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By Hans Jacobs and Adolf Wanner

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DFS DIVE-CONTROL BRAKES FOR GLIDERS AND AIRPLANES*

By Hans Jacobs and Adolf Wanner

The vital need for greater safety in the face of the rising aerodynamic quality of gliders has resulted in the design of a structurally very simple brake flap, the testing and installation of which on several glider types, is described. The beneficial effects of the DFS dive-control flap on the flight characteristics form, aside from the braking effect, the main reason for general use. Installed for experimental purposes on an airplane with a view to lowering the terminal velocity in a dive, the results proved satisfactory. The present report therefore is a survey of the progress and the present state of dive-control flaps for gliders and airplanes.

INTRODUCTION

The past few years have revealed that performance gliders, because of their high aerodynamic quality, can reach speeds through control errors, especially when stunting or flying in clouds, where the stresses frequently exceed the existing strength and cause accidents. The design specifications for gliders specify 25 × G/F as ultimate dynamic pressure for load case C. But the terminal velocity of gliders in diving ranges between 400 and 500 kilometers per hour. On the other hand, an increase in strength requirements, especially of our large-span gliders would hardly be compatible with the weight problem. So, leaving aside this aspect, there remain but two ways of raising the safety of gliders, namely, improvement of flight characteristics or application of a controllable aerodynamic impairment device.

Undoubtedly, improved flight characteristics will contribute to the general amelioration of safety of the gliders, although without being able to prevent the very

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*"DFS Sturzflugbremsen an Segel- und Motorflugzeugen." Jahrbuch 1938 der deutschen Luftfahrtforschung, pp. I 313 - I 318; and Luftbremsen für Segelflugzeuge," Luftwissen, July 1937, pp. 207-210.

high speeds caused by over-control or operating errors. But the principapl purpose of an aerodynamic impairment is to keep, through increasing the dive-drag coefficient, the terminal dynamic pressure within the limits established in the design specifications. Then, too, it is important whether this drag increase is obtained through disturbance of the smooth aspect of the lift distribution along the wings - that is, through increased induced drag - or whether it is caused by increased parasite area of the glider, or by both. On the other hand, such a drag-increasing device should not create secondary phenomena, introducing new hazards such as oscillations, vibrations, etc.; nor impair the flight performances.

These considerations ultimately led to an arrangement which was installed and tried out in different versions.

The first basic tests were carried out on the Rhönsperber-type of glider. The operating principle is shown in figure 1. In normal flight, the brake flaps are retracted in the wing, leaving a smooth surface exposed to the air. A typical characteristic of the DFS brake flap is the slots between the extended flap and the outer surface of the wing. Tests on gliders with brake flaps, but minus slot, revealed the onset of the braking action to be too abrupt and harsh, a marked impairment of the flight characteristics with brake flaps extended, and increased danger of oscillation phenomena at any part of the airplane because of the absence of wake turbulence (fig. 2). Extended, the brake flaps are practically at right angles to the aerodynamic profile chord (fig. 3) in the flow conditioned by angle of attack and profile form.

To keep the manual force required for retraction and extension always within controllable limits, the actuation kinematics were so chosen that the air loads on both brake surfaces balance one another, leaving only occurring differential forces to be overcome by hand. According to wind-tunnel measurements, the dimensions of the drive elements can be so designed as to enable the pilot to apply manual forces at any flying speed. To extend the flaps requires a pull over the first two-thirds of the lever distance, and a push over the last one-third. For closing the flaps, the operation is the opposite. This means that the brake flaps, once they are fully extended, are kept open by the air forces - a very desirable feature in cloud flying. The actuating forces themselves are contingent upon profile form, location, and size of brake surface and the kinematics of the drive.

The achieved braking action was computed from the dive barogram (fig. 4) with and without brake flaps and amounted to 54 percent - i.e., the maximum diving speed dropped from 415 kilometers per hour to 190 kilometers per hour, with an interference surface 0.650 m^2 or 4.3 percent of the wing area, which includes the region from the outer surface of the wing to the upper edge of the brake surface, slot included.

From the attained terminal velocities follows a mean drag increase of

$$\Delta c_{w_o} = \frac{G}{\frac{\rho}{2} F} \left[\frac{1}{v^2_{BK}} - \frac{1}{v^2} \right] = 0.0864$$

which increase, referred to unit of interference surface, gives a drag coefficient of

$$c_{w_{BK}} = \frac{15.1}{0.65}\, 0.0864 = 2.007$$

a value which, in consequence of the flap-wing interference is about 72 percent higher than the coefficient of a flap plate of equal aspect ratio in free air flow.

How the braking effect makes itself felt throughout the whole speed range of the Rhönsperber, is evident from figure 5. But the suitability of the flaps depends, aside from the braking effect, largely also on their effect on the flight characteristics. In a searching experimental investigation with the most diversified shapes and sizes of flaps, one arrangement was developed as standard and its effect on the flight characteristics of different gliders, ascertained.

The brake surfaces were placed on movable segment levers (fig. 1). The suction side flap is actuated direct by a torque tube T, the pressure side flap by push rods. In the pilot's cabin the drive is operated by a hand lever and tension rods. With this arrangement, an accurate check on the changes in flight qualities was obtained. The stability about the lateral axis remained the same, only the response of the elevator was damped - which, in fact, is beneficial for pulling out from a dive, since then the accelerations specified in the stress analysis can no longer be reached. Just as beneficial is the marked damping in yaw of the brakes on the stability about the longitudinal axis. The pilot perceives the glider unusually stable, particularly in the curves, even with released controls. The spin-retarding moment becomes in many types so pronounced as to make spinning impossible unless the center of gravity is pushed abnormally backward. Evolutions, such as nose-over, barrel roll, chandelle, or inverted flight with brake flaps extended, require considerable speed margin, since all motions are considerably slowed down and damped.

