Jan. 11, 1938. B. P. DAWES 2,104,974

FUEL HEATER FOR INTERNAL COMBUSTION ENGINES

Filed June 15, 1936 3 Sheets-Sheet 1

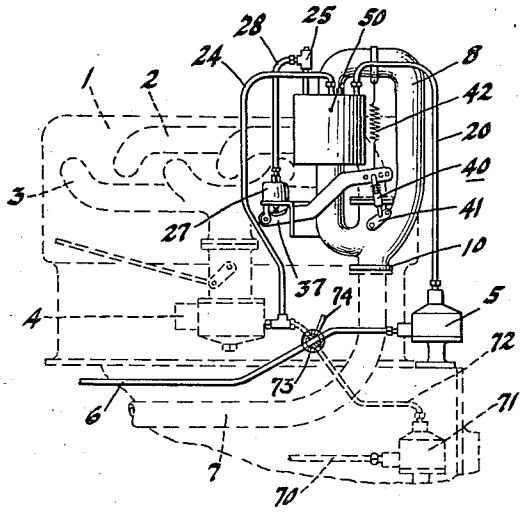

Fig. 1

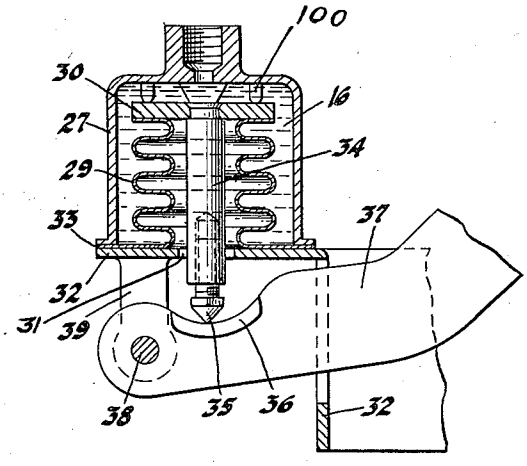

Fig. 4

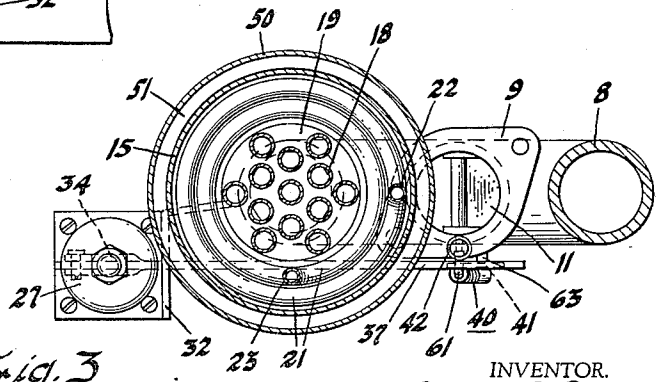

Fig. 3

INVENTOR.
Bailey P. Dawes
BY
Barnes, Kisselle, Laughlin & Raisch
ATTORNEYS

Jan. 11, 1938. B. P. DAWES 2,104,974

FUEL HEATER FOR INTERNAL COMBUSTION ENGINES

Filed June 15, 1936 3 Sheets-Sheet 2

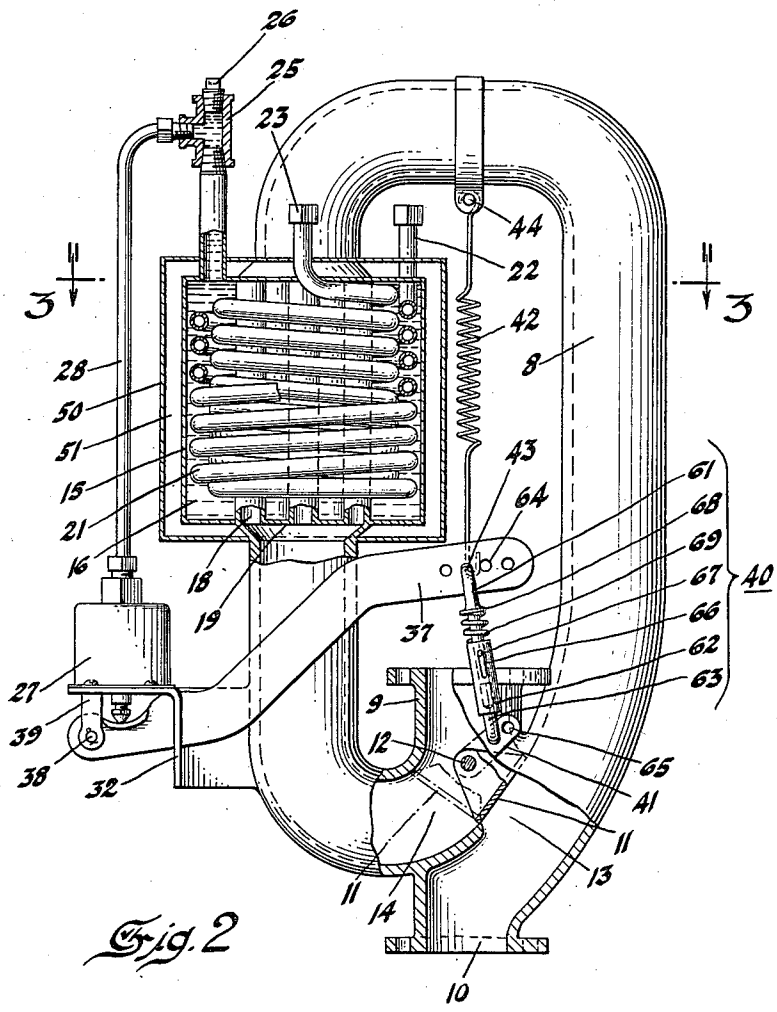

Fig. 2

INVENTOR.
Bailey P. Dawes
BY
Barnes, Kisselle, Laughlin & Raisch
ATTORNEYS.

