To: Mr. Chas J. McCarthy

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

SPECIAL REPORT 9

PRESENT STATUS OF LATERAL-CONTROL DEVICES

FOR USE WITH SPLIT FLAPS

By Fred E. Weick
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The increased use of split flaps for the dual purpose of reducing the landing speed and shortening the landing glide of airplanes has established as acute the problem of obtaining satisfactory lateral control to be used in conjunction with the flaps without the sacrifice of any of the effectiveness of the flaps. A large amount of work is being done on this problem by various organizations and individuals. Several of the devices developed seem usable, some of them unquestionably so. The present paper attempts to summarize the most promising results obtained to date.

I. Ordinary Ailerons

Ordinary ailerons as now used on conventional airplanes give satisfactory lateral control at angles of attack in the ordinary flying range below the stall, but do not give control above the stall. The hinge moments, and therefore the control force required to operate the ailerons, can be held within satisfactory limits by means of any of several forms of balance arrangement. Ordinary ailerons may be used in conjunction with split flaps in any of the three arrangements shown below.

A. <u>Conventional ailerons with flap confined to inner portion of wing (fig. 1)</u>. - With this arrangement a part of the span of the flap must be sacrificed. With the ailerons covering approximately 40 percent of the span of the wing, a split flap over the remaining 60 percent will give between two thirds and three fourths of the lift increase obtainable with the flap along the entire span. If, as seems to be true in some cases, the increase in drag at low speeds is the main feature desired from the flap, the drag of the partial-span flap can be increased by deflecting it to a larger angle than that giving the highest lift coefficient (this can be done with no great

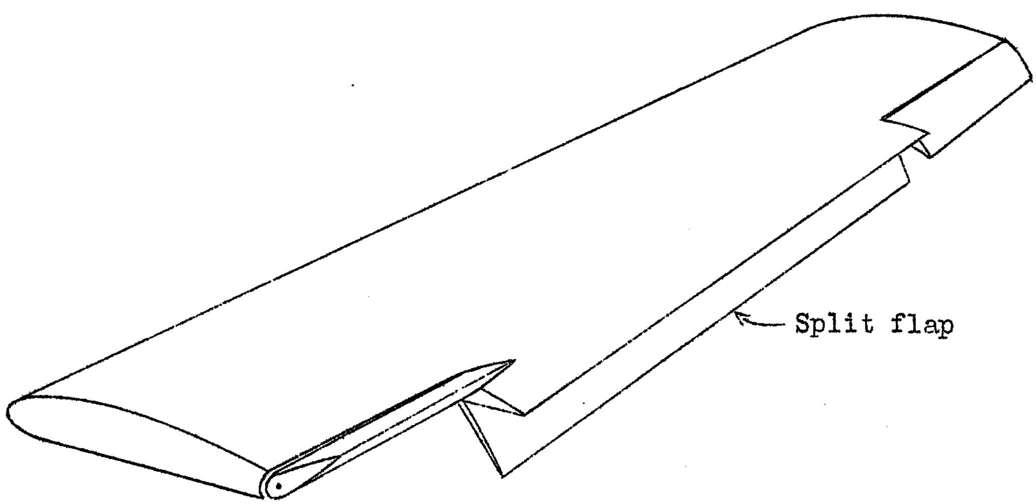

Figure 1.- Conventional ailerons with flap confined to inner portion of wing.

loss in lift if the flap is not cut away at the center also), and this arrangement with ordinary ailerons should be reasonably satisfactory in regard to both performance and control. Inasmuch as outboard ailerons have been satisfactorily used with other kinds of flaps in the center portion of the wing in several cases, no further tests of this arrangement seem required at the present time.

B. Simple split flap ahead of narrow conventional ailerons. - A split flap can be located in the under surface of the wing ahead of conventional ailerons. When retracted the arrangement is as shown in figure 2(a). If a simple form of split flap is used which is hinged at its forward edge, the appearance when deflected is as shown in figure 2(b). The flap in this forward position gives somewhat less than three fourths of the lift increase of the same flap in the usual rear position (see N.A.C.A. T.N. No. 422), the loss in lift being about the same as with case A above. Wind-tunnel tests indicate that reasonably satisfactory control should be possible at angles of attack below the stall with the flap in either the deflected or the retracted position.

