Aug. 23, 1955 L. M. GREENE 2,716,228

AIRPLANE STALL WARNING DEVICES

Filed April 28, 1951 2 Sheets-Sheet 1

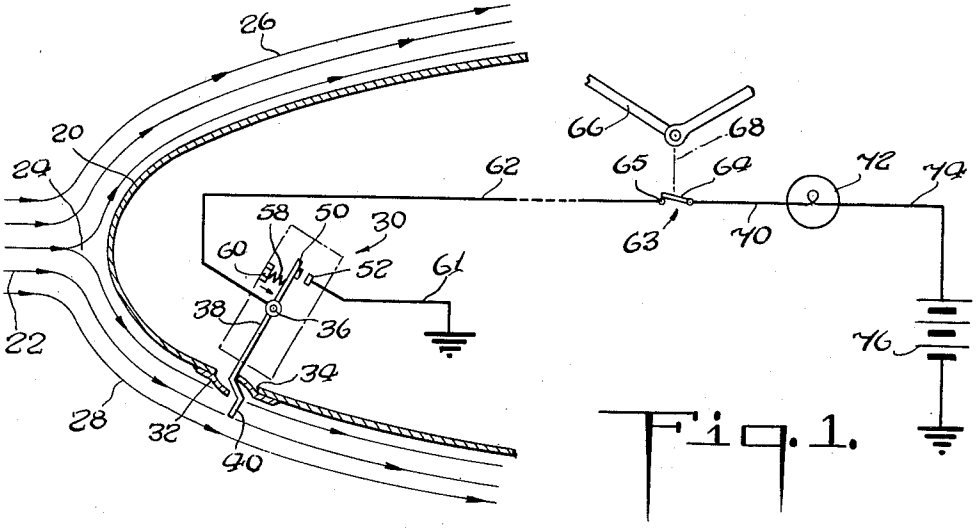


Fig. 1.

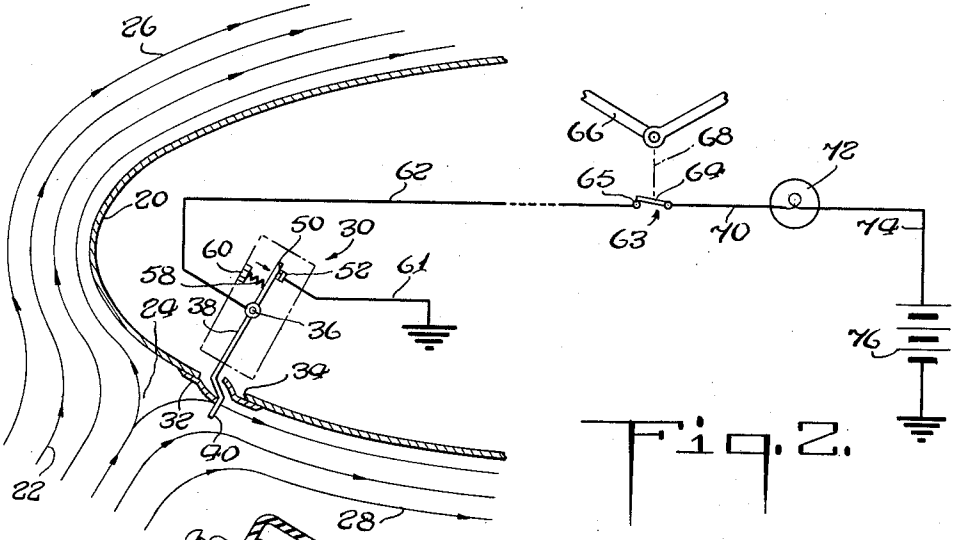


Fig. 2.

