuel line will be greatly reduced.

Around the wall of the cylinder 24 there are located a series of air ports 59, the same being located at such an elevation that they will just be fully uncovered at the upper limit of the plunger stroke. Until the piston 25 reaches a sufficient elevation to uncover the ports 59 there will be developed a suction within the cylinder which will draw in a partial charge of air through the connection 49; and at the same time the necessary amount of liquid fuel will also be drawn in and mixed with said air above the position of the needle valve and during the movement through the passages 47. This small charge of air and fuel will be extremely rich, much richer than in fact should be used in the cylinder of the engine, and as has already been explained the predominating portion of the air necessary for the proper explosive mixture in the cylinder is supplied independently and through the main air supply valve 16.

As soon as the piston 25 reaches a sufficient elevation to uncover the ports 59 the suction beneath the piston will be broken and the valve 44 will seat. At the same time air or vapors will rush into the cylinder through the ports 59 to equalize the pressure below the piston. Immediately thereafter the piston on its down stroke will close the ports 59 and commence to deliver the charge thus trapped.

There is a delivery port 60 reaching backwardly from the lower end of the cylinder 24 and branching into a pair of branches 61 and 62 (see Figs. 3 and 5). The ends of these branches are plugged by the blocks 63 as shown at Fig. 5. Reaching upwardly from the two branches 61 and 62 are the passages 64 and 65 which lead into chambers 66 and 67 corresponding to the two working cylinders 10 and 11. The ball check valves 68 and 69 placed between the passages 64 and 65 and the chambers 66 and 67 respectively, prevent any backward movement from the respective working cylinders. The upper ends of the chambers 66 and 67 are blocked by the blocks 70.

Reaching sidewise from the chambers 66 and 67 are the passages 71 and 72 which lead into the working cylinders at positions close to the upper or compression ends thereof. If desired, spray heads 73 and 74 may be placed at the discharge ends of the passages 71 and 72, said spray heads being provided with relatively small spray openings 75 so as to create a turbulent condition within the cylinder with consequent increase in the firing speed.

It will be understood that the operations of the pistons 25 are so timed with respect to the movements of the working pistons 12 that the admission of the fuel charge into the working cylinder takes place after the scavenging has been completed and just before the valve 19 closes. As a consequence the gas pressure existing in the working cylinder which is receiving the charge is only slightly above atmospheric or in some cases may be slightly below atmospheric. At this time the gas pressure existing in the other working cylinder of the pair is very high since the piston of such working cylinder is at its upper or compressed position. The check valves 68 and 69 serve to prevent any back flow from the working cylinders to the fuel pump; and due to the presence of said check valves the fuel pump will always select and deliver its charge to the working cylinder which is ready to receive it.

Under rapid operation the inertia of the liquid fuel coming to the fuel pumps may seriously affect the siphoning action of the fuel delivered through the small ports 50 under control of the needle valves 51 and consequently excessive quantities of air may be drawn in. In order to equalize the conditions of air supply to the fuel pump as much as possible at all speeds, I prefer to establish a relatively long air column in each of the air connections 41 and 42 at a position close to the delivery end of such connection leading into the passage 49 of the pump. As a matter of convenience these air columns are established by coils 76 and 77 in the air supply pipes, said coils having a sufficient length to establish air columns of appreciable inertia in comparison to the inertia of the fuel columns so that the effects of inertia on the fuel and on the air will be substantially balanced against each other.

In the operation of the device, with the

butterfly valve 34 at a given setting, the air for the pump will be drawn in past said butterfly valve and through the tube 76 or 77 as the case may be, past the orifice 50 (the liquid fuel standing somewhat below the same due to control of the float chamber 55), and will be drawn past the valve 44 into the pump cylinder 24. Due to the rapid up movement of the piston 25 there will exist a partial vacuum within the cylinder, and the extent thereof will be somewhat determined by the amount of opening of the throttle valve 34. Manifestly the amount of fuel which will be aspirated on said stroke will be somewhat controlled by the rate of air flow through the passage 49 and past the orifice 50. In any case however, as the pump piston reaches the top of its stroke the ports 59 will be uncovered so as to allow an inrush of air into the cylinder, which inrush will immediately build up the air pressure in the cylinder to atmospheric and establish the presence of a full charge of air in the cylinder. The fuel charge will however have been taken into the cylinder prior to the inrush of air.

(As the speed of the engine is increased the plunger 36 will be drawn down so as to partially close the ports 40.) This action will result in a further resistance to the flow of air past the throttle valve, which resistance will be increased as the motor speed increases. The plunger 36 never moves down low enough to completely close the ports 40, such result being insured by proper design of the spring 38, the turns of which will close up before the plunger 36 can completely close the ports 40.

The inertia effect due to the pulsating nature of the column of air flowing through the pipe 76 is necessarily affected by the fact that the air column is highly compressible and expansible instead of being non-compressible as in the case of a solid or liquid. The action of the valve 36 will largely serve to offset the compressible or expansible nature of the air column and will serve in connection with the long air columns 76 and 77 to so regulate the intermittent air supplies through the pipe 76 that the proportions of air delivered through the pipe 76 and fuel delivered through the orifice 50 will be substantially constant through a wide range of operating rates at any setting of throttle valve opening.

