Sept. 23, 1947. H. B. HOLTHOUSE 2,427,674

AIRCRAFT HEATING APPARATUS WITH ALTITUDE RESPONSIVE COMBUSTION AIR SUPPLY

Filed June 29, 1944 2 Sheets-Sheet 1

FIG. 1

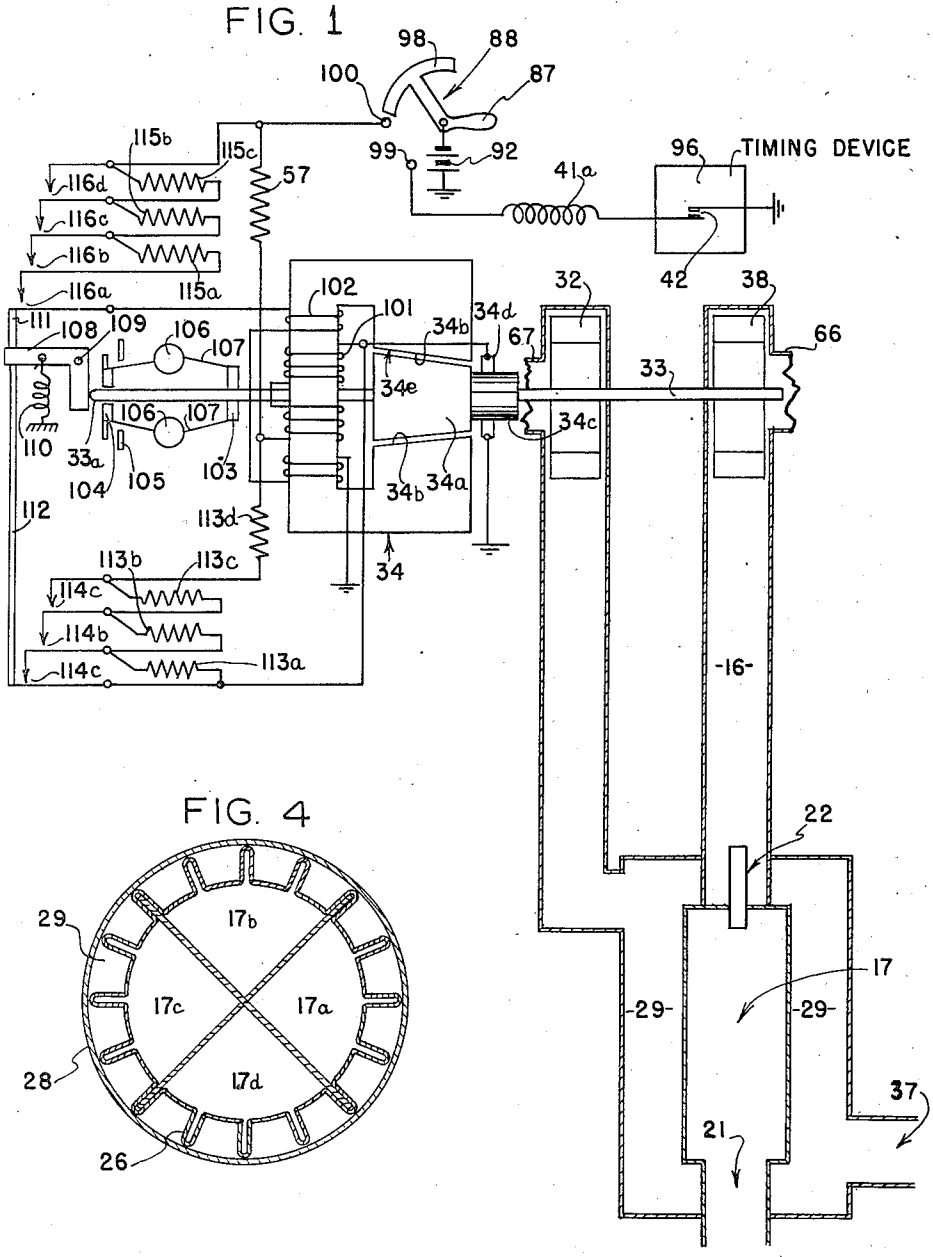


FIG. 4

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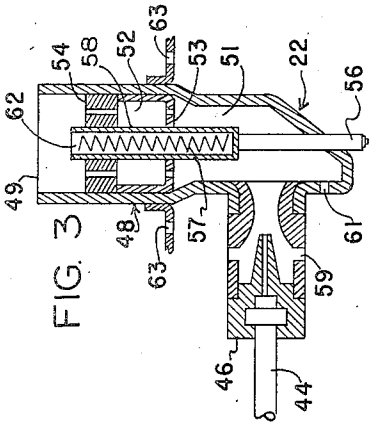
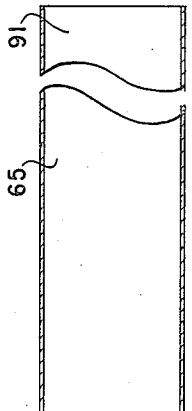