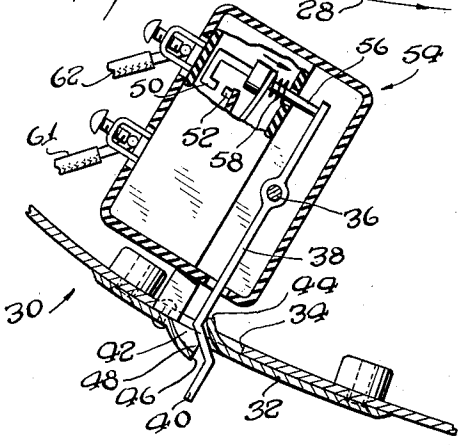


Fig. 3.

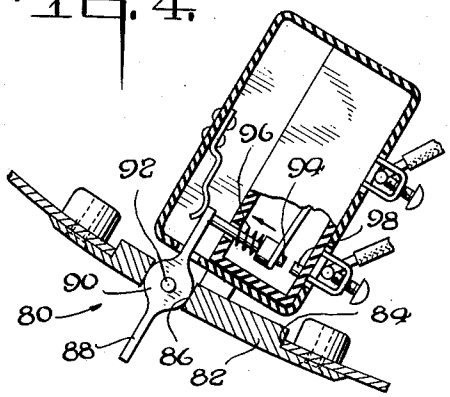
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Aug. 23, 1955 L. M. GREENE 2,716,228

AIRPLANE STALL WARNING DEVICES

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Fig. 4.



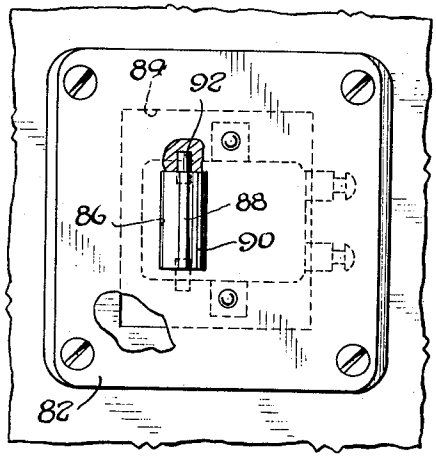
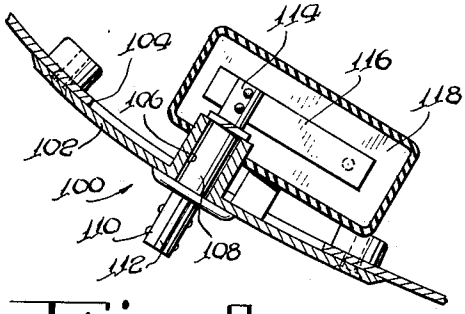


Fig. 5.

Fig. 6.



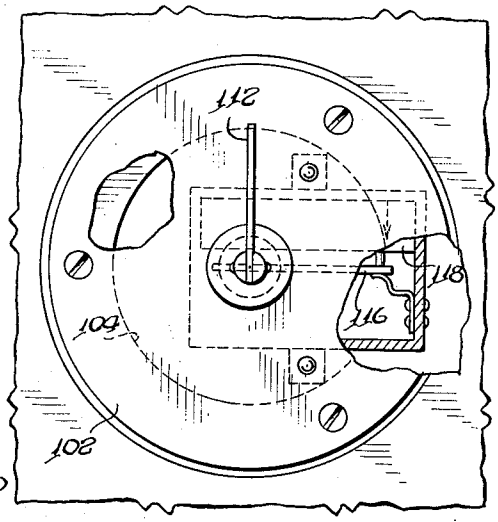


Fig. 8.

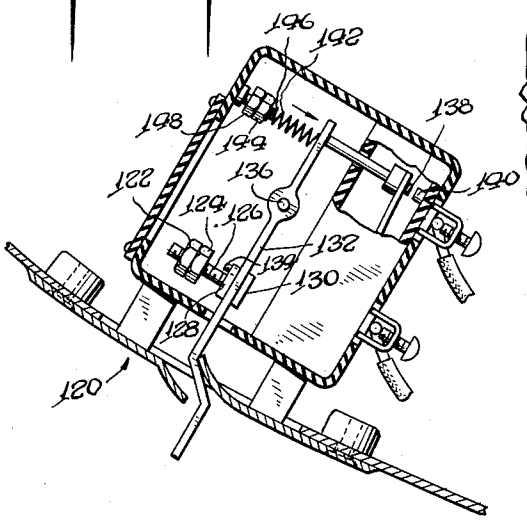


Fig. 7.

