

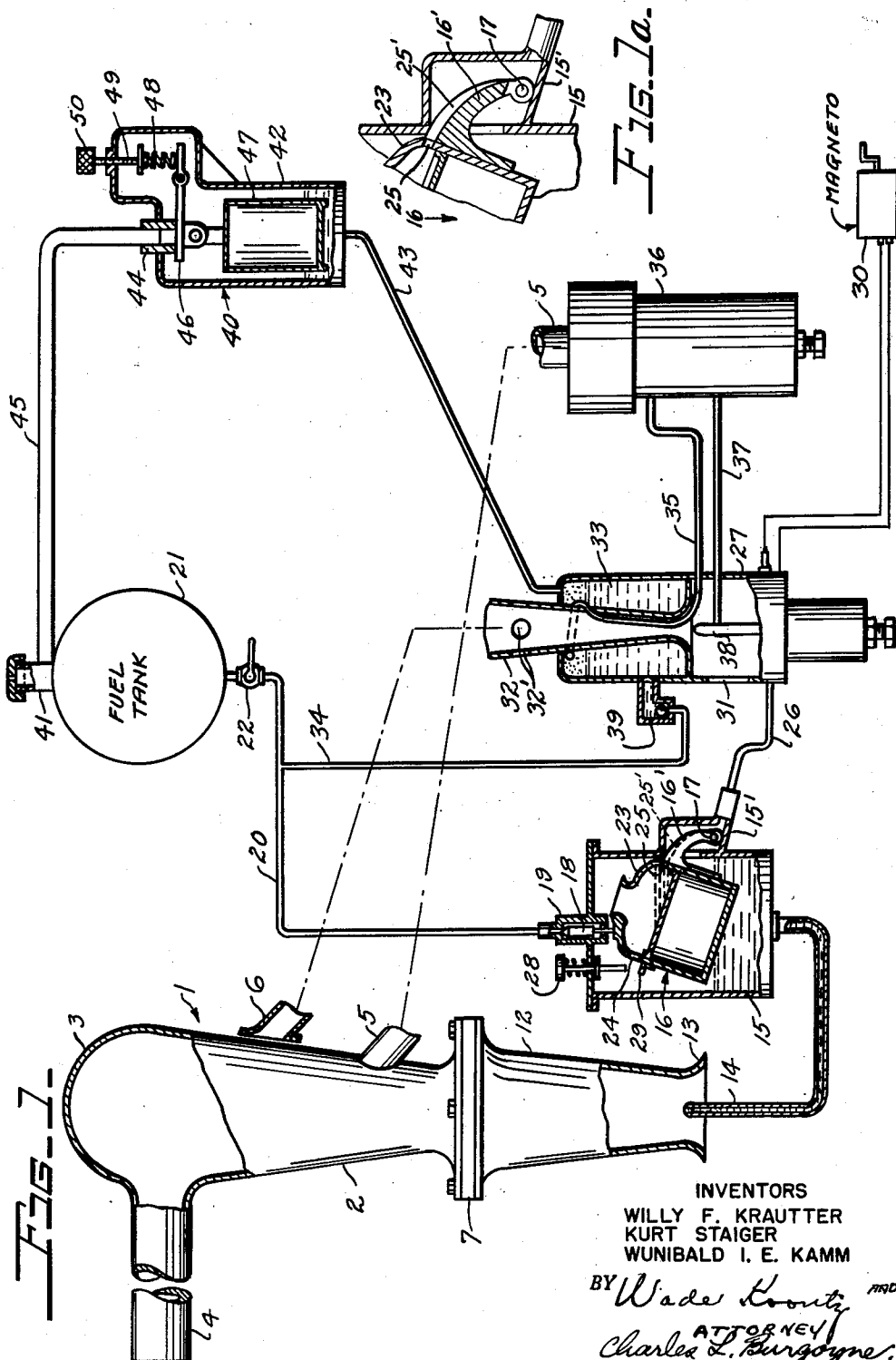
Dec. 16, 1952

W. F. KRAUTTER ET AL
PULSE JET HEATER WITH AUTOMATIC STARTING
AND CONTROL SYSTEM THEREFOR

2,621,718

Filed Dec. 7, 1950

3 Sheets-Sheet 1



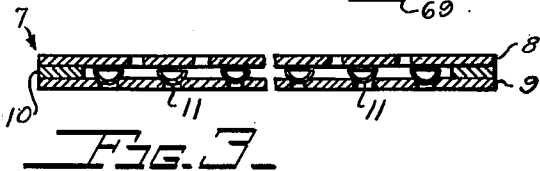
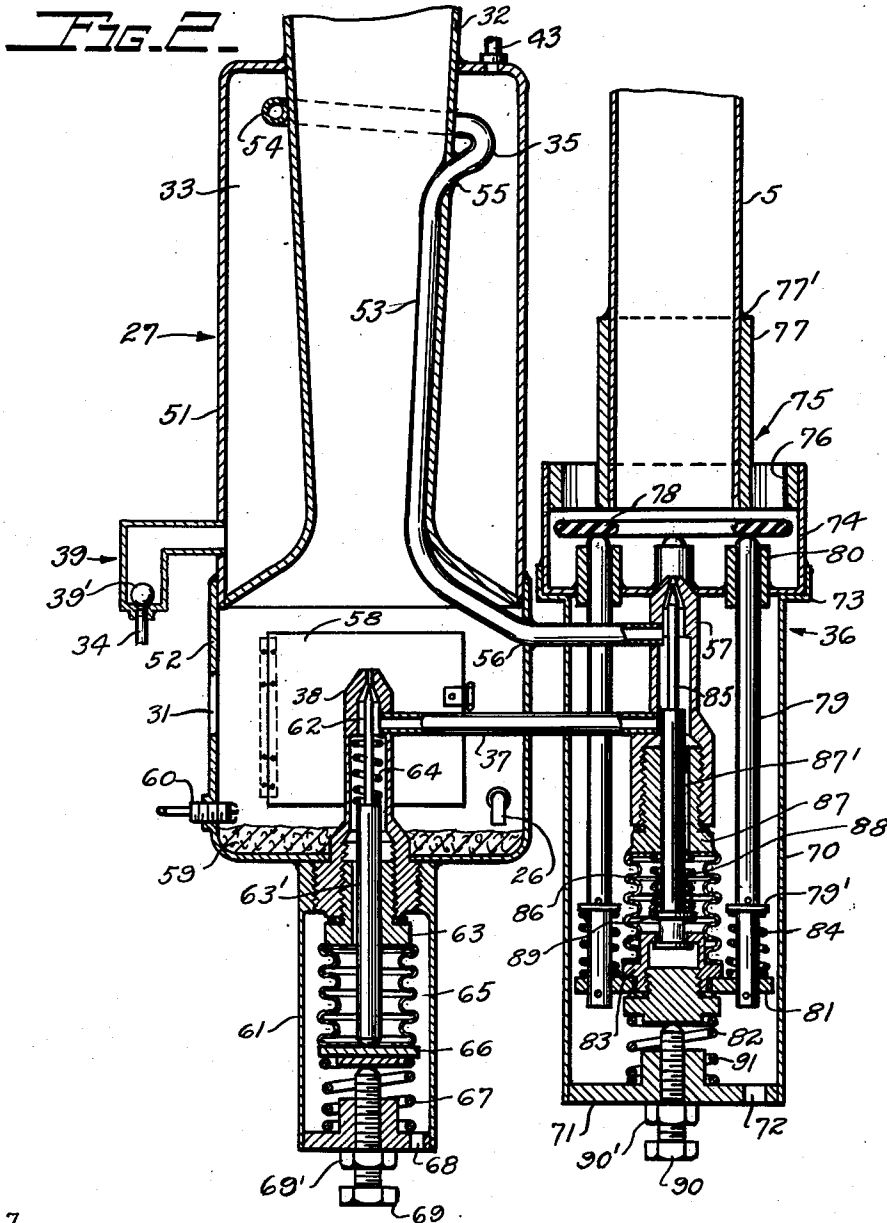
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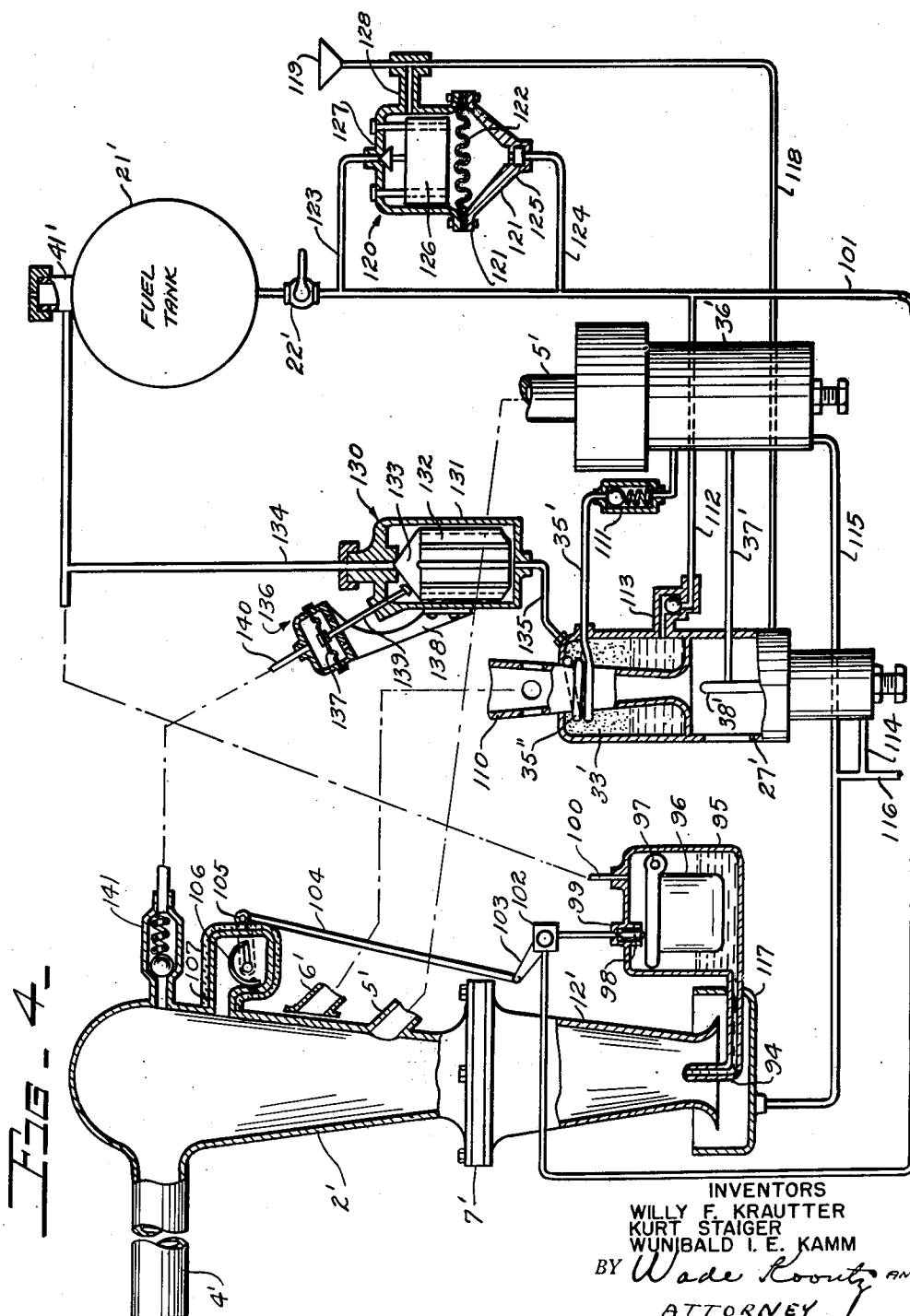
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UNITED STATES PATENT OFFICE

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PULSE JET HEATER WITH AUTOMATIC
STARTING AND CONTROL SYSTEM
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Application December 7, 1950, Serial No. 199,696

6 Claims. (Cl. 158—28)

(Granted under the act of March 3, 1883, as
amended April 30, 1928; 370 O. G. 757)

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The invention described herein may be manufactured and used by or for the United States Government for governmental purposes without payment to us of any royalty thereon.

