

Flight performance measurements on twelve sailplanes

By H. J. Merklein and H. Zacher

Report by the Scientific Flight Research Establishment Munich (FFM)
(formerly German Soaring Research Establishment. DFS)

Introduction

The flight performances of various sailplanes is often a subject for discussion, but nearly always the views expressed are based on personal experience with one or another particular sailplane. Apart from that, there is a considerable lack of clarity regarding the definition of "flight performance". Whereas one person will base his remarks on calculated or guessed performance in straight flight, another thinks about effectiveness in thermal circling. Someone else will be concerned with the speed polar as influenced by air turbulence or roughness caused by insects on the smooth wing, which are often decisive in competition work. To obtain a complete insight into the capabilities of a sailplane, a wide range of factors must be taken into account, including not only flight performance, but flying characteristics.

Unfortunately, most of the points indicated above do not lend themselves to objective measurements. Flying qualities (7) will not be considered in this report. Although performance in thermals or turbulent air is most important, comparative measurements are out of the question, because of the difficulty of reproducing such weather conditions. They can only be studied by the direct and comparative method of flying in contests or general experience. A speed polar in straight flight or in circling can only be determined

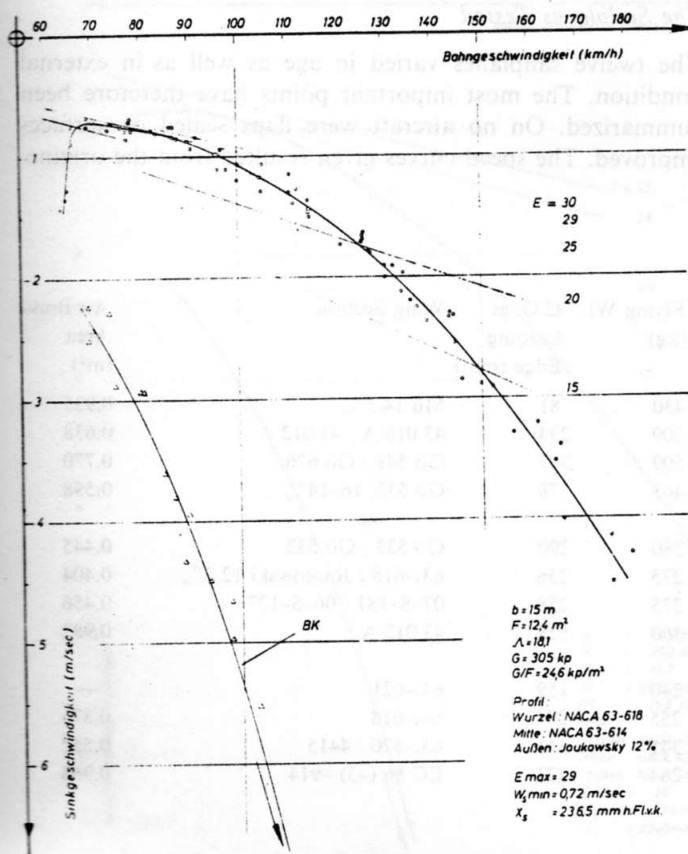


Fig. I Ka 6 CR, speed polar

in very still air, that is, in weather conditions that do not permit soaring. However, such polars do give a good insight into the performance, and combined with flying characteristics investigations also give some measure of the worth of a sailplane.

