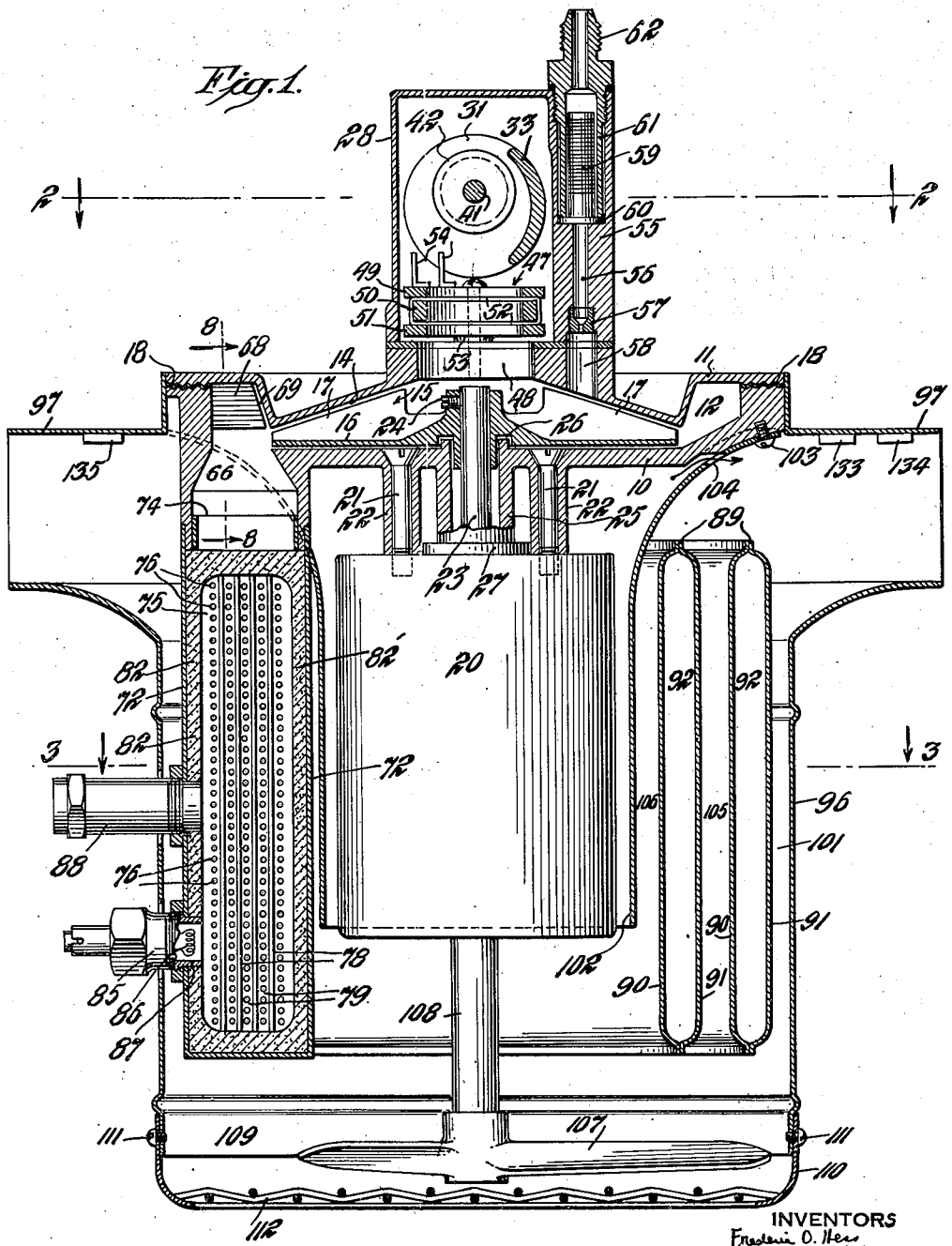
June 14, 1949. F. O. HESS ET AL 2,473,372

UNIT TYPE AIRPLANE HEATER

Filed June 20, 1944 6 Sheets-Sheet 1

Fig. 1.



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June 14, 1949. F. O. HESS ET AL 2,473,372

UNIT TYPE AIRPLANE HEATER

Filed June 20, 1944 6 Sheets-Sheet 2

Fig. 2.

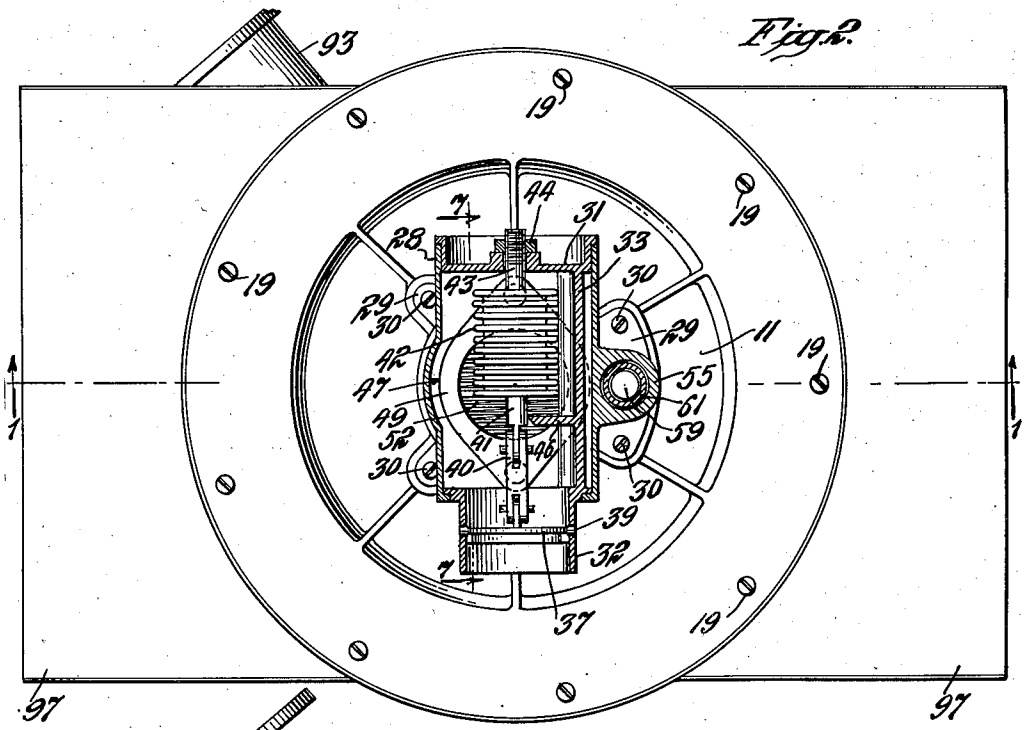
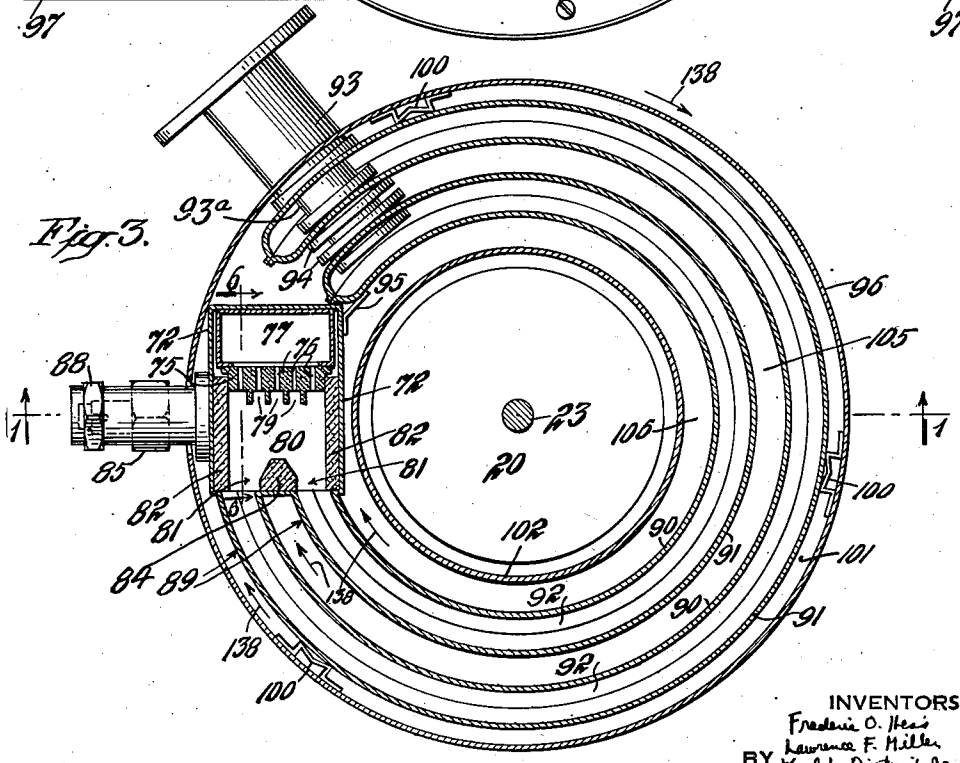


Fig. 3.



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UNIT TYPE AIRPLANE HEATER

Filed June 20, 1944 6 Sheets-Sheet 3

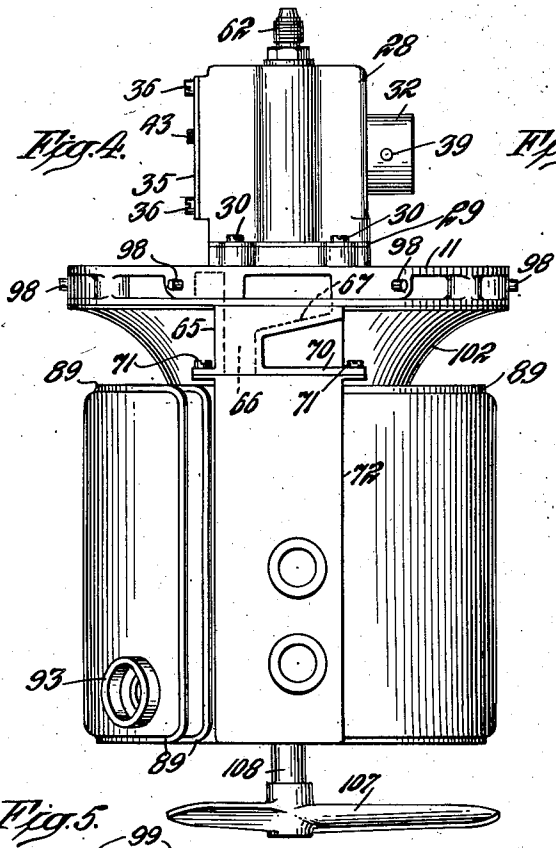


Fig. 4.

