Oct. 27, 1964 C. H. GRANT 3,154,267

CONTROLLED TEMPERATURE FLOW AROUND AIRFOILS

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Fig. 1

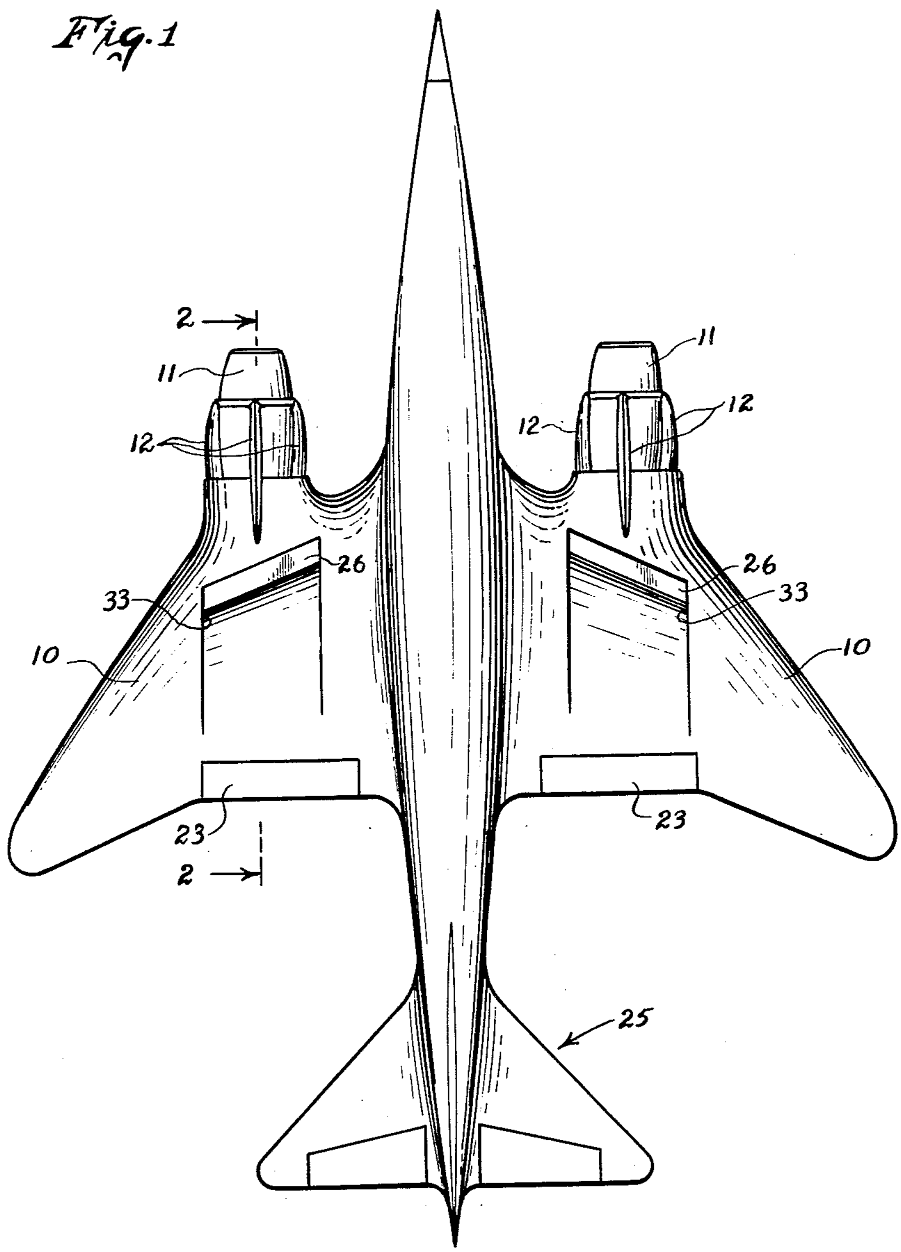


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Fig. 2

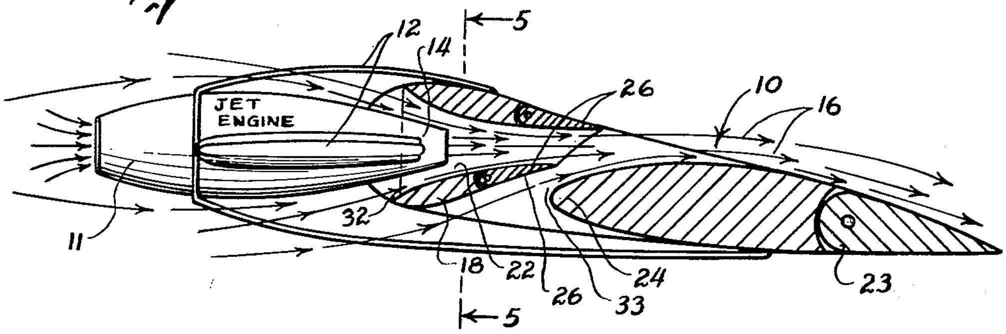



Fig. 3

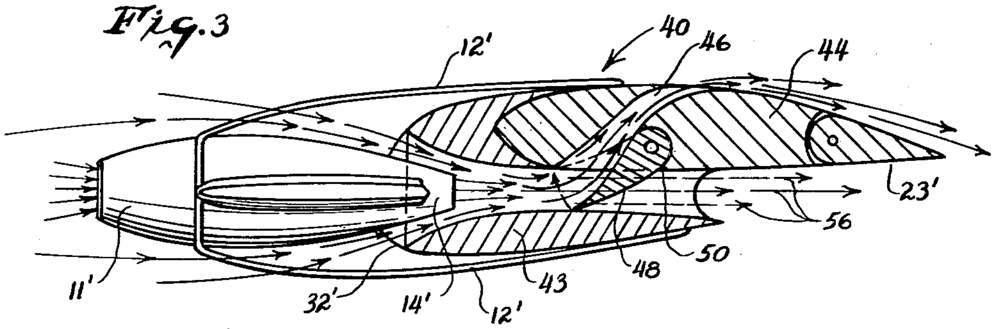



Fig. 4

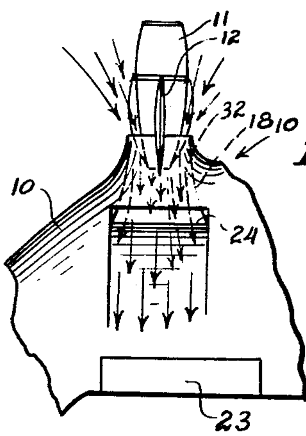



Fig. 5

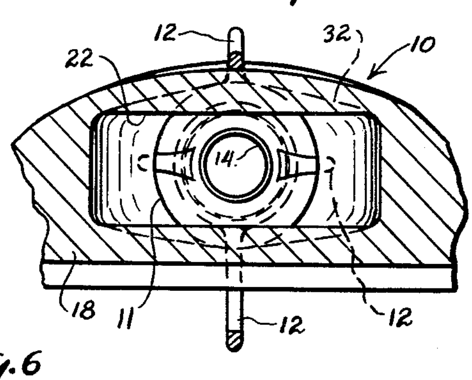
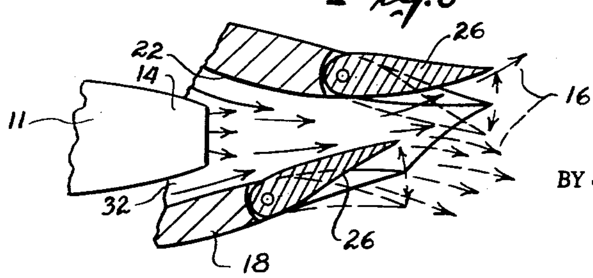



Fig. 6

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# 3,154,267
# CONTROLLED TEMPERATURE FLOW AROUND AIRFOILS

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14 Claims. (Cl. 244—15)

This invention relates to the increase in the pressure differential on different sides of an airfoil by discharging the exhaust gases from a jet engine across a portion of the airfoil surface. More particularly, the invention relates to the control of the temperature of the exhaust gases that are discharged over the airfoil and this is obtained by supplying diluent gas, such as air, to the exhaust gases to reduce their temperature and to increase the volume of the gas flow over the airfoil. In the preferred embodiment of the invention, the jet engine is located ahead of a sustaining airfoil of an aircraft and the flow of exhaust gas from the engine is used to increase the lift of the airfoil.