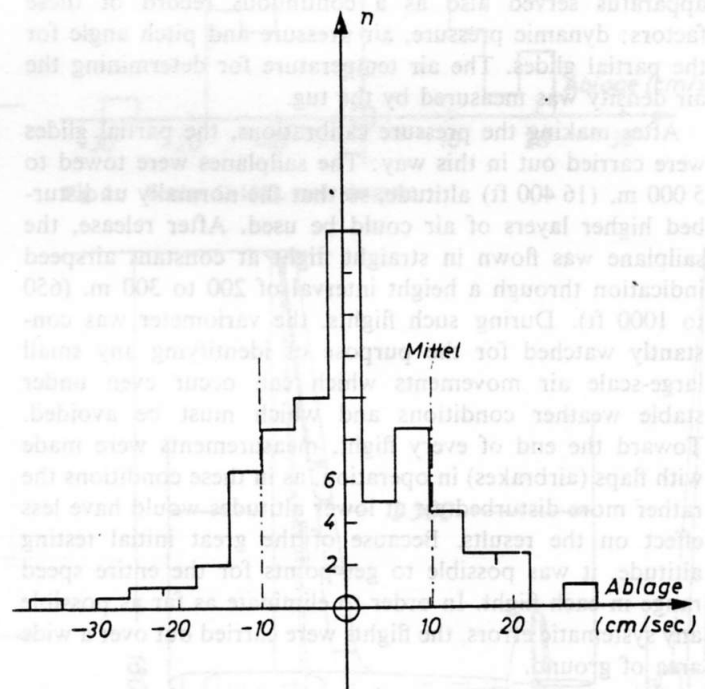


Fig. II Ka 6 CR, error diagram

To obtain the speed polars for sailplanes, various methods have been used in the past, such as deceleration and towing measurements. However, only the partial glide system (1, 2, 3, 4), as described below, has been really successful. This method was therefore chosen by the FFM (even as it was chosen by the DFS twenty-five years ago) when it was decided to measure performances of a large number of newer sailplanes.

Method of measurement

If the results of performance measurements are to permit logical conclusions to be made as well as comparison with other measurements, certain facts must be known in addition to checking the main parameters. These facts are:

- Flying weight (wing loading);
- Centre of gravity position;
- Errors in the airspeed measuring equipment.

Flight performance measurements are worthless unless these three factors are taken into account.

Whereas flying weight and centre of gravity position are easily determined, the determination of the pressure error involves a number of problems. Not only must the error in the speed indicator itself be found, but also the errors in the static and total pressures or their difference (the error in the dynamic pressure) which can only be found in flight. As a result of the flow over the aircraft, the static pressure is most likely to be in error, and as a result the dynamic pressure can also be erroneous. In making measurements on sailplanes, the static pressure was calibrated by the DFS-60 suspended head, and the total pressure calibrated by a Kiel head (8). The measured values were not only read off an airspeed indicator but also off a French optical multigraph. This apparatus served also as a continuous record of these factors: dynamic pressure, air pressure and pitch angle for the partial glides. The air temperature for determining the air density was measured by the tug.

After making the pressure calibrations, the partial glides were carried out in this way: The sailplanes were towed to 5 000 m. (16 400 ft) altitude, so that the normally undisturbed higher layers of air could be used. After release, the sailplane was flown in straight flight at constant airspeed indication through a height interval of 200 to 300 m. (650 to 1000 ft). During such flights, the variometer was constantly watched for the purpose of identifying any small large-scale air movements which can occur even under stable weather conditions and which must be avoided. Toward the end of every flight, measurements were made with flaps (airbrakes) in operation, as in these conditions the rather more disturbed air at lower altitudes would have less effect on the results. Because of the great initial testing altitude, it was possible to get points for the entire speed range in each flight. In order to eliminate as far as possible any systematic errors, the flights were carried out over a wide area of ground.

Because of the accuracy of the recorders, not much scatter was expected when the measurements were reduced to ground level conditions. The sinking speed was within 2% and forward speeds within 1 to 1.5 km/h which was parti-

cularly important for low speed flight. The graph I showing the Ka 6 CR (D-4390) indicates all the measured points. The scatter is average compared to other results, but considerably greater than expected from the measuring equipment. Because of the varying turbulence, atmospheric influences on the aircraft (e. g. change of surface texture and slits due to temperature, humidity, insects) and small angles of yaw and control surface movements at low speeds, the points do not lie within a narrow band. Mainly because of scatter due to weather, a great number of measurements were necessary so that the resulting polar would indicate a high degree of probability.

As the scatter between individual measurements indicates, the weather conditions were not constant. In addition, it was not always possible to make the same number of measurements on each flight, so that the polar curves shown have differing probabilities. One can express these conditions if one plots the frequency of all the sinking speed deviations from the polar (see Figure). The shape of and area beneath the deviation curve (ideally a Gaussian distribution) give a clear means of comparing various measurements.

An attempt was initially made to determine mathematically the polars from the principle of least squares by EDP (electronic calculator) (9) but it was found that a free-hand curve was actually better in practice because it was easier to take account of irregularities in the shape of the polar. As several examples indicated, there are always deviations from the classical polar shape, partly due to wing section, partly due to structural deviations or surface conditions. Naturally one would not draw discontinuities or a local bend in a curve unless the incidence curve, determined from the pitch measurements, indicated such facts.