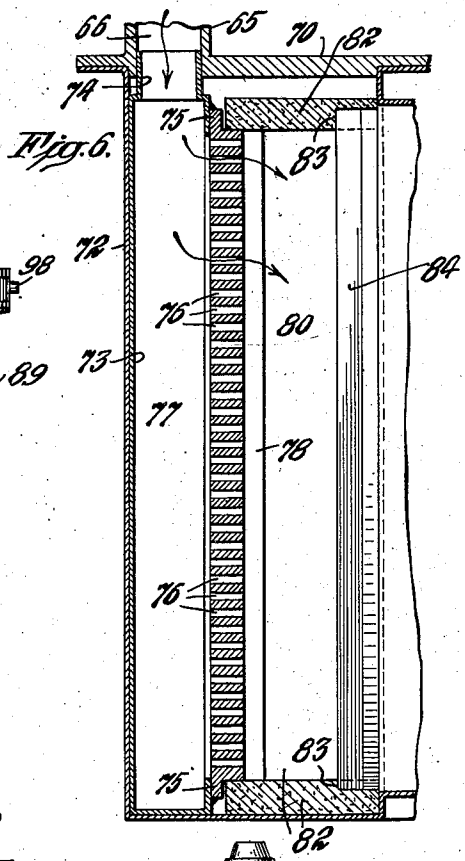


Fig. 6.

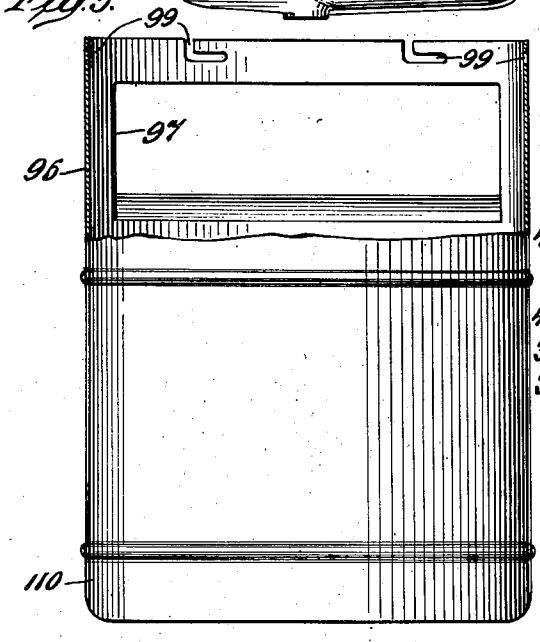


Fig. 5.

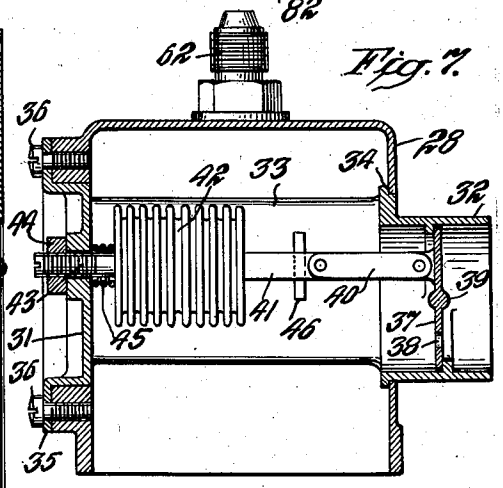


Fig. 7.

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UNIT TYPE AIRPLANE HEATER

Filed June 20, 1944 6 Sheets-Sheet 4

Fig. 8

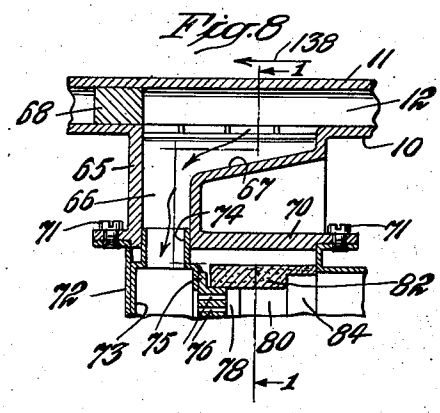
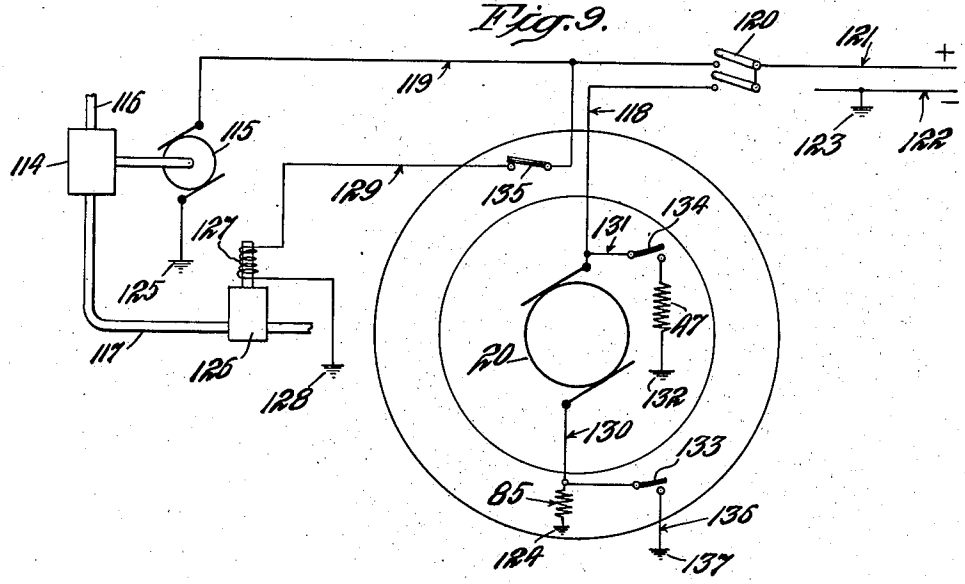


Fig. 9.



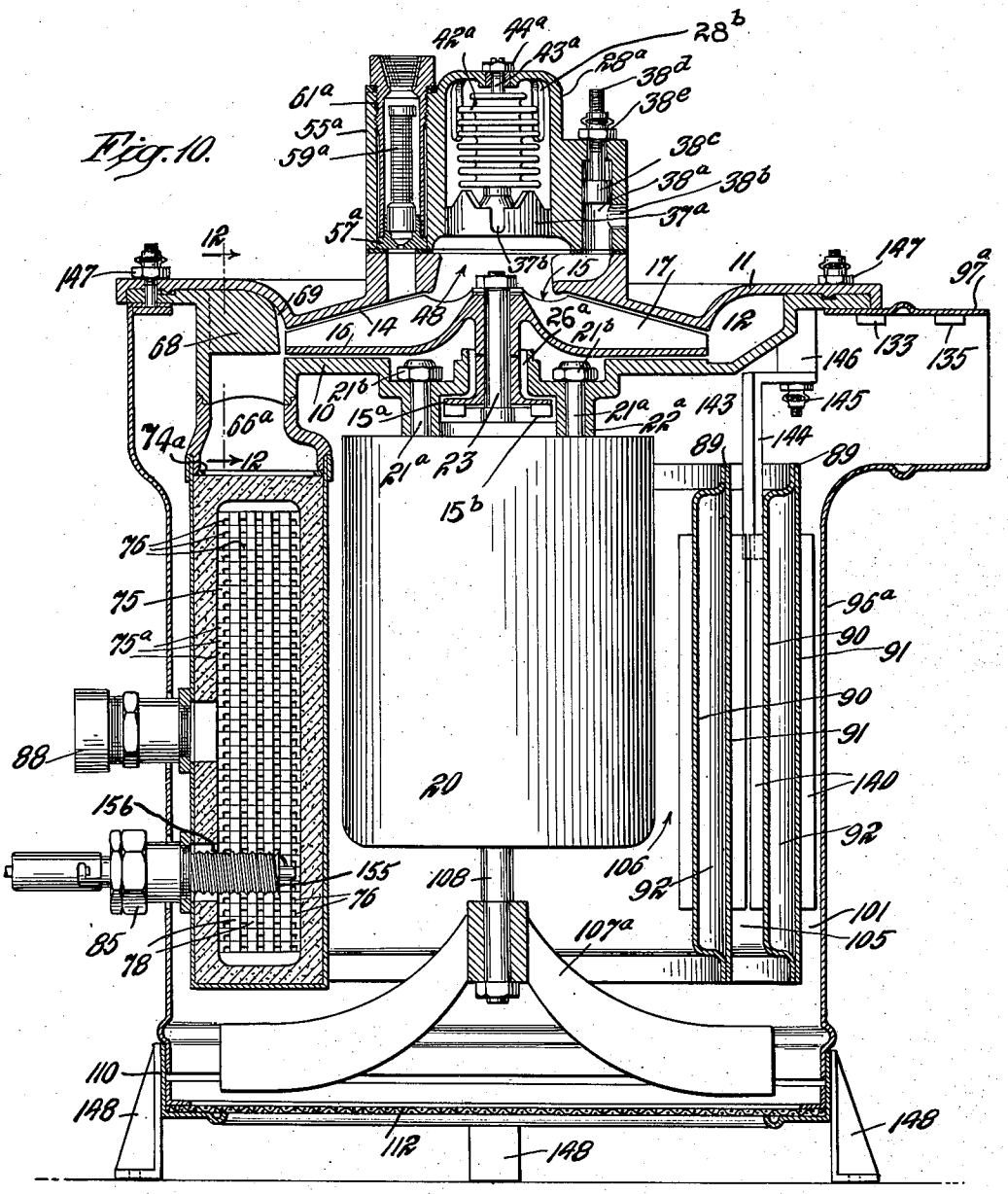
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UNIT TYPE AIRPLANE HEATER

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Fig. 10.



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UNIT TYPE AIRPLANE HEATER

Filed June 20, 1944 6 Sheets-Sheet 6

Fig. 11.

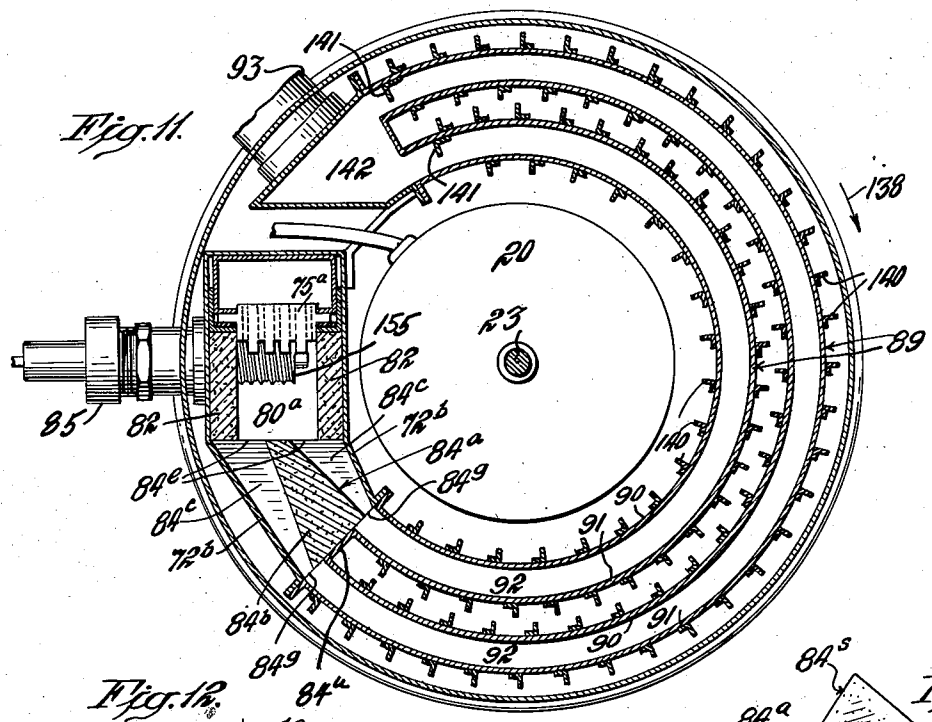


Fig. 12.