It is an object of this invention to combine a jet engine and an airfoil in such relation that the exhaust gases from the jet engine flow over the surface of the airfoil in a direction to increase the pressure differential between opposite sides of the airfoil. Another object is to provide a first passage through which the gases from the jet engine flow to the airfoil, and a second passage through which diluent gas is supplied to the first passage for cooling the gases in the first passage before they strike the airfoil.

Another object of the invention is to provide a shroud through which exhaust gases from the jet engine flow to the airfoil, and to have an open end at the upstream end of the shroud for receiving air or other gas for mixing with the exhaust gases.

A more specific object of the invention is to provide an improved jet-propelled aircraft in which the lift of a sustaining airfoil is increased by discharging the exhaust from a jet engine across a portion of the airfoil to increase its lift. The discharge of the exhaust gases with cooling diluent gas is directed over the top surface of the sustaining airfoil in one embodiment of the invention; and in another embodiment, the gases are directed along the lower surface of the airfoil and there is a deflector for causing flow of the gases up to a wing slot and then across the top surface of the airfoil rearward of the slot. Other objects, features and advantages of the invention will appear or be pointed out as the description proceeds.

In the drawing, forming a part hereof, in which like reference characters indicate corresponding parts in all the views:

FIGURE 1 is a top plan view of an aircraft made in accordance with this invention;

FIGURE 2 is an enlarged vertical, sectional view on the line 2—2 of FIGURE 1;

FIGURE 3 is a sectional view, similar to FIGURE 2, but showing a modified form of the invention;

FIGURE 4 is a fragmentary, diagrammatic, top plan view showing the gas flow around and from one of the engines shown in FIGURE 1; with modified slot;

FIGURE 5 is an enlarged, sectional view taken on the section line 5—5 of FIGURE 2; and

FIGURE 6 is an enlarged detail view showing the deflectors for controlling the direction of air flow in the construction shown in FIGURE 2.

FIGURE 1 shows an aircraft having wings comprising principally airfoil sections **10** to which are connected jet engines **11** by supports **12**. The jet engines **11** have tail pipes **14** which discharge exhaust gases rearwardly, as indicated by arrows **16** (FIGURE 2).

Each tail pipe **14** extends into a shroud **18** which



preferably is contoured into the airfoil **10**, as indicated in FIGURES 1 and 4. A passage **22** (FIGURE 2) extends through the shroud **18** and the downstream end of the passage **22** is adjacent to a leading edge **24** of the airfoil section **10**. The gases discharged from the passage **22** flow over the top surface of the airfoil section **10** to reduce the pressure on the top surface of the airfoil section and thereby to increase its lift.

The airfoil section **10** has a flap and aileron **23** at its trailing edge operated by link mechanism in the conventional manner. The flap and aileron **23** is in the jet stream that flows across the airfoil section **10**; and in the preferred construction the jet engines **11** (FIGURE 1) are close enough together, and the aircraft tail assembly **25** is wide enough, so that flight control surfaces of the tail assembly are also in the jet streams. As these streams travel rearwardly they spread and thus affect a greater width of the tail assembly. The feature by which the flaps and ailerons **23** and the tail assembly **25** are in the jet streams provides control of the aircraft when it has little or no forward speed.

The passage **22** has deflectors **26**, best shown in FIGURE 6, and these deflectors can be shifted to change the angle at which the stream of gas discharges from the passage **22**. The deflectors **26** are operated by control links and may be operated in unison or independently, and in the latter case they also control the velocity at which the stream of gas is discharged from the shroud.

In order to reduce the temperatures of the exhaust gases from the jet engine **11**, before these gases strike the airfoil surface, means are provided for supplying a diluent gas which will mix with the hot gases from the jet engine to reduce the temperature of the exhaust gases, and also to increase their volume. In the construction shown in FIGURE 2, these means include a clearance between the upstream end of the shroud and the tail pipe **14** of the jet engine. This clearance leaves a passage **32** which is annular as shown in the drawing, and which is directed forwardly so that air from the atmosphere enters the passage **32** and flows rearwardly into the passage **22** where it contacts with and blankets the stream of exhaust gases from the tail pipe **14**. There is ultimate mixing of the air with the exhaust gases, and resulting cooling of the gases.