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2,716,228

AIRPLANE STALL WARNING DEVICES

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Application April 28, 1951, Serial No. 223,596

10 Claims. (Cl. 340—27)

This invention relates to airplane stall warning devices and, more particularly, is concerned with that type of stall warning device which is mounted on the nose of an airfoil and is operated by changes in the conditions of air in the region of the device (static pressure, kinetic pressure, direction of air movement, etc.) resulting from a shift in the position of the separation point with respect to the airfoil. Such shift is caused by a variation of the angle of attack of the airfoil relative to the local air mass so that the device properly might be termed an "angle-of-attack-responsive stall warning indicator," the device being set to give warning of danger when the angle of attack of an airfoil reaches a value at which stall is imminent.

A present-day commercial stall warning device of the character described includes a vane mounted on the nose of an airfoil in a position which is crossed by the downwardly moving separation point shortly before stall. The vane is arranged to actuate an electric switch. A biasing means, which may or may not be built into the switch, urges the vane downwardly and the switch to an open position. During safe flight the separation point is above the vane so that the air pressure acts in the same direction as the biasing means. Upon approach to stall the separation point will pass across the vane whereby the air pressure will oppose the biasing means but will not, at the point of crossover, attain an overriding value. At a predetermined prestall position, however, the air pressure will have reached a sufficiently high value to overcome the biasing means whereby to flip the vane up and close the switch, with consequent energization of a suitable alarm circuit. Thus, mere passage of the separation point over the vane is not enough to operate a vane to open-switch position; a slight overtravel of the separation point also is needed, such overtravel representing an increase in the angle of attack.

Since force is the primary consideration in flipping the vane, once the vane has been crossed by the separation point, factors other than angle of attack influence the amount of overtravel necessary to actuate the device. The principal additional factor is airspeed, an increase in which increases the force acting on the vane. As a result, the alarm will sound at a lesser angle of attack, i. e. earlier, for higher airspeeds and at an increased angle of attack, i. e. later, for lower airspeeds, despite the fact that there is no change in the angle of attack at which stall occurs. Although this variation is not a defect in a present-day commercial stall warning device of the character described because the device can be positioned to give at least the required degree of warning for the lower airspeeds, it is a drawback inasmuch as an additional unneeded and unwanted margin of warning is furnished at higher airspeeds.

It is pointed out that if stall is approached at or near the minimum speed necessary for level flight, the airplane must lose altitude in order to gain speed and thus maintain control. This loss of altitude represents a hazard if the stall occurs at a low flight altitude. Accordingly, an

ample margin of warning is required at low airspeeds. Approach to stall at high airspeeds normally can be avoided without loss of altitude and therefore does not require as much time for recovery. Hence a shorter warning is indicated. Nevertheless, a present-day commercial stall warning indicator functions in a manner just opposite to what is desirable, lowering the margin of warning where it should be increased and annoyingly increasing the margin of warning where it should be lowered.

Another and related drawback of current stall warning devices is that in gusty air, momentarily increased airspeed and angle of attack will cause intermittent operation of the device at slow, but safe, flight speeds. This is irritating and undesirable.

One phase of the present invention is concerned with the provision of a stall warning device of the character described which is not susceptible to the foregoing drawbacks.

More specifically, it is an object of this phase of my invention to provide a stall warning device of the character described which furnishes an increased margin of warning at low airspeeds and a reduced margin at high airspeeds and thus will enable a pilot to execute a normal slow speed landing approach in up to moderately gusty air conditions, and with the slight maneuvering accelerations required to control the airplane, without having these gusts or slight maneuvers intermittently set off the stall warning alarm.