FIG. 3



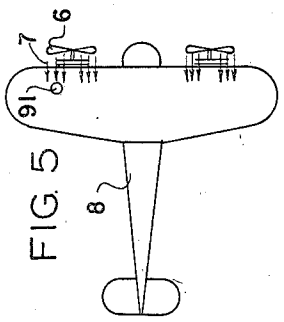


FIG. 5

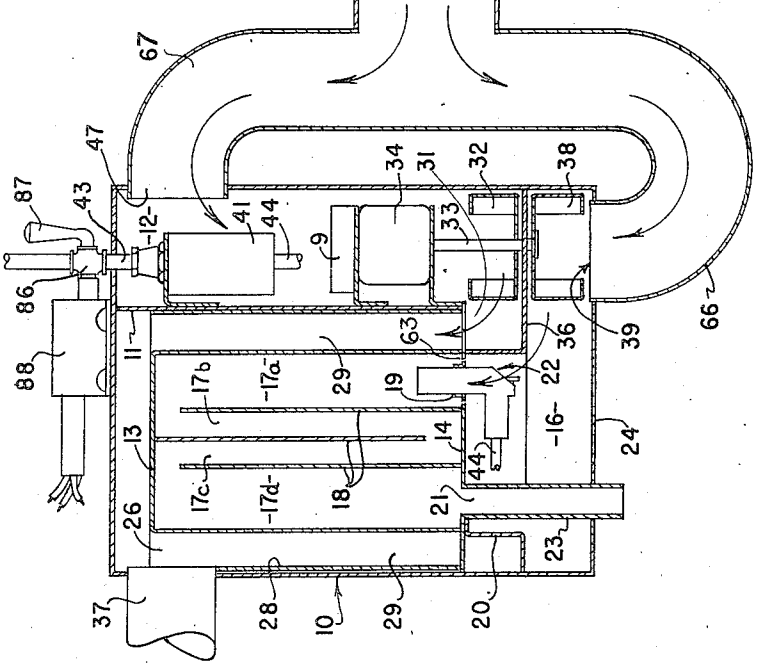


FIG. 2

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Patented Sept. 23, 1947

2,427,674

UNITED STATES PATENT OFFICE

2,427,674

AIRCRAFT HEATING APPARATUS WITH ALTITUDE RESPONSIVE COMBUSTION AIR SUPPLY

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Application June 29, 1944, Serial No. 542,730

11 Claims. (Cl. 158—28)

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The present invention relates to heating apparatus and more particularly to improvements in aircraft heaters of the internal combustion type adapted for uniformly reliable operation over a wide range of altitudes.

Many types of internal combustion heaters are available which will operate satisfactorily at the temperature and atmospheric pressure conditions prevailing at ground levels. In fact, certain of the commercially available heaters of this type are capable of operating with satisfaction at altitudes of approximately 15,000 feet. When this altitude is exceeded, however, the usual heater becomes unreliable and may become wholly inoperative due to the reduced oxygen content in the rarefied atmospheres at high altitudes and the cold temperatures encountered at such altitudes. As disclosed in applicant's co-pending application Serial No. 435,845, filed March 23, 1942, now Patent No. 2,400,116, issued May 14, 1946, this problem is in part obviated by utilizing a motor, preferably of the series wound direct current type, having a drooping speed-load characteristic, to drive the combustion air moving means, whereby the motor speeds up to increase the volume of air delivered to the combustion chamber as the density of the air decreases with increasing altitude. This novel arrangement solves the problem entirely in operating an internal combustion heater at altitudes ranging up to approximately 20,000 feet. At still higher altitudes, however, other means must be relied upon for further increasing the volume of air delivered to a heater combustion chamber if satisfactory combustion is to be obtained.