In addition to the pressure, produced by the winds of flight for causing air to enter the passage **32**, there is also an aspirator action by the exhaust gases issuing from the tail pipe **14** through the interior passage of the shroud, which includes a Venturi longitudinal section with passageway diameters established by design to produce the desired suction of air into the shroud.

In the construction illustrated, there is a second stage of dilution and cooling of the exhaust gases. This second stage is obtained by having a slot of clearance **33** between the shroud rearward end and a leading edge of the airfoil **10** immediately behind the downstream end of the passage **22**. If the shroud is built into the wing, then the clearance **33** is a slot; but if the shroud is located out in front of the wing and is not a part of it, then the clearance **33** is not a slot because it has no end closure. Air forward of the airfoil **10** flows upwardly through the clearance **33** and forms a cooling boundary layer between the wing and the stream of gases flowing from the downstream end of the shroud passage **22**.

The amount of air flowing upwardly through the clearance **33** depends upon the speed of flight of the aircraft and also upon the setting of the deflectors **26**. The discharge end of the passage **22** is preferably elongated in a span-wise direction, as shown in FIGURE 4; and the clearance **33** is a clearance between the downstream end of the passage **22** and the surface of the airfoil over which the stream of exhaust gases discharges.

In FIGURE 3, a jet engine **11'** is supported from an airfoil **40** by a support **12'**. The jet engine **11'** has a tail pipe **14'** which extends into a shroud attached to or forming a part of the airfoil **40**. This construction, shown in FIGURE 3, differs from that shown in FIGURE 1 in that the shroud **43** is of a different shape and position relative to the wing. The downstream end of the passage through the shroud **43** directs the stream of exhaust gases, and diluent air, across the bottom surface of a rearward section **44** of the airfoil **40**. There is a slot **46** opening through the airfoil **40** and the exhaust gases can be deflected upwardly through the slot **46** by means of a deflector element **48**. This deflector element swings about a pivot **50** and can be moved angularly about this pivot **50** by suitable operating links so as to control the proportion of the exhaust gases that pass across the lower surface of the airfoil section **44** and the proportion that passes upwardly through the slot **46** and across the upper surface of the airfoil section **44**.

With the deflector element **48** in the position illustrated in FIGURE 3, all of the exhaust gases are deflected upwardly through the slot **46** as indicated by the arrows shown in solid lines. The exhaust gases which pass beneath the airfoil section **44**, when the deflector **48** is in a raised, or partially-raised position, are indicated by the broken line arrows **56**. The supply of diluent air to the exhaust gases in FIGURE 3 is the same at the upstream end of the shroud **43** as in the case of the shroud **18** in FIGURE 2. The annular clearance is indicated around the tail pipe of the motor **11'** by the reference character **32'**. In FIGURE 3, however, there is only one stage of cooling and dilution of the exhaust gases from the engine **11'**, there being no passage in FIGURE 3 corresponding to the clearance **33** of FIGURE 2.

In FIGURE 2 the shroud **18** is located above the median cord line of the airfoil section **10**; but in FIGURE 3 the shroud is located below the median cord line. While the invention has been illustrated and described as applied to an aircraft airfoil, it will be understood that the invention is not so limited and that it can be used for changing the pressure differential on opposite sides of an airfoil which is vertical or horizontal, and the jet engine may be used as a pump for producing the flow of gases even though it is not a propulsion jet engine for an aircraft.

It will also be understood that the supply of diluent air, or other gas, for cooling the exhaust gases from the jet engine, and increasing the volume of the gases, can be applied to the passage from the jet engine tail pipe by other means than the open upstream ends of the shrouds **18** and **43**, shown in FIGURES 2 and 3. For example, the diluent air or gas can be introduced into the stream of exhaust gases from the jet engine by any ducts or passages which communicate with a passage through which the exhaust gases are flowing before the exhaust gases come in contact with a surface of the airfoil. Preferably the mixing of the cooling air with the exhaust gases takes place before the exhaust gases strike the inside surface of the shroud, avoiding overheating of the shroud.