For trials of the brakes, the following flight conditions were used as basis and practically executed:

1. Flight in clouds without blind flying instruments; the pilot no longer controls the airplane.

2. Stunting; the pilot drops from a roll or inverted flight in a steep slip.

3. Inverted flight; the pilot attempts to return the glider to normal with a half nose-over.

In all three cases the maximum diving speed reached with extended brakes, did not exceed the speed from the preceding dive tests. On releasing all controls, the airplane zooms out of these diving positions, immediately loses speed, and goes into stable curves after quickly settling down to a medium speed.

Apart from the safety in cloud flying, the brake flap is also an ideal landing aid, since it enables the pilot to raise the sinking speed from 0.7 meter per second to 3 to 4 meters per second.

In flights with the brake flaps extended at only one wing-half, the glider remained fully operational; the resulting rolling moment was readily compensated by a slight aileron deflection.

After a great many flights and wind-tunnel measurements, the additional stresses caused by the brake flap may be summed up as follows:

In the A stress case the lift distribution in the outer region of the wing is more complete - which, by equal load factor, is equivalent to a rise in bending stress. On the basis of the available data, the load factor $n = 4$ is, however, attainable at a narrower pull-out radius with brake flaps extended than in flight without flaps, because of the marked damping effect. The measurements so far disclosed that with the usual flap arrangement the $\frac{dc_a}{d\alpha}$ with brake flap was smaller than the $\frac{dc_a}{d\alpha}$ without brake flap. Besides, there is no call for the pilot in cloud flying, for which the brake flap was originally intended as safeguard, to pull up with an acceleration corresponding to a safety factor of 4.

The highest possible dynamic pressure in load case C with brake flaps can, on the basis of the chosen flap dimensions, be put at $\frac{25}{2} \frac{G}{F} = q_{terminal}$ which, according to the design specifications, corresponds to the dynamic pressure of stress case C with safety factor 2 without consideration of the additive or subtractive brake flap stresses.

Example: Rhönsperber, Urubu.

$V_{terminal}$ with brake flaps = 191 km/h (flight test data).

$q_{terminal}$ with brake flaps = 176.4 kg/m² at $\rho = \frac{1}{8} \left(\frac{kg\ s^2}{m^4}\right)$.

$q_{failure}$ (design specifications) = $25 \frac{G}{F} = 406$ kg/m².

Factor of safety: $j = \frac{406}{176.4} = 2.3$, provided the brake flaps create no additional stress.

This reduction in terminal dynamic pressure with brake flaps to the safe dynamic pressure of stress case C conformable to the design specifications has, moreover, the result that the pilot does not need to execute control movements which exceed or even reach the safe load factor of stress case A or E.

The stresses due to the wing torque are lower, since by proper flap arrangement, it is always possible to assure a negative Δc_{m_0}; hence the safety factor for the diffusion of the torque is greater than 2.

The higher tangential stress of the wing structure, as a result of the frontal drag of the brake flaps, is in the C case, according to a check on the Rhönsperber, of the order of magnitude of the landing case and sideslip landing.

Additional bending moments are produced in the outside wing in the C case which, in first approximation, are attributable to the change in zero setting angle through the brake flap. But in the usual arrangements $\Delta\alpha_0$ is quite small.

The horizontal tail-surface load necessary for the moment compensation about the lateral axis in the C case becomes less, since the zero-moment increase Δc_{m_0} is negative.

These brake-flap arrangements, when installed in different types of gliders and tried out, supplied a lot of experimental data. On the Rhönbussard and the Rhönadler (figs. 6 and 7), they furnished nothing radically new, although here also the favored flight condition with extended brake flaps, was the stable curve with slight banking and medium speed.

On the Minimoa (fig. 8), the hitherto ineffectual mass distribution of the rudder manifested itself as control flutter. It consisted of a sudden flexural fuselage vibration about the normal axis at the stationary terminal velocity of 195 kilometers per hour, of very high amplitudes and a frequency of around 400 min^{-1}. The vibration continued as far as the fore port of the fuselage. It could be readily reproduced by manual excitation on the ground, and then successfully removed by weight-balancing the rudder.

Another unusual phenomenon occurred on the Reiher (fig. 9), where the brake flaps manifested disagreeable phenomena as landing aid. In this glider the longitudinal dihedral of the wings along the span was purposely a minimum with a view to optimum performance. The result was that the wing load at all points was approximately equally distant from the obtainable maximum, and a disturbance in a certain region of the wing infected the neighboring sound floor to some extent and forced the disturbance upon it. So when pulling the brake flaps, this is what happened: immediately after extension, the sinking speed rose from, for instance, 0.7 meter per second to 1.5 meters per second; after 2 to 3 seconds' flight with extended flaps there was a second rise in sinking speed to 2.5 meters per second. On retraction of the brake flaps the effect lagged behind for the same time period, which was very disagreeable for landing. Examination of the flow with streamers and motion-picture camera disclosed a break-away of flow over the entire wing between fuselage and brake flaps on the upper side. A 40-percent flap reduction on the suction side removed this lag - probably because the disturbances emanating from the brake flaps were no longer severe enough to exert a permanent effect on the inside wing.

The few examples quoted indicate the importance of the following factors:

1. Brake flap location along wing chord, in open and closed position.

2. Profile form.

3. Height of ventilating slot.

4. Lift distribution of wing along its span, especially at the location of the brake flap.

5. Location of brake flaps along span (danger to horizontal tail surfaces or to aileron due to vibration phenomena).

The installation of the brake flaps including operating mechanism in a glider, amounts to about 5 percent of the total cost. Despite many glider failures in cloud flying, the expense together with lack of sufficient experience in cloud flying, seemed to act as a deterrent to general acceptance. The Rhön Contest, however, proved that storm-cloud flights up to 8,000 meters could be successfully achieved with gliders fitted with brake flaps without much danger, while a number of gliders without brake flaps in the same storm cloud, could not withstand the stresses due to gusts or control errors. Following this practical proof, the DFS air brake for gliders was declared mandatory and hereafter no glider will be officially approved unless fitted with such dive-control safeguards.