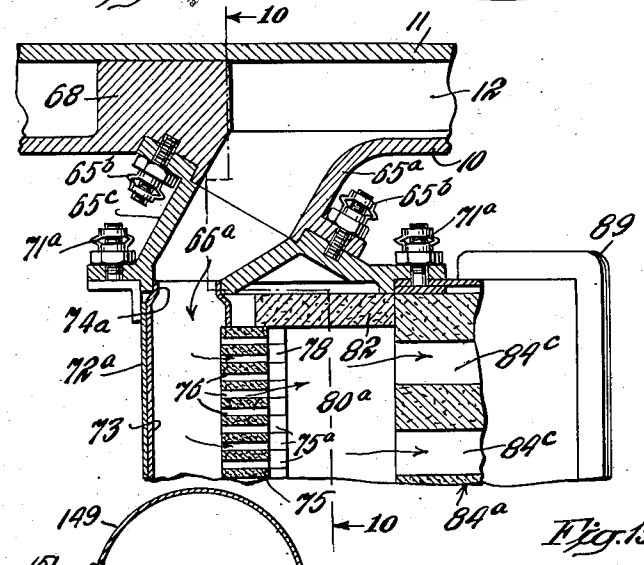


Fig. 13.

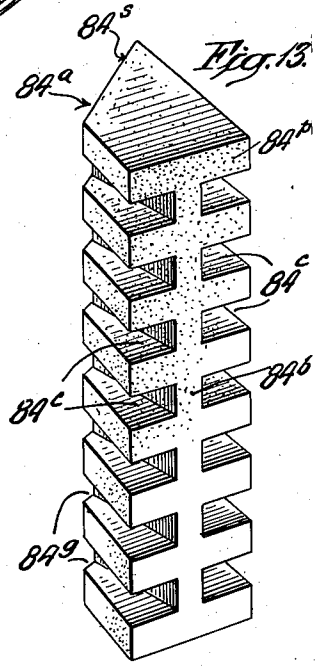


Fig. 14.

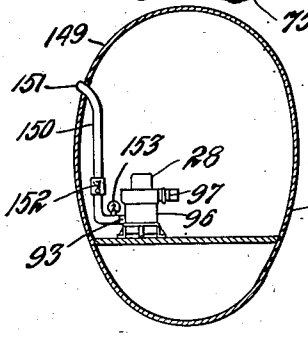
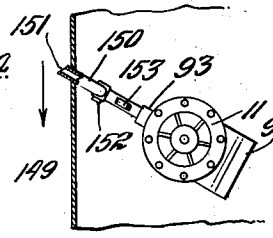


Fig. 15.



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Patented June 14, 1949

2,473,372

UNITED STATES PATENT OFFICE

2,473,372

UNIT TYPE AIRPLANE HEATER

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Application June 20, 1944, Serial No. 541,258

7 Claims. (Cl. 126—110)

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This invention relates to heaters, and is especially concerned with heaters of the kind operated with a gaseous or liquid fuel.

While the heater of the invention is of great utility for effecting heating wherever a compact heater of light weight is required in which the heat output per pound of heater is exceptionally high, it is especially useful for heating airplanes. The present tendency toward self-contained heaters which are compact and of unusually large heating capacity has brought about an intensive study of the problem of improving the performance and operation of heaters. This is especially true of aircraft heating in which the heater must be light in weight and as small as possible so that it will occupy a minimum amount of space. Further, a heater suitable for airplane heating must be capable of producing large quantities of heat to maintain the interior of an airplane comfortable when the temperature of the atmosphere may be as low as minus 60° F., and when the airplane is at ground level and in flight at altitudes as high as 40,000 feet and higher. Since the density of air at altitudes of 22,000 feet and 40,000 feet is about one-half and one-fourth, respectively, of the density of air at sea level, it will be evident that provision must be made to maintain the proper ratio of air to fuel as well as insure stable combustion conditions at all times, so that reliable heater operation will be effected under all of the operating conditions encountered in aircraft heating.

It is an object of the invention to provide an improved self-contained heater which is extremely efficient and compact and in which the heat output per pound of heater is exceptionally high.

Another object of the invention is to provide such a heater which is capable of maintaining the interior of an airplane comfortable and performs reliably under all of the operating conditions encountered in aircraft heating.

A further object of the invention is to provide an improved heater having a refractory lined combustion chamber in which the lining is heated to incandescence to promote substantially complete combustion of a fuel mixture and also accelerate the rate at which combustion is effected.

A still further object of the invention is to provide an improved heater having a heating space in which the pressure may be reduced below that of atmospheric pressure without having the full effect of such reduction in pressure reflected

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back to a combustion chamber in which combustion is accomplished and from which high temperature heating gases pass into the heating space.

A still further object of the invention is to provide an improved heater including an impeller housing, electric driving motor, burner and heat exchanger constructed as a single unit and in such a manner that the heater parts are accurately aligned and rigidly secured to the impeller housing.

A still further object of the invention is to provide an improved self-contained heater of simplified construction which can be readily assembled.

The novel features which we believe to be characteristic of our invention are set forth with particularity in the claims. The invention, both as to organization and method, together with further objects and advantages thereof, will be better understood from the following description taken in connection with the accompanying drawings forming a part of this specification, and of which:

Fig. 1 is a vertical sectional view, taken on lines 1—1 of Figs. 2, 3 and 8, of a heater embodying the invention;

Fig. 2 is a horizontal sectional view, taken on line 2—2 of Fig. 1, to illustrate parts of the heater more clearly;

Fig. 3 is a horizontal sectional view taken on line 3—3 of Fig. 1;

Fig. 4 is a side elevation of the heater illustrated in Figs. 1 to 3 removed from the casing;

Fig. 5 is a side elevation, partly broken away, of the heater casing within which the unit shown in Fig. 4 is positioned;

Fig. 6 is a fragmentary vertical sectional view, taken on line 6—6 of Fig. 3, to illustrate the burner more clearly;

Fig. 7 is a fragmentary sectional view taken on line 7—7 of Fig. 2;

Fig. 8 is a fragmentary sectional view taken at line 8—8 of Fig. 1;

Fig. 9 is a view diagrammatically illustrating an electrical control system for the heater shown in Figs. 1 to 8 inclusive;

Fig. 10 is a vertical sectional view of a heater, similar to Fig. 1 and taken on line 10—10 of Fig. 12, illustrating a modifiation of the invention;

Fig. 11 is a horizontal sectional view of the heater shown in Fig. 10;

Fig. 12 is a fragmentary vertical sectional view taken at line 12—12 of Fig. 10;

Fig. 13 is an enlarged perspective view of a part of the heater shown in Figs. 10 and 11, to illustrate a detail more clearly;

Fig. 14 is a cross sectional view of an airplane diagrammatically illustrating a heater therein like that of Figs. 1 to 9 or Figs. 10 to 13 inclusive; and

Fig. 15 is a fragmentary plan view looking down upon the heater shown in Fig. 14.

Referring to Fig. 1, a heater which is shown embodying the invention includes a pair of adjacent bodies or plates 10 and 11 providing a fan or impeller housing which forms an outer annular diffusing chamber 12 and an inner chamber 14 in communication therewith and within which is disposed a rotatable impeller 15. The impeller 15 includes a bottom circular disk 16 having integrally formed therewith a plurality of vertical fins or blades 17 in spaced apart relation and extending radially outwardly from the hub to the peripheral edge of the disk 16. A suitable gasket 18 is interposed between the ribbed surface portions at the peripheral edges of the plates 10 and 11 which are secured together by a number of screws 19, as shown most clearly in Fig. 2.

A motor 20 is secured to the impeller housing by studs 21 which extend through tubes 22 formed integrally with plate 10 and against the bottom ends of which the motor is tightly drawn. A shaft 23 of the motor 20, to which the impeller 15 is secured by a set screw 24, extends upwardly into the chamber 14 through a hollow sleeve 25 which is also formed integrally with plate 10. The hub of the impeller 15 and upper end of sleeve 25 are formed to provide a labyrinth packing 26, and the sleeve may be provided with a packing gland 27 at its lower end for the shaft, so that leakage from the chamber 14 will be prevented. The tubes 22 accurately align the impeller parts and the motor shaft 23 and, together with the studs 21, provide a rigid and unitary impeller and motor construction.

A casing 28 provided with a flange 29 at its lower open end is secured by screws 30 to a boss or raised portion at the top face of plate 11, as shown most clearly in Fig. 2. The flange 29 is of irregular shape and the boss on the plate 11 to which it is secured is of similar shape, so that the casing 28 can be secured to the plate 11 only when the flange 29 and boss are in alignment. The casing 28 is open-ended to receive an insert having a closed cylindrical head 31 at one end and a hollow tubular part 32 at the opposite end which are connected by an arcuate-shaped wall section 33, as shown in Figs. 1, 2 and 7. As seen in Fig. 7, one end of the wall section 33 adjacent the tubular part 32 is formed with a shoulder 34 which fits against one end wall of the casing 28, and the closed cylindrical head 31 is provided with a flange 35 which is secured by screws 36 to bosses formed at the end wall of casing 28.

A butterfly valve 37 having an opening 38 therein is pivoted at 39 within the tubular part 32 and pivotally connected by a link 40 to a pin 41 which is secured to one end of a bellows 42. A threaded pin 43 secured to the opposite end of bellows 42 passes through a slightly enlarged unthreaded opening in the cylindrical head 31 and receives a lock nut 44. The initial adjustment of the bellows 42 is accomplished by moving the lock nut 44 on the pin 43, and the lock nut 44 is held firmly against the cylindrical head 31 by a coil spring 45 disposed about the pin

43 between the bellows 42 and the inner surface of the cylindrical head. The bellows 42 operates responsive to atmospheric pressure to move the butterfly valve 37 from its closed position with decrease in atmospheric pressure and toward its closed position with increase in atmospheric pressure to control the flow of air into the tubular part 32 during operation of the heater, as will be explained hereinafter.

In order to insure proper alignment of the bellows 42 and link 40 and always obtain accurate movement of the butterfly valve 37 with expansion and contraction of the bellows, the pin 41 engages and freely moves past the tapered end of a guide plate 46 which is formed integrally with and is at right angles to the wall section 31.

