May 7, 1946. L. W. BEAVEN 2,399,783

FUEL PREHEATING DEVICE

Filed Oct. 4, 1943

Fig. 1

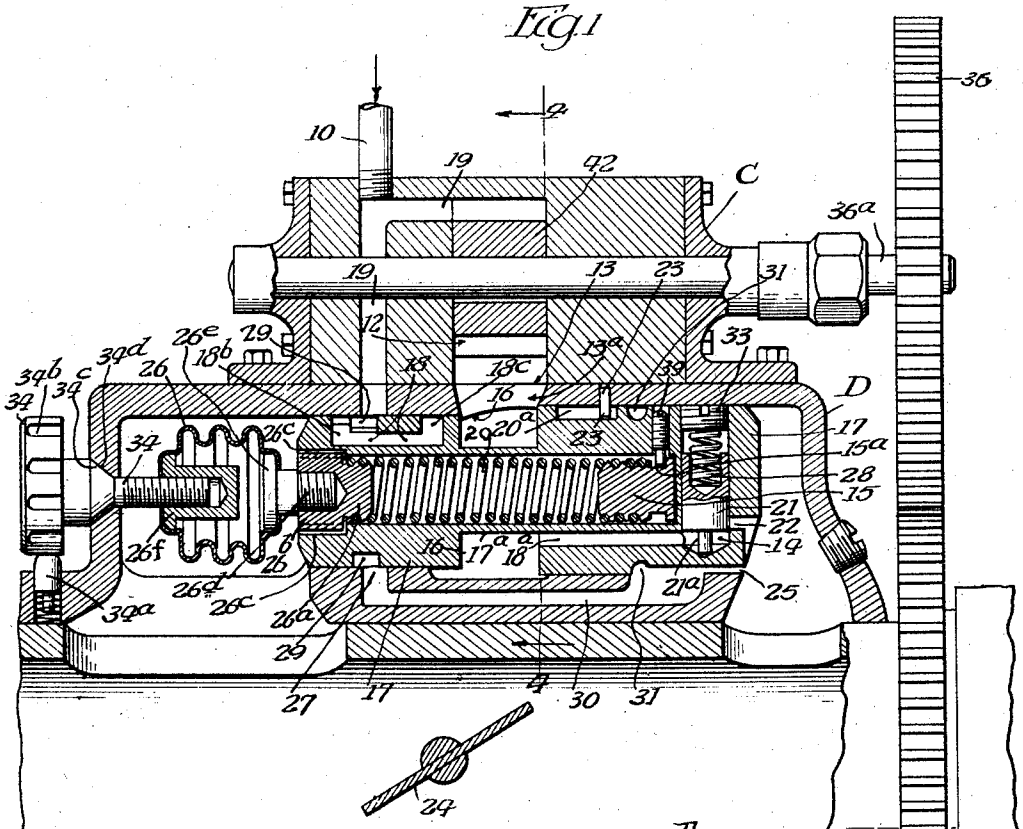


Fig. 2

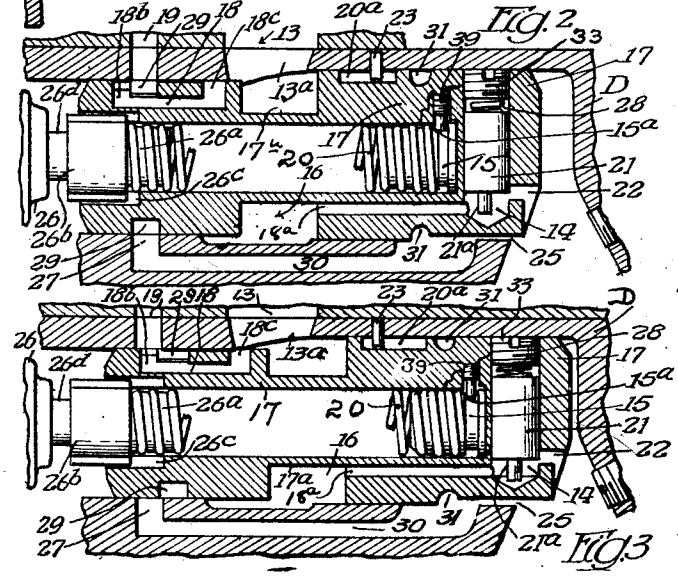
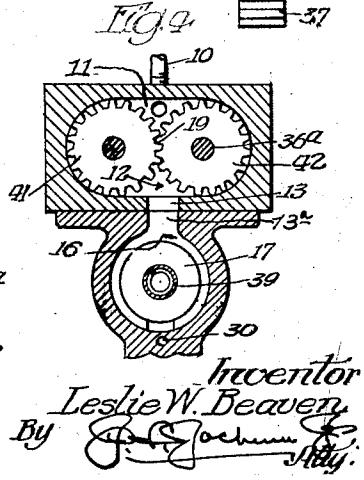


