The invention is concerned with an airplane wing having one or a plurality of flaps movably connected to the trailing edge of the wing for deflecting the propeller slip stream for producing lift and also for producing drag, for example, when landing the aircraft of which the wing forms part. The flap according to the invention, or the rearmost flap in the case of a plurality of flaps has a pronounced concave underside and a very small side angle at the trailing edge of the flap. When the flap is in retracted position, as for normal flight, the underside is covered by platelike elements so that it is not concave and, upon extension of the flap, as for starting and landing, the cover element or elements is or are moved to such position as to render the concavity of the underside fully effective. Arrangements of this type are disclosed in patent application Serial No. 130,785, filed August 11, 1961.

It is an object of the invention to provide an improved design of flaps at the trailing edge of airplane wings whereby the flaps are made more rigid and are made more effective when in the retracted position for normal flight and when in the protracted or extended position for starting and landing.

In a preferred embodiment of the invention reinforcing elements in the form of ribs or webs extending normal to the longitudinal axis of the flap are provided at the underside of the flap which is concavely curved around the longitudinal axis of the flap. The reinforcing elements have a lower edge which approximately coincides with the chord of the concave curvature of the underside of the flap. The reinforcing elements are provided at least at the ends of the flap but may also be placed at intermediate locations of the flap and divide the cavity at the underside into a plurality of juxtaposed sections. The reinforcing elements considerably increase the bending resistance of the flap. They also facilitate mounting of devices for actuating the flap as well as of devices for coordinating the movement of the flap and that of cover elements closing the cavity at the underside of the flap during normal flight and being adjacent to the concave underside of the flap when the flap is in extended position. The reinforcing elements also facilitate mounting of resilient means controlling the relative position of the flap and of the cover element or elements and of means for controlling the force of such resilient means in response to the relative position of the flap and the cover elements. The reinforcing elements do not only laterally confine the cavity at the underside of the flap but can also include guide means for guiding and abutments for limiting the movement of the cover elements relative to the flap.

It is a further object of the invention to provide improved cover means for covering the cavity formed by the convexly curved underside of a flap at the trailing edge of an airplane wing and improved means for correlating the movement of the cover means and the movement of the flap.

In a preferred embodiment of the invention the cover means cover only a part, preferably the forward part of the cavity formed by the convexly curved underside of the flap when the flap is in retracted position. In this way the air forms a whirl in the cavity which does not impair smooth flow of the air below the flap.

The novel features which are considered characteristic of the invention are set forth with particularity in the appended claims. The invention itself, however, and additional objects and advantages thereof will best be understood from the following description of embodiments thereof when read in connection with the accompanying drawings herein.

FIG. 1 is a diagrammatic cross sectional illustration of a flap according to the invention in retracted position. FIG. 2 is a plan view of the flap shown in FIG. 1 in extended position and with a portion broken off. FIG. 3 is a diagrammatic cross sectional view of a modified cover plate arrangement. FIG. 4 is a diagrammatic illustration of a detail of the arrangement shown in FIG. 1. FIG. 5 is a diagrammatic cross sectional illustration of a modified cover plate according to the invention. FIG. 6 is a diagrammatic illustration of a device for coordinating the pressure of a spring acting on a cover plate according to the invention to the relative position of the cover plate and the contiguous flap. FIGS. 7 and 8 are diagrammatic cross sectional views of a flap equipped with cover plates according to the invention and of a mechanism for coordinating the position of the cover plates to the position of the flap, in two different operating positions. FIGS. 9 and 10 are diagrammatic cross sectional views of further modifications of a flap and cover plate arrangement according to the invention, in two different operating positions.

FIGS. 11 and 12 are diagrammatic cross sectional illustrations of another modification of a flap and cover plate arrangement according to the invention. FIG. 13 is a diagrammatic cross sectional illustration of a modification of the arrangement shown in FIGS. 11 and 12. FIG. 14 is a diagrammatic cross sectional illustration of a further modification of the arrangement shown in FIGS. 11 and 12. FIGS. 15 and 16 are diagrammatic cross sectional illustrations of a multi-flap arrangement according to the invention in two different operating positions.

FIGS. 17 and 18 are diagrammatic cross sectional views of a modified multi-flap arrangement in two different operating positions.

Referring more particularly to FIGS. 1 and 2 of the drawing, numeral 1 designates a flap swingably connected to the trailing portion of a wing or flap 2 of which only a part is shown, as it does not form part of the invention. For the same reason the wingable connection of the flap 1 to the element 2 and means for actuating the flap are only partly and schematically shown. The flap 1 has an underside concavely curved around the longitudinal axis of the flap and forming a cavity.