The Sailplanes Tested

The twelve sailplanes varied in age as well as in external condition. The most important points have therefore been summarized. On no aircraft were flaps sealed or surfaces improved. The speed curves given resulted from the original

Table

Type	Registration	Span (m)	Aspect Ratio	Wing Area (m ²)	Flying Wt. (kg)	C.G. at Leading Edge (mm)	Wing Section	Air Brake Area (m ²)
Bergfalke II	D-1217	16.6	15.6	17.7	430	81	Mü 14.5%	0.935
Bocian	D-1587	18.1	16.2	20.0	509	234	43 018 A / 43 012 A	0.638
Kranich III	D-1398	18.0	15.6	21.1	509	387	Gö 549 / Gö 676	0.770
K 7	D-1800	16.0	14.6	17.5	465	78	Gö 533, 16-14%	0.598
K 8	D-1590	15.0	15.9	14.1	280	290	Gö 533 / Gö 532	0.445
Ka 6 CR	D-4390	15.0	18.1	12.4	275	236	63,-618 / Joukowski 12.5%	0.404
Ka 6 BR/S	D-8390	15.0	18.1	12.4	275	258	07-S-181 / 06-S-137	0.456
Jaskolka	HB-604	16.0	18.8	13.6	360	528	43 012 A	0.982
D 34 b	D-4607	12.7	20.0	8.0	240	159	64,-621	—
D 34 d	D-4607	12.7	17.5	9.2	255	274	64,-618	0.376
Skylark 3 F	RAF 146	18.2	20.5	16.1	341	341	63,-620 / 4415	0.552
Phönix T	D-8385	16.0	17.8	14.4	264	372	EC 86 (-3) -914	0.968

Notes:

1. Flying weight based on load of 90 kg or 2 × 90 kg except in the case of the PHOENIX.

2. Air brake area includes area of any slit or gap that may be present.

maximum lift coefficient. The airbrake effectiveness was less than expected. It was clear that they were over-estimated by pilots because of their sudden initial effect.