C. Split flap deflected rearward and downward. - If, as shown in figure 2(c), the split flap ahead of the aileron is moved to the rear as the trailing-edge portion is deflected downward, a double advantage is obtained. The deflected flap is located in the most effective region for

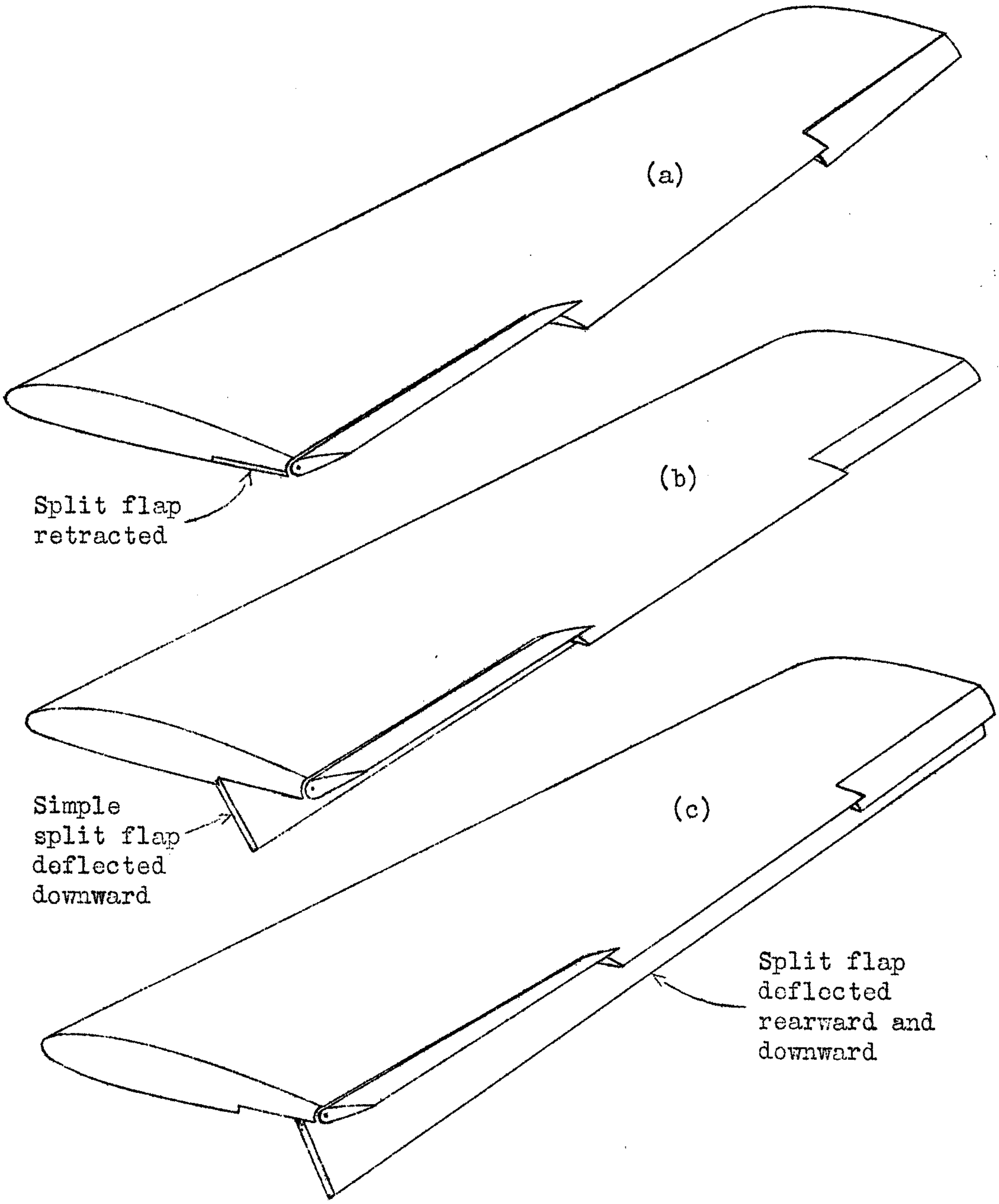

Figure 2.- Split flaps mounted ahead of narrow conventional ailerons.

