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[54] **LIFT AND CONTROL AUGMENTER FOR AIRFOILS**
10 Claims, 8 Drawing Figs.

[52] **U.S. Cl.** **244/42**
[51] **Int. Cl.** **B64c 21/04**
[50] **Field of Search** 244/42, 42.4, 42.41, 42.6, 42.61, 42.62

[56] **References Cited**

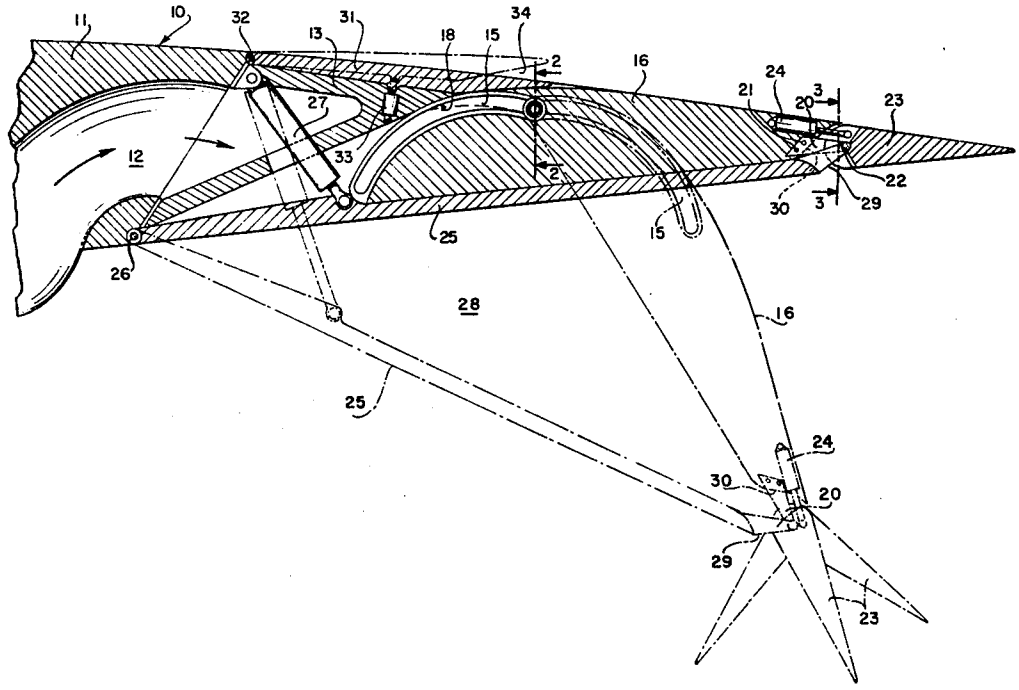
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ABSTRACT: Means is herein provided for augmenting the lift and controllability of an aircraft by blowing compressed air through spanwise slots in a multiple trailing edge flap system on the aircraft's airfoils. The mechanism consists of a main flap, with rotary and translation motion relative to the associated airfoil; a lower surface flap which is hinged to both the airfoil and the main flap; and an airflow directional control device rotatably mounted to the aft end of the main flap.

Downward deflection of the flap mechanism creates a spanwise duct between the main and lower surface flaps, through which compressed air, extracted from a suitable source, is allowed to flow. The air is ejected at high velocity from multiple spanwise slots provided in the flap mechanism. The resultant jet sheets impart a downward momentum to the air passing over the associated airfoil increasing the circulating flow around its chordwise sections and imparting an upward reaction. The airflow directional control device may be utilized both to vary lift symmetrically on the aircraft and to provide roll control by differential action.