It is an object of the present invention, therefore, to provide improved aircraft heating apparatus in which completely reliable operation over a wide altitude range is obtained through the provision of an exceedingly simple arrangement for accentuating the described characteristic of the air moving motor to speed up as the density of the air moved thereby decreases with increasing altitude.

According to another object of the invention, a motor including differentially related series and shunt field windings is used to drive the combustion air moving means and facilities are provided for changing the current flow through at least one of the field windings or armature of the motor in the correct sense to accentuate the described speed characteristic of the motor as the altitude of heater operation is increased.

In accordance with a further and more specific object of the invention, the desired increase

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in speed of operation of the air moving motor with increasing altitude of heater operation is at least in part obtained by automatically changing the length of the air gap separating the motor armature from the adjacent pole pieces as the altitude of heater operation is changed.

More generally stated, it is an object of the present invention to provide improved aircraft heating apparatus of the internal combustion type which is completely reliable in operation over a wide range of altitudes.

The invention both as to its organization and method of operation, together with further objections and advantages thereof will best be understood by reference to the following specification taken in connection with the accompanying drawings, in which:

Fig. 1 is a diagrammatic view of improved aircraft heating apparatus characterized by the features of the present invention;

Fig. 2 is a longitudinal sectional view of the apparatus shown in Fig. 1 illustrating the mechanical construction and arrangement thereof;

Fig. 3 is a side sectional view of the fuel conditioning unit forming a part of the apparatus shown in Figs. 1 and 2;

Fig. 4 is an end sectional view of the combustion chamber provided in the apparatus; and

Fig. 5 is a diagrammatical illustration of the manner in which the combustion and circulating air delivery conduit as provided in the apparatus of Figs. 1 and 2 is arranged with respect to one of the propellers of an aircraft in which the apparatus is installed.

Referring now to the drawing and more particularly to Fig. 1 thereof, the present improved heating apparatus is diagrammatically illustrated as comprising means defining a combustion chamber 17 which is surrounded by an air circulating chamber 29 having an outlet opening 37 through which air heated by contact with the walls defining the combustion chamber 17 may be discharged to the space to be heated. The combustion chamber is provided with an inlet for admitting a fuel and air mixture from a fuel conditioning unit 22 which is positioned within an air pressure chamber 16, and with a discharge orifice 21 through which the products of combustion are discharged after burning within the chamber 17. Combustion air for supporting combustion within the chamber 17 is first delivered to the chamber 16 under pressure by means of a fan 38 and is then admitted to the combustion chamber from the pressure chamber in the manner specifically described below. Air is circu-

lated through the chamber 29 and discharged through the opening 37 into the space to be heated by means of a second fan 32 to which air is admitted through a conduit 67. These two fans, which are preferably of the well known sirocco type, are commonly mounted for rotation upon the rotor shaft 33 of a compound wound direct current motor 34. In brief, this motor comprises a field structure having tapered pole faces 34b spaced from a tapered armature 34a so that an air gap 34e of generally conical configuration is provided therebetween. It is equipped with a series field winding 101 which is adapted to be energized in series with the windings of the armature 34a through the customary commutator 34c and brushes 34d from a direct current source 92. This series energizing circuit also includes a fuel and air heating element 57 which is included in the fuel conditioning unit 22, and one or more of three resistors 113a, 113b and 113c which shunt the series winding 101 and have the function of variably controlling the voltage applied to the armature. The motor 34 further comprises a small shunt winding 102 which is differentially related to the series winding 101 and is arranged for energization from the source 92 over a circuit which may include a variable number or none of the resistors 115a, 115b and 115c. This differential winding is such size that the flux produced thereby is incapable of predominating over the flux produced by the series winding 101 over the operating speed range of the motor and yet is of sufficient size to appreciably weaken the series field when fully energized.

For the purpose of changing the speed-load characteristic of the motor 34 in a manner such that the air moving fans are rotated at increasingly higher speeds with a decrease in the density in the air moved thereby, a speed responsive device 9 is provided which is driven by the rotor shaft 33. This device has the functions of controlling the length of the air gap 34e separating the armature periphery from the pole faces of the field pole pieces, controlling the energization of the differential shunt winding 102, and controlling the voltage applied to the armature 34a. It is schematically illustrated as comprising fly balls 106 supported by resilient elements 107 between two rings 103 and 104, the first of which is rigidly mounted upon the shaft 33 and the second of which is movable axially of this shaft. More specifically, the arrangement is such that when the shaft 33 is rotated at a predetermined speed, the fly balls 106 act to move the ring 104 into engagement with a stationary bearing ring 105 carried by the motor housing in any conventional manner. After such engagement and during a continuing increase in the speed of rotation of the shaft 33, the sleeve 104 coacts with the bearing ring 105 to move the shaft 33, the armature 34a and the fans 32 and 38 to the left as viewed in Fig. 1 of the drawings, thereby to increase the length of the air gap 34e. In this regard it is noted that the construction of the motor is such that substantial movement of the shaft 33 and the parts carried thereby between two predetermined axial positions is permitted. Likewise, the fans 32 and 38 must be freely axially movable within their housings to permit the described axial displacement of the shaft 33.

