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DEVELOPMENT OF TAILLESS AND ALL-WING GLIDERS AND AIRPLANES

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DEVELOPMENT OF TAILLESS AND ALL-WING GLIDERS AND AIRPLANES*

By Robert W. E. Lademann

Tailless airplanes are characterized by having all their control surfaces, especially the elevator, incorporated in the wings. If a wing, with the center of gravity of the whole airplane correctly located, is sufficiently stable in all directions, i.e., if the airplane, for any analytically infinitely small oscillation, is automatically and aperiodically damped and returns to its normal position, it is said to have inherent stability.

The longitudinal stability of inherently stable wings rests on the fact that the wing tips, due to an aerodynamic sweepback, generate a moment which tends to return the airplane to its normal position. The static directional stability is obtained by an always-present dihedral angle due to the taper of the wings and by wing-tip ailerons. The lateral stability is a function of the dihedral and sweepback and also of the wing contour.

Inherent stability is not absolutely restricted to wing sections or profiles with a fixed center of pressure, but in many tailless airplanes the shifting of the c.p. is utilized for increasing the restoring moment about the lateral axis, as, for example, in Lippisch's "Model 4" (1926) with Dunne plan form and Joukowsky profiles. On the other hand, the use of profiles with a fixed c.p. facilitates constructive development, as well as the computations. An inherently stable wing, according to R. v. Mises, may also be a normal rectangular wing with fixed c.p. and with c.g. located far enough back, which is replaceable, however, by a sufficiently large dihedral angle.

Most tailless and inherently stable airplanes have highly cambered profiles producing the greatest lift in the middle portion of the wing span and, at the wing tips, slightly cambered and symmetrical profiles with negative

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*"Schwanzlose und Nurflügler." Die Luftwacht, February, 1932, pp. 62-69.

angle of attack. This arrangement also affords the greatest protection against spins. Nevertheless, there are other possible stable systems, e.g., a straight wing having profiles with a fixed c.p. and dihedral angle, that is, with c.g. located far aft, in which case the wing tips also produce lift. The latter have a negative sweepback and may also have a negative dihedral, because a negative sweepback requires a more complete lift distribution. This principle was well exemplified by Colonel Duchesne's models in 1911, which were also tested by Lippisch in 1926 in the improved forms corresponding to the aerodynamic development. The induced drag of these types increases, especially at large angles of attack, this being a result of the more complete lift distribution. Such wings are very sensitivo to misplacements of the c.g. and also with respect to directional stability.*

Nature provides us with examples of all-wing aircraft in the winged seeds of the maple and of the "Zanonia Makrokarpa" (investigated by Ahlborn), etc., which served as prototypes of inherently stable models for pioneers like Pline (1870), Igo Etrich (1890), Caslant and José Weiss (1900).

The British painter and aviator José Weiss studied bird flight from 1900 to 1916 at Cornwall on the Atlantic coast and thus arrived at the tailless type of airplane. As a result of his tests, he developed the important Weiss law of enlargement, which substitutes a wing loading of $G/F^{1.33}$ for G/F and indicates a great weakening of the Lanchester principle. He accordingly developed tailless models with a thin profile, which had a pronounced positive camber in the central portion and a negative camber at the wing tips. These models had a high wing loading. A man-carrying glider, built on these important principles, was also tried out in the Aumberley Mountains (1908-1916). The models soared to a height of 500 m (1640 ft.)

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*This fact is utilized by soaring sea birds in strong gusts by a similar position of the wings, since they are dependent on the utilization of the aerodynamic impulses. Compare also the recent investigations of Professor Moltschtenof in "Struktur und Impulsmenge der Böen."

and a distance of 9.7 km (6 miles).* There was built, moreover, a Weiss two-engine tailless monoplane, which profoundly influenced the Handley Page airplanes.

In 1905 Weiss met Igo Etrich at the international model contest in Paris, where it was found that both had arrived independently at the same forms. Etrich had developed the "Taube" through transition from flora to fauna, which, however, due to external conditions, did not receive the merited attention. (Since 1928 Etrich has continued his studies in another direction.)

The use of elastic parts is common to all these wings, whether derived from flora or fauna. They are therefore suited only for relatively slow flight. Even now this question is entirely open. Energetic advocates of the partially elastic type are Etrich (at least until very recently), Crocco, and also Kirchner with his glider "La Pruvo" and the new "La Pruvo" model (1931-2).