In the illustrated example the nose of the flap 1 is formed by a tubular spar 3 which supports reinforcing or stiffening elements 5 formed as ribs or webs. These stiffening elements divide the cavity formed by the concave underside of the flap into a plurality of sections juxtaposed in the direction of the wing spread. Since the stiffening elements are very thin they cause practically no resistance or adverse drag in the direction of flight. Openings 5" may be provided in the ribs for reducing the weight thereof. The stiffening elements 5 have a marginal lower portion coinciding approximately with the chord of the curvature of the underside of the flap. For further increasing the rigidity of the flap, the space within the skin around the flap is filled with a filler material, preferably of honeycomb design.

The tubular spar 3 may carry the bearings of the mechanism for lifting the flap. It is assumed that the swing axis of the flap is coaxial of the spar 3. A pin
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4 may be provided extending into a bearing, not shown, for swingably supporting the flap. In lieu of the provision of a pin 4 the spar itself may have a portion 4' extending beyond the spar webs 5 as shown in FIG. 2. Numeral 12 in FIG. 2 designates means for tilting the flap which means are pivoted to a lateral rib 5. A like tilting means may be pivoted to the rib 5 at the other end of the flap. As seen in FIG. 1 an elbow joint 113—117 is provided interconnecting the element 2 and the flap 1. The joint is bent when the flap is retracted, as shown in FIG. 1, and is extended when the flap is protracted.

A rigid plate 7 is pivotally connected at 8 to the underside of the spar 3. A second rigid plate 7' is pivotally connected at 8' to the trailing edge of the flap. The plates 7 and 7' overlap at 9 and form a tight cover for the cavity formed by the concave undersurface of the flap 1, when the plates are in the position shown in solid lines in FIG. 1. When the flap 1 is extended, i.e. moved downward, as seen in FIG. 1, the air pressure moves the plates 7, 7' into the cavity formed by the concave underside of the flap 1 against the pressure of springs, not shown, into the positions indicated by dotted lines in FIG. 1 and renders the concave surface effective. Because of the provision of two plates, the retracted plates closely follow the curvature of the underside of the flap 1. When the flap is in the retracted position shown in FIG. 1, the plates are held by springs, not shown, in the position shown in solid lines in FIG. 1. The plates are provided with lateral protuberances 11 in slots 10 in the ribs or webs 5 for guiding and limiting the swing movements of the plates. The protuberances of one plate may be independent of those of the neighboring plates to afford independent rocking of the plates. As indicated in FIG. 2, elements 11' may be provided, extending through the slots 10 and interconnecting the plates placed in juxtaposed compartments formed by the webs 5.

As shown in FIG. 3, the plate 7 may be constructed and arranged to swing outward instead of into the cavity upon extension of the flap 1 whereby the left end of the concave undersurface of the flap is extended and the effect of the concavity is increased.

The plates may be constructed and actuated in a manner, for example, as shown in the patent application Serial No. 130,785, filed August 11, 1961. Spacers and springs may be provided which counteract the air pressure and press the plates outward against a suitable abutment. The spring tension may be changed in dependence on the extent of tilt of the flap for coordination of the spring tension to the changing air pressure whereby the plates are pressed by the air pressure into the cavity at the underside of the flap when the latter is in the extended position. The plates may be mechanically linked to the flap for coordinated movement. The connection of the plate 7' at 8' to the trailing edge of the flap may be constructed so as to afford swinging as well as sliding of the plate in a direction normal to the wing axis. In this way the active surface of the flap is increased when the flap is extended. The plates may be composed of several plates which are connected by hinges whose axes are parallel to the swing axis of the plates whereby the plates can follow more closely the curvature of the underside of the flap 1 when the plates are retracted.

FIG. 4 shows an arrangement using a spring 111 for outward pressing of the plate 7. The spring extends between the concave undersurface of the flap 1 and the plate 7 and is wound around an arcuate element 110 having one end connected to the flap 7, the second end extending into the flap 1. The second end is provided with a plate 109, limiting outward movement of the element 110.

FIG. 5 illustrates another way of limiting the movement of the plate 7. Here, the plate 7 extends beyond its fulcrum 8 and abuts against the spar 3 for limiting the outward movement of the plate.

The arrangements shown in FIGS. 4 and 5 can equally well be used in connection with the plate 7'.