It should be understood that the airfoil does not have to be part of the shroud. Such an arrangement is only for structural convenience. The shroud has no functional value as an airfoil, or part of it.

The gases discharged from the passage **22** in FIGURE 2 are substantially parallel to the top surface of the airfoil section **24** when the deflectors **26** are in their mid positions. Deflection of the exhaust gases and mixed diluent gas downwardly against the top surface of the airfoil forward portion **24**, of wing **10**, by downward movement of the deflectors **26**, will increase the velocity of the gas flow up to a certain point and will then cause turbulence and a breaking away of the gas stream from the airfoil section.

Upward deflection of the deflectors **26** will cause the gas stream to break away from the surface of the airfoil section **10** before reaching the trailing edge of the airfoil section, and will thus decrease the lift. The higher the deflectors **26** are moved, the sooner the gas stream will break away from the airfoil section **10** and the greater will be the loss of lift. Thus the invention can be used for decreasing the lift of the wing when desirable. Therefore, by use of this device on the two opposite wing halves, of an aircraft, thus creating a lift differential on the opposed wing halves, aileron effect is produced (roll about longitudinal axis of aircraft) both while the plane is at rest and while in forward motion. The flaps **23** can also be used as ailerons.

While mixing of the diluent air with the exhaust gases from the jet engine is unavoidable, the structure illustrated in the drawing produces a certain amount of laminar flow. For example, by introducing air around the tail pipe **14** of the jet engine **11** through an annular space, there is a layer of cooler air surrounding the stream of air which issues from the tail pipe **14**. Thus the hot gas from the jet engine is separated from the side walls of the passage **22** through the shroud **18**. This results in much less heating of the walls of the shroud than would occur if the diluent air were thoroughly mixed with the exhaust gases.

As the gases travel rearwardly along the passage **22** there is an increased mixing of the cooler surrounding air with the hot exhaust gases at the center of the stream. As the mixing stream of exhaust gases and cooling air passes over the top surface of the airfoil section **24**, the stream of air moving upwardly through the clearance **33** produces another layer of cool air flow between the top surface of the airfoil section **24** and the mixed gases that are flowing from the downstream end of the passage **22** through the shroud. While this air flow from the clearance **33** also tends to mix with the other gases flowing rearwardly over the airfoil section to some degree, it does reduce the heating of the top surface of the airfoil section because the boundary layer flow through the slot is not turbulent but has been previously established as a flow of air by the said slot, and which as a flow, resists the breaking-down effect of the jet air flow from the shroud rear opening and thus forms a coating of air boundary layer flow over the upper surface of the wing, as well as a cooling agent of the impinging hotter jet and air flow. Therefore, the wing is heated by the jet gases less than if the same amount of air were mixed with the exhaust gases before flowing from the shroud.

In FIGURE 2 there is a layer of cool air surrounding the hot gases from the tail pipe **14'** as the gases flow through the shroud and past the deflector **48**. The amount of mixing which occurs depends partly on velocity of flow, partly on the smoothness of the inside surfaces at the passages and upon the length of the passages. It is a feature of the invention, however, that the cooling and diluent gas is introduced so as to surround the hot stream of exhaust gas from the jet engine, and ultimately to mix with these exhaust gases.

This feature need not be used for all embodiments of the invention and cooling of the exhaust gases may be obtained by injecting fluid into the jet flow from the tail pipe as it passes through the shroud or air may be directed into the jet tail pipe from the outside atmosphere in various ways to mingle with the exhaust gases. However, more cooling medium is thoroughly mixed with the exhaust gases before they are discharged from the shroud.

The preferred embodiments of the invention have been illustrated and described, but changes and modifications can be made, and some features can be used in different combinations without departing from the invention as defined in the claims.