Since linear outlines and rigid surfaces were required for technical and economical reasons, the forms borrowed from nature were conventionalized. This was first accomplished by Captain Dunne. Sources of weakness in his airplanes were the thin, almost uniform profiles, unfavorable at low speeds, and the pronounced lift reduction at the conically warped wing tips. Here belongs also the braced low-wing monoplane "Simplex" of René Arnoux (1911) with its pusher propeller and rectangular fuselage. The wing had a low fineness ratio and a symmetrical profile, flat on the bottom and curved on the top, with an S twist. The requisite longitudinal balance was obtained by giving the trailing edge, which constituted about a third of the uniform wing chord, a negative angle of attack, whereby the altitude control was to be insured by regulation of the propeller thrust. In 1910-11 Berner also tried out an inherently stable and decidedly conical

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*The Weiss enlargement law of mechanical creations is explained in a treatise "Notes on Giant Aeroplanes" written with the collaboration of Alexander Keith. It contains the experimental and enlargement laws up to very large all-wing airplanes. The life work of José Weiss has been very charmingly described by his son Bernhard José Weiss in "Gliding and Soaring Flight."

model wing.*

In 1911-1913 Robert Mallet tested a large number of inherently stable wings with positive and negative dihedral and sweepback, which, according to Duchesne, exhibit stability for a given form, magnitude and location of the inertia ellipsoid. Similar airplanes with wing tips extended forward were also designed by Lippisch in 1926 and by Dr. Alfred King in 1928. Mallet's best models had a pronounced sweepback and dihedral, tapered wings with curved trailing edge and well-rounded tips. Mallet also investigated wings, which, according to Dunne's prototype, could be developed into a right circular cone, as well as wings with divided tips like the "Aasgeier" (fig. 1), which were recently tested again at Rossitten. Mallet's inherently stable wings were surfaces with potential curves, because they represented the developable surfaces of cylinders and cones. The models of over 2 m span flew freely, even when captive, in a wind of 20 m/s (66 ft./sec.). The largest model, with a span of 4.5 m (14.76 ft.), had tapered wings with rounded tips and a uniform decrease in the angle of attack with mostly thin profiles. Most of the models, weighing 15 to 20 kg (33 to 44 lb.), flew at a velocity of about 12.5 m/s (41 ft./sec.). The Mallet type, even with thin profiles, has good stability.

According to Mallet, the directional stability of flattened M wings (as subsequently in Wenk's model) depends on the ratio of the half-span to the height of the wing, i.e., directional instability is produced by a pronounced dihedral of the inner or central portion of the wing. The best arrangement is for the wing roots and tips to be horizontal. An inherently stable wing, with a forward sweep and variable angle of attack, has poor lateral stability, low speed and a small L/D ratio, but better lift distribution. The stability can be increased, especially for wings with forward sweep, by dividing the tips into several parts. Good aileron efficiency with long lever arms is thus obtained without affecting the inherent stability of the wing as a whole. Mallet's models flew without keel or rudder. The model wings were

*Compare also the British patents of the Blaire Atholl Company according to Dunne, as regards the development of a rectangular wing into a right circular cone and the experiments of G. Eiffel in "La Résistance de l'Air et l'Aviation."

so designed, with forward sweep, that their roots met at the rear in the plane of symmetry, and the air flowed under the wings toward the plane of symmetry (1914 Eiffel laboratory tests). Such models, however, flew very slowly, due to the more perfect circulation distribution.

For historical completeness, the tailless gliders of the painter Soldenhoff are here mentioned, some of which, of the Etrich and Weiss types, also had inherently stable wings with very short tails (1913).

The experiments of the students Adaridi, Wischnef and Scherschewski on the Gulf of Finland, with models of 20 cm to 3 m (7.87 to 118 in.) span, were performed more systematically (1911-1916). Tests were made with tailless and "Ente" airplanes having inherently stable main wings of the Weiss, Etrich and Dunne types with Joukowsky or Eiffel profiles. From these there was derived a semi-elastic wing with gradual transition to the fuselage.* The investigation demonstrated the extraordinary stability of an inherently stable wing with elastic tips. Here also directional instability and a tendency to turn into the wind are produced by an excessive positive dihedral.

The tailless types gradually receded, because the development of more efficient aircraft engines enabled the flight of aerodynamically less perfect airplanes. The desired rapid improvement in flight performances was preferably obtained by increasing the efficiency of the engines. Only a few investigators, like Etrich, Offermann and Weiss still occupied themselves with tailless airplanes. Not until 1920 was the work of the pioneers resumed at different points, since the post-war time required economical airplanes. The science of modern aerodynamics has provided the requisite knowledge for construction and the preliminary assumptions for stability calculations, for profiles with fixed c.p. yielding the maximum lift, and lastly for artificially increasing the circulation by means of slotted wings, by removing the boundary layer by pressure or suction, and by forward control surfaces with or without slotted wings and their combinations.

