March 4, 1947. H. J. DE N. McCOLLUM 2,416,935

ALTITUDE COMPENSATING HEATING SYSTEM

Filed Aug. 27, 1942 2 Sheets-Sheet 1

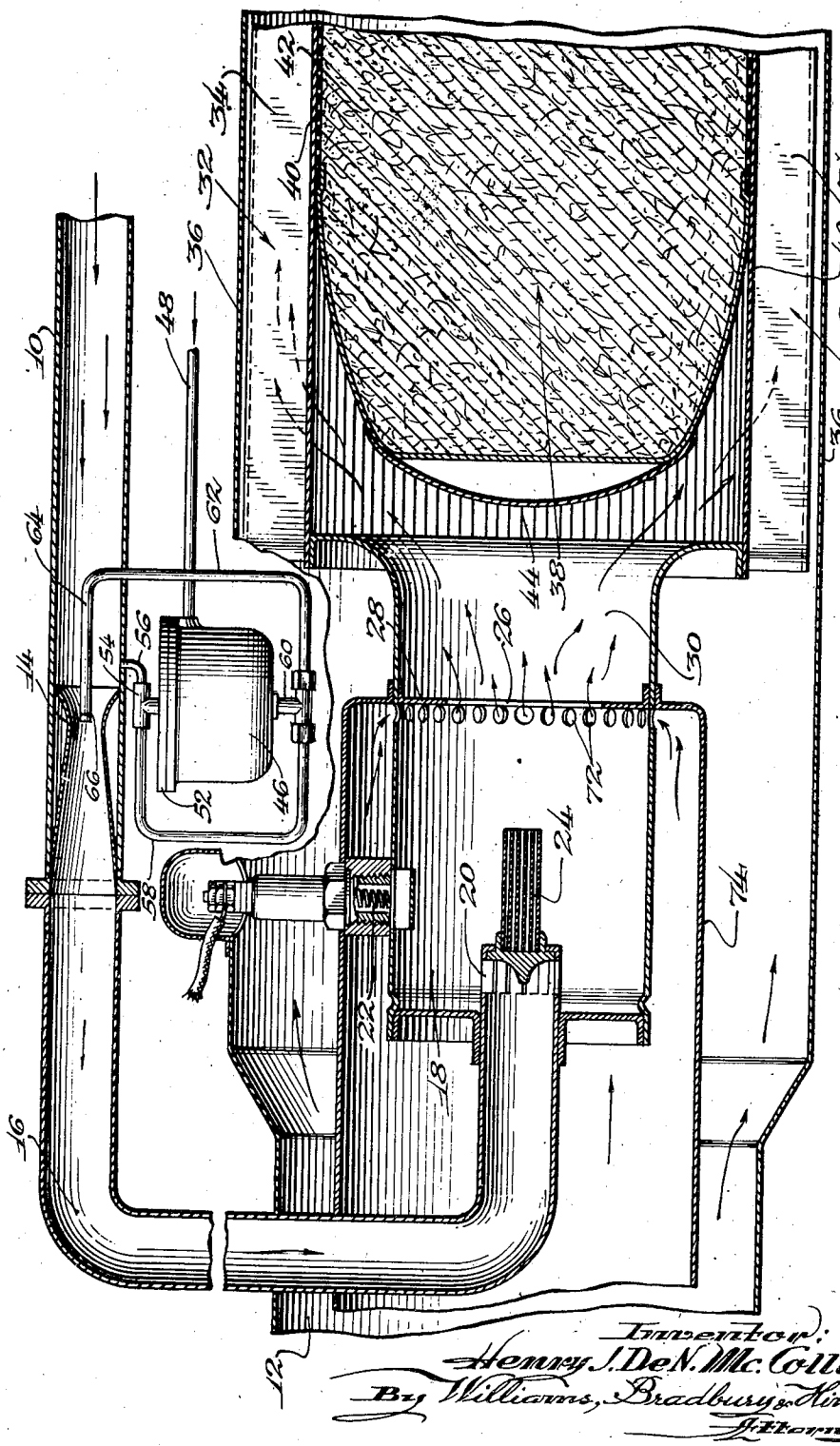


Fig. 1.