Trials on the FW 56 Type (Stösser)

The development of air brakes on gliders, described in the foregoing, was to provide greater safety in flight.

The favorable experiences gained therefrom, suggested with a good deal of promise, their application on airplanes as well - where, however, the intended purpose was to assure a reduction in terminal dive velocity. The assumption of the same pull-out accelerations from a dive gives (reference 1) a pull-out altitude dependent on diving speed up to level flight. And this pull-out height is, in fact, approximately in inverse proportion to the speed.

The experiments recounted hereinafter were made on an FW 56 type airplane (Stösser). Besides the past experiences on gliders, there were available at the start of the tests only Kramer's wind-tunnel studies on devices intended for a similar purpose. Not until the flight tests had been completed, did the DFS proceed to comprehensive wind-tunnel investigations within the scope of applicability ascertained by practical experimentation. This reduced the multiplicity of variations to the best practical arrangements and afforded basic data directly useful to the designer. The plan sketch of the brake flap used in the free-flight tests is shown in figure 10. Contrary to the usual versions heretofore used on gliders, the suction-side flap was extended in flow direction, the pressure-side flap against the flow direction. This placed the lower flap ahead of the upper and promised certain advantages for the brake effect in diving.

The design of the FW 56 made it incumbent to locate the brake flaps between main and auxiliary strut (figs. 11-13). The horizontal tail surfaces are located within the zone of the ailerons in order to keep them as much as possible out of the principal interference zone of the flaps. Since this was apt to induce aileron flutter, the design provided for progressive enlargement of the flap surfaces. In figure 10, the flap surfaces B are so disposed on segment levers S that the individual brake flap of lenticular section fits on these levers in a kind of lattice truss. The lenticular shape for the individual flap elements was decided upon after a study of gliders with different cross-sectional forms, because even a slight flap deflection allows the passage of air and so prevents a jerking start of the braking action.

In relation to the wing chord, the flap locations were:

0.45 t, suction side

0.28 t, pressure side

The flaps are operated by hand lever L from the pilot's cockpit (fig. 14). The individual steps of the arrangement are illustrated in figure 15.

The experiments started with arrangement I disclosed great forces when the speed had barely reached 130 kilometers. The pressure-side area of the flap facing the air stream was too great, making it impossible to extend the flap above 150 kilometers per hour. After reducing the surface on the pressure side (arrangement Ia), the force ratio of suction-side to pressure-side flap, perceptible in the amount of manual force needed, was much more favorable. Extension became possible up to a speed of 270 kilometers per hour. This force ratio of suction-side to pressure-side flap was retained in the other versions through geometrically similar enlargement of the brake surfaces, in order to prevent overstressing through too-rapid flap extension at very high speeds in the absence of free-flight test data on the load distribution along a wing with brake flaps.

The aileron vibrations anticipated as a result of the particular location of the brake flaps, were slight, with version No. I at low speeds, and which - with elevator released - showed the control stick to be following the aileron deflections and deflecting up to 4 centimeters to the right and the left. These shocks abated considerably as the speed was increased - its last trace at 300 to 350 kilometers per hour, being a barely perceptible vibration on the stick. With the greater brake area of version II, the vibration phenomena on the ailerons at low speeds, were more noticeable, but they also abated at increasing speed and became unimportant in a vertical dive. Version III served for exploring the effect of the slot between the two brake-surface elements on the aileron vibrations. It was found that covering these slots resulted in far more severe and harsh vibration phenomena throughout the whole speed range. Even in vertical diving the shocks of the control stick, caused by the aileron vibrations, were quite severe.

The observed aileron vibrations were in every case purely flexural about the aileron axis and in not a single case led to traceable wing flutter. The explanation for the abatement of vibration amplitudes with increasing speed, lies in the growth of the vortex frequency λ per second, with the flight speed v (reference 2):

$$\lambda = \frac{K\_v}{P}$$

where K is a constant, fairly independent of the surface dimensions and form, of around 0.18 for rectangular plates, and P the plate area projected perpendicular to the direction of flow.

It may be mentioned in this connection that no tail-vibration phenomena of any kind were observed. This is causatively associated with the variation of the vortex train emanating from the brake surfaces, explored by wool-tuft photographs along the lateral and longitudinal axis on the suction side of the wing (fig. 16). This rather primitive method afforded a very clear insight into the flow phenomena.

The interpretation of several flight records is reproduced in figure 17, where curves of equal deflection from the direction of undisturbed flow are outlined. The extent and degree of the effect of the flap without slot in the plane of the brake surface on the airfoil flow are quite plain.

The smoke photographs of the flow about an airfoil with dive-control flaps in figures 18a,b,c, are very instructive. Figure 18a, showing the brake flaps retracted in the profile surface, brings out the total destruction of the circulation and the formation of a strong vortex band with low vortex frequency behind the brake surfaces. The slot, created by the emergence of the surfaces from the flow in profile proximity, still effectuates a comparatively good adherence even behind the brake flaps (fig. 18b). Two separate vortex trains with high frequency emanating from the brake surface, pass to the suction and pressure sides of the profile. Figure 18b corresponds to test arrangement III (fig. 18c), resembling arrangement II, emphasizes the stabilization of the flow pattern and the pacification of the vortex field behind the brake surfaces through the additional slot within the flap plane, without causing any substantial reduction in the total height of the vortex field.