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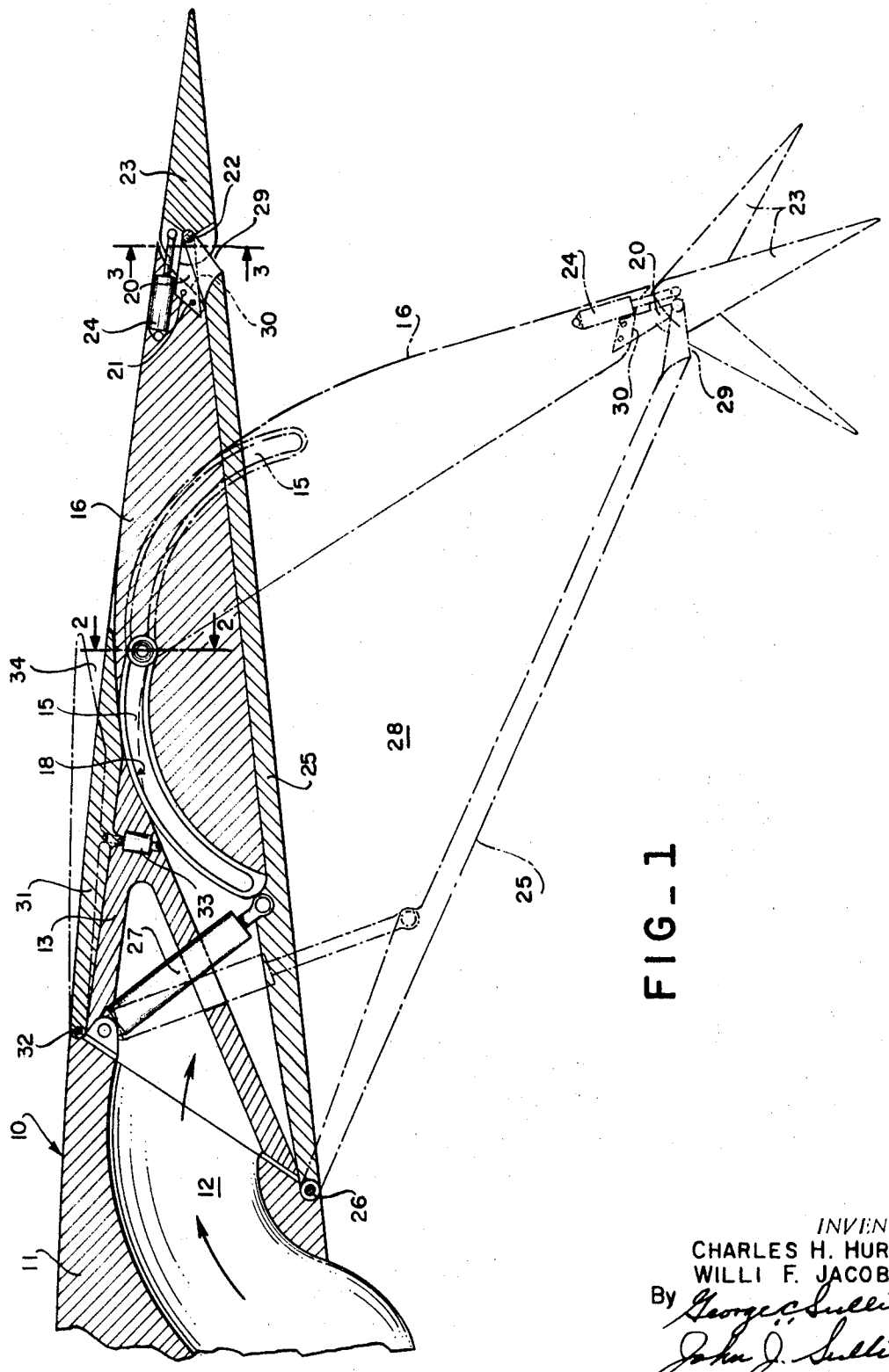


FIG_1

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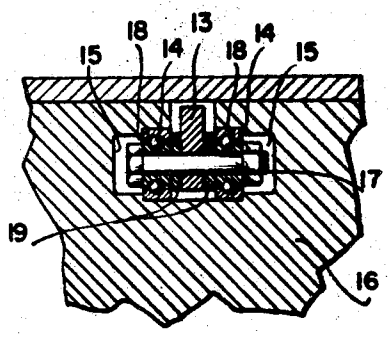