An electrical heating element 47 is mounted on the plate 11 directly over the central opening 48 therein which constitutes the air inlet to the chamber 14. The heating element 47 comprises three superimposed flat plates 49, 50 and 51 each having an opening approximately the size of the opening 48 in plate 11, as shown in Fig. 1. A wire 52 is wound or coiled about the intermediate plate 50 with adjacent turns close together and distributed over the entire area of the opening in the plate, as best shown in Fig. 2. The three flat plates are secured together in any suitable manner, and the bottom plate 51 may be provided with lugs 53 at each end, one of which is seen in Fig. 1, at which regions the heating element may be secured by screws (not shown) to the plate 11 at each side of the opening 48. The flat plates 49, 50 and 51 may be formed of any suitable insulating material and the wire 52 may be of a suitable high resistance alloy, such as, for example, nichrome and the like. As shown in Fig. 1, the heating element 47 may be provided with suitable terminals 54 to which the ends of the wire 52 may be secured, as by brazing, for example.

Intermediate the ends of casing 28 and at one side thereof is integrally formed a hollow vertical post 55, as best shown in Figs. 1 and 2. The passage or opening 56 in the bottom part of post 55 is of reduced diameter, and at its lower end is threadedly secured an orfice member 57. The opening 56 is in alignment with an opening 58 in plate 11 which in turn is in communication with chamber 14 at a region between the hub and peripheral edge of the impeller 15. The passage or opening of larger diameter in the upper part of post 55 receives a suitable filter 59 having a flange 60 at its lower end. The filter 59 is held in position by a tubular member 61 which fits against the flange 60 in the space between the filter and inner surface of the post 55, and is threadedly secured at an intermediate region to the upper end of the post 55. The upper end of tubular member 61 is provided with a nipple connection 62 to connect the tubular part to a suitable source of supply of liquid fuel, such as, for example, gasoline and the like.

Air for combustion is drawn through the inlet or tubular part 32 past the butterfly valve 37 and flows downwardly within casing 28 into the inner chamber 14 of the impeller housing. This movement of combustion air is effected by the impeller 15 into the path of movement of which is discharged liquid fuel issuing from the orifice member 57. Atomization of the liquid fuel is effected by the impeller 15, and the mixture of combustion air and atomized fuel passes radially outward

into the annular or circular diffusing chamber 12.

As shown most clearly in Figs. 4 and 8, the bottom plate 10 is provided with a short hollow leg 65 having a passage 66 therein which is in communication with the diffusing chamber 12. The upper part of passage 66 is formed with a ramp 67 which slopes downwardly in the direction of rotation of the impeller 15. The bottom plate 10 is also formed with a lug or block 68 having one face thereof in vertical alignment with the straight side wall of passage 66, as seen in Fig. 8. The block 68 fits snugly between the plates 10 and 11 when the latter are secured together and is slightly narrower than the width of the diffusing chamber 12 to provide a gap 69 at the inner wall of the diffusing chamber, as shown most clearly in Fig. 1. By providing the block 68 and hollow leg 65 with the ramp 67, a right angle change in the direction of flow of the air and fuel mixture is readily effected from the horizontally disposed diffusing chamber 12 into the vertical passage 66.

The hollow leg 65 is provided with a flange 70 at its lower end, and to this flange is removably secured at 71, as by screws, for example, the upper open end of a vertical metal shell 72. The shell 72 is normal to the plane of rotation of the impeller 15 and forms a housing for a burner including a manifold 73 having an upper inlet end 74 of reduced cross section which fits snugly within the lower end of passage 66, as shown in Figs. 6 and 8. A side wall 75 of the manifold 73 is formed with a plurality of small apertures or openings 76 which are disposed in vertical rows extending the full length of the inlet chamber 77 formed by the manifold 73. The side wall 75 is provided with a plurality of ridges 78 extending the full length of the manifold 73 to form small channels or grooves 79 into which the mixture of air and fuel is discharged from the outlet ends of the small openings 76.

The apertured wall 75 forms the inlet of a refractory lined combustion chamber 80 having two spaced apart elongated outlets 81 substantially coextensive with the manifold 73. As shown in Figs. 1, 3 and 6, a hollow rectangular block 82 formed of a suitable high temperature refractory material, such as, for example, silicon carbide and the like, is positioned within the metal shell 72 to provide the refractory lining for the combustion chamber 80. The refractory block 82 bears against the side walls of the metal shell 72 and at one end overlies the peripheral edges of the apertured side wall 75. The opposite end of the refractory block 82 adjacent the outlets 81 fits snugly against an end wall of the metal shell 72, as seen in Figs. 3 and 6.

The top and bottom of the refractory block 82 are notched at their inner surfaces at 83 to receive the upper and lower ends, respectively, of a vertical post 84 which is also formed of a suitable high temperature refractory material, such as, for example, silicon carbide and the like. The post 84 is of the shape shown in Fig. 3, and, when the post is held in the refractory block 82 and the latter is positioned within the metallic shell 72, the widest flat side of the post bears against an end wall of the metal shell 72 within which are housed the burner parts just described.

The metal shell 72 is formed with several threaded openings which are in alignment with openings in the hollow refractory block 82 when the latter is disposed within the metal shell, as shown in Fig. 1. An electrical ignitor 85 is threadedly secured to one of the openings in the shell 72 to effect combustion of the mixture of air and fuel supplied to the combustion chamber 80. The electrical ignitor may be of a hot wire type having a heating element 86, and the inner part 87 extending through the opening in the refractory block 82 may be formed of a suitable high temperature refractory material which will withstand the high temperatures produced within the combustion chamber 80. A hollow tube 88 having a suitable glass partition therein is threadedly secured to the other opening in the metal shell 72 and serves as an observation port through which the combustion chamber 80 may be viewed.

The heated products of combustion produced in combustion chamber 80 pass through the outlets 81 into a pair of hollow heat dissipating elements 89 which are annular in form and one of which is concentric within the other. Each element 89 is formed of spaced apart sheets of metal 90 and 91 united at their top and bottom edges by welding. The vertical edges of the metal sheets at one end of the elements 89 are welded to the metal shell 72 at the regions of the combustion chamber outlets 81, and the vertical edges thereof at the rear of the metal shell 72 are united by welding, as shown most clearly in Fig. 3. The heat dissipating elements 89 form annular heating spaces 92 of substantially the same height as the combustion chamber 80 and provide paths of flow for the heated products of combustion which are considerably longer than the heights of the heating spaces. The products of combustion pass from the elements 89 through an outlet 93 which is connected by a tube 93a to both of the heating spaces 92. As shown in Fig. 3, the ends of the elements 89 adjacent the outlet 93 are connected to each other at 94 and to the metal shell 72 by a bracket 95, so that accurate positioning of the elements 89 with respect to other parts of the heater will be obtained.

An outer casing 96 having a plurality of rectangular duct sockets 97 at its upper part encloses the elements 89. The bottom plate 10 of the impeller housing is provided with a number of spaced apart pins 98 at its periphery which fit into bayonet slots 99 at the top edge of casing 96 for removably securing the latter to the impeller housing, as shown most clearly in Figs. 4 and 5. As shown in Fig. 3, a number of U-shaped straps 100 are welded to the inner surface of casing 96 and bear against the lower part of the outer element 89 to hold the elements in position and form an annular space 101 of substantially uniform width between the outer element 89 and casing 96.

Between the motor 20 and inner element 89 is positioned a shield 102 of sheet metal which is annular in form and flares outwardly at its upper end. The shield 102 is secured by screws 103 to the underside of plate 10 and is formed with slots 104 at the regions of the duct sockets 97, as shown most clearly in Fig. 1. The annular spaces 101, 105 and 106 serve as paths of flow for air to which heat is given up by the heat dissipating elements 89. The air to be heated is circulated through the heater by a fan 107 which is fixed to a shaft 108 extending downwardly from the motor 20. The fan 107 is positioned in a space 109 between the elements 89 and an end cover 110 which is removably secured at 111 to the casing 96 and provided with a screen 112 through which is drawn air to be heated. The air circulating fan 107 is of a propeller type which is designed as a volume fan in contrast to

a pressure fan and is capable of circulating large volumes of air.

Liquid fuel is supplied under pressure to the heater just described by a pump 114 which is driven by an electric motor 115, as shown in Fig. 9. The pump 114 is connected by a conduit 116 to a suitable source of supply of liquid fuel and delivers fuel under pressure through a conduit 117 which is connected to the nipple connection 62 at the top of post 55. The motors 20 and 115 are connected by conductors 118 and 119 and a double pole switch 120 to the positive side 121 of a suitable direct current source of electrical energy having its negative side 122 grounded at 123. The circuits for the motors 20 and 115 are completed by ground connections indicated at 124 and 125, respectively.

In the conduit 117 is provided a solenoid operated control device which includes a valve 126 operated by a solenoid coil 127 having one terminal grounded at 128 and the opposite terminal connected by a conductor 129 to the conductor 119. The ignitor 85 is connected in a conductor 130 which connects motor 20 to ground at 124, and the air heater 47 is connected in a conductor 131 having one end connected to conductor 118 and its other end grounded at 132.

Three thermal devices 133, 134 and 135 are provided in the electrical circuits just described to control the operation of the heater. The thermal device 133 is provided in a conductor 136 which is connected at one end to conductor 130 between the motor 120 and ignitor 85, and grounded at its other end at 137. The thermal device 134 is provided in conductor 131 between conductor 118 and the air heater 47, and the thermal device 135 is provided in conductor 129 between solenoid coil 127 and conductor 119. Although the thermal devices 133, 134 and 135 are diagrammatically illustrated as being of a bimetallic type, it is to be understood that the thermal devices may be of any suitable type and positioned within the duct sockets 97, as diagrammatically shown in Fig. 1.

When it is desired to operate the heater the switch 120 is closed to complete the electrical circuits for the motors 20 and 115. When operation of the heater is first started the thermal device 135 is closed, so that closing of switch 120 also completes the circuit for solenoid coil 127 to cause opening of valve 126. With motor 115 energized and driving pump 114, liquid fuel received from the source of supply through conduit 116 is pumped through conduit 117 past valve 126 into the upper part of hollow post 55 to which the conduit 117 is connected, as previously described. The liquid fuel passes through the filter 59 which holds back any foreign matter which may accompany the fuel, and the fuel then flows downwardly through passage 56 and is discharged from the orifice member 57 into the impeller chamber 14 through the passage 58 in the plate 11.

The motor 20, which is energized when the switch 120 is closed, drives the impeller 15 to cause air for combustion to be drawn into the inlet or tubular part 32. The combustion air is drawn past the butterfly valve 37 and flows downwardly in casing 28 through the air inlet opening 43 into the chamber 14 of the impeller housing formed by plates 10 and 11. The small stream of liquid fuel squirting downwardly into chamber 14 from the orifice member 57 strikes the rotating impeller 15 and is mechanically atomized and mixes with the combustion air. The mixture of combustion air and fuel, which is in liquid phase but in mist or spray form, passes from chamber 11 to the annular diffusing chamber 12 in which uniform mixing of the fuel and combustion air takes place. The impeller 15 is driven in a clockwise direction as viewed in the drawings, and in the direction indicated by the arrow 138 in Figs. 3 and 8. Thus, the air and fuel mixture passes from the horizontal annular chamber 12 into vertical pasage 66 in the direction indicated by the arrows in Fig. 8, the downwardly sloping ramp 67 in the upper part of passage 66 and block 68 in the annular passage 12 providing an efficient arrangement to cause a change in direction of the air and fuel mixture from the annular chamber 12 into the vertical manifold 73. The gap 69 at the inner surface of the block 68 permits some of the air and fuel mixture to recirculate about the annular chamber 12 and prevents the building up of an excessive pressure in the part of the annular chamber communicating with the vertical passage 66. The part of the annular chamber 12 into which some of the air and fuel mixture passes through the gap 69 is a region of reduced pressure in which eddies are produced, thereby contributing to the uniform mixing of the combustion air and atomized fuel in the annular chamber before the mixture passes into the manifold 73 through the vertical passage 66.

