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STALL WARNING INDICATOR

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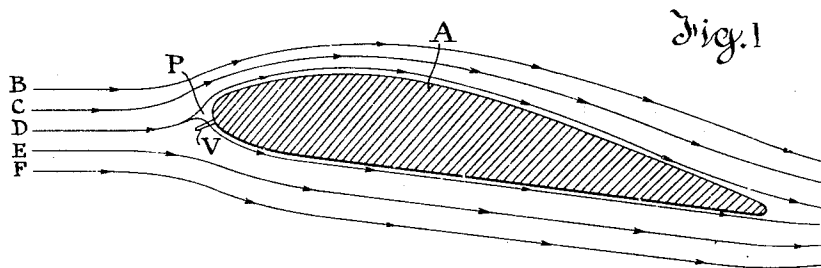


Fig. 1

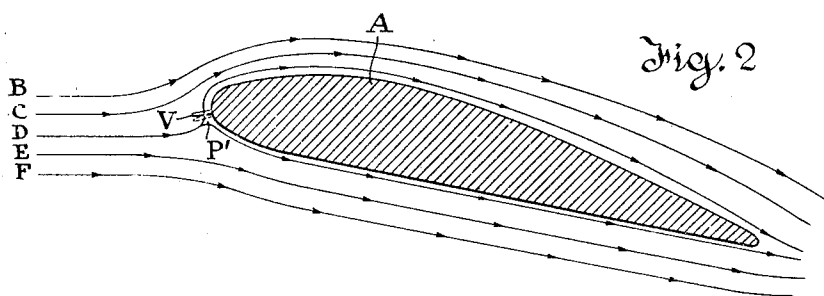


Fig. 2

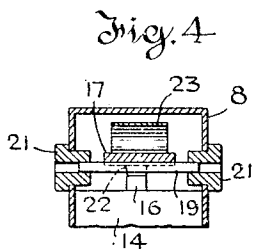


Fig. 4

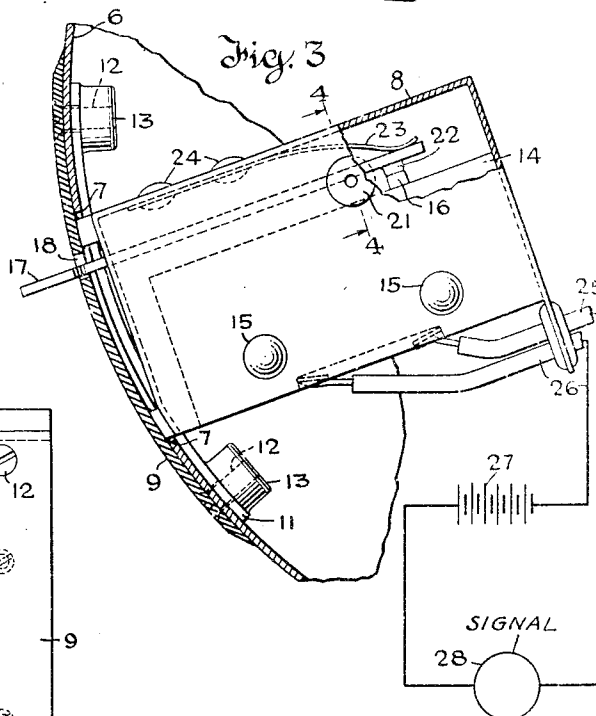
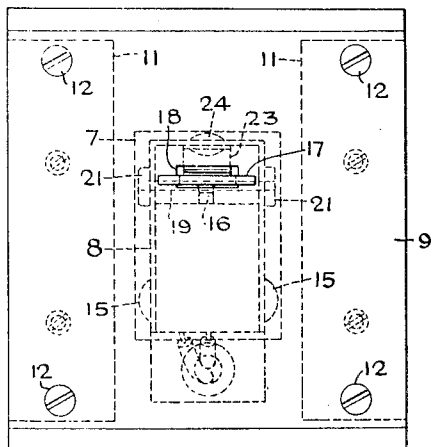


Fig. 3

Fig. 5



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STALL WARNING INDICATOR

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Commerce

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4 Claims. (Cl. 177-311)

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This invention relates to stall warning indicators for use in airplanes. The importance of such a device is indicated by the fact that at the present training rate in this country casualties attributed to stalls occur at the rate of two per week.

It is known that for any given airfoil the lift coefficient increases steadily with increased angle of attack until a critical value is reached. Thereupon, further increase of the angle of attack entails a sudden and marked decrease of the lift coefficient. This effect is independent of velocity, and is a concomitant of stalling. Angle of attack is thus a good criterion for determining the imminence of stalling conditions.