As the fuel pump pistons 25 move down on the working strokes there may be a slight seepage of mixture upward past said pistons and delivering out of the upper ends of the cylinders 24. Such seepage will be extremely small. Nevertheless, in order to avoid any loss of fuel due to this cause I have provided an arrangement whereby such seepage will be trapped and returned to the interior of the cylinder 24. For this purpose I have provided a shell 78 surrounding the uper portion of each of the cylinders 24 and having its upper end 79 flanged over and turned inwardly a sufficient distance to establish a relatively small central opening 80 for the accommodation of the pump connecting rod 26. This shell 78 establishes an annular passage 81 leading from the upper end of the cylinder and piston downwardly into communication with the inlet air ports 59 already referred to. As a consequence the charges of air drawn inwardly through the ports 59 are received in the first instance from a position around the connecting rod 26 and around the upper end of the piston itself, so that any vapors seeping up past the piston will be trapped and drawn down and restored into the cylinder on the next suction stroke of the piston.

While I have herein shown and described only a single embodiment of the features of my invention, still I do not intend to limit myself thereto, except as I may do so in the claims.

I claim:

1. Fuel supply means for an internal combustion engine comprising in combination means for pumping intermittently in harmony with the working piston movements of the engine, means for delivering primary air charges of size variable under control of the operator, and corresponding charges of fuel, to said pumping means, and connections for the delivery of secondary air supply charges to said pumping means to supplement said primary air charges and establish full volume charges, substantially as described.

2. Fuel supply means for an internal combustion engine comprising in combination means for intermittently forming combustible charges comprising primary air charges of variable size under control of the operator, means for admitting thereto fuel charges in inverse proportion thereto, and means for admitting thereto secondary air charges to supplement said primary air charges to establish full volume charges for delivery to the working cylinder of the engine, substantially as described.

3. Fuel supply means for an internal combustion engine comprising means for intermittently drawing primary air charges through a suitable connection under control of the operator and for drawing fuel charges with said primary air charges and in proportion thereto, connections for supplementing said primary air charges with secondary air charges to establish full volume charges after the fuel charges have been drawn in, and connections for the delivery of all of said charges to the working cylinders of the engine, substantially as described.

4. Fuel supply means for internal combustion engine comprising in combination a reciprocating pump, connections for the sup-

ply of primary air charges to said pump and of volume under control of the operator, and for the supply of corresponding charges of fuel into the pump together with said primary air charges, connections for the supply of secondary air charges to said pump to supplement said primary air charges, and connections for the delivery of all of said charges to the working cylinders of the engine, substantially as described.

5. Fuel supply means for an internal combustion engine comprising in combination a reciprocating pump, connections for the delivery of charges of primary air and fuel to said pump intermittently, means for varying the amount of air in said air charges, connections for the delivery of secondary air charges to said pump after the supply of said primary charges of air and fuel, to supplement the same and establish full charges in the pump cylinder, and connections for the delivery of full charges to the working cylinders of the engine, substantially as described.

6. Fuel supply means for an internal combustion engine comprising in combination a reciprocating air pump, a connection for the supply of primary air and fuel to said pump, means for varying the amount of air taken into said pump at each stroke according to the requirements of engine operation, connections for the admission of secondary air charges to said pump to insure full charges of air for delivery to the working cylinders of the engine, and suitable connections from the pump cylinder for the delivery of said air charges and fuel to the working cylinder of the engine, substantially as described.

7. Fuel supply means for an internal combustion engine comprising in combination a reciprocating air pump including a cylinder and a piston working therein, an inlet connection to the lower end of the cylinder, primary air supply and fuel connections to said inlet connection, a check valve in said connection for retaining the charge against back flow therethrough, a secondary air port extending through the upper portion of the cylinder, said secondary air port being normally covered and sealed by the piston and uncovered by the piston at the upper limit of movement thereof to admit a secondary air charge into the cylinder to establish the full volume of air within the cylinder at the upper limit of piston stroke, together with a suitable delivery connection from the cylinder to the working cylinder of the engine, substantially as described.

8. A method of forming and supplying fuel charges for the operation of an internal combustion engine which consists in intermittently drawing primary air charges of variable amount under control of the operator, aspirating fuel charges into said primary air charges and in inverse proportion thereto, thereafter drawing secondary air charges into said primary charges in quantities sufficient to establish complete charges of definite size, and thereafter delivering said complete charges into the working cylinder of the engine, substantially as described.

9. A method of forming and supplying fuel charges for the operation of an internal combustion engine which consists in drawing intermittent primary charges of air of variable size under control of the operator, and simultaneously drawing fuel charges thereinto in proportion to said primary air charges, and thereafter delivering said primary charges of air and fuel, together with supplemental air charges, into the working cylinder of the engine, substantially as described.

10. A fuel pump for the purpose specified comprising in combination a cylinder, a piston working therein, a mixture inlet valve in the floor of the cylinder, a chamber beneath said valve, an air supply connection leading into said chamber, a fuel port leading into the air supply connection adjacent to the chamber, a fuel supply passage leading to said port, means for delivering fuel to said passage and an expansion chamber in close proximity to the position of said port and having its lower portion in communication with the fuel supply connection, the upper portion of said expansion chamber being sealed in air tight fashion substantially as described.

11. A fuel pump for the purpose specified comprising in combination a cylinder, a piston working therein, a mixture inlet valve in the floor of the cylinder, a chamber immediately beneath the said valve, an air supply connection leading into said chamber, a fuel supply port in the lower part of the air supply connection adjacent to said chamber, a needle valve controlling said fuel supply port, a connection for the delivery of fuel to said port in regulated elevation and a sealed chamber adjacent to the needle valve and in connection with the fuel supply at a point below the fuel supply port, substantially as described.

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