The mixture of air and fuel passes from the manifold 73 through the small inlet openings 76 into the refractory lined combustion chamber 80 in which ignition of the combustible mixture is effected by the ignitor 85. As seen in Fig. 9, the ignitor 85 is connected in series relation with the motor 20 and is energized when the switch 120 is closed to start operation of the heater. By providing a large number of small inlet openings 76 through which the mixture of air and fuel is discharged from manifold 73, as best seen in Fig. 1, the mixture is subdivided into a multiplicity of small streams which project into the combustion chamber 80. When ignition is effected a plurality of small flames are produced, and the flames thus produced and maintained at the apertured inlet 75 are distributed over an area substantially coextensive with the cross sectional area of the combustion chamber 80.

By providing a large number of small inlet openings 76 to produce a multiplicity of relatively small and short flames, a substantial portion of the burning of combustion is initiated at the region of the refractory lined combustion chamber adjacent to the inlet. With this arrangement a relatively high average temperature is produced and developed at the inlet end of the combustion chamber 80. After a short interval of time, the flames maintained in the combustion chamber 80 effect such heating of the refractory lining that the latter is heated to a high incandescent temperature.

The heating of the refractory lining to incandescence contributes to the maintenance of high combustion chamber temperatures and also brings about rapid flame propagation. This is clearly evident by the change in length of the flames as the refractory lining becomes heated. Each of the flames produced at the apertured inlet wall 75 consists of an inner cone of unburned air and fuel and an outer cone constituting the portion of the flame in which the combustion reaction is taking place. When operation of the heater is first started and the refractory lining is relatively cool, the inner cones of the individual flames are relatively long in length. As the inner refrac-

tory lining becomes heated, the inner cones of the individual flames become increasingly shorter and shorter; and, when the inner refractory lining becomes heated to incandescence, the inner cones of the individual flames become appreciably shorter from their original lengths when initially produced. This is due to the fact that the air and fuel mixture introduced into the combustion chamber in finely divided streams is subjected to intense heat radiated from the highly heated surfaces of the inner refractory lining, thereby effecting substantially complete burning of the mixture within the combustion chamber before the mixture reaches the outlets 81.

When a mixture of air and atomized gasoline is supplied to the combustion chamber 80, combustion chamber temperatures as high as 2000° F. and higher are developed and maintained, and gases consisting substantially entirely of heated products of combustion are discharged through the outlets 81 into the heating spaces 92 of element 89 at a temperature nearly equal to the temperature developed in the combustion chamber. Since the mixture of air and fuel is introduced into the combustion chamber 80 at temperatures of 70° F. and lower, and are heated to a temperature of 2000° F. and higher, the gases expand at least four and one-half fold and at a rate directly proportional to increase in absolute temperature. In view of the fact that the gases undergo considerable expansion in the combustion chamber, relatively large volumes of high temperature gases are discharged from the combustion chamber into the annular heating spaces 92.

The channels or grooves 79 formed by the ridges 78 at the outlet ends of the small inlet openings 76 also contribute to the maintenance of the stable combustion conditions in the combustion chamber 80 under widely varying operating conditions, as will be explained more fully hereinafter. When the mixture of air and atomized fuel is discharged from the openings 76 into the chamber 79, expansion of the mixture takes place in the channels with a corresponding decrease in the velocity at which the mixture enters the combustion chamber. In this way any tendency for the flames to blow off from the inlet openings 76 under adverse operating conditions is reduced, and the flames will always remain rooted to the discharge ends of the inlet openings.

The refractory post 84 forms a part of the refractory lining for the combustion chamber 80 and the surfaces thereof facing the interior of the chamber and the outlets 81 are also heated to incandescence to assist in bringing about substantially complete combustion of the air and fuel mixture in the chamber. In addition, the refractory post 84 heated to incandescence during operation of the heater serves to effect reignition of the air and fuel mixture in the event flow of the mixture is interrupted momentarily or operation of the heater is stopped for a short interval of time and is then resumed. The refractory post 84 also protects a portion of the shell 72 against which it bears from the high temperatures developed in combustion chamber 80. The refractory post 84 is shaped to subdivide the heated products of combustion discharge from combustion chamber 80, so that the high temperature gases are divided more or less equally between the two heat dissipating elements 89.

Since the air circulating fan 107 is driven by the motor 20, air is circulated upwardly through the heater when operation is first started by closing the switch 120. The air is drawn by the fan 107 through the screen 112 into the space 109 and is then subdivided and passes upwardly through the annular spaces 101, 105 and 106. Heat from the high temperature gases passing through the annular heating spaces 92 is given up to the air flowing upwardly in the spaces 101, 105 and 106, and the heated air is discharged from the heater from the duct sockets 97. The metal sheets 90 and 91 forming the heating spaces 92 provide a relatively extensive heat transfer surface so that efficient heating of air is effected. Since the chemical reaction of combustion is substantially completed in combustion chamber 80, and the high temperature gases enter the heating spaces 92 at practically the temperature developed in the combustion chamber, the maximum temperature differential between the high temperature gases and air to be heated is obtained at the region of the elements 89 adjacent the inlet end of the heating spaces 92. Since the high temperature gases flow horizontally about the annular spaces 92 and throughout the height of these spaces, and the air to be heated flows vertically upwardly through the annular spaces 101, 105 and 106, the air is progressively heated as it passes upwardly over the outer surfaces of the metal sheets 90 and 91 and is heated to the highest possible temperature when passing over the extreme upper edges of the elements 89. Stated another way, there is a rising temperature gradient of the air passing upwardly through the annular heating spaces 101, 105 and 106 and, since the coolest air contacts the extreme lower edges of the elements 89, these regions of the elements are at the lowest temperature due to heat transfer from the high temperature gases to the air first contacting such regions. Since the extreme upper edges of the elements 89 are last contacted by the air to be heated, and these regions of the elements are at the highest temperature due to horizontal flow of the high temperature gases in the annular spaces 92, the air passing upwardly through the annular spaces 101, 105 and 106 will be heated to the highest possible temperature at the instant the air passes out of heat exchange relation with the elements 89.

The air circulating fan 107 rotates in a clockwise direction as viewed in the drawings, and in the direction of the arrow 138 in Fig. 3. With such rotation of the fan 107, a whirling movement is imparted to the air passing upwardly in the annular spaces 101, 105 and 106 which is in a clockwise direction and generally counter-current to the counterclockwise flow of the high temperature gases in the annular heating spaces 92 from the combustion chamber 80 to the outlet connection 93. By providing a heat exchanger in which the high temperature gases and air to be heated are in counterflow with the air leaving and last contacting the highest temperature regions of the elements 89, an efficient arrangement is provided for heating large volumes of air circulated through the heater by the fan 107.

The circulation of the fan 107 in a clockwise direction also prevents excessive heating of the metal sheets 90 and 91 at regions adjacent to the metal shell 72 in that portions of the air stream in the annular space 105 are constantly being positively directed against the closed end of the space 105 at the region of the vertical post 84, as best shown in Fig. 3. If the fan 107 circulated in a counter-clockwise direction, the part of the space 105 adjacent the end closed

off by the metal shell 72 would form a region of lower pressure in which the movement of air is not as rapid as in other parts of the space in which positive flow of air takes place. In such lower pressure region localized eddying of air would occur with consequent excessive heating of the metal sheets 90 and 91, because heat then would not be given up sufficiently rapidly to the air to be heated from the parts of the metal sheets at the vicinity of the lower pressure region.

Some of the air drawn into the space 109 by the fan 107 also passes upwardly in the annular space between the motor 20 and shield 102 to effect cooling of the motor. After flowing over the surfaces of motor 20, such air passes through the slots 104 in shield 102 which are directly opposite the duct sockets 97 and mixes with heated air passing upwardly through the annular spaces 101, 105 and 106. The upper flared portion of shield 102 provides a curved surface opposite the duct sockets 97, so that an abrupt change in direction of flow of heated air is avoided.

The annular heating spaces 92 provide a relatively long path of flow for the high temperature gases which is considerably longer than in prior heater constructions in which the high temperature gases simply pass in a path of flow substantially equal to the width of the metal sheets 90 and 91. The spent products of combustion are discharged from the heating spaces 92 through the outlet connection 93 which is located in the extreme bottom part of the elements 89 at the rear of the metal shell 72, as best shown in Fig. 4.

After ignition has been accomplished in combustion chamber 80 and the heated air discharged through the duct sockets 97 is at a predetermined temperature, such as 160° F., for example, the normally open thermal device 133 in one of the duct sockets 97 closes to complete a circuit from one terminal of motor 20 through conductors 130 and 136 to the ground connection at 137. In this way a low resistance circuit is completed for motor 20 around igniter 85 after ignition has been established in combustion chamber 80, so that only a small current will pass through ignitor 85 during operation of the heater and thus prevent overheating of the heating element 86 which is constantly subjected to the high temperatures developed in the combustion chamber.

The thermal device 134 is normally open during operation of the heater and closes and completes the circuit for the air heater 47 when operation of the heater is first started by closing the switch 120 and the temperature is below 70° F., for example. The air heater 47 is especially useful in certain applications of the heater, as will be described presently, and, when the need arises for heating combustion air drawn into the inlet or tubular part 32 and prior to entering the impeller chamber 14, the air heater comes into play to heat the combustion air sufficiently so that reliable ignition of the mixture of air and atomized fuel will be obtained in the combustion chamber 80 under extremely cold operating conditions. After combustion is initiated in combustion chamber 80 and the air discharged from the duct sockets 97 is heated to about 70° F., the thermal device 134 located within one of the duct sockets opens to disconnect the air heater 47 from the source of electrical supply.

The thermal device 135, which is also located within one of the duct sockets 97, is normally closed and opens when undesirable overheating of the heater occurs. When overheating of the heater does occur, and the air is heated to a predetermined high temperature of about 450° to 500° F., for example, the thermal device 135 opens and the circuit for the solenoid coil 127 is opened whereby valve 126 closes and shuts off flow of fuel to the heater. However, opening of the thermal device 135 does not affect the energization of the motors 20 and 115 and these motors will continue to drive the circulating fan 107 and fuel pump 114, respectively. The continued operation of fan 107 when overheating occurs tends to bring about rapid cooling of the heater; and, when the temperature of the heater falls below the predetermined high temperature, the thermal device 135 again closes to energize solenoid coil 127 and open valve 126 to permit fuel to be pumped to the heater. Thus, when overheating of the heater does occur the heater does not shut down completely but intermittent operation takes place which is extremely desirable in certain uses of the heater. If the operating condition causing overheating of the heater persists, the heater will operate intermittently to effect heating of air until overheating occurs at which times combustion of air and fuel in combustion chamber 80 is temporarily stopped. When the air temperature falls sufficiently to effect closing of thermal device 135, heater operation is again resumed in the manner just explained.