Fig. 3



Fig. 4



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2,399,783

## FUEL PREHEATING DEVICE

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Application October 4, 1943, Serial No. 504,873

6 Claims. (Cl. 261—29)

This application is a continuation in part, of application, Serial No. 474,421, filed February 2, 1943, which latter application is in turn a continuation of original application, Serial No. 400,811, filed July 2, 1941.

The present invention relates to an improved device for feeding the relatively heavy fuel oils as a dispersion of air in oil, to internal combustion engines with spark ignition, thereby replacing the usual carburetors which are employed for the lighter volatile, more expensive, and more inflammably dangerous fuels such as gasoline, naphtha, etc. The device is particularly adapted for use with the well-known revolving radial cylinder type of aeroplane engine, and in the accompanying drawing this improved device is shown, although only the engine feed pipe is illustrated. In the specification, the expression "dispersion of air in oil" is used to designate a mixture of air in liquid fuel, such as gas-charged bubbles in fuel oil.

The apparatus is co-ordinated with an oil pump of the positive type preferably a gear pump, with a special kind of by-pass relief valve to shunt, from the pressure side to the intake or suction side of the pump, the excess of oil which is not required for the fuel consuming unit which it is designed to feed. The apparatus is so proportioned to its task that there is a considerable circulation of excess oil through the by-pass, and it is so arranged that primary air is drawn into the oil circulating in this by-pass, where said air is mixed and whipped by the action of the gear teeth into a suitable dispersion of air in oil. Moreover, since this is caused to occur under a selected pressure, any desired heat can be promptly generated by compression, and the tiny bubbles of the mixture are thereby caused to be filled with the explosive vapors of the lighter fractions of the fuel oil, the heavier ends forming the envelope of each bubble. That part of the mixture which is allowed to escape for use as fuel, escapes to a lesser pressure. Upon release then, the bubbles burst, violently shattering the films of heavy oil around them, while the released vapors within the bubbles condense as infinitesimal fog particles, due to the drop in temperature which is a natural phenomenon of such pressure release. The device, therefore, within a few seconds transforms a comparatively heavy fuel oil which it is normally impossible to ignite cold, into a combustive explosive fuel, which is sufficiently unstable, when turbulently mixed with the secondary intake air and is recompressed in the engine cylinders, to be ignited by electric spark. The device also has the ability to fluctuate its fuel feed automatically, in direct proportion to speed and to the density of the secondary air in the air intake pipe of the engine, so that the proportions of fuel and oxygen set by manual adjustment are not disturbed by air density changes or engine load. This feature is particularly suited to aeroplane engines, wherein intake air pressures fluctuate from fractions of an atmosphere at great elevations, to plus sea level pressures in supercharging for maximum power.

The present invention effectively performs these functions by controlling the thickness of the sheet of the dispersion of air in oil that is issued from a spray-port into the intake conduit leading to the engine.

The primary object of this invention is the elimination of fire losses in aviation, of lives and property, resulting from fuel fires, by enabling the use of safe fuel oil for fuel instead of the highly dangerous and more expensive gasoline, whose toll is already appalling; and by methods which are much more simple and efficient than those of other fuel oil burning power equipment now in use.