FIG_2

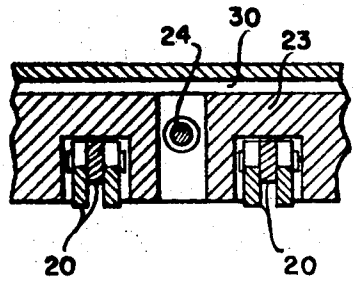


FIG_3

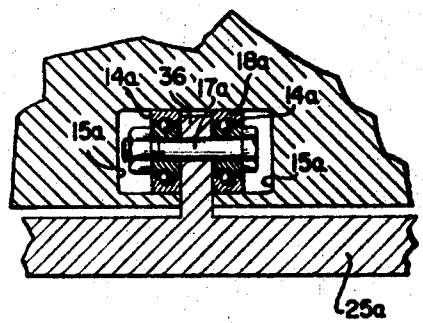


FIG_5

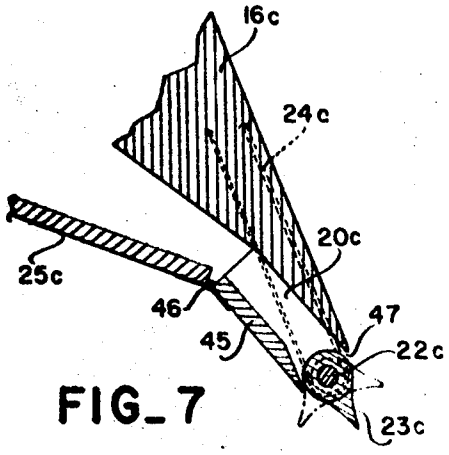


FIG_7

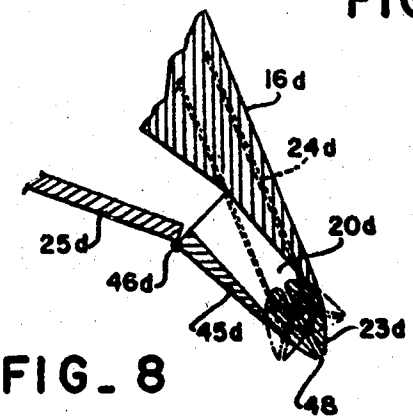


FIG_8

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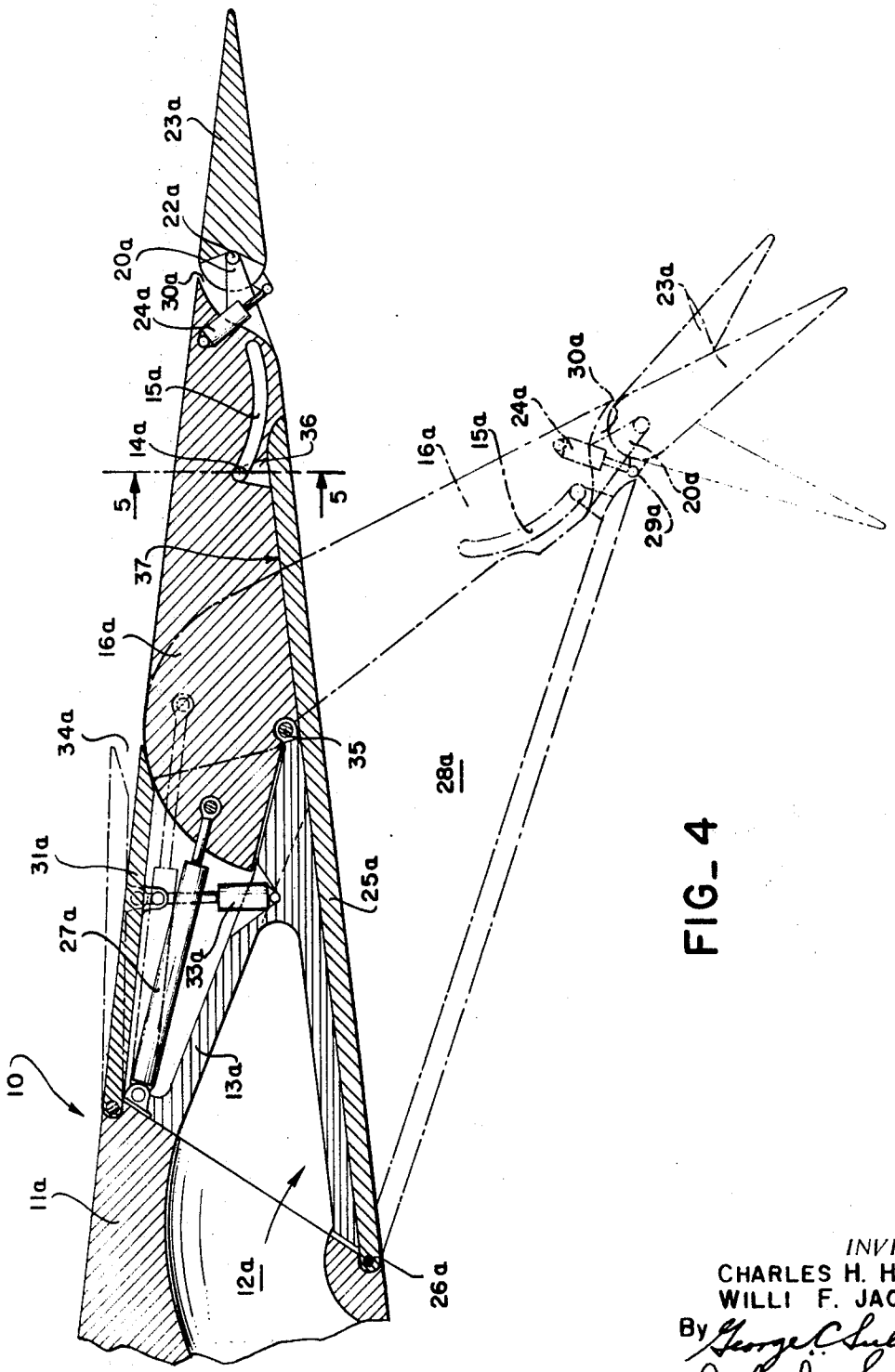


