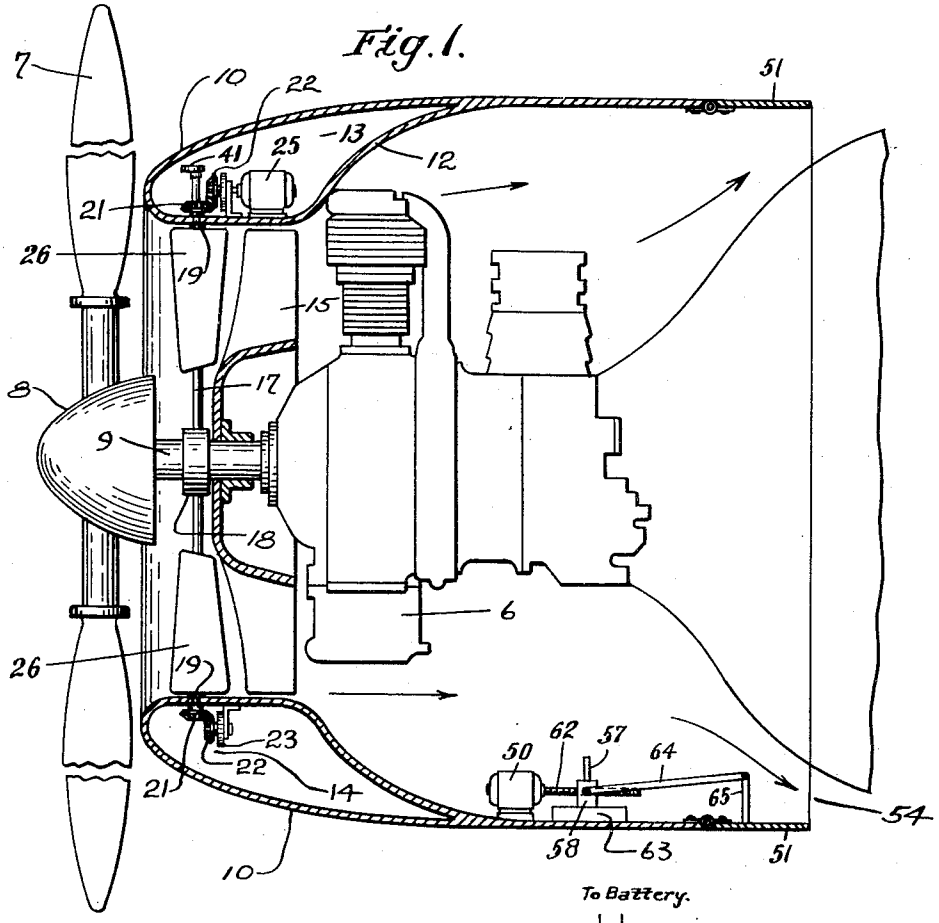
Sept. 4, 1945. H. F. HAGEN 2,384,088

FAN COOLING SYSTEM

Filed June 29, 1943 2 Sheets-Sheet 1

Fig. 1.



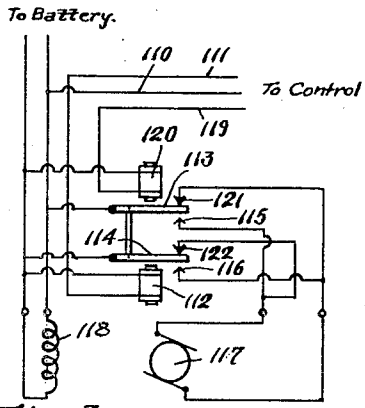


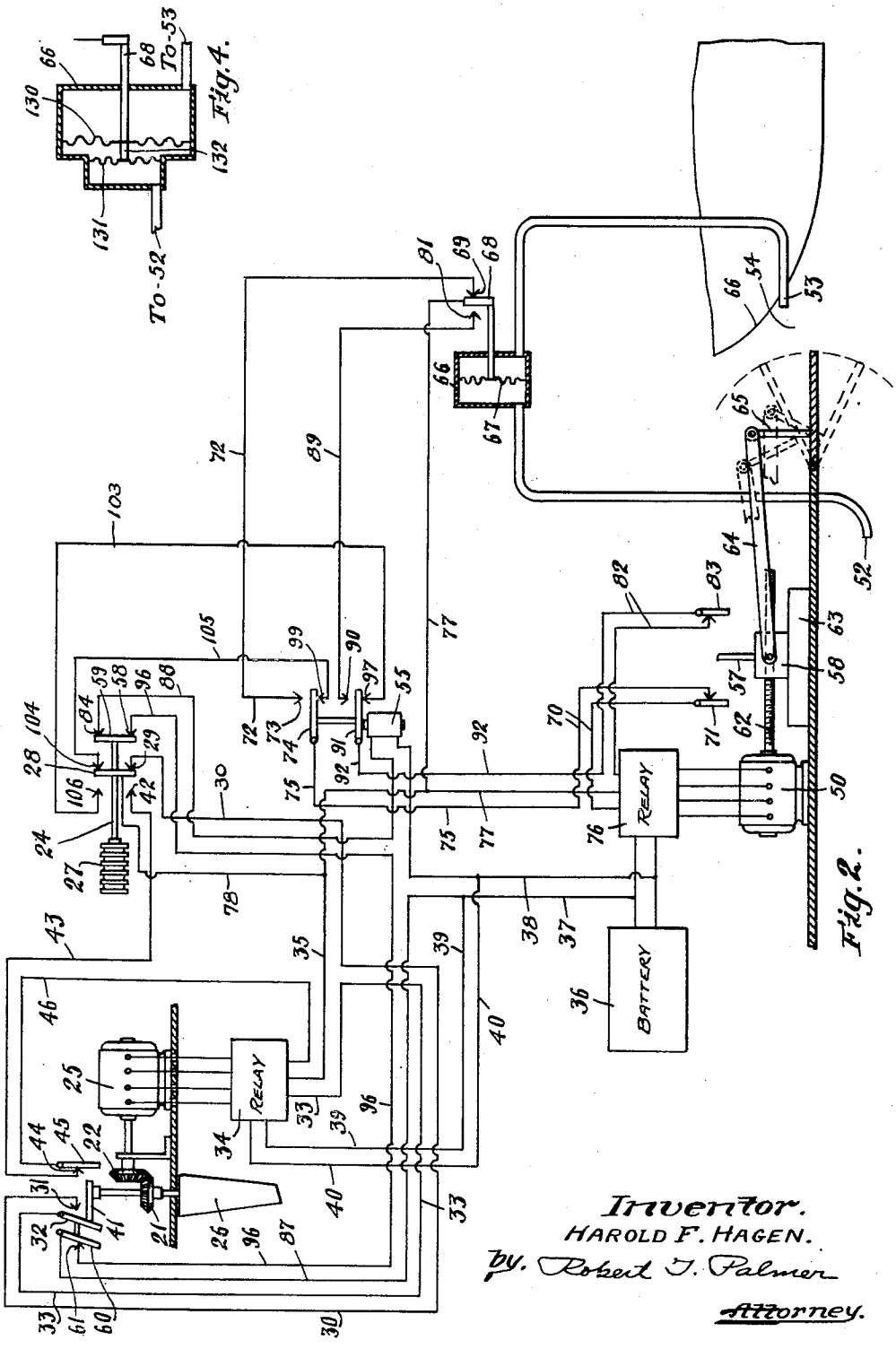
Fig. 3.