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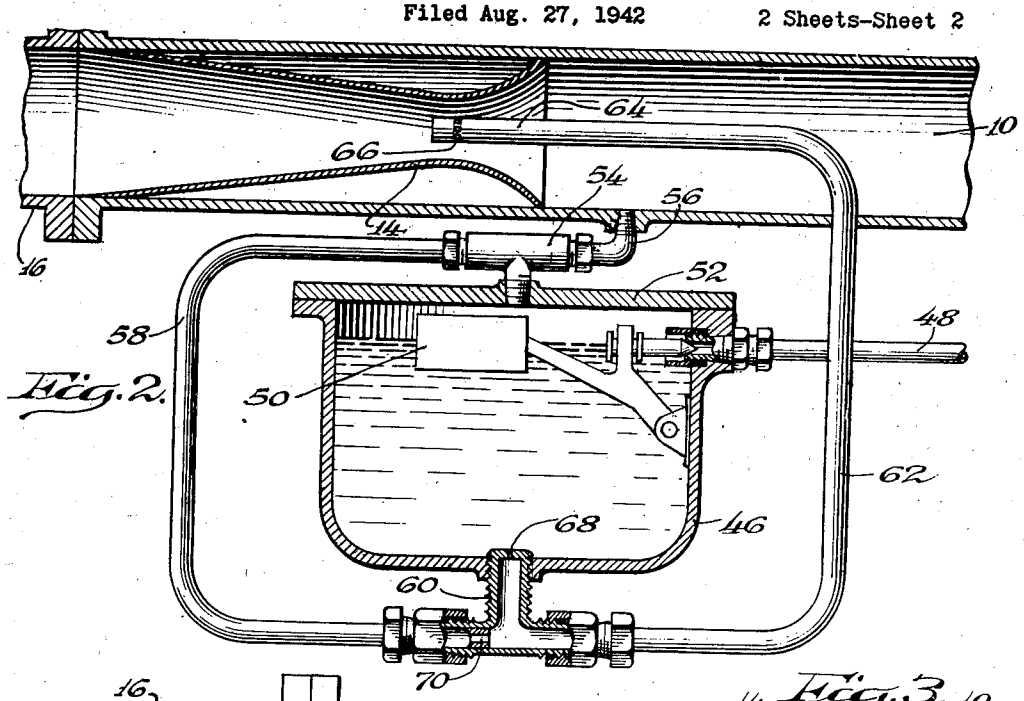


Fig. 2.