FIG_4

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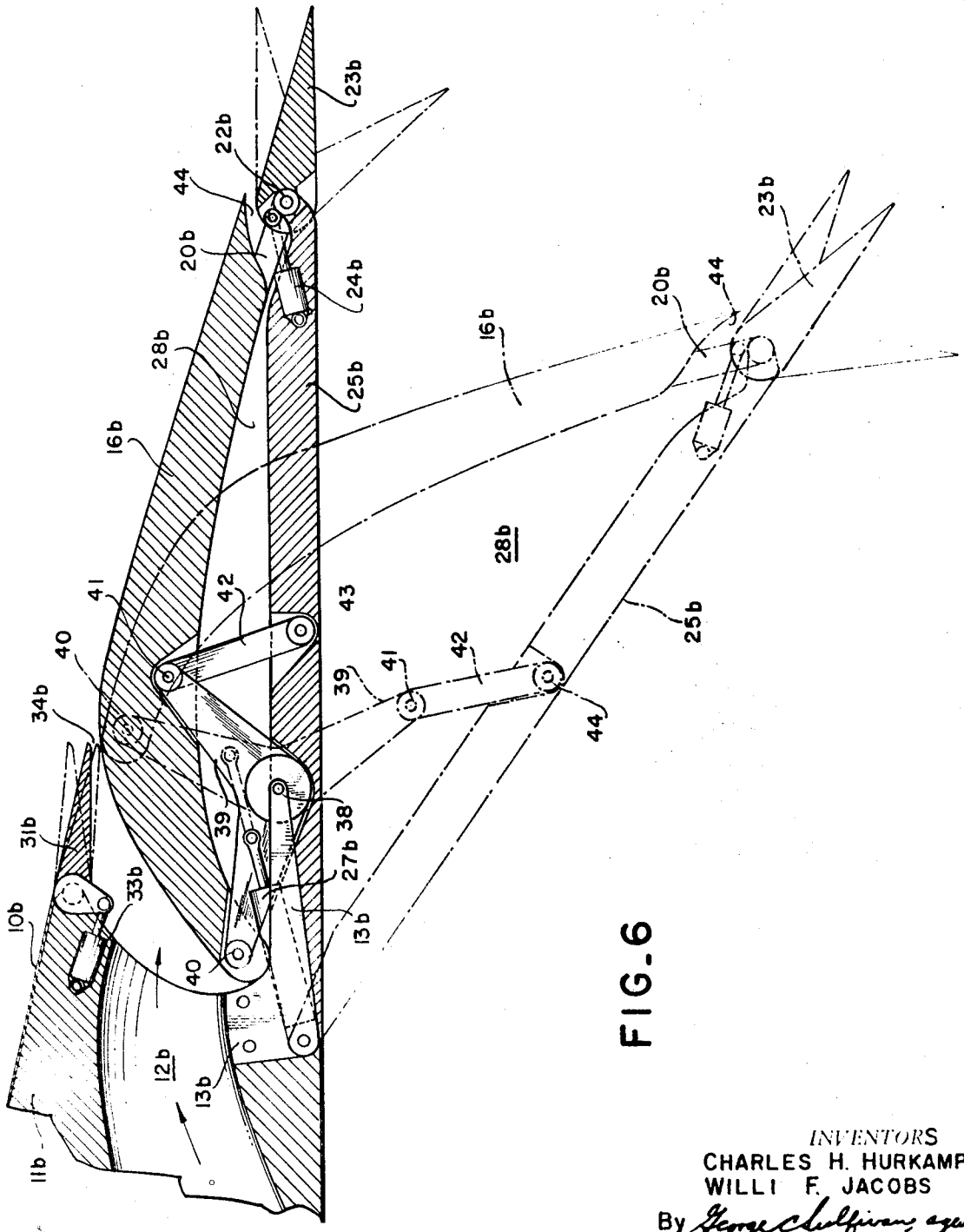


FIG. 6

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LIFT AND CONTROL AUGMENTER FOR AIRFOILS

This invention relates to lift an control surfaces for aircraft, and more particularly to such surfaces incorporating augmenters to enhance the operation and performance of the aircraft over a wide range of flight conditions and regimes.

Heretofore various schemes have been proposed, including arrangements based on the so-called "boundary layer control" and the "jet flap" principles in order to augment the lift and controllability of an airfoil or airplane wing when moving through the air. Both the "boundary layer control" and "jet flap" principles are predicated on an expulsion of a jet sheet of compressed air or gas from the rearward portion of the control surface or wing. The action of this jet sheet imparts a downward momentum to the air passing over the associated wing surface increasing the circulatory flow around the chordwise sections of the wing as well as imparting an upward reaction to the wing due to the downward force of the jet.

Boundary layer control by blowing is usually defined as blowing the jet sheet from a slot located on the upper surface of the wing at or near the junction between the relatively fixed structure of the wing and the downwardly moving or hinged trailing edge flap. Sufficient momentum is provided to entrain and increase the speed of the otherwise slow-moving low-energy boundary layer air adjacent the wing surface. This effect in turn causes the flow of free air to turn or bend downward following the contour of the flap in its deflected position. Without the jet, the free air tends to become detached or separated from the flap creating turbulence and limiting the amount of lift provided by the wing.

It has been found that a relatively small amount of blowing air momentum is required to maintain airflow attachment to the wing surface. Additional air momentum, i.e., increasing the mass and velocity of the airflow over the wing surface causes the lift to increase, although at a lower rate reaching a practical maximum as determined by the available supply of blowing air and the maximum limits of the duct cross section available.

The jet flap principle is usually defined as directing the jet sheet of gas or air from a slot or nozzle located in the trailing edge of the wing in a generally downward and rearward direction. This, in effect, creates the equivalent of a rearward extension of the wing chord thus increasing the effective angle of attack and the circulation around the wing. The jet flap sometimes employs a high-energy jet blast of air or gas blown from a slot or nozzle at the hinge line or knee of the deflected trailing edge flap. In this way, both boundary layer control and high-lift supercirculation are accomplished while the flap acts as a deflector.

Although the jet flap can and does provide high-lift characteristics, the high local velocities associated with blowing over the upper surface of the flap increase friction drag which deenergizes the jet stream. Also high-velocity blowing over the angularly disposed or deflected flap is generally accompanied with some airflow separation or detachment along the rear of the flap with the result of further diminishing the effectiveness of this type of jet flap arrangement.

The present invention endeavors to combine the principles of boundary layer control and jet flap in such a manner that they complement one another in optimum fashion and the objectionable features of the jet flap system referred to above are avoided. At the same time the arrangement herein proposed is so designed that a relatively small amount of air is directed out through a slot in the knee of a jet deflector flap to provide flow attachment while the bulk of the blowing air is discharged through a slot in or near the trailing edge of the flap where it will produce maximum effect.