Inventor.
HAROLD F. HAGEN
by. Robert J. Palmer
Attorney

Sept. 4, 1945. H. F. HAGEN 2,384,088

FAN COOLING SYSTEM

Filed June 29, 1943 2 Sheets-Sheet 2



Patented Sept. 4, 1945

2,384,088

UNITED STATES PATENT OFFICE

2,384,088

FAN COOLING SYSTEM

Harold F. Hagen, Millis, Mass., assignor to B. F. Sturtevant Company, Boston, Mass.

Application June 29, 1943, Serial No. 492,713

18 Claims. (Cl. 244—53)

This invention relates to the cooling of heat exchangers in moving vehicles and relates more particularly to the cooling of internal combustion engines used in aircraft.

This application is a continuation-in-part of my copending application, Serial No. 450,478, filed July 10, 1942.

It is the general practice to cool radial type airplane engines by the impact or ram of the air through which the airplanes are moving, against the surfaces of the engines. The higher powered engines are enclosed within cowls which act as air pumps in that differences in pressure are provided between the entrances to and the exits from the cowls, resulting in the flow of air over the cooling surfaces of the engines.

The cowls are provided with flaps at their air exit louvres which are adjustable to vary the discharge areas for varying the volumes of air through the cowls. The induction action of the flaps is also used at times for aiding the cowl action when its ram action is insufficient.

The work required for providing cowl action and flap action is taken from the propeller thrust. This work can be done more effectively and more efficiently over a wide operating range, by propeller fans located within the engine cowls, the fans being designed and operated to provide all the pressure required for cooling, the cowls and the flaps providing no pressure and doing no work.

If such a fan is designed to do all the work at say 30,000 feet elevation, then at lower altitudes, due to the greater air densities, higher air pressures than are required are provided by the fan; the engine is overcooled, and the fan absorbs more power than is needed, from the engine. It is desirable therefore, to be able to vary the pressure provided by the fan in accordance with cooling requirements. This can be done by adjustable spin vanes located in the inlet to the fan. When lower air pressures are desired, the vanes are adjusted to give increased spin to the air entering the fan, this resulting not only in decreased air pressure from the fan but in decreased fan power.

When the fan is doing all the work, the rearward velocity of the air discharged from the exit louvres is at least equal to the velocity of the airstream past the airplane. It may be equal to the velocity of the propeller slipstream or at any velocity between the airstream and slipstream velocities. If it is discharged at velocities higher than the slipstream velocity, the additional work done is not required and represents a loss in engine efficiency. If the air is discharged at a velocity below the airstream velocity, then the cowl or the flaps are doing work; there is drag and a loss in engine efficiency.

It should be understood that where a cowl does work, the air entering the cowl has its velocity reduced by the resistance in its path so that the velocity of the air leaving the cowl exit louvres is considerably reduced below that of the airstream. The difference between the entering and the leaving velocity results in an undesired drag. When outlet flaps are used to increase the air flow by induction, there is considerable additional drag to be overcome. The relative velocities close to the flaps may be high but the static pressure due to the induction action of the flaps will be below atmospheric. Before the air can pass beyond the influence of the airplane, the pressure will have to be increased to that of the atmosphere and this requires additional energy.

While it is preferred to have a fan do all the work in cooling an airplane engine, it seems economical to have cowl action aid a fan at extreme loads. For example, at altitudes from sea level to 30,000 feet, a fan may be provided to do all the work. Between 30,000 feet and 40,000 feet, cowl action may advantageously be used for aiding the fan.

A feature of this invention resides in providing a fan for cooling a heat exchanger such as an airplane engine; in varying the volume of air provided by the fan under thermostatic control, and within the range where the fan can do all the work, automatically varying the air exit area of the cowl for maintaining the air discharged at a velocity which will result in minimum engine power.