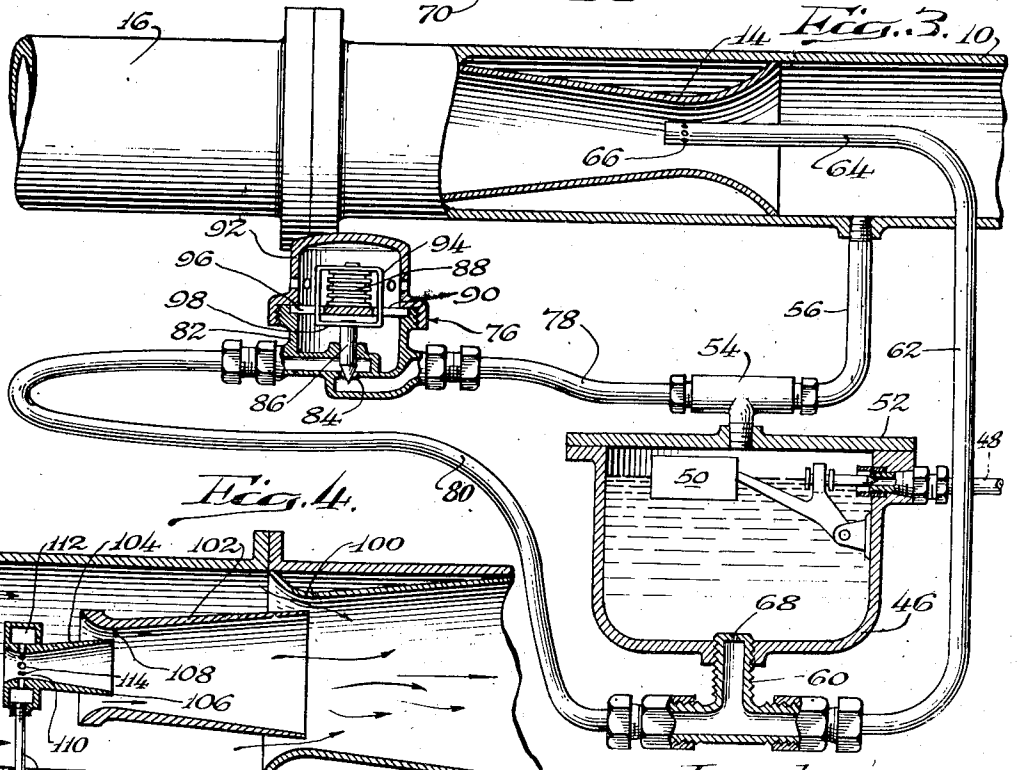


Fig. 3.

Fig. 4.

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UNITED STATES PATENT OFFICE

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ALTITUDE COMPENSATING HEATING SYSTEM

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Application August 27, 1942, Serial No. 456,335

3 Claims. (Cl. 158—28)

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The present invention relates to altitude compensating heating systems. More specifically, it relates to a novel heating system of the internal combustion type particularly adapted for use in aircraft which includes features that automatically adapt the heating system to operate efficiently at varying altitudes.

As will be pointed out in greater detail presently, an internal combustion heating system in general comprises a carbureting arrangement for providing a mixture of liquid fuel and air, this mixture being conducted to a combustion chamber where it is ignited and burned, the products of combustion passing through a heat exchanger where the heat is exchanged to a fresh air stream. The products of combustion eventually pass through an exhaust conduit to a position outside the aircraft, while the heated fresh air flows from the heating system to the compartments within the aircraft intended to be heated.

The principal object of the present invention is to provide an internal combustion heating system of the above outlined general type which has novel means for automatically adapting the heater to operate efficiently at different altitudes.

Yet another object of the present invention is to provide a novel heating system of the internal combustion type which is automatically adapted to operate at different atmospheric pressures.

Another object of the present invention is to provide a novel aircraft internal combustion heater which is well adapted for operation at any altitude within the range of the aircraft.

Still another object of the present invention is to provide a novel internal combustion aircraft heater automatically adapted for operation at varying altitudes, and which includes its own carbureting system, the heater together with the carbureting system, being well adapted to operate at low pressure differentials and at varying air pressures.

Other objects and advantages will become apparent from the following description of a preferred embodiment of my invention illustrated in the accompanying drawings. In the drawings, in which similar characters of reference refer to similar parts throughout the several views,

Fig. 1 is a somewhat diagrammatic view of a heating system embodying the present invention shown in longitudinal vertical section.

Fig. 2 is a longitudinal vertical sectional view of a detail of the mechanism illustrated in Fig. 1.

Fig. 3 is a longitudinal vertical sectional view of an alternative altitude compensating heating system, and

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Fig. 4 is a longitudinal sectional view of an alternative arrangement for introducing a liquid fuel into a slowly moving air stream.

The heating system illustrated in Fig. 1 of the drawings is intended to receive air for its operation from one or more rams, these rams being located at the leading edge of the airplane wing or in some other position where they face forwardly against the moving air stream. Air from the ram or rams passes into a carburetor intake conduit 10 and into a main heater conduit 12. Air entering the conduit 10 passes through a Venturi throat 14 where a combustible mixture is formed in a manner to be described presently. From here the combustible mixture flows through a passage 16 to a heater combustion chamber 18. It enters the combustion chamber through a plurality of radially arranged ports 20 formed by striking out vanes from the side walls of a cylindrical tube. Inasmuch as these vanes are inclined somewhat from a straight radial position the mixture enters the combustion chamber 18 with a swirling motion.