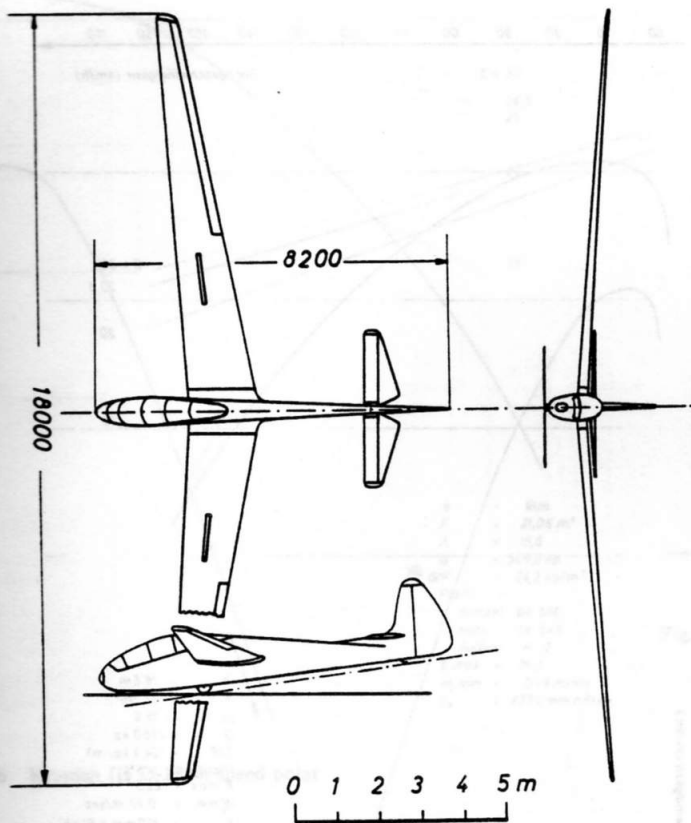


Fig. 2a Bocian D-1587

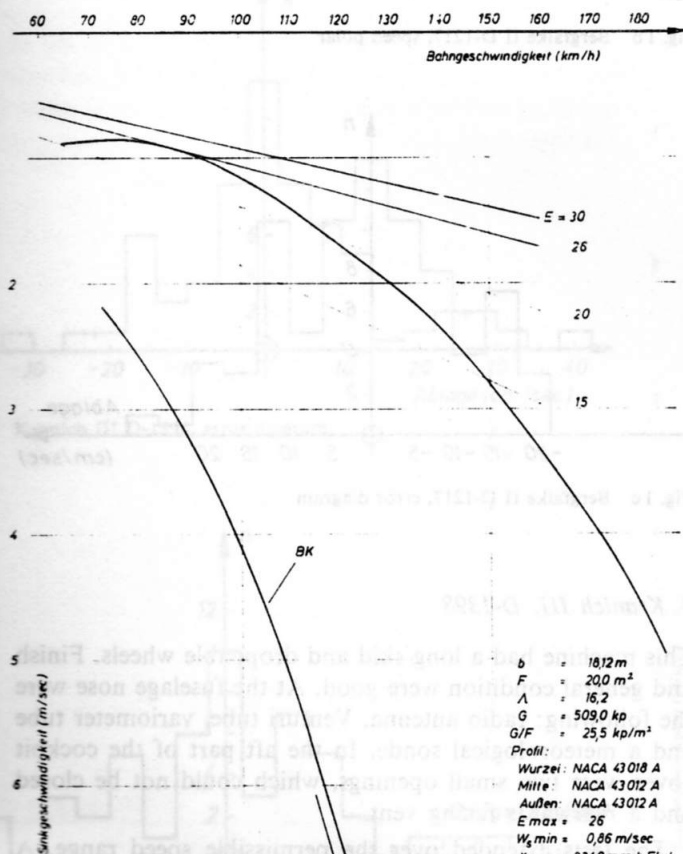


Fig. 2b Bocian D-1587, speed polar

$b = 18,12 \text{ m}$
 $F = 20,0 \text{ m}^2$
 $\Lambda = 16,2$
 $G = 509,0 \text{ kp}$
 $G/F = 25,5 \text{ kp/m}^2$
 Profil:
 Wurzel: NACA 43018 A
 Mitte: NACA 43012 A
 Außen: NACA 43012 A
 $E_{\text{max}} = 26$
 $W_{\text{min}} = 0,86 \text{ m/sec}$
 $X_S = 2340 \text{ mm h.Flvk.}$

