Mr. Eric Arnholdt
7108 Seacliff Road
McLean, Virginia 22101

Dear Eric:

The airfoil we are working with and the one you describe in your patent are similar only in that they both include a slot. However, the concept of the slot was invented at least thirty years ago; and of course, is no longer patentable. This is indicated by your claim in which the slot is obviously ungeneric. The shape of the airfoil that we are working with and the one that you have described are totally different. The upper surface on our airfoil has very gradual curvature while yours is built with extreme undulating curvature.

While you did not ask for comments on your airfoil, I assume that since you sent the letter you might be interested in comments. Your airfoil shape is based on a common misconception that lift is produced by an airfoil because the air travels farther on the upper surface than on the lower surface. As any aerodynamicist knows, this is not fundamental to producing lift. In fact, on the airfoil we are working with, the air travels farther on the lower surfaces than on the upper and yet this airfoil is more effective in producing lift at high speeds than any airfoil so far conceived.

Yours very truly,

Dr. Richard T. Whitcomb
Head, 8-Foot Tunnels Branch
Mr. Dick Whitcomb  
Mr. Jim Blackwell jr.  

Gentlemen,

I recently heard of your paper on tests with a supercritical wing and thought that you might be interested in a concept of mine which could conceivably be used to delay the shock until the trailing edge.

Attached you will find a copy of a patent issued to me recently which embodies the concept of an undulating upper surface and a tapering passage from the pressure side of the airfoil, exiting on the upper surface in the vicinity of the lower portion of the undulation.

While my thoughts were primarily directed towards a high activity low speed airfoil, I have mentioned the possibility of so designing the upper surface so as to prevent deceleration of the fluid flow on the upper surface from supersonic to subsonic until the flow reaches the trailing edge.

The drawing on the patent is only an approximation done by the illustrator; I visualize a sharper leading edge for any purpose. Also, the degree of undulation shown on the drawing may be a bit exaggerated.

It would appear to me that use of the undulating surface versus the flat top surface on which you ran your tests would result in a more even chordwise distribution of the low pressure area and a greater total lift coefficient.

The passage from the pressure surface to the top surface can be varied in shape and opening size to produce the desired flow and velocity emitted onto the top surface. Also it can be augmented, if desired, by use of bleed air.

I anticipate transferring to Argentina about July 1, and would appreciate hearing from you by that time.

Sincerely

Eric Arnholdt

P.S. While I am with F.A.A., I am not an engineer, but a flight operations pilot type. In a friend of Clay Staple.
This invention relates to improvements in airfoils, and has for its primary objects to provide an airfoil having an increased lift-to-drag ratio and thus an increased lifting or sustaining efficiency; to provide such an airfoil in which the span thereof may be substantially decreased in proportion to its chord, to secure more even distribution of the low pressure area over the airfoil, thus creating a more even distribution of the lifting or pulling force over the entire airfoil; and to provide such an airfoil which permits the use of a higher angle of attack and/or a lower relative velocity with respect to fluid through which the airfoil moves, without stalling or undue loss of efficiency.

It is known that the lift or pull over an airfoil section results from the low pressure area created by the acceleration of air or other fluid over its upper or suction surface. The amount of acceleration of the fluid and therefore the magnitude of the total pressure differential between the upper and lower surfaces of the airfoil is a function of the distance traveled by the fluid from the leading edge to the trailing edge as it flows over the oppositely directed surfaces of the airfoil.

Normally, in designing a high-lift airfoil, a greater acceleration of fluid over the top or suction surface is achieved by increasing the thickness or camber of the airfoil section. This, however, produces an increased drag by presenting a larger frontal or leading edge surface which, at higher velocities, results in a less efficient airfoil due to the less satisfactory lift-to-drag ratio which results.

The conventional airfoil section shape increases in thickness or camber from the leading edge to a point approximately 20% to 50% of the chord of the airfoil and then decreases in thickness or camber rather uniformly to the trailing edge. Thus, the greatest acceleration of fluid flow and the area of lowest pressure and greatest lift or pull is located at approximately 30% of the chord. The other areas on the upper or suction surface of the airfoil have a relatively slower fluid flow, and across the valleys between undulations, and generally, by transmitting fluid through a passage within the airfoil from the pressure surface thereof to the lower or suction surface for a greater portion of the chord of the airfoil than has heretofore been possible, for the purpose of achieving a more efficient airfoil having a lower aspect ratio. The advantages of this are obvious in instances where a short wing span or propeller or rotor diameter may be desired.

In accordance with the present invention, the path of flow of fluid over the upper or suction surface of the airfoil is materially increased by forming the suction surface of the airfoil is an undulating one in which the undulations extend spanwise of the airfoil, and by causing the fluid to pursue a path substantially conforming to these undulations in flowing across the suction surface of the airfoil. The means for achieving this latter function in accordance with the invention may assume varying forms so long as it is adapted to deliver air at high velocities into and across the valleys between undulations, and generally tangentially to the curvature of the bottoms of these valleys, the velocity of the fluid thus introduced being sufficiently greater than that of the fluid flow across the undulations from the leading edge to create a reduced pressure in the valley or valleys such as will deflect the mainstream of fluid into them and cause it to follow the curvature of the bottoms of the valleys as well as the crests of the undulations.

In one exemplification of the invention, this is achieved by transmitting fluid through a passage within the airfoil from the pressure surface thereof to the lower or bottom portion of the valley or valleys, and causing said fluid to be discharged into the valley or valleys in the form of constricted jet streams.