Within the chamber 18, combustion is initiated by an igniter 22 of the hot wire type, this igniter being electrically energized and more fully disclosed in my co-pending application, Serial No. 447,345, filed June 17, 1942, for "Heating apparatus." As explained in that application, after combustion has been well started, the igniter 22 can be deenergized and if subsequently combustion fails for any reason, the combustible mixture will be reignited by a reigniter 24 formed of a spirally coiled sheet of heat and corrosion resistant material such as "Inconel," for instance. This reigniter is more fully disclosed in my copending application, Serial No. 410,039, filed September 8, 1941, now Patent No. 2,396,868, issued March 10, 1946.

From the combustion chamber 18, the hot products of combustion pass through a central opening 26 in an annular baffle 28 and into a secondary combustion zone 30 from which they flow into a heat exchanger 32. This heat exchanger is generally cylindrical and has a plurality of longitudinally extending U-shaped hollow fins 34 which form channels through which the products of combustion pass. These fins are enclosed within a tubular housing 36 through which air is passed from the ram, not shown but connected to the pipe 12, to the space to be heated.

A generally cylindrical acoustic silencer 38 is located within the space surrounded by the annularly arranged heat exchanger fins 34. This silencer is comprised of a generally cylindrical

container having perforated side walls 40 which enclose a quantity of acoustic silencing material 42, such as glass wool or stainless steel wool, for instance. The silencer effectively damps out pulsations in the combustible mixture, thereby preventing burning from taking place in surges within the combustion chamber, thus eliminating the phenomenon known as "motor boating." In order to distribute the hot products of combustion from the secondary burning zone 30 to the tubular fins 32, the end 44 of the acoustic silencer 38 facing the combustion chamber is rounded so as to distribute the moving gases smoothly outwardly.

A carburetor float bowl 46 is located below the venturi 14 and receives liquid fuel through a pipe 48. This pipe is connected to the float bowl near its upper edge and the fuel enters the bowl through a conventional float valve 50, so arranged and adjusted as to keep the bowl as nearly full of fuel as possible.

The float bowl is closed by a cover 52 having an opening connected to a T-fitting 54, one branch of the T being connected by an elbow 56 to the portion of the conduit 10 immediately ahead of the venturi 14. The other branch of the T-fitting 54 is connected by a conduit 58 to one branch of a T-fitting 60 threaded through the lower surface of the float bowl 46, the other branch of the fitting 60 being connected by a conduit 62 to a carburetor jet tube 64 having a plurality of outlet jet openings 66 located axially of the low zone of the venturi 14.

The end of the T-fitting 60 threaded into the bowl 46 is closed excepting for a small orifice 68 which permits gasoline or other liquid fuel to flow from the bowl 46 into the fitting 60. The branch of the T-fitting 60 connected to the conduit 58 is similarly closed excepting for a small orifice 70 having approximately four times the area of the orifice 68.

The above described carbureting system functions as follows:

A portion of the air flowing through the conduit 10 enters the elbow 56 at a high pressure point in the conduit. The remaining air flows through the Venturi throat 14, thus producing a low pressure area surrounding the jets 66. The pressure differential thus produced causes a flow of air through the elbow 56, T-fitting 54, conduit 58, T-fitting 60 including the orifice 70, conduit 62, and jets 66. The high pressure side of this system is communicated to the space above the fuel in the bowl 46 through the downwardly extending branch of the T-fitting 54, while the low pressure side of the system is communicated to the orifice 68. Fuel, therefore, flows through the orifice 68 and is atomized and partially vaporized by the jet of air flowing through the orifice 70. The fuel in its atomized and vaporized condition is carried with the air stream through the conduit 62 to the jet tube 64 where it passes through the jet openings 66 into the air stream flowing through the venturi 14.

The above arrangement permits fuel to be introduced into the air stream passing through the venturi 14 even though the pressure differential produced by the venturi is comparatively small. This is because the fuel flows through the jet 68 by gravity as well as by whatever pressure differential exists, and further by the fact that the fuel passing upwardly through the tube 62 to the jets 66 is in an atomized and vaporized condition and is mixed with a considerable quantity of moving air. The density of the column of fuel being lifted therefore is comparatively low.