With the described arrangement, movement of the shaft 33 axially to the left may be utilized to control in steps the value of the resistance shunting the series field 101, and also to control the energization of the differential field 102. To this end, the end 33a of the shaft is arranged to engage an L-shaped rocker arm 108 pivoted at 109 and engaging contact closing members 111 and 112 respectively associated with the contacts 116 and 114. A tension spring 110 is utilized to tension one leg of the arm 108 into engagement with the end 33a of the shaft 33 for the purpose of maintaining the shaft 33 and the parts carried thereby in the position at which the shortest air gap 34e prevails between the periphery of the armature 34a and the pole faces 34b. In maintaining the shaft 33 in this position the arm 108 also holds the contact actuating elements 111 and 112 in settings such that the respective associated contacts 116a to 116d, inclusive, and 114a to 114c, inclusive, are open. The electrical equipment for the heating apparatus further comprises a solenoid actuated pump 41 having a winding 41a arranged for intermittent energization through a pair of contacts 42 which are adapted to be periodically opened and closed through the action of a timing device 96. This device may be of any conventional form. A manually operable two-step switch 88, comprising a wiper arm 98 and a pair of associated contacts 99 and 100, is provided for selectively controlling the energization of the winding 41a and the various described windings of the motor 34.

Referring now more specifically to the construction and arrangement of the heater, the combustion chamber 17 is shown in Figs. 1 and 4 as being divided longitudinally into four axially extending but connected passages 17a—17d by a partition member 18 of substantially X-shape. The combustion chamber inlet 19 and outlet 21 are formed in the bottom portion 14 of the dish-shaped member 20 in communication with the passages 17a and 17d, respectively. The air and fuel mixing unit 22 is located within the inlet 19 and extends within the air supply chamber 16. The outlet 21 is provided with a tail pipe 23 extended through the air supply chamber 16 and outwardly from the heater at the housing end 24.

The outer wall or body portion of the combustion chamber 17 is provided with angularly spaced axially extending fins 26. These fins have a sleeve 28 positioned about the outer ends thereof to form an annular air circulating passage 29 surrounding the combustion chamber 17. Air to be heated is admitted into the passage 29 through an inlet 31 connecting the passage with the mechanical compartment 12 and is in part circulated through the passage 29 by the fan 32 located within the compartment 12. The compartment 12 and air passage 29 are separated from the air pressure chamber 16 by a sealing or partition member 36 extended transversely of the housing 10. From Fig. 2 of the drawings, it will be seen that the air supply chamber 16 is defined by the member 20, the partition member 36, and the end 24 of the housing 10. Air circulated by the fan 32 is thus confined to travel within the compartment 12 and passage 29 and is discharged from the passage through an outlet 37 which is connected to a space to be heated.

The air supply chamber 16 receives air from the fan 38 located therein and mounted on the motor shaft 33 which is journaled in the partition plate 36. An inlet 39 for the fan 38 is provided in the housing end 24. Fuel for the pump 41 is supplied thereto from a suitable source (not shown) through a pipe 43 and is delivered through a pipe 44 to a fuel injection nozzle 46 forming a part of the air and fuel mixing means 22. The

pump 41, motor 34 and fan 32 are thus all located within the mechanical compartment 12, which is provided with an inlet 47 for supplying air to the fan 32 for delivery to the air passage 29.

Briefly considered, the air and fuel mixing means 22 includes a casing member 48 which is closed at one end and opens into the passage 17a at the opposite end 49 thereof. A mixing chamber 51 is located at the closed end of the casing 48, and is separated from an equalizing chamber 52 by a perforated plate member 53. The equalizing chamber 52 in turn is both defined and separated from the combustion chamber passage 17a by a perforated heat insulating plate 54 spaced inwardly from the end 49 of the casing 48. Extended substantially axially through the casing 48 and supported in the partition plates 53 and 54 to project outwardly from the closed end of the casing 48 is a combination electric heating and igniting unit 56 which includes a resistance coil 57 supported in a spaced relation within a metal tube 58.