FIG. 6 shows an arrangement for changing the tension of the spring counteracting the air pressure. An angle lever 104 is pivotally connected to the element 2 at 105 and to the flap 1 at 106. A spring 108 is interposed between the free end 107 of the angle lever 104 and the plate 7. With this arrangement the spring 108 is not only compressed by the air pressure acting on the plate 7 upon extension of the flap 1 but the support 107 of the spring is also displaced so that the force of the spring is reduced.

In the embodiment of the invention shown in FIGS. 7 and 8 the plate 7 which is hinged at 8 to the tubular spar 3, has a portion 7' extending forward of the spar, covering the space between the spar and the rear portion 2 of a wing or of another flap, when the flap is in retracted position. The plates 7 and 7' are thereby in the position shown in FIG. 7. When the flap is extended the plates assume the position shown in FIG. 8 and follow closely the curved undersurface of the flap. The plate portion 7' projects outward and increases the effective undersurface of the flap. It also clears the space between the spar 3 and the portion 2 so that this gap becomes fully effective. The flap 1 is actuated by the mechanism 12 shown in FIGS. 1 and 2. An angle lever 115 is pivotally connected at 119 to the element 2 and at 120 to the spar 3. The free arm 121 of the angle lever presses against a pin 122 connected to the plate 7. When the plate 1 is swung the plate 7 into the cavity of the flap 1 when the latter is extended, i.e. in the position shown in FIG. 8. The plate 7' is pressed to the position shown in FIG. 7 by a spring 112 and is pressed into the cavity of the flap by the air pressure when the flap is extended. In lieu of the short overlap 9 of the arrangement shown in FIG. 1 an elastic plate 123 is made fast on the plate 7' and is sufficiently wide to close the gap between the plates 7 and 7' at all positions thereof. The plate 123 affords reliable movement of the plates 7 and 7' from the position shown in FIG. 7 to that shown in FIG. 8 and conversely.

In the embodiment shown in FIGS. 9 and 10 a flexible sheet having an elastic portion 13 and an unelastic portion 125, for example woven material, is provided for covering the cavity at the underside of the flap 1. The sheet is made fast at 14 on the trailing edge of the flap. The forward edge of the sheet portion 13 is made fast on an element which does not take part in the lifting movement of the flap. In the illustrated example the forward edge of the sheet is made fast at 15 on the wing or flap portion 2. The sheet portion 13 rests on a portion of the circumference of the spar 3 and is stretched between the fastenings 14 and 15 when the flap is in the retracted position shown in FIG. 9. When the flap 1 is swung to the extended position shown in FIG. 10 the tension of the sheet is reduced, because the fastening at 15 does not take part in the movement of the flap and the sheet is pressed by the air pressure against the underside of the flap 1. The concavity of the underside of the flap 1 is now fully effective. The air pressure may be assisted by a suction effect produced by the provision of vents 126 in the flap 1. The sheet may be made entirely of elastic material, for example rubber.

Another modified arrangement using an elastic covering for the cavity on the underside of a flap is shown in FIG. 11 and 12. The flap has reinforced portions as in the previously described modifications. An elastic sheet 16, for example flexible sheet metal, forms the underside of the flap in retracted position. The sheet may extend forward of the spar 3 and close the clearance between the spar and the rear portion 2 of a wing or of a second flap. The flexible sheet 16 is preferably connected at 17 to the trailing edge of the flap 1. The sheet is also connected at 18 to an eccentric coaxially rotatable on the spar 3. The connection 18 is held in
fixed relation to the element 2 by an arm 127 so that the connection 18 is moved to the angular position 18' upon extension of the flap 1 to the position shown in FIG. 12 whereby the sheet is bent into the cavity at the underside of the flap until it assumes the position shown in FIG. 12 wherein it is adjacent to the concave underside of the flap. The forward portion of the sheet 16 is thereby removed from the gap between the elements 2 and 3 and forms an enlargement of the active underside of the flap. The elements 2 and 1 are also connected by an elbow joint 113 to 117 which is bent when the flap 1 is in the retracted position shown in FIG. 11 and is extended when the flap is in the protracted position shown in FIG. 12.

Instead of hinging the sheet 16 to the rear edge of the flap, a combined hinge and sliding connection schematically shown in FIG. 13 may be provided affording extension of the sheet rearwardly beyond the trailing edge of the flap and enlargement of the underside of the flap.

As shown in FIG. 14, spacers 19 may be interposed between the underside of the flap 1 and the sheet 16 forming a clearance 20 through which air flows in the direction of the arrows when the flap is in the extended position, the air leaving the clearance 20 through an opening 21 in the rear portion of the flap. This prevents change from laminar to turbulent flow of the air at the trailing edge of the flap even when the angle of deviation of the extended flap is very great.