What is claimed is:

1. In an aircraft,

(*a*) an airfoil that has a rigid portion and that has a flight control element at the trailing edge of the rigid portion, (*b*) a jet engine that propels the aircraft and that has an exhaust,

(*c*) a first passage through which exhaust gases from the engine flow, said first passage having an outlet adjacent to and directed toward a surface of the airfoil ahead of the flight control element and in position to direct the exhaust gases from the jet engine over an external surface of the rigid portion of the airfoil and over the surface of the control element,

(*d*) a second passage leading into the exhaust gas stream that flows from the first passage, the second passage having an inlet end located above the leading edge of the rigid portion of the airfoil and facing in a direction to receive air that flows from the leading edge over the top surface of said rigid portion, said inlet end of said second passage being located ahead of the outlet of the first passage.

2. The apparatus described in claim 1 and in which the jet engine has a tail pipe through which the exhaust gases are discharged into the first passage and the second passage is in a shroud into which the tail pipe extends, the shroud being spaced from the tail pipe and having an open area into which air is aspirated by the flow of the exhaust gases into the shroud, the downstream end of the shroud constituting the first passage.

3. The apparatus described in claim 1 and in which the jet engine is supported ahead of the wing, and the upstream end of the second passage faces in the direction of flight of the aircraft whereby air is forced into the second passage by the winds of flight.

4. The apparatus described in claim 3 and in which the first passage is a shroud into which the jet engine exhausts, and the second passage is a clearance between the engine and the upstream end of the shroud whereby a layer of cool air enters the shroud and passes through the shroud around the stream of hot exhaust gas from the engine.

5. The apparatus described in claim 1 and in which the end of the first passage is spaced from the airfoil and leaves clearance through which atmospheric air flows across the airfoil between the airfoil surface and the mixed gases from the first pasage to still further reduce heating of the airfoil surface by the exhaust gases from the jet engine.

6. The apparatus described in claim 1 and in which there are deflector means in the path of the gases from the first passage for controlling the flow of the gases over the surface of the airfoil.

7. The apparatus described in claim 6 and in which the outlet end of the first passage is in position to supply gases for flow over both sides of the airfoil, and the deflector means are adjustable to control the proportionate air that flows over the respective sides of the airfoil.

8. The combination comprising an airfoil, a jet engine extending ahead of the airfoil, a shroud into which the jet engine exhausts, the downstream end of the shroud being in position to discharge gases toward and across an external surface of the airfoil, and the upstream end of the shroud facing forward and in position to receive air directly and at least partially by the ram effect of the winds of flight and thereby to entrain cool air which flows with the exhaust gases through the shroud to reduce heating of the shroud and airfoil surface by the exhaust gases.



9. The combination described in claim 8 and in which the downstream end of the shroud has an opening that is elongated in a direction spanwise of the airfoil.

10. The combination described in claim 8 and in which the combination includes also a deflector in the path of the gases discharged from the shroud, and the deflector is movable into different angular positions to control the direction of flow of said gases with respect to the surface of the airfoil over which said gases flow.

11. In an aircraft, a sustaining airfoil, a jet engine for propelling the aircraft in flight, a support for the engine connected with the airfoil and holding the engine in a position ahead of the airfoil, a shroud extending around a portion of the rearward end of the engine and into which the exhaust from the engine is discharged, the shroud having an open upstream end facing forward and in position to receive air directly and at least partially by the ram effect of the winds of flight and thereby to entrain cool air for travel with the exhaust gases from the engine through the shroud to reduce the heating of the shroud by the exhaust gases and increasing the volume of gases flowing from the shroud, said shroud having a downstream end adjacent to a surface of the airfoil and from which the gases from the shroud are discharged at high velocity across a portion of the surface of the airfoil.

12. The aircraft described in claim 11 and in which the downstream end of the shroud extends in a direction to discharge the gases rearwardly and generally parallel to the top surface of the airfoil to increase its lift, the downstream end of the shroud being spaced above the airfoil and leaving a slot through which a further supply of air flows over the top surface of the airfoil to further reduce the heating of the airfoil by the stream of exhaust gases from the jet engine.

13. The aircraft described in claim 11 and in which the downstream end of the shroud extends in a direction to discharge the gases rearwardly and across the underside of a portion of the airfoil, a slot through the airfoil, a deflector at the lower end of the slot movable into different angular positions to deflect gases from the shroud upwardly through the slot and over the upper portion of the airfoil rearward of the slot.

14. The aircraft described in claim 11 and in which the shroud is a portion of the airfoil.


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