high lift (T.N. No. 422), and the force required to deflect the flap is reduced. Recent tests in the N.A.C.A. 7 by 10 foot wind tunnel show that conventional ailerons with any of the conventionally used deflection linkages (equal up-and-down or differential) will give reasonably satisfactory rolling and yawing moments at angles of attack below the stall with the flap deflected in the position illustrated in figure 2(c). With the flap retracted, the wing and ailerons operate in the normal manner of present conventional airplanes. The narrow ailerons should require reasonably low control force, but if desired, they may be balanced to reduce the hinge moments by any of the ordinary means, such, for example, as the inset hinge. The arrangement shown in figure 2(c) seems the most satisfactory of those combining split flaps with ordinary ailerons, and it is now being fitted to a small parasol monoplane for flight tests at Langley Field, Va.

II. External Ailerons

Two promising locations have been found for external ailerons, or ailerons composed of separate airfoils attached to but apart from the main wing. One of the favorable locations is just above the trailing edge of the main wing, and the other is just above the nose. In either case, the external ailerons give a slight increase in drag over that with conventional ailerons which fall within the contour of the wing.

A. External ailerons just above the trailing edge (fig. 3). - This form of aileron has been used by Mr. E. F. Zaparka on airplanes equipped with the Zap flap. Recent development work which has been carried on by Mr. Zaparka in conjunction with the B/J Company is described in a paper given a short time ago before the A.S.M.E (reference 1).

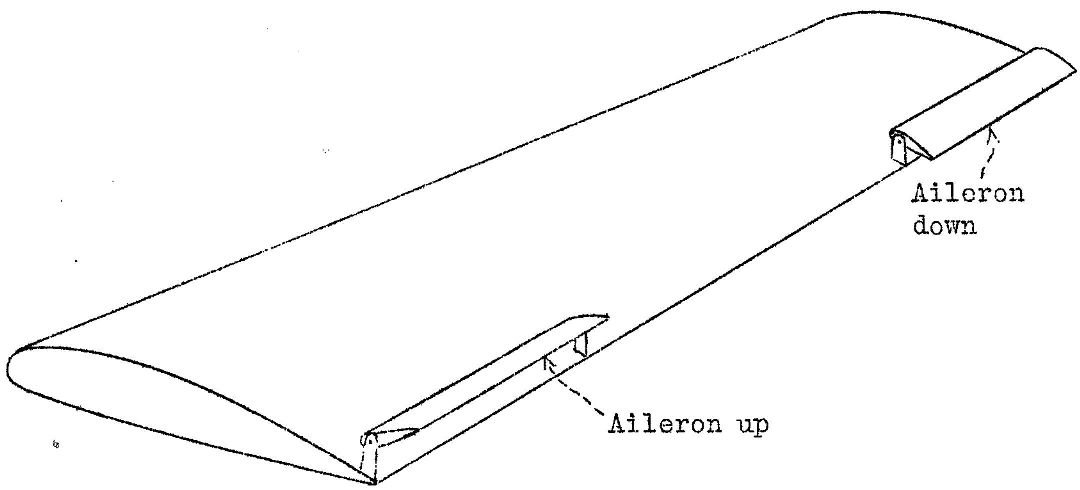

Figure 3.-External ailerons above trailing edge of wing.

Wind-tunnel tests made for the Zap Development Corporation, and also tests made by the National Advisory Committee for Aeronautics (not yet published) show that, when ailerons of this type are given a suitable differential motion, rolling moments of moderate magnitude are obtained at angles of attack below the stall. The rolling moments are slightly higher with a split flap fully deflected than with it retracted. The ailerons are similar to ordinary ailerons in that the rolling moment coefficients are approximately constant over the angle-of-attack range below the stall and then fall off above it, but they are unlike ordinary ailerons in that they are free from adverse yawing moments, which fact should make them less dangerous than the ordinary ailerons at the angles of attack above the stall. Flight tests have borne out these conclusions, but have also brought out the fact that the control forces required are very great at high aircraft speeds (reference 1). If the aileron hinge axis is moved sufficiently far to the rear to give a reasonable control force at high speed on a fast airplane, the ailerons will be overbalanced at low speeds. This condition has been partly overcome by work which is still being carried on by the Zap Development Corporation in conjunction with the B/J Company, in which the aileron airfoils are provided with fixed slots.