In substance, therefore, the concept underlying the instant invention is the combination with the aerodynamic characteristics of a mechanical flap of a blowing boundary layer control and a jet flap. This allows for controllability of the aircraft by the highly effective jet deflection control of the mainstream

at the trailing edge of the flap. Moreover, the arrangement allows for a spanwise duct for the passage of the compressed air or gas by an enlargement of the flap cross section in the deflected position. This constitutes a real advantage in present day aircraft by removing this structure from the primary wing interior where space is at a premium for fuel storage compartments and various accessories necessary for the operation of the aircraft.

More specifically, the instant lift and control augmenter comprises an articulated trailing edge flap mechanism pivotally connected to the aft end of the relatively fixed wing structure. This mechanism is formed by multiple flap elements pivotally associated one with another and with the wing structure to provide an automatic expansion in profile upon its deflection producing an internal duct communicating with an appropriate fluid pressure conduit in the wing structure. During such expansion fluid discharge slots are produced at and along the hinge line formed by the flap and the adjacent upper wing structure, and also adjacent the trailing edge of the flap. The effective size of these slots may be made to vary by configuring the adjacent flap and wing structure surfaces as a function of their deflection. Preferably, the slots associated with the trailing edge of the flap include actuators for their additional, independent regulation.

With the above and other objects in view as will be apparent, this invention consists in the construction, combination and arrangement of parts all as hereinafter more fully described, claimed and illustrated in the accompanying drawings wherein:

FIG. 1 is a transverse section taken through the rear portion of an airfoil such as, for example, an airplane wing showing an articulated flap mechanism designed and constructed in accordance with the teachings hereof with the several components thereof disposed in their inoperative position, i.e., in the high-performance flight condition of the aircraft, the operative position of said components, i.e., their other extreme position, being shown in broken lines.

FIG. 2 is a section taken along line 2–2 of FIG. 1 to show primarily the mounting and connection of the main flap element to the relatively fixed wing structure by which it is capable of concurrently rotating and linearly translating;

FIG. 3 is a section taken along the line 3–3 of FIG. 1 to show primarily the interconnection of the several flap elements in the area trailing edge slots;

FIG. 4 is a section similar to FIG. 1 of an alternate form or embodiment of the invention showing a somewhat different manner of interconnecting the several flap elements to permit substantially the same articulation thereof;

FIG. 5 is a section taken along line 5–5 of FIG. 4 and corresponds to the section shown in FIG. 2;

FIG. 6 is a section similar to FIGS. 1 and 4 of still another alternate form or embodiment of the invention showing a different linking arrangement interconnecting the several flap elements to accomplish substantially the same articulated movement thereof;

FIG. 7 is a section similar to FIGS. 1, 4, and 6 of the aft extremity only of the mechanism showing an alternate form of coacting flap elements in the area of and regulating the effective discharge direction of the trailing edge slot or slots; and

FIG. 8 is a section similar to that shown in FIG. 7 of another alternate arrangement of coacting flap elements in the area of the trailing edge slots.

Referring more specifically to the drawings, FIGS. 1, 4, and 6 depict alternate mechanical means of achieving the general objectives of the invention. Each of these embodiments shows a typical cross section taken through the aft portion of an aircraft wing 10 which can be considered as representative of sections taken along the entire span of the exposed portion of the wing. In all instances, fixed structure of the wing is provided with one or more internal ducts through which compressed air or gas is supplied. The source per se of this air or gas is unimportant to the invention, it being merely provided by either bleed air from the primary propulsion system of the aircraft or by some appropriate, auxiliary power unit or units.

Considering first the embodiment illustrated in FIGS. 1, 2, and 3, 10 designates an aircraft wing and 11 designates fixed structure thereof including an internal duct 12 adapted to convey air or gas from a suitable source. The structure 11 carries a series of supporting brackets 13 immovably secured thereto and projecting in an aft direction therefrom. At their aftmost extremity these brackets 13 each retain a set of rollers 14 which are rotatably mounted thereon, and which are adapted to mount within a curved slot 15 in a primary flap 16. The flap 16 is thereby supported and capable of rearward movement thereon relative to the fixed wing structure 11. To this end, the end of each bracket 13 is pierced by a hole adapted to receive and mount a bolt 17 which serves as an axle on which a roller 14 is mounted on each side of the bracket 13. The rollers 14 are retained in position by the head and the nut of bolt 17 working in conventional manner in opposition one to another and appropriate spacers 19. Thus located, each roller 14 is adapted to engage a surface or track 18 that defines the slot 15 in the flap 16 which thereby permits the flap 16 to roll freely thereon.

At its rear extremity the flap 16 carries a series of supporting brackets 20 rigidly attached thereto as at 21 and extending aftwardly therefrom. At its aft end each bracket 20 mounts a pivot bearing 22 to which an auxiliary flap 23 is hinged. A series of power actuators 24 pivotally connected at opposite ends to the primary and auxiliary flaps 16 and 23 serves to control the angular movement of the auxiliary flap 23 with respect to the main flap 16. These actuators 24 may be hydraulically, electrically, mechanically, or otherwise operated, the means for the adjustment thereof being unimportant so far as the present invention is concerned.