The heating system as above described has the orifices 68 and 70 so proportioned that a mixture of the proper degree of richness will pass to the combustion chamber 18 at the maximum air density under which the heater is intended to operate, that is, at sea level pressure. As the airplane climbs to higher altitudes, the mixture as thus supplied will become too rich. This is because the quantity of fuel introduced at the Venturi throat is substantially unaffected by the density of the air flowing through the venturi. The quantity of oxygen in the final mixture, however, is directly affected by the density of the air flow through the Venturi throat and, therefore, the lower the density of the air passing through the venturi the richer the resulting mixture.

To compensate for the increased richness of the mixture supplied to the combustion chamber 18 at higher altitudes, I have provided the side wall of the combustion chamber in a position adjacent the baffle plate 28 with a plurality of circumferentially arranged perforations 72. These perforations, as well as the combustion chamber 18, are surrounded by a tubular member 74 connected to a ram, not shown. Air from the outside, therefore, flows inwardly through the perforations continuously while the airplane is in motion. Since this air enters through the circumferentially arranged perforations 72 in a position adjacent the baffle 28, the fresh air will be intimately mixed with the products of combustion issuing from the combustion chamber 18, the mixture passing through the opening 26 in the baffle plate 28, and into the secondary combustion zone 30.

At low altitudes, the mixture entering the combustion chamber 18 is of approximately the ideal degree of richness. Combustion, therefore, takes place rapidly and is substantially completed before the mixture reaches the fresh air which enters through the perforations 72. Combustion is, therefore, substantially unaffected by the inward flow of fresh air. On the other hand, at higher altitudes when the mixture entering the combustion chamber 18 does not have sufficient oxygen completely to burn the fuel mixed therewith, only partial combustion takes place in the combustion chamber 18, the mixture flowing from this chamber including a considerable quantity of unburned fuel and carbon monoxide. The fresh air entering through the perforations 72 is intimately mixed with this partially burned mixture, thereby supplying sufficient additional oxygen to convert the remaining liquid fuel and carbon monoxide into substantially completely oxidized elements. Under these high altitude conditions, burning will take place within the secondary combustion zone 30 and the amount of burning that takes place in this zone will depend upon the degree of excess richness of the mixture entering the combustion chamber 18.

The perforations 72 are properly proportioned in size and number so that sufficient air flows therethrough to complete the combustion at the maximum operating altitude of the airplane. Sufficient air, therefore, is always present to complete combustion before the gases pass into the heat exchanger 32. On the other hand, the air entering the combustion chamber through the perforations 72 is never present in great enough quantity to quench combustion taking place within this portion of the apparatus.

In heaters of the present type, where the sev-

eral elements used in the construction must weigh as little as possible, it frequently happens that under some operating conditions hot spots will be formed within the portion of the heat exchanger where the hot products of combustion enter. That is, there may be isolated spots that become heated faster than the heat can be conducted away. The result is that occasionally heat exchangers may warp or burn through under adverse operating conditions. The present arrangement aids in combating this effect in the following manner:

At low altitudes, where the air taken into the heating system is normally moderate in temperature, the temperature of the air leaving the combustion chamber will be comparatively hot. The products of combustion are diluted by the air entering the perforations 72, thus tempering the products of combustion issuing from the combustion chamber before they are introduced into the heat exchanger, thereby reducing the tendency of portions of the heat exchanger to overheat. On the other hand, at high altitudes where the air entering the perforations 72 is used to support combustion, this air has no substantial tempering effect but this tempering effect is not needed inasmuch as the air entering the heating system will be extremely cold, thereby lowering the temperature of the heating system as a whole. In other words, a heater properly constructed to operate without burning through at low altitudes when the air entering the system through the perforations 72 is used for tempering purposes, should also operate satisfactorily at high altitudes even though under these conditions the air entering through the perforations 72 is used to support combustion.

In Fig. 3 of the drawings, I have shown an altitude compensating arrangement adapted for use with a heater having no auxiliary air inlets of the type provided in the above described embodiment by the perforations 72. A heater of this type, that is, one not having the auxiliary air inlets, is illustrated and described in my co-pending application entitled "Heating Apparatus," Serial No. 447,345, filed June 17, 1942, now Patent No. 2,403,188, issued July 2, 1946.

