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DEVELOPMENT OF LIGHT AND SMALL AIRPLANES

By G. Lachmann

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It would be premature to speak now of any completed development of these post-war forms of airplane construction. However, certain standards have been established in the use and dimensions and shape of individual parts, which justify a survey of the previous development and enable the drawing of conclusions for the future. Retrospective reports on a period of development when things were still strongly in flux have, in the form of statistical displays, little of interest to engineers. I have therefore endeavored to select only the most important lines of development and have limited the description of individual airplanes to a few typical examples.

Any classification of the different types of airplanes should be based on logical distinctions. At the present time there is considerable confusion in the use of the terms "light airplane," "small airplane" and "glider with auxiliary engine." Classification is possible by horsepower, weight, or dimensions. The last way seems the least expedient, since small airplanes

* "Die Entwicklung leichter und kleiner Flugzeuge im In- und Auslande." From "Berichte und Abhandlungen der Wissenschaftlichen Gesellschaft für Luftfahrt" (a supplement to "Zeitschrift für Flugtechnik und Motorluftschiffahrt"), July, 1925, pp. 84 to 95.

are possible both with a small load per horsepower and a large wing loading (racing airplanes), and conversely with a small wing loading and a large load per horsepower.

Classification on the basis of horsepower is likewise indefinite, especially for airplanes whose horsepower is near the lower limit. We sometimes read of the so-called "brake horsepower." This term is, however, extremely elastic, as may be seen on the brake diagram of a small rapid engine (Fig. 1). We often find brake horsepower of 6.5 HP. given, though a glance at the brake diagram shows that the engine furnishes 2.5 to 3 times that at the basic revolution speed. On the other hand, light engines offer many possibilities of development, so that it is probable that the present values of the weight per horsepower can yet be considerably lowered and the horsepowers correspondingly increased. On the contrary, the structural weight of an airplane seems to have already nearly reached its minimum value.

I have therefore decided to use the term "light airplane" for any airplane having an empty weight (dead load) of not over 250 kg (551 lb.). The so-called "glider with auxiliary engine" is automatically included in this class. The term "small airplane" has been most generally adopted for airplanes above this limit and not exceeding 600 kg (1323 lb.), although this designation, as we have seen, is illogical and insufficient.

Development of Airplanes of Medium Weight
(Up to 600 kg (1323 lb.) dead load)

Germany.- Under the restrictions in airplane construction, as laid down by the "Entente" and promoted by the appearance on the market of suitable small air-cooled engines, after the expiration of the prohibition of airplane building, there was produced in Germany a whole series of airplanes of 35-70 HP. Space is lacking for a complete description of all the different types, which are, however, well enough known through reports in numerous technical publications.

We may designate this first stage of development in Germany as one of type formation and of search for possibilities of application. The method was to build an airplane on chance, either to be left to further development, or to fill an existing need, or to develop new possibilities of application. Of course there was generally some definite possibility of employment, which was often expressed in the designation of the type. In the following compilation, the best-known German types (in 1923) are arranged according to their prospective use.

Sport Airplanes	Training Airplanes	Commercial Airplanes (Monoplanes)
Rieseler Mark monoplane	Dietrich Gobiet biplane	Junkers Limousine
Sablatnig mono.	Junkers monoplane	Caspar Limousine
Entler biplane	Udet monoplane	Udet Limousine
Udet monoplane	Heinkel monoplane	Dornier Libelle

This list does not include Heinkel's small airplane for use on submarines and for exclusively military purposes.

The development has now entered on a new stage. The applicability of these airplane types has been demonstrated with considerable clearness. No airplane in this group has been able to demonstrate its availability as a pure sport airplane. This group likewise contains no successful commercial airplane for the rapid transportation of passengers and freight.

In spite of numerous boasts and statements of such possibility, there is here an extraordinary exaggeration of the actual need. The technical conditions for this use are also far from being fulfilled. Rapid commercial transportation by airplane requires an extensive development of the ground organization, which must include, in the neighborhood of every large city, a landing place provided with shelters, where mechanics can take charge of the airplanes and make repairs, refill with fuel, etc., and from which the inner part of the city can be quickly reached by motor vehicles.

As exclusive uses, there remain only the training of aviators and the carrier service by means of light limousines on branch lines which serve as feeders for the international air lines. To these uses there will probably be added in future, to a still greater degree, the supervisory service of high-tension electric lines.

The past year has witnessed in Germany a great increase of interest in aviation and in the number of those desirous of learning to fly. The demand for suitable training airplanes has been satisfactorily met and training schools have been established in many parts of the country by firms interested in the sale of their airplanes. The following table gives the most important characteristacs of the new German airplane types which have appeared during the past year.

Make and Type	Engine	Dead load kg (lb.)	Useful load kg (lb.)	Wing span m (ft.)	Wing area m² (ft.²)
Dietrich Gobiet high-wing D.P. VIIIa	50-55 HP. Siemens air-cooled	300 (661)	210 (463)	9.66 (31.69)	13.5 (145.3)
Udet low-wing U 10	50-55 HP. Siemens air-cooled	315 (694)	Max. 255 (562)	10.6 (34.78)	14 (150.7)
Junkers high-wing T 19	70 HP. Junkers or 80 HP. Siemens	480 (1058) 470 (1036)	270 (595) 350 (772)	-- -- -- --	21.2 (228.2) 21.2 (228.2)

Make and Type	Engine	Dead load kg (lb.)	Useful load kg (lb.)	Wing span m (ft.)	Wing area m (ft.)
Junkers	80 HP.	515	250	-	21.2
high-wing.	rotary	(1135)	(551)	-	(228.2)
monoplane	120 HP.	535	250	-	21.2
W 23 E	rotary	(1179)	(551)	-	(228.2)
Biplane	120 HP.	590	230	-	33.2
W 23 D	rotary	(1301)	(507)	-	(357.4)
Focke-Wulf	75 HP.	570	400	13.9	27
Limousine A 16	Siemens	(1257)	(882)	(45.6)	(290.6)
Heinkel	80 HP.	522	190	11	17
low-wing H E 18	Siemens	(1151)	(419)	(36.1)	(183.0)

Make and Type	Wing load kg/m² (lb./ft.²)	Load per HP. kg/HP. (lb./HP.)	Speed at sea level km/h (mi./hr.)
Dietrich			
Gobiet			
high-wing	38	93	145
D.P. VIIa	(7.78)	(205)	(90)
Udet	Max.		
low-wing	40.6	9.82	155
U 10	(8.32)	(21.65)	(96)
Junkers	35.4	10.7	140
high-wing	(7.25)	(23.59)	(87)
T 19	38.7	10.2	138
	(7.93)	(22.49)	(86)

Make and Type	Wing load kg/m² (lb./ft.²)	Load per HP. kg/HP. (lb./HP.)	Speed at sea level km/h (mi./hr.)
Junkers	36	9.6	133
high-wing	(7.37)	(21.2)	(83)
monoplane	37	6.5	150
W 23 E	(7.58)	(14.33)	(93)
Biplane	24.7	6.8	125
W 23 D	(5.06)	(15)	(78)
Focke-Wulf	36	13	130-140
limousine A 16	(7.37)	(28.66)	(81-87)
Heinkel	41.8	10.2	140
low-wing H E 18	(8.56)	(22.49)	(87)

Development in Other Countries

Even before the prohibition of German airplane building had been somewhat modified, the construction of light and small airplanes had been begun in other countries. This was mainly a reaction to the overdue army deliveries. The various firms attempted, by the delivery of airplanes for private and sport purposes, to open a new market. A list published in "Aeronautics," in 1920, contains a collection of 28 sport airplanes built in England, France, Italy, Sweden and America, including a few light airplanes. Of the airplanes listed, only 15, however, had been tested in flight.