Owing to the smallness of the brake surfaces, the braking effect with versions I and Ia was light, as anticipated. Version II caused a considerable change; the braking effect reduced the terminal dive velocity of 490 kilometers per hour without brakes, to 330 kilometers per hour. With slot closed on version III, the braking effect produced no perceptible change. For speed reduction with version II, the average drag increase due to dive-control flaps, is

$$\Delta c_{w_o} = 0.0705$$

or, equivalent to a drag coefficient of

$$\Delta c_{w_{BK}} = 1.25$$

referred to the unit of total interference area of the brakes, which again comprises the area from the outside of the wing to the outer edge of the brake surfaces including the slots.

The corresponding coefficient for the rectangular airfoil with brake-flap ratio resembling version II, was

$$c_{w_{BK}} = 1.35$$

The difference between these coefficients and those from free gliding tests is probably due to the substantially greater slot between outside of wing and lower edge of brake flap on the FW 56.

Other than a barely perceptible decline in elevator response and damping of accelerated flight stages, there was no noticeable change in the general flight characteristics resulting from the different brake-flap arrangements.

No flight evolutions were made with extended brake flaps - merely dives, control-change curves, sideslipping, stalls, spins, and landings.

Curve flight with ailerons produced small forces which tended to return the controls to normal with arrangements I and Ia. The restoring forces did not increase with arrangement II. Sideslipping with extended brake flaps disclosed no oscillation phenomena on tail, or other disagreeable features with respect to the airplane without brake flaps.

Any effect of arrangements I and Ia on the stall or spin was not noticeable. Arrangement II was accompanied by a spin-retarding moment but not large enough to prevent spinning altogether. The spinning process itself and recovery from a spin disclosed nothing unusual.

The pull-out from a dive - where changes in inclination were altogether unimportant, whether with or without brake flaps - with flaps extended, was materially damped.

Experiments giving information about pull-out radius, pull-out altitude, and accompanying accelerations, have not yet been made. Tests explaining the brake-flap effect on the spinning process should also prove interesting. Although the marked damping in yaw of these flaps is apparent, there is no definite information regarding the effect of the flap extension during a steady spin.

The whole flight-test program on gliders and on the airplane was carried out by Flight Captain Hanna Reitsch, whose wholehearted cooperation, in no little measure, contributed to the successful termination of the program.

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ANALYTICAL STUDY OF THE DRAG OF THE DFS DIVE-CONTROL BRAKE*

By Adolf Wanner

The application of various available wind-tunnel data on airfoils with full-span air-brake flaps of the type of the DFS dive-control brake (fig. 1) discloses substantial discrepancies in the specific drag coefficients from the free-flight measurements. These discrepancies are readily explained as a consequence of applying the two-dimensional wind-tunnel data to the three-dimensional flows in flight tests. In airfoils with brake flaps (BF) spanning only 10 percent of the semispan, the drag of the flaps themselves is supplemented by so-called "induced drag portions." These portions may be explained first, as being due to the change in effective angle of attack at the location of the brake flaps; and second, to the lateral diffusion of the disturbance beyond the range of the brake flaps (fig. 17). The first portion, the supplementary wing twist induced by the brake flaps, is determined from wind-tunnel tests (two-dimensional problem) and analytically computed by approximation on the assumption of applicability of the method of calculation of the airfoil theory. The second portion, the effect of the lateral velocity distribution, so far is not amenable to numerical solution. The investigation of the interference zone indicates, as expected, an almost symmetrical diffusion at both flap tips (fig. 17). Since consideration of the crosswise portion contributes only minor drag increases, the preponderant effect falls to the second portion. Flight tests indicated that 25 to 40 percent of the total drag of the brake flap was due to the induced drag.

However, pending determination of the amount of induced drag from further tests and the possibility of its prediction, it is desirable to know of some approximate method by means of which the drag increase resulting from fitting brake flaps on the upper and the lower surfaces of a wing, can be evaluated. In addition, the demands on the wing arising as a corollary to the brake flaps, must be met.

The arguments hereinafter deal only with brake-flap designs similar to those developed by the German Institute for Gliding and previously described arrangements.

*"Zur Berechnung des auf DFS-Sturzflugbremsen entfallenden Widerstandes." Luftwissen, vol. 6, no. 5, May 1939, pp. 171-172.

The brake flaps are located on the wing - generally between 30 and 60 percent along the chord (BK extended) and 20 to 50 percent along the semispan. The two principal versions are shown in figure 19.

If readily vibrating parts, such as control surfaces and tail, are present in the vortex field of the brake flaps, version B is preferable because of the higher frequency in the shedding vortex band. The reference area for the drag increase comprises the total disturbance-producing area of the brake flaps, from the outer surface of the wing to the outer edge of the brake flap including the slots; that is,

$$F_{BK} = h\, b_{BK}$$

Then the drag increase Δc_{w_o} due to the brake flaps, referred to the wing area F, becomes

$$\Delta c_{w_o} = c_{w_{BK}} \frac{F_{BK}}{F}$$

Inversely, the use of the dynamic pressure relations likewise gives the size of the brake flaps necessary to limit the terminal dynamic pressure to a certain extent.

For the application of the cited $c_{w_{BK}}$ values, it is important to observe that the effect of the slot s is of some significance. While no systematic data on this subject are available, past experience has shown that the height of the slot s can range within the limit of 0.20 + 0.33 h without introducing appreciable errors in the calculation.

In the stress analysis of brake flaps the total drag increase (in kg) is distributed over the flaps as an active force. This assumption is confirmed by wind-tunnel tests, in which pressure measurements in the brake-flap surface of a practical design indicate an almost uniform load distribution. These measurements further disclose that about 25 percent of the total drag forces are applied at the wing; i.e., that the brake-flap drag from the pressure record amounts to only 75 percent of the drag from the force measurement. Hence, the assumption of the total drag increase applied as a rectangular distribution over the brake-flap area, leaves one on the safe side.

The frontal forces acting on the wing in a dive must be removed at the wing-fuselage juncture; they are especially important on large-span sailplanes. Here the judicious use of brake flaps, etc., affords a reduction.