B. <u>External ailerons located above the nose portion of the wing (fig. 4)</u>. - N.A.C.A. wind-tunnel tests (not yet published) have shown the position just above and slightly back of the leading edge of the main wing to give higher rolling moments than most others, as well as satisfactory yawing moments. The rolling-moment coefficient increases in magnitude as the angle of attack is increased up to and through the stall (these ailerons are similar to spoilers in this respect), and fair values are maintained to very high angles of attack. This location has also been found

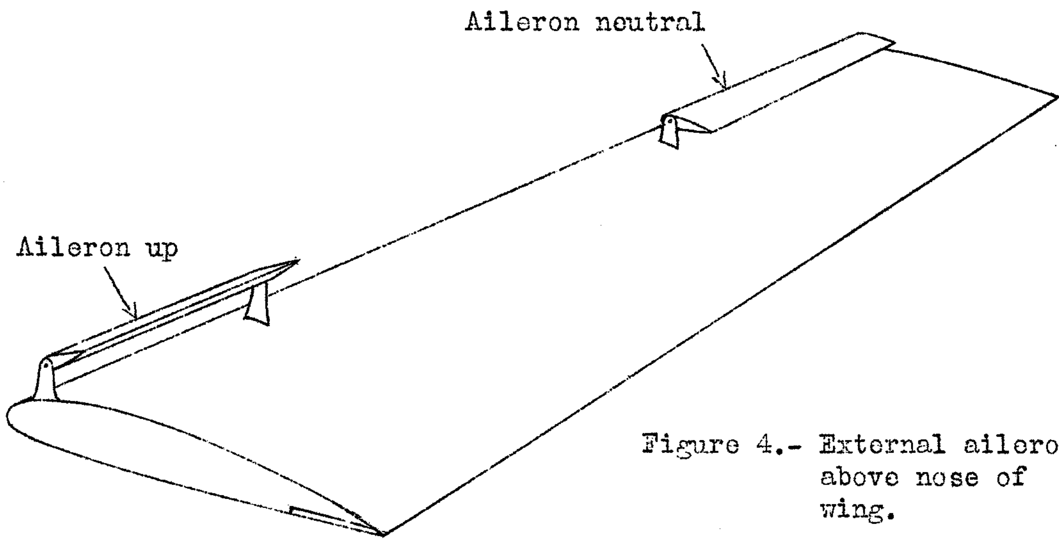

Figure 4.- External ailerons above nose of wing.

promising in an investigation carried on during approximately the same period as the N.A.C.A. tests at California Institute of Technology, in cooperation with the Douglas and Northrop companies (reference 2). Flight tests have been made on external ailerons in approximately this same location both by the National Advisory Committee for Aeronautics at Langley Field and by the Douglas and Northrop companies on the West Coast. In the West Coast tests the ailerons were given an extreme differential motion, and a lag or delayed action was found to exist when the controls were deflected. In the tests at Langley Field, the ailerons were given two types of deflection, in both of which the ailerons were moved one at a time. With one type of deflection the trailing edge of the aileron was moved up only, and with the other type the trailing edge was moved down only, these opposite deflections being selected because the wind-tunnel tests showed that moving the aileron in either direction from a critical neutral position reduced the lift on the adjacent portion of the wing. When tested in flight, these ailerons also had lag when given the deflection in which the trailing edge moved downward, but they were free from lag when the trailing edge was given the individual upward deflection. In the ordinary flying range the acceleration in roll was found to be only about half as great as that obtained with ordinary ailerons of approximately the same size, but the final rate of roll was greater than that obtained with ordinary ailerons. The latter condition was not considered advantageous by the pilots. The ailerons gave moderate control at the angles of attack above the stall. As in the case of the external ailerons in the rear position, however, the control force was found to be high at the high speeds, even with the aileron hinge axis moved as far back as possible without resulting in overbalance at low speed. The work dealing with external ailerons in the forward location is still in progress, both on the West Coast and at Langley Field.