A lower surface flap 25 is continuously hinged as at 26 along its forward edge to the fixed wing structure 11 and similarly along its rear edge to each of the auxiliary flap support brackets 20, e.g., through the pivot bearing 22. Thus mounted, the lower surface flap 25 is adapted to move in a generally angular motion to and from extended and retracted positions being actuated by appropriate means such as a power cylinder 27 pivotally secured at opposite ends to a convenient part of the fixed wing structure 11 and the lower surface flap 25. Thus, actuation of the cylinder 27, i.e., the extension and contraction thereof, serves to move the main flap 16 and the lower surface flap 25 away from each other producing a fluid chamber 28 in communication with the duct 12. This chamber 28 terminates in an outlet 29 between the aft end of the lower surface flap 25 and the main flap 16. Due to the sliding pivotal connection through the rollers 14 operating between the main flap 16 and the fixed wing structure 11, the main flap 16 is concurrently translated in a generally aft direction as it is rotated downwardly.

The mounting of the brackets 20 and their respective pivot bearings 22 is such that the auxiliary flap 23 is disposed in spaced relation to the aft end of the main flap 16 creating a fluid passage 30. The effective size of the passage 30 is small relative to the outlet 29, being intended to pass only sufficient fluid when operative to maintain the airflow over the upper surface of the auxiliary flap 23 attached at all times. This leaves the maximum amount of fluid available through duct 12 and chamber 28 to pass through the outlet 29.

Preferably an upper surface flap 31 is also provided between the fixed wing structure 11 an the main flap 16. This upper flap 31 overlies and encloses the several brackets 13, being continuously hinged as at 32 at its forward end to the fixed wing structure 11. Its angular motion relative to the structure 11 is regulated by a series of power actuators 33 connected at one end to the under surface of the upper surface flap 31 and at the other end to the associated bracket 13. The several actuators 33 are interconnected through suitable means for operation in unison following any conventional practice. Extension of the actuators 33 thus serves to rotate the upper surface flap 31 with respect to the brackets 13 and associated surface of the main flap 16 producing a rear slot 34 of desired cross-sectional dimension. Where a constant cross section of this slot 34 is desired, the upper surface flap 31 may be merely fixed and contoured with respect to the associated surface of the main flap 16 whereby deflection and rearward translation of the main flap 16 as above described automatically produces the slot 34.

In the embodiment of the invention illustrated in FIG. 4, the same end result is obtained by the operation of the several flap elements through a slightly modified structural arrangement. In this case, a series of supporting brackets 13*a* carried by and extending rearwardly from fixed structure 11*a* of the wing 10*a* retain pivot connections 35 on which a main flap 16*a* is mounted for free and unrestricted rotation by appropriate actuating means such as one or more cylinders 27*a*.

An auxiliary flap 23*a* is hinged to the main flap 16*a* through a series of pivot bearings 22*a* each supported by a bracket 20*a* fixed to and projecting rearwardly from the main flap 16*a*. Power actuators 24*a* are used to control the angular movement of the auxiliary flap 23*a* relative to the main flap 16*a*. The mounting of the brackets 20*a* and their respective pivot bearings 22*a* is such that the auxiliary flap 23*a* is disposed in spaced relation to the aft end of the main flap 16 creating a passage 30*a*.

A lower surface flap 25*a* is continuously hinged as at 26*a* along its forward edge to the fixed wing structure 11*a* and at its rear edge is provided with a series of rigidly connected brackets 36 each of which supports a pair of rollers 14*a*. Each pair of rollers 14*a* is mounted on a bolt 17*a* acting as an axle on which one roller 14*a* is disposed on each side of its bracket 36. Thus located each pair of rollers 14*a* operates within complemental curved slots 15*a* in the main flap 16*a* adjacent the aft end thereof. The curvature of the slots 15*a* and the lower contour of the main flap 16*a* is such that a flush lower surface is established when the flap mechanism is in the inoperative position, i.e., undeflected. This is accomplished by forming the main flap 16*a* with a depression or cavity 37 having a base wall disposed in the plane of the brackets 13*a* so that when the lower surface flap 25*a* is retracted its inner surface abuts the brackets 13*a* and main flap 16*a* and its outer face forms an aerodynamically clean and smooth continuation of the adjacent surfaces of the wing structure 11*a* and main flap 16*a*.

Also when the flap mechanism is operative, i.e., extended or deflected, a fluid chamber 28*a* with outlet 29*a* is produced between the main flap 16*a* and the lower surface flap 25*a*, while a fluid passage 30*a* is opened between the main flap 16*a* and the auxiliary flap 23*a* to discharge air or gas from the duct 12*a* over the upper surface of the auxiliary flap 23*a* The dimension of the chamber 28*a* is adjusted or regulated over a desired range of angular movement of the flap mechanism during its deflection.

As in the case of the embodiment of FIG. 1, the size of the outlet 29*a* is substantially greater than that of the exit from the passage 30*a* so that maximum fluid from the duct 12*a* and chamber 28*a* is employed in the jet flap function and only enough fluid employed in the boundary layer function to lubricate the upper surface of the auxiliary flap 23*a*.