Another phase of the present invention is concerned with structural improvements in a stall warning device of the character described.

Present-day commercial stall warning indicators are located within the nose of an airfoil, the vane being pivoted in back of the skin so that it is necessary to provide an aperture in the airfoil within which the vane can swing. This aperture permits entry of foreign particles which either could jam the vane or circulate within the hollow interior of the wing.

It is one of the objects of the second phase of my invention to provide a stall warning device having a construction such that no aperture is required in the nose of the airfoil for the vane to move to and fro.

It is another object of the second phase of my invention to provide a stall warning device of the character described wherein all or part of the bias on the vane is supplied by a variably positioned mass so that the operation of the device has certain flight response characteristics imparted thereto which differ from those obtained through the use of a purely spring-biased vane, the latter not being affected by an airplane's acceleration.

It is another object of the second phase of my invention to provide a stall warning device of the character described wherein means is provided to adjust the spring-biasing force on the vane so as to select or adjust the margin in advance of stall at which the device will give an alarm.

Other objects of my invention will in part be obvious and in part will be pointed out hereinafter.

My invention accordingly consists in the features of construction, combinations of elements and arrangements of parts which will be exemplified in the devices hereinafter described and of which the scope of application will be indicated in the appended claims.

In the accompanying drawings, in which are shown various possible embodiments of my invention,

Fig. 1 is a schematic circuit diagram including a fragmentary chordwise sectional view through the nose of an airfoil having mounted therein a stall warning device constructed in accordance with the present invention, said device being drawn to an oversize disproportionate scale for the purpose of illustration, the airfoil being shown

at an angle with respect to a local air mass corresponding to normal level flight;

Fig. 2 is a view similar to Fig. 1, but showing the airfoil at an increased angle dangerously close to stall, said angle being one at which the stall warning device will energize an alarm;

Fig. 3 is a cross-sectional, uniformly scaled, enlarged view through the device and a fragment of the skin of the airfoil;

Fig. 4 is a view similar to Fig. 3 of a stall warning device embodying a modified form of my invention;

Fig. 5 is a front view of the device shown in Fig. 4;

Fig. 6 is a view similar to Fig. 4 of a stall warning device embodying another modified form of my invention;

Fig. 7 is a front view of the device shown in Fig. 6; and

Fig. 8 is a view similar to Fig. 6 of a stall warning device embodying a further modified form of my invention.

Referring now in detail to the drawings, and more particularly to Figs. 1–4, the reference numeral **20** denotes the nose of a conventional chord-section of a standard airfoil. The streamlines **22** indicate the direction of flow of a local air mass. Said mass divides at a separation point **24** to form a stream **26** flowing above the wing and another stream **28** flowing beneath the wing.

Pursuant to the first phase of my invention I provide a stall warning device **30** which in Figs. 1 and 2 is shown to a disproportionate scale in order that the operation of the device may be more clearly understood. The actual size of the device is small in comparison to an airfoil. Said device includes a mounting plate **32** which is snugly secured over an opening **34** in the nose of the airfoil, the plate being suitably shaped to conform to the contour of the airfoil in its vicinity. The plate carries a pivot **36** on which a vane **38** oscillates about an axis parallel to the span of the airfoil. The tip **40** of said vane extends through an opening **42** in the plate whereby to project into the airstream. The rear edge **44** of the opening **42** acts as an aft stop for the vane **38** and the front edge **46** as a fore stop.

In order to minimize the area of the opening presented to the airstream, the aft edge **44** is offset inwardly of the airfoil, the fore edge **46** is offset outwardly, and the vane is formed with an offset **48** extending transversely of the length of the vane through the space between the aft and fore edges.