This effect is examined on the Reiher-type glider, which has a span of 19 meters. The distribution of the profile drag along the span at zero lift, the terminal dynamic pressure, and the size of the brake flaps limiting the terminal dynamic pressure, are known. The length of the brake flap is therefore about 0.10 b/2; its location is defined with respect to tail and ailerons free from disturbance. According to the foregoing arguments, the forces acting on the dive-control flaps, can now be combined in one single force, applied at the center of the brake flap; the moment of this force with respect to the wing attachment, is of interest in the analysis. The change in the total angle of attack of the airplane for diving without brake flaps, is quite small with the given arrangement and is therefore disregarded in the following:

NOTATION

c_{w_0} is the drag coefficient of glider without brake flaps, at $c_a = 0$.

$c_{w_{0_{BK}}}$, drag coefficient of glider with brake flaps, at $c_a = 0$.

$\Delta c_{w_0} = c_{w_{0_{BK}}} - c_{w_0}$, increment of drag due to brake flaps.

q_0, terminal dynamic pressure without brake flaps, kg/m^2.

$q_{0_{BK}}$, terminal dynamic pressure with brake flaps, kg/m^2.

v_0, terminal velocity without brake flaps, for $\rho_0 = 0.125 \frac{kg\ s^2}{m^4}$.

$v_{0_{BK}}$, terminal velocity with brake flaps, for $\rho_0 = 0.125 \frac{kg\ s^2}{m^4}$.

c_{w_p}, profile drag of airfoil section.

Applied to the Reiher, it is:

$$c_{w_o} = 0.0193$$

$$q_o = \frac{315}{19.20 \times 0.0193} = 850 \text{ kg/m}^2$$

$$v_o = 420 \text{ km/h}$$

$$v_{o_{BK}} = 200 \text{ km/h demanded}$$

$$q_{o_{BK}} = 193 \text{ kg/m}^2$$

$$c_{w_{o_{BK}}} = 0.0850$$

$$\Delta c_{w_o} = 0.0657$$

Hence, the drag portion W_{BK} acting on the brake flaps, follows at:

$$W_{BK} = \Delta c_{w_o} F q_{o_{BK}} = 0.0657 \times 19.2 \times 193 = 243.4 \text{ kg}$$

i.e., half the amount to each wing.

From the given distribution c_{w_p} along the span, the frontal drag bending moments M_S can be ascertained. For v_o = 420 km/h, we find M_S = 427.3 m kg, and for v_o = 200 km/h, we find M_S = 99.0 m kg; this value is supplemented by the moment from the brake-flap drag. The effect of the location of the brake-flap center on the total bending moment can be seen in figure 20. From this figure, it can be ascertained whether or not the chosen flap location is advantageous from the viewpoint of frontal pressure distribution.

SUMMARY

The present article describes how, on the basis of wind-tunnel and free-flight tests, the drag increase on brake flaps of the type of the DFS, can be predicted. Pressure records confirm a two-dimensional load distribution along the brake-flap surface. Aerodynamically, the location of the brake flaps along the span is of importance for reasons of avoidance of vibration and oscilla-

tion phenomena on control and tail surfaces; statically, because of the magnitude of the frontal drag in diving with respect to the bending moments, which may become decisive for the dimensions of the wing attachment and for the wing covering.

Translation by J. Vanier,
National Advisory Committee
for Aeronautics.

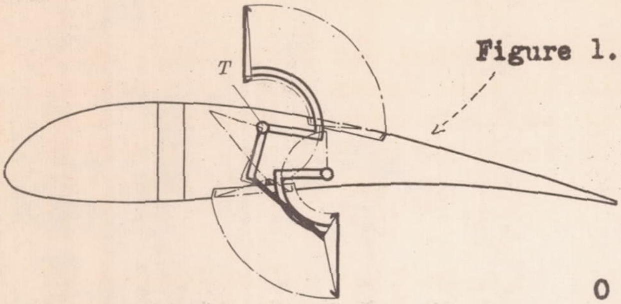


Figure 1.- Operating sketch of air brake. T = drive shaft.

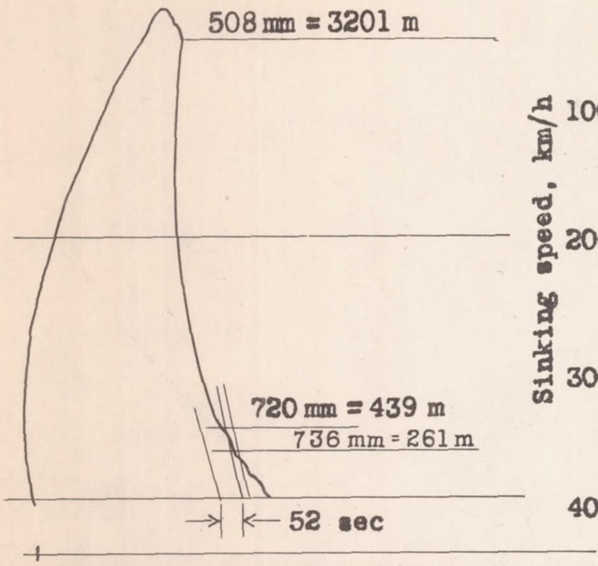
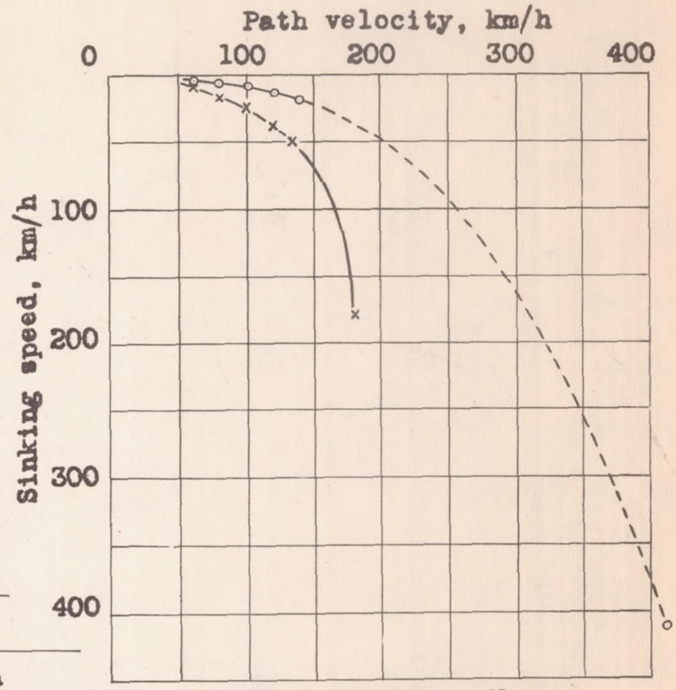