The present invention relates to a pulse jet heater having operatively associated therewith an automatic starting and control system.

Briefly stated the present invention resides in a heater of the pulse jet resonant type and particularly resides in a starting and control system for such a heater including means to preheat one spot on the wall of the heater combustion chamber in order to ignite a fuel-air mixture flowing to the combustion chamber from a vapor generator, thus providing a starting flame in the combustion chamber and a secondary pulsing action which starts the flow of primary fuel into the chamber along with air for combustion. The present invention provides refinements in a heater and control system as described and particularly provides for means to automatically regulate fuel flow to the heater starting components and to terminate fuel flow thereto after the primary combustion process is fully started.

The primary object of the invention is to provide a pulse jet resonant type of heater including a starting system which is entirely automatic, at least as it relates to regulation of fuel flow from a fuel tank to the heater and to the components of the heater starting system.

A further object of the invention is to provide a heater starting system including a float controlled priming device to supply a priming fuel charge to a torch flame unit in response to elevation of a float having a fuel collecting basin thereon and including a fuel regulating valve under control of the float for maintaining an adequate supply of fuel in the float chamber from whence it is free to flow to a primary fuel jet associated with the heater itself.

Another object of the invention is to provide a heater starting system including a float chamber having a flexible wall subject to a static head of liquid fuel and adapted to displace a limited quantity of fuel for flow from the float chamber to prime a torch flame unit automatically and including also a float actuated valve adapted to stop the flow of fuel into the float chamber after sufficient fuel has collected therein to provide an adequate torch flame unit priming charge.

Another object of the invention is to provide a pulse jet resonant type heater having a combustion chamber and a primary fuel charging means associated therewith and wherein the combustion chamber is provided with a pressure

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actuated valve at one point in the wall thereof for communicating pressure to a pressure actuated means adapted to open an escape valve for venting a fuel boiler or vaporizer forming part of the heater starting system, whereby the further flow of fuel vapor therefrom to the heater starting system will be reduced to negligible quantities when combustion of primary fuel is started in the combustion chamber to thereby deenergize the heater starting system.

Another object of the invention is to generally improve the reliability and safety of starting and control systems for heaters of the pulse jet resonant type.

The above and other objects of the invention will become apparent upon reading the following detailed description in conjunction with the accompanying drawings, in which:

Fig. 1 is a schematic view of the present pulse jet heater and control system and showing certain components in vertical cross section.

Fig. 1a is an enlarged fragmentary view of the hinge connection for a hollow float shown in Fig. 1.

Fig. 2 is a vertical cross section taken through a preferred embodiment of two of the principal components of the heater starting and control system.

Fig. 3 is a cross section taken through the automatic air and fuel valve mounted within the heater at the lower end of the combustion chamber.

Fig. 4 is a schematic view of the present pulse jet heater and control system and including certain refinements not present in the system of Fig. 1.

For a description of the first or principal form of the invention reference is made to Fig. 1 of the drawings wherein the resonant pulse jet heater itself is designated by numeral 1. The heater proper includes a vertically arranged combustion chamber 2 of downwardly tapering cross section, and provided with an enlarged rounded dome section 3. At one side near the upper end the chamber 2 has an exhaust pipe or tail pipe 4 connected thereto. The tail pipe is of such length and configuration that it is acoustically tuned to a desired resonant frequency. The length and cross sectional area of the tail pipe with relation to proportions of the combustion chamber will determine the resonant frequency and experiments will soon show the most desirable length for the tail pipe in a given installation. The chamber 2 is fed at one side by a combustion starting conduit 5 and above the conduit 5 is a

heating conduit 6 which stops short of the chamber wall whereby a hot blast issuing from conduit 6 first heats one limited area of the chamber wall and then escapes to the atmosphere. Both of the conduits 5 and 6 are part of the heater starting system to be described below. At the lower end of the combustion chamber is an automatic check valve 7 which may have a form as shown in Fig. 3. The check valve takes the form of spaced plates 8 and 9 having perforations which are out of register. The plates are maintained in spaced relation by the intermediate ring 10 and between the spaced plates are hemispheres 11 which rest in perforations of the bottom plate 9 when back pressure in the chamber 2 forces the hemispherical elements 11 into flow stopping relation as shown. The plates 8 and 9 are suitably secured, as by welding, to the chamber 2 and to the air and fuel manifold 12 respectively. The manifold 12 is of downwardly tapering construction with a flaring mouth 13 at the lower end into which extends in central relation a fuel feed pipe 14 to supply a primary fuel flow to the chamber 2. The pulsing action inherent in the present heater construction results in a rapidly recurrent suction effect within the combustion chamber, whereby the air flow induced in the manifold 12 causes liquid fuel to be picked up in successive spurts from the fuel feed pipe 14 for combustion within the chamber 2. The general arrangement and mode of operation of the heater is the same as previously disclosed in our copending applications identified as follows: application Serial No. 129,861 filed November 28, 1949, application Serial No. 144,556 filed February 16, 1950 and application Serial No. 189,876, filed October 12, 1950. The present invention is concerned principally with the automatic starting and control system for the heater device described briefly above.

Fuel is supplied to the feed pipe 14 from an adjacent reservoir 15 from which liquid fuel, preferably gasoline or other low gravity hydrocarbon, flows by gravity into pipe 14. A hollow float 16 mounted for limited turning movement about pivot 17 is adapted to control the position of a fuel control valve 18 slidably situated in a small housing 19 connected by pipe 20 with the fuel tank 21. A shut-off valve 22 is employed in the tank outlet line to shut off the heater altogether when desired. The valve 18 which opens the line 20 by dropping below the outlet end of the line 20 is moved to closed position by contact with the upper end portion of the float 16 when the liquid level in the reservoir 15 rises to a level approximately as shown. At the upper end of the float 16 there is a narrow necked catch basin 23 into which fuel may flow from the lower end of housing 19 when the valve 18 is open and when the float is in a lower position than that illustrated. Above the bottom wall the catch basin has opposite outlet apertures 24 and 25 which are intended for overflow outlets to fill the reservoir 15 and priming pipe 26 respectively. The outlet 25 opens into a groove or channel 25' formed in the upper side of a hinge arm 13' pivoted at 17 in a reservoir side chamber 15'. The chamber 15' is connected by the priming pipe 26 to the lower end end of a torch lamp housing 27. In order to force the float 16 downwardly, in case the basin 23 empties without desired initiation of combustion in lamp housing 27, there is provided a spring retracted push rod 28 extending upwardly through the upper end wall of reservoir 15. The float 16 carries a projection 29 for engagement by push rod 28. Thus in cases where it is necessary to

refill the basin 23 in order to provide more priming fuel, the float 16 may be pushed down manually below the floating position shown so that fuel flow may be restarted through pipe 20 and into the basin 23. Then on release of the push rod 28 the float will rise again to the position shown, to spill part of the fuel in basin 23 into priming pipe 26.