In the operation of the air and fuel mixing means 22, the fuel delivered to the nozzle 46 by the pump 41 is directed into the mixing chamber 51, the fuel nozzle being located within the air supply chamber 16 and mounted directly on the casing 48 to communicate with the mixing chamber. A portion of the air for mixing with the fuel enters the nozzle 46 from the air chamber 16 through ports 59 in the fuel nozzle and travels with this fuel into the mixing chamber 51. Additional air from the air chamber 16 is admitted directly into the mixing chamber 51 through apertures 61 formed in the casing 48 about the fuel injection nozzle 46. The fuel within the mixing chamber 51 is heated to at least a fuel vaporizing temperature by the combination unit 56 to facilitate its thorough mixing with the air. The casing 48, partition plate 53 and tube 58 are constructed of a good heat conducting material so as to readily transfer the heat radiated by the coil 57 to the air and fuel mixture. From the mixing chamber, the vaporous air and fuel mixture passes through the perforated plate 53 into the equalizing chamber 52 which, in cooperation with the heat insulating plate 54, acts to reduce the turbulence in the mixture and to disperse the mixture substantially uniformly over the entire cross section of the casing 48. This combustible mixture then passes through the apertured plate 54 and across the open end 62 of the tube 58 into the effective igniting zone of the coil 57, thereby to ignite the combustible mixture.

Admission of fuel to the pump 41 is controlled by a valve unit 86 which is connected in the supply line 43 and includes the valve and switch actuating element 87. This element is extended through the body of the unit 86, is provided with an operating handle at one end, and is operatively connected at its opposite end with the control switch 88. The arrangement is such that upon movement of the actuating element 87 to fully close the valve unit 86, the switch 88 is operated to its open circuit position.

For the purpose of utilizing the air pressure developed during flight of an aircraft 3 in which the apparatus is installed, to assist in delivering combustion air to the combustion chamber 17 and circulating air to the circulating chamber 29, and more specifically, to create air pressures at the inlet openings 39 and 47 which assist in the transmission of air to the chamber 17 and through the chamber 29, conduit means are provided which include a common portion 65 having an opening 91 extending to the outside of the craft and facing in the direction of flight. In other words, the opening 91 faces against the direction of air flow about the surfaces of the craft in which the apparatus is installed. More specifically, and as best shown in Fig. 5 of the drawings, this opening faces directly into the slip stream, indicated at 7, generated by the propeller 6 of one of the engines of the aircraft 8. It has been found that with this arrangement, the air pressure developed within the entrance part of the conduit 65 during operation of the aircraft remains reasonably constant regardless of the speed of operation of the craft and regardless of the altitude at which the craft is operated. Otherwise stated, the air pressure within this portion of the conduit 65 is positively generated by the propeller 6, such that fluctuations therein are largely eliminated even though the craft is operated over a wide range of speeds and altitudes.

From the above explanation, it will be understood that to initiate operation of the heating apparatus, the valve and switch operating element 87 is first actuated to a position wherein the contact wiper 98 engages the contact 100. With the arm 98 in this position, a circuit is completed for energizing the heating element 57 in series with the series field 101 and the armature 34a of the motor 34. Accordingly, the heating element 57 is energized to vaporize any fuel collected within the fuel conditioning unit 22, and the fan 38 is started in operation to scavenge the combustion chamber 17 of any combustion products accumulated therein, all before operation of the fuel pump 41 is initiated to deliver fuel to the conditioning unit. After a short time interval, the switching and valve actuating element 87 may be thrown to the "run" position wherein fuel is admitted to the inlet side of the pump 41 through the feed line 43. Also in response to this operation the contact wiping arm 98 and the contact 99 are engaged to energize the operating magnet 41a of the fuel pump 41 through the intermittently closed contacts 42 which are constantly actuated by the timing device 96. Accordingly, the fuel feed system is rendered operative to deliver fuel to the fuel conditioning unit 22. In this unit the fuel is vaporized and mixed with the combustion air traversing the air inlet opening 39 and is discharged into the combustion chamber 17 for ignition, all in a manner which will be fully apparent from the preceding explanation. In this regard it will be understood that combustion air is delivered to the fuel conditioning unit 22 for mixture with the vaporized fuel over a path which includes the common conduit 65, the branch conduit 66, the chamber 16 and the orifices through the housing of the fuel conditioning unit and associated nozzle. Combustion air is also delivered to the combustion chamber 17 through the passages 63 which surround the fuel conditioning unit 22 in the end wall 14. Thus, it will be apparent that the pressure which forces combustion air into the combustion chamber 17 is in part derived from operation of the fan 38 and in part by the pressure developed within the conduits 65, 66 and 67 as a result of the air driven into the entrance end of the conduit 65 by the propeller 6. More specifically, as the propeller 6 of the craft in which the equipment is installed is operated, a substantial and reasonably constant air pressure is built up within the conduit 65 at the inlet sides of the fans 32 and 38.