Jan. 11, 1938. B. P. DAWES 2,104,974

FUEL HEATER FOR INTERNAL COMBUSTION ENGINES

Filed June 15, 1936 3 Sheets-Sheet 3

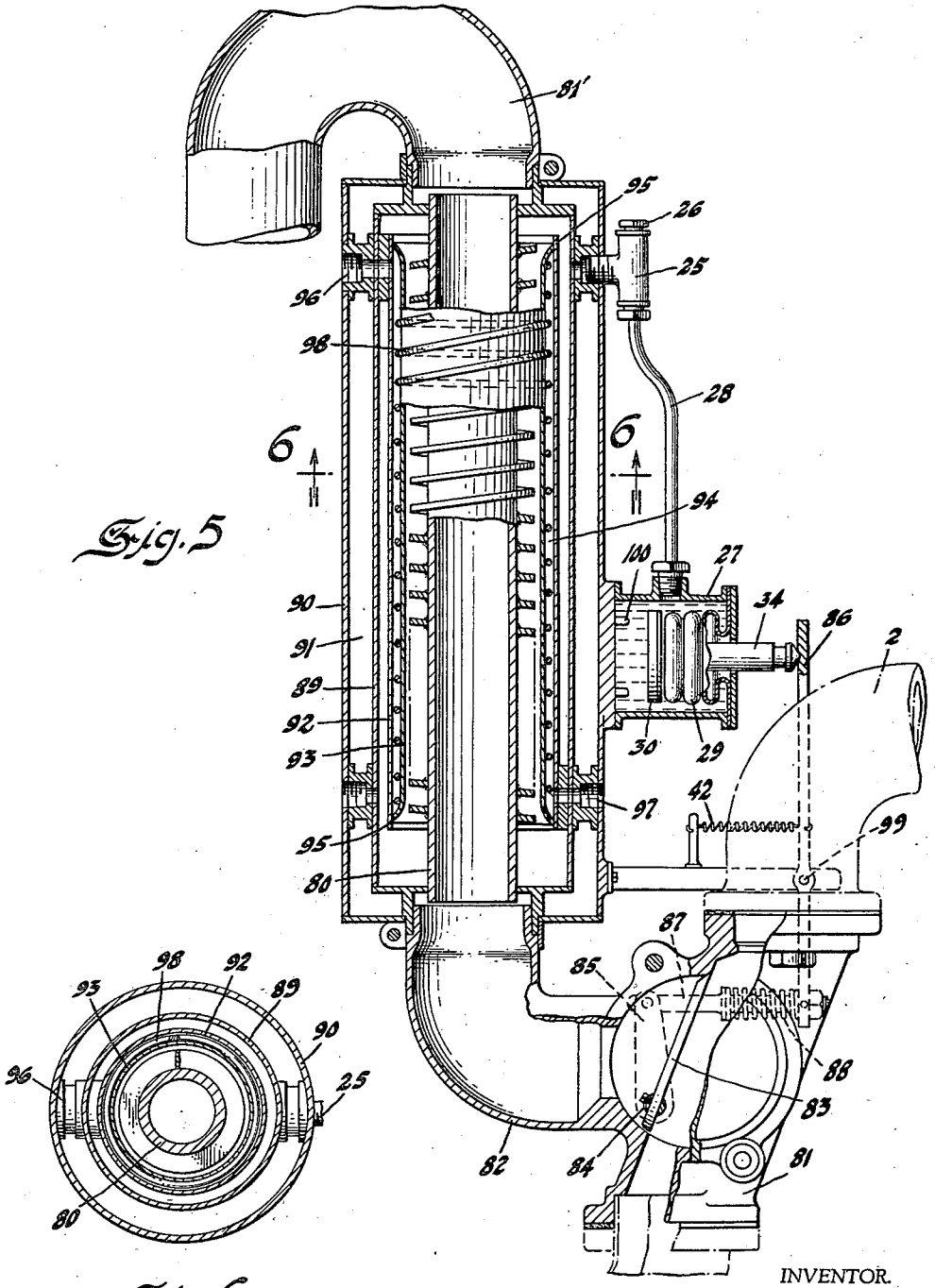

Fig. 5

Fig. 6

INVENTOR.
Bailey P. Dawes
BY
Barnes, Kisselle, Raughlin & Raisch
ATTORNEYS.

UNITED STATES PATENT OFFICE

2,104,974

FUEL HEATER FOR INTERNAL COMBUSTION ENGINES

Bailey P. Dawes, Detroit, Mich.

Application June 15, 1936, Serial No. 85,203

15 Claims. (Cl. 257—2)

This invention relates to a fuel heater for internal combustion engines. This application is a continuation in part of copending application Serial No. 13,454, filed March 28, 1935.

In the operation of the fuel heating device shown in the above-mentioned copending application, it has been found highly desirable to control the temperature range of the fuel which is being heated within a very few degrees. The exact temperature and the permissible range within which this temperature may vary will depend upon the type of fuel that is being conditioned. Where ordinary domestic fuel oil was heated preparatory to being passed through a carburetor installed as standard equipment on a well-known make of passenger car and then burned in the motor of this car, it was found that the most desirable temperature for this fuel oil when used in this motor was about 275° F. When this temperature of the heated fuel varied only 5° F. above or below the desired temperature of 275° F. poorer performance on the part of the motor was noticeable. This indicates very clearly that a high degree of accuracy in the control of the temperature to which the fuel is heated before being passed through the carburetor is very desirable.

The patent to Gerli, et al. 1,323,264 shows a heater for use with internal combustion engines in which the exhaust gases are utilized for the purpose of raising the temperature of the fuel prior to the time the fuel is fed to the carburetor. The structure shown by Gerli, et al. includes a housing and a conduit through the housing for the purpose of passing gas from the exhaust of the motor through the housing. The housing is partially filled with a liquid heat transferring solution which serves to transfer heat from the exhaust conduit to an auxiliary chamber located within the housing in contact with the heat transferring medium, which chamber is adapted to contain liquid fuel. The inventors contemplated the use of a water and alcohol solution for the heat transfer liquid. A bypass for the exhaust is provided and cooperates with a butterfly valve so that the hot gases from the exhaust motor may have any desired portion thereof directed through the chamber to heat the heat transfer liquid. This butterfly valve is controlled by means of a diaphragm, one side of which is exposed to the interior of the housing and consequently, when the liquid within the housing boils, the pressure of the vapor therefrom acts upon the diaphragm which in turn actuates the butterfly valve to reduce the proportion of the exhaust gases passing through the housing and consequently reduce the amount of heat applied to the heat transfer liquid.

Whereas Gerli, et al. use vapor pressure to control their bypass exhaust valve and thereby incur the dangers incident to the use of vapor pressure, the instant invention contemplates utilizing the expansion of the heat exchange liquid to hydraulically control the exhaust bypass valve. In order to heat their fuel to a different temperature Gerli, et al. have to change the proportion of his alcohol-water mixture whereas in the instant invention it is merely necessary to increase or decrease the actual amount of heat exchange liquid used. Further, by using hydraulic pressure created by the expansion of the heat exchange liquid, the instant invention makes available considerable more power for operating the exhaust control bypass and obtains a much more sensitive thermostatic control than could be obtained by the use of vapor pressure. This permits the controlling of the temperature of the fuel within a much smaller temperature range than possible with the Gerli, et al. type of vapor pressure controlled heater.