In England in 1920-21 the inherently stable wing "Alula" was developed with a measured L/D ratio of 21.

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*A similar type was patented by Georg Wojewetzki in England in 1924 and tested in the wind tunnel of the National Physics Laboratory.

The leading edge had a negative dihedral, while the trailing edge had no dihedral. The whole wing was bent upward at the tips, like the Zanonia, these tips providing the necessary longitudinal balance. A large airplane was designed, and then a pursuit plane was built with Alula wings, which proved to have very poor controllability. In 1921 the racing plane "Simplex" was built on similar lines as a medial-wing monoplane with a short fuselage terminating at the rear in a vertical edge (keel effect). The tractor propeller was driven by a 300 hp engine. Unfortunately this racer was considered too dangerous to be flown.

In Germany the first tailless airplane, the "Feldberg," designed by Dr. F. Wenk (Weltensegler-Flugzeugwerke) with M wing and negative angle of setting of the wing tips, was tested at Sylt. The very narrow rectangular wing had a thin section with a stiffener running its whole length on the under side. The short fuselage was streamlined. Because of its inherent weakness, it was destroyed in 1921. The thick cantilever high-wing monoplane "Baden-Baden-Stolz" was built in 1922. Its wing also had the characteristic M shape, the central portions having a positive dihedral and the outer portions a decided taper. Unfortunately, this promising type was not developed further. Recently, Wolf Hirth and Wenk have been working on a similar type.

A. Lippisch, I. Tscheranowski and Captain Hill first, and almost simultaneously, applied the results of the more recent theory of flow. Lippisch first built a monoplane developed from the Dunne wing with a pronounced sweepback into the triangular tapered wing of his latest semi-all-wing "Flying Triangle" having a dissymmetrical, maximum-lift profile with a fixed center of pressure, as worked out by him in the R.R.G. (Rhön-Rossitten-Gesellschaft).*

In 1929-30 Captain Latimer Needham in England built a tailless, two-engine sport monoplane, the "Halton Meteor," provided with forward control surfaces for rapidly increasing the leveling-off longitudinal moment. Lippisch

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*Rhön models (1920) in collaboration with Espenlaub. Also partially by derivation from the works of Max Munk for the National Advisory Committee for Aeronautics. The Munk profiles have been known since 1925, but were first published by Lippisch in 1929. They play an important role in the construction of the R.R.G. tailless gliders.

is likewise working out a system of forward control surfaces based on the Handley Page slotted wing. These surfaces might also take the form of auxiliary surfaces over the leading edge of the wing. The introduction of the forward control surfaces from submarine construction constitutes an important innovation, especially for high-speed airplanes. The forward control surfaces are necessarily similar to the Handley Page system of controls with the trailing edge in the form of an elevator, in order to afford an important local increase of the lift coefficient in the middle of the wing, since the air flow begins to separate at the middle of most inherently stable wings. A further help is the use of wing profiles with artificial lift increase. Thus far no experiments have been tried with removal of the boundary layer by pressure or suction in the middle of an inherently stable wing, but probably will be soon.

In 1922 B. Tscheranowski tried a glider with a wing having the shape of a parabolic segment, in which the aerodynamic sweepback with corresponding profile development could exercise a good stabilizing effect. This all-wing glider exhibited excellent longitudinal stability in its trial flights but, unfortunately, developed a considerable diving moment due to the faulty profile. The experiments also demonstrated the possibility of directional control without a regular rudder.* In 1930 the first powered all-wing airplane, the "Parabola Bitsch VII," appeared with a tractor propeller and a 100 hp Bristol engine. The very thin profiles of this airplane are composed of sections of logarithmic spirals by a simple graphic method. The trailing edge of the wing consists of flaps with slot effect for altitude and lateral control.

In 1920-23 the tailless "Charlotte" I and II of the Berlin Polytechnic Institute appeared. These gliders may be regarded as improved "Zanonias." Professor Hoff, Parseval, Tank and Winter participated in their design. The rectangular fuselage of the Charlotte was short and pointed in front with a pronounced keel, while the wings had very thin profiles and were braced by two V struts. Good directional control is obtained by the one-sided operation of both pairs of ailerons. The stability conditions

*The various models and full-sized airplanes had a triangulated lattice structure, which was largely indeterminate.

were determined by Professor Parseval in numerous model tests. Both types exhibited good flight characteristics, but, unfortunately, were not further developed.