So long as the aircraft in which the illustrated heating equipment is installed is operated at low altitudes the speed of operation of the motor 34 remains substantially constant. Accordingly, combustion air is delivered to the chamber 17 at a substantially uniform rate entirely adequate for satisfactory combustion therewithin. In this regard, it is noted that the fans 32 and 38 are of relatively large size such that at the air densities which prevail at ground level and low altitudes, the motor 34 is slightly overloaded. Accordingly, at such altitudes the speed of operation of the motor is held down due to the load imposed thereon by the two fans 32 and 38, although this speed is entirely adequate to insure that the requisite amount of combustion air will be supplied to the combustion chamber 17. Further, the volume of air circulated through the chamber 29 at such levels is entirely adequate to carry off the major portion of the heat developed by the combustion of the fuel mixture within the chamber 17.

As previously indicated, the motor 34 has all of the characteristics of a series wound direct current motor, such that it will inherently seek a speed at which it is fully loaded. In other words, the motor seeks to retain a constant load thereupon and to this end will change its speed of operation in response to tendencies of the load to increase or decrease. Accordingly, when the heating apparatus and more properly the aircraft in which this apparatus is installed is operated at altitudes ranging from 15,000 feet upward, the motor 34 tends to speed up as a result of the tendency of the load on the fans 32 and 38 to decrease, due to the decreasing density of the air at such altitudes. As the motor 34 speeds up, the volume of air delivered to the combustion chamber 17 is increased to correspondingly increase the amount of oxygen available for supporting combustion within this chamber. Concurrently, the volume of air passed through the air circulating chamber 29 is increased to compensate for the decrease in the heat-absorbing properties of the air as the density thereof decreases.

From the above explanation it will be understood that as the altitude of aircraft operation is increased above 15,000 feet, the speed of operation of the motor 34 progressively increases. Incident to this increasing speed of rotation of the shaft 33 the sleeve 104 is moved to the right under the influence of the centrifugally actuated fly balls 106 until a point is reached at which this sleeve engages the stationary bearing ring 105. During the continuing increase in the speed of rotation of the shaft 33 which occurs incident to a further increase in the altitude of operation of the craft, this shaft and the parts carried thereby are moved axially to the left as viewed in Fig. 1 of the drawings to correspondingly increase the length of the air gap 34*e* separating the periphery of the armature 34*a* from the pole faces 34*b*. As a result, the field in which the armature 34 is rotating is correspondingly decreased to produce a corresponding increase in the motor speed. In other words, increasing the air gap 34*e* in a progressive manner has the effect of progressively accentuating the characteristic of the motor to speed-up with decreasing density of the air moved by the two fans 32 and 38. This characteristic is further accentuated through the action of the arm 108 to progressively close the contacts 114*a*, 114*b* and 114*c*, in the sequence named, for the purpose of progressively decreasing the resistance of the path shunting the series winding 101 thereby correspondingly weakening the field produced by this series-winding. Concurrently with the weakening of the field in the described manner, the voltage applied to the armature 34*a* is obviously increased to still further increase the speed of the motor for any given load. A still further accentuation in the "series unwind" characteristic of the motor 34 is obtained through movement of the arm 108 to first energize the differential winding 102 and to then progressively increase the energization of this winding. Thus following engagement of the sleeve or collar 104 with the bearing ring 105 and during continued movement of the shaft 33 to the left, the arm 108 is pivoted in a clockwise direction about its pivot point 109 against the action of the tension spring 110. As this pivotal movement of the arm 108 proceeds, the contacts 114*a*, 114*b* and 114*c* are successively closed in the order named to successively exclude the resistors 113*a*, 113*b* and 113*c* from the path shunting the series winding 101, until at the maximum speed of operation of the motor only the residual resistor 113*d* is connected in shunt with this winding. Concurrently, with the described step by step decrease in the current traversing the series winding 101 and accompanying increase in voltage applied to the armature 34*a*, the arm 108 acts through the contact closing member 111 successively to close the contacts 116*a*, 116*b*, 116*c* and 116*d*. Incident to closure of the contacts 116*a* a circuit is completed by way of the brush 98, the contact 100 and the three series connected resistors 115*c*, 115*b* and 115*a* for energizing the differential shunt winding 102 from the current source 92. Energization of this winding serves further to reduce the effective field in which the armature 34*a* is operating, thereby further to accentuate the described speed-load characteristic of the motor 34. As the sequential closure of the contacts 116 proceeds in the manner just described, the three resistors 115*a*, 115*b* and 115*c* are successively excluded from the energizing circuit for the winding 102 thereby progressively to increase the energizing of this winding and thus progressively decrease effective field in which the armature 34*a* is rotating.