Although not to be limited thereto, the heater of the invention is especially adapted for use as an airplane heater. It is for this reason that the valve 37, the bellows 42 and interconnecting mechanism are provided to control the admission of combustion air to the heater with changes in altitude of an airplane in which the heater may be installed. The valve 37 and bellows 42 form what is referred to as an altitude compensator, so that larger volumes of combustion air may be supplied at increasingly higher altitudes to maintain a proper weight ratio of air to fuel as the air density decreases.

In the illustrated embodiment the valve 37 may be so adjusted that it is in its closed position when the heater is being operated at sea level. In order to provide an adequate supply of combustion air under these conditions, an opening 38 is formed in the valve 37, as shown most clearly in Fig. 7. It has been found that by making the opening 38 of sufficient size, and driving the combustion air impeller with a series type motor which increases in speed with increase in altitude, the altitude compensator may be adjusted so that valve 37 will remain closed to a predetermined high altitude of 15,000 feet, for example, and yet provide sufficient combustion air for maintaining stable combustion conditions in combustion chamber 80.

At altitudes above the predetermined high altitude, however, the decrease in air density is such that it is desirable to supply larger volumes of air to the heater to maintain a desired weight ratio of air to fuel. Therefore, the bellows 42 and valve 37 are so adjusted that decrease in atmospheric pressure at altitudes above 15,000 feet, for example, causes bellows 42 to expand and move valve 37 from its closed position until it is fully open at an altitude of about 30,000 feet. This need for increasing the volume of combustion air supplied to the heater with decrease in air density is necessary because the rate at which fuel is supplied to the heater by the pump 114 is practically constant throughout all operating condi-

tions varying from sea level to an altitude of 30,000 feet or higher.

In Figs. 10 to 13 inclusive is illustrated a modification of the invention which is generally like the heater shown in Figs. 1 to 8 and just described and differs therefrom primarily in that the altitude compensator and combustion chamber are of different construction. In order to simplify the description of the heater shown in Figs. 10 to 13 inclusive, parts similar to those in the embodiment first described are referred to by the same reference numerals.

In Fig. 10 the altitude compensator includes a casing 28*a* provided at the lower open end with outwardly extending lugs (not shown) having openings to receive studs for removably securing the casing to the upper plate 11 of the impeller housing in a manner similar to that shown in Fig. 2. A threaded pin 43*a* secured to the upper end of an expansible and contractible bellows 42*a* extends through a threaded opening in the upper part of casing 23*a* and receives a lock nut 44*a*. A vertically movable main valve 37*a* snugly fitting within the casing 28*a* is secured to the lower end of bellows 42*a*. The main valve 37*a* is formed with a cylindrical sleeve having a plurality of spaced apart U-shaped slots 37*b* which terminate a short distance from the closed bottom of the valve. The bellows 42*a* operates responsive to atmospheric pressure to move main valve 37*a* downwardly with decrease in atmospheric pressure and upwardly with increase in atmospheric pressure.

Alongside of the chamber housing the bellows 42*a* is formed a vertical cylindrical space 38*a* having an inlet opening 38*b*. An auxiliary valve 38*c* within space 38*a* is secured to a stud 38*d* which threadedly engages an opening in casing 28*a*. The position of the auxiliary valve 38*c* with respect to the opening 38*b* is adjusted by axial movement of the stud which may be held in any desired position by a lock nut 38*e*.

The main valve 37*a* is preferably adjusted so that it is in a closed position when the heater is being operated at sea level. Under these conditions combustion air is supplied through inlet opening 38*b* and passage 38*a* into the inlet 48 of the impeller chamber 14. As in the embodiment first described, the altitude compensator may be adjusted so that main valve 37*a* will remain closed to a predetermined high altitude and auxiliary valve 38*c* positioned to provide sufficient combustion air under these conditions to maintain stable combustion in the heater.

At altitudes above the predetermined altitude, such as 15,000 feet, for example, the decrease in air density makes it desirable to supply larger volumes of combustion air to maintain the desired weight ratio of air to fuel. Hence, the bellows 42*a* and valve 37*a* are so adjusted that decreases in atmospheric pressure at altitudes above 15,000 feet, for example, causes bellows 42*a* to expand and partially open the slots 37*b*, whereby additional combustion air is drawn in through the slots 28*b* at the top of casing 28*a*, the interior of casing 28*a* and the slots 37*b* into the inlet 48 of the impeller chamber 14. The opening of the slots 37*b* in main valve 37*a* gradually increases with increase in altitude until the slots are wide open at a predetermined high altitude, such as 30,000 feet, for example.

The casing 28*a* is formed with a hollow post 55*a* similar to the post 55 in Fig. 1. Liquid fuel delivered from a source of supply in a manner similar to that illustrated in Fig. 9 and described above is pumped through a conduit which is connected to the upper part of post 55*a*. A filter element 59*a* is removably held in position within post 55 by a sleeve 61*a* threadedly secured to the post, and an orifice member 57*a* is threadedly fixed in position below the filter element. After passing through the filter element 57*a*, the fuel is discharged through orifice member 57*a* into the impeller chamber 14 in which the fuel is mechanically atomized by the impeller 15, and the mixture of combustion air and atomized fuel passes radially outward into the annular diffusing chamber 12.

As shown in Fig. 12, the bottom plate 10 of the impeller housing is formed with a hollow leg 65*a* secured at 65*b* to a hollow fitting 65*c* which in turn is removably secured at 71*a* to the upper open end of a metallic shell 72*a* in which the burner parts are housed. The hollow leg 65*a* and fitting 65*c* together form a vertically extending passage 66*a* which slopes and is inclined in the direction of rotation of the impeller 15, as in the embodiment first described. A block 68 having a narrow gap 69 at the inner face thereof is formed integrally with the bottom plate 10 at the region of the annular chamber 12 and in the vicinity of the passage 66*a*, as shown in Fig. 12, to effect an efficient change in direction of flow of the air and fuel mixture from the annular chamber 12 into the vertical passage 66*a*.

The burner housed in metallic shell 72*a* includes a sheet metal manifold 73 having an upper inlet end 74*a* which fits snugly within the bottom of the fitting 65*c*. The side wall 75 of manifold 73 is formed with a plurality of small openings 76 and vertically extending ridges 78, as in the embodiment first described. In Figs. 10 and 11 the wall 75 is shown as being formed of a plurality of thin plates 75*a* of refractory material which are stacked together and held in place in the manifold 73 in any suitable manner. The individual plates 75*a* are formed with shallow grooves or channels which form the small openings 76 when the plates are stacked together.

The refractory lined combustion chamber 80*a* is formed by a hollow rectangular block 82 of suitable high temperature refractory material which fits snugly about the apertured wall 75, as best shown in Fig. 11. The metallic shell 72*a*, in the direction of flow of the fuel into chamber 80*a*, is longer than the shell 72 previously described and includes side walls 72*b* at an angle to the part of the shell within which is disposed the hollow rectangular block 82. The outer ends of the side walls 72*b* are secured, as by welding, for example, to the ends of the metal sheets 90 and 91 forming the annular heating elements 89.

Within the part of the metal shell 72*a* having the side walls 72*b* is disposed a block 84*a* of suitable high temperature refractory material, such as, for example, silicon carbide and the like. The block in horizontal cross section is of substantially the same shape and size as the trapezoidal space bounded by the side walls 72*b*, outer end of block 82 and the extreme outer ends of the side walls 72*b*, as shown in Fig. 11, the side walls of the block 84*a* converging slightly from the chamber 80*a* to the heating spaces 92 in the same manner as the side walls 72*b*.

The block 84*a* is formed with horizontal U-shaped slots at opposite sides of an upright portion 84*b*, the two vertical rows of slots forming passages 84*c* communicating at one end at 84*e* with the chamber 80*a* and at the other end at 84*g* with the heating spaces 92. The passages 84*c* are wider at the inlet ends 84*e* than at the

outlet ends 84g and collectively form a restricted outlet or discharge orifice through which high temperature gases pass from the combustion chamber 80a to the heating spaces 92. The block 84a when viewed from the combustion chamber 80a in the direction of the heating spaces 92 appears as illustrated in Fig. 13, the face 84p overlying and abutting the outer edge of the hollow rectangular block 82 at 84e and the face 84s bearing against the wall 34u at the inlet end of the heating spaces 92.

The face 84p of the refractory block 84a forms a part of the refractory lining for the combustion chamber 80a and is heated to incandescence during operation of the heater to promote substantially complete combustion of the air and fuel mixture in the chamber, as in the embodiment first described. The face 84p when heated to incandescence also functions in the same manner as the refractory post 84 in Fig. 3 to effect reignition of the air and fuel mixture in the event flow of the fuel mixture is interrupted momentarily or operation of the heater is stopped for a short interval of time and is then resumed.

Substantially complete combustion of the air and fuel mixture is accomplished in combustion chamber 80a in the same manner explained above in connection with the first embodiment. By providing the restricted outlet at 84e, a pressure is developed in combustion chamber 80a which is higher than the pressure in the heating spaces 92 into which the high temperature gases pass through the passages 84c. By heating the refractory lining to incandescence and developing as high a pressure as possible in combustion chamber 80a, the temperature at which combustion is accomplished is increased so that rapid flame propagation and a high rate of combustion are effected.

In the embodiment of Figs. 10 to 13 the side walls 72b of the metal shell 72a form a continuation of the innermost and outermost metal sheets 90 and 91 of the heat dissipating elements 89, and heat is given up from the heated gases flowing in passages 84c to air to be heated which flows over the outer surfaces of the metal walls 72b. The passages 84c gradually decrease in size from the inlet end 84e to the outlet end 84g in order that the heated gases will enter the heating spaces 92 at as high a velocity as possible after initial cooling of the gases in the passages 84c, as the result of giving up heat to the air flowing over the outer surfaces of the walls 72b.

The high temperature gases pass through the annular heating spaces 92 and give up heat to air passing over the outer surfaces of metal sheets 90 and 91 in the same manner described above in the first embodiment. A plurality of vertical fins 140 are secured, as by welding, for example, to the metal sheets 90 and 91 to increase the effective heat dissipating surface of the elements 89.

As shown most clearly in Fig. 11, the discharge end of each heating space 92 is provided with a vertically extending baffle 141 which extends from the extreme bottom of the metal sheets 91 and terminates a short distance from the upper ends of the sheets. The baffles do not extend completely across the space between the sheets 90 and 91 but do serve to deflect the flow of a substantial portion of the gases upwardly over the top edges of the baffles and then downwardly in the outlet chamber 142 from the lower end of which the gases are discharged through the outlet 93.

