NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

Technical Memorandum No. 181.

SOARING FLIGHT AND THE RHÖN CONTESTS.

By Wilhelm Hoff.

From "Zeitschrift des Vereines deutscher Ingenieure," November 11, 1922.

January, 1923.

SOARING FLIGHT AND THE RHÖN CONTESTS.*

By Wilhelm Hoff.

Explanation of soaring flight. Static and dynamic soaring flight. Results of the Rhön contest. Description of the most important gliders. Notes on Soaring Flight Contests in France and England.

The daily papers have referred to the importance of the 1922 Rhön soaring flight contests, organized privately by the South-West Group of "Der Deutsche Luftfahrt Verband" and "Der Deutsche Modell und Segelflug Verband" under the honorary presidency of the "Wissenschaftliche Gesellschaft für Luftfhart." The problems set in the Rhön contests are not merely problems of sport, but invólve a serious scientific issue which may prove of use to air traffic.

"Soaring" flight means a flight which does not depend on power supplied by a power plant carried in the craft, but on the power of the wind in which the flight is made. In this connection we distinguish between "static" soaring flight in which the airplane is carried in a long glide by an upward current of air, and "dynamic" flight in which the wind is in a general horizontal direction.

---

* Soaring flight is treated in many ways at present in aviation technical magazines. In "The Soaring Flight of Birds and its Theory" published in the "Berichte und Abhandlungen der Wissenschaftlichen Gesellschaft für Luftfahrt" No. 9, August, 1923, (Oldenbourg, Munich) Th. Dreisch has given a comprehensive view of the whole question. In the "Zeitschrift für angewandte Mathematik und Mechanik" No. 2, 1922, p. 207, (published by the "Zeitschrift des Vereines deutscher Ingenieure", Berlin) W. Hoff has published a paper, "Soaring Flight and the Rhön Contests," treating of all known theories and of the practical results of the Rhön contest. We shall refer to these works in the present paper. The "Rhönheft" of the "Zeitschrift für Flugtechnik und Motorluftschiffahrt," 1923, p. 261, and following, in which is brought together all the data obtained experimentally by various technicians, is recommended.

In static soaring flight the glider is designed for a very low sinking speed, v (m/sec). The sinking speed will be the smallest when the

$$v_{min} = \sqrt{\frac{2\,g\,W}{\left(\frac{C_L^3}{C_D^2}\right)_{max}\,\rho\,S}}$$

is complied with. In this formula:

S = Wing area (sq.m)

W = Weight of glider (kg)

V = Speed of flight (m/sec)

v = Sinking speed (m/sec)

C_L = Coefficient of lift) depending on angle of attack

C_D = Coefficient of drag)

ρ = Density of the air (kg/m^3)

g = Acceleration due to gravity (m/sec^2)

$q = \frac{\rho V^2}{2g}$ dynamic pressure (kg/m^2)

The coefficients C_L and C_D are obtained from the total air force ascertained for unit pressure and unit wing area by splitting it up into its component parts, the one perpendicular, the other parallel to the air current.

The monoplane "Vampyr" of the Hanover "Akademische Fliegergruppe" which was so successful last year and this year, had a wing load $W/S = 11\ kg/m^2$ (2.253 lbs/ft^2) and a ratio

$$\frac{C_L^3}{C_D^2} = 300.$$

With a mass density $\frac{\rho}{g} = 0.125$ kg/m^4 sec^2 the smallest theoretical sinking speed is $v_{min} = 0.77$ m/sec (2.526 ft/sec).

The western slope of the Wasserkuppe in the Rhön mountains, over which the successful static soaring flights were made, has a mean rise of about 1 : 6. Assuming that the wind is blowing parallel to the slope, it must have a velocity of over 4.7 m/sec (15.42 ft/sec) to sustain the glider in the air. If the wind is stronger, the glider can climb until it enters a layer of air in which the wind components given above only just exceed the sinking speed of the craft. On the 24th of last August, Hentzen on his "Vampyr," in a westerly wind of 10 (32.8 ft) to 12 (39.37 ft) m/sec, attained an altitude of about 350 m (1148.29 ft) above his starting point or 300 m (984.25 ft) above the summit of the Wasserkuppe.