Also, an optional upper surface flap 31*a* is hinged as at 32*a* to the wing structure 11*a* along the length thereof adjacent its aft end. The angular motion of this upper surface flap 31*a* is regulated by one or more power actuators 33*a*, the opposite ends of each of which are secured to the upper surface flap 31*a* medially of its length and to the bracket 13*a*. The operation of the several actuators 33*a* in unison by appropriate interconnecting means thus serves to regulate the effective size of an opening or slot 34*a* between the aft end of the upper surface flap 31*a* and the main flap 16*a* where it is desired that this be variable.

FIG. 6 shows still another alternate construction of an articulated flap system which is preferred in certain applications. The fixed structure 11*b* of the wing 10*b* includes rigidly attached brackets 13*b* intermittently spaced and each provided with a pivot 38 to which is mounted a bellcrank lever 39 consisting of two radial angularly spaced mounting pivots 40 and 41. One of these pivots, e.g., pivot 40, is attached to the main flap 16*b* while the other pivot 41 is attached to a link 42

which in turn is attached to the lower surface flap 25*b* as at 43. This bellcrank 39 is rotated by a linear powered actuator 27*b* or the like which causes the leading edge of the main flap 16*b* to move in a circular path or arc in a rearward and upward direction whereby the aft end thereof is deflected downward.

The lower surface flap 25*b* is concurrently forced downwardly in an arc or a circular path about its hinge by the combined action of the main flap 16*b* and the link 42 acting on it. Any slight binding created by these combined actions will be relieved by deflection of the main and lower flap structures 16*b* and 25*b*. Moreover, the use of the link 42 to assist in rotating the lower surface flap 25*b* is optional, since it is not necessary to achieve the desired result as described. It is preferred, however, in providing the lower surface flap 25*b* with an intermediate point of support against the load created by pressure against its interior surface exerted by the fluid or compressed air from the duct 12*b* and in the chamber 28*b*.

FIG. 6 also shows an optional configuration for the auxiliary flap 23*b* which is interchangeable with those shown in FIGS. 1 and 4. In this instance a single slot 44 is provided adjacent the upper surface between the main flap 16*b* and the auxiliary flap 23*b* while the joint between the lower surface flap 25*b* and the auxiliary flap 23*b* is substantially sealed as for example by rubbing contact. A powered linear actuator 24*b* which may be attached to either the main flap 16*b* or the lower surface flap 25*b* as desired in the manner shown for example where it is pivotally connected to the lower surface flap 25*b*. The length of the auxiliary flap 23*b* may be selected to any predetermined extent, the minimum being substantially a cylinder rotating about its pivot 22*b*.

In FIGS. 7 and 8, there is shown alternate structures and arrangements for the auxiliary flap 23, 23*a* and 23*b* as previously described in connection with the embodiments of the invention illustrated in FIGS. 1, 4, and 6. Referring to FIG. 7, this alternate auxiliary flap is formed by a continuous rotatable, generally cylindrical body 23*c* hinged as at 22*c* to the trailing edge of the main flap 16*c* along a hinge line which may be supported by intermittent brackets or ribs 20*c*. The ribs 20*c* connect the main flap 16*c* with a continuous lower surface slat 45 which is hinged to the lower surface flap 25*c* by means of a continuous hinge 46. Fluid escape outlets 47 are formed between the end of the slat nd the rotatable cylinder 23*c* and also between the main flap 16*c* and the rotatable cylinder 23*c*. Thus fluid is discharged from the chamber 28*c* at the aft end of the articulated flap mechanism to perform the jet flap function. In this case the actuation means for adjustment and deflection of the auxiliary flap 23*c* may be in the form of an appropriate series of cables 24*c* which are wound over and around grooves i the flap or cylinder 23*c*.

Referring to FIG. 8, a continuous rotatable, generally cylindrical body 23*d* is employed that incorporates a series of intermittent slots 48 in communication with the chamber 28*d* defined by the main flap 16*d* and lower surface flap 25*d*/ slot 45*d* for the discharge of fluid therefrom. The cylinder 23*d* is hinged to the trailing edge of the main flap 16*d* through ribs 20*d* which interconnect the main flap 16*d* with the slat 45*d* hinged as at 46*d* to the lower surface flap 25*d*. The main flap 16*d* and the lower continuous slat 45*d* are intended to substantially bear against the periphery of the cylinder 23*d* so that the sliding joint thereby created may be considered as tight. This is not critical, however, inasmuch as fluid leakage around the cylinder 23*d* does not prevent the operation thereof as a jet flap. The rotation of the cylinder 23*d* is accomplished by means of and through a cable arrangement 24*d* as previously described in connection with the mechanism shown in FIG. 7.