The device **30** further includes a pair of contacts **50**, **52**. One of the contacts, e. g. the contact **50**, is operated by oscillation of the vane **38**. The other contact **52** is stationary. For the sake of simplicity the moving contact **50** has been shown as being mounted directly on the vane and the other contact as being supported by the plate **32**. However, it will be understood that it is within the scope of my invention to employ a switch having an actuating element operated by movement of the vane. Such form of the device is preferred commercially and is illustrated in Fig. 3 wherein the reference numeral **54** denotes a single-pole, single-throw switch of a standard type in which a stationary and movable contact are contained in a casing having an actuating element **56** which controls the movable contact. Said actuating element projects through the casing and is engaged by the vane **38** for the purpose of operating the switch.

The device **30** further includes means for biasing the contacts together, that is to say, the contacts **50**, **52** and the switch **54** are of the type known as "normally closed." Furthermore, said biasing means urges the vane forwardly against the fore stop **46**. (The biasing direction for each spring herein is denoted by a small arrow shown alongside the spring.) In Figs. 1 and 2 I have shown a spring **58** provided for this purpose, said spring being held under compression between the far end of the vane **38** and a seat **60**. It will be obvious that, instead of having the compression spring located on the face of the vane opposite from the movable contact as shown, I may employ a tension spring located on the same face of the vane as said contact. Alternatively the spring could be disposed on the opposite side of the pivot **36** or a torsion spring at the pivot could be employed. Moreover, in a commercial embodiment of my invention the switch **54** may be of the type known as a "momentary" switch (see Fig. 3), this being a switch having its own biasing means for urging the contacts to an idle position, in this case a position in which the contacts are closed.

The mounting plate, vane, vane pivot, biasing means and switch jointly constitute a unitary assembly which is handled and installed as a single piece of equipment.

The contacts **50**, **52** are series connected in an alarm circuit. For example, a lead wire **61** running from the stationary contact **52** is grounded on the metal frame of the airplane. Another lead wire **62** runs from the movable contact **50** to an airborne-sensing switch **63** including a pair of contacts **64**, **65** which are normally open, i. e. biased apart. The movable contact **64** of the second switch is actuated in a closing sense by any suitable mechanism which affords a sure indication that the aircraft is airborne. One suitable mechanism is a landing gear torque knee schematically indicated at **66**. This knee forms part of the supporting structure of an airplane wheel, the knee being designed to yield slightly when transmitting the weight of the aircraft through its wheel to the ground. Accordingly, when the aircraft is on the ground the knee is tensed. A link **68** connects the knee to the actuating element of the switch **63** in such fashion that when the knee is relaxed it will close the switch and when the knee is tensed it will permit the switch to open.

A lead wire **70** runs from the switch **63** to an alarm or indicating device such, for instance, as a lamp **72**. Another lead wire **74** runs from the lamp to one terminal of a battery **76** or other suitable source of electric energy whose other terminal is grounded to the metal frame of the airplane. Thus, if the contacts **64**, **65** of the switch **63** are closed and the contacts **50**, **52** of the switch **54** are closed, the lamp will light. Said lamp is in the cockpit of the airplane and will serve as a warning to the pilot that a stall is imminent. Instead of a visual signal there may be substituted an audible signalling device such for instance as a horn which can be energized from the battery, or a tactile device such as a vibrator which is attached to the control stick of the airplane and likewise can be actuated from a battery.

The tip **40** of the vane is located on the lower forward surface of the wing, being situated at a region on said surface which is slightly aft of the separation point when the wing is at the pre-stall attitude for which a warning is to be given. In other words, as the separation point moves downwardly, upon approach to stall, the device is positioned to give a warning of the imminence of stall before the separation point reaches the tip of the sensing vane. In this respect the instant device differs from present-day commercial stall warning devices wherein the warning is not given until after the separation point has passed over the tip of the sensing vane.