The Swiss, Soldenhoff, after an unsuccessful experiment with a "compound wing,"* built several characteristic all-wing airplanes having a very pronounced sweepback (38°) and rectangular or tapered wings with a dihedral of only 6.5° and a pusher propeller. The wing profiles were cambered in the middle, symmetrical in the center of each semispan and either symmetrical or with camber reversed at the wing tips. Fitted with only one pair of ailerons, the first Soldenhoff tailless airplanes had no rudder. End plates were used only once (and that wrongly) over the middle of each half-wing. Soldenhoff is fundamentally opposed to end plates, because the consequent slight diminution in the induced drag can be offset by a very slight increase in span. Experiments with large models show that turns can be made very well by means of ailerons alone without the aid of wing-tip rudders.

The "Luftfracht" company had Langgut design an all-wing airplane of 50 m (164 ft.) span with three 420 hp Liberty engines. Peculiar features of this airplane are the use of two pairs of balanced rudders and the distribution of the weight along the span so as to correspond as closely as possible to the distribution of the lift, thus reducing to a minimum the bending moments of the spars. Langgut and Lippisch apparently followed very much the same line of reasoning.

Haydn also built a tailless glider on the plan of the Zanonia and the José Weiss. His interesting productions were not continued after 1926.

In 1928-29 Dr. Alfred King developed a tailless type with a forward sweep. According to the 1930 patent, this type was easy to maneuver, as demonstrated by tests.

We have shown how practice and theory adequately cover the static directional and lateral stability. An investigation of the dynamic stability of tailless airplanes

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*Soldenhoff's "compound wing" was intended to utilize the gyroscopic effect of the air vortices, produced by steps on the pressure side of the wing, for maintaining the stability.

by Routh is not yet completed, but is very important on account of the wholly different form and magnitude of the combined action of the aerodynamic forces and moments, as well as the different form of the inertia ellipsoid. The possibility of wing forms with neutral and with positive longitudinal stability has been demonstrated. Neutral stability, however, can be of importance only for pursuit planes. With the correct weight distribution (according to Fuchs and corresponding, under certain conditions, to the lift distribution) along the wing and the construction of the wing tips with symmetrical or even lattice profiles, protection against spins is fully insured.* The presence of lattice profiles may correspond, though not necessarily, to the requirements of inherent stability in the selection of the profile, though this is still an open question.

According to the method of Schirmanof's Russian experiments, Lippisch also shows that backswept wings like the "Storch" and tapering wings with a straight trailing edge may possess good directional stability. Even a straight cylindrical wing and, still more, a tapering wing may have great directional stability, which increases, below the separation point, with the angle of attack. Positive and especially negative dihedral angles, in simple cylindrical and tapering wings, suffer a considerable reduction in the directional stability.** In the separation phenomenon, which begins in the middle of inherently stable wings, the longitudinal stability, especially with the use of floating ailerons, is theoretically and experimentally but little endangered, due to the wing warping. Also the location of the rudders at the wing tips fully insures directional stability, even in the stalled condition.

The experimental airplanes of Dr. A. Kupper must be

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*By lattice profiles is here meant, in general, thin profiles ("plate profiles") provided with transverse slots. They are aerodynamically advantageous, due to the fact that the normal forces increase almost linearly up to angles of attack of 90°, so that, according to W. Schmidt, they should have an L/D ratio of only 8 (?).

**Cf. footnote on page 2. A sea bird always flies from the trough to the crest and must therefore have directional stability. This he obtains by giving his wings a negative dihedral. By continually varying his course he reacts on the gusts, which he converts into lifting power.

regarded as limiting cases of inherently stable wings with minimum sweepback, in which the requisite aerodynamic stabilizing moments are kept small by the use of profiles with fixed c.p. and pronounced variation of the lift moment according to the angle of attack (i.e., $dc_a/d\alpha$ large), so that small lever arms, that is, a slight sweepback with a corresponding lift reduction at the wing tips, will suffice. Though the vertical control surfaces are not at all necessary according to the experiments, nevertheless, if they are used, they should take the form of end plates with attached wing-tip rudders, which would improve the maneuverability.*

Since 1929 Rudolf Schul has been investigating models with new inherently stable wings characterized by the fact that each outer portion of the wing forms a hollow half-cone with its open side down and its vertex coinciding with the end point of the leading edge of the central portion of the wing. The Göttingen and Munk profiles are used, including the N.A.C.A. profile M 12. According to the model tests, good lift-drag ratios are obtainable, even with a smaller aspect ratio, which, according to Schul, is attributable to the favorable effect of the wing tips on the marginal vortices. Schul's models exhibited remarkable stability in straightening out from any attitude of flight.