It is an object of this invention to produce a device for heating fuel preparatory to being burned in an internal combustion engine to a temperature which will be accurately controlled under all operating conditions. This object has been achieved by coordinating the temperature to which it is desired to heat the fuel with a predetermined volume of a liquid in heat exchange relation with the exhaust gases, the said liquid having a sufficiently high boiling point so that it will not vaporize during the normal operating temperature ranges to which it is subjected, so that the expansion and contraction of the liquid itself incident to the rise and fall of the temperature of the liquid is utilized to control the flow of exhaust gases through the heater and thereby maintain the temperature of the fuel approximately constant. In particular this object has been achieved by utilizing the expansion and contraction of the liquid semi-insulator or heat conductor which conducts the heat from the hot exhaust gases to the fuel for effecting accurate control of the temperature to which the fuel is heated. The expansion and contraction of this semi-insulator operates through a bellows which is connected with a by-pass valve in the exhaust line which regulates and controls the amount of exhaust gases permitted to pass through the heater.

This invention also contemplates a fuel heat-

ing device for an internal combustion engine which accurately heats the fuel to a predetermined desired temperature under all operating conditions regardless of whether the motor is idling or whether the car is being driven at a high speed. In other words, the heater heats the fuel to an approximately constant predetermined desired temperature irrespective of whether a large amount of heat is available in the exhaust gases for heat exchange as when the motor is running at high speed, or whether a lesser amount of heat is available for interchange, as when the motor is idling, and irrespective of the amount of air which is passing around the motor and heater to air cool the same.

In the drawings:

Fig. 1 shows the improved fuel heater assembled with any well-known type of internal combustion engine having a conventional carburetor and fuel pump.

Fig. 2 is a vertical sectional view partly in elevation of the fuel heater.

Fig. 3 is a section along the line 3—3 of Fig. 2.

Fig. 4 is a detail of the bellows and lever arm for controlling the exhaust by-pass valve.

Fig. 5 shows a view similar to Fig. 2 of a modified form of the heater.

Fig. 6 is a section along the line 6—6 of Fig. 5.

Referring more particularly to the drawings there is shown a conventional form of internal combustion engine 1 having an exhaust manifold 2 and a fuel intake manifold 3. The fuel intake manifold 3 is connected with a conventional carburetor 4. The motor is also provided with a fuel pump 5 which is connected with a fuel supply line 6 leading to any suitable fuel supply reservoir.

Inasmuch as the fuel heater or conditioner utilizes the heat of the exhaust gases, it is preferably mounted between the exhaust manifold 2 and the exhaust pipe 7. The conduit for connecting the exhaust manifold 2 with the exhaust pipe 7 is herein shown as a pipe in the form of a loop 8 having an inlet 9 and an outlet 10. A butterfly valve 11 is pivotally mounted in the pipe 8 on the pin 12 to control the ports 13 and 14. In the position shown in the full lines of Figure 2, the exhaust gases will pass from the manifold 2 through the inlet 9, then through the pipe 8 and the outlet 10 into the exhaust pipe 7. When the butterfly valve is moved to the dotted line position, the port 13 will be opened and the port 14 closed thus cutting off the flow of exhaust gases through loop 8. Consequently the exhaust gases will pass from the manifold through the inlet 9 and directly through the outlet 10 into the exhaust pipe 7. At this time, of course, some of the gases will pass upwardly in a counterclockwise direction (Figure 2) in the loop 8, but the valve 11 being closed the port 14 will prevent any appreciable circulation of gases through the loop 8.

The heater comprises a casing 15 which is filled with any high boiling liquid 16 such as paraffin or any other mineral wax, corn oil, glycerin and the higher boiling alcohols and glycols, such as ethylene glycol. In selecting the heat conductor or semi-insulator for use in the casing 16 several factors must be considered; first, the conductor preferably should be a high boiling liquid that will not vaporize when brought in contact with the exhaust conduit and heated to a temperature within the temperature ranges encountered during the normal operation of the heater; secondly, the conductor likewise should not carbonize when brought in contact with the exhaust conduit; thirdly, the conductor should not conduct sufficient heat to the fuel in the heating coil at a temperature high enough to carbonize this fuel. Among the numerous liquids which will satisfy these conditions the above-mentioned liquids have been found suitable. It is, of course, understood that these liquids are in a liquid state when the vaporizer is in operation, that is, when the hot exhaust gases are passing through the conduit but when the engine is not running, the paraffin or other high boiling liquid may solidify if the same is of a solidifying nature at the atmospheric temperatures encountered.

For heating the heat transfer liquid 16 within the casing 15, the casing has mounted therein a multi-tubular heating unit comprising a plurality of parallel tubes 18 through which the hot exhaust gases pass. The tubes 18 are mounted in the head 19 at each end of the casing 15. The tubes 18 communicate with the exhaust gas conduit 8 but are sealed with a fluid-tight seal to the head 19 so that none of the liquid 16 within the casing 15 will escape into the tubes and exhaust conduit. The liquid 16 will circulate about the tubes in heat exchange relation therewith. Such a multi-tubular heater effects a very rapid heating of the heat exchange liquid within the casing 15 and consequently rapidly heats the fuel within the fuel line.

The fuel may be conducted from the fuel tank into the heater in any suitable manner. As shown, the fuel line 6 is connected with the pump 5 which forces the fuel through the fuel line 20 into the heating coils 21. The fuel line may be coiled about the multi-tubular heater in spaced relation therewith and in spaced relation with the casing 15 as many times as desired. As herein shown, the fuel line is coiled about the heater twice. The fuel enters the heating coil as at 22 and is exhausted from the heating coil at 23 where it is conducted by the pipe line 24 to the carburetor 4. After being treated in the conventional carburetor 4, the fuel passes through the intake manifold 3 to the motor 1 where it is burned.

For controlling the temperature to which the fuel is heated and for maintaining the temperature of the fuel as it is exhausted from the heater approximately constant, it is proposed to utilize the expansion pressure of the heat exchange liquid 16 itself within the casing 15 to control or regulate the flow of the hot exhaust gases through the heater tubes 18. To this end the casing 15 is provided with a filler tube 25, the outer end of which is closed by the removable threaded plug 26. The filler tube 25 is connected with a cylinder 27 by the tube 28. A bellows 29 provided with a top 30 is mounted within the cylinder 27. The inside of the bellows 29 is open to atmosphere through the port 31 and has a fluid-tight seal around its bottom circumferential flange 33 with the cylinder 27 and the cylinder support base 32.