France.- Here are to be mentioned: the Potez, of duralumin construction, equipped with a 50 HP. Potez engine, subsequently with a 45 HP. Anzani; the Spad with a 45 HP. Anzani, subsequently built as a training airplane with two seats abreast and an 80 HP. Le Rhone engine; the Caudron with an 80 HP. Le Rhone; the De Monge with a 45 HP. Anzani engine; and the Farman sport biplane with a 45 HP. Anzani or a 60 HP. Le Rhone engine. All the types mentioned were biplanes, with a single pair of struts on each side. They were of very simple and often primitive form.

England.- A. V. Roe and Co. produced the "Avro Baby" (Fig. 5), known for its remarkable flights.* This airplane,

*In 1920, London-Rome, without stop to Turin; in 1921, London-Moscow; 1280 km (nearly 800 miles) non-stop flight in Australia.

whose performances have not yet been equaled with an engine of such low power (35 HP.), was doubtless the best small airplane at that time outside of Germany. It is therefore of special interest for us to study its construction more in detail, especially as regards the weight, in order to compare it with the present German types. The principal measurements and weights are given in the following table (by courtesy of A. V. Roe & Company).

Span of upper wing,	7.6 m	(24.93 ft.)
Span of lower wing,	7.0 "	(22.97 ")
Length,	6.5 "	(21.33 ")
Chord,	1.22"	(4.00 ")
Wing area, total	16.5 m²	(177.6 sq.ft.)
Aileron ", 4 × 0.3 m,	1.2 "	(12.9 ")
Stabilizer area,	1.22"	(13.1 ")
Elevator " ,	0.79"	(8.5 ")
Rudder "	0.65"	(7.0 ")

Weights

Cell.

Wings with ailerons and strut fittings,	50.8 kg (112 lb.)
Struts,	5.4 " (11.9 ")
Brace-wires,	2.0 " (4.4 ")
Total weight of cell,	58.2 " (128.3 lb)
Wing loading,	3.5 kg/m² (0.717 lb./sq.ft.)

Weights (Cont.)

Fuselage.

Fuselage with covering and engine hood,	54.0 kg	(119.05 lb.)
Steering mechanism with cables,	5.9 "	(13.01 ")
Instruments, lighting system, etc.,	3.1 "	(6.83 ")
Total	63.0 "	(138.89 ")

Landing Gear.

Struts and axle,	9.50 kg	(20.94 lb.)
Wheels,	8.39 "	(18.50 ")
Tail skid,	1.81 "	(3.99 ")
Total	19.70 "	(43.43 ")

Tail Group.

Stabilizer and elevator,	7.50 kg	(16.53 lb.)
Rudder,	1.56 "	(3.44 ")
Total	9.06 "	(19.97 ")

Weight of airplane without power plant, about 150 kg (330 lb.).

Power Plant.

Engine (35 HP. Green) with magnetos,	93.00 kg	(205.03 lb.)
Exhaust pipe,	2.26 "	(4.98 ")
Radiator with piping, empty	10.90 "	(24.03 ")
Water in engine and radiator,	9.06 "	(19.97 ")
Propeller,	5.45 "	(12.02 ")
Oil tank with radiator and piping,	1.81 "	(3.99 ")

Weights (Cont.)

Power Plant (Carried over)	122.48 kg	(270.02 lb.)
Fuel tank with pump and piping,	6.80 "	(14.99 ")
Total	129.28 "	(285.01 ")
Dead weight of complete airplane with radiator water,	280.00 kg	(617.29 lb.)
Useful load (pilot, 36 kg (79.4 lb.) fuel, and 6.4 kg (14.1 lb.) oil,	115.00 "	(253.53 ")
Weight of airplane in flying order,	395.00 "	(870.82 ")

Wing loading, 24 kg/m² (4.92 lb./sq.ft.).

Load per horsepower, 11.00 kg (24.25 lb.).

Performances

Maximum speed at sea level,	137 km (85 mi.)/hr.
Speed at 900 m (2953 ft.) with 25% excess of power,	115 " (71 ")/hr.
Theoretical landing speed,	64 " (40 ")/hr.
Radius of action,	630 " (391 miles).

It was first built as a single-seater and afterwards converted into a two-seater.

There were also built in England, by the Austin Company, some five "Whippets" with 45 HP. Anzani engines. Aside from a few "Avro Babies" sent abroad (chiefly to India), airplanes of this type were not adopted to any considerable extent in England. The costs for purchase and upkeep were too high for private ownership. Then, too, there was the competition of the many army airplanes offered at low prices by the Aircraft Disposal Company.

America.- Here the principal companies endeavored to create a demand for sport airplanes. Some eight different types of medium-weight airplanes were brought out by 1920, four of which were flown, playing, however, more or less the role of experimental types. There has, as yet, been no general adoption of such airplanes for sport or for private touring. No considerable number has been sold, excepting for training airplanes, when combined with military purposes. A light messenger airplane, the so-called "Messenger Biplane," was constructed at McCook Field. This was a single-seat fuselage biplane with struts but no brace-wires. It was also tested with a removable landing gear. Of more recent types (ostensibly for private purposes but chiefly used for training purposes) we may mention the "Skylark" biplane of the Bethlehem Aircraft Corporation and the Longren biplane, both equipped with Lawrence three-cylinder air-cooled engines; also the training airplane of Huff Daland and Dayton Wright, the "Swallow," with a 90 HP. Curtiss engine, and the "Swanson Freeman" biplane with an 80 HP. Le Rhone engine.

Czechoslovakia.- The Avia Works (Milos Bondy in Prague) in 1920 produced the Avia BHI, a low-wing sport monoplane with struts. It was first equipped with a 35-40 HP. Austro-Daimler engine and subsequently with a 50 HP. Gnome and a 45 HP. Anzani. The same type was recently equipped with a 60 HP. Walter radial engine, both as a two-seat (Avia BH IX) and as a single-seat (BHX) training airplane for the army.

Italy.- Several years ago Macchi built a light biplane and equipped it with a 35 HP. Anzani engine, but we have heard nothing further of its use.

From the above review, we conclude that while attempts have been made in nearly all countries since the war to employ medium-weight airplanes for private purposes, such attempts have met with some degree of success only in Germany, the employment of such airplanes in other countries being almost exclusively for military purposes.

Development of Light Airplanes

Germany.- The true light airplane, sometimes designated as a "glider with an auxiliary engine," was developed in Germany from the two components: the medium-weight airplane and the glider, the latter constituting, undoubtedly, the stronger influence, both aerodynamically and structurally. Gliding or soaring flight reached its climax in Germany in 1922 with the hour flights of Hentzen and Martens. It then required but another step to produce a serviceable light airplane. There were two reasons why this step was not taken. First of all there were no suitable light engines. Klemperer had tried everywhere without attracting any interest or consideration. Then there was the one-sided development in the direction of pure soaring flight, as the result of an over-estimation of the immediate practical and technical accomplishment of the desired result.

After the 1923 Rhön soaring-flight contest, the light airplane (Fig. 7) built by the Aachen Airplane Company made several successful flights in the Rhon Mountains. This airplane was one of the first German light airplanes. It was a semi-cantilever high-wing monoplane, developed from a Rheinland glider. The supporting surface consisted of a middle section, rigidly attached to the fuselage, and two easily removable wings attached to the middle section by bolts. The plywood fuselage had a nearly rectangular cross section. The entrance was through a side door. It was driven by a Mabeco motorcycle engine, whose revolution speed was reduced in the ratio 3 : 1. It had a starting device, with whose aid the engine could easily be set in motion from the pilot's seat. The chief characteristics are:

Span	12.7 m (41.67 ft.)
Wing area	15.0 m² (161.5 sq.ft.)
Length	5.5 m (18.04 ft.)
Weight in flying order (without pilot)	160.0 kg (353.00 lb.)
Speed	75.0 km (47 mi.)/hr.