III. Floating Ailerons

The most promising types of floating ailerons may be classed as external ailerons also, because they are not a part of the useful or lifting portion of the wing. Two forms of floating aileron have been developed which appear feasible for use in connection with wings having flaps. One of these is the narrow-chord type such as that used on the Curtiss Tanager, which is suitable for use in connection with an externally braced or biplane-type structure (fig. 5). The other is the floating-tip type on a highly tapered wing (fig. 6) (reference 3), somewhat similar to that used on the original Stout "Sky Car." Both types give reasonably good lateral control with moderate rolling moments and no appreciable yawing moments. Both give control at angles of attack above the stall, and they also improve the lateral stability above the stall to some extent. With the narrow-chord type as used on the Tanager, it may be difficult to secure sufficient control without obtaining high-control stick forces, and the drag of the supports must be appreciable. The floating aileron on the tip of an exter-

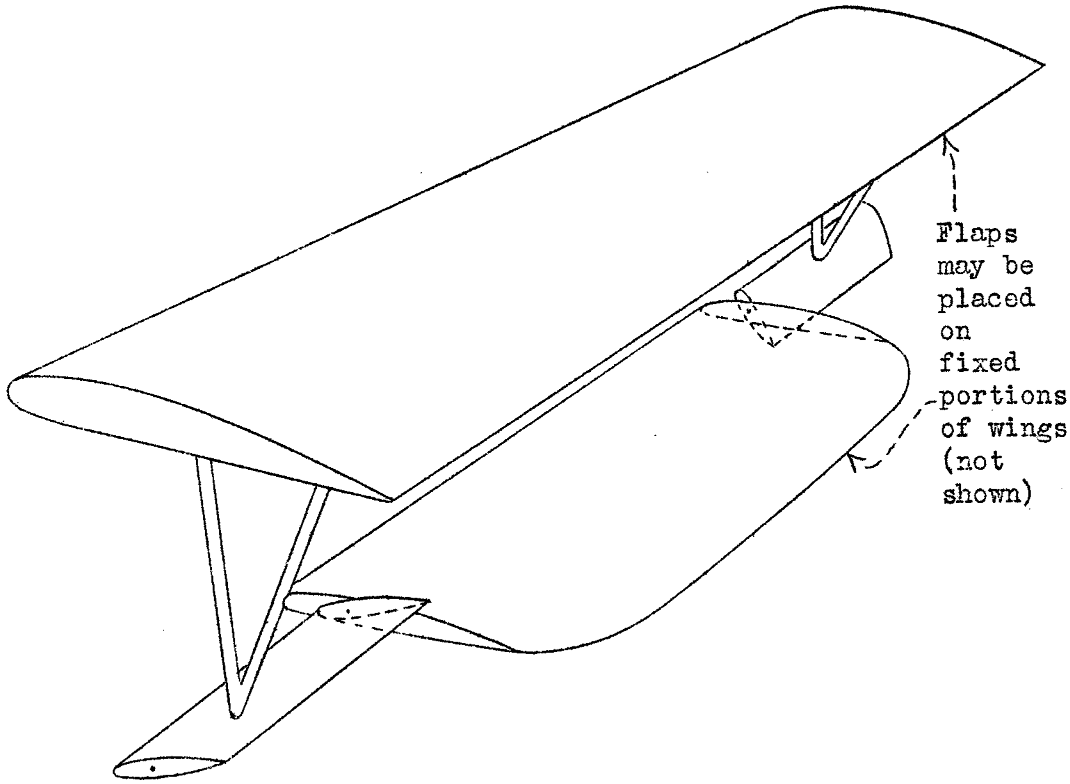

Figure 5.-Narrow chord floating ailerons on biplane type structure.