Another feature of this invention resides in providing, when the fan has been adjusted to do maximum work and the engine requires additional cooling, that the automatic control of the velocity of the air discharged from the cowl be discontinued and that the thermostatic control then adjust the air exit area of the cowl for modifying the cowl action in accordance with cooling requirements.

An object of the invention is to reduce the power required for cooling heat exchangers in moving vehicles.

Another object of the invention is to control the air volumes supplied by a fan for cooling a heat exchanger in a moving vehicle, in accordance with variations in temperature of the heat exchanger, and to maintain the air leaving the heat exchanger and merging into the air stream

passing the exterior of the vehicle at a velocity which will result in minimum engine power.

The invention will now be described with reference to the drawing, of which:

Fig. 1 is an elevation view, partially in section of an air cooled airplane engine mounted within a cowl; having a propeller fan within the cowl, and having spin vane controls and flap controls embodying this invention;

Fig. 2 is a schematic diagram illustrating the controls of Fig. 1 together with control and energizing circuits therefor;

Fig. 3 is a schematic diagram of the wiring of the relays of Fig. 2, and

Fig. 4 is a sectional view of the form of diaphragm chamber 66 which would probably be used instead of the one illustrated diagrammatically by Fig. 2, for compensating for the effect of the heated air discharged from the cowl.

Fig. 1 illustrates the application of this invention to the cooling of an airplane engine. The engine 6 is a conventional, radial, air cooled engine, and while for the convenience of illustration, it is shown as having a single row of cylinders, it may, of course, have two rows of cylinders as have the higher powered engines to which this invention is particularly applicable. The conventional propeller 7 having the streamlined hub 8, is mounted on the outer end of the engine shaft 9.

The cowl 10 is around the engine 6 and at its front or upstream end has the inner wall 12 which forms the chamber 13 for enclosing the spin vane adjusting mechanism indicated generally by 14.

The propeller fan 15 is mounted on the shaft 9 adjacent the engine 6. This fan preferably is similar to that disclosed in my copending application, Serial No. 357,767, filed September 21, 1940. The blades of the fan 15 have airfoil sections as disclosed in said application with chords which decrease in width from base to tip as illustrated by Fig. 1.

The spin inducing vanes 26 are mounted in the entrance to the cowl between the propeller 7 and the fan 15. The bases of the vanes 26 are secured to the rods 17, the lower ends of which are pivoted in the outer housing of the bearing 18 for rotation therein. The bearing 18 is supported by the shaft 9 and serves to support the inner ends or bases of the vanes 26.

The vanes 26 are attached at their tips to the rods 19 which are pivoted in the inner wall 12 of the cowl 10. The rods 19 have mounted therein the bevel gears 21 which mesh with the bevel gears 22 which are mounted on the levers 23. The levers 23 of all of the vanes are interconnected by linkage as disclosed in my Patent No. 1,989,413 which issued January 29, 1935, whereby all vanes may simultaneously be rotated.

The vanes are rotated by the motor 25 to the shaft of which the uppermost of the bevel gears 22 is attached.

The vanes 26 may be adjusted from a position where the maximum desired spin is imparted to the air entering the fan to wide open position where they have no effect upon the air. As the spin is increased, the volume of air moved by the fan is decreased and the power required by the fan is correspondingly decreased.

The vanes may be adjusted to provide counter spin for increasing the air pressure over that which could be provided by the fan alone. Thus they may be adjusted, for example, from counter spin positions of say 35° to spin inducing angles of say 80°.

In the following description V_x is to be understood as representing the difference in velocity between that of the air stream moving past the airplane, and that of the air discharged from the cowl back into the atmosphere. When the fan is doing all the work, it is preferred that the velocity of the air discharged from the cowl be that of flight, or that it have a value between the velocity of flight and the absolute velocity of the propeller slipstream. Between these two cowl discharge velocities, the fan will efficiently aid the propeller thrust in moving the airplane through the air.

The thermostat 27 which responds to engine temperatures adjusts the vanes 26 by the motor 25 to open the vanes when the engine is too hot and to move the vanes towards closed position when the engine is too cold.

During the time the thermostat 27 is in control of the vanes, the impact tube 52 which is exposed to the airstream velocity, and the impact tube 53 which is exposed to the velocity of the air in the exit louvres 54, adjust the flaps 51 by the motor 50 to maintain $V_x=0$ throughout the range of adjustment of the vanes. V_x would vary with variations in the speed of the airplane and with variations in the air volume supplied by the fan if these controls were not provided.

When the vanes have been opened to extreme wide open position or counter spin position, the limit switch armature 32 is moved by the cam 41 on an extension on one of the pivot rods of one of the vanes 26 to open the circuit of the thermostat to stop the motor 25. At the same time, the armature 60 closes the energizing circuit of the relay solenoid 55 which acts to disconnect the vane closing contacts of the thermostat 27 from control of the vane adjusting motor 25 and places the thermostat in control of the motor 50 which adjusts the flaps 51. The motor 50 then adjusts the flaps towards open position for aiding in the cooling action when the engine is too hot and draws the flaps inwardly when the engine is too cold.

When the thermostat is satisfied after having been in control of the flaps, it opens contacts which cause the solenoid 55 to become deenergized and restores the thermostat to control of the spin vanes and the impact tubes to control of the flaps.

If the engine becomes too cool, the thermostat closes controls which cause the motor 25 to rotate the vanes towards closed position. The cam 41 is rotated so that the limit switch armature 32 is released to strike the contact 31 and to close the circuit to the thermostat 27 which will also permit the motor 25 to again rotate the vanes towards open position.