Another forerunner of the German light airplane was the Daimler monoplane (Fig. 8) on which Schrenk made remarkable flights, some of them with a passenger. It was a normal cantilever high-wing monoplane of 12.6 m (41.3 ft.) span and 24 m² (258 sq.ft.) wing area. It was driven by a motorcycle engine which furnished 12 HP., according to the statement of the Daimler Company. Martens experimented with a small Ilo engine mounted on the front end of the "Strolch." Its power was too small, however, to produce more than extended gliding flights. With this device, Martens made a number of flights in the Rhön during the winter of 1923-24 and at Rossiten in the spring of 1924. It was also at Rossiten that Budig tried out his well-known small biplane with its automatic stabilization, which was equipped with a Victoria motorcycle engine. Its power was also too small, so that it never made any but short flights.

In 1924 the constructive activity in Germany in the field of the light airplane was dependent on foreign light engines, it being only recently that the Siemens-Schuckert Company has remodeled a motorcycle engine for use on light airplanes. This engine gave good results on the high-wing monoplane "Habicht" of Blume and Henzen (Fig. 9). It has two cylinders in V arrangement with double valves suspended in the cylinder head. It furnishes 20 HP. at 3500 R.P.M. The revolution speed of the propeller is reduced by gearing to 1500 R.P.M.

Most of the constructors used light English engines

(Douglas and Blackburne). Fig. 12 shows the "Kolibri" of the Udet Airplane Company of Munich-Ramersdorf which, under the pilotage of Udet, made the best showing in this year's (1924) Rhön contest. It is a high-wing airplane of 200 kg (441 lb.) dead load, with plywood fuselage. It is equipped with a 750 cm³ (45.77 cu.in.) Douglas engine. The over-weight of the one-seat type in Germany is due chiefly to a compromise on the engine. Two-seaters have thus far been built only by the Aachen Glider Company, the Caspar Works in Travemünde and Messerschmidt in Bamberg.

France.- The first decided impetus in the development of light airplanes doubtless came from France. In contrast with the glider development which took place in 1920 in Germany and which sought to develop the light airplane by systematic research with the formation of independent types, we find in France, soon after the war - if we disregard the experiments with "aviettes" (flying bicycles), which were not of much technical importance - light airplanes derived to a considerable extent from the earlier types of large airplanes.

In 1919 Farman produced a light monoplane (the "Moustique") of very simple form and only 100 kg (220 lb.) dead load, which was first equipped with a 20 HP. ABC engine and later with a 16 HP. Salmson engine. Greater interest was attracted by De Pischof's light airplanes "Avionette" and "Estafette" which embodied, to a large extent, the endeavor to simplify the types and reduce them to their smallest dimensions, by making each structural element serve as many purposes as possible. On the basis of this correctly conceived and successfully applied principle of light construction, a dead load of only 102 kg (225 lb.) was realized in the all-metal biplane "Avionette."

A few years after the war, the reawakened interest of France in war preparedness turned the attention of manufacturers again to the construction of heavy airplanes of great power. Moreover, certain influential circles (including Fouck) energetically opposed the tendency, which had taken root in France after the German Rhön successes, toward the construction of light and small airplanes, with the argument that progress in airplane building lay only in increasing the power and speed. Subsequently, the results of soaring flight led in France to the construction of light airplanes very similar to the successful soaring airplanes or gliders. A noteworthy representative is the Dewoitine cantilever high-wing monoplane of 12.6 m (41.34 ft.) span, which has been flown with various engines (15 HP. Clerget, 16 HP. Salmson and 15 HP. Vaslin engine

The English successes turned many French constructors (Breguet, Mignet, Bleriot, Beaujard Viratelle, Ligreau, Marais, etc.) to the light airplane. It is not necessary to consider all the types in detail. They are nearly all single-seat high-wing monoplanes, showing no particular structural improvement on the German and English types. Between June 27 and August 10, 1924, the round-flight contest organized by the "Association Francaise Aerienne" took place in France. It started from Buc and covered a total distance of 1800 km (1118 miles) which had to be flown in eight stages. Only three of the entrants passed the preliminary test, which consisted of a horizontal flight of 50 km (31 miles) and a climb to 2000 m (6562 ft.). The total results were lamentable. Only one airplane, a Farman monoplane, piloted by Drouhin, was able to complete the contest with an average speed of 85.553 km (53.16 miles) per hour.

England.- The English light airplane contest at Lympne (Oct. 8-13, 1923), added a strong impetus to the development of the light airplane. Vigorously promoted by almost all the English airplane constructors, it led to surprising results. I have already given a detailed report of this contest at a meeting of the Wissenschaftlichen Gesellschaft für Luftfahrt, so I can now confine myself to the most important English results, which were as follows:

1. The important point in the development of the light airplane consists in increasing the reliability of the small engines.

2. The type to be generally adopted in future is not the single-seater and certainly not the glider with an auxiliary

engine, but the light reliable two-seater.

The most noteworthy single-seaters, which were developed by the contest and adopted to a limited extent as training airplanes by the R.A.F., are the De Havilland DH 53 (Fig. 14) and the Parnall Pixie, both low-wing monoplanes with top struts.

The DH 53, although it won no prize at Lympne, exhibited remarkable flight characteristics and excellent structural properties and is a typical representative of English aircraft construction from the simple and logical viewpoint. Recently this airplane has been equipped with the Blackburne "Tomtit" 698 cm^3 (42.59 cu.in.) engine, instead of the Douglas 750 cm^3 (45.77 cu.in.). The flying weight of the airplane was thus somewhat increased, from 236 to 240 kg (520 to 529 lb.), but its flight characteristics were considerably improved. I am indebted to Mr. Walker, the chief engineer of the De Havilland Works, for the following data:

R.P.M. of propeller (direct drive) at sea level,	3050
R.P.M. while climbing,	3000
R.P.M. in horizontal flight,	3400
Horizontal speed at sea level,	117 km (73 mi.)/hr.
Horizontal speed at 2000 m (6562 ft.),	103 km (64 mi.)/hr.
Climbing speed at sea level,	1.95 m(6.40 ft.)/sec.
Climbing speed at 2000 m (6562 ft.),	0.725 m(2.38 ft.)/sec.
Climbing speed at 3000 m (9842 ft.),	0.49 m (1.61 ft.)/sec.
Climbing time to 3000 m (9842 ft.)	38.5 minutes.

The maximum speed of the Parnall Pixie II is 160-170 km (100-105 miles) per hour and its ceiling is about 4500 m (14764 ft.).

Aside from military purposes, no noteworthy demand for single-seat light airplanes has been created. On the one hand, the original cost is still too high for private persons interested in sport and pleasure flights and, on the other hand, single-seaters are not adapted to the development of sport flying on a club basis, since there is no possibility of learning. It may be worth while for the same classes in Germany, who are still advocating the use of single-seaters, to learn that only four of the successful airplanes at the Lympne contest have gone into private hands, namely, one each of the DH 53, Parnall Dixie, ANEC and Avro.

I do not fear to say here that the English are a stage ahead in light-airplane building, because after the experience of their first contest, they have proceeded with decision to the development of the light two-seater. These endeavors were assisted in a decisive manner by the rules and regulations for this year's (1924) contest at Lympne. The fact that this year's contest, in contrast with last year's, is purely national clearly expresses the purpose of encouraging the British airplane factories to make light airplanes suitable for military training. The demand is for two-seaters with dual control, which possess the airworthiness certificate of the Air Ministry as regards their static safety and which have demonstrated their flight characteristics by previous trial flights. The stroke volume of the engine must not exceed 1100 cm³ (67 cu.in.). (Some constructors rightly consider this limit too small for a thoroughly reliable airplane. Captain Geoffry De Havilland, who was considered one of the most promising contestants, is said to have withdrawn from the contest for this reason.) Easy assembling and dismantling and stowing in a small space, in the dismantled condition, are required. The very strict flight test provides for a point evaluation of the speed, climbing ability, speed range, quick start and short take-off run. Airplanes with a landing speed of over 72 km (44.7 mi.)/hr., or a minimum speed of less than 96 km (59.7 mi.)/hr. are automatically debarred.