The top plate 30 of the bellows 29 supports a depending plunger 34, the outer end 35 of which takes the form of a screw so that the over-all length of the plunger 34 can be adjusted. The end 35 of the plunger engages a suitable seat 36 on a lever 37 pivotally supported as at 38 on the bracket 39. The bracket 39 is carried by the support bracket 32. The lever 37 is yieldably held against the end 35 of the plunger by a tension spring 42, one end of which is connected to the

lever as at 43 and the other end of which is connected as at 44 to a clamp about the exhaust pipe 8. The spring 42 has sufficient strength so that the force of this spring acting through the lever 37 against the plunger 34 will compress any entrapped gas or vapor in the system so that the same acts substantially as if there were no gas between the liquid 16 and bellows 29. The other end of the lever 37 is connected with a crank arm 41 fixed upon the pin 12 which carries the butterfly valve 11 by a one-way lost motion connection in the form of a rod 61, sleeve 62, and a rod 63 fixed on the end of the sleeve. Rod 61 is pivotally and adjustably connected to the lever 37 in any one of the holes 64, and the rod 63 is pivotally and adjustably connected to the crank arm 41 in any one of the openings 65. The sleeve 62 is provided with a pair of diametrically opposed slots 66 which have a sliding engagement with a pin 67 fixed in the rod 61. The rod 61 also is provided with an annular shoulder 68. A coil spring 69 is mounted between the upper end of the sleeve 62 and the shoulder 68. The tension of the coil spring 69 yieldably holds the pin 67 against the upper ends of the slots 66. Hence, when the bellows 29 expands, causing the end 35 of the plunger 34 to rise, the spring 42 will pull upwardly on the rod 61 and the positive engagement between the pin 67 and the upper ends of the slots 66 will turn the crank 41 in a counter-clockwise direction tending to move the valve 11 from the dotted line position to the full line position shown in Figure 2.

When the reverse of this movement takes place, that is, when the bellows 29 is collapsed due to the expansion of the heat exchange liquid 16, the clockwise movement of the lever 37 will act through the rod 61, shoulder 68, coil spring 29, sleeve 62 and rod 63 to turn the crank 41 in a clockwise direction, thus tending immediately to move the butterfly valve 11 from the full line position of Figure 2 to the dotted line position where the valve closes the port 14. When the port 14 is closed the exhaust gases cease to flow through the heater tubes 18. However, the expansion of the heat exchange liquid 16 and the consequent collapsing of the bellows 29 may not stop immediately. If, after the valve 11 closes the port 14, any further contraction of the bellows 29 takes place, the one-way lost motion connection between the crank 41 and the lever 37 comes into play, that is, the rod 61, owing to the slidable relation of the pin 67 in the slots 66, will slide downwardly within the sleeve 62 compressing the coil spring 69 but without causing any further clockwise movement of the lever 41. This one-way lost motion connection between the lever 37 and crank 41 will take care of any excess expansion of the heat exchange liquid 16 after the port 14 is closed and before the liquid begins to contract.

After the heater unit has been assembled to the motor, plug 26 is removed and a suitable heat exchange liquid such as glycerine poured through the mouth of the filler tube 25 until the casing 15, filler tube 25, pipe line 28 and cylinder 27 are completely filled with the liquid. Care should be taken so that no air pockets are left within these members. The motor is then started and the exhaust gases passed through the heater 18. The temperature of the fuel being exhausted from the heater, as at 23, is taken. For this purpose a thermometer may be installed somewhere in the line 24 between the heater and the carburetor. At this time, of course, the butterfly valve 11 is in the full line position shown in Figure 2 closing port 13 so that the exhaust gases pass through port 14, heater tubes 18, around the loop 8 and out through the outlet 10 into the exhaust pipe 7. When the fuel reaches the temperature desired, e. g. 275° F. in case of domestic fuel oil, the plug 26 is screwed or otherwise secured in the end of the filler tube 25. During the heating up process of the liquid 16 some will have overflowed, due to the expansion of the liquid, out through the mouth of the filler tube 25 thus insuring that the casing 15, filler 25, pipe line 28, and cylinder 27 are completely filled with the liquid. While the fuel is at the temperature desired, the end 35 of the plunger 34 is adjusted so that it contacts with the seat 36 of the lever 37 and permits the valve 11 to nicely close the port 13. The lever 37 will be yieldably held against the end 35 of the plunger by the spring 42, one end of which is connected to the lever as at 43 and the other end supported from the exhaust loop 8 as at 44.

As the hot exhaust gases continue to flow through the heater tubes 18, the temperature of the liquid 16 within the casing 15 and consequently the temperature of the fuel will tend to rise. However, since the liquid 16 is trapped in the casing 15, filler tube 25, tube 28, and cylinder 27, and since the liquid 16 expands but does not vaporize, the hydraulic pressure created by the expansion of the liquid 16, due to this rise in temperature, will be exerted against the bellows 29 causing the same to collapse downwardly. It is, of course, understood that the liquid 16 will be between the bellows 29 and the inside wall of the cylinder 27. As the bellows collapse downwardly the plunger 34 will exert its force against the lever arm 37 which, through the connection 40, will cause the arm 41 to swing clockwise as viewed in Figures 1 and 2, which in turn causes the butterfly valve to shift from the full line position (Figure 2) where the port 13 is closed toward the dotted line position in Figure 2 tending to close the port 14. As the valve 11 is shifted from the full line toward the dotted line position, the amount of exhaust gases which pass through the port 14 is decreased and eventually cut off thus decreasing the amount of heat exchanged between the exhaust gases, the heat exchange liquid 16 and the fuel which is passing through the fuel coil 21.

After the valve 11 has moved to, or toward, the dotted line position where it closes the port 14, any drop in temperature of the heat exchange liquid 16 will cause the reverse of this operation to take place, namely, the heat exchange liquid within the casing 15, filler tube 25, tube 28, and cylinder 27 will contract. This in turn will permit the bellows 29 to expand. The force of spring 42 acting through lever 37 and plunger 34 and in some measure supplemented by the spring tension of the bellows itself, will cause the bellows to expand in a commensurate degree to the decrease in volume of the liquid 16 so that no air gap or vacuum will be formed in the heat exchange liquid 16 circuit comprising the casing 15, filler tube 25, tube 28, and cylinder 27 or between the bellows 29 and the heat exchange liquid as the liquid 16 contracts. Of course, when the engine is shut off the heat exchange liquid 16 will contract appreciably and a vacuum will be formed in the circuit of the liquid 16, that is, in one or more of the following members: cylinder 27, tube 28, filler tube 25 and casing 15 depending upon the amount the liquid 16 contracts which, of course depends