Limit switches are provided for opening the control circuits of the motor 50 for preventing operation of the motor when the flaps are adjusted to either of the two extreme positions. A limit switch is also provided for opening the control circuit of the motor 25 for preventing operation of the motor after the vanes have been adjusted to fully closed position.

All limit switches while preventing the operation of the motors in one direction do not however, prevent their operation in the other direction so that, for example, while the thermostat may act to prevent the motor 25 from trying to continue to open the vanes when they are fully open, it is still in condition to operate the motor in the other direction. In other words, the mo-

tors are not disconnected from the battery by the limit switches.

The detail operation of the circuits of Figs. 2 and 3 will now be described.

The motor **25** rotates the spin vanes **26** towards open or closed position, depending upon the direction of rotation of the motor.

The thermostat **27** which may be of the bellows type, has the arm **24** to which are attached the armatures **28** and **59** which are electrically insulated from each other. When the engine temperature is too high, the armature **28** moves to the right with reference to Fig. 2 of the drawings and strikes the contacts **29** and **104**, and the armature **59** moves to strike the contacts **58** and **84**. When the engine is too cool, the armature **28** is moved to the left against the contacts **42** and **106** and the armature **59** is moved away from the contacts **58** and **84**. When the thermostat is satisfied, the armatures **28** and **59** are separated from their associated contacts.

The thermostat **27** is normally in control of the motor **25**. When the engine temperature is too high, the thermostat moves its armature **28** to the right, causing it to strike the contact **29** for causing the motor **25** to rotate in a direction to open the vanes. This is accomplished by the armature **28** closing a circuit including the contact **29**, the wire **30**, the contact **31**, the limit switch armature **32**, the wire **33**, the relay **34**, the wire **35** and the armature **28**. Electric current is supplied from the battery **36** to the relay **34** through the wires **37**, **38**, **39**, and **40**. The relay connects the field winding of the motor **25** to its armature as illustrated by Fig. 3, so that the motor rotates the vanes towards open position.

The drawings illustrate the vanes as having been adjusted to their extreme open or counter spin position. The limit switch armature **32** has been moved to the left by the cam **41** on the extension **42** of one of the vane pivot rods. This has caused the armature **32** to move away from the contact **31**, opening the above described circuit and stopping the motor **25**.

If the engine is too cool, the thermostat **27** will move its armature **28** to the left causing it to strike the contact **42** and to close the circuit including the contact **42**, the wire **43**, the limit switch contact **44** and the armature **45**, the wire **46**, the relay **34** the wire **35** and the armature **28**. This causes the relay to connect the field of the motor **25** to its armature in reverse to its previous condition so that the direction of rotation of the motor **25** is reversed so that it adjusts the vanes towards closed position. If the thermostat is not satisfied before the vanes reach the fully closed position, the previously described cam **41** moves the limit switch armature **45** away from its contact **44** when the vanes are fully closed, thus opening the last described circuit and stopping the motor **25**.

During the time the thermostat **27** is in control of the spin vanes, the motor **50** acts to adjust the flaps **51** in the exit louvres **54** so that $V_x=0$. The flaps **51** are conventional flaps interconnected so that adjustment of one affects adjustment of all. The impact tube **52** is exposed to the airstream velocity or to the slipstream velocity whichever may be preferred, and the impact tube **53** is exposed to the velocity of the air in the exit louvres. When the velocities at the two impact tubes are equal, then $V_x=0$. If they become unequal as the spin vanes are adjusted, then the control now to be described causes the motor **50** to adjust the flaps for so changing the velocity of the air from the exit louvres so that throughout the entire range of adjustment of the spin vanes by the motor **25**, $V_x=0$. The motor **50** has a threaded shaft **62** which rotates within the screw jack **58** which has internal threads meshing with the threads on the shaft **62** so that upon rotation of the shaft **62**, the jack **58** is moved towards or away from the motor depending upon its direction of rotation.

The screw jack **58** is slidably attached to the base **63**. One end of the connecting rod **64** is rotatably attached to the jack **58** and its other end is rotatably attached to the crank arm **65** attached to one of the flaps **51**. When the motor **50** rotates its shaft **62** in one direction, the jack is advanced away from the motor to place through the connecting rod **64** and the crank arm **65**, the flaps **51** out into the slipstream as illustrated by the lower dotted outlines of Fig. 2. In this position, the cowl is wide open and its action is maximum. When the shaft **62** is rotated in the other direction by the motor **50**, the jack is moved towards the motor and acts to draw the flaps inwardly into the exit louvre **54** as illustrated by the upper dotted outline of Fig. 2, so as to restrict the space between the flaps and the air guiding edge **66** of the structure, thereby causing an increase in the velocity of the air through the louvre **54**.

The impact tubes **52** and **53**, when the thermostat **27** is in control of the spin vanes, act to control the motor **50** for adjusting the flaps so that $V_x=0$. The impact tube **52** connects into the diaphragm chamber **66** on one side of the diaphragm **67** while the impact tube **53** connects into the chamber **66** on the other side of the diaphragm.

The diaphragm **67** has connected thereto, the contact arm **68** which when the airstream velocity is greater than that of the air from the exit louvres, moves to the right (facing Fig. 2) against the contact **69**, closing a circuit including the contact **69**, the wire **72**, the contact **73**, the armature **74**, the wire **75**, the wires **70**, the limit switch **71**, the relay **76**, the wire **77**, and the contact arm **68** of the diaphragm **67**. This connects as shown by Fig. 3, the field and armature of the motor **50** together for causing the motor **50** to rotate in a direction to draw the flaps **51** inwardly for restricting the outlet passage for increasing the velocity of the air therethrough. During the operation just described, the thermostat **27** would be in control of the spin vanes so that the cam **41** would not have moved the limit switch armature **60** against the contact **61** for energizing the solenoid **55**, so that the solenoid **55** would be deenergized and the armatures **74** and **91** would be against the contacts **73** and **90** respectively.