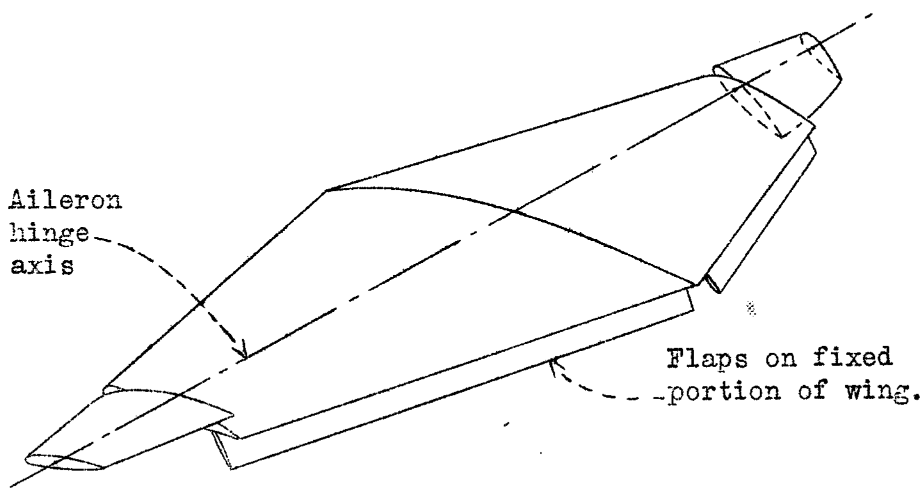

Figure 6.-Floating tip ailerons on highly tapered wing.

nally tapered wing should give no particular difficulty in either of these respects but the over-all span must be increased, the span of the fixed portion of the wing being determined by the climbing performance desired. Both types of floating aileron have been flown with reasonably satisfactory results. It is thought that further flight tests of floating ailerons on an airplane with a highly tapered wing may be desirable, but due to the pressure of other work none are scheduled for the immediate future.

IV. Upper-Surface Ailerons

These ailerons are formed by deflecting the upper trailing-edge portion of the wing which is left above the split flaps (fig. 7). They are deflected upward individ-

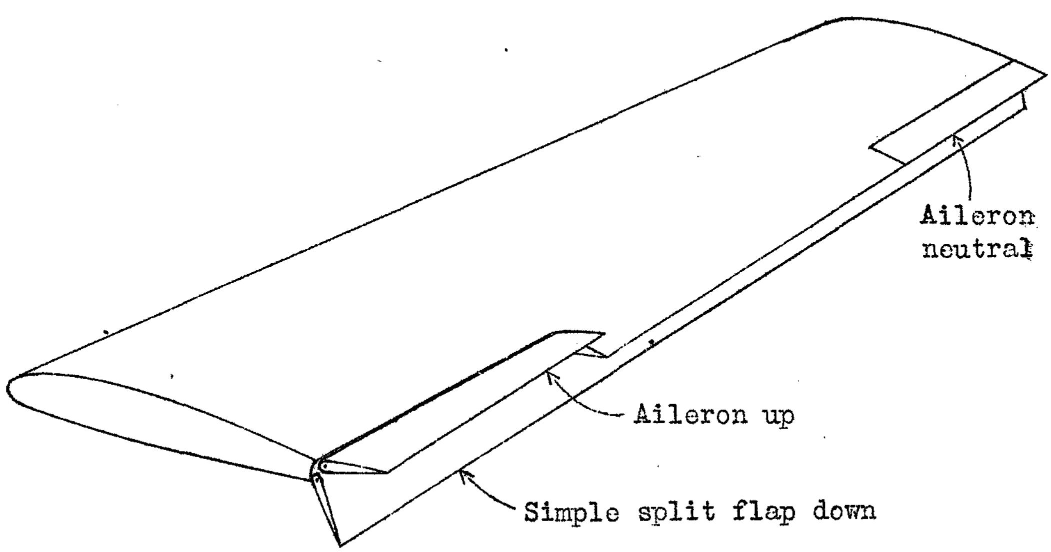

Figure 7.- Upper surface ailerons.

ually. Wind tunnel and flight tests made at Langley Field both show that while moderate rolling control can be obtained at angles of attack below the stall with the flap either deflected or retracted, if simple unbalanced upper-surface ailerons are used the control forces required are excessively high even though the ailerons have a narrow chord. Work is now being carried on in the 7 by 10 foot tunnel to investigate the possibility of obtaining suitable reduction of hinge moment by means of proper hinge location and aileron shape.