Although an air heater 47 like that shown in Fig. 1 and described above is not embodied in the modification of Figs. 10 to 13, it is to be understood that such an air heater may be included in a manner generally like that illustrated in the first embodiment. In the modification of Figs. 10 to 13 the casing of motor 20 is provided with studs 21a which pass upwardly through sleeves 22a formed integrally with the bottom plate 10, and the motor is drawn tightly against the ends of the sleeves by nuts 21b. A suitable labyrinth packing is provided at 26a to prevent leakage of the air and gas mixture from the impeller chamber 14.

The modification of Figs. 10 to 13 does not include a shield 102 like that shown in Fig. 1 between the motor 20 and the inner annular element 89. As best shown in Fig. 10, air to be heated is drawn through the screen 112 into the bottom of the heater by the air circulating fan 107, and the air then passes upwardly through annular space 101 between the casing 96a and the outer element 89, annular space 105 between the two elements 89, and annular space 106a between the motor 20 and the inner element 89. The air which has been heated in these passages passes into the space 143 at the upper part of casing 96a from which it is discharged through a single duct socket 97a within which may be located thermal devices 133 and 135 similar to those previously described in connection with the first embodiment.

As shown in Fig. 10, the lower ends of angle members 144 are secured to the outer element 89 and the upper ends thereof are removably secured at 145 to bosses 146 formed on the bottom plate 10, thereby providing a rigid and unitary heater structure. The outer casing 96a is removably secured at its upper end at 147 to the outer edge portions of the plates 10 and 11. Suitable flanged legs 148 may be secured to the end cover 110 to facilitate the mounting of the heater in an airplane or other place of use.

When the heater of the invention is installed in an airplane 149, as diagrammatically shown in Figs. 14 and 15, combustion air may be drawn into the impeller chamber 14 from the immediate surroundings of the heater within the airplane. A suitable connection 150 may be provided from the outlet 93 to the exterior of the ship for discharging the spent products of combustion overboard. It is desirable to operate the heater with the heating spaces 92 at a pressure below that of atmospheric, and this may be accomplished by providing the connection 150 from the outlet 93 to the exterior of the ship in such a manner that a suction effect will be produced at the extreme outer end 151 during flight of the airplane which is reflected back to the annular heating spaces 92. A suitable adjustable valve 152 may be provided in connection 150 and a pressure gauge 153 may be connected between the valve and the outlet 93.

When the heater illustrated in Figs. 10 to 13 inclusive and described above is operated in an airplane, the valve 152 may be adjusted so that the pressure in the heating spaces is reduced below the pressure of the atmosphere within the interior of the airplane by an amount, for example, which is equivalent to as much as five inches of water column. By providing a restricted outlet at 84e for the combustion chamber 80a and a restriction to the flow of the high temperature gases at 84g before entering the heating spaces 92, the full effect of the negative pressure produced in the heating spaces is not reflected back into the combustion chamber 80a. Thus, even though a defi-

nite negative pressure is produced in the heating spaces **92**, combustion can be accomplished in the chamber **80***a* at a higher pressure than that prevailing in the heating spaces so that combustion conditions will not be adversely affected by the negative pressure prevailing in the heating spaces.

Since combustion is accomplished at the highest possible temperature in chamber **80***a* by restricting the combustion chamber outlet, as explained above, and under such conditions the products of combustion are heated to the highest possible temperature, it will be immediately evident that it is of considerable advantage to be able to maintain the heating spaces at a definite negative pressure with respect to the atmospheric pressure of the environment in which the heater is being operated, and yet prevent the full negative pressure in the heating spaces being reflected or transmitted back to the combustion chamber **80***a*.

Further, the provision of a restricted outlet for the combustion chamber **80***a* promotes stable combustion over a wide range of operating conditions encountered in airplane heating. When movement of an airplane in flight is relied upon to develop the negative pressure in the heating spaces **92**, as just explained, the negative pressure produced at the extreme end **151** of the connection **150** may vary over a wide range which is dependent upon a number of factors including the speed and altitude of the airplane as well as the turns or banks of the ship in flight. The negative pressure developed during flight of the airplane due to these factors may vary over a pressure range equivalent to 15 or more inches of water column.

In some cases the resistance in the connection **150** alone may be sufficient to produce and develop the desired negative pressure in the heating spaces, and it may be desirable under certain conditions to provide a restriction like that of the valve **152** which is either adjustable or fixed when the resistance in the connection alone is not sufficient. Although the negative pressure in the heating spaces **92** may vary over a considerable range, and at certain times may tend to be higher than desired, this is not detrimental to reliable operation of the heater because of the independence of the manner in which combustion is accomplished in the combustion chamber **80***a* and the provision of the restricted outlet between this chamber and the heating spaces **92** into which the high temperature gases pass.

In the embodiment of Figs. 1 to 8 the outlets **81** for the combustion chamber **80** are not restricted to the same extent as the outlets **84***e* in the modification of Figs. 10 to 13. When the combustion chamber outlets are not restricted sufficiently, the full effect of the negative pressure developed in the heating spaces **92** may be reflected back to the refractory lined combustion chamber. In such case it is desirable to provide a valve **152** or other suitable fixed restriction, such as a small orifice, for example, in the connection **150** so that the negative pressure developed in the heating spaces **92** will not exceed a predetermined maximum value. It is to be understood, however, that in the embodiment of Figs. 1 to 8 the refractory post **84** and hollow refractory block **82** may be shaped to provide outlets **81** which are sufficiently restricted like the restricted outlets **84***e* in the modification of Figs. 10 to 13, so that the full effect of the negative pressure developed in the heating spaces **92** will not be reflected or transmitted back to the combustion chamber and the combustion accomplished in the combustion chamber will be more or less independent of the negative pressure prevailing in the heating spaces **92**.

It has previously been stated that expansion of the air and fuel mixture passing through the small inlet openings **76** takes place in the channels or grooves **79** formed between the ridges or walls **78**. This is particularly helpful when the heater of the invention is employed in aircraft heating, because the proportion of air in the mixture increases with increase in altitude in order to maintain the desired weight ratio of air to fuel. Since larger volumes of air mix with a given amount of fuel with increase in altitude, the expansion of the mixture in the grooves **79** with consequent reduction in velocity helps to overcome any tendency for the flames to blow off the discharge ends of the inlet openings **76**. The fact that combustion is accomplished in a refractory lined combustion chamber in which heat is radiated from the incandescent lining also contributes to maintain stable combustion conditions at all times, and hence insure the flames always being rooted to the discharge ends of the inlet openings.

The air heater **47** in the embodiment of Figs. 1 to 8 is particularly useful when it becomes necessary to start operation of the heater at extremely low temperatures, such as minus 40° F. and lower, which sometimes occurs in aircraft heating. In such case the closing of the switch **120** in Fig. 9 completes the circuit for the air heater **47** because thermal device **134** will then be in its closed position. This effects heating of the combustion air being drawn into the impeller chamber **14** by the impeller **15**, and helps to facilitate rapid ignition of the air and fuel mixture in the combustion chamber by the electrical ignitor **85**. When the heater reaches a temperature of about 70° F., as previously explained, the thermal device **134** opens and disconnects the heater **47** from the source of electrical energy.

The heater provided is extremely efficient and capable of producing an exceptionally high heat output per pound of heater. In a heater which has been built and generally like that illustrated in Figs. 10 to 13, and from which the drawings were made to scale, the heat output is about 2,000 B. t. u. per hour per pound of heater. The heater just referred to is 8 inches in diameter, 14 inches in over-all height and weighs approximately 12 pounds. The motor for driving the air fan **107***a* and impeller **15**, and corresponding to the motor **20**, is a high speed series motor rated at ⅛ H. P. The motor speed at sea level is about 10,000 R. P. M. and at an altitude of 30,000 feet is about 15,000 R. P. M.

The fact that a series motor operates at increasingly higher speeds with increase in altitude, due to decrease in air density, is particularly helpful in maintaining the desired weight ratio of combustion air to fuel under all of the varying operating conditions encountered in airplane heating. By properly adjusting the altitude compensator, and taking into consideration the rate at which the speed of the motor **20** increases with increase in altitude, it is possible to maintain the desired weight ratio of air to fuel under all operating conditions from sea level to altitudes of 30,000 feet and higher.

The heater referred to above and weighing

about 12 pounds, is capable of producing 25,000 B. t. u. per hour at sea level and about 19,000 B. t. u. per hour at an altitude of 30,000 feet. The heater is capable of producing an average temperature rise of about 300° F. and a maximum temperature rise of 400° F. when air to be heated is circulated through the heater, and discharges heated air at the rate of about 150 cubic feet per minute. When gasoline is employed as the liquid fuel, the fuel consumption is about 1½ pounds of gasoline per hour (¼ gallon) to produce the heat output stated above, and with this rate of fuel consumption the heater efficiency is about 85 per cent.

During operation of the heater the mixture of relatively cool combustion air and atomized fuel passing from the annular chamber **12** into the manifold **73** exercises a cooling effect and keeps down the temperature of the manifold. In the heater referred to above the cross sectional area of the small openings **76** in the apertured inlet wall are about 0.3 square inch. The pressure of the mixture of combustion air and atomized fuel at the upper part of the manifold **73** is equivalent to about 1½ inches of water column, and it has been observed that this pressure remains substantially constant under all operating conditions from sea level to an altitude of 30,000 feet and higher. The pressure drop of the air and fuel mixture through the small inlet openings **76** is equivalent to about ½ inch of water column.

The combustion effected in the refractory lined combustion chamber is exceptionally clean, and, after many hours of heater operation, there has been a complete absence of carbon deposit in the combustion chamber. The fact that liquid fuel is introduced into the combustion chamber in an atomized condition is a distinct advantage when leaded gasoline is employed as the fuel, because the likelihood of lead vapors condensing in the small inlet openings **76** is avoided. In the heater actually built and operated under the most adverse conditions, the small inlet openings have remained free and open although operated at all times with leaded gasoline of high octane rating.

The heater of the invention is formed of a relatively few parts and is readily assembled and aligned. After securing the motor **20** to the bottom plate **10** by the studs **21** in the embodiment of Figs. 1 to 8, and positioning the impeller **15** at the upper end of the shaft **23** by set screw **24**, the plates **10** and **11** are then secured together. The annular shield **102** may then be secured to the underside of the plate **10** by screws **103**, as shown in Fig. 1. The altitude compensator including the bellows **42** and valve **37** are mounted on a single part which is inserted into the open-ended casing **28**, as shown in Fig. 7 and previously described. The casing **28** is secured to the top plate **11** so that the hollow post **53** is in alignment with the passage **58** in top plate **11**, and it is for this reason that the flange **29** of casing **28** is of irregular shape and similar to that of the boss or raised portion on top plate **11** to which the casing is secured, as previously described.

The annular elements **89** and metal shell **72** are formed as a single unitary structure, and the upper end of the shell **72** is secured to the flange **70** at the bottom of the leg **65** which is formed integrally with the bottom plate **10**, as best shown in Fig. 4. With this arrangement, the annular elements **89** are properly positioned and aligned concentrically about the motor **20** which is also secured to the bottom plate **10**. The metal shell **72** serves as the housing for the burner parts and is easily accessible by simply removing the shell from the hollow leg **65**. Before securing the shell **72** to the leg **65**, the burner parts comprising the manifold **73** and the hollow refractory block containing the post **84** are simply slid into the shell **72** within which the parts snugly fit, as best shown in Fig. 6.