During normal flight, the lower airstream **28** flowing from the separation point beneath the wing will force the vane **38** against the aft stop **44** holding the contacts **50**, **52** of the switch **54** open against the spring **58**. When the angle of attack increases, the separation point shifts downwardly and rearwardly toward the vane. As a near stall condition is approached the separation point moves quite close to the vane until the position shown in Fig. 2 is reached at which the air flow velocity in the region of the separation point is so considerably diminished so that the air pressure no longer is sufficient to hold the vane against the aft stop in opposition to the force of the spring **58**. Thereupon the spring **58** will shift the

vane to the fore stop **46** causing the contacts **50, 52** to close and the stall warning signal to be energized, providing that the switch **60** likewise is closed. From the foregoing it will be appreciated that a stall warning device embodying the present invention further differs from commercial stall warning devices in a second respect, to wit, that in a present-day device the biasing force urges the contacts to open position and the vane toward its aft stop, being overcome by air pressure to signal a stall warning, whereas in a device such as hereinabove described the biasing force urges the contacts to closed position and the vane toward its fore stop, overcoming air pressure in order to signal a stall warning.

In the use of a stall warning device embodying the present invention the air pressure holding the vane against the aft stop in opposition to the biasing force is greater at higher air speeds than at lower air speeds. Therefore, at higher air speeds the vane will close the switch contacts later, i. e. at a higher angle of attack closer to stall, so that said device has a lesser margin of warning at higher air speeds than at lower air speeds, this being a highly desirable feature.

Furthermore, in gusty air conditions the increase in the angle of attack caused by gusts will shift the separation point toward the vane, that is, toward a position of alarm. Nevertheless at the same time the increased air speed caused by the addition of the gust airspeed to the flight airspeed is in a compensating direction because it increases the pressure of air holding the vane in the non-stall warning position. Thus, gusts will not intermittently sound the alarm with the frequency of a commercial stall warning device.

When the airplane is on the ground and is either stationary or moving (during take-off), the air pressure acting on the tip of the vane may be insufficient to hold the vane against the aft stop, so that the contacts **50, 52** will close. This would sound the alarm despite the fact that no danger of stall exists. It is to prevent such an annoying occurrence that the airborne-sensing switch **63** is included in the circuit. This switch will have its contacts open as long as the landing gear torque knee is tensed under the weight of the airplane. But as soon as the airplane is airborne and stall danger can exist the switch **63** closes so that if then the air pressure acting on the vane does not suffice to hold it against the aft stop, the airplane is in a pre-stall position and it will be necessary to properly maneuver the same so as to avoid stall.

In Figs. 4 and 5 I have shown a stall warning device **80** embodying a modified form of my invention, the same being of such construction that there is not presented to the airstream an undesirable open space. In accordance with the instant embodiment of my invention such space is eliminated by pivoting the sensing vane for rotation about an axis parallel to the span of the airfoil and at or immediately adjacent the skin of the wing. More specifically, the device **80** includes a mounting plate **82** covering an aperture **84** in the skin of the airfoil and suitably secured thereto. The center of the mounting plate is formed with an opening **86** through which a sensing vane **88** extends. The portion of said vane located in the opening is thickened to form a shaft **90** whose opposite ends are indented in registry to receive the tips of pivot pins **92** lying substantially in the plane of the airfoil skin and supported by the mounting plate. The projecting portion of the vane which is located on the outer surface of the airfoil is adapted to function as a sensing means, while the portion of the vane located in the interior of the airfoil is adapted to function as the actuating element, i. e. the element for operating a pair of switch contacts.

It will be observed that the vane **88** is dynamically balanced, that is to say, the portions of the vane on both sides of the pivot have the same weight and the space from their centers of gravity to the pivot are equal. In contrast to a dynamically unbalanced vane such as shown in Fig. 1 which is influenced by acceleration, the vane **88** is not so affected.

The device **80** is suitably connected to an alarm or indicating device.

The location of the device **80** and the idle relationship of its contacts will depend upon the desired mode of operation. Thus, if said device is to operate in the same fashion as the first form described herein, the vane will be positioned slightly aft of the location of the separation point in the imminent pre-stall attitude of the airfoil and a contact **94** carried by the inner end of the vane will be biased by a spring **96** toward engagement with a contact **98**, said spring also biasing the sensing tip of the vane forwardly. During normal flight the air pressure acting on the outer end of the vane will force the vane against the aft stop and hold said contacts apart.