After the heater is fully started, the normal function of the float operated valve 18 is the regulation of fuel flow into the reservoir 15 by periodic opening and closing action of the valve as the fuel level in the reservoir fluctuates downwardly and upwardly. The valve 18 includes a stem at the lower end having considerable clearance with the housing 19 to permit fuel flow downwardly. Thus the fuel flows down around the valve stem and is directed thereby, so that when the mouth of basin 23 becomes located just under the stem all fuel flow will gravitate into the basin. After the float rises and flow continues the fuel will finally begin to strike outside the mouth of the basin, to continue filling up the reservoir to a level where final valve closing action will occur. It is clear that this construction, whereby all incoming fuel runs down around the valve stem, provides a definite point where flow into the basin 23 ceases and subsequent flow outside the basin mouth starts for supplying only the reservoir itself. Finally when the reservoir is partly filled as shown the float 16 will rise sufficiently to raise valve 18 to a point where the conical upper end thereof effectively stops fuel flow from the feed pipe 20 until such time as consumption of fuel lowers float 16 and reopens valve 18.

The fuel which reaches the bottom of torch housing 27 is absorbed by fibrous wicking material and when a spark is provided therein by operation of magneto 30 the fuel will ignite and burn in the presence of air entering by way of port 31. The burning mixture flows up the combustion tube 32 thus heating fuel in the annular fuel vaporizer 33 which is partly filled with fuel by way of conduit or feed pipe 34. Vaporized fuel flows from vaporizer or boiler 33 by way of tube 35 to an enclosed fuel nozzle in the housing 36 supplying a combustible vapor to the conduit 5 for flow into the combustion chamber 2 and also supplying vaporized fuel for return flow by way of tube 37 to a fuel nozzle 38 directed up the combustion tube or flue 32. The vapor issuing under pressure from the nozzle then ignites from the flames rising off the priming charge in the bottom of housing 27 and the burning vapors follow the tube 32 up to the flame directing tube 6 terminating adjacent to the combustion chamber wall. Additional air may be admitted to the combustion tube 32, as at 32', to further intensify the torch flame. The wall of chamber 2 now develops a hot spot to cause combustion to start as fuel vapors flowing in tube 5 reach the chamber. The limited supply of fuel is now capable of starting a resonant pulse jet action in the chamber, which causes an alternating rise and fall of pressure in the chamber 2. The effect of this pulse jet action is to cause primary fuel and air to flow periodically up the manifold 12 and into the combustion chamber 2, thus starting the pulse jet heater in steady operation. The constructional details of the heater starting components will be described below (see Fig. 2). It is noted however that a simple ball check valve 39 serves to prevent return flow of fuel in the feed pipe 34

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once the pressure in vaporizer 33 increases appreciably.

Further included in the starting and control system of Fig. 1 is a pressure control valve assembly 40 connected between the vaporizing chamber 33 and the vent tube 41 at the upper side of fuel tank 21. The assembly 40 comprises a float chamber 42 connected at its lower end by tube 43 to the upper end of vaporizing chamber 33. A valve seat element 44 at the upper end of chamber 42 is connected by tube 45 to the tank vent tube 41. Pivotaly mounted within the chamber 42 is a flap valve 46 connected at one end to a float 47 depending therefrom and biased to valve closing position by means of a light spring 48. The spring force is adjustable by means of a threaded adjusting screw 49 having a grip portion 50 outside the float housing.

The pressure control valve is so adjusted that fuel in liquid form is required to close the valve 46 by causing the float 47 to be elevated to the position shown. This condition will come about when the vaporizing chamber 33 is almost filled and vapors flowing up the tube 43 are so cooled on their way to the float chamber 42 that they condense and cause the float 47 to be lifted. It should be understood that filling of the chamber 33 above normal limits provides such a volume of liquid therein as to lower the average fuel temperature and particularly lower the fuel temperature near the outside wall of the chamber 33. Thus the vapors flowing up the relatively long tube 43 will condense to liquid form and cause upward action of float 47. This action closes valve 46 and gradually increases the pressure in chambers 42 and 33 to cause firm seating of ball valve 39, thus preventing more flow of fuel into vaporizing chamber 33 until the surplus fuel is vaporized. Float chamber 42 should be above vaporizing chamber 33 in order to allow condensate to drain back into the chamber 33.

The pressure control valve is further operative to correct a low level fuel condition in vaporizing chamber 33. Considering the chamber 33 with only a small amount of liquid fuel therein it is seen that the superheated vapors now flowing up the tube 43 will flow past the float 47 without condensing sufficiently to cause lifting of the float to its valve closing position. Thus the vapor will flow on to the fuel tank 21 by way of tube 45 and gradually condense by the time the tank is reached. Therefore the pressure in the vaporizing chamber 33 will be kept down, so that the static head of fuel in tank 21 can lift the ball valve 39 and refill the vaporizing chamber 33 at least to near normal levels.