Judging from the character of the rules and regulations, it would seem to be the fate of the light-airplane movement to glide into purely military channels. According to newspaper reports, however, the English Air Ministry is planning a broader and more general use. Preparations have already been begun for instituting, at suitable places with the support of the authorities, private associations for the quickening or awakening of the "air sense" among the English youth. The final steps in this direction will be taken when satisfactory two-seaters become available. These associations are designed, on the one hand, to afford former military aviators and reserve officers of the R.A.F. the opportunity to continue their training and, on the other hand, to enable others to learn to fly under their guidance. It is hoped to reduce the cost per flight-hour to 5-5.7 shillings ($1.20-$1.37).

America.- Here the light-airplane movement is still too much in flux and in the initial stage for any definite report. According to "Aviation" only five light airplanes with motorcycle engines had been built by private constructors (Indian, Harley Davidson, Ace) up to April, 1924. Of the older forerunners, going back to 1919-20, apparently only the "Bellanca" biplane of Maryland, with a 35 HP. Anzani engine and a dead load of 180 kg (397 lb.) was actually flown.

The same circles which tried in vain to have soaring flight adopted in America, are now endeavoring to arouse interest in the light airplane. The opposition seems to be due partly to a certain lack of understanding, in many influential circles, of the tasks and purposes of the light airplane. There still seem to be many aviators, even in America, who condemn in advance any airplane of less than 200 HP. The institution of contests for the production of practically useful airplanes arouses little interest on the part of the public, which prefers the thrills of pure speed tests.

The structural development is still at the standpoint of the single-seater, due to the lack of suitable light American engines. The power of the light airplane engines (15 HP. at 2200 R.P.M. and 50 lb. weight) designed by the Army Air Service and built by the Steel Production Engineering Company of Springfield, Ohio, is not sufficient for two-seaters. Among the more recent types, the high-wing monoplanes of Mummert and Allen are both equipped with Harley Davidson engines.

In the other countries, the light-airplane movement has gained a foothold only in isolated cases. In Holland, Van Carley has built a high-wing monoplane of noteworthy design and equipped with a 25 HP. three-cylinder Anzani engine (Fig. 16). In Czecho-Slovakia, a low-wing monoplane, resembling the DH 53 and equipped with a Vaslin engine, is being built by the Avia Works. In Italy a light monoplane "Pegna Rondin" was tested in 1923, with a 400 cm^3 (24.4 cu.in.) ABC engine. This was a typical glider with an auxiliary engine and structurally somewhat resembled the Aachen glider "Blaue Maus" (Blue Mouse). There has also been built: in Spain, a biplane, Alfaro II, with a Bristol "Cherub" engine; in Finland, a light monoplane by Adaridy; in Hungary, a light airplane by Trotzkai. Individually, these offshoots are of no special structural interest and are worthy of note only in so far as they indicate the present extent of the light-airplane movement.

General Constructive Fiducial Lines

All general fiducial lines for the construction of a machine or vehicle are derived originally from the "purpose" of the machine. By "purpose" is not meant any one of the many application possibilities (sport, traffic, training, etc.), but the technical principle or task. The purpose of the light airplane is safe and cheap flight with the least weight of structural material. In this definition, safety precedes the economical aspects. In my opinion, it is much more important that light and small airplanes, principally employed for private purposes, should be very easy to fly and able to land on very small places and have perfectly reliable engines, than that they should be able to increase their speed or reduce their fuel consumption by 5 or 10%. The term "safe" comprises the general static structural safety, as well as the stability and control characteristics and the reliability of the engine, while the term "cheap" comprises the economical aspect.

It is purposeless and directly obstructive to further development to over-emphasize in these airplanes the factor of economy, especially as regards passenger and freight transportation, before the question of reliability has been satisfactorily solved and the confidence of the public has been gained.

Safety Problem

The essential factor for safety in the air is the reliability of the engine. This is partially guaranteed by its suitable construction. The most important structural problems lie in the realization of a small weight per horsepower, the elimination of vibrations, and the maintenance of the requisite temperature.

equilibrium of all parts by sufficient cooling and lubrication. In addition to these essential conditions, the degree the engine is taxed during normal flight has a decisive effect on its reliability and length of life. It is a technical truism that an engine which is continually taxed almost to the limit of its power wears out very rapidly and can offer no guaranty of perfect reliability. The secret of the remarkable reliability of the engines (B.M.W., Rolls Royce "Eagle" and Napier "Lion") installed in the commercial airplanes of the international lines is mainly due to their reserve power in cruising flight.*

This fundamental principle of sparing the engine by giving it a maximum power 30-50% in excess of that ordinarily required must be applied with equal strictness to light and small airplanes, in which there is often an inadmissibly high loading of the engine in normal flight as, for instance, in the new feeder airplanes and in various light airplanes.

In the so-called "glider with auxiliary engine" the reserve power is supposed to be rendered possible by the gain in wind energy. This extremely attractive possibility naturally exists only where suitable air currents can be generated as a result of the conformation of the land or of thermal effects. Therefore I believe that it is not correct and expedient to seek the minimum power for a light airplane fully independent of such local

* Cases are on record where an airplane equipped with a Napier "Lion" engine has flown 160,000 km (99,420 mi.) without a forced landing outside a regular landing field, and 16,000 km (9944 mi.) without the engine being overhauled.

conditions. Judging from the present status of light construction and aerodynamic knowledge, we have probably very closely approached the minimum power for flying at 100-120 km (63-75 mi.) per hour.* The wonderful results of pure gliding and soaring flight have led many people in Germany to exaggerate the pure aerodynamic possibilities, so that they do not sufficiently realize the importance of increasing the power by improving the engines.

A further reasonable requirement is perfect structural safety in all flight positions and on the ground. This, in turn, is conditioned on a thorough static calculation and strength testing of the individual parts on the basis of predetermined safety factors. There is yet no standard in the choice of load factors, since the D.V.L. has yet published no new regulations. Most manufacturers therefore follow the old regulations of the "Bau- und Liefervorschriften" and take either the load factors given in Section V or higher values of their own estimation as the basis for the static calculation. In England, the stipulations of the Air Ministry for the obtention of an airworthiness certificate are taken as the basis for the structural safety of all light airplanes. In the De Havilland monoplane, which is especially suited for stunt flying, the wing spars have a safety factor of 4-5 against failure (hence a load factor of 12-15).

There is a growing demand, though still relatively little developed, for sure and sufficient steering effect in all flight

* At lower speeds, the dependence on wind and weather is too great.

positions, especially at low speeds. The fact that the rudder pressure is proportional to the square of the velocity necessitates (especially for light airplanes, on account of their small wing loading) a considerable enlargement of the rudders and careful attention to their shape and cross-sectional area. We still find many antiquated shapes of rudders and other tail planes, due simply to the individual taste of the constructor, although (almost exclusively in English and American literature) we have the results of numerous researches on the best aerodynamic shapes of control surfaces, especially of the ailerons. Lack of space forbids my going more into detail on this subject.* A considerable improvement in the action of the directional rudder and of the ailerons seems to have been effected by the differential rudder recently introduced by De Havilland. The principle of this device consists in the fact that the deflection of the lowered aileron is somewhat less than that of the lifted aileron. This diminishes the contrary lateral moment, which is created by the ordinary equally deflected ailerons and which greatly reduces the effect of the directional rudder, especially at large angles of attack.

A deplorable accident, which happened this year (1924) and which cost the lives of two brave pilots, has again called attention to the somewhat neglected question of fire protection by means

* It is treated exhaustively in the book "Leichtflugzeugbau" just published by R. Oldenbourg (Mk. 6.50).

of special fire bulkheads on light and small airplanes.

The safety of taking off and of landing depends chiefly on the strength of the landing gear and on the minimum speed. There is no sense in reducing the weight and drag of the landing gear to such an extent as to endanger the safety of the airplane. Moreover, the landing gear share of the drag is less than is generally supposed. It is not more than 8-10% of the total drag of a light airplane of the De Havilland monoplane type.