Stall warning devices dependent on this principle have been proposed, but have not met all requirements. In such devices, use was made of a forward-projecting vane remote from the airfoil, and hinged at its rear to swing between limit stops, so as to shift suddenly, if the angle of attack was increased beyond a chosen value known to be safe. Such devices are operative, but not very sensitive. They are subject also to secondary disturbing effects.

The present invention makes use of means to sense displacement of the separation point of the airfoil, which gives an intensified, sharper and more reliable indication of approach to the stalling angle. The separation point, some times called the stagnation point, is that point on the leading edge of an airfoil at which the air flow divides into two streams, one passing over and the other under the airfoil.

To sense the displacement of the separation point the sensing element should be at, or very near to the surface of the airfoil. Otherwise the crisp differentiation there offered by division into two sharply divergent flows will be impaired or lost altogether.

At the separation point the two flows diverge very sharply and in fact move in nearly opposite directions. Assuming that flying conditions are maintained, the separation point moves from an upper limit corresponding to a low angle of attack, to another and lower limit corresponding to the maximum permissible angle of attack. The sensing element which responds to the direction of flow is placed close to but not at the lower limit so that it will respond before stalling actually occurs.

The invention will now be described with reference to the accompanying drawings, in which

Figure 1 is a diagrammatic representation of the air flow past an airfoil under conditions of

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normal flight. In this view the normal position of a sensing vane is diagrammatically indicated.

Figure 2 is a similar view showing the airfoil at an angle of attack which slightly exceeds the safe limit and thus involves approach to stalling conditions. In this view the normal position of the sensing vane is indicated in dotted lines and the displaced or danger position in full lines.

Figure 3 is a section through the leading edge of an airplane wing, showing on an enlarged scale one form of stall warning indicator involving the invention. The parts are in normal position.

Figure 4 is a fragmentary section on the line 4-4 of Figure 3 indicating the form of the housing and the supporting bearings for the sensing element.

Figure 5 is a face view of the device shown in Figure 3.

Referring first to Figures 1 and 2, A represents a cross-section through a conventional airfoil and the stream lines B, C, D, E, F indicate paths of air flow around the airfoil. The middle line D divides at P, which is the separation point for the conditions indicated in Figure 1.

In Figure 2 a larger angle of attack is indicated, one assumed to be beyond a safe limit, but short of the stalling angle. In this figure the separation point has moved to P'. The letter V indicates some element for sensing the direction of flow. This element V will be assumed to be a shiftable vane which projects a short distance from the leading edge of the airfoil and is so located that it is below the separation point P in Figure 1 and above the separation point P' in Figure 2.

Thus the air stream in Figure 1 urges the vane V downward to the position there indicated. Under the conditions of Figure 2 the air stream acts reversely on the sensing element and urges it upward to the full line position indicated in Figure 2. This shift can be availed of to operate a signal so as to indicate by the upward movement of the vane that a dangerous or stalling condition is being approached.

It is by no means essential that a vane be used, but a vane very close to the leading edge of the wing is sufficiently sensitive and is the simplest sensing element which has so far been considered.

When a vane is used as the sensing unit, it is placed between the limits defining the extreme positions of the separation point so that the air stream will act reversely on the sensing unit before a stalling condition is reached.

A simple method has been devised to determine the separation point while in flight for any

desired condition of flight, but since this method is not a part of the invention, discussion is unnecessary. The invention contemplates that the sensing vane V will be located substantially at the point of transition from a safe to a risky angle. The location will be the same for all identical airfoils so that the mounting can be standardized for any standardized airplane.

In Figure 3 the skin 6 at the leading edge of an airplane wing has an aperture bounded at 7 and designed to pass the box-like housing 8 which is received within the wing and encloses the switch and switch actuating mechanism (the illustrated example being intended to control an electric signal circuit). Housing 8 is spot welded at its outer end to a mounting plate 9 which overlies skin 6, conforms to the wing contour and closes the aperture in the leading edge.

Clamping strips 11 are mounted behind the skin 6 at each side of the aperture and plate 9 is connected to these by screws 12 which pass through plate 9, skin 6 and engage locking sockets 13 carried by strips 11. In this way the skin is reinforced locally and the device is rigidly mounted, preserving the wing contour.

A "Microswitch" indicated by the numeral 14 applied to its body is fixed in housing 8 by rivets 15. "Microswitch" is a trade name for a switch of large capacity which shifts upon very slight axial actuating motion of its stem 16. Switches of this type can be had in single and multiple embodiments and can be had biased open or biased closed. Any type suited to the circuit or circuits to be controlled may be used but a single switch biased to open, and closed by axial inward motion of stem 16, is sufficient for illustrative purposes. The use of such a switch is assumed.