Considering now the preferred construction of the starting system components reference is made to Fig. 2. The torch housing 27 is preferably made of two sections 51 and 52 of cylindrical form assembled in telescopic relation and welded together at their overlapping margins. Secured interiorly of the upper housing section 51 in concentric relation thereto is a chimney or combustion tube 32 having a flared mouth at the lower end and having a diverging annular wall thereabove. Between the tube 32 and the housing section 51 is an annular space 33 providing a fuel space wherein fuel may be heated and vaporized. Vaporized fuel may escape by way of the control tube 43 to the pressure control valve assembly 40. The main flow of vaporized fuel is by way of the tube 53 having its upper end opening at 54 into the fuel space 33 and having an intermediate portion passing

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through the wall of tube 32 at 55 and continuing along the inside of the wall below the housing section 51 to finally pass through the wall of housing section 52 and 56. The tube continues into the adjacent nozzle housing 36, with the lower end of the tube secured into the nozzle 57 below the outlet thereof. Farther below the nozzle outlet a second tube 37 connects the interior of nozzle 57 with the interior of nozzle 38 located centrally within the torch housing 27.

Returning now to the torch unit or housing 27 it is noted that the fuel supply conduit 34 connects with the fuel chamber 33 by way of a ball valve 39 having a gravity-seated ball element 39' therein. Vapor pressure in the chamber 33 is adapted to close the ball valve against the static head of liquid fuel in the fuel tank and fuel supply line. The lower housing section 52 includes an inspection door 58 for viewing the flame and also for lighting the fibrous wicking 59 by a match in case the spark plug 60 fails to cause ignition. The wicking 59 is supplied with fuel through the priming pipe 26, as previously described. An aperture 31 in the wall of housing section 52 supplies air for combustion of fuel therein, as well as combustion in the upwardly extending chimney 32. The fuel nozzle 38 is threaded into a tubular housing 61 welded or otherwise secured on the bottom wall of torch housing section 52, with the nozzle 38 extending into the housing section centrally thereof. The nozzle 38 has a flow governing needle valve 62 slidable therein and guided by a bushing 63 threaded into the lower end of the nozzle 38. A coil spring 64 tends at all times to open the needle valve. It is noted that a narrow passage 63' in the bushing 63 transmits pressure developed within the nozzle to a bellows 65 secured at its upper end to the bushing 63. The lower end of the bellows is secured to a disk 66 forming an abutment for the lower end of needle valve 62. The bellows is biased toward a collapsed condition by a compression spring 67 extending between the disk 66 and the bottom wall of housing 61. An aperture 68 in the bottom wall admits atmospheric pressure into the housing 61 and an adjustment screw 69 threaded through this same wall acts as a limiting abutment or stop for the disk 66 and thus determines the maximum amount of opening for the needle valve 62. The setting of the screw 69 may be fixed by means of a locknut 69'.

The torch flame lamp including housing 27 and parts therein acts to produce a hot spot on the wall of combustion chamber 2. This in turn acts to fire a stream of combustible vapors passing along conduit 5 into the combustion chamber. The vapors are produced by a combustion starter or vapor metering device included within the housing 36. The housing itself comprises a cylinder 70 having a bottom wall 71 apertured at 72 to admit atmospheric pressure. The upper end of the cylinder is outwardly and upwardly flanged, as at 73, to receive a cup-like top wall member 74 opening upwardly and receiving therein a fitting 75 welded, brazed or otherwise secured rigidly within the upper end of the member 74. A series of holes 76 arranged in circular manner pass through the fitting 75 and an upward tubular extension 77 on the fitting receives the vapor tube 5 and is secured thereto as at 77'. The lower end of the fitting 75 provides a downwardly facing valve seat against which is seated a circular valve element 78 of rubber or other resilient material. A group of valve control

rods 79 support the valve element 78 and are slidably mounted in short tubular guides 80 welded in the lower wall portion of the member 74. At their lower ends the rods 79 support a ring 81 having two interfitting and threaded elements 82 and 83 mounted centrally therein. Each of the rods 79 carries a washer or flange 79' near its lower end serving as an abutment for a light compression spring 84 extending downwardly to contact the ring 81. The upper threaded element 83 is hollowed out to slidably receive the lower headed end of a needle valve element 85, so as to allow limited movement of the element 85 with respect to the elements 82 and 83 and the ring 81. Encircling the element 83 and fixed thereto is a bellows 86 having its upper end fixed to a threaded nipple 87 within which is guided the needle valve element 85. A narrow groove 87' internally of the nipple 87 transmits pressure within the hollow nozzle 57 to the interior of the bellows 86. As may be seen in the drawing, the nipple or bushing 87 is threaded into the lower end of the nozzle 57. A light coil spring 88 surrounds the needle valve element 85 near its lower end and has its opposite ends abutting the bushing 87 and an annular shoulder 89 above the headed lower end of valve element 85. The lower limit of the assembly 81-83 is determined by an adjustable stop member 90 threaded into the wall 71 and maintained in adjusted position by a locknut 90'. The assembly 81-83 is biased away from the wall 71 by means of a compression spring 91.

Operation

The heater and starting system as shown in Figs. 1 to 3 forms a complete and efficient apparatus to burn liquid fuel, such as gasoline, in a chamber from whence the hot products of combustion may flow by way of an exhaust pipe for space heating, for warming up machinery and engines in cold climates or for heating living quarters by the use of a heat transfer unit through which the hot gases from the heater are passed. To start the apparatus after filling the fuel tank 21, the operator must turn on the fuel valve 22. Fuel now gravitates to the fuel reservoir 15 by way of pipe 20 and to the fuel vaporizer 33 by way of pipe 34 and ball valve 39. When fuel first flows down the pipe 20 and past valve 18, the float 16 is down in a level position and the first fuel enters the catch basin 23 on top of the float. As it reaches the overflow hole 24 the fuel runs out to start filling the reservoir 15 and feed pipe 14. As the reservoir becomes partly filled the float rises and begins to spill fuel out of the hole 25, part of which runs into the reservoir and part of which runs over the hinge arm 15' and into the side chamber 15' and pipe 26. As the float rises farther the flow of fuel down the stem of valve 18 falls outside of the catch basin 23 and fills the reservoir 15 to a level where the valve 18 is closed, as in Fig. 1. The float 16 having tilted still farther, more fuel flows into side chamber 15' and by way of pipe 25 to the bottom of housing 27. Now the operator turns the magneto 30 to fire the torch flame unit, whereupon flames rise from the wicking 59 to start heating the fuel in the vaporizing chamber 33. As the fuel heats up, the vapor generated in the chamber 33 flows down the tube 35. The tube includes a portion 53 within the combustion tube 32 whereby the vapor is superheated to prevent excessive condensation on the way to the fuel nozzles.