The landing speed is determined by the magnitude of the wing loading and the maximum lift. In light airplanes of the present type, the most economical wing loading lies between 40 and 50 kg/m² (8-10 lb./sq.ft.); in airplanes of medium speed, between 50 and 65 kg/m² (10-13 lb./sq.ft.). When the wing area is further reduced, the induced drag increases faster than the wing section (or profile) drag decreases. In light airplanes and also in airplanes of medium weight, for the sake of a high load per horsepower and climbing ability, a smaller wing loading is generally taken, 20-25 kg/m² (4-5 lb./sq.ft.) for light airplanes and 30-40 kg/m² (6-8 lb./sq.ft.) for airplanes of medium weight. The Parnall Pixie II is the only light airplane with a wing loading of approximately 40 kg/m² (8 lb./sq.ft.). Even with this wing loading, the theoretical landing speed, with thick wings having high lift coefficients, hardly exceeds the landing speed of our old B airplanes. For high-powered airplanes, a long flattening-out in landing, especially in forced or emergency landings, is very inconvenient. It seems desirable to overcome this disadvantage by special devices (e.g., by wing flaps), preference being naturally given to the device which will not only lessen the lift-drag ratio, but simultaneously, by increasing the lift, diminish the landing speed. The reserve power of the engine is of decisive importance for the length of the take-off run and the safety of the take-off on a small field, especially when surrounded by trees or houses. For this reason, it also seems desirable, on light and medium-weight airplanes, not to approach the upper limit of the load per horsepower too closely. A climbing speed of at least 1.5-2 m (4.9-6.6 ft.) per second is absolutely necessary for both airplane types, if the pilot is to be spared several anxious minutes every time he takes off.

We do not have the official measurements of the take-off and landing runs of the light airplanes. This year's (1924) Samland coast flight at Königsberg afforded us the opportunity, however, to obtain these distances for the best-known German airplanes of medium weight. These are given in the following table, from which it is obvious that considerable improvement in this respect is still desirable.

Type	Take-off run	Landing run
Mark I	171.0 m (561.0 ft.)	48.85 m (160.3 ft.)
Mark II	102.5 " (336.3 ")	49.22 " (161.5 ")
Udet I	220.0 " (721.8 ")	125.60 " (412.1 ")
Udet II	173.0 " (567.6 ")	121.20 " (397.6 ")
Albatros	185.5 " (608.6 ")	111.50 " (365.8 ")
Junkers	225.5 " (739.8 ")	98.57 " (323.4 ")
Dietrich-Gobiet	149.0 " (488.8 ")	137.05 " (449.6 ")

Economy Problem

The simple cost of production (for materials and labor) of a medium-weight airplane of wood and steel tubing is approximately the same as that of the engine. Any saving in the cost of the materials is possible only through a saving in the quantity used. The labor costs can be greatly reduced by so designing the parts that they can be made independently of one another and then assembled in the simplest possible manner. This method, which is borrowed from modern machine shops, especially automobile factories, greatly accelerates the assembling. Individual groups, such as the engine and its accessories (throttle, switchboard, oil tank, fire bulkhead, etc.) (Fig. 17), the tail group (Fig. 18) and the steering controls (Fig. 19), can be assembled separately. The figures illustrate the construction of the Udet U 10 (Fig. 3).

All-metal construction is employed in Germany only by Dornier and Junkers and in England by Short and Bristol in light airplanes. It presupposes many years of manufacturing experience and under any conditions is necessarily more costly than wood construction. In metal construction the ratio of the cost of materials to that of labor is about 2 : 1. The same ratio now applies approximately to small wooden airplanes with steel-tube fuselages, when made in lots of 8-10. The simple production costs of all-metal airplanes, in comparison with wooden airplanes or those of mixed construction, are therefore decidedly affected by the ratio of the costs of the different materials. The relative costs would not be greatly affected by quantity production, as the same advantages would accrue to both kinds of construction. The production costs of metal airplanes are therefore now more than twice the cost of similar wooden airplanes. This great difference in the original cost constitutes the chief reason why light metal airplanes have not yet been adopted, notwithstanding their incontestable superiority, especially in the matter of longevity.

It means a considerable saving in the costs of upkeep and operation, if the wings can be folded, with a few motions of the hands, against the sides of the fuselage and the tail skid can be hooked on to a motor vehicle for transportation on the ground. The importance of such details can be appreciated only by an airplane pilot, or better still by a flying constructor, who has had personal experience in cross-country flights. One must have personally undergone the experience of making a forced landing with a difficultly dismantable airplane, together with all the difficulties of obtaining shelter, of guarding it in an open field and of transporting it along the highways, in order to be able to appreciate fully the great practical importance of this question. The under-estimation of such aviation problems, which are naturally of especial importance for airplanes which must be as independent as possible of prepared aviation fields, is due to the fact that most constructors have seen the airplane only on the drawing board, but not in the air nor in practical operation.

As mentioned at the beginning, I have intentionally left till the last the discussion of the economical aspect of the transportation problem because, in comparison with the other aspects of the problem, there is the least need of further improvements. The economy of flight is determined as well by pure aerodynamic principles (high lift-drag ratio and propeller efficiency), as also by structural moments. It is of prime importance for the useful load to constitute a large share of the full load. In the best airplanes, the useful load is already nearly equal to the dead load, a technical performance which surpasses all other transportation means of similar speed.

The Samland coast flight contest, already referred to, affords a good means for comparing the flight economy of successful German small airplanes. The results of this contest are given in the following table.

Airplane	Engine	Hourly gasoline consumption	Mean speed per hour
Albatros	70 HP. Siemens	18.4 kg(40.6 lb.)	148.4 km(92.2 mi.)
Dietrich Gobiet	70 HP. "	23.9 " (52.7 ")	121.59 "(75.6 ")
Stahlwerk Mark	35 HP. Baer	11.4 " (25.1 ")	105.10 "(65.3 ")
Junkers	70 HP. Siemens	23.7 " (52.2 ")	149.96 "(93.2 ")
Udet	55 HP. "	9.4 " (20.7 ")	145.24 "(90.2 ")
Udet	55 HP. "	13.0 " (28.7 ")	140.10 "(87.1 ")

Table (Cont.)

Airplane	Engine	Useful load	Minutes to climb 1000 m (3281 ft.)
Albatros	70 HP. Siemens	210 kg (463 lb.)	7.4
Dietrich Gobiet	70 HP. "	250 " (551 ")	15.8
Stahlwerk Mark	35 HP. Baer	104 " (229 ")	15.6
Junkers	70 HP. Siemens	350 " (772 ")	8.9
Udet	55 HP. "	220 " (485 ")	13.4
Udet	55 HP. "	220 " (485 ")	7.6

In light -airplane construction, the striving after the maximum "weight-strength" led to the employment of light metal for many parts which had previously been made of steel. This principle must, of course, not be carried so far as to endanger the reliability of functioning, which requires a certain rigidity of construction. There must be no place where one may not take hold. Furthermore, the question of the permissible flexibility, especially of the wings, is very important, in order to avoid dangerous vibrations. The reliability of the ailerons is largely dependent on the torsional rigidity of the wings. The wing weight of 4-5 kg/m² (0.8-1 lb./sq.ft.) of the Udet low-wing monoplane U 10 represents a lower limit for a cantilever monoplane with a wing loading of 40 kg/m² (8.2 lb./sq.ft.) which will be difficult to reduce very much. With the above-mentioned increase in the use of light metal for the wings and ailerons, the low weight per unit area was obtained by increasing the width of the rib intervals toward the wing tips in proportion to the decreasing load.

Greater reductions in weight appear possible in the construction of the fuselage. The following table gives the weights of three different fuselage types.