The wing of Abrial's glider, at the Rhön in 1931, was similar to the "Flying Triangle." This cantilever low-wing monoplane has a thick tapered wing of 1.5 to 2 m (4.92 to 6.56 ft.) span. The Lachmann slots are used by both Abrial and Lippisch.

At the Rhön in 1931, a member of the Hessian Academic Aero Club exhibited a remarkable tailless all-wing model of about 1 m (3.28 ft.) span with a very thick profile, small aspect ratio, large wing loading and consequent high speed. In shape it resembled the "Parabola," but its

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*According to the investigations of Nagel, the end plates diminish the induced drag in correspondence with the ratio of the height to the span, which is equivalent to increasing the span. According to the Russian works of Krassilschtikof (Z.A.H.I., Moscow), wing-tip plates have less effect and produce considerable additional drag when wrongly used, as by Soldenhoff, Funay and others.

trailing edge had an elliptical cutaway to which a circular elevator was fitted.

Aerodynamically the all-wing type enables a considerable shortening of the span, amounting to 30 or 40 per cent as compared with the conventional types, as well as a pronounced reduction in the wing loading. The inherently stable wing has many possible applications, due to its many advantages and great diversity of shapes. The inherently stable, tailless, all-wing airplane, with great static longitudinal stability, spinproof shape, decentralized power distribution and correct weight distribution throughout the span, a high fineness ratio and maximum commercial efficiency, is the necessary and satisfactory airplane for long flights. When such a wing is designed for a low rate of vertical descent, a new and promising type of glider is obtained. In a wing having minimum static longitudinal stability (neutral) and supporting wing tips without wing-tip rudders (King type), with the introduction of bow elevators, a promising form of combat plane is obtained, on which the absence of the customary tail surfaces leaves a free field of fire toward the rear.

Translation by Dwight M. Miner,
National Advisory Committee
for Aeronautics.

TABLE I

The Principal Constructors Who Participated in
the Development of Tailless Gliders and Airplanes

	To 1900	1901-1910	1911-1920	1921-1931
Germany	Friedrich Ahlborn	Berner	Erich Offer-man*	Haydn, Nihm, Hüttmann, Winter, Wenk, Kirchner, King, Lippisch, Langgut, Schul, Kupper, Köhl
England		José Weiss with A. Keith, J. W. Dunne	José Weiss with A. Keith, J. W. Dunne	Lathimer-Needham, G. T. R. Hill, F. R. and J. Granger
France			Robert Mallet, G. Eiffel, René Arnoux, Moreaux**	George Abrial, René Arnoux
Switzer-land			Alexander Soldenhoff	Soldenhoff with Langgut
United States		Twining***	Twining	Curtiss
Austria	Igo Etrich	Igo Etrich		Igo Etrich****
Russia			Boris Adaridi with Alex. Boris Scher-schewski and W. Wischnef	B. I. Tschera-nowski

*Previous to 1914, Offermann was occupied chiefly with "Enten," which had inherently stable main wings.

**Moreaux built a tailless high-wing monoplane with pusher propeller. The wing was designed after Mallet and Eiffel.

***The Curtiss Airplane and Motor Co. built in 1930 a tailless biplane of the Dunne type.

****In 1906-12 Professor Twining investigated inherently stable tailless airplanes, which had a very similar appearance to the subsequent "Alula" type.