The first essential is to preheat the fuel by mixing it with air to form a foamy emulsion, or dispersion of air in fuel oil, and by compressing said foam to make it hot, thereby causing the lighter and more volatile fractions to be vaporized into the heated air within the bubbles comprising the foam, thereby forming a tinder which when recompressed in the engine it is designed to feed, can be ignited by electric spark and which when ignited will enkindle the heavier fractions comprising the fragments of the envelopes of the bubbles. A necessary step is the fragmentation or atomization of that part of the fuel not evaporated by the heat of compression, which is principally the part forming the films or envelopes of the bubbles. This occurs when they escape from the compression of the fuel pump, to the lesser pressure in the engine feed pipe, where they explode violently from internal pressure, shattering the film into fine fragments which can be further heated by the hot parts of the engine thru which the mixture passes on its way to the firing chambers in the cylinders.

This hot foamy emulsion is formed in the pump and by-pass channels connected thereto, air being picked up by the suction side of the pump from the engine feed pipe on the engine side of the throttle, and whipped and mixed with the

oil by the pump gears as it is forced repeatedly around the by-pass circuit and simultaneously compressed by the pump.

Another object is to feed the heated foamy emulsion to the engine in substantially the proper proportions to satisfy the chemistry of efficient combustion within the cylinders, and thruout the full range of air density variations encountered in service.

The problem of apportioning the weight of fuel to the weight of air in a proper fuel air ratio involves a positive pump, positively driven by the engine so that there is a constant ratio between fuel pumped and air drawn in by the engine, at a density of one. This fuel air ratio is approximately 1:15 at sea level. At 20,000 feet where the density falls to .532 the ratio enriches to $\sqrt{.532}\times 15$ or about 1 to 11, varying as the square root of the density, and therefore means are required to compensate for density variations.

The means I have provided is a fuel by-passing valve in the form of a differential piston whose ends are of slightly different diameters, with a narrowed neck in its intermediate portion, said piston slidably mounted in a case or cylinder, slip fitted to the two diameters, and so mounted with reference to the engine throttle that the air pressure on each side of the throttle is exerted separately on each end of the piston, the larger end area being exposed to the air pressure on the engine side of the throttle and the smaller to the incoming ambient air, or compressed ambient air if the engine has a supercharger.

The fuel pressure is exerted about the mid section of the differential piston, so that increased pressure causes the piston to move longitudinally toward the larger diameter, which is to the right in the drawing, to a fuel by-passing position to relieve the pressure, said movement being opposed by an adjustable regulating pull spring, said spring opposition being in turn opposed by the net pneumatic thrust on the said differential piston, induced by the resistance to air flow, imposed by the throttle, which is located interveningly between the exposed ends of said differential piston 17. The characteristics of the spring are such as will compensate in the ratio required as before shown. Compensation for density changes due to temperature changes, is provided by Sylphon bellows, thermostatic bi-metal coil, or other suitable means. But no further means is required for density changes due to altitude, because throttle position effects the pressure drop across the throttle, and it is immaterial whether the density of air being fed to the engine is changed by altitude or throttle.

Among other objects, the invention aims to provide a device of the character herein described, which is simple in construction, novel in the arrangement of its parts, and dependable in the performance of its functions. Furthermore, this improved feed and preheating device is economical to manufacture, and it may therefore be sold at a reasonable retail price to the user. Other objects, advantages, and characteristics will be apparent from the following specification and claims.

In the drawing:

Fig. 1 is a view, partly in vertical section and partly in elevation, of this improved fuel preheating device installed upon the intake conduit or hollow main shaft of a rotary, radial cylinder engine, the position of the ports indicating the engine is just starting.

Fig. 2 shows the position of the ports at approximately full feed.

Fig. 3 shows the position at approximately full by-pass.

Fig. 4 is a detail sectional view, on a smaller scale, of the pump.

The drawing is to be understood as being more or less schematic, and it is for the purpose of disclosing details of a preferred form in which this improved fuel feeding apparatus may be made.