If the velocity of the air from the exit louvres is greater than that of the airstream than that of the airstream, then the diaphragm **67** will move to the left and will move the contact arm **68** against the contact **81**, closing a circuit including the contact **81**, the wire **89**, the contact **90**, the armature **91**, the wire **92**, the wires **82**, the limit switch **83**, the relay **76**, the wire **77**, and the diaphragm contact arm **68**. This would connect the field and armature of the motor **50** to reverse the direction of rotation of the motor causing it to move the flaps **51** outwardly until the diaphragm **67** reaches mid-position at which time the circuit is disconnected.

When the motor **25** under control of the thermostat **27** has adjusted the vanes to maximum

spin position, the cam 41 moves the limit switch armature 45 away from the contact 44 and opens the circuit including the wire 43, the contact 42, the thermostat armature 28, the wire 35, the relay 34, the wire 46, the limit switch armature 45, and contact 44, thus opening the circuit which energizes the motor 25 to rotate in a direction to close the spin vanes.

The motor 25 will be energized to rotate in the opposite direction for adjusting the spin vanes towards open position when the engine requires cooling and the thermostat accordingly moves its arms 28 against the contact 29 as previously described.

When upon a demand by the thermostat 27 for cooling, the spin vanes have been fully opened and the engine is still too hot, the cam 41 moves the armatures 32 and 60 to the left (facing Fig. 2) causing the armature 32 to open the previously described circuit including the contact 31, for stopping the motor 25, and causing the armature 60 to strike the contact 61 and to close the circuit including the contact 61, the wire 96, the contact 58, the armature 59, the contact 84, the wire 88, the solenoid 55, the wires 37 and 38, the battery 36, and the wire 87 and the armature 60, causing the energization of the solenoid 55 and causing its armature 91 to be pulled away from the contact 90 and against the contact 97, and causing the armature 74 to be pulled away from the contact 73 and against the contact 99.

This disconnects the impact tubes 52 and 53 and the diaphragm 67 from control of the flap adjusting motor 50 and places the motor 50 under control of the thermostat 27 as has been described.

The thermostat 27 then adjusts through the motor 50, the flaps outwardly for increasing the volume of air through the cowl and for producing the induction of air from the exit louvres by the flaps if this is desired.

If the engine is too warm, the thermostat 27 moves its armature 28 against the contact 104, closing the circuit including the contact 104, the wire 105, the contact 99, the armature 74, the wire 75, the wires 70, the limit switch 71, the relay 76, the wire 77, the wire 78, the armature 28 and energizing the motor 50 to rotate in a direction to move the flaps 51 into the slipstream as has been described.

If the engine is too cold, the thermostat 27 moves its armature 28 against the contact 106, closing the circuit including the contact 106, the wire 103, the contact 97, the armature 91, the wire 92, the wires 82, the limit switch 83, the relay 76, the wires 77 and 78 and the armature 28. This energizes the motor to rotate in a direction to draw the flaps in towards closed position.

The armature 59 on the thermostat arm 24, and its associated contacts 58 and 84 are in the energizing circuit of the solenoid 55 which as has been described, switches the thermostat to control of the flaps when the spin vanes are wide open and the engine is still too hot. When the thermostat becomes satisfied while in control of the flaps, its armature leaves the contacts 58 and 84 and opens the deenergizing circuit of the solenoid 55, causing it to restore control of the spin vanes to the thermostat and the control of the flaps to the impact tubes.

The limit switch 71 serves to stop the motor 50 to prevent it from attempting to draw the vanes inwardly when they have reached their extreme inward position. This is accomplished by the opening of the limit switch 71 by the lever 57 on the jack screw 58 and by the opening of the previously described circuit including the switch 71.

The limit switch 83 serves to stop the motor 50 to prevent it from attempting to move the flaps outwardly when they have reached their extreme outward position. This is accomplished by the opening of the switch 83 by the lever 57 on the jack screw 58 and the opening of the previously described circuit including the switch 83. The opening of the limit switch while it stops the motor 50 from rotating in one direction, will not prevent the motor from rotating in the other direction when the controls call for same. The same applies to the limit switch 83.

Fig. 3 illustrates the internal circuits of the relays 34 and 76 and the connection of their components to the fields and armatures of the motors 25 and 50 respectively for causing the reversal thereof when the motor controls call for reversal. It will have been observed that the center wire of the three wires entering the lower side of the relay 34 and of the three wires entering the upper side of the relay 76, is connected to a control contact arm (of the thermostat 27 or of the diaphragm 67). The wires on each side of the center wire lead to contacts so that upon movement of a control contact arm in one direction, a circuit is closed between the center wire and one of the side wires and upon movement of the control contact arm in the other direction, a circuit is closed between the center wire and the other of the side wires.

When a circuit is closed between the center wire 110 and the outer wire 111, the solenoid 112 is energized by the battery. This causes the solenoid armatures 113 and 114 to be pulled down against the contacts 115 and 116 respectively. The contacts 115 and 116 are connected to the armature 117 of a motor. The soleniod armatures 113 and 114 are connected to the battery so that upon energization of the solenoid 112, the motor armature 117 is connected to the battery. The motor field winding 118 is connected directly to the battery so that upon energization of the solenoid 112, the armature and field of the motor are connected together and to the battery and the motor rotates in one direction.