Table II

Designation		Lippisch, model 1921-22	Lippisch "Experiment 64, 1925	Lippisch "Storch" 1928	Lippisch "Fl. Dreieck" 1930-31	Kirchner "Futurum" 1930	Soldenhoff-Langgut 1929	Langgut Commercial Airplane 1929	Haydn "Haydn" 1925-26	Nihm "Zaunkönig" 1927	Schul-Marczinsky "Stadt Magdeburg" 1930-31	Wenk "Feldberg" 1921
Type[1]		whM	chM	shM	cmM	shM	wlM	cA	chM	shM	shM	swhM
Engine			—	7/9 PS DKW	28/32 PS „Cherub"	—	28/32 PS „Cherub"	3×420 PS „Liberty"	—	—	—	—
Length	m		2,20	3,80	4,20		4,79	23,40	4,20	3,66	3,10	3,50
Height	m		1,10	2,00			1,68	5,50	1,30	1,60	1,20	
Span	m	11,00	10,00	12,37	13,00	8,60	10,00	50,00	6,00	8,97	14,00	16,00
Wing area	m²	12,00	12,00	18,50	25,00	12,40	17,00	500	16,00	12,56	26,00	17,00
Chord in middle	m		1,50	1,87	3,00		2,00	12,00		1,80	1,20	1,45
Chord at tip	m		1,30	1,17	0,85		1,80	8,00		1,00		1,45
Aspect ratio		10,08	8,34	8,26	6,76	5,95	5,88	5,00	2,25	6,40	7,52	15,05
Sweepback			~3°	~16°			37°	24,5°		10°	—	
Dihedral				~2°			6,5°			—	—	
Profile[2]				J	RRG		G, E	G, E		sG	M. 12	
Aileron area	m²		1,30	1,86	2,76		1,77	27,73	—	1,90		
Elevator area[3]	m²		—	—	2,76	—	—	82,00	—	1,14	—	—
Rudder area	m²			1,60			—	—		0,71		—
Weight of fuselage	kg		16,0		160	14,0	184					
Weight of wing	kg		42,0		}160	}26,0	}96					
Weight of control surfaces	kg		—									
Weight of structure	kg	44,0	58,0	170	320	40	280	5 600	80,0	45,0	210	48,0
Total weight	kg	114	128	250	520	110	480	16 800	140	125	280	118
Wing loading	kg/m²	9,5	10,7	13,5	20,8	8,9	28,2	33,6	8,8	10,0	10,8	6,6
Power loading	kg/hp	—	—	27,8	13,3	—	19,2	13,3	—	—	—	—

Designation		Wenk "Baden-Baden-Stolz" 1922	Kupper "Uhu" 1929	Kupper "Muster 5" 1930	Winter "Charlotte I" 1922	Winter "Charlotte II" 1923	Tscheranowski "Parabola" 1924	Tscheranowski "Parabola VII" 1930-31	Hill "Pterodactylus IA" 1925-26	Hill "Pterodactylus IIB" 1930	Latimer-Needham "Halton-Meteor" 1928
Type[1]		chM	chM	chM	shM	shM	cA	cmM	shM	shM	cmM
Engine		—	—	—	—	—	—	100 PS „Lucifer"	30/40 PS „Cherub"	75 PS „Genet"	2×32 PS „Cherub"
Length	m	3,50		2,00	4,50	4,10	3,75	4,70			3,73
Height	m	1,20		1,16		1,50	1,25		2,30		
Span	m	14,50	17,00	13,00	15,20	14,50	10,00	12,14	13,70		18,36
Wing area	m²	16,00	24,00	10,60	20,00	19,50	20,00	30,00	20,70		16,72
Chord in middle	m			1,00		1,50	3,75	3,70	2,80		1,98
Chord at tip	m					2,30	0	0	1,52		0,58
Aspect ratio		13,15	12,05	15,95	11,55	10,78	5,00	4,91	9,07		10,70
Sweepback					—	—					24°
Dihedral			—	—		3°	—	7°	—		2,5°
Profile[2]			E	E			G		RAF	RAF	E
Aileron area	m²				2,80		5,00		5,10		2,78
Elevator area[3]	m²	—			2,80	2,60	—	—			–
Rudder area	m²	—			0,66	1,00	0,80		1,20		1,47
Weight of fuselage	kg	32,0		22,0	39,0	38,0	—				
Weight of wing	kg	58,0		}36,4	44,0	47,5	42,0	}800	165		
Weight of control surfaces	kg	10,0			21,0	14,5	8,0				
Weight of structure	kg	100,0	122	58,4	104	133	50,0	612	208		160
Total weight	kg	170	192	128,4	174	203	120	850	300		260
Wing loading	kg/m²	10,6	8,0	12,1	8,7	10,4	6,0	28,3	14,5		15,6
Power loading	kg/hp	—	—	—	—	—	—	8,5	7,5		4,06

m x 3.28083 = ft. m² x 10.7639 = sq.ft. kg x 2.20462 = lb. kg/m² x .204818 = lb./sq.ft. kg/hp x 2.17442 = lb./hp

Table II (continued)