For the purpose of illustration the apparatus is shown and herein described as applied to a spark-ignited internal combustion engine of the rotary radial cylinder type. The letter A designates an intake pipe or conduit such as a hollow main shaft of the engine, and is stationary, while the cylinders, (not shown), revolve about the same. The atmospheric air enters the pipe A and is controlled by the usual engine throttle or butterfly valve 24 which is preferably manually operated. The rotating gear 37, that turns with the engine cylinders, is preferably disposed about the intake pipe or main shaft A, and said gear is in mesh with a gear 36 that is fast upon the pump spindle 36*a*. The pump casing C is suitably anchored to the intake pipe preferably by straps $C^1$ and comprises meshed gears 41 and 42, the latter of which is secured to the spindle 36*a*. An oil inlet pipe 10 leads into the suction intake side 11 of the pump casing C to supply the fuel to the pump, and there is a discharge duct 13 leading out of the compression side 12 of the pump casing. The inner face of the pump casing C is suitably shaped to facilitate holding or otherwise securing it to the adjacent face of the control valve casing D.

In the valve casing is a reciprocatory piston 17, which is of a length and diameter to substantially fill the bore of the casing D, and substantially midway of its length its diameter is reduced to provide a neck portion 17*a*, adapted for registration with an annular pressure chamber 16 that is partly formed in the inner face of the casing wall. The pressure chamber has an inlet port 13*a* that communicates with the lateral discharge duct 13 from the pump and receives the fuel under pressure from the latter. The ends of the piston 17 are exposed, and are both acted upon by fluid pressure in the pipe A, one on one side and the other on the other side of the throttle 24. When the fuel under sufficient pressure passes through the duct 13 into the chamber 16, the piston 17 will be moved to the right from the position shown in Fig. 1, as it has a slightly larger diameter on the engine side of the neck portion 17*a* than on the other side.

A delivery duct 18*a* for the fuel oil leads from the larger shoulder of the neck in the valve body, and said duct communicates at its end with a chamber 14 that is provided with a spray discharge port 22 through the end of the piston 17. The chamber 14 provides a guide or housing for a small hollow valve plunger 21 that is disposed with its axis transverse to the axis of the main valve piston or body 17, and may be provided with a stop 21*a* projecting from its inner end, that is adapted to abut the inner end of the bore forming the chamber 14. This spray-valve piston 21, when at rest, normally closes the spray-port 22, and it is maintained in this position by means of a spring 28, the stress of which may be controlled by a screw member 33.

The valve or piston 17 is provided with a longitudinal opening in which is arranged a coil ten-

sion spring **20**, one end of which engages about a plug **15**, the latter being provided with a circumferential recess **15***a*, into which pins **39** project to maintain the plug seated. The plug has a free fit within the piston, adapting it to automatically aline itself with the fitting at the other end of the spring. The other end of the spring is threaded about a reduced portion **26***a* of a member **26***b*, a portion of the latter being shaped to fit recesses **26***c* in the end of the piston **17** to maintain it against rotation with respect to the piston, but for movement, under adjustment, lengthwise of the piston to vary the tension or stress thereof. A suitable temperature compensator **26**, such as of a bellows type, is connected to the spring **20** by means of a screw **26***d*, screwed into the member **26***b*, the head **26***e* being secured to the compensator. Secured also to the compensator **26** is a nut **26***f*, and into this nut is screwed an adjusting device **34** having a beveled portion **34***c* seated in a recess **34***d*, to prevent rotational creeping. A spring-controlled locking device **34***a* engages in suitable recesses or notches in the head of the adjusting device **34**, to lock the parts controlled thereby in adjusted position. By the use of this mechanism, the automatic action of the piston **17** may be controlled and varied.

Annular grooves **31** and **29**, the latter also functioning as part of an air bleed channel later described, are provided in the piston **17**, and are adapted to recover seepage, and drain the same into a return passage **30** which extends through the wall of the casing to a narrow slot or bleeder port **27**, and thence to passage **19**. A passage **25** is provided in the casing D, which communicates with the passage **31**, so that an air inlet duct will be provided, and which also has communication with the return passage **30**.