However, said device **80** may be constructed to operate as shown, described and claimed in my United States Letters Patent No. 2,478,967, issued August 16, 1949, for Stall Warning Devices for Airplanes. In that event the device **80** is so located that the separation point crosses over the vane shortly before the pre-stall attitude is reached and the contacts **94, 98** will be open in idle position, being biased thereto by the spring **96** acting as shown in Fig. 4 to urge the sensing tip of the vane aftwise.

Another form of stall warning device **100**, which presents no aperture to the airstream, is illustrated in Figs. 6 and 7. Said device **100** includes a mounting plate **102** covering an aperture **104** in the skin of an airfoil and suitably secured thereto. The center of the mounting plate is formed with a through opening **106** in which a shaft **108** is journalled, said shaft being transverse, and preferably substantially normal, to the skin of the airfoil. The shaft projects on both sides of the mounting plate. The outer end **110** of the shaft carries an eccentrically disposed vane **112** which extends in the same general direction as and preferably substantially parallel to the span of the airfoil. The vane may extend outward or inboard of the shaft.

The inner leg **114** of the shaft carries a blade **116** engaging a switch **118** which is carried by the mounting plate. This switch is of a conventional momentary type and includes two contacts and a biasing means. In the event the device **100** is to operate in the same fashion as the device **30**, the vane **112** is located slightly aft of the position of the separation point at incipient stall and the biasing means of the switch **118** urges the contacts thereof to closed position and the vane toward its foremost position. Should the device **100** be constructed for use in accordance with my aforesaid Letters Patent, the vane **112** will be positioned to be crossed by the separation point slightly prior to incipient stall and the biasing means of the switch **118** will urge the contacts thereof to open position and the vane toward its extreme aft position. In either event said device **100** will be suitably connected to an alarm or indicating device.

Another stall warning device **120** embodying my invention is shown in Fig. 8. The stall warning device **120** is similar in all respects to the device **30** except for the biasing means. In the device **120** said biasing means constitutes both a weight and a spring. The weight consists of a pair of nuts **122, 124** screwed on a threaded spindle **126** having an end **128** formed with a shoe **130** which is slidable along a vane **132**. Said shoe carries a set screw **134** for holding the weight in any adjusted position. The weight may be located on either side of the pivot pin **136** for the vane. The location of the vane, and whether its contacts **138, 140** are normally open or closed, is determined, as noted heretofore, by the mode of operation desired for the stall warning device **120**.

It will be understood that by using a weight for furnishing the biasing force on the vane and contacts, by virtue of the moment of the weight about the pivot I am

able to incorporate in the stall warning device additional flight response characteristics and, more particularly, a characteristic which is a function of the value and direction of normal acceleration acting on the airplane, so that the action of the stall warning device will further be modified by the absolute attitude (attitude with respect to the earth) of the airplane and by acceleration as well as by the angle of attack with respect to the local air mass.

The biasing means for the vane **132** further includes a compression spring **142** abutting at one end against the vane and at the other end against a variably positioned seat constituting by way of example a nut **144** screwed on a threaded rod **146** carried by the mounting plate. A lock nut **148** screwed in the spindle holds the nut **144** in any adjusted position.

Depending upon the nature of the response required to different flight conditions the two biasing means can be adjusted to give different degrees of influence from zero upward.

Each of the devices **80**, **100** and **120** is designed and adapted to be handled and installed as a single unit.

It thus will be seen that there are provided devices which achieve all the objects of my invention and are well adapted to meet the conditions of practical use.

As various possible embodiments might be made of the above invention, and as various changes might be made in the embodiments above set forth, it is to be understood that all matter herein described, or shown in the accompanying drawings, is to be interpreted as illustrative and not in a limiting sense.