Designation	Lippisch model 1921-22	Lippisch "Experiment 64, 1925	Lippisch "Storch" 1928	Lippisch "Fl. Dreieck" 1930-31	Kirchner "Futurum" 1930	Soldenhoff-Langgut 1929	Langgut Commercial Airplane 1929	Haydn "Haydn" 1925-26	Nihm "Zaunkönig" 1927	Schul-Marczinsky "Stadt Magdeburg" 1930-31
Type[1]	whM	chM	shM	cmM	shM	wlM	cA	chM	shM	shM
Maximum speed km/h	—	—	120	180	—	175	260	—	—	—
Landing speed km/h	—	—	45,0	60,0	—	40,0	80,0	—	—	—
Specific speed[4] km/h	44,4	45,8	53,0	66,0	42,9	85,0	83,5	42,6	45,6	45,9
Speed of vertical descent m/s	0,74	0,86	0,98	1,37	0,93	1,67	1,97	1,50	0,95	0,70
Flying range km	—	—			—	1300	600	—	—	—
Flying time h	—	—			—	10	2,6	—	—	—
Lift drag ratio			20,0	22,0	15,0		20,0			20,0
Criterion of climb	228	230	280	177	174	164	138	62,3	178	350
Span loading[5]	0,94	1,28	1,64	3,07	1,48	4,80	6,72	3,89	1,56	1,43
Remarks	With cooperation of Espenlaub Dunne wings	Dunne wings pusher propeller DKW engine	With pusher propeller	With pusher propeller		With pusher propeller; load factor 6	Design not carried out; 3 tractor propellers		Copied from model 6 of Lippisch tail Surfaces added later	NACA profile M12 in center portion of wing

Designation	Wenk "Feldberg" 1921	Wenk "Baden-Baden-Stolz" 1922	Kupper "Uhu" 1929	Kupper "Muster 5" 1930	Winter "Charlotte I" 1922	Winter "Charlotte II" 1923	Tscheranowski "Parabola" 1924	Tscheranowski "Parabola VII" 1930 31	Hill "Pterodactylus IA" 1925-26	Hill "Pterodactylus IIB" 1930	Latimer-Needham "Halton-Meteor" 1928
Type[1]	swhM	chM	chM	chM	shM	shM	cA	cmM	shM	shM	cmM
Maximum speed km/h	—	—	—	—	—	—	—		107		200
Landing speed km/h	—	—	—	—	—	—	—		44,0		40,0
Specific speed[4] km/h	37,4	48,4	40,8	50,4	42,5	45,7	30,3	76,7	55,0		56,8
Speed of vertical descent m/s	0,51	0,60	0,55	0,66	0,69	0,67	0,58				0,93
Flying range km	—	—	—	—	—	—	—				400
Flying time h	—	—	—	—	—	—	—				2
Lift drag ratio		20,0	16,0	18,0			19,6				
Criterion of climb	427	320	425	445	290	370	400				288
Span loading[5]	0,44	0,81	0,66	0,76	0,75	0,97	1,20	5,78	1,60		1,46
Remarks	Thin profiles		Also tried unsuccessfully as a powered airplane				Göttingen profiles 386 and 486	With pusher propeller; profiles log. spir, d/t=0.077 (d=285mm)	With tractor propeller; profile RAF airscrew 4; 6° decrease in angle of attack	With pusher propeller	Automatic HP slotted wing; rudder-control wheel in bow; rotatable wing tips as elevators and ailerons.

1) M = monoplane; h = high wing; m = medial wing; l = low wing; A = all-wing; w = wire braced; s = strut-braced; c = cantilever.

2) M = Munk; G = Göttingen; J = Joukowsky; RRG = Rhön-Rossitten Gesellschaft; E = special profile; s = symmetrical profile.

3) When there are two pairs of ailerons, the inner pair is sometimes to be regarded as elevators.

4) The specific speed is an aerodynamic characteristic, derived from $G/F = c_a q$ for $c_a = 1$ to $v_e = 4\sqrt{G/F}$ (m/s); it represents the pressure-head speed, at which the airplane flies with $c_a = 1$.

5) The span loading is a static-constructive characteristic, which, in the form G/b^2 is decisive for the speed of vertical descent.

km/h x .62137 = mi/hr. m/s x 3.28083 = ft/sec. km x .62137 = mi.

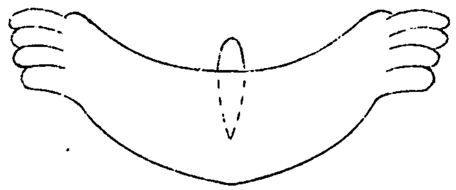

Fig. 1 Mallet's "Assgeier" glider with divided wing tips.