The foregoing and other features and advantages of the invention will be more readily apparent by reference to the accompanying drawings, in which:

FIGURE 1 is a cross-sectional view of an airfoil in accordance with one specific exemplification of the invention.

FIGURE 2 is a substantially enlarged section through a portion of the airfoil structure shown in FIGURE 1.

FIGURE 3 is a fragmentary plan view of the structure shown in FIGURE 2.

Referring now in detail to the accompanying drawings, and first considering the structure illustrated in FIGURES 1 to 3 inclusive, the airfoil which is designated 10 in its entirety has leading and trailing edges 11 and 12 respectively and relatively spaced pressure and suction surfaces 13 and 14 arranged so that as the airfoil moves through or relatively to a fluid, in the direction of its leading edge 11, the fluid will be divided by the leading edge 11 to flow across the opposed surfaces 13 and 14 and merge again after passing beyond the trailing edge 12. As is usual, the pressure surface 13, corresponding to the lower surface of an airplane wing or the rear face or surface of a propeller or the like, is substantially flat or has but a nominal curvature in the direction of the chord of the airfoil. However, the upper surface 14 is formed with a plurality of undulations, the crests of which are designated at 15, these being but two in FIGURE 1, though obviously there may be a considerably greater number of undulations and the chordal dimen-
sion of the airfoil may be increased to the extent neces-
sary to accommodate them.

The numeral 16 designates the valley between each pair of adjoining crests 15 of the undulations. As will be readily apparent from FIGURES 1 and 2, the crest por-
tions 15 of the undulations are convexly curved, while the valley 16 between them is concavely curved in such man-
ner that the faces of the valley areas 16 and 15 merge smoothly with each other.

For causing the fluid or air to follow an undulatory path over the suction surface 14 conforming substan-
tially to the undulatory curvature of said surface as de-
defined by the respective crests 15 and intervening valleys 16 thereof, the airfoil of the present exemplification is
formed with a fluid passage 17 communicating with the
valley 16 adjacent its bottom through a restricted orifice
or nozzle 18 which opens into the valley and is directed
substantially tangentially to the curvature thereof in a di-
rection chordally of the airfoil and rearwardly toward the
trailing edge 12 thereof.

It will be understood that air or other fluid may be sup-
plied to the orifice 18 from a suitable source which might conceivably comprise a compressor or compressors on an
aircraft of which such airfoil is a component. However, in the present embodiment, the fluid is caused to follow the
manner by arranging the passage 17 to extend completely through the airfoil structure and to open through its pres-
sure surface 13.

The passage 17 extends substantially diagonally for-
wardly or toward the leading edge 11 from its orifice 18
to its mouth 20 which opens through the lower or pressure
surface 13 of the airfoil. By virtue of the diagonal in-
clination of the passage 17, its enlarged mouth 20 may
function somewhat in the manner of an air scoop to de-

erate its pressure air stream which enters the valley 16 tan-

ciently along said suction surface and

14 will be through a substantially greater path than that
of the air flow over the pressure surface 13, due to the
fact that such air or fluid flow over the surface 14 is
carried to substantially follow the undulations thereof.

Thus as the fluid moves relatively past the leading edge
11, it is deflected upwardly to move over the crest area 15
adjacent the leading edge, following which it is deflected
downwardly toward the bottom of the valley 16 by the
inacting action of the inflowing high velocity and re-
duced pressure air stream which enters the valley 16 tan-
gentially to the curvature of its bottom through the re-
stricted orifice 18. In addition to deflecting the main air-
stream downwardly after the latter has passed over the
leading crest 15, the fluid jet issuing through the orifice 18
normally will have attained a higher velocity than the
main airstream and will impart added velocity to the lat-
ter, thereby further contributing to the reduction of air
or fluid pressure over the surface 14. The air or fluid
then will pass over the next succeeding crest 15, following
which the above-described action may be repeated by the
action of a further jet orifice 18' and associated supply
passage 17'.

Thus with the use of one or more orifices 18 in the val-
leys between adjoining undulations or following each und-
ulation, the suction or pressure surface 14 of the airfoil
14 of the airfoil may be caused to substantially follow the
curvature of the undulations to increase the length of its
path of flow and thereby to accelerate its flow to a high
velocity which may be maintained over substantially the
entire area of the suction surface 14, from the leading
to the trailing edge thereof. Because of the chordal dimen-
sion of the airfoil may be substantially

In this application, I have shown and described but a
minimum number of specific exemplifications of the
invention simply by way of illustration of the preferred
mode contemplated by me of practicing the invention.

Having thus described my invention, I claim:

An airfoil having conventional leading and trailing
edges, the leading edge being defined by a fixed para-

sides of the airfoil.

To increase the velocity and lower the pressure
of the fluid within the passage 17 as it passes ther-
through, the passage 17 is formed to converge toward its
restricted end or outlet orifice 18 in the manner which is
best illustrated in FIGURE 2.

As is shown in FIGURE 3, the passage 17, together with
its mouth 20 and discharge orifice 18, is substanc-
tially coextensive in a sparsely direction with the airfoil
structure in its entirety, being interrupted or bridged at in-

This air or other fluid is caused to enter the mouth 20 in the preferred embodi-
ment, both due to the scooping action of the mouth 20 as well as to the difference in pressure existing on opposite
sides of the airfoil.

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sides of the airfoil.
into bottom of said valley, whereby a stream of high velocity fluid is supplied into said passage and through said nozzle.

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MILTON BUCHLER, Primary Examiner.

B. BELKIN, Assistant Examiner.