A vane 17 projects through a slot 18 in plate 9. The vane carries a journal pin 19 which turns in bearing bushings 21 fixed in housing 8. Behind fulcrum pin 19 the vane carries a thrust boss 22 which engages the stem 16.

If the outward bias on stem 16 could readily be made precisely what is needed the structure above described would be complete. However, it is desired to use commercial micro-switches, and in commercial switches as now manufactured the outward bias is somewhat greater than is desired. Hence a countervailing bow spring 23 is riveted to housing 8 at 24 so as to react in opposition to the bias exerted through stem 16 and reduce but not reverse the bias effective on vane 17. Figure 3 shows the device in its normal position, from which the vane will move the parts if subjected to an upward-flowing stream of air.

As a refinement the forward end of vane 17 may be made of frangible material, so that it will be demolished if struck. Thus mechanical injury to the sensing element destroys the instrument instead of rendering it unreliable though apparently operative.

The wires 25, 26 are part of any suitable signal or control circuit. This can be of any known form and typically might include some source 27 of electric current and some device 28, for example a visual or audible signal or some controller. The essential thing is that it attract the pilot's attention or set in motion some corrective mechanism. Such signals and controllers have been proposed and are typical of devices operable by the sensing mechanism which is the subject of the present invention.

Basically the invention recognizes the fact that stalling conditions are created by an excessive angle of attack however produced and the fur-

ther fact that the angle of attack can be most accurately determined during flight by sensing the position of the separation point.

Therefore the invention, as a method, contemplates sensing the displacement of the separation point and correcting the angle of attack in accordance with the indication of such displacement. The method is carried out even when the correction is made manually by the pilot. The method thus is broader than any particular mechanism used to assist in its performance.

While electric transmission of the response of the sensing device is simple, instantaneous and convenient, other signal transmitting mechanisms are known and could be substituted.

The device is intentionally made without adjustments. In assembling the desired characteristics are secured by careful selection of spring 23 and by filing boss 22. After switch 14 is attached by rivets the device is practically tamper-proof, and if damaged must be replaced as a unit.

The device is mounted on the wing with the vane 17 located according to the principles set forth as to vane V of Figures 1 and 2. Standardized templates can be used to assure its proper location on the particular wing for which it is designed.

While the shiftable vane is the simplest known sensing device, others could be used within the broad scope of the invention, and might control various signals through various intermediate connections.

What is claimed is:

1. The combination with an airfoil having a front separation point which shifts over the outer surface thereof with respect to a limit as the angle of attack varies, the approach to said limit substantially coinciding with the approach to stalling conditions, sensing means comprising a movable vane extending through the outer surface of said airfoil and having at least one portion located within the range of influence of said shifting separation point and arranged to function on approach of said point to said stalling conditions, and indicating means controlled by said sensing means.

2. A stall sensing unit for insertion in the leading edge of an airfoil, comprising a housing, a mounting plate conforming to the contour of the airfoil provided with a slot, a vane mounted within said housing and extending outwardly through said slot, means for biasing said vane toward normal operating position, and an electric switch operated by said vane, whereby when said unit is mounted in the leading edge of an airfoil within the limits of fluctuation of the separation point, said vane will be operated upon a movement of the separation point as the angle of attack approaches a stalling point of the airfoil.

3. The combination with an airfoil having a front separation point which shifts over the outer surface thereof with respect to a limit as the angle of attack varies, the approach to said limit substantially coinciding with the approach to stalling conditions, a stall sensing unit for insertion in the leading edge of the airfoil, comprising a mounting plate conforming to the contour of the airfoil and provided with a slot, a housing mounted on the concave side of the mounting plate, a vane mounted within said housing extending outwardly through said slot, an electric switch operated by said vane, means for biasing said vane toward normal operating position and indicating means operated by said sensing unit where-

by when said unit is mounted in the leading edge of said airfoil within the limits of fluctuation of the separation point, said vane will be shifted to give a warning when the angle of attack of the airfoil approaches a stalling point.

4. The combination with an airfoil having a front separation point which shifts over the outer surface thereof with respect to a limit as the angle of attack varies, the approach to said limit substantially coinciding with the approach to stalling conditions, sensing means comprising a movable vane extending through the outer surface of said airfoil and having at least one portion located within the limits of fluctuation of said shifting separation point and arranged to function on approach of said point to said stalling conditions, a support for said movable vane, and a mounting plate for said support adapted to conform to the curvature of the airfoil and to be secured thereto, and indicating means controlled by said sensing means.

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