The carbureting arrangement shown in Fig. 3, is, with the exception of an altitude control valve 76, essentially similar to the arrangement shown in Fig. 2. For this reason, the same numerals are used to indicate the same elements in the two figures. The induction tube 10, the venturi 14, the float bowl 46, the T-fittings 54 and 60, the orifice 68, and the jet tube 64, may all be considered as identical with the similar elements in Fig. 2. In Fig. 2, a passage 58 is shown as connecting the T-fitting 54 with the T-fitting 60, so that air from a high pressure point within the induction tube 10 can be mixed with the fuel passing through the port 68. In the embodiment shown in Fig. 3, the T-fitting 54 is connected by a tube 78 to the inlet side of the altitude control valve 76, while the outlet side of this altitude control valve is connected to a conduit 80 leading to the lower T-fitting 60. Thus, air passed from a high pressure point within the induction tube 10 to the lower T-fitting 60 must flow through the automatic altitude control valve 76.

This automatic control valve is composed of a housing 82 having inlet and outlet passages communicating through a valve seat 84. A vertically slidable needle valve pin 86 is located above the seat 84, so that the higher the needle valve pin 86 is raised relative to the valve seat, the greater the flow between the inlet and outlet passages. Since these inlet and outlet passages are connected to the tubes 78 and 80, the flow through these tubes, and, therefore, the flow from the T-fitting 54 to the lower T-fitting 60, will be determined by the vertical position of the valve pin 86.

Directly above the valve pin, a Sylphon bellows 88 is supported upon a horizontal plate 90 secured at its edges between the housing 82 and a perforated cap 92. A yoke 94 is secured to the top of the bellows 88 and has downwardly extending arms which pass through slots 96 in the plate 90. At their lower ends the downwardly extending arms of the yoke are secured to a cross piece 98 attached to the upper end of the needle valve pin 86.

At sea level, the air pressure communicated to the outside of the Sylphon bellows 88 through the perforations in the cap 92 causes the bellows to assume such a length that the valve pin 86 is positioned off its seat 84 the proper distance to permit the appropriate amount of air to flow through the tube 78, valve 76, and tube 80 to the T-fitting 60, to form the proper heater mixture when the heater is operating under sea level conditions. As the airplane rises, the pressure imposed upon the outer surface of the Sylphon bellows 88 will be less than at sea level. Consequently, the bellows will expand, thereby lifting the needle valve 86 somewhat. This permits a more rapid flow of air through the tube 78, valve 76, and tube 80 to the T-fitting 60. This, in turn, reduces the pressure differential between the T-fitting 60 and the upper surface of the fuel within the bowl 46. The decrease in this pressure differential decreases the rate of fuel flow through the orifice 68 and thus a less quantity of fuel is carried upwardly to the jet tube 64, thereby reducing the richness of the mixture supplied to the heater.

The above described control valve, it will be seen, operates to reduce the richness of the mixture as the airplane flies into more rarefied air conditions, thereby insuring that the heater at all times, under all altitude conditions, receives the proper mixture for efficient operation.

In Fig. 4, I have shown an arrangement for introducing fuel into a moving air stream, such as the air stream through the carburetor induction tube 10, when the rate of air flow therethrough is extremely low. This arrangement comprises a comparatively large diameter Venturi throat 100 through which the air is caused to flow, thus producing a low pressure area at the narrowest point within the throat. A second venturi 102 is arranged with its outlet end at the low pressure area within the throat of the venturi 100, thereby causing the air leaving the Venturi tube 102 to be at substantially the same pressure as the air within the low pressure point of the venturi 100. A third Venturi tube 104 is arranged with its outlet end 106 located at the low pressure point 108 of the Venturi tube 102, thereby still further reducing the pressure of the air leaving the Venturi tube 104. The low pressure point 110 of the Venturi tube 104 is, therefore, extremely low. The throat of the Venuri tube 104, however, may be too small to accommodate a jet tube of the conventional type. Under these conditions, I surround the low pressure point of the Venturi tube 104 with an annular chamber 112 which communicates with the Venturi throat through a plurality of jet passages 114 drilled through the side wall of the

throat, the annular space 112 being connected by a tube 116 to the fuel source.