Fuselage type	Airplane	Engine	Bare fuselage
Wood and wire	Avro Baby	35 HP. Green	54 kg (119 lb.)
Steel tubing	Dietrich Gobiet	55 HP. Siemens	42 " (92.6 ")
Plywood with supporting cover	Udet	55 HP. Siemens	39.3" (86.6 ")

In the steel-tubing fuselage, the saving in weight has not yet been carried very far, so that the two types may be considered as having approximately the same weight. The construction of the steel-tubing fuselage, however, requires a less number of hours' work (116 hours, including covering and varnishing), so that one can be completed in 3.5 to 4 days by four workmen. The weight of this type can be diminished by the use of light-metal tubing.

The method adopted by Loessl on the Caspar monoplane is noteworthy for its great reduction in the weight of the fuselage. This consists in making a steel-tubing "chassis" for the engine, wings, landing gear and seat, while a light plywood fuselage forms the connection with the tail group. There is some question, however, as to the effect of moisture on the behavior of this type of fuselage.

A more practical method than the comparison of the so-called "transport economy" (especially with the performances of other means of rapid transportation) is the comparison of the costs of passenger transportation by replacing, in the expression for the "transport economy," the useful load by the number of persons carried:

$$V = \frac{n\ v_m}{b}$$

in which n = the number of persons, v_m the mean speed and b the fuel consumption per hour. This method has the disadvantage of comparing airplanes which differ greatly in their mean speeds. The values of V are therefore of very practical importance, since they give the fuel consumption x in kilograms per person per kilometer. The following table gives comparative data for various vehicles.

Vehicle	n Persons carried	v_m Mean speed per hour
Motorcycle	2	60 km (37 miles)
Touring car	4	50 " (31 ")
Medium-weight airplane	2	130 " (80 ")
Light one-seat "	1	100 " (62 ")
Light two-seat "	2	100 " (62 ")
Runabout auto	2	50 " (31 ")

Table (Cont.)

Vehicle	n Persons carried	b Fuel cons. per hour	x Pfg Fuel cost per person per km
Motorcycle	2	3.6 kg(7.9 lb.)	1.20
Touring car	4	8.4 " (18.5 ")	1.68
Medium-weight airplane	2	16.8 " (37.0 ")	2.58
Light one-seat airplane	1	5.4 " (11.9 ")	2.16
Light two-seat "	2	7.2 " (15.9 ")	1.44
Runabout auto	2	4.2 " (9.3 ")	1.68

(As regards the value of b, it should be noted that an increment of 12% was added to the fuel consumption, so as to include the oil consumption. The cost of gasoline was assumed to be 40 Pfg per kg.)

It is obvious from the above comparison that the cost of the fuel is of relatively small importance and that the light airplane compares very favorably, as regards economy, with other forms of rapid transportation. It does not, therefore, seem justifiable to place the question of economy last.

Special Structural Considerations

Monoplane or biplane.- The structural development of light and medium-weight airplanes has assumed a decided trend toward the monoplane. The former thin-winged biplane with struts and steel diagonal wires or cables are now regarded in Germany as out of date. For a given wing area and span, a given lift and the same wing section or profile, a cantilever biplane is inferior to a cantilever monoplane, on account of the unfavorable ratio of the thickness to the span of the wing. For the same span, lift and speed, the induced drag of a biplane is indeed somewhat smaller. According to the Prandtl multiplane theory, the drag of a biplane is known to differ from that of a monoplane by a factor k, whereby k, for example, has a value of 0.779 for a ratio h/b (gap/span) of 0.15, the span of both wings being the same. Moreover, the induced drag is relatively small with the now prevalent dimensions and weight and power relations. Fig. 22 shows the distribution of the drag on a De Havilland D.H.53, a normal light monoplane with wing struts. It is obvious that the induced drag plays a subordinate role to the profile drag and the fuselage drag. There is therefore no sense in going to extremes in the span of this type of airplane, as in gliding and soaring airplanes.

The more favorable ratio of wing thickness to span assures the monoplane, under otherwise like conditions of drag and lift, the advantage of a smaller weight than a cantilever biplane or one built only with torsional end struts. The "old-school" girder construction weighs less, but (as demonstrated by the calculation of examples) the additional drag of the struts and wires is greater than the slight reduction in the profile drag through the employment of a thin wing section. Practical experience has demonstrated that the aerodynamic advantages of the cantilever monoplane hardly offset the smaller weight of the strut-and-wire type, though the differences are not so important as has generally been assumed. To illustrate this, I will compare two English light airplanes, the De Havilland monoplane and the "Gannet" biplane (Fig. 15) of the Gloucestershire Aircraft Company, which have the same engine, Blackburne "Tomtit" of 698 cm³ (42.6 cu.in.) stroke-volume, and for which, due to the courtesy of both firms, we have abundant data.

1. Gannet biplane.- Weight in flying order with 10.8 liters (2.85 gallons) gasoline and pilot (76 kg = 168 lb.) . . . . 209.00 kg (461.0 lb.)

Engine	36.20 kg (79.8 lb.)		
Pipes, etc.	4.54 " (10.0 ")		
Tanks	2.26 " (5.0 ")		
Gasoline	6.55 " (14.4 ")		
Oil	0.66 " (1.5 ")		
Propeller	2.26 " (5.0 ")		
Sundries	4.54 " (10.0 ")		
Total weight of power plant		57 kg	(126 lb.)
Weight of cell		76 "	(168 ")
Total weight of airplane (without pilot)		133 "	(293 ")
Wing loading	21.8 kg/m² (4.46 lb./sq.ft.)		
Load per horsepower	8.4 kg/HP. (18.5 lb./HP.)		

2. Weight of DH 53 in flying order	250 kg	(551 lb.)
Weight of cell under same assumptions for power plant	107 "	(236 lb.)
Wing loading	21.6 kg/m²	(4.42 lb/sq.ft.)
Load per horsepower	9.6 kg/HP.	(1.97 lb./HP.

With almost the same wing loading, the load per horsepower for the monoplane is about 11.5% more than for the biplane. This difference apparently suffices to offset the aerodynamic advantages of the monoplane, since both airplanes have approximately the same maximum speed, 117 km (73 miles) per hour.

Hence it would be somewhat premature for us to conclude, without further consideration, that the cantilever monoplane, on account of its aerodynamic superiority, is necessarily the best form for light and small airplanes. The real reason for the superiority of the monoplane over the braced biplane is rather of a structural nature. It consists in the simplification of the structural form and type and in the increased safety of operation through the elimination of numerous parts, such as struts, wires and fittings. The biplane, however, has incontestable advantages for certain special purposes (e.g., training airplanes), where it is important to have the minimum wing loading in a convenient form.

Low-wing or high-wing.- The position of the wing on a monoplane is determined from a series of structural, aerodynamic and flying considerations, without its being right or expedient to adopt either one exclusively. From the pure aerodynamic viewpoint, the mutual effects of the propeller slipstream and the wing position on the magnitude of the air forces play a decisive role. Several years ago in the Göttingen laboratory, I carried out a series of systematic researches in this connection and found that the location of the wing in the middle of the fuselage was decidedly the worst, and that the low-wing type with a high propeller axis worked better, as regards the ratio of the additional lift to the additional drag, than the usual high-wing type with the propeller axis lying on the pressure (lower) side of the wing. The high-wing type with a high propeller axis gave the best results. I did not investigate the parasol monoplane type which has a gap between the fuselage and wing. Practical experience with the latter type, however, seems to indicate very favorable aerodynamic conditions.

Structurally, the low position of the wing is the simplest. It enables the location of the seats above the wing spars, while the high-wing arrangement necessitates the placing of the seats between the spars, and the parasol type requires a special cabane. In England, the low-wing type with wing struts (semicantilever) is preferred, since it enables an easy adjustment of the angle of attack and dihedral. Moreover, the English emphasize the possibility, in the low-wing type, of arranging the tail group above the wing and of thus avoiding, especially at large angles of attack, the disturbing effect of the boundary layer released from the wing.