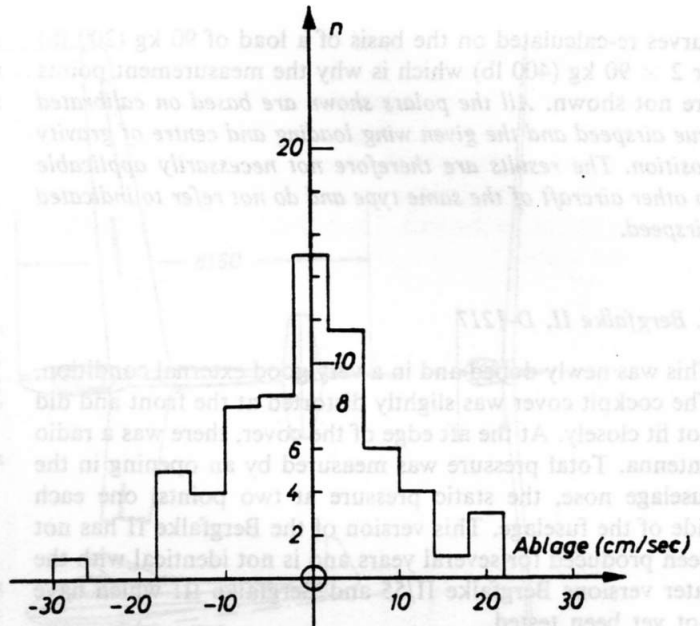


Fig. 2c Bocian D-1587, error diagram

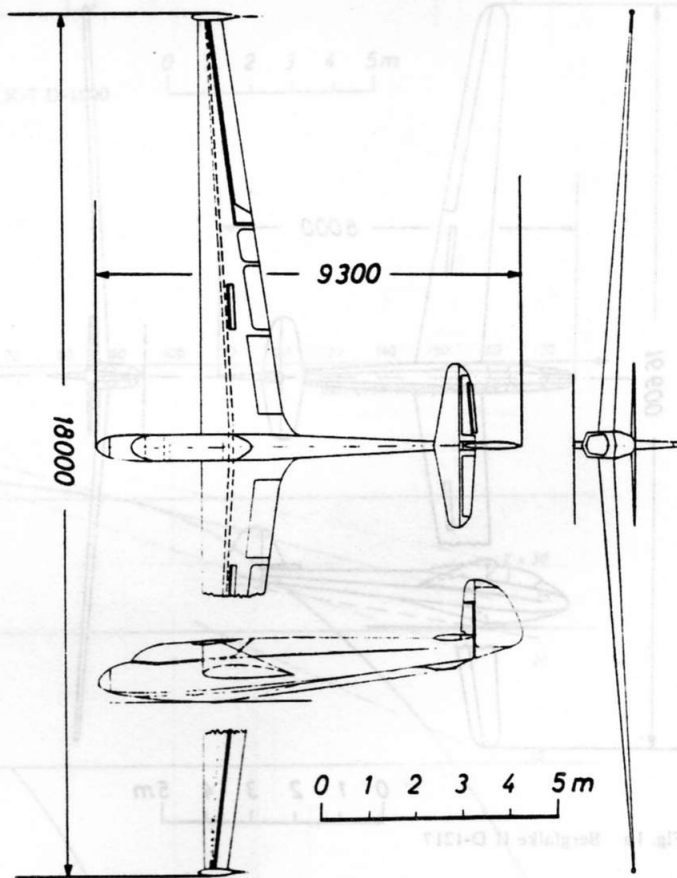


Fig. 3a Kranich III D-1398

4. K-7, D-1800

A production machine in good condition. A radio antenna was attached to the rear of the cockpit cover. Dynamic pressure was measured by a tube at the fuselage nose and two static openings, one on each side of the fuselage nose.

In slow flight it was remarked how quickly the stall followed the minimum sink condition. The tests confirmed the very good airbrake effectiveness already noted in operations.

curves re-calculated on the basis of a load of 90 kg (200 lb) or 2×90 kg (400 lb) which is why the measurement points are not shown. All the polars shown are based on calibrated true airspeed and the given wing loading and centre of gravity position. The results are therefore not necessarily applicable to other aircraft of the same type and do not refer to indicated airspeed.

1. Bergfalke II, D-1217

This was newly doped and in a very good external condition. The cockpit cover was slightly distorted at the front and did not fit closely. At the aft edge of the cover, there was a radio antenna. Total pressure was measured by an opening in the fuselage nose, the static pressure at two points, one each side of the fuselage. This version of the Bergfalke II has not been produced for several years and is not identical with the later versions Bergfalke II/55 and Bergfalke III which have not yet been tested.

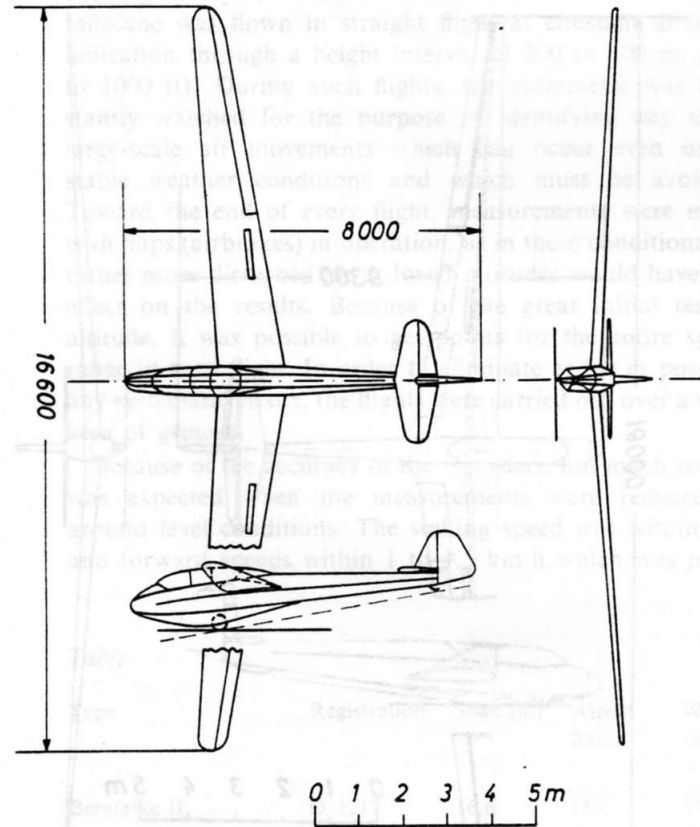


Fig. 1a Bergfalke II D-1217

The speed polars confirm above all the extraordinarily good behaviour at low speeds. The stall, with or without air brakes, is under full control and takes place gradually.