When the circuit is closed between the center wire 110 and the outer wire 119, the solenoid 120 will become energized by the battery. The solenoid 112 will be deenergized since at this time, the control contact arm will have moved to open the circuit between the wires 110 and 111. Upon energization of the solenoid 112, the armatures 113 and 114 will be pulled upwardly to strike the contacts 121 and 122 respectively. The contacts 121 and 122 are connected to the motor armature 117 but in such a way that the armatures 113 and 114 connect the motor armature to the battery in reverse to the connection through the previously described contacts 115 and 116 so that the motor is energized to rotate in a direction reverse to that it rotates when the solenoid 120 is energized.

It is recognized that the air through the exit louvres 54 is heated and expanded by heat from the engine and that this should be taken into account. It seems desirable therefore, that the diaphragm chamber 66 be constructed as illustrated by Fig. 4 in which the air from the impact tube 53 acts against a large diaphragm 130 while the air from the impact tube 52 acts against a smaller diaphragm 131, the two diaphragms

being interconnected by the lever 132 for simultaneous movement.

While in the foregoing, the cowl has been described as doing work during peak loads, the invention is not limited to having the cowl do any work. The adjustment of the spin vanes for volume control and the adjustment of the area of the air exit louvres for maintaining $V_x=0$ comprise features of this invention which may be used when the fan is designed to do all the work at all loads.

These is seen to be an increased saving in engine power as V_x varies from a positive value to zero due to reduction in drag. This invention decreases the drag by increasing the velocity of the air discharged from the cowl to approach a velocity between that of flight and that of the propeller slipstream.

In the annexed claims, "airstream" means the air passing the exterior of the vehicle or airplane, and in the case of a vehicle having a tractor propeller, may be the propeller slipstream, and "relative velocity" means the velocity of the vehicle or airplane relative the airstream as distinguished from the velocity relative the earth.

While one embodiment of the invention has been described for the purpose of illustration, it should be understood that the invention is not limited to the exact apparatus and arrangement of apparatus illustrated, as modifications thereof may be suggested by those skilled in the art without departure from the essence of the invention.

What is claimed is:

1. A system for cooling a heat exchange surface in a vehicle moving through air, comprising means defining an air passage for taking in air from the direction of movement of the vehicle and for discharging the air from the vehicle towards the rear thereof, said passage enclosing said surface, a fan in said passage for moving air therethrough, means for controlling the volume of air moved by said fan, means including means responsive to variations in the temperature of said surface for adjusting said volume control means for varying the volume of air through said passage, means for varying the air discharge area of said passage, and means including means responsive to variations in the relative velocity between said vehicle and the airstream for adjusting said discharge area varying means.

2. A system for cooling a heat exchange surface in a vehicle moving through air, comprising means defining an air passage for taking in air from the direction of movement of the vehicle and for discharging the air from the vehicle towards the rear thereof, said passage enclosing said surface, a fan in said passage for moving air therethrough, means for controlling the volume of air moved by said fan, means including means responsive to variations in the temperature of said surface for adjusting said volume control means for varying the volume of air through said passage, means for varying the air discharge area of said passage, and means including means responsive to variations in the velocity of the air from said surface for adjusting said discharge area varying means.

3. A system for cooling a heat exchange surface in a vehicle moving through air, comprising means defining an air passage for taking in air from the direction of movement of the vehicle and for discharging the air from the vehicle towards the rear thereof, said passage enclosing said surface, a fan in said passage for moving air therethrough, means for varying the volume of air moved by said fan, means including means responsive to variations in the temperature of said surface for adjusting said volume control means for varying the volume of air through said passage, means for varying the air discharge area of said passage, and means including means responsive to variations in the relative velocity between said vehicle and the airstream and to variations in the velocity of the air from said surface for adjusting said discharge area varying means.

4. A cooling system for an airplane engine having a cowl around the engine, said cowl having means for varying the air discharge area thereof, comprising a propeller fan in said cowl rotatable by said engine, spin vanes in the inlet to said fan, means including means responsive to the temperature of said engine for adjusting said vanes for varying the volume of air moved by said fan, and means including means responsive to the relative velocity between the airplane and the airstream for adjusting said discharge area varying means for varying the velocity of the air discharged from said cowl.

5. A cooling system for an airplane engine having a cowl around the engine, said cowl having means for varying the air discharge area thereof, comprising a propeller fan in said cowl rotatable by said engine, spin vanes in the inlet to said fan, means including means responsive to the temperature of said engine for adjusting said vanes for varying the volume of air moved by said fan, and means including means responsive to the velocity of the air discharged from said cowl for adjusting said discharge area varying means for varying the velocity of the air discharged from said cowl.

6. A cooling system for an airplane engine having a cowl around the engine, said cowl having means for varying the air discharge area thereof, comprising a propeller fan in said cowl rotatable by said engine, spin vanes in the inlet to said fan, means including means responsive to the temperature of said engine for adjusting said vanes for varying the volume of air moved by said fan, and means including means responsive to the relative velocity between the airplane and the airstream and to the velocity of the air discharged from said cowl for adjusting said discharge area varying means.

7. A cooling system for an airplane engine having a cowl around the engine, said cowl having means for varying the air discharge area thereof, comprising a propeller fan in said cowl rotatable by said engine, spin vanes in the inlet to said fan, means including means responsive to the temperature of said engine for adjusting said vanes for varying the volume of air moved by said fan, means including means responsive to the relative velocity between the airplane and the airstream and to the velocity of the air discharged from said cowl for adjusting said discharge area varying means for varying the velocity of the air discharged from said cowl, and means including means actuated when said vanes have been adjusted to their maximum air volume position and said engine is still too hot, for disconnecting said temperature responsive means from control of said spin vanes and for connecting said temperature responsive means to control of said discharge area varying means, whereby said temperature responsive means acts to adjust said area varying means towards open position for affecting additional cooling by action of said cowl.