The valve piston or body **17** is provided with a passage **18** to the left of the neck portion **17***a*, and is adapted to form communication between the pump discharge opening **13** and a by-pass return duct or passage **19** leading to the pump casing. This passage **18** also has communication with a longitudinal channel **18***c* in the piston **17**. The disposition of the groove **18***c* and the other end **18***b* of the passage **18**, are such that when the valve piston **17** is in the position shown in Fig. 1, the passage **18** will be closed at the end **18***c* but the end **18***b* will be open to the passage **19**, via the portion of passage **29** which intersects and connects with passage **18**. When the piston is moved so that the circumferential groove **29** is in registration with the passage **19**, it will also be in communication with the narrow opening or slot **27** and, by reason of the narrow slot **27**, the air flow will be restricted, thereby avoiding excessive loss in the suction required to draw in fresh fuel oil from the inlet pipe **10**. In the drawing, Fig. 1, the piston **17** is shown in the position it will assume when the engine is just starting.

In order to maintain the valve piston **17**, at all times, in proper relation to the various parts and passages, and prevent its rotation thereof, there may be provided a key-way slot **20***a* in the piston, into which a pin or projection **23** extends, which pin is supported by a fixed portion of the casing and also acts as a stop.

It is thought that the operation of this improved feed device will be fully understood from the foregoing description, but, briefly stated, it is substantially as follows:

The engine or motor is initially rotated by either manual or mechanical means, and a jet of priming gasoline is preferably sprayed into the intake passage A, in any suitable manner (not shown), to serve for starting the engine. The cranking movement causes the gear **36** to turn in a direction to compress the oil in the pump and force the fuel through the discharge duct **13** into the casing D, filling the annular compression chamber **16**, which extends around the neck **17***a* of the piston **17**, and also filling the channel **18** as well as the chamber **14**, whereupon the pressure rises until a sufficient force is exerted against the head of the spray-valve piston **21**, to force it backwardly against the stress of the spring **28**, until the port **22** is opened to allow some of the oil to escape. By this time the priming gasoline will have caused the engine to start, and the speed pickup from cranking speed to running speed, increases the hydraulic pressure too fast to be relieved through the port **22**, as the capacity of the pump is intentionally excessive, in order to insure an adequate circulation in the by-pass channels at all times. There is then a continuing rise of pressure in the casing D, which acts with greater thrust on the right barrel of the plunger or piston **17** than on the left barrel, due to the larger diameter of the former. This will shift the plunger or piston when such pressure overcomes the exerted pressure of the spring **20**.

Air which enters from the intake passage A, through channel **25**, will pick up, from the annular grooves **31** and **29**, any seepage oil that is deposited therein. The air will pass through the channel **30**, port **27**, passage **29**, and duct **19**, to the intake or suction side **11** of the pump chamber, where it is picked up by the pump gears and compressed, along with the oil, to make the hot emulsion. The capacity of the air bleed slot **27** is made inadequate to abort the vacuum generated on the intake side of the pump at running speed, and it may be completely closed at cranking speed if desired, by lengthening the slot **20***a*, so that the spring **20** will pull the piston **17** far enough to the left. At starting, no emulsion is needed, as the engine is then running on gasoline. The degree of opening through slot **27** at the time is a matter of choice, depending on the particular installation on which the device is to be used and the amount of resistance to flow in the fuel feed pipe lines, due to the lift and other resistance to flow. A nominal resistance is necessary, to prevent the engine suction from drawing fuel past the pump and through the restricted air bleed passages, so that the pump may draw air away from the engine intake manifold through the air bleed passages. As shown, the device is adapted for installations where the fuel tanks are below the pump, and the total line resistance is sufficient, without other means. In practice, the engine throttle is never closed and therefore the pressure drop across the orifice **25** is never very great. When the engine is running, the hydraulic pressure from the pump holds port **22** open and there are then two fuel paths open to the engine, one through port **25** and the other through port **22**. The engine suction is equal on the two ports and is on opposite sides of the fuel pump but the running pump unbalances this condition, for its suction is made superior to that of the engine and opposite in direction. Therefore air is drawn from the engine intake, through the air bleed channels **25—30—27—29—19** to the pump, to make the emulsion. The air bleed channel is made subject to the vacuum existing in the engine intake pipe, rather than to ambient air pres-

sure so that the portion of air used for foaming, will be as tenuous as the air used for combustion, thereby preserving a constant fuel-air ratio in the emulsion. The bleeding of a restricted amount of air into the suction side of the pump of course reduces the pump vacuum somewhat, but the flow of air and oil in the two branches will still be inversely proportional to their resistances and flow will still be maintained in the fuel pipe so long as the remaining vacuum in the supply pipe 10 is sufficient to overcome the flow resistance in that line.