After securing the fan **107** to the shaft **108**, the outer casing **96** can then be slipped over the elements **89** and rotated slightly so that the bayonet slots **99** at the top edge of the outer casing are locked by the pins **98** at the periphery of the plate **10**. The assembly of the heater is then completed by securing ignitor **85** and hollow tube **88** in the openings provided for these parts in the metal shell **72**, as shown in Fig. 1.

In the heater of Figs. 10 to 13 the altitude compensator is of simpler construction than that in the embodiment of Figs. 1 to 8 and fewer parts are employed in that no combustion air heater **47** or annular shield **102** about the motor **20** are included in the structure. The ignitor **85** in Fig. 10 is of a different type than that shown in Fig. 1 and described above and includes a ceramic core **155** having a helical groove about which is wound a hot wire heating element **156**. The ceramic core **155** is positioned close to the apertured wall **75** with the ridges **78** being cut away to form a recess to receive the ceramic core, as shown in Fig. 11.

In the embodiment of Figs. 10 to 13 the labyrinth packing **26***a* is formed by the hub of the impeller **15** and the hub of a rotatable element **15***a* which is secured to the shaft **23** in any suitable manner before the motor **20** and bottom plate **10** are secured together. The element **15***a* is formed with a plurality of blades **15***b* so that, in the event an occasional drop of fuel should pass downwardly from the packing **26***a*, it will not enter the upper end of the motor **20** but will be thrown radially outward by the blades **15***b* between the hollow sleeves **22***a* into the space **143**. Such fuel vaporizes and mixes with the heated air in space **143** and passes out of the heater through the duct socket **97***a*.

The assembly of the heater of Figs. 10 to 13 is generally similar to that of the first embodiment just described. In the assembly of the modification of Figs. 10 to 13, the refractory block **84***a* is slipped into the metal shell **72***a* at the uncovered part normally occupied by the manifold **72** and then moved sidewise into the covered part of the shell **72***a* having the side walls **72***b*. The hollow refractory block **82** and manifold **73** are then positioned within the shell **72***a*, so that the apertured wall **75** fits snugly within one end of the hollow block **82**, as shown most clearly in Fig. 11.

It will now be understood that in the first embodiment and in the modification of Figs. 10 to 13 the parts of the burner assembly are insertable in and removable from the metallic shell or housing **72** and **72***a* when the heating unit is disconnected from the bottom plate **10** of the impeller housing, thereby facilitating inspection and repair of the heater when this becomes necessary. From the above it will now be understood that the heater parts are readily assembled to form a single compact unit, and that the heater parts are accurately aligned and rigidly secured to the plates **10** and **11** forming the impeller housing.

In view of the foregoing, it will now be seen that a compact and light weight heater has been provided in which the heat output per pound of

heater is exceptionally high and in which dependable and reliable operation is assured under different operating conditions, particularly those existing when the heater is employed for heating an airplane.

In the installation of the heater in the airplane 149, as diagrammatically illustrated in Fig. 14, the connection 150 extends upwardly from the heater. Condensation of water vapor accompanying the exhausted gases may take place in the exhaust connection, and in practice it is desirable to lead the connection for the exhaust gases downwardly from the heater, so that any condensate formed therein will drain by gravity and be discharged overboard.

Although several embodiments of the invention have been shown and described, it will be apparent to those skilled in the art that changes can be readily made and that certain features can be used independently of others without departing from the spirit and scope of the invention. In the heater of the invention, for example, the apertured inlet wall of the refractory lined combustion chamber may be formed of brass or other suitable material as well as refractory material. Further, the negative pressure in the heating spaces 92 may be produced by a blower provided in the connection through which the gases are exhausted from the heater at the outlet 93. Such a blower may be driven by a separate electric motor or it may be like the blower which delivers combustion air and fuel to the heater and arranged to be driven by the same electric motor driving the air circulating fan and impeller 15. We therefore aim in the appended claims to cover all such changes and modifications as fall within the true scope of the invention.

What is claimed is:

1. A heater comprising structure including a blower adapted to supply a combustible fuel mixture under pressure, said blower comprising a pair of removably secured opposing wall members providing an inner chamber having an inlet and an outer annular diffusing chamber immediately adjacent to and communicating with the inner chamber substantially about the entire periphery thereof, a rotatable impeller in the inner chamber, the outer annular chamber having an outlet for discharging combustible fuel mixture therefrom under pressure, a burner unit, means for removably securing said burner unit to one of said wall members to receive the combustible fuel mixture adapted to be discharged from the outlet of the outer annular chamber, a hollow heat dissipating element connected to receive heated gases from the burner unit and through which such gases are adapted to pass, means including a fan for circulating air to be heated in heat exchange relation with the hollow element, and means including a motor removably secured to said one of said wall members for driving the impeller and the fan.

2. A heater comprising structure including a blower adapted to supply a combustible fuel mixture under pressure, said blower comprising a pair of removably secured opposing wall members providing an inner chamber having an inlet and an outer annular diffusing chamber immediately adjacent to and communicating with the inner chamber substantially about the entire periphery thereof, a rotatable impeller in the inner chamber, the outer annular chamber having an outlet for discharging combustible fuel mixture therefrom under pressure, means providing a housing having an opening, a burner unit insertable into and removable from the housing through the opening therein, said burner unit including a shell and refractory means, said shell having an apertured wall and an inlet adapted to be positioned adjacent the open end of the housing and said refractory means providing a refractory lined combustion chamber adjacent the apertured wall, means for removably securing said housing at the opening therein to one of said wall members to close the opening and connect the inlet of the shell for the latter to receive combustible fuel mixture discharged from the outlet of the outer annular chamber, a hollow heat dissipating element communicating with the combustion space and through which heated gases from the latter are adapted to pass, means including a fan for circulating air to be heated in heat exchange relation with the hollow element, and means including a motor removably secured to one of said wall members for driving the impeller and the fan.

3. A heater comprising a frame having an outlet opening, a blower mounted in said frame to supply a combustible fuel mixture under pressure through said outlet opening, means providing a substantially straight elongated housing having an opening at one end thereof, a burner unit insertable into and removable from the housing through the opening therein, said burner unit comprising means providing a substantially straight elongated inlet space having an apertured side wall and an inlet adapted to be positioned adjacent to the open end of the housing and refractory means providing an elongated refractory lined combustion chamber alongside the inlet space adjacent to said apertured wall, said apertured wall and elongated combustion chamber being substantially coextensive with the length of the inlet space, a hollow heat dissipating element extending from a side wall of the housing and communicating with the combustion chamber and through which heated gases from the latter are adapted to pass, said hollow element being substantially coextensive with the length of the combustion space, and means for removably securing the housing at the open end thereof to said frame to close the outlet opening in said frame and cause the combustible fuel mixture to be delivered under pressure to the inlet space through the inlet of said burner unit.

4. A heater comprising a blower including a casing providing an inner chamber having an inlet and an outer annular diffusing chamber immediately adjacent to and communicating with the inner chamber substantially about the entire periphery thereof, a rotatable impeller in the inner chamber for drawing air therein through the inlet, means providing a passage through which liquid fuel is adapted to pass from a source of supply into the inner chamber for atomization therein by the rotatable impeller, said outer chamber having an outlet for the mixture of air and atomized fuel, a burner unit including structure providing an elongated inlet space having one end thereof communicating with the outlet of said outer annular chamber and a combustion space and an apertured wall therebetween, said elongated inlet space in its longest dimension being substantially normal to the plane of rotation of the impeller and extending from said casing at the outlet of the outer chamber whereby said burner unit and casing may be readily separated, a hollow element communicating with the combustion space and through which heated gases from the

latter are adapted to pass, means including a fan for circulating air to be heated in heat exchange relation with the hollow element, and means for driving the impeller and the fan.

5. A heater comprising a blower including a casing providing an inner chamber having an inlet and an outer annular diffusing chamber immediately adjacent to and communicating with the inner chamber substantially about the entire periphery thereof, a rotatable impeller in the inner chamber for drawing air therein through the inlet, means providing a passage through which liquid fuel is adapted to pass from a source of supply into the inner chamber for atomization therein by the rotatable impeller, said outer chamber having an outlet for the mixture of air and atomized fuel, a burner unit including structure providing an elongated inlet space having one end thereof communicating with the outlet of said outer annular chamber and a combustion space and an apertured wall therebetween, means to attach said burner to said casing with said elongated inlet space in its longest dimension being substantially normal to the plane of rotation of the impeller and extending from said casing at the outlet of the outer chamber, means including a member in the outer annular chamber at the down stream side of the outlet thereof to facilitate the change in direction of the air and fuel mixture from the outer annular chamber into the elongated inlet space substantially normal thereto, a hollow element communicating with the combustion space and through which heated gases from the latter are adapted to pass, means including a fan for circulating air to be heated in heat exchange relation with the hollow element, and means for driving the impeller and the fan.

6. A heater comprising a blower including a casing providing an inner chamber having an inlet and an outer annular diffusing chamber immediately adjacent to and communicating with the inner chamber substantially about the entire periphery thereof, a rotatable impeller in the inner chamber for drawing air therein through the inlet, means providing a passage through which liquid fuel is adapted to pass from a source of supply into the inner chamber for atomization therein by the rotatable impeller, said outer annular chamber having an outlet for the mixture of air and atomized fuel, an annular-shaped heating unit adjacent to and at one side of said casing, said heating unit including a hollow element and burner structure providing an elongated inlet space having one end thereof communicating with the outlet of said outer annular chamber and a combustion space and an apertured wall therebetween, means to attach said heating unit to said casing with said elongated inlet space in its longest dimension being substantially normal to the plane of rotation of the impeller and extending from said casing at the outlet of the outer chamber, said hollow element communicating with the combustion space and through which heated gases from the latter are adapted to pass, means including a fan for circulating air to be heated in heat exchange relation with said heating unit, and a motor having shaft means to which the fan and impeller are secured.

7. A heater comprising a blower including a casing providing an inner chamber having an inlet and an outer annular diffusing chamber immediately adjacent to and communicating with the inner chamber substantially about the entire periphery thereof, a rotatable impeller in the inner chamber for drawing air therein through the inlet, means providing a passage through which liquid fuel is adapted to pass from a source of supply into the inner chamber for atomization therein by the rotatable impeller, the outer chamber having an outlet for the mixture of air and atomized fuel, a burner unit including structure providing an elongated inlet space having one end thereof communicating with the outlet of said outer annular chamber and an elongated combustion space alongside of the inlet space and an apertured wall therebetween, means to attach said burner unit to said casing with said elongated inlet space in its longest dimension being substantially normal to the plane of rotation of the impeller and extending from said casing at the outlet of the outer chamber, said apertured wall and elongated combustion space being substantially coextensive with the length of said inlet space, and a hollow element communicating with the combustion space and through which heated gases from the latter are adapted to pass, said hollow element being substantially coextensive with the length of the combustion space, means including a fan for circulating air to be heated in heat exchange relation with the hollow element, and means for driving the impeller and the fan.

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