The vapor pressure in the nozzles 57 and 33 now develops to cause opening of the needle valves 85 and 62 by actuation of the bellows 86 and 65. Since the torch flame at nozzle 33 should start before vapor is allowed to escape from the nozzle 57, the spring 67 opposing expansion of bellows 65 is made more responsive than the spring 91 under the bellows 86. For example the needle valve 62 in nozzle 33 may be made to open at a vapor pressure of 25 p. s. i. and the needle valve 85 in nozzle 57 may be made to open at a vapor pressure of 120 p. s. i., these responses being determined by the relative strength of springs 67 and 91. It may now be assumed that the needle valve 62 has opened after expansion of bellows 65 and corresponding downward movement of the disk 66, which determines the position of the needle valve in conjunction with the valve biasing spring 64. The vapor flowing from the nozzle 33 now ignites by reason of the flames rising off the wicking 59, thus starting a substantial torch action up the combustion tube 32 to cause a hot spot to form at one point on the combustion chamber wall. Furthermore the fuel in vaporizing chamber 33 now heats up still more to increase the vapor pressure at the nozzles 57 and 33. As the pressure in bellows 86 increases the member 83 moves along the lower end of the needle valve 85 from the original position adjacent to flange 89 to the position shown (Fig. 2). The needle valve remains closed during this portion of the bellows expansion, in spite of the spring 88, because the upper end of the needle valve is subject to atmospheric pressure while the lower end is subject to very substantial positive pressures. It is understood of course that the upper pointed end of the needle valve is tightly engaged in the conical opening at the upper end of the nozzle 57. Now as the bellows expands still more, the member 83 at the lower end of bellows 86 acts to positively open the needle valve 85 whereupon the excess downward force caused by spring 88 snaps the valve open and allows full flow of vapor from the nozzle 57. The position of the needle valve as shown in Fig. 2 corresponds to the condition where the valve has just been positively moved away from its contact with the conical valve seat but has not yet snapped fully open to a position where the flange 89 will contact the upper end of member 83. As the valve is opened slightly to the position shown, the fluid pressure will become the same on all surfaces thereof and the coil spring 88 will have the desired effect of causing sudden full opening of the valve. As the bellows 86 expanded it also caused the rods 79 to move downward slightly and thus the air valve 78 opens sufficiently to allow flow of air through passage 76. The air and fuel vapor mixture now flows into the combustion chamber 2 by way of tube 5 where the mixture ignites, due to the presence of the hot spot on the chamber wall. The initial explosion of the fuel and air in the chamber 2 is followed by a condition of low pressure whereby fuel and air start flowing up the manifold 12 to start the pulse jet action of the heater. The steady flow of fuel vapor from the nozzles 57 and 33 soon lowers the vapor pressure to a point where both needle valves 85 and 62 close and the starting system ceases to function until the next start. Fuel continues to flow steadily into the fuel feed pipe 14 from the reservoir 15, the float 16 acting to open and close the fuel valve 18 to keep a maximum amount of fuel in the reservoir 15. The slight up and down movement of the float 16 will

not be sufficient to let any fuel into the basin 23, therefore the wicking 59 in housing 27 will not be supplied with any additional fuel until the reservoir 15 is emptied or until the float 16 is pushed down by means of the push rod 23. To stop the pulse jet heater it is merely necessary to close the main fuel valve 22, whereupon the fuel remaining in the reservoir 15 is used up entirely by normal flow through the feed pipe 14.

Modified fuel control system

The modified fuel control and starting system of Fig. 4 is shown in association with a pulse jet heater of the resonant type, including a combustion chamber 2', an exhaust pipe 4', inlet valve 7' and inlet manifold 12' all exactly similar to corresponding elements as previously described. Fuel and air flows through the manifold 12' and automatic valve 7' just as in the principal form of the apparatus and the fuel issues into the manifold from the feed pipe 94 supplied by gravity with liquid fuel from the reservoir 95, in which is pivotally mounted a float 96 turning about the pivot 97. A valve element 98 is reciprocally mounted in a small cylinder 99 on the upper wall of the reservoir 95. Thus the float is adapted to open and close the valve 98 as the fuel level in the reservoir falls and rises to thus maintain a constant fuel quantity in the reservoir. In order to vent the reservoir 95 to allow atmospheric pressure on top of the fuel, there is provided a tube 100 extending from the reservoir to the vent tube 41' on top of fuel tank 21'. Fuel is supplied to the reservoir 95 by way of the fuel feed pipe 101 having a fuel shut-off valve 22' interposed therein close to the tank. Fuel flowing in pipe 101 is also under control of the thermostatically controlled valve 102, so that fuel flow to the reservoir 95 is not started until the hot spot on the chamber wall at the conduit 6' is well developed. The valve 102 includes an actuating arm 103 connected by a rod 104 to a pivoted arm 105 actuated by a bimetallic element 106 in a small housing 107 open at one end to the combustion chamber 2'. The outer surface of the housing 107 may be coated with an insulating layer, as shown.

The heater starting components including housings 27' and 36' are exactly similar to those shown in Fig. 2, except that the vapor flow tube 35' is arranged in a coil 35'' within the vaporizing chamber 33'. As before the combustion tube 110 of the torch flame unit extends to a nozzle-like element 6' which stops short of the combustion chamber wall. A check valve 111 is interposed in the vapor flow tube 35' in order to prevent vapor flow to the fuel nozzles until there is sufficient pressure developed to provide an effective flame at nozzle 38' of the torch flame unit. Fuel flow to the vaporizing chamber 33' is by way of pipe 101, branch pipe 112 and ball check valve 113. Possible fuel condensation or leakage into the lower portions of housings 27' and 36' is drained away by pipes 114 and 115 into the drain pipe 116. The pipe 115 also includes a branch extending to the bottom of a drip pan 117 under the outlet end of fuel feed pipe 94 and also under the flared mouth of manifold 12'.