In dynamic soaring flight, power is imparted by the vertical wind. Some years ago it was theoretically demonstrated by Knoller and Betz that a cambered wing will be driven forward when exposed to a wind whose direction in altitude changes according to a law of sines, if the wind has, on the whole, sufficiently strong oscillations. Lately, Katzmayr in model tests in the Vienna Aeromechanical Laboratory, demonstrated a reduction of drag and the forward movement occurring even with actual lift, so that the Knoller-Betz theory has been proved by wind tunnel tests.

The Knoller-Betz theory rests on the hypothesis that when the wind is of uniform strength the vibrations of the air follow the law of sines. In an ordinary wind such simple ratios do not

exist, since there are oscillations which always vary in direction and magnitude. The efficiency $\eta \left(\frac{kgm}{s} \cdot \frac{1}{m^2}\right)$ which we may take, in an intermittent wind, as the specific pressure of the current, gives for sine oscillations of the direction of the wind and for a fixed ratio k between the upper and mean velocities of the wind, the simple relation:

$$\eta = \frac{3 \rho C^2 V^3}{4 g}$$

For a mean wind velocity V = 10 m/sec (32.8 ft/sec), with C = 0.2 and a mass density $\frac{\rho}{g} = 0.125$ kg/m^4 sec^2, this gives:

$$\eta = 3.75 \frac{kgm/s}{m^2} = \frac{0.05 HP}{m^2}$$

that is, by eliminating irregularities from a wind varying, according to the law of sines, from 8 to 12 m/sec (26.25 or 39.37 ft/sec), we get 1/4 HP per square meter (023 HP/ft^2) of the cross-section of the stream.

The data on dynamic soaring flight gained in experiments are not yet applicable to full-sized craft and one of the main reasons for continuing such experiments is to obtain data which can be thus applied.

Von Karman has suggested a general theory of soaring flight. He introduces laws of sines for the movements of the wind and center of mass. The wave course is so calculated that when the center of mass moves according to the law of sines, it assumes a higher position and there is an increase in power. Von Karman concludes that in a first approximation the increase in height

Δy(m) is affected for a certain time by the ratio of the velocity variation in the gusts, u_1 m/sec, to the mean speed of advance, V_o m/sec, and by the height h(m) of the wave motion:

$$\Delta y = h \frac{u_1}{V_o}$$

Von Karman has also suggested another general theory, that power is engendered by rotation. In this the center of mass may move either in an orbit eccentric to the whirling vortices, or simply describe a circle, the velocity of the wind changing according to a quadratic law of sines. In the latter case, power is engendered when, with changing direction, the center of mass turns steadily to windward of the increase in velocity.

Finally, Wolfmüller conceived a method of soaring, in which two aircraft lying at different altitudes in air strata differing in strength or direction are coupled together by means of a cable, so that they mutually tow each other. Unfortunately, this kind of soaring has little chance of success, because the steering and stability of such a pair would be difficult to manage and would be too much for the strength of the connecting cable.

The Rhön mountains, situated in Central Germany, have been known to students at Darmstadt for the last ten years as a most suitable place for gliding and soaring practice. Their performances, accomplished on lightly built gliders which they had made themselves, are worthy of great consideration.

It was not until 1930 that a small soaring Flight Club, mainly promoted by Civil Engineer Oskar Ursinus of Frankfort on the Main, came to the Rhön, in order to take up again the almost

forgotten experiments with engineless aircraft. The contest of 1920 was followed by those of 1921 and 1922. The figures reached in the performances have constantly increased, as shown in the following table:

Table.