After the engine has started a further increase of speed will increase the movement of the piston 17 to the position where the passage 27 in the casing D will register fully with the annular passage 29 in the piston 17, that is, to the full fuel load position, and the full open position of the air-bleed line, as shown in Fig. 2. This is necessary because maximum fuel feed requires maximum primary air for maximum emulsion.

Any further movement of the piston in the same direction will open the pressure relief by-pass, by bringing the passage 18c into communication with chamber 16, whereby oil will escape through the passages 18c, 18, 18b, and duct 19, to the pump chamber 11. The relief of the pressure will not be complete, but it is halted by the tendency of the spring 20 to throttle the by-pass, resulting in a measured escapement of the oil at the spray port 22, due to a related pressure in the chamber 14.

The pump, having an intentional surplus capacity, causes continuous and rapid by-passing of the fluid, which whips and intimately compresses the emulsion, making it homogeneous, fine-textured and hot. It must be remembered that the rise in temperature of air is as instantaneous as is the rise of pressure.

It is an instantaneous result of compressing a given amount of specific heat in a given amount of air, into a smaller space, thereby achieving a higher concentration of heat, as well as of air, without any time loss.

The priming gasoline is soon consumed, but the fuel oil is quickly prepared, and fuels the engine, which, as soon as it is warmed up, will respond to throttle changes without distortion of the fuel and air proportions to which the device has been adjusted, notwithstanding that throttle changes cause variations in the density of the air entering the engine.

The thermostatic means 26 shown, is a Sylphon gas filled bellows and is adapted in its manufacture to increase its coupled length upon heating and to shorten it upon cooling. This faculty will cause it to correct the tension of the regulating spring 20, for temperatures other than that to which it had been previously set, thereby correcting for changed density of ambient air due to variations in the temperature thereof.

It will be seen that both ends of the piston 17 are exposed to and are affected by the same barometric variations or air pressure changes on each side of the throttle, which occur in the passage A. Any sudden reduction of throttle will cause the spinning engine to suddenly raise the degree of vacuum in passage A on the engine side of the throttle 24. It must be remembered that the initial adjustment of the running engine is made under a certain vacuum in passage A. A more closed throttle creates a higher vacuum, while a wider throttle creates a lower vacuum. The higher vacuum reduces the fuel feed by shifting the piston against the adjusted spring tension on the piston 17. Upon opening the throttle, the vacuum falls and the increased air pressure adds to the adjusted spring tension. The actual fuel feed changes occur in the form of changes in the size of the jet of emulsion issuing from the spray-port 22 as a direct result of the movements of the piston 21, which is brought about by changes of the hydraulic pressure upon the emulsion through the by-pass variations.

The only function of the vacuum control is to modify the rate of the fuel flow to the engine, in direct proportion to the relative density of the air flow. The air and fuel required by the engine is proportional to its revolutions, times relative density, and the pump being geared to the engine, pumps in direct proportion to the engine speed. The vacuum control, through the medium of the piston 17, spring 20, throttle and other parts, modifies the fuel feed rate, in direct proportion to the relative density of the air. This preserves the proportions required for combustion at all densities and speeds, regardless of altitude, throttle position or load.

While the preferred form of the invention has been shown and described, it is to be understood that various changes may be made in the details of construction and in the combination and arrangement of the several parts, within the scope of the claims, without departing from the spirit of this invention.

What is claimed as new is:

1. A fuel preheating device embodying a hollow casing; an elongated piston reciprocable therein; a lateral shoulder on said piston; said casing provided with an annular channel adjacent said shoulder; said casing having an inlet passage communicating with said channel; a pump adapted to force fuel under pressure into said inlet passage, whereby to move said piston; a spray-port in the end of said piston; an automatically returnable valve normally closing said spray-port; means establishing communication between said spray-port and said annular channel, whereby fuel under pressure is rendered effective upon said valve to move the latter; means embodying an intake conduit in said casing adapted to feed air into the suction side of said pump, whereby an emulsion of fuel and air is created within said pump; and a by-pass in said piston opened by movement thereof adapted to control pressure in said casing by establishing communication between said inlet passage and said conduit.