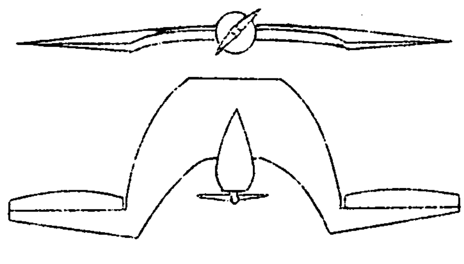

Fig. 3 King's tailless airplane (1928) with negative sweepback and dihedral.

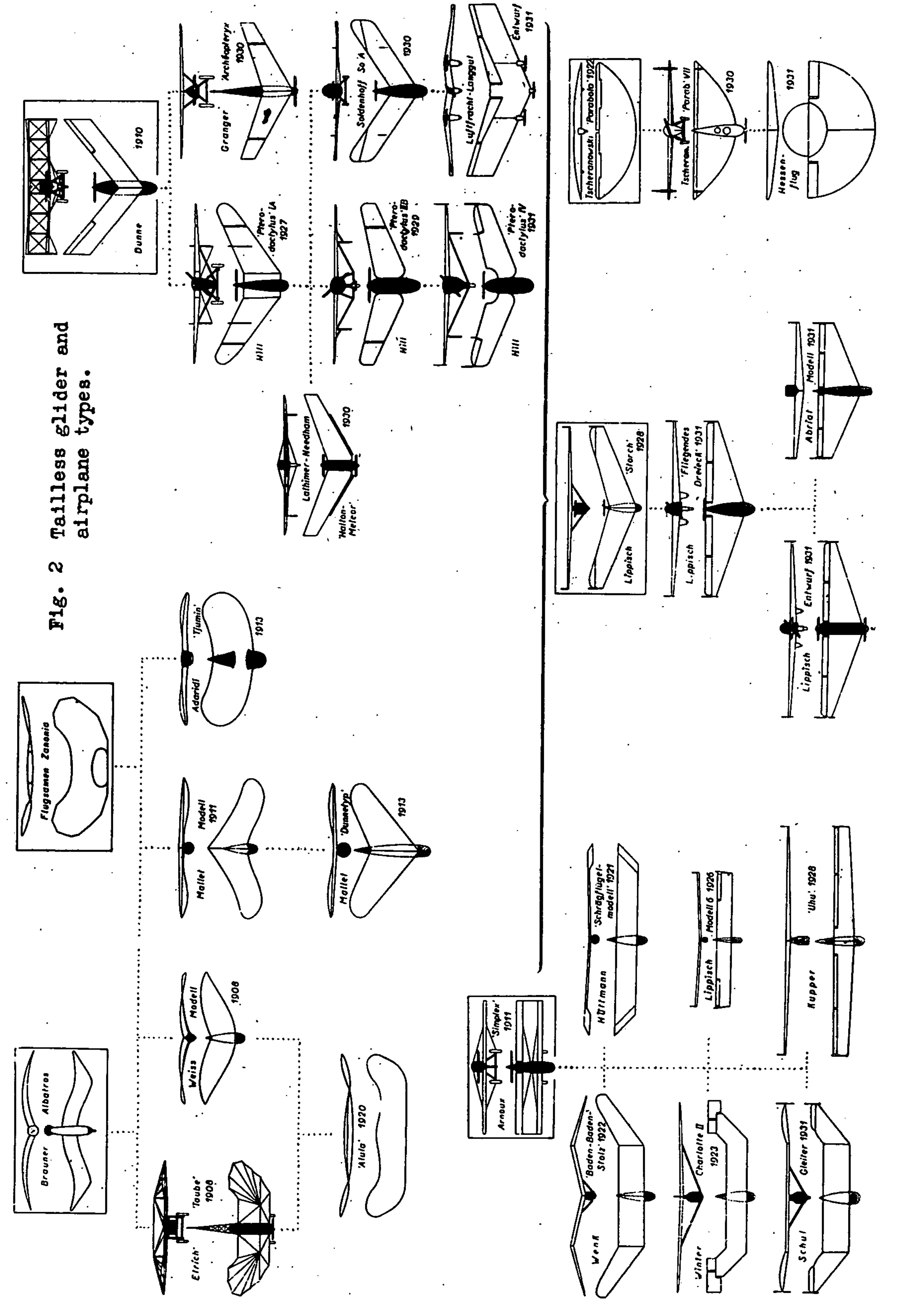

Fig. 2 Tailless glider and airplane types.