Meetings		1920	1921 Meeting: Autumn		1922
Number of entries		25	45		53
Number of airplanes admitted		7	11		19
Number of flights during contest		44	119		110
Total distance flown	km.	7.78	60.42		137.51
	mi.	4.83	37.54		85.44
Total flying time	hr.		1		14
	min	11	51		10
	sec.	43	7		48
Mean length of flights	km.	0.18	0.51		1.25
	mi.	0.11	0.32		0.77
Mean duration	sec.	16	56		463
Maximum Performances					
Distance	km.	1.83	3.90	7.50	10.00
	mi.	1.14	2.42	4.66	6.21
Duration	hr.				3
	min.	2	5	21	10
	sec.	22.4	33	37	
Sinking speed	m/sec.	+0.63	+0.78	+0.01	-0.02
	ft/sec.	+2.07	+2.56	+0.03	-0.07
Height reached above starting point	m.			> 30	350
	ft.			65.62	1148

The technical progress achieved is mainly due to the praiseworthy efforts of "Die Flugwissenschaftliche Vereinigung" and "Das Aerodynamische Institut" at Aachen, the Aero-technical Socie-

ties in Dresden and Stuttgart, the Bavarian Aero Club and the Bavarian Aviators Club, both in Munich, the "Akademische Fliegergruppen" connected with the Technical High Schools at Darmstadt and Hanover, and the North Bavarian "Luftfahrtverband" in Nuremberg. The efforts of the Associations were seconded by some of the German Aviation firms and by some new enterprises.

Pilots Blume, Botsch, Brenner, Hackmack, Harth, Hentzen, Hübner, Klemperer, Koller, Leusch, Von Löszl, Martens, Muttray, Pelzner, Schrenk, Schulz, Seiffert, Spiess, Stamer, and two-thirds of the students in the Technical High Schools of Germany, deserve the thanks of all Clubs for having converted the theories of science into facts. On the 22nd of last September, the President of the Republic received the successful aviators and the aviation clubs and expressed the thanks of all Germans. Unfortunately, there were some serious accidents. Eugen von Löszl and Werner Leusch lost their lives in pursuit of the great goal.

The technical development of gliders was due to the influence of four noteworthy types.

The first of these four types developed the system of steering by means of the weight of the pilot, as described twelve years ago on this periodical,* by Dr. F. Bendemann. Pelzner of Nuremberg brought this system to a high state of perfection. This line of development may be considered as having reached its limit. For short flights, such gliders will continue to be used on account of their low cost of production.

* "Zeitschrift des Vereines deutscher Ingenieure" 1910, p. 888.

The second type is the power-driven airplane. Elimination of the engine, the propeller, and the fuel tanks involved a redistribution of weight by moving the pilot's seat forward. This made it possible to greatly reduce the height of the landing gear. Monoplanes with a large span are conducive to a reduction of air resistance and to a saving of weight. The slight adjustments necessary for easy manipulation are more readily made on a monoplane with cantilever wings.

In 1920 Klemperer of the Aachem "Flugwissenschaftliche Vereinigung" perfected a monoplane, the "Schwarzer Teufel," in the construction of which many new ideas were embodied. The finely constructed cantilever wings and fuselage made by the students, and the successful determination of air resistance make this glider the first example of the high educational value of glider construction. This glider was the inspiration for much of the later construction. Unfortunately, both in the "Schwarzer Teufel" and its young sister "Blaue Maus" sufficient attention was not paid to the wing section, so that its performances were not so good as might otherwise have been expected.

In the 1921 contest we had the "Vampyr" designed by Dr. G. Madelung, assisted by the students of the Hanover Technical High School and Prof. Pröll, and Technical Director Dorner, of the Hanover "Waggonfabrik" and built by that factory. This monoplane was all that could be desired in workmanship. In this glider a definite attempt was made for the first time to obtain a low sinking speed by a suitable choice of wing section and

span. The connection between wing and fuselage, the structure of the torsion-resisting wing spar and the arrangement of the ribs are the results of extremely careful calculations. The strong nose, assuring safety to pilots in landing, and the use of "footballs" as landing gear are innovations worthy of imitation. The lateral control of this monoplane is much improved this year by the substitution of wing warping for ailerons, and the better results obtained are due, in great part, to this modification. In 1921 and 1922 the most sensational performances, the last of which was the world-famous flight of several hours, were obtained by the pilots Martens, Blume and Hentzen.

Fokker's biplane is a remarkable aircraft. It is very lightly built and has a lifting surface of 36 square meters (387.5 sq.ft). Fokker arrived from Holland when the meeting was over, and made a record flight of 13 minutes with a passenger.