In spite of its incontestable structural advantages, there exists in Germany, the origin of the low-wing type, a growing aversion to this type on the part of the pilots. They much prefer the parasol monoplane, both on account of the greater protection it affords the occupants in the event of capsizing and also on account of its smaller tendency to pitch. The latter characteristic, which is naturally important for sport airplanes, merits special attention. According to the Hopf theory, pitching can be eliminated only when the tail-heavy gyroscopic moment is able to offset the nose-heavy aerodynamic moment produced by the pitching. The magnitude of the gyroscopic moment can be greatly reduced by placing heavy masses above and below the center of gravity. It is therefore easier to keep a high-wing airplane or a biplane from pitching than a low-wing airplane, since the wing, which contributes largely to the moment of inertia about the lateral axis, is often located, in the low-wing type, at or very near the height of the center of gravity. In fact, practical experience seems to confirm this theory. My personal experience and observations are limited to the Dietrich Gobiet airplanes. It is remarkable how easily and surely the well-known biplane DP IIa and the high-wing monoplane DP VIIa can be brought out of pitching by a gentle pressure. Because of lack of confidence on the part of the pilots, we have less practical information concerning the behavior of the low-wing monoplane.

Conclusion.- I will close the purely technical discussion with a few general remarks. I hope my comparison of German and foreign accomplishments has shown that the development of the light and small airplane is in good hands in Germany. In considering the development of flying machines, it would be a mistake to overlook the fliers. The former military aviators are on the decline and a younger generation must be trained to replace them, if there is not to come a time when our German commercial airplanes will be flown by foreign pilots. In the training of this generation, I behold the real mission of the light airplane, though not in fulfilling the slogan "To every one his own airplane." Any considerable sale to private owners is hardly probable at the present time. I certainly believe, however, that it is possible for the numerous clubs already in existence and still to be organized, to acquire two-seat light airplanes with dual control. On the one hand, this would furnish former pilots the opportunity to renew their aviation practice, while on the other hand, these pilots could train new pilots and thus transmit to them their own enthusiasm as a living tradition, not from a military standpoint (which would be madness in the face of the air fleets of our former adversaries), but for the welfare and maintenance of our peaceful air traffic. In my opinion, these objects merit the support of the government authorities just as much as the soaring-flight movement. Thus it will be possible to develop not only new airplane pilots, but also a new type of aviator which, for the first time since the beginnings of aviation, has now become scarce, namely, the flying airplane constructor.

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

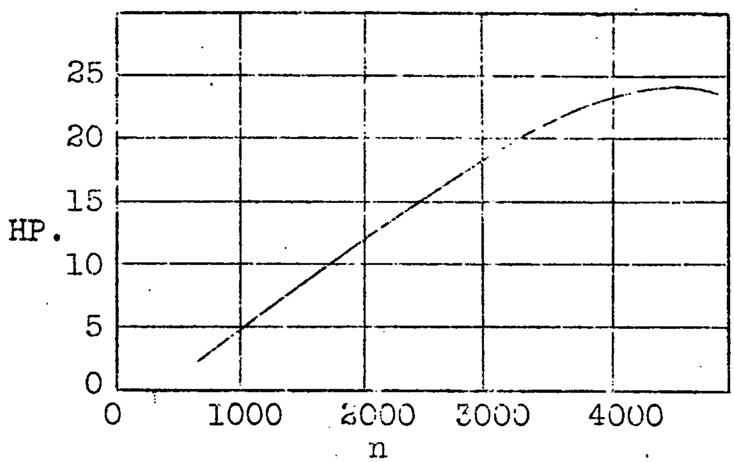

Fig.1 Brake horsepower of "Blackburne" 697 cm^3 (42.5 cu.in.) engine.

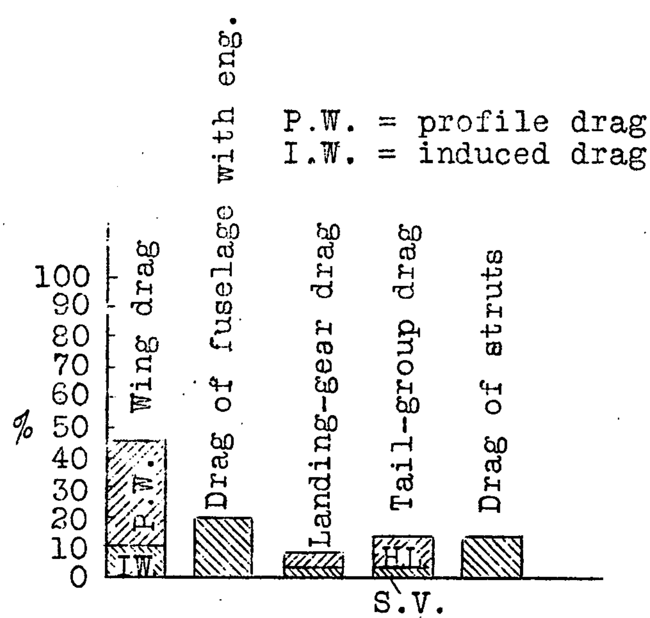

Fig.22 Distribution of drag in a light airplane.

Fig.2 Junkers

Fig.3 Udet U10

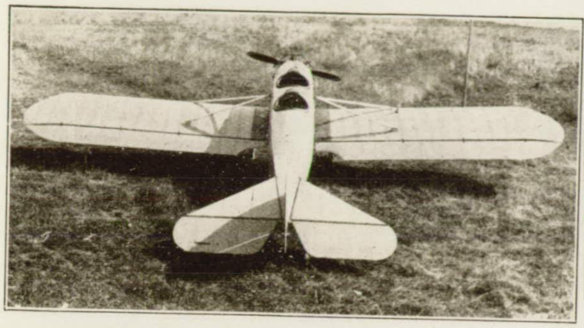

Fig.4 Heinkel

Fig.5 Avro "Baby"

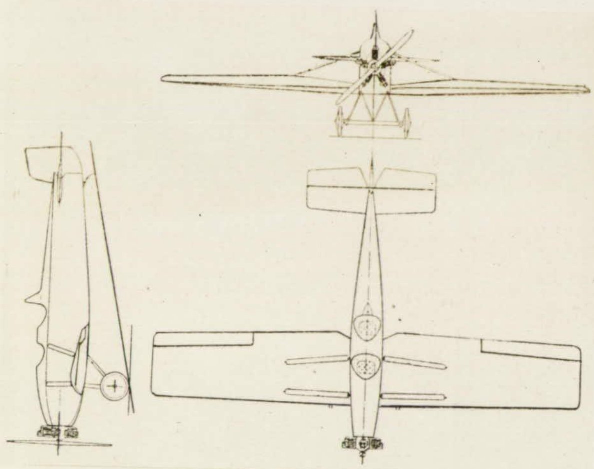

Fig.6 Avia low-wing airplane

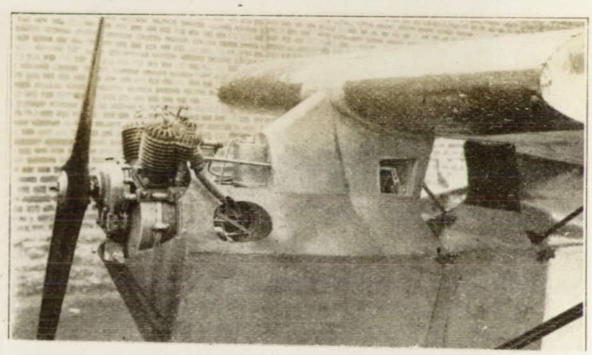

Fig.7 Engine installation in first light airplane of "Aachen"

Fig.8 Daimler light airplane

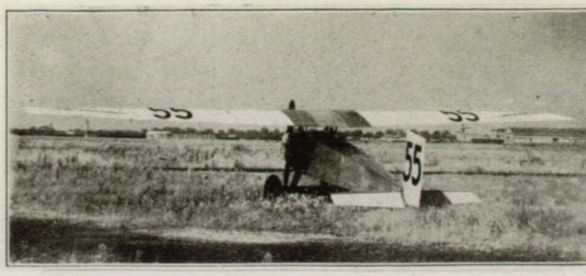

Fig.9 Blume & Hensen light Airplane "Habicht"