Having thus described the invention, I claim as new and desire to secure by Letters Patent:

1. In combination, an airfoil having a separation point which shifts over the nose thereof with respect to a limit as the angle of attack varies, the approach to said limit substantially coinciding with the approach to stall conditions, a movable vane, a pair of contacts actuated by said vane, said vane being in one position when the contacts are open and in another position when the contacts are closed, and means to bias said vane to contact-closed position, said vane being disposed slightly aft of the location of the separation point as said point approaches said limit.

2. In combination, an airfoil having a separation point which shifts over the nose thereof with respect to a limit as the angle of attack varies, the approach to said limit substantially coinciding with the approach to stall conditions, a vane mounted for movement fore and aft of the airfoil in a region slightly aft of the location of the separation point as said point approaches said limit, a switch actuated by said vane, and means to bias said vane fore.

3. In combination, an airfoil having a separation point which shifts over the nose thereof with respect to a limit as the angle of attack varies, the approach to said limit substantially coinciding with the approach to stall conditions, a vane mounted for movement fore and aft of the airfoil in a region slightly aft of the location of the separation point as said point approaches said limit, a normally closed switch actuated by said vane, and means to bias said vane fore.

4. A stall warning device for installation on a leading edge of an airfoil in a region slightly aft of the location of the separation point as the airfoil approaches stalling conditions, said device including a mounting means, a vane carried by said mounting means, means supporting said vane on said mounting means for movement between a fore position and an aft position, and means biasing the vane to the fore position and an indicating means actuated by said vane.

5. A stall warning device for installation on a leading edge of an airfoil in a region slightly aft of the location of the separation point as the airfoil approaches an attitude of stall, said device including a mounting means, a vane carried by said mounting means, means supporting said vane on said mounting means for movement between a fore position and an aft position, means biasing the vane to the fore position, and a switch having a pair of contacts in closed position when the vane engages the fore stop and in open position when the vane engages the aft stop.

6. A stall warning device comprising a mounting means for securing the device to the leading edge of an airfoil within the range of influence of the shifting separation point, a shaft, means to secure said shaft to said mounting means for rotation about an axis transverse to the general plane of the airfoil in the region of the mounting means, the outer ends of said shaft projecting beyond said mounting means, an eccentric vane carried by said outer end and extending in the general direction of the span of the airfoil, and a switch arranged to be actuated by rotation of said shaft.

7. A stall warning device comprising a mounting means for securing the device to the leading edge of an airfoil within the range of influence of the shifting separation point, a sensing vane, means to pivotally secure said vane to the mounting means for movement in a generally fore and aft direction, means to bias said vane in a chordwise direction, said means including a mass carried by said vane, means to selectively adjust the position of said mass with respect to the axis of pivoting and an indicating means actuated by said vane.

8. A stall warning device comprising a mounting means for securing the device to the leading edge of an airfoil within the range of influence of the shifting separation point, a sensing vane having a tip projecting from the external surface of the mounting means, means to mount said vane for fore and aft movement, a spring arranged to bias said vane in a chordwise direction, means to vary the biasing force of the spring, and a second means to bias said vane in a chordwise direction, said means including a mass carried by said vane, means to selectively adjust the position of said mass with respect to the axis of pivoting and an indicating means actuated by said vane.

9. In combination, an airfoil having a separation point which shifts over the nose thereof with respect to a limit as the angle of attack varies, the approach to such limit substantially coinciding to the approach to stall conditions, a vane, means to mount said vane for fore and aft movement, fore and aft stops for limiting the movement of said vane, means to bias said vane against the fore stop, said vane being disposed slightly aft the location of the separation point as said point approaches said limit and an indicating means actuated by said vane.

10. In combination, an airfoil having a separation point which shifts over the nose thereof with respect to a limit as the angle of attack varies, the approach to said limit substantially coinciding with the approach to stall conditions, a vane mounted for movement fore and aft of the airfoil in a region slightly aft of the location of the separation point as said point approaches said limit, means to bias said vane fore and an indicating means actuated by said vane.

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