In any of the systems shown in FIGS. 1, 4, or 6, the extension of the main actuators 27, 27*a*, or 27*b* and the admission of compressed air or gas into the chamber 28, 28*a* or 28*b* causes the flap mechanism to assume a predetermined angular position as shown in phantom lines in each of the FIGS. 1, 4, and 6. Several such positions may be available through the use of stops or locks which per se are not a part of the invention and therefore have not been shown. The fluid entering the flap chamber 28, 28*a*, or 28*b* is constrained by the main/upper surface flap 16, 16*a* and 16*b*/31, 31*a* and 31*b* and lower surface flaps 25, 25*a* and 25*b* respectively and will travel in both spanwise directions thereof. Simultaneously the fluid will be ejected at relatively high velocity through selected spanwise slots or outlets at 29 and 30, 29*a* and 30*a*, 44, 47, or 48, as the case may be, followed by optional fluid ejection through another spanwise slot or outlet at 34, 34*a*, or 34*b*. These fluid sheets in combination with the external flow of free air produce the boundary layer control and jet flap effects previously described.

In any fixed position of angular deflection, the auxiliary flaps 23, 23*a*, or 23*b* of either FIG. 1, FIG. 4, or FIG. 6 or the rotary cylinders 23*c* or 23*d* of FIGS. 7 and 8 may be moved at the will of the operator or pilot. Symmetrical movement of these auxiliary flap elements 23, 23*a*, 23*b*, 23*c*, or 23*d* on the opposite wings 10 of the aircraft can be employed to provide limited orientation of the resultant lift and drag vectors for control of the climb or glide slope of the aircraft. On the other hand differential movement of these elements 23, 23*a*, 23*b*, 23*c*, or 23*d* can be employed to provide correction of asymmetrical lift or lateral trim as well as primary roll control. Another means of providing lateral control is that of differentially regulating the height of the upper surface flap 31, 31*a*, or 31*b* and the adjacent opening 34, 34*a*, or 34*b*. The two means can also be used in various combinations.

In each case, i.e., the embodiments of FIGS. 1, 4, and 6, opposite ends of the flap elements 16, 16*a*, and 16*b*, 31, 31*a*, and 31*b*, and 25, 25*a*, and 25*b* are provided with suitable means to close the respective chambers 28, 28*a*, and 28*b* at all times. Such closure means may comprise any conventional structure and arrangement such as for example bellows or other expandible and collapsible sheets of suitable material. Elastic fabrics have also been employed in similar type applications. Since such closure means per se forms no part of the present invention, it is not illustrated lest it detract from the invention claimed.

While shown and described in what is believed the most practical and preferred forms or embodiments, it is apparent that departures from the illustrated specific structures will suggest themselves to those skilled in the art. Such variations and innovations may be made without departing from the spirit and scope of the invention as covered by the appended claims.

What we claim is:

1. A lift and control augmenter for an airfoil of an aircraft comprising:

a fluid-conveying duct mounted internally of said airfoil;

an articulated flap mechanism pivotally connected to the aft end of said airfoil and formed by hinged flap elements defining an internal fluid chamber communicating with said airfoil duct, said flap mechanism including a main flap, a pivotal and translational connection between said main flap and said airfoil, an upper and lower flap element hinged at one end at and along the aft end of said airfoil and adapted to overlie and define at least a portion of the exterior upper and lower surfaces respectively of said main flap, and an actuator between said airfoil and each said upper and lower flap element operative to deflect the latter relative to the former and concurrently move said main flap rearwardly along a path determined and described by said pivotal and translational connection;

a first fluid outlet from said chamber at and along the upper surface of said flap mechanism medially of the aft end thereof and the aft end of said airfoil;

a second fluid outlet adjacent the aft end of said flap mechanism, said first and second outlets being in a relatively closed position when said flap mechanism is disposed in its undeflected position relative to said airfoil; and

means to locate said outlets in a relatively open position and to regulate the effective transverse dimension of said

second outlet concurrently with the deflection of said flap mechanism.

2. The augmenter of claim 1 including a control associated with said second outlet to vary the direction thereof angularly relative to said flap mechanism.

3. The augmenter of claim 1 wherein said pivotal and translational connection includes an arcuate slot in said main flap, and a roller connected to and carried by said airfoil in constant engagement with said slot.

4. The augmenter of claim 1 wherein said pivotal and translational connection includes a lever pivotally connected at one end to the forward end of said main flap and at the other end to a fixed point relative to said airfoil aft of said forward main flap end when said flap mechanism is undeflected as aforesaid.

5. The augmenter of claim 4 wherein said lever is one arm of a bellcrank, the other arm of which is pivotally connected to a link pivotally connected in turn at its other end to said lower flap element aft of said fixed point.

6. The augmenter of claim 1 including an auxiliary flap at the aft end of said main flap mounted for rotation thereon to and from various deflected positions.

7. The augmenter of claim 6 wherein said auxiliary flap is rotatably mounted at the aft end of said main flap with its opposite surfaces disposed in the plane of the corresponding surfaces of the upper and lower flaps when in the neutral position, and said second outlet is disposed in a predetermined position about said auxiliary flap so as to discharge fluid when operative in preselected quantities adjacent the upper and lower surfaces of said auxiliary flap.

8. The augmenter of claim 6 wherein said auxiliary flap is rotatably mounted at the aft end of said main flap and is pierced by a passage in communication with said fluid chamber.

9. The augmenter of claim 7 wherein said quantity of fluid discharged adjacent the upper surface of said auxiliary flap is appreciably less than that discharged adjacent the lower surface of said auxiliary flap.

10. The invention of claim 1 wherein said airfoil is a fixed wing on each side of the fuselage of the aircraft and one said lift and control augmenter is associated with each said wing.