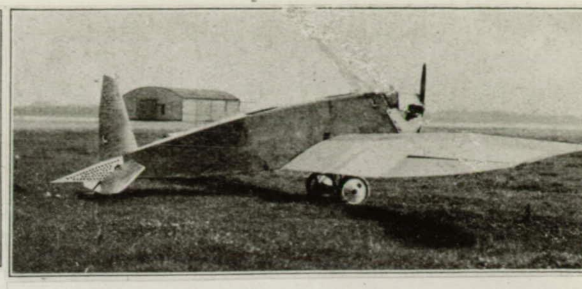

Fig.10 2-seat light airplane C17 of the Caspar Works

Fig.11 Light airplane of the "Bahubedarf" Co.(Darmstadt)

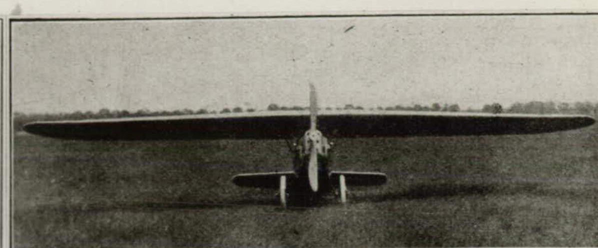

Fig.12 "Kolibri" of the Udet Airplane Co. Munich

Fig.14 D.H.53 monoplane

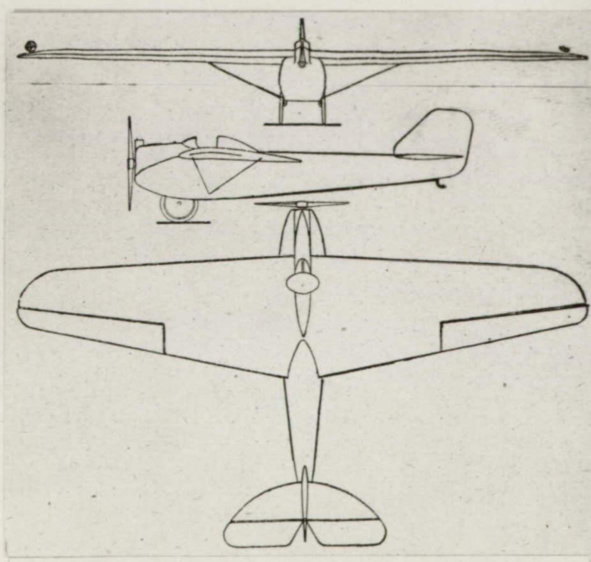

Fig.13 Breguet light airplane

Fig.15 "Gannet" biplane of Gloustershire Aircraft Works

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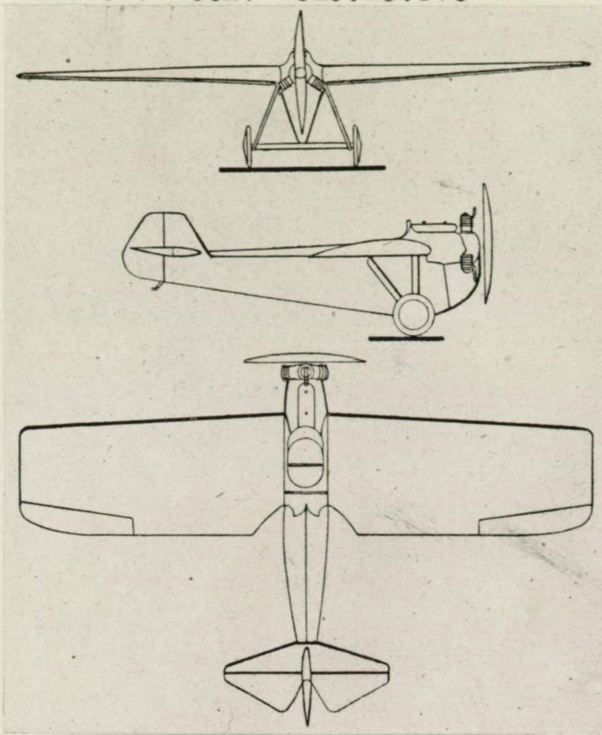

Fig.16 Light airplane of Van Carley, Holland

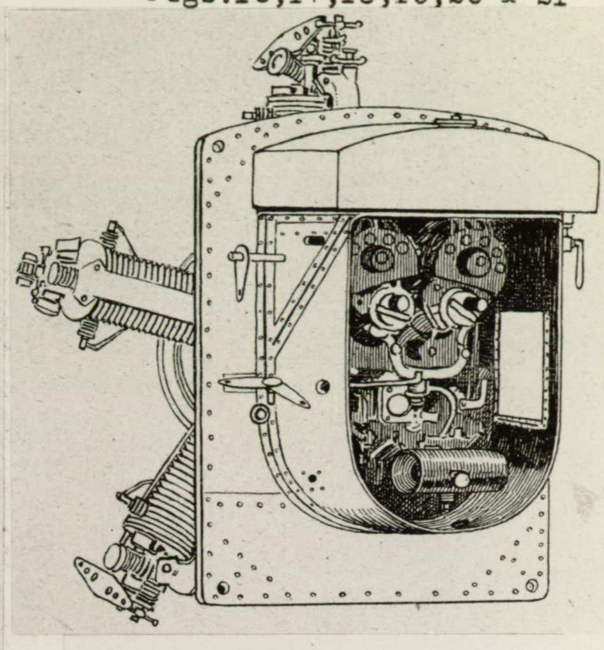

Fig.17 Engine of Udet U10, with fire bulkhead

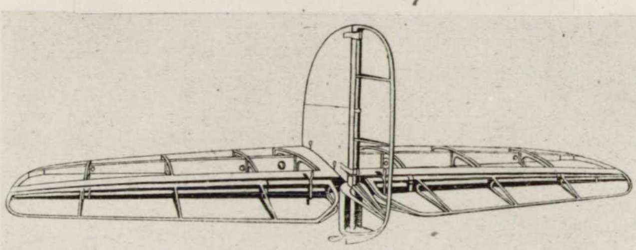

Fig.18 Tail group of Udet U10

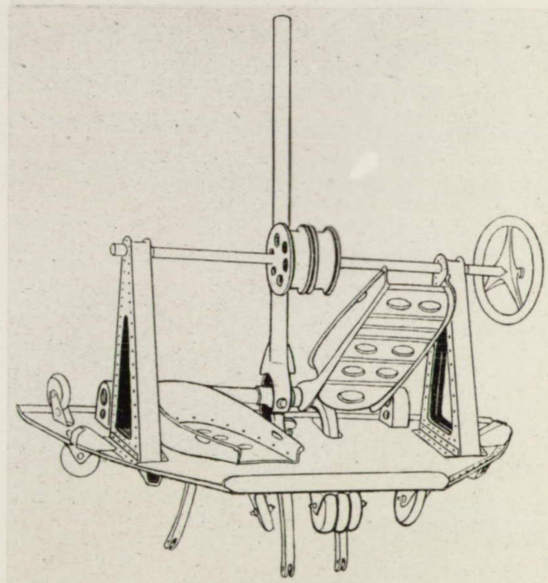

Fig.19 Steering-control group

Fig.21 Wood & wire fuselage frame of Avro "Baby"

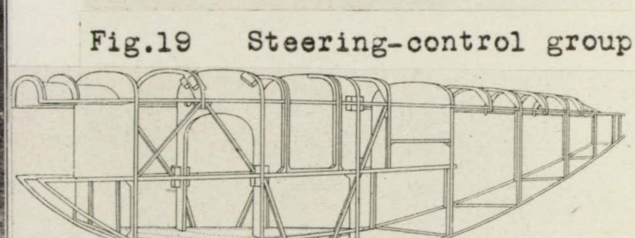

Fig.20 Frame for plywood fuselage (Kolibri.)