upon the temperature to which the liquid 16 falls when the engine is not operating. When the heat exchange liquid 16 is glycerin, this glycerin usually contains a small percentage (usually 2–5%) of water which vaporizes at the normal operating temperature of the glycerin. However, the important thing is that in the operation of the heater after the heat exchange liquid 16 once arrives at the proper temperature so that the fuel oil is being heated to the temperature desired, the spring 42 must be of sufficient strength so that the force of the spring acting with considerable mechanical advantage through the lever 37 against the plunger 34 will compress any entrapped gas or vapor in the system and act substantially as if there were no gas whatsoever between the liquid 16 and the bellows 29. Thus, the slightest decrease or increase in the volume of the liquid 16 will find an immediate response in the bellows 29, lever 37, arm 67, to control the valve 11 and increase or decrease the flow of exhaust gases through the heater. In other words, the bellows 29 contracts and expands only, and in a like amount, as the liquid glycerin expands and contracts and the bellows 29 is not contracted or expanded by any increase or decrease of vapor pressure. This arrangement makes the hydraulically operated thermostatic control for the exhaust control valve 11 very sensitive and enables the temperature to which it is desired to heat the fuel to be controlled within a very limited range. This in turn will permit the spring 42, acting through lever 37 and plunger 34, to expand the bellows 29 withdrawing the plunger 34 upwardly and thus permitting the spring 42 to rotate the lever 37 in a counter-clockwise direction and through the connection 40 turn the crank arm 41 in a counter-clockwise direction and shift the butterfly valve 11 from the dotted position, Figure 2, to or toward the full line position. This will increase the amount of exhaust gases flowing through the heater 17 tending to raise the temperature of the heat exchange liquid 16 and permit a greater heat interchange between the exhaust gases, the heat exchange liquid 16 and the fuel passing through the heater coil 21. This process continues automatically and maintains the temperature of the fuel being exhausted from the heater into the line 24 approximately constant.

Since a fuel heater of this type will be subjected to varying heat conditions, provision must be made to accommodate such conditions, for instance, in the winter the atmospheric temperature will be much lower than in the summer and at low driving speeds much less cooling air will be blown past the heater than at high driving speeds. To neutralize or negative these changing conditions, it is proposed to insulate the casing 15 with a suitable heat insulating arrangement. Preferably this heat insulation arrangement takes the form of a casing 50 which completely surrounds the casing 15. The end as well as the side walls of the casing 50 are spaced from the end and side walls of the casing 15 to provide a dead air space 51 completely around the casing 15. Preferably the inside of the casing 50 is hermetically sealed against the outside atmosphere. It has been found that this insulation against changing temperature conditions of the heating unit has played a vital part in making the entire fuel heating system operable under all driving and seasonal temperature conditions.

It is proposed to start and initially operate the motor on gasoline. To this end the gasoline fuel pump 71 is connected by a pipe line 70 with a tank or supply of gasoline and with the carburetor 4 by the pipe line 72. A two-way valve 73 having an operating handle 74 is mounted both in the gasoline pipe line 72 and in the fuel oil pipe line 6. In the position of the valve 73 shown the pipe line 6 is open whereas the pipe line 72 is closed. However, if the valve is turned 90° the gasoline feed line 72 to the carburetor will be opened and the oil fuel line 6 closed. After the engine is operated a short while on gasoline so that the heater is warmed up, the valve 73 is operated to open the fuel oil line 6 and to close the gasoline line 72 whereupon the motor will be run with fuel oil rather than gasoline.

It is an object of this invention to render high boiling distillates suitable for use as fuel in internal combustion engines. The high boiling distillates referred to are petroleum and other distillates which have a higher boiling point than gasoline. More specifically these high boiling distillates include the numerous fuel oils which are burned both in domestic as well as in industrial heating plants, including such fuels as kerosene, and fuel oil Nos. 1, 2 and 3. The boiling and flash points as well as the viscosity of these various fuels cover a wide and well-known range.

In Figs. 5 and 6 there is shown a modified form of heater. In this arrangement a finned pipe 80 is connected at one end by the elbow 82 to the exhaust pipe 81 which connects with the exhaust manifold 2 and at the other end by a pipe 81′ which leads back to the exhaust pipe. The flow of exhaust gases through the finned tube 80 is controlled by a valve 83 mounted on a pin 84 which is journalled in the exhaust pipe 81. An arm 85 is fixed to the pin 84 on the outside of the exhaust pipe 81 and is connected to the bottom end of a lever 86 by means of a rod 87. One end of the rod 87 has a fixed pivotal connection with the arm 85 and the other end has a sliding connection with the lower end of the lever 86 and an expansion coil spring 88 is threaded over the rod 87 and mounted between the lower end of the lever 86 and a shoulder fixed on the rod 87. Coil spring 88 serves the same purpose as coil spring 69 in the principal form of the invention, that is, when the valve 83 is closed any further expansion of the heat exchange liquid 16 acting through the bellows 29 and plunger 34, against the lever 86 will permit the lower end of the lever 86 to travel along the rod 87 against the tension of the spring 88 and thus prevent destruction of any of these parts or of the valve 83 and arm 85. The finned tube 80 is surrounded by a liquid-tight casing 89 having a liquid-tight seal at each end with the tube 80. The casing 89 contains the heat exchange liquid 16. A casing 90 surrounds the casing 89 and is spaced therefrom to provide a dead air space 91 or a space from which the air has been exhausted to provide heat insulation of the casing 91.

The fuel chamber in this modified form comprises a pair of tubes 92 and 93 positioned one within the other in spaced relation to provide a fuel chamber 94 and welded together at their ends as at 95 to provide a liquid-tight seal. The outer tube is provided with a fuel inlet 96 and a fuel outlet 97, or vice versa. To prevent direct flow of the fuel from the inlet 96 to the outlet 97, it is proposed to provide a circuitous passageway. This has been accomplished by means of a helical coil wire 98 positioned over the tube 93 and between this tube and tube 92. The wire from which the helix 98 is made has a diameter

approximately equal or slightly less than the distance between the inner tube 93 and outer tube 92. It is only necessary that the helix wire have sufficient diameter to provide sufficient impedance to the flow of the fuel oil so that the major part of the fuel oil does not flow directly from inlet 96, through the chamber 94 to the outlet 97. In other words, the helical wire 98 acts as a baffle to prevent direct flow of oil through the chamber 94 from inlet to outlet and thus effects a more efficient heat exchange between the oil in the chamber 94 and the heat exchange liquid 16 in the casing 89.