8. A cooling system for an airplane engine hav-

ing a cowl around the engine, said cowl having means for varying the air discharge area thereof, comprising a propeller fan in said cowl rotatable by said engine, spin vanes in the inlet to said fan, means including means responsive to the temperature of said engine for adjusting said vanes for varying the volume of air moved by said fan, means including means responsive to the relative velocity between the airplane and the airstream and to the velocity of the air discharged from said cowl for adjusting said discharge area varying means for varying the velocity of the air discharged from said cowl, means including means actuated when said vanes have been adjusted to their maximum air volume position and said engine is still to hot, for disconnecting said temperature responsive means from control of said spin vanes and for connecting said temperature responsive means to control of said discharge area varying means, whereby said temperature responsive means acts to adjust said area varying means towards open position for affecting additional cooling by action of said cowl, and means including means actuated when said area varying means has been adjusted for minimum cowl action and said engine is still too cool, for restoring control of said spin vanes to said temperature responsive means.

9. A cooling system for an airplane engine having a cowl around the engine, said cowl having means for varying the air discharge area thereof, comprising a propeller fan in said cowl rotatable by said engine, spin vanes in the inlet to said fan, means including means responsive to the temperature of said engine for adjusting said vanes for varying the volume of air moved by said fan, means including means responsive to the relative velocity between the airplane and the airstream and to the velocity of the air discharged from said cowl for adjusting said discharge area varying means for varying the velocity of the air discharged from said cowl, means including means actuated when said vanes have been adjusted to their maximum air volume position and said engine is still too hot, for disconnecting said temperature responsive means from control of said spin vanes and for connecting said temperature responsive means to control of said discharge area varying means, whereby said temperature responsive means acts to adjust said area varying means towards open position for affecting additional cooling by action of said cowl, means including means actuated when said area varying means has been adjusted for minimum cowl action and said engine is still too cool, for restoring control of said spin vanes to said temperature responsive means, and means including means responsive to the relative velocity between the airplane and the airstream for varying the position at which said area varying means has been adjusted for minimum cowl action.

10. A cooling system for an airplane engine having a cowl around the engine, said cowl having means for varying the air discharge area thereof, comprising a propeller fan in said cowl rotatable by said engine, spin vanes in the inlet to said fan, means including means rsponsive to the temperature of said engine for adjusting said vanes for varying the volume of air moved by said fan, means including means responsive to the relative velocity between the airplane and the airstream and to the velocity of the air discharged from said cowl for adjusting said discharge area varying means for varying the velocity of the air discharged from said cowl, and means including means actuated when said vanes have been adjusted to their maximum air volume position and said engine is still too hot, for disconnecting said temperature responsive means from control of said spin vanes, for disconnecting said velocity responsive means from control of said area varying means, and for connecting said temperature responsive means to control of said discharge area varying means, whereby said temperature responsive means acts to adjust said area varying means towards open position for effecting additional cooling by action of said cowl.

11. A cooling system for an airplane engine having a cowl around the engine, said cowl having means for varying the air discharge area thereof, comprising a propeller fan in said cowl rotatable by said engine, spin vanes in the inlet to said fan, means including means rseponsive to the temperature of said engine for adjusting said vanes for varying the volume of air moved by said fan, means including means responsive to the relative velocity between the airplane and the airstream and to the velocity of the air discharged from said cowl for adjusting said discharge area varying means for varying the velocity of the air discharge from said cowl, means including means actuated when said vanes have been adjusted to their maximum air volume position and said engine is still too hot, for disconnecting said temperature responsive means from control of said spin vanes, for disconnecting said velocity responsive means from control of said area varying means, and for connecting said temperature responsive means to control of said discharge area varying means, whereby said temperature responsive means acts to adjust said area varying means towards open position for affecting additional cooling by action of said cowl, and means including means actuated when said area varying means has been adjusted for minimum cowl action and said engine is still too cool, for restoring control of said spin vanes to said temperature responsive means, and for restoring control of said area varying means to said velocity responsive means.

12. A cooling system for an airplane engine having a cowl around the engine, said cowl having means for varying the air discharge area thereof, comprising a propeller fan in said cowl rotatable by said engine, spin vanes in the inlet to said fan, means including means responsive to the temperature of said engine for adjusting said vanes for varying the volume of air moved by said fan, means including means responsive to the relative velocity between the airplane and the airstream and to the velocity of the air discharged from said cowl for adjusting said discharge area varying means for varying the velocity of the air discharged from said cowl, means including means actuated when said vanes have been adjusted to their maximum air volume position and said engine is still too hot, for disconnecting said temperature responsive means from control of said spin vanes, for disconnecting said velocity responsive means from control of said area varying means, and for connecting said temperature responsive means to control of said discharge area varying means, whereby said temperature responsive means acts to adjust said area varying means towards open position for affecting additional cooling by action of said cowl, means including means actuated when said area varying means has been adjusted for minimum cowl action and said engine is still too cool, for restoring control of said spin vanes to said tem-

perature responsive means, and for restoring control of said area varying means to said velocity responsive means, and means including means responsive to the relative velocity between the airplane and the airstream for varying the position at which said area varying means has been adjusted for minimum cowl action.