V. Spoilers

Various spoiler arrangements have been tested by the National Advisory Committee for Aeronautics both in the wind tunnel (references 4 and 5) and in flight (not yet published). These spoilers have consisted essentially of plates or surfaces arranged to project from the upper surface of a portion of the wing in order to reduce the lift over that portion. The spoilers located near the nose of the wing gave control at angles of attack above the stall, but unfortunately had a definite lag or delayed action due to an initial but imperceptible tendency to roll in the wrong direction. The time from the deflection of the control to the start of the roll in the desired direction averaged about one half second, which is sufficient to eliminate the spoilers in that location as a possible satisfactory control. The lag was found in flight with each of the three different forms of spoiler tested; the first being a flap set in the upper surface and hinged at the front edge; the second, a retractable spoiler projecting out through a slot in the upper surface of the wing; and the third, the retractable spoiler cut to saw-tooth form. These results seem to eliminate the spoiler located in the forward portion of the wing as a satisfactory lateral-control device when used by itself but, if control above the stall is of sufficient importance, a satisfactory arrangement free from lag can be obtained by the proper combination of spoilers and ordinary ailerons. The spoilers can be arranged to reduce the aileron hinge moments, if desired, either by means of their location or their connecting linkage.

In regard to control at angles of attack above the stall, the flight tests have shown that the lateral instability above the stall may be so violent as to eliminate the possibility of handling the airplane satisfactorily even with an effective lateral control. This seems to indicate that even for occasional emergency use only, control above the stall may have but slight value unless it is accompanied by stability.

If the spoilers are moved sufficiently far back along the chord of the wing, there is no doubt that the lag can be eliminated for there is no lag with the upper-surface ailerons, which are the same as the flap-type spoilers in the rearmost possible position. Unfortunately, however, as the spoiler is moved back its effectiveness in giving control at angles of attack above the stall is lost. The present plans are to continue flight tests to find the most forward spoiler location free from lag. The next test will be made with the retractable-type spoilers near the trailing edge of the wing (fig. 8), where they will give approximately the same rolling and yawing moments as the upper-surface ailerons but with the advantage of very low control forces, for with this type of spoiler the hinge moments can be made to be practically zero.

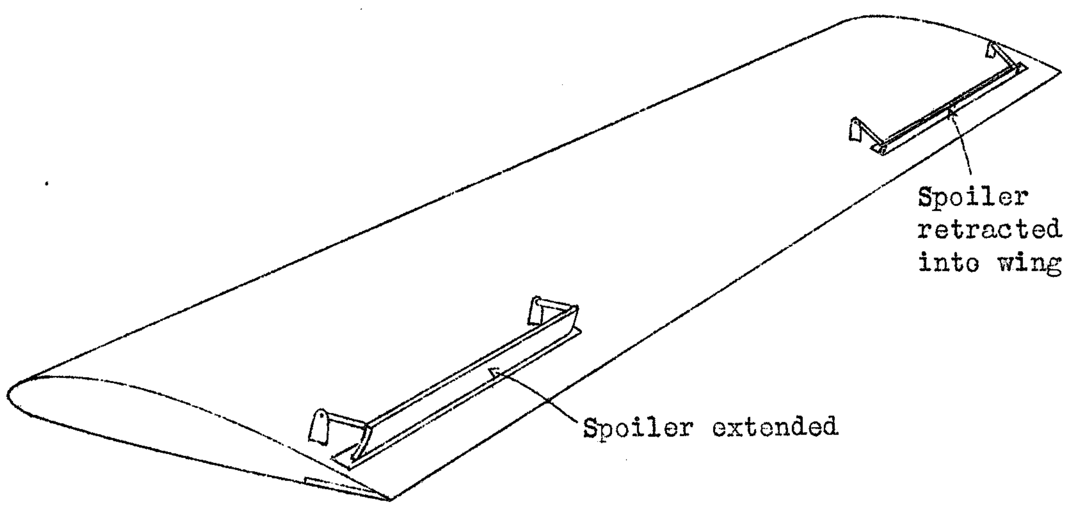

Figure 8.- Retractible spoilers.

Concluding Remarks

Considerable work is being done on the problem of providing satisfactory lateral-control devices for use with split flaps, and several forms under development show promise, but no form giving full benefit of a properly located full-span flap has as yet been proved entirely satisfactory in flight. Although the external ailerons above the trailing edge of the wing and the spoilers at the rear of the wing both appear quite promising, it would seem that probably the most satisfactory immediate solution of the problem, including the obtaining of light and smoothly graduated control forces, would in most cases be obtained by the use of the arrangement in which the flap is retracted ahead of ordinary narrow-chord ailerons and is deflected to the rear as well as downward when in use (fig. 2(c)).

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., August 8, 1933.

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