2. Bocian SZD-9bis, D-1587

This was a production aircraft. Finish and general condition were good. There was a Prandtl tube on the fuselage nose for airspeed measurement. A radio antenna was attached to the fuselage side.

The measurements covered the permissible speed range with the exception of slow speed flight. Because of the

unfavourable position of the Prandtl tube, the airspeed reading became constant, i. e. independent of the true speed, so that a true measurement was no longer possible.

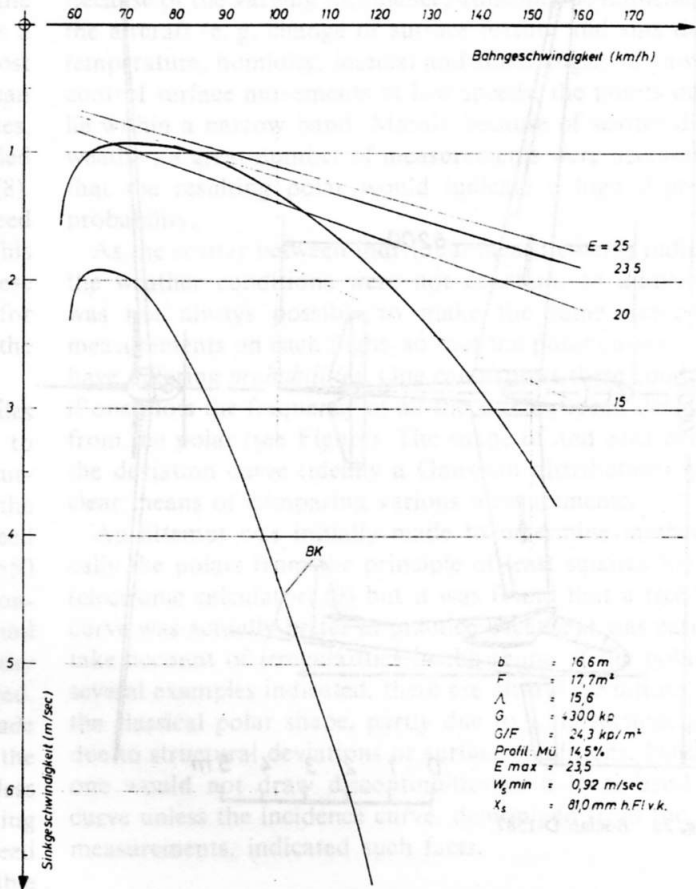


Fig. 1b Bergfalke II D-1217, speed polar

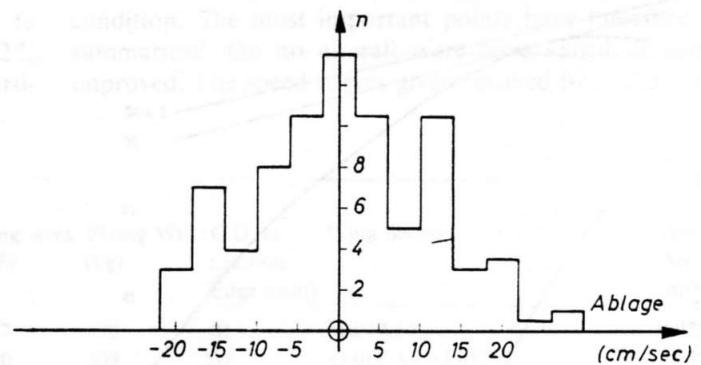


Fig. 1c Bergfalke II D-1217, error diagram

3. Kranich III, D-1398

This machine had a long skid and droppable wheels. Finish and general condition were good. At the fuselage nose were the following: radio antenna, Venturi tube, variometer tube and a meteorological sonde. In the aft part of the cockpit cover were two small openings, which could not be closed and a rearwards facing vent.