A portion of the air flowing through the induction tube passes through the throat of the forward venturi 100, this portion of the air being aspirated into the throat of the second venturi 102, which, in turn, is aspirated into the third venturi 104. The three stages of pressure-drop therefore produce a low pressure area within the throat of the venturi 104 sufficient to feed fuel to the air stream flowing through the device under extremely adverse conditions. It will be appreciated that although in this embodiment of the invention I have shown an arrangement of three Venturi tubes to produce a three-stage pressure drop, it may be advisable under some conditions to provide a four-stage pressure drop, while under less adverse conditions, a two-stage drop may be sufficient.

From the above description of preferred embodiments of my invention, it will be seen that a heating system incorporating the present invention is well adapted to operate under varying air pressure conditions and, further, that such a heating system fulfills all of the objectives set forth for the invention in an earlier portion of this specification.

While I have shown and described particular embodiments of my invention, it will be apparent to those skilled in the art that numerous modifications and variations may be made without departing from the underlying principles of the invention. I therefore desire, by the following claims, to include within the scope of the invention all such modifications and variations by which substantially the results thereof may be obtained by substantially the same or equivalent means.

I claim:

1. An altitude compensating internal combustion aircraft heater comprising combustion chamber means, carbureting means separate from the combustion chamber adapted to form a combustible mixture of a liquid fuel and air, means forming a passage connecting said carbureting means with the combustion chamber and discharging said mixture into said chamber, means associated with the combustion chamber means for igniting said combustible mixture therein, heat exchanger, conduit means connecting the combustion chamber with the heat exchanger to conduct the products of combustion to said heat exchanger and providing a secondary combustion zone between the chamber and said heat exchanger, a tubular jacket around the combustion chamber for introducing additional air into said chamber, the combustion chamber means having ports in its wall at the connection between said chamber and said conduit means and the jacket including an end wall adjacent said ports and serving to direct the air therethrough, and an annular baffle at the said connection positioned to force said air to flow transversely of the general direction of movement of gases from the combustion chamber to the secondary combustion zone.

2. An altitude compensating internal combustion aircraft heater comprising combustion chamber means, carbureting means separate from the combustion chamber adapted to form a combustible mixture of a liquid fuel and air which will burn efficiently at sea level atmospheric pressure, means forming a passage connecting said carbureting means with the combustion chamber and discharging said mixture into said chamber, means associated with the combustion chamber means for igniting said combustible mixture therein, a heat exchanger, conduit means connecting the combustion chamber with the heat exchanger to conduct the products of combustion to said heat exchanger and providing a secondary combustion zone between the chamber and said heat exchanger, means introducing additional air into the combustion chamber at the connection between said chamber and said conduit means for cooling the products of combustion at sea level atmospheric pressure and for providing supplemental air to complete combustion of the mixture in the secondary combustion zone when operating at higher altitudes, and an annular baffle at the said connection providing a central opening for the flow of gases from the combustion chamber to said secondary combustion zone and positioned to force said additional air to flow transversely of the general movement of gases through said central opening to facilitate admixture of said air therewith.

3. An altitude compensating internal combustion aircraft heater comprising means forming a cylindrical combustion chamber, carbureting means separate from the combustion chamber adapted to form a combustible mixture of a liquid fuel and air, means forming a passage connecting said carbureting means with the combustion chamber and discharging said mixture into said chamber, said passage terminating within said chamber and axially thereof adjacent one end and having lateral outlets with inclined baffles which initiate a whirling motion of the mixture discharged into the chamber, means adjacent said end of the combustion chamber for igniting said combustible mixture therein, an annular baffle plate at the opposite end of the combustion chamber providing a central opening for the flow of the products of combustion and any unburned gases from said chamber, a heat exchanger, conduit means extending from said baffle to the heat exchanger to conduct said products of combustion and other gases to the heat exchanger and providing a secondary combustion zone between the chamber and said heat exchanger, the portion of the cylindrical wall of the combustion chamber adjoining said baffle plate having ports therethrough, and means to feed air through said ports over the surface of said plate toward its central opening for admixture with the gases flowing through said opening into the secondary combustion zone.

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