Priming fuel for the wicking in the torch flame unit may be supplied by a pipe 118 and fuel may be supplied manually through a funnel 119. However the preferred manner is through the action of a special fuel feed component 120. The device 120 includes a two-part housing 121 and between the two parts thereof a highly flexible

diaphragm 122 is provided. The pipe 123 extends from the fuel pipe 101 to the upper side of the housing 121, while a similar pipe 124 extends from the fuel pipe 101 to the lower side of the housing 121. At the point where the pipe 124 enters the housing there is a restriction 125, to give a delayed action in elevating the diaphragm after the upper part of the housing has filled with fuel and the float 126 has risen to cause the valve element 127 to close off the pipe 123. Now with the upper part of the housing partly filled with fuel, the static pressure on the lower side of diaphragm gradually forces it upward to displace some fuel for flow through the housing extension 128 and thence down the feed pipe 118 to the wicking in housing 27'. It is understood of course that the upper part of the housing 121 will not usually fill quite up to the level of housing extension 128 before the valve element 127 closes off the feed pipe 123. Subsequent raising of the fuel level in the upper part of the housing 121 is accomplished by pressure which develops slowly as fuel enters the pipe 124 and moves through the choke 125. As the fuel level in the upper part of the housing 121 is raised the valve 127 becomes more firmly seated and no further influx of fuel occurs until the next time the system is started by turning on the main fuel valve 22'.

In the present heater control system there is provided a pressure control valve unit 130 associated with the torch flame unit for controlling the fuel level therein and also for venting accumulated air found therein, especially when it is time to start up the heater. As in the system of Fig. 1, the pressure control valve 130 includes a housing 131 having a float 132 slidably mounted therein. The walls of the float may be of ribbed or fluted construction to minimize frictional resistance to float movement. The upper end of the float is cone-shaped to provide a valve element 133 adapted to close a valve seat inside the housing at the lower end of tube 134 extending to the fuel tank vent 41'. Such closing action will not occur until there is sufficient liquid fuel accumulated in the housing 131 to cause lifting action of the float 132. Fuel vapor, air and liquid may enter the lower end of housing 131 by way of the inlet tube 135 extending from the upper end of the fuel vaporizing chamber 33'. The passage of air or fuel vapor into the housing 131 has little effect on the float 132, since such gaseous flow is merely vented by way of the tube 134 to the fuel tank vent 41'. Thus the pressure control valve 130, as well as the similar valve 40 in Fig. 1, acts to de-aerate the fuel vaporizing chamber as the fuel and fuel vapor displaces accumulated air which enters the chamber when the system is shut down.

Another feature of the valve 130 is the float control device 136 comprising a two-part housing having a diaphragm 137 secured between the two parts of the housing. The housing section nearest to the control valve 130 is provided with a mounting arm or bracket 138 fastened on one side of the float housing 131. A push rod 139 fixed to the diaphragm 137 extends into the housing 131 to actuate the float 132 when pressure on the upper side of diaphragm 137 exceeds the pressure on the lower side thereof. The lower side of the diaphragm is exposed to atmospheric pressure because of holes in the lower part of the diaphragm housing. The upper side of the diaphragm is exposed to the pressure of the combustion chamber 2', such pressure being communicated by way of tube 140 and check valve

141. As soon as resonant combustion is established the pressure rise will cause actuation of the push rod 139 and float 132 will be forced down. This will help to lower the vapor pressure in the chamber 33' more quickly, so that the starting system will cease operation by closing of the fuel nozzles in the torch flame unit and the heater starting unit of Fig. 2.

Operation of modified fuel control system

In general the operation and use of the modified system shown in Fig. 4 is the same as in the previously described system. The combustion chamber, torch flame unit and heater starting unit are almost identical in construction and arrangement in both forms of the apparatus. The auxiliary control units are somewhat different and in Fig. 4 the control units are more numerous in order to offer the ultimate in automatic control of the present type of heater.

In order to start the heater, the fuel valve 22' is first turned on. Fuel will not flow past the thermostatically controlled valve 102, since the control element 105 is cold. However fuel will flow through branch 123 and partly fill the upper part of housing 121. Fuel flow will stop as the float 126 rises to close the outlet end of branch pipe 123. Fuel pressure will gradually cause a pressure build-up below diaphragm 122 to lift the diaphragm and displace some fuel into the housing extension 128 and thence down pipe 113 to the wicking in the bottom of torch flame unit 27'. The fuel vaporizing chamber 33' will also fill up at least part way by way of the branch pipe 112. Now the fuel absorbed by the wicking in the torch flame unit is ignited by a match or by means of a spark plug 60 (see Fig. 2). The fuel in chamber 33' is now vaporized by the heat of the burning fuel rising up along tube 110, and the fuel vapor will flow by way of tube 35', valve 111 and tube 37' to the nozzle 38'. Now the vaporized fuel will begin to issue from the nozzle 38' as the pressure rises sufficiently to retract the needle valve within the nozzle. A torch flame now flows up the tube 110 to develop a hot spot on the combustion chamber wall and to further vaporize fuel in chamber 33'. When the vapor pressure rises sufficiently the fuel nozzle in the heater starting unit 36' opens to start a flow of fuel vapor to the combustion chamber. Since the hot spot has been developing in the meantime the thermostatic control will have heated sufficiently to open valve 102 and permit flow of liquid fuel to the reservoir 95 and to the fuel feed pipe 94. The fuel vapor flowing in the tube 5' will fill up the combustion chamber and will fire from the hot spot on the chamber wall. The sudden drop in pressure in the chamber after the first explosion will cause some air and fuel to be sucked in by way of the automatic air-fuel valve 7'. This new charge will fire and the resonant pulse jet action will begin. Since the vapor pressure in chamber 33' will now be reduced to a very low level, the nozzles in the torch flame unit and heater starting unit will close to put the starting apparatus out of operation. Since the pressure developed in the combustion chamber 2' will maintain the vapor escape line 134 open by reason of the diaphragm 137 and push rod 139, any temporary vapor pressure in the chamber 33' due to residual heat will be vented to the tank vent 41'. The pulse jet heater will now continue in operation as long as fuel is supplied by way of the pipe 101 and reservoir 95.