13. A cooling system for an airplane engine having a cowl around the engine, said cowl having means for varying the air discharge area thereof, comprising a propeller fan in said cowl rotatable by said engine, volume control means for varying the volume of air moved by said fan, means including means responsive to the temperature of said engine for adjusting said volume control means for varying the volume of air moved by said fan, means including means responsive to the relative velocity between the airplane and the airstream and to the velocity of the air discharged from said cowl for adjusting said discharge area varying means for varying the velocity of the air discharged from said cowl, and means including means actuated when said volume control means has been adjusted to its maximum air volume position and said engine is still too hot, for disconnecting said temperature responsive means from control of said volume control means and for connecting said temperature responsive means to control of said discharge area varying means, whereby said temperature responsive means acts to adjust said area varying means towards open position for affecting additional cooling by action of said cowl.

14. A cooling system for an airplane engine having a cowl around the engine, said cowl having means for varying the air discharge area thereof, comprising a propeller fan in said cowl rotatable by said engine, volume control means for varying the volume of air moved by said fan, means including means responsive to the temperature of said engine for adjusting said volume control means for varying the volume of air moved by said fan, means including means responsive to the relative velocity between the airplane and the airstream and to the velocity of the air discharged from said cowl for adjusting said discharge area varying means for varying the velocity of the air discharged from said cowl, means including means actuated when said volume control means has been adjusted to its maximum air volume position and said engine is still too hot for disconnecting said temperature responsive means from control of said volume control means and for connecting said temperature responsive means to control of said discharge area varying means, whereby said temperature responsive means acts to adjust said area varying means towards open position for affecting additional cooling by action of said cowl, and means including means actuated when said area varying means has been adjusted for minimum cowl action and said engine is still too cool, for restoring control of said volume control means to said temperature responsive means.

15. A cooling system for an airplane engine having a cowl around the engine, said cowl having means for varying the air discharge area thereof, comprising a propeller fan in said cowl rotatable by said engine, volume control means for varying the volume of air moved by said fan, means including means responsive to the temperature of said engine for adjusting said volume control means for varying the volume of air moved by said fan, means including means responsive to the relative velocity between the airplane and the airstream and to the velocity of the air discharged from said cowl for adjusting said discharge area varying means for varying the velocity of the air discharged from said cowl, means including means actuated when said volume control means has been adjusted to its maximum air volume position and said engine is still too hot, for disconnecting said temperature responsive means from control of said volume control means and for connecting said temperature responsive means to control of said discharge area varying means, whereby said temperature responsive means acts to adjust said area varying means towards open position for affecting additional cooling by action of said cowl, means including means actuated when said area varying means has been adjusted for minimum cowl action and said engine is still too cool, for restoring control of said volume control means to said temperature responsive means, and means including means repsonsive to the relative velocity between the airplane and the airstream for varying the position at which said area varying means has been adjusted for minimum cowl action.

16. A cooling system for an airplane engine having a cowl around the engine, said cowl having means for varying the air discharge area thereof, comprising a propeller fan in said cowl rotatable by said engine, volume control means for varying the volume of air moved by said fan, means including means responsive to the temperature of said engine for adjusting said volume control means for varying the volume of air moved by said fan, means including means responsive to the relative velocity between the airplane and the airstream and to the velocity of the air discharged from said cowl for adjusting said discharge area varying means for varying the velocity of the air discharged from said cowl, and means including means actuated when said volume control means has been adjusted to its maximum air volume position and said engine is still too hot, for disconnecting said temperature responsive means for control of said volume control means, for disconnecting said velocity responsive means from control of said area varying means, and for connecting said temperature responsive means to control of said discharge area varying means, whereby said temperature responsive means acts to adjust said area varying means towards open position for effecting additional cooling by action of said cowl.

17. A cooling system for an airplane engine having a cowl around the engine, said cowl having means for varying the air discharge area thereof, comprising a propeller fan in said cowl rotatable by said engine, volume control means for varying the volume of air moved by said fan, means including means responsive to the temperature of said engine for adjusting said volume control means for varying the volume of air moved by said fan, means including means responsive to the relative velocity between the airplane and the airstream and to the velocity of the air discharged from said cowl for adjusting said discharge area varying means for varying the velocity of the air discharged from said cowl, means including means actuated when said volume control means has been adjusted to its maximum air volume position and said engine is still too hot, for disconnecting said temperature responsive means from control of said volume control means, for disconnecting said velocity responsive means from control of said area varying means, and for connecting said temper-

ature responsive means to control of said discharge area varying means, whereby said temperature responsive means acts to adjust said area varying means toward open position for affecting additional cooling by action of said cowl, and means including means actuated when said area varying means has been adjusted for minimum cowl action and said engine is still too cool, for restoring control of said volume control means to said temperature responsive means, and for restoring control of said area varying means to said velocity responsive means.

18. A cooling system for an airplane engine having a cowl around the engine, said cowl having means for varying the air discharge area thereof, comprising a propeller fan in said cowl rotatable by said engine, volume control means for varying the volume of air moved by said fan, means including means responsive to the temperature of said engine for adjusting said volume control means for varying the volume of air moved by said fan, means including means responsive to the relative velocity between the airplane and the airstream and to the velocity of the air discharged from said cowl for adjusting said discharge area varying means for varying the velocity of the air discharged from said cowl, means including means actuated when said volume control means has been adjusted to its maximum air volume position and said engine is still too hot, for disconnecting said temperature responsive means from control of said volume control means, for disconnecting said velocity responsive means from control of said area varying means, and for connecting said temperature responsive means to control of said discharge area varying means, whereby said temperature responsive means acts to adjust said area varying means towards open position for affecting additional cooling by action of said cowl, means including means actuated when said area varying means has been adjusted for minimum cowl action and said engine is still too cool, for restoring control of said volume control means to said temperature responsive means, and for restoring control of said area varying means to said velocity responsive means, and means including means responsive to the relative velocity between the airplane and the airstream for varying the position at which said area varying means has been adjusted for minimum cowl action.

HAROLD F. HAGEN.