In order to save weight and cost the plate or plates provided at the underside of the flap 1 may be so constructed as to close only a portion, preferably the forward portion of the concavity when the flap is in the retracted position. The air in the unclosed part of the concavity forms a vortex which does not impair the flow of the air along the underside of the retracted flap.

An arrangement for covering only the forward portion of the cavity at the underside of a retracted flap 1 is diagrammatically shown in FIGS. 15 and 16. Numerals 2 and 1 connected to the trailing edge of the wing. The underside of the rearmost flap 1 is concave and forms a cavity 1'. The angle formed by the top side and by the underside of the flap 1 at the trailing edge thereof is very small. A plate 7 is swingingly connected at 8 to the end of the flap 1. The plate 7 covers the forward part of the cavity 1' and leaves the rear part of the cavity open when the flap is in the retracted position as shown in FIG. 15. The plate 7 is held in the normal flight position (FIG. 15) by a spring 111 which presses the plate outward, the extent of the outward movement being limited by an abutment, for example as shown in FIG. 4. If it is desired to close the clearance between the flaps 2 and 1 during normal flight, the plate 7 is provided with a forward portion 7" extending forwardly beyond the fullcrum 8. When the flap 1 is retracted, the plate 7, 7" forms part of the underside of the wing profile.

When the flap 1 is protracted as shown in FIG. 16, the plate 7, 7" is pressed by the air pressure against the action of the spring 111 into the cavity at the underside of the flap 1 so that the concave underside becomes fully effective. This movement of the plate is automatic. If desired, a mechanism, for example, as used in the previously described and illustrated embodiments of the invention may be provided whereby the movement of the cover plate 7, 7" is made dependent on the movement of the flap 1.

FIGS. 17 and 18 illustrate an arrangement wherein a cover plate 7 is connected movably parallel to itself and to the flap 1 by means of parallel links 130, 131. In normal flight, with the flap 1 in retracted position, the plate 7 and the links 130, 131 are in the position shown in solid lines in FIG. 17. The plate covers the clearances or slots between the trailing edge of the wing 2' and a first flap 2 and between the flaps 2 and 1 and covers the forward part of the cavity 1' at the underside of the flap 1. Means, not shown, corresponding to those used in connection with other embodiments of the invention described hereinbefore are provided for holding the plate 7 in the position shown in FIG. 17. When the flap 1 is extended the plate 7 moves into the position shown in dotted lines in FIG. 17 and in solid lines in FIG. 18, abutments being provided suitable for holding the plate in the extended position. With the plate 7 in protracted position, there is an air passage 132 between the plate and the flap 1 which considerably increases the braking effect of the arrangement. A suitable linkage, not shown, is provided for coordinating the movements of the flap 1 and of the plate 7. Though a support of the plate 7 on the flap 1 is shown, effecting movement of the plate parallel to itself, it is within the scope of the invention to support the plate 7 in a manner to perform a different movement. The plate 7 may be made less wide than shown in FIGS. 17 and 18 and cover only the slot between the flaps 1 and 2, or may be made so narrow that neither the slot between the wing 2' and the flap 2 nor the slot between the flaps 2 and 1 are closed by the plate. The plate 7 may be made to extend farther to the rear so that the entire cavity 1' is covered during normal flight. In this case there is also the desired air passage between the plate 7 and the flap 1.

Although arrangements with more than one flap at the trailing edge of the airplane wing are shown in FIGS. 15 to 18, the cover plate systems shown in these figures can equally well be used in combination with wings having only one flap at the trailing edge.

1. A flap swingingly connected to the trailing edge of an airplane wing and adapted to be swung between a retracted position wherein the flap is substantially in line with the airplane wing and an extended position wherein the flap is at an angle with respect to the airplane wing, said flap comprising an underside concavely curved around the longitudinal axis of the flap and forming a cavity, plate means movably connected to the underside of the flap and constructed and arranged so as to cover at least a part of said cavity when the flap is in the retracted position and to be adjacent to said underside when the flap is in the extended position, and a plurality of stiffening elements rigidly connected to said flap and extending normal to the longitudinal axis of the flap, said stiffening elements having a lower marginal portion coinciding substantially with the chord of the curvature of the underside of the flap.

2. A flap as defined in claim 1 wherein said having a nose portion formed by a tubular spar, said stiffening elements being connected to said spar.

3. A flap according to claim 2 wherein the longitudinal axis of said tubular spar coincides with the swing axis of said flap.

4. A flap according to claim 3 wherein said spar forms the swing axis of said flap.

5. A flap as defined in claim 1 including actuating means for swinging the flap, said actuating means being connected to at least one of said stiffening elements.