Figure 4.- Dive barogram with extended air brakes.



o Without brake flaps
× With " "
——— Flight test data
----- Computed from polars

Figure 5.- Speed diagram of Rhönsperber with and without air brakes.

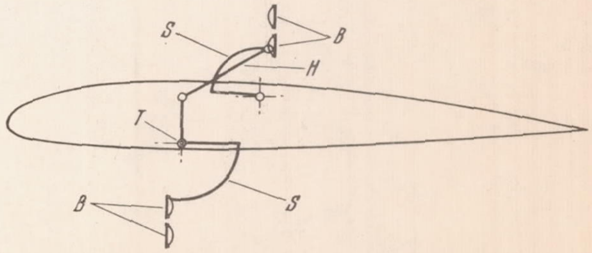


Figure 10.- Dive control brake drive on power glider FW 56 (Stösser)

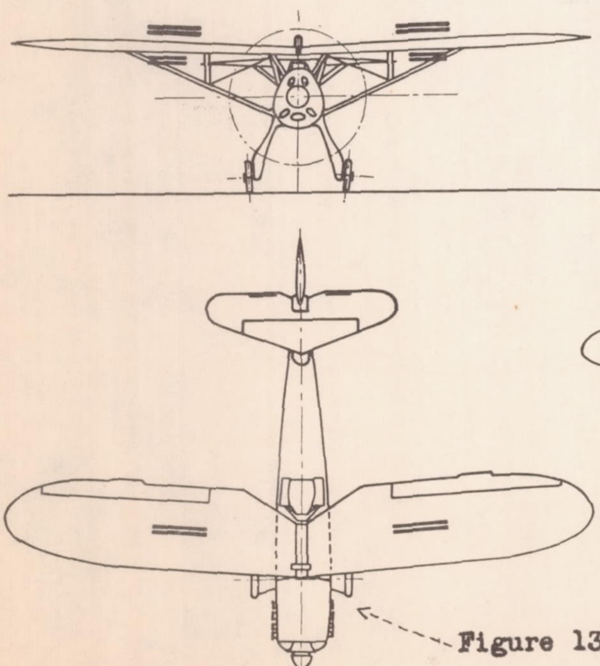


Figure 13.- Brake flap version on Stösser

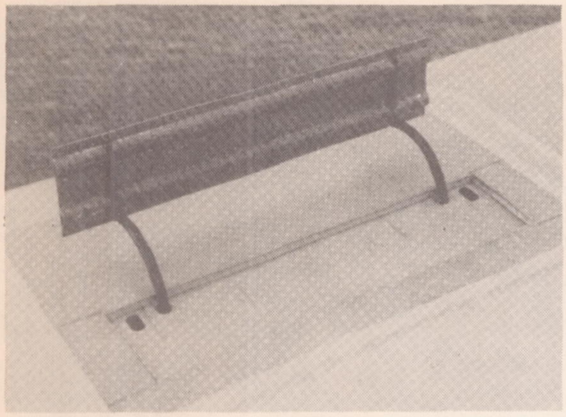


Figure 2.- Air brake fitted on suction-side.

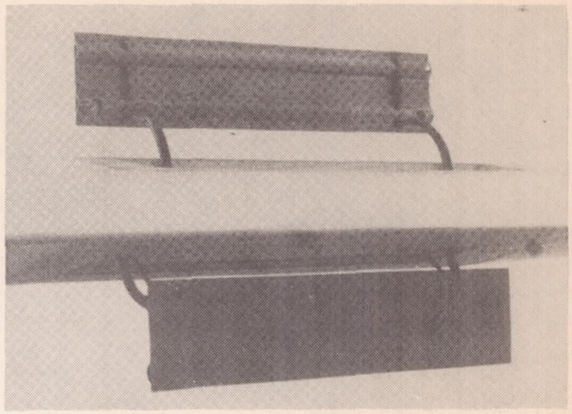


Figure 3.- DFS air brake fitted on glider, seen from trailing edge.

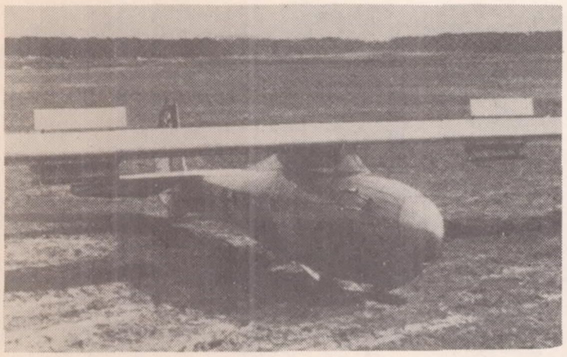


Figure 6.- Brake flaps fitted on Rhönbussard.