The tests extended over the permissible speed range. A definite stall was achieved in normal flight in spite of the difficulty in flying steadily in the neighbourhood of the

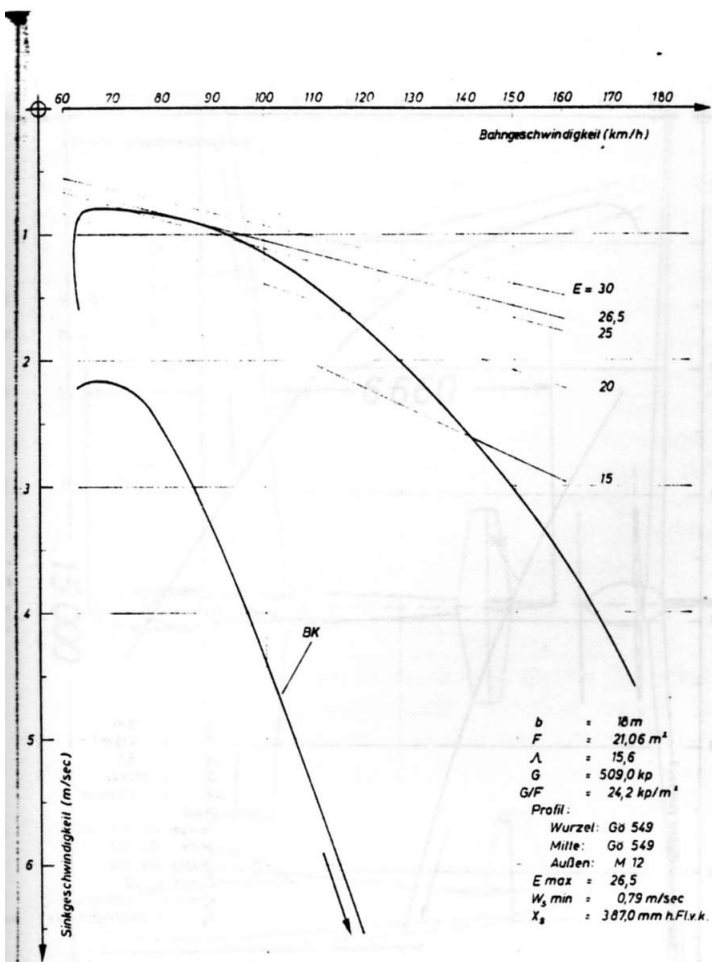


Fig. 3b Kranich III D-1398, speed polar

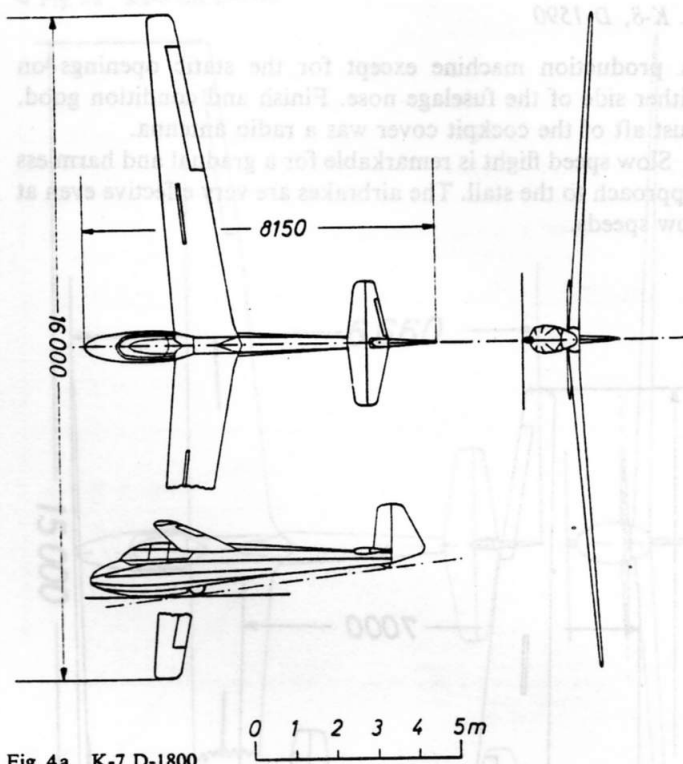


Fig. 4a K-7 D-1800

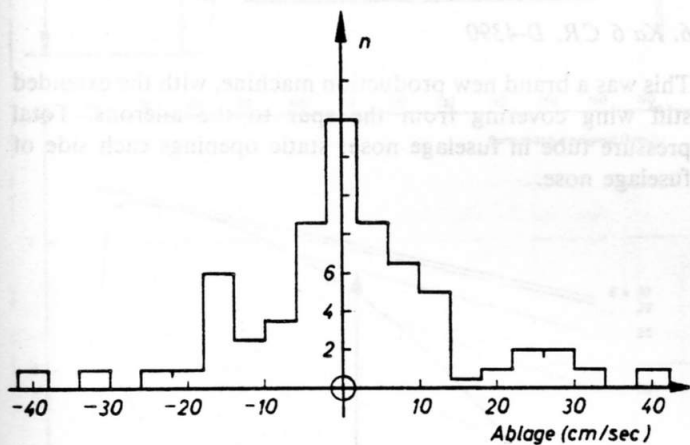


Fig. 3c Kranich III D-1398, error diagram

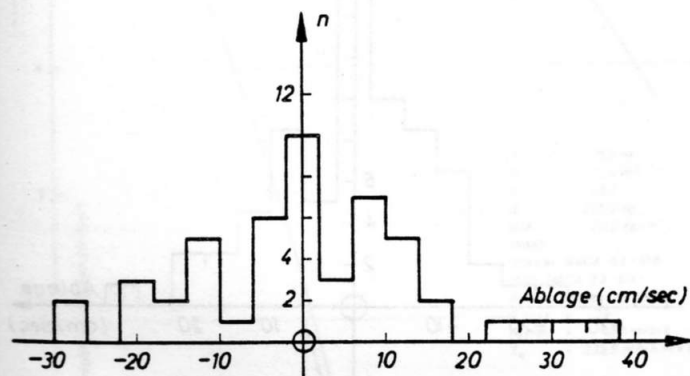