6. A flap as defined in claim 1 including a skin forming the surface of said flap, and a filler material within said skin for making the flap rigid.

7. A flap as defined in claim 1 wherein said stiffening elements include means for limiting the movement of said plate means.

8. A flap as defined in claim 1 having a nose portion and a trailing edge portion, said plate means including two substantially rigid plates, one of said plates being hinged to said nose portion for swinging around an axis parallel to the longitudinal axis of said flap, the second of said plates being movably connected to said trailing edge portion for swinging around an axis parallel to the longitudinal axis of said flap.

9. A flap as defined in claim 8 wherein each of said
plates has a marginal portion, said marginal portions facing each other and overlapping each other when said plates are in the position for covering said cavity.

10. A flap as defined in claim 1 wherein said stiffening elements divide the cavity formed by said concavely curved underside into a plurality of sections juxtaposed in the direction of the longitudinal axis of the flap, said plate means comprising a plurality of individual portions, each of said portions being placed in one of said sections and being movably connected to said flap independent of the other portions.

11. A flap according to claim 10 wherein said portions of said plate means are interconnected for simultaneous movement.

12. A flap swingably connected to the trailing edge of an airplane wing and adapted to be swung between a retracted position wherein the flap is substantially in line with the airplane wing and an extended position wherein the flap is at an angle with respect to the airplane wing, said flap comprising an underside concavely curved around the longitudinal axis of the flap and forming a cavity, plate means movably connected to the underside of the flap, and a plurality of stiffening elements rigidly connected to said flap and extending normal to the longitudinal axis of the flap, stiffening elements having a lower marginal portion coinciding substantially with the chord of the curvature of the underside of the flap, said plate means away from said flap for forming an air passage between said flap and said plate means upon extension of said flap.

13. A flap swingably connected to the trailing edge of an airplane wing and adapted to be swung between a retracted position wherein the flap is substantially in line with the airplane wing and an extended position wherein the flap is at an angle with respect to the airplane wing, said flap comprising an underside concavely curved around the longitudinal axis of the flap and forming a cavity, plate means movably connected to the underside of the flap, and a plurality of stiffening elements rigidly connected to said flap and extending normal to the longitudinal axis of the flap, stiffening elements having a lower marginal portion coinciding substantially with the chord of the curvature of the underside of the flap, said flap having a trailing edge portion, said plate means being flexible and being connected to said trailing edge portion of said flap, said plate means having a forward portion extending around and being engaged with a part of said nose portion, said plate means having a main portion covering said cavity when said flap is in retracted position and being pressed by the air pressure against said concavely curved underside when said flap is in extended position.

14. A flap as defined in claim 13 wherein said flexible plate means has an elastic and an unelastic portion.

15. A flap swingably connected to the trailing edge of an airplane wing and adapted to be swung between a retracted position wherein the flap is substantially in line with the airplane wing and an extended position wherein the flap is at an angle with respect to the airplane wing, said flap comprising an underside concavely curved around the longitudinal axis of the flap and forming a cavity, plate means movably connected to the underside of the flap, and a plurality of stiffening elements rigidly connected to said flap and extending normal to the longitudinal axis of the flap, stiffening elements having a lower marginal portion coinciding substantially with the chord of the curvature of the underside of the flap, said flap having a nose portion, said flexible plate means having a forward portion extending around and being engaged with a part of said nose portion, said plate means having a main portion covering said cavity when said flap is in retracted position and being pressed by the air pressure against said concavely curved underside when said flap is in extended position.
21. A flap swingably connected to the trailing edge of an airplane wing and adapted to be swung between a retracted position wherein the flap is substantially in line with the airplane wing and an extended position wherein the flap is at an angle with respect to the airplane wing, said flap comprising an underside concavely curved around the longitudinal axis of the flap and forming a cavity, plate means movably connected to the underside of the flap, and a plurality of stiffening elements rigidly connected to said flap and extending normal to the longitudinal axis of the flap, said stiffening elements having a lower marginal portion coinciding substantially with the chord of the curvature of the underside of the flap, a clearance being provided between said flap and the trailing edge of the airplane wing, said flap comprising a nose portion and a trailing edge portion, said plate means being placed opposite said underside and substantially parallel to said flap, link means swingably linking said plate means to said flap and affording swinging of said plate means toward said flap for closing the clearance between said flap and the trailing edge of the airplane wing and for at least partly closing said cavity when the flap is in retracted position and affording swinging of said plate means away from said flap for forming an air passage between said flap and said plate means upon extension of said flap.

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