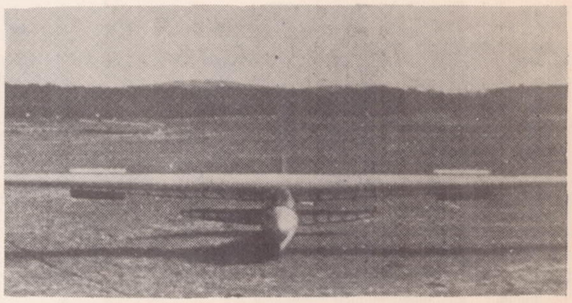


Figure 7.- Brake flaps fitted on Rhönadler.

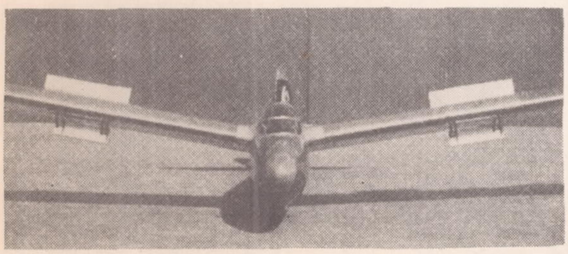


Figure 8.- Brake flaps fitted on Göppingen 3-Minimoa.

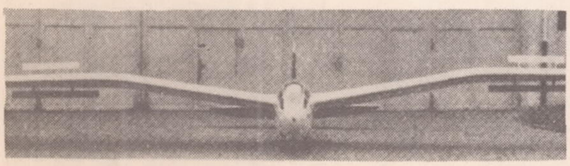


Figure 9.- Brake flaps fitted on Reiher.

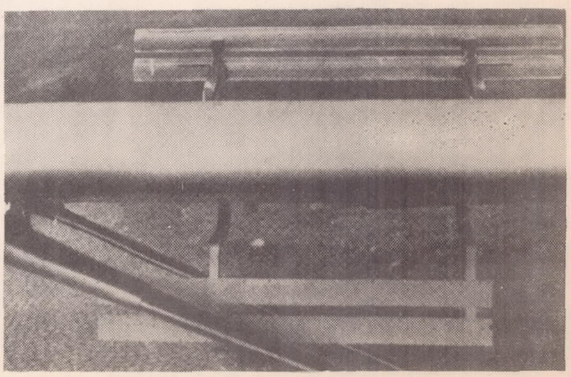
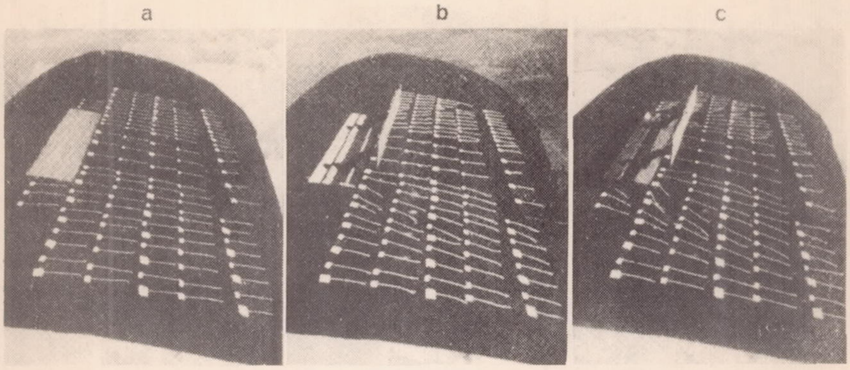


Figure 11.- Air brakes on Stösser.



a, Flaps retracted
b, " extended, version II
c, " " , " III

Figure 16.- Wool tuft record of flow.

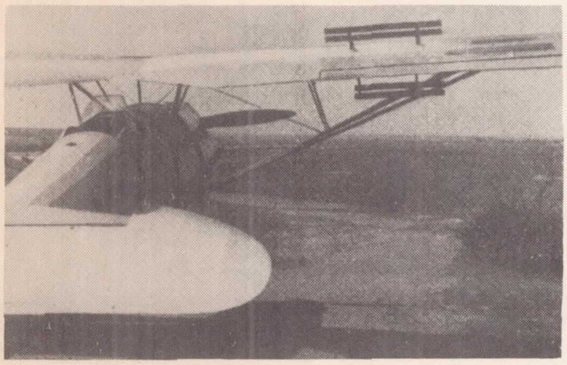


Figure 12.- Air brakes on Stösser extended.

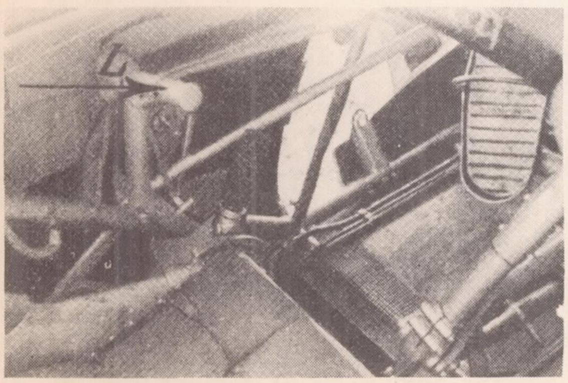


Figure 14.- Pilot's operating lever.