2. A fuel preheating device embodying a hollow casing, an elongated piston reciprocable therein; said casing provided with an annular channel; said casing having an inlet port communicating with said channel; a pump adapted to force fuel under pressure through said inlet port to said channel; means on said piston that is influenced by the pressure of the fuel thereon to move said piston; a spray-port in the end of said piston discharging through one end of said casing; an automatically returnable valve normally closing said spray-port; means establishing communication between said spray-port and said annular channel, whereby fuel under pressure is rendered effective upon said valve to move the latter; means embodying an intake conduit in said casing adapted to feed air into the suction side of said pump, whereby an emulsion of fuel and air is created within said pump; and a by-pass in said piston opened by movement thereof adapted to control pressure in said

casing, whereby excess pressure is shunted back to the suction side of said pump.

3. A fuel preheating device embodying a feed pipe; a casing into said feed pipe; an elongated piston reciprocable in said casing; a lateral shoulder on said piston; said casing provided with an internal annular channel adjacent said shoulder; an inlet port communicating with said channel; a pump adapted to force fuel under pressure through said inlet port against said shoulder to move said piston; a valve-controlled spray-port in the said piston discharging into said feed pipe; means establishing communication between said spray-port and said annular channel, whereby fuel under pressure is adapted to actuate the said valve, whereby to regulate the thickness of the spray sheet; and means extending from an open end of said casing to the suction side of said pump, said means adapted to supply air to said pump, whereby an emulsion of fuel and air is created, said means including a by-pass in said piston opened by movement thereof.

4. A fuel preheating device embodying a casing, a piston reciprocable therein; a by-pass in one end of said piston; said casing provided with an internal annular channel; an inlet port communicating with said channel; a pump adapted to force fuel under pressure through said inlet port to said channel, whereby to move said piston towards one end of said casing; an outlet port in another portion of said casing discharging into the suction side of said pump; a spray-port in the said piston; means extending through said piston establishing communication between said spray-port and said annular channel; an automatically returnable valve interposed in said means and normally closing said spray-port, whereby fuel under pressure is adapted to move said valve; and a conduit leading from the said casing to said piston by-pass, said conduit adapted to receive fuel seepage and air from outside said casing and convey the same to said pump through said by-pass and discharge port, whereby an emulsion of fuel and air is created in said pump.

5. A fuel preheating device embodying a feed pipe; a casing opening into said feed pipe; a piston reciprocable in said casing; a by-pass in the said piston; said casing provided with an internal annular channel; an inlet port communicating with said channel; a pump adapted to force fuel under pressure through said inlet port to said channel, whereby to move said piston towards one end of said casing; an outlet port in another portion of said casing discharging into the suction side of said pump; a valve-controlled spray-port in the said piston discharging into said feed pipe; means extending through said piston establishing communication between said spray-port and said annular channel, whereby fuel under pressure is adapted to move said valve to control the thickness of the spray-sheet; and a conduit leading from the said casing to said piston by-pass, said conduit adapted to receive fuel seepage, and air from outside said casing, and convey the same to said pump through said by-pass and discharge port, whereby an emulsion of fuel and air is created in said pump.

6. A fuel preheating device embodying a casing having an open end; a piston reciprocable therein; a neck dividing said piston into two portions, one of which is wider than the other; a by-pass in one portion of said piston; said casing provided with an internal annular channel, said channel together with the space between the said portions of the piston providing a compression chamber; an inlet port communicating with said chamber; a pump adapted to force fuel under pressure through said inlet port to said chamber, whereby to move said piston towards one end of said casing; an outlet port in the said casing discharging to the suction side of said pump; a valve-controlled spray-port in the said piston; means extending through said piston establishing communication between said spray-port and said compression chamber, whereby fuel under pressure is adapted to actuate the valve controlling said spray-port; means for conveying air through said casing and said piston to said pump; and means for shunting fuel from said compression chamber through said piston and returning the shunted fuel to said pump.

LESLIE W. BEAVEN.