By a proper correlation of the three related sets of described facilities for accentuating the "series unwind" characteristic of the motor 34 this motor may be designed to operate at substantially any desired speed for any desired altitude of aircraft operation. In other words, the described facilities for increasing the length of the air gap 34*e*, decreasing the energization of the series winding 102, increasing the voltage applied to the armature 34*a*, and energizing and progressively increasing the energization of the differential winding 102, all in response to increasing altitude of operation, permit the speed-load characteristic of the motor 34 to be so predetermined that an extremely wide variation of motor speed is obtained in response to the change in air load imposed upon the fans 32 and 38 which occurs as the altitude of operation of the apparatus is changed. Although not specifically explained above, it will be understood that as the altitude of operation of the apparatus decreases to increase the load imposed upon the fans 32 and 38, by virtue of the increasing density of the air moved thereby, the spring 110 acts in conjunction with the fly ball actuated sleeve 104 progressively to decrease the length of the air gap

34e, increase the energization of the series winding 101 and decrease the energization of the differential shunt winding 102. The manner in which this is accomplished will be fully apparent from the above explanation. It will also be understood that the altitude at which the described facilities for accentuating the "series unwind" characteristic start to operate is determined by the position of the bearing ring 105 relative to the movable ring 104 in a direction axially of the shaft 33. By making the ring 105 adjustable along the shaft 33, the altitude at which these facilities start to function may be varied as desired.

While one embodiment of the invention has been disclosed, it will be understood that various modifications may be made therein which are within the true spirit and scope of the invention as defined in the appended claims.

I claim:

1. In aircraft heating apparatus of the internal combustion type, means defining a combustion chamber, air moving means for delivering combustion air to said combustion chamber, a motor for driving said air moving means, said motor having the characteristic of increasing its speed with decreasing density of the air moved by said air moving means, whereby said air moving means tends to speed up as the density of the air decreases with increasing altitude, and means responsive to increasing speed of said motor for increasing the rate at which the speed of said motor increases with decreasing density of the air moved by said air moving means.

2. In aircraft heating apparatus of the internal combustion type, means defining a combustion chamber, air moving means for delivering combustion air to said combustion chamber, a motor for driving said air moving means, said motor having the characteristic of increasing its speed with decreasing density of the air moved by said air moving means, whereby said air moving means tends to speed up as the density of the air decreases with increasing altitude, and means responsive to increasing altitude of operation of said apparatus for progressively increasing in steps the rate at which the speed of said motor increases with decreasing density of the air moved by said air moving means.

3. In aircraft heating apparatus of the internal combustion type, means defining a combustion chamber, air moving means for delivering combustion air to said combustion chamber, a motor for driving said air moving means, said motor having the characteristic of increasing its speed with decreasing density of the air moved by said air moving means, whereby said air moving means tends to speed up as the density of the air decreases with increasing altitude, and means including a speed responsive device driven by said motor for increasing the rate at which the speed of said motor increases with decreasing density of the air moved by said air moving means when the density of the air moved by said air moving means falls below a predetermined value.

4. In an aircraft heater of the internal combustion type, means defining a combustion chamber, air moving means for delivering combustion air to said combustion chamber, a motor for driving said air moving means, said motor including differentially related series and shunt field windings and having the characteristic of increasing its speed with decreasing density of the air moved by said air moving means, whereby said air moving means tends to speed up to increase the volume of air delivered to said combustion chamber as the density of the air decreases with increasing altitude, and means responsive to increasing altitude of operation of said heater for changing the current flow through at least one of said windings in the correct sense to accentuate the described speed characteristic of said motor.