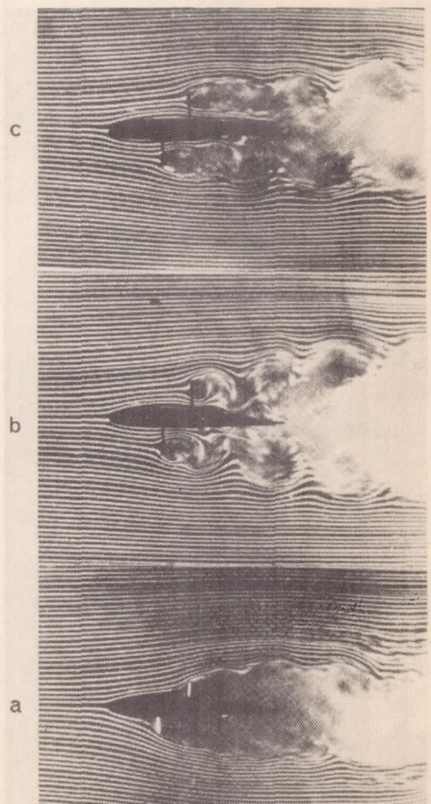
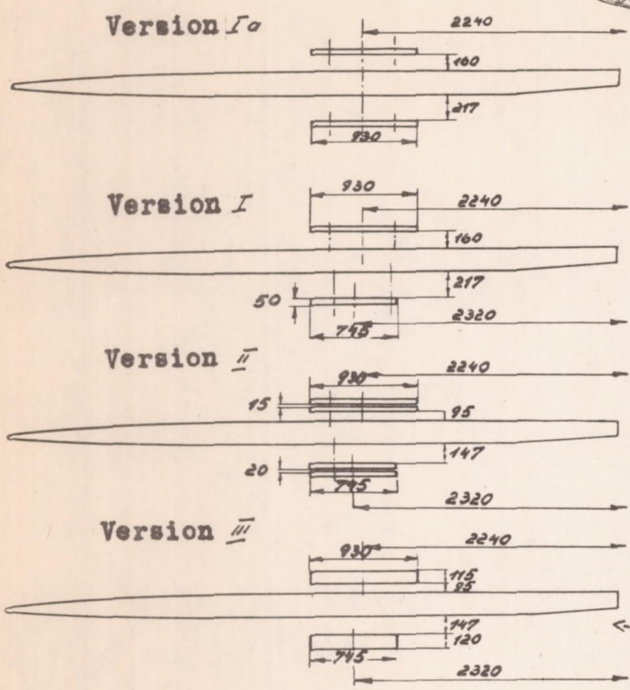


Figure 18.- Smoke photographs.

Figure 19.- Design versions of DFS dive control brakes.



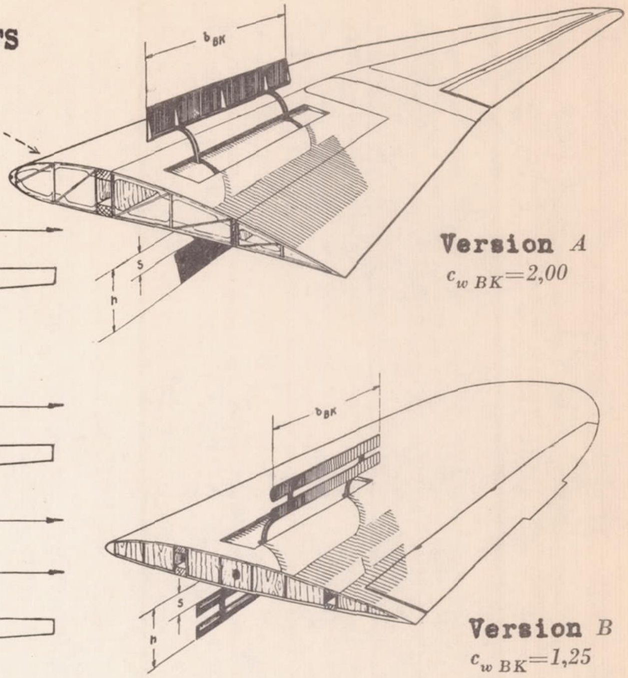
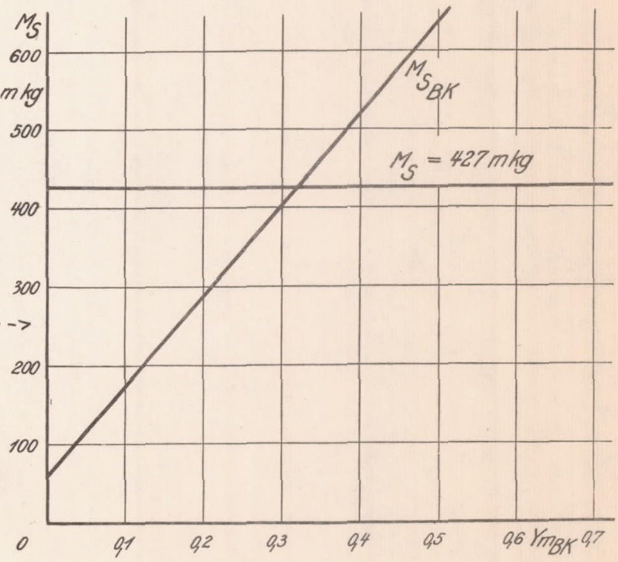


Figure 15.- Brake flap versions for flight tests.

Figure 20.- Moment of frontal pressure plotted against location of brake flap center Y_{mBK}



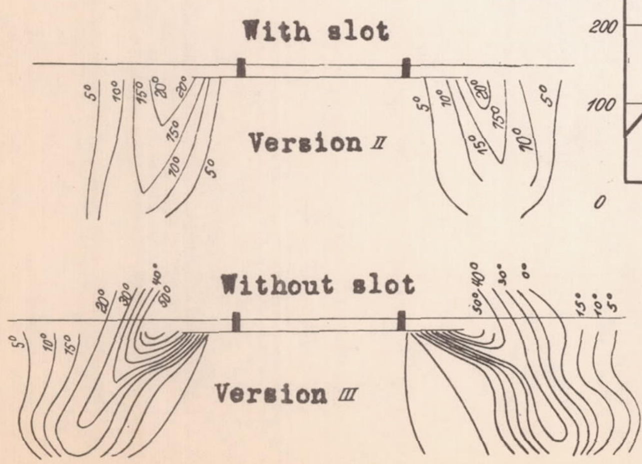


Figure 17.- Curves of equal deflection from direction of undisturbed flow.