The operation of this modified form is substantially the same as that of the principal form. When the engine is not running, the fuel heater, of course, cools down to atmospheric temperature. At such temperature the glycerin contracts considerably so that the bellows 29 expands against the stops 100 and the exhaust valve 83 is wide open. As soon as the engine is put in operation the exhaust gases are deflected by the valve 83 and pass through the elbow 82 and finned tube 80, then through the tube 81' back into the exhaust line 81. In passing through the heater the heat from the exhaust gases is taken up by the glycerin and transferred to the fuel oil in the chamber 94. As shown, the fuel oil within the chamber 94 has reached, and slightly exceeded, the desired temperature. At this time the heat exchange liquid 16, which preferably is glycerin, has expanded and caused the bellows 29 to collapse which projected the plunger 34 to the right and swung the lever 86 about its pivot 99. The lever 86 acted through the rod 87 and arm 85 and swung the valve 83 closed, thus cutting off the flow of exhaust gases through the tube 80. The temperature of the glycerin 16 will now begin to fall and thus cause a contraction of the glycerin. As the glycerin contracts, the spring 42, acting against lever arm 86 and assisted somewhat by the tension of the bellows 29, causes the bellows to expand until the plate 30 reaches the stops 100. As the bellows 29 expands the spring 42 swings the lever 86 counterclockwise and thus through the rod 87 and arm 85 gradually opens the valve 83 permitting a gradual increase in the flow of exhaust gases through the pipe 80. This flow of exhaust gases through the heater reaches a maximum when the bellows plate 30 abuts the stops 100. Preferably at the time the plate 30 reaches the stops 100, the temperature of the fuel oil in the chamber 94 reaches the desired temperature and the casing 89, filler tube 25, tube 28, and cylinder 94 are completely filled with glycerin or other heat exchange liquid 16. Any further rise in temperature of the glycerin will cause it to expand and thereby contract the bellows which, operating through the mechanism described, gradually closes the valve 83 and cuts off the flow of exhaust gases through the heater.

In the modified form of the invention the spring 42 is positioned between the fulcrum 99 of the lever 86 and the plunger 34 whereas in the principal form of the invention the plunger 34 is positioned between the spring 42 and the fulcrum 38 of the lever 37. Thus, in the modified form, the spring 42 acts with less mechanical advantage than the plunger 34 and also with less mechanical advantage than the spring 42 in the principal form of the invention. Therefore, the spring 42 in the modified form of the invention will have to be a stronger spring than that of the principal form. The important thing in both cases is that the spring 42 must be of sufficient strength so that the force of the spring acting through the levers 37, 86 against the plunger 34 will compress any entrapped gas or vapor in the system and act substantially as if there were no gas between the liquid 16 and the bellows 29.

I claim:

1. A heater for higher boiling distillates utilizable as fuel for an internal combustion engine comprising a conduit through which the hot exhaust gases from the engine are passed, a reservoir containing a liquid in heat exchange relation with the said conduit, a heating chamber through which the higher boiling distillate is passed mounted within the reservoir in spaced relation with the conduit and in heat exchange relation with the said liquid whereby a heat exchange is effected between the hot exhaust gases in the conduit and the distillate in the heating chamber, a valve for controlling the flow of hot exhaust gases through the said conduit, and heat responsive means for operating the said valve to control the flow of hot exhaust gases through the conduit, said heat responsive means including a thermo-expandible liquid in heat exchange with said aforementioned heat exchange liquid, said thermo-expandible liquid having a predetermined volume at a predetermined temperature to which said fuel distillate is heated, a fluid pressure responsive element actuated by the hydraulic pressure created by the expansion of the said thermo-expandible liquid beyond the said predetermined liquid volume as the temperature of the said thermo-expandible liquid increases and operative connections between said fluid pressure responsive element and the said valve whereby the valve is actuated to control the flow of exhaust gases through said heater conduit.

2. A heater for higher boiling distillates utilizable as fuel for an internal combustion engine comprising a conduit through which the hot exhaust gases from the engine are passed, a reservoir containing a high boiling liquid in heat exchange relation with the said conduit, the said high boiling liquid having a boiling point above the normal operating temperatures to which it is raised in transferring the heat from the exhaust gases to the fuel distillate, a heating chamber through which the higher boiling distillate is passed mounted within the reservoir in spaced relation with the conduit and in heat exchange relation with the said liquid whereby a heat exchange is effected between the hot exhaust gases in the conduit and the distillate in the heating chamber, a valve for controlling the flow of hot exhaust gases through the said conduit, and heat responsive means for operating the said valve to control the flow of hot exhaust gases through the conduit, said heat responsive means including a thermo-expandible liquid in heat exchange relation with said aforementioned heat exchange liquid, said thermo-expandible liquid having a boiling point above the temperature to which the heat exchange liquid is raised in the normal operation of the heater and having a predetermined liquid volume at a predetermined temperature to which said fuel distillate is heated, a container for said thermo-expandible liquid, a fluid pressure responsive element in the container actuated by the hydraulic pressure created by the expansion of the said thermo-expandible liquid beyond the said predetermined liquid volume as the temperature of the said thermo-expandible liquid increases and operative connections be-

tween said fluid pressure responsive element and the said valve whereby the valve is actuated to control the flow of exhaust gases through said heater conduit.

3. A heater for high boiling distillates comprising a conduit through which hot gases are passed, a reservoir containing a high boiling, heat-exchange liquid in heat exchange relation with the said conduit, said liquid having a boiling point above the normal operating temperatures to which it is subjected, a heating chamber through which the high boiling distillate is passed mounted within the reservoir in spaced relation with the conduit and in heat exchange relation with the high boiling liquid whereby a heat exchange is effected between the hot gases in the conduit and the distillate in the heat chamber, the said high boiling liquid approximately filling the said reservoir when the high boiling distillate is at a predetermined desired temperature, and valve means responsive to the expansion of the high boiling liquid incident to a rise in temperature of the high boiling liquid as the temperature of the distillate tends to exceed the predetermined desired temperature and responsive to the contraction of the high boiling liquid incident to a drop in temperature of the high boiling, heat exchange liquid as the temperature of the distillate tends to drop below the predetermined desired temperature whereby the valve means is regulated to control the flow of hot gases through the said conduit and thereby maintain the temperature to which the high boiling distillate is heated within a predetermined desired range.