5. In an aircraft heater of the internal combustion type, means defining a combustion chamber, air moving means for delivering combustion air to said combustion chamber, a motor for driving said air moving means, said motor including differentially related series and shunt field windings and having the characteristic of increasing its speed with decreasing density of the air moved by said air moving means, whereby said air moving means tends to speed up to increase the volume of air delivered to said combustion chamber as the density of the air decreases with increasing altitude, a speed responsive device driven by said motor, and means controlled by said speed responsive device for changing the current flow through at least one of said windings in the correct sense to accentuate the described speed characteristic of said motor as the altitude of operation of the heater is increased from a predetermined value.

6. In an aircraft heater of the internal combustion type, means defining a combustion chamber, air moving means for delivering combustion air to said combustion chamber, a motor for driving said air moving means, said motor including an armature and having the characteristic of increasing its speed with decreasing density of the air moved by said air moving means, whereby said air moving tends to speed up to increase the volume of air delivered to said combustion chamber as the density of the air decreases with increasing altitude, a speed responsive device driven by said motor, and means controlled by said speed responsive device for increasing the current flow through said armature as the altitude of operation of said heater increases, thereby to accentuate the described speed characteristic of said motor.

7. In an aircraft heater of the internal combustion type, means defining a combustion chamber, air moving means for delivering combustion air to said combustion chamber, a motor for driving said air moving means, said motor including stator pole pieces and an armature separated by an air gap, and means responsive to increasing altitude of operation of said heater for increasing the length of said air gap to increase the speed of rotation of said armature, thereby to increase the volume of air delivered to said combustion chamber with increasing altitude of operation of said heater.

8. In an aircraft heater of the internal combustion type, means defining a combustion chamber, air moving means for delivering combustion air to said combustion chamber, a motor for driving said air moving means, said motor including stator pole pieces and an armature separated by an air gap, and speed responsive means driven by said motor for increasing the length of said air gap in response to increasing altitude of operation of said heater, thereby to increase the speed of rotation of said armature and thus increase the volume of air delivered to said combustion chamber.

9. In an aircraft heater of the internal combustion type, means defining a combustion chamber, air moving means for delivering combustion air to said combustion chamber, a motor for

driving said air moving means, said motor including stator pole pieces and an armature constructed to be separated by a conical air gap and having the characteristic of increasing its speed with decreasing density of the air moved by said air moving means, whereby said air moving means tends to speed up to increase the volume of air delivered to said combustion chamber as the density of the air decreases with increasing altitude, and means responsive to increasing altitude of operation of said heater for moving said armature and stator pole pieces relative to each other in the correct direction to increase the length of said air gap, thereby to accentuate the described speed characteristic of said motor and thus further increase the volume of air delivered to said combustion chamber with increasing altitude of operation of said heater.

10. In an aircraft heater of the internal combustion type, means defining a combustion chamber, air moving means for delivering combustion air to said combustion chamber, a motor for driving said air moving means, said motor including stator pole pieces and an armature constructed to be separated by a conical air gap and having the characteristic of increasing its speed with decreasing density of the air moved by said air moving means, whereby said air moving means tends to speed up to increase the volume of air delivered to said combustion chamber as the density of the air decreases with increasing altitude, and speed responsive means driven by said motor for moving said armature and stator pole pieces relative to each other in the correct sense to increase the length of said air gap as the speed of said motor increases,

thereby to accentuate the described speed characteristic of said motor and further thus increase the volume of air delivered to said combustion chamber with increasing altitude of operation of said heater.

11. In an aircraft heater of the internal combustion type, means defining a combustion chamber, air moving means for delivering combustion air to said chamber, a motor for driving said air moving means, said motor having the characteristic of speeding up as the density of the air moved by said air moving means decreases with increasing altitude, thereby to increase the volume of air delivered to said combustion chamber as the altitude of operation of said heater is increased, a speed responsive device driven by said motor, and means responsive to operation of said device for automatically accentuating said characteristic of said motor as the altitude of operation of said heater is increased, thereby to reduce variations in the amount of combustion supporting oxygen delivered to said combustion chamber over a wide range of altitudes.

HARRY B. HOLTHOUSE.

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