The embodiments of the invention herein shown

and described are to be regarded as illustrative only and it is to be understood that the invention is susceptible of variations, modifications and changes within the scope of the appended claims.

We claim:

1. In a pulse jet heater of the resonant type including walls forming a combustion chamber provided with an air-fuel inlet, a fuel control and starting system comprising, a fuel tank, conduit means to conduct liquid fuel from said tank to said air-fuel inlet, a torch flame unit near said combustion chamber and including a housing and connected combustion tube extending upwardly to a point near to but just short of the wall of said combustion chamber, means forming a fuel vaporizing chamber in heat transfer relation with respect to said combustion tube, a first fuel nozzle in said torch flame unit, a first spring actuated means normally closing said first fuel nozzle, a heater starting unit near said torch flame unit and including a housing and connected tube extending into said combustion chamber, a second fuel nozzle in said heater starting unit, a second spring actuated means normally closing said second fuel nozzle and exerting more closing force than said first spring actuated means, means to supply vaporized fuel to the interior of said second fuel nozzle and to the interior of said first fuel nozzle from said fuel vaporizing chamber, and first and second pressure responsive means subject to the fuel vapor pressure to open said first and second fuel nozzles respectively.

2. In a pulse jet heater of the resonant type including walls forming a combustion chamber provided with an air-fuel inlet, a fuel control and starting system comprising, a fuel tank, conduit means to conduct liquid fuel from said tank to said air-fuel inlet, a torch flame unit near said combustion chamber and including a housing and connected combustion tube extending upwardly to a point near to but just short of the wall of said combustion chamber, means forming an annular fuel vaporizing chamber within said housing and around said combustion tube, conduit means to conduct liquid fuel from said tank to said fuel vaporizing chamber, a first fuel nozzle in said torch flame unit, a first spring actuated means normally closing said first fuel nozzle, a heater starting unit near said torch flame unit and including a housing and connected tube extending into said combustion chamber, a second fuel nozzle in said heater starting unit, a second spring actuated means normally closing said second fuel nozzle and exerting more closing force than said first spring actuated means, means to supply vaporized fuel to the interior of said second fuel nozzle and to the interior of said first fuel nozzle from said fuel vaporizing chamber, a first pressure responsive means connected with the interior of said first fuel nozzle to open the nozzle at a first predetermined vapor pressure, and a second pressure responsive means connected with the interior of said second fuel nozzle to open the nozzle at a second predetermined vapor pressure greater than said first predetermined pressure.

3. In a pulse jet heater of the resonant type including walls forming a combustion chamber provided with an air-fuel inlet, a fuel control and starting system comprising a fuel feed pipe and nozzle extending to a point within said air-fuel inlet, means for feeding liquid fuel to said fuel feed pipe including a float chamber, a pivotally mounted float in said float chamber, a

fuel inlet valve movably mounted above said float and adapted to be closed by said float as said float is raised by partial filling of said float chamber, a torch flame unit near said combustion chamber and including a housing and connected combustion tube extending upwardly to a point near to but just short of the wall of said combustion chamber, wicking in said torch flame unit housing, means to admit air to said torch flame unit housing, a priming conduit extending from said float chamber to the wicking in the torch flame unit housing, and means on said float to collect liquid fuel and divert at least part of the collected fuel to said priming conduit upon tilting of said float as said float chamber starts to fill.

4. In a pulse jet heater of the resonant type including walls forming a combustion chamber provided with an air-fuel inlet, a fuel control and starting system comprising, a fuel feed pipe and nozzle extending to a point within said air-fuel inlet, means including a fuel tank for feeding liquid fuel to said fuel feed pipe, a torch flame unit near said combustion chamber and including a housing and connected combustion tube extending upwardly to a point near to but just short of the wall of said combustion chamber, wicking in said torch flame unit housing, means to admit air to said torch flame unit housing, a priming unit including a housing divided by a movable wall element, conduit means to supply liquid to both sections of the divided housing from said fuel tank, means to conduct fuel from an overflow pipe connected with one of said divided housing sections above the other section to said wicking, and choke means in the conduit means leading to said other section in order to retard application of maximum pressure on said movable wall element.

5. In a pulse jet heater of the resonant type including walls forming a combustion chamber provided with an air-fuel inlet, a fuel control and starting system comprising, a fuel tank, conduit means to conduct liquid fuel from said tank to said air-fuel inlet, a torch flame unit near said combustion chamber and including a housing and connected combustion tube extending upwardly to a point near to but just short of the wall of said combustion chamber, means forming an annular fuel vaporizing chamber within said housing and around said combustion tube, conduit means to conduct liquid fuel from said tank to said fuel vaporizing chamber, a fuel nozzle in said torch flame unit, means to conduct vaporized fuel to said fuel nozzle, a pressure control unit including a housing enclosing a float and float actuated

valve means, conduit means extending from the upper wall of said fuel vaporizing chamber to said pressure control unit housing, and a vapor escape conduit controlled by said float actuated valve means and communicatively extending from an upper portion of said pressure control unit housing to an upper portion of said fuel tank.

6. In a pulse jet heater of the resonant type including walls forming a combustion chamber provided with an air-fuel inlet, a fuel control and starting system comprising, a fuel tank, conduit means to conduct liquid fuel from said tank to said air-fuel inlet, a torch flame unit near said combustion chamber and including a housing and connected combustion tube extending upwardly to a point near to but just short of the wall of said combustion chamber, means forming an annular fuel vaporizing chamber within said housing and around said combustion tube, conduit means to conduct liquid fuel from said tank to said fuel vaporizing chamber, a fuel nozzle in said torch flame unit, means to conduct vaporized fuel to said fuel nozzle, a pressure control unit including a housing enclosing a float and float actuated valve means, conduit means extending from the upper wall of said fuel vaporizing chamber to said pressure control unit housing, a vapor escape conduit controlled by said float actuated valve means and communicatively extending from an upper portion of said pressure control unit housing to an upper portion of said fuel tank, and pressure responsive means connected by a pressure sensing tube to said combustion chamber for opening said float actuated valve means when resonant combustion is started in said combustion chamber.

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