4. A heater for high boiling distillates comprising a conduit through which hot gases are passed, a reservoir containing a high boiling, heat exchange liquid in heat exchange relation with the said conduit, a heating chamber through which the high boiling distillate is passed mounted within the reservoir in spaced relation with the conduit and in heat exchange relation with the high boiling liquid whereby a heat exchange is effected between the hot gases in the conduit and the distillate in the heat chamber, the said high boiling liquid approximately filling the said reservoir when the high boiling distillate is at a predetermined desired temperature, a valve for controlling the flow of the hot gases through the said conduit, and a plunger operatively connected with the said valve hydraulically actuated by the expansion of the high boiling liquid incident to a rise in temperature of the high boiling liquid as the temperature of the distillate tends to exceed the predetermined desired temperature and actuated by the contraction of the high boiling liquid incident to a drop in temperature of the high boiling heat exchange liquid as the temperature of the distillate tends to drop below the predetermined desired temperature whereby the valve is regulated to control the flow of gases through the conduit to thereby maintain the temperature to which the high boiling distillate is heated within a predetermined desired range.

5. A heater for high boiling distillates comprising a conduit through which hot gases are passed, a reservoir containing a high boiling heat exchange liquid in heat exchange relation with the said conduit, a heating chamber through which the high boiling distillate is passed mounted within the reservoir in spaced relation with the conduit and in heat exchange relation with the high boiling liquid whereby a heat exchange is effected between the hot gases in the conduit and the distillate in the heat chamber, the said high boiling liquid approximately filling the said reservoir when the high boiling distillate is at a predetermined desired temperature, a valve in open position permitting the hot gases to pass through the conduit and in closed position preventing the hot gases from flowing through the conduit, an expansible member in contact with the heat exchange liquid and operative connections between the expansible member and the said valve, the expansion of the high boiling liquid while in a liquid state incident to a rise in temperature of the high boiling liquid as the temperature of the distillate tends to exceed the predetermined desired temperature creating hydraulic pressure which contracts the expansible member and through its operative connections moves the valve toward closed position, and the contraction of the heat exchange liquid while in a liquid state incident to a drop in temperature of the heat exchange liquid as the temperature of the distillate tends to drop below the predetermined desired temperature contracts the expansible member and through the operative connections tend to move the valve toward open position whereby the flow of the hot gases through the conduit is controlled and the temperature to which the high boiling distillate is heated maintained within a predetermined desired range.

6. A heater for high boiling distillates comprising a conduit through which hot gases are passed, a reservoir containing a high boiling liquid in heat exchange relation with the said conduit, said liquid having a boiling point above the normal operating temperatures to which it is heated in effecting heat exchange between the exhaust gases and the high boiling distillate, a heating chamber through which the high boiling distillate is passed mounted within the reservoir in spaced relation with the conduit and in heat exchange relation with the high boiling liquid whereby a heat exchange is effected between the hot gases in the conduit and the distillate in the heating chamber, valve means for controlling the flow of hot gases through the said conduit, and means responsive to the hydraulic pressure created by the expansion of said high boiling liquid incident to a rise in temperature below the boiling point of said liquid for operating the said valve to control the flow of hot gases through the conduit.

7. A heater for high boiling distillates used as fuel for an internal combustion engine comprising a conduit through which the hot exhaust gases of the internal combustion engine are passed at a temperature above the carbonizing temperature of the fuel distillate, a reservoir containing a high boiling, heat exchange liquid for maintaining the high boiling, heat exchange liquid in heat conducting relation with the exhaust conduit, said liquid having a boiling point above the temperature to which it is heated in transferring heat from the exhaust gases to the fuel distillate, a conduit through which the fuel distillate is passed mounted within the reservoir in spaced relation with the exhaust conduit and in heat conducting relation with the high boiling liquid in the reservoir whereby the heat from the exhaust gases is conducted by the high boiling liquid in the reservoir to the fuel distillate in the second mentioned conduit to heat the fuel distillate to a temperature below the carbonizing temperature of the fuel distillate, a valve for controlling and cutting off the flow of exhaust gases through the conduit, and means including

the heat exchange liquid within the reservoir responsive to a change in temperature of the heat exchange liquid for operating the said valve to control the flow of exhaust gases through the conduit whereby the temperature to which the fuel is heated may be kept within a desired predetermined range.

8. A heater for high boiling distillates used as fuel for an internal combustion engine comprising a conduit through which the hot exhaust gases of the internal combustion engine are passed at a temperature above the carbonizing temperature of the fuel distillate, a reservoir containing a high boiling liquid for maintaining the high boiling liquid in heat conducting relation wth the exhaust conduit, said liquid having a boiling point above the normal temperature to which it is raised in heating the said fuel distillate, a conduit through which the fuel distillate is passed mounted within the reservoir in spaced relation with the exhaust conduit and in heat conducting relation with the high boiling liquid in the reservoir whereby the heat from the exhaust gases is conducted by the high boiling liquid in the reservoir to the fuel distillate in the second mentioned conduit to heat the fuel distillate to a temperature below the carbonizing temperature of the fuel distillate, means responsive to the expansion and contraction of the heat exchange liquid while in a liquid condition operatively connected with the said valve whereby the said valve is actuated by the expansion and contraction of the heat exchange liquid to control the flow of exhaust gases through the exhaust conduit whereby the temperature to which the fuel is heated is maintained within a predetermined range.

9. A heater for high boiling distillates used as fuel for an internal combustion engine comprising a conduit through which the hot exhaust gases of the internal combustion engine are passed at a temperature above the carbonizing temperature of the fuel distillate, a valve for controlling the flow of exhaust gases through said conduit, a reservoir containing a high boiling, heat exchange liquid for maintaining the high boiling liquid in heat conducting relation with the exhaust conduit, said high boiling liquid having a boiling point above the normal operating temperatures to which it is heated in effecting heat exchange between the exhaust gases and the fuel distillate, a conduit through which the fuel distillate is passed mounted within the reservoir in spaced relation with the exhaust conduit and in heat conducting relation with the high boiling liquid in the reservoir whereby the heat from the exhaust gases is conducted by the high boiling liquid in the reservoir to the fuel distillate in the second mentioned conduit to heat the fuel distillate to a temperature below the carbonizing temperature of the fuel distillate, a bellows in liquid-tight sealed relation with the heat exchange liquid, operative connections between the bellows and the said valve including a lever and a spring operatively connected with the said bellows and the said lever whereby as the high boiling liquid expands the bellows contracts and swings the said lever about its fulcrum against the resistance of the said coil spring to close the said valve and when the said high boiling liquid contracts the said spring swings the said lever and expands the said bellows commensurately with the decrease in volume of the high boiling, heat exchange liquid, the connection between the spring and the lever and the connection between the bellows and the said lever being such that the spring has a greater power arm than the said bellows.