The adherents of the third group follow the teachings of the Government Constructor Harth who, with his younger assistant Messerschmitt, has been working quietly for years, unnoticed by the technical world. The main idea in the Harth and Messerschmitt glider was the perfecting of the steering devices. They therefore made the wing with a special axis of rotation and obtained the elevator control by the rotation of the wing itself. By the judicious use of the control cable, the wings can be warped in and out as required. Lateral control is obtained by means of lateral movements of the steering lever. The glider "S.10" resembles the one on which Harth remained in the air last

year 21 min. 37 sec. with a loss of altitude of about 13 m. (40 ft.) between starting point and landing point.

Before the glider of Harth and Messerschmitt was known to the public, Von Löszl and Finsterwalder tried gliders of similar design, the one piloted by Koller giving very good results. This year both men had greatly improved their gliders, but still, in consequence of unforeseen misfortunes, only Von Löszl was able to make satisfactory flights after the contest was over.

The Darmstadt "Akademische Fliegergruppe" had better luck with the "Geheimrat" monoplane, designed by Hoffman and built by the "Bahnbedarfs" Company, Darmstadt. In this glider, the elevator action produced by warping the wings could be replaced or supplemented by the usual elevator. Lateral control was obtained by means of ailerons. After a few trial flights, Hackmack succeeded in making a flight of 1 hr. 18.5 min. On the same day he reached an altitude only slightly below that attained by the hitherto unbeaten "Vampyr".

The fourth and last group consists of those gliders which are inherently stable and in which the aim is to ride on the wind. The extraordinarily fine flying qualities shown by the small models are so convincing that there can be no doubt as to the success of a larger type. The most noteworthy example of this group is the glider designed by Wenk and built by the Baden-Baden Glider Company. The peculiar arrangement of the wing gives longitudinal and lateral stability without the help of special controls.

The description of these gliders is very far from including the whole of the remarkable details of construction realized. By the side of gliders carefully designed and built by experts, there were others, which were constructed without suitable tools or materials.

Ferdinand Schultz, a school teacher in East Prussia, and Espenlaub, a Swabian carpenter, each built a glider according to his own ideas, and both obtained recognized results.

The gliders were started off by means of an elastic cable. In a favorable wind this was stretched by the starting squad until the glider rose like a kite and attained sufficient speed, when the men let go.

The description of the Rhön contests would be incomplete without an allusion to the simple communal life of the contestants with their scientific patrons and advisers on the airy slopes of the Wasserkuppe. Seldom indeed have technical experiments been conducted amid such lovely scenery.

The first object in view (data on static soaring flight) has been attained. The second and more difficult goal, dynamic soaring flight, has not yet been achieved. As a first step in this direction, distance flights are contemplated instead of duration flights, as heretofore. The first 30 kilometer (18.64 mi.) flight will be an important event. Flights over rough water, a further very serious task, are also planned. We are not yet able to predict the probable result.

Up to now, numerous students who, as aviators in the war had

experienced the joy of flying, have come forward to carry out the tests. But if the old dream of mankind, to learn the tireless flight of birds, is to go forward towards fulfilment, then the young and vigorous "Aviation Clubs" in the schools must be helped in every way, either by providing them with the requisite materials or by enlisting the support of young students, who will later take the place of their elders in aviation activities.

After the close of the Rhön contest, the French, touched in their national honor by the results obtained in Germany, also attempted soaring flights in the volcanic country of the Puy de Combegrasse. From details received, it would appear that the French still have much to learn. According to all appearances, the Darmstadt students of 1913, in choosing the region which has now become classic ground for soaring flight in Germany, were more fortunate than the French promoters, who might have profited by the German experiences of 1920 and 1921. It is to be supposed that next year they will choose a more suitable place. The French gliders differed in many ways from the German, whether to their advantage the future will show, and this we must follow very attentively. The performances in the French contest of 1922 correspond approximately to those of the 1921 Rhön contest.

England also, stimulated by the Rhön successes, held a contest on the Sussex Downs near Lewes. Exact details are not yet at hand, but the results already announced (Fokker, 37 min. 6 sec., Raynham, 1 hr. 53 min., and Maneyrol on a Peyret tandem monoplane, 3 hr. 30 min.) show that the Rhön organization has there a powerful and successful rival.

Translated by Paris Office, National Advisory Committee for Aeronautics.