10. A heater for high boiling distillates used as fuel for an internal combustion engine comprising a conduit through which the hot exhaust gases of the internal combustion engine are passed at a temperature above the carbonizing temperature of the fuel distillate, a valve for controlling the flow of exhaust gases through said conduit, a reservoir containing a high boiling, heat exchange liquid for maintaining the high boiling liquid in heat conducting relation with the exhaust conduit, said high boiling liquid having a boiling point above the normal operating temperatures to which it is heated in effecting heat exchange between the exhaust gases and the fuel distillate, a conduit through which the fuel distillate is passed mounted within the reservoir in spaced relation with the exhaust conduit and in heat conducting relation with the high boiling liquid in the reservoir whereby the heat from the exhaust gases is conducted by the high boiling liquid in the reservoir to the fuel distillate in the second mentioned conduit to heat the fuel distillate to a temperature below the carbonizing temperature of the fuel distillate, a bellows in liquid-tight sealed relation with the heat exchange liquid, operative connections between the bellows and the said valve including a lever and a spring operatively connected with the said bellows and said lever whereby as the high boiling liquid expands the bellows contracts and swings the said lever about its fulcrum against the resistance of the said coil spring to close the said valve and when the said high boiling liquid contracts the said spring swings the said lever and expands the said bellows commensurately with the decrease in volume of the high boiling, heat exchange liquid, the connection between the spring and the said lever being positioned a greater distance from the fulcrum of said lever than the distance the said connection between the bellows and the said lever is positioned from said fulcrum whereby the spring operates to expand the bellows with a great mechanical advantage and the bellows acts against the lever and the resistance of the said spring with a high mechanical disadvantage so that the valve is actuated solely during the expansion and contraction of said high boiling, heat exchange liquid and is substantially irresponsive to any entrapped vapor pressure.

11. A heater for high boiling distillates used as fuel for an internal combustion engine comprising a conduit through which the hot exhaust gases of the internal combustion engine are passed at a temperature above the carbonizing temperature of the fuel distillate, a valve controlling the flow of exhaust gases through said conduit, a reservoir containing a high boiling, heat exchange liquid for maintaining the high boiling liquid in heat conducting relation with the exhaust conduit, a conduit through which the fuel distillate is passed mounted within the reservoir in spaced relation with the exhaust conduit and in heat conducting relation with the high boiling liquid in the reservoir whereby the heat from the exhaust gases is conducted by the high boiling liquid in the reservoir to the fuel distillate in the second mentioned conduit to heat the fuel distillate to a temperature below the carbonizing temperature of the fuel distillate, a bellows in liquid-tight sealed relation with the heat exchange liquid, operative connections be-

tween the bellows and the said valve whereby the change in volume of the said heat exchange liquid operates through the bellows to regulate the said valve to control the flow of exhaust gases through the exhaust conduit whereby the temperature to which the fuel is heated is maintained within a predetermined desired range.

12. A heater for high boiling distillates comprising a conduit through which hot gases are passed, a reservoir containing a high boiling liquid in heat exchange relation with the said conduit, said liquid having a boiling point above the normal operating temperatures to which it is heated in effecting heat exchange between the exhaust gases and the high boiling distillate, a heating chamber through which the high boiling distillate is passed mounted within the reservoir in spaced relation with the conduit and in heat exchange relation with the high boiling liquid whereby a heat exchange is effected between the hot gases in the conduit and the distillate in the heating chamber, valve means for controlling the flow of hot gases through the said conduit, means responsive to the hydraulic pressure created by the expansion of said high boiling liquid incident to a rise in temperature below the boiling point of said liquid for operating the said valve to control the flow of hot gases through the conduit, and heat insulating means surrounding the reservoir for the high boiling liquid.

13. A heater for high boiling distillates comprising a conduit through which hot gases are passed, a reservoir containing a high boiling liquid in heat exchange relation with the said conduit, said liquid having a boiling point above the normal operating temperatures to which it is heated in effecting heat exchange between the exhaust gases and the high boiling distillate, a heating chamber through which the high boiling distillate is passed mounted within the reservoir in spaced relation with the conduit and in heat exchange relation with the high boiling liquid whereby a heat exchange is effected between the hot gases in the conduit and the distillate in the heating chamber, valve means for controlling the flow of hot gases through the said conduit, means responsive to the hydraulic pressure created by the expansion of said high boiling liquid incident to a rise in temperature below the boiling point of said liquid for operating the said valve to control the flow of hot gases through the conduit, and a closed casing completely surrounding the reservoir for the heat exchange liquid and in spaced relation with the walls of the said reservoir whereby a heat insulating dead air space is provided completely surrounding the said reservoir.

14. A heater for higher boiling distillates utilizable as fuel for an internal combustion engine comprising a conduit through which the hot exhaust gases from the engine are passed, a reservoir containing a high boiling liquid in heat exchange relation with the said conduit, the said high boiling liquid having a boiling point above the normal operating temperatures to which it is raised in transferring the heat from the exhaust gases to the fuel distillate, a heating chamber through which the higher boiling distillate is passed mounted within the reservoir in spaced relation with the conduit and in heat exchange relation with the said liquid whereby a heat exchange is effected between the hot exhaust gases in the conduit and the distillate in the heating chamber, a valve for controlling the flow of hot exhaust gases through the said conduit, heat responsive means in contact with the high boiling, heat exchange liquid, and operative connections between said heat responsive means and the said valve whereby whenever the high boiling liquid reaches a predetermined temperature range the said heat responsive means actuates the said valve to control the flow of hot exhaust gases through the conduit and maintain the temperature of the fuel distillate within a predetermined range.

15. A heater for high boiling distillates used as fuel for an internal combustion engine comprising a conduit through which the hot exhaust gases of the internal combustion engine are passed at a temperature above the carbonizing temperature of the fuel distillate, a valve for controlling the flow of exhaust gases through said conduit, a reservoir containing a high boiling, heat exchange liquid for maintaining the high boiling liquid in heat conducting relation with the exhaust conduit, said high boiling liquid having a boiling point above the normal operating temperatures to which it is heated in effecting heat exchange between the exhaust gases and the fuel distillate, a conduit through which the fuel distillate is passed mounted within the reservoir in spaced relation with the exhaust conduit and in heat conducting relation with the high boiling liquid in the reservoir whereby the heat from the exhaust gases is conducted by the high boiling liquid in the reservoir to the fuel distillate in the second mentioned conduit to heat the fuel distillate to a temperature below the carbonizing temperature of the fuel distillate, a bellows in liquid-tight sealed relation with the heat exchange liquid, operative connections between the bellows and the said valve including a lever and a spring operatively connected with the said bellows and the said lever whereby as the high boiling liquid expands the bellows contracts and swings the said lever about its fulcrum against the resistance of the said coil spring to close the said valve and when the said high boiling liquid contracts the said spring swings the said lever and expands the said bellows commensurately with the decrease in volume of the high boiling, heat exchange liquid.

BAILEY P. DAWES.