Fig. 4c K-7 D-1800, error diagram

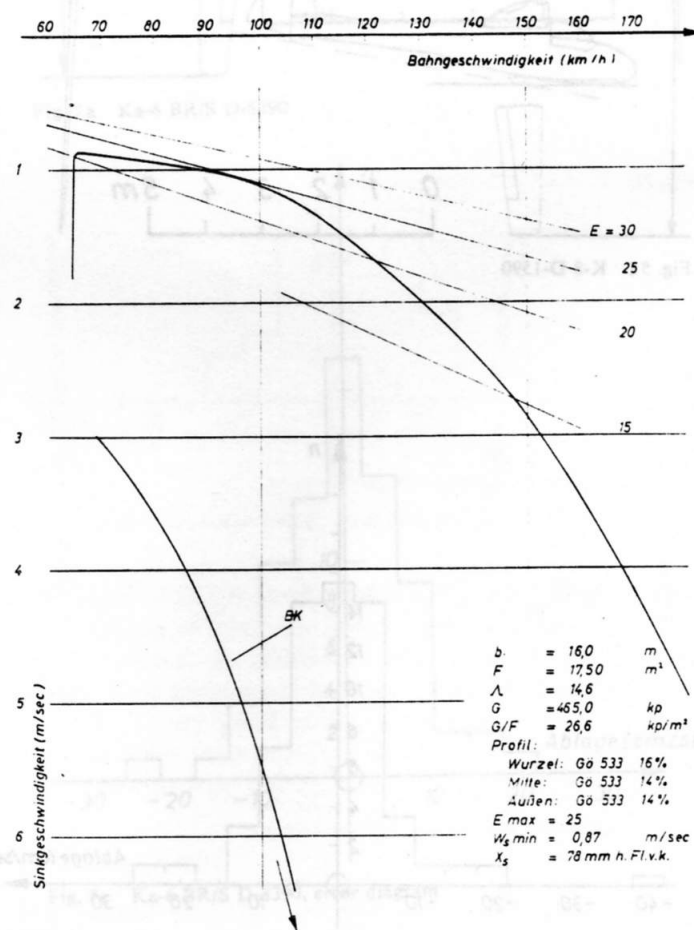


Fig. 4b K-7 D-1800, speed polar

5. K-8, D-1590

A production machine except for the static openings on either side of the fuselage nose. Finish and condition good. Just aft of the cockpit cover was a radio antenna.

Slow speed flight is remarkable for a gradual and harmless approach to the stall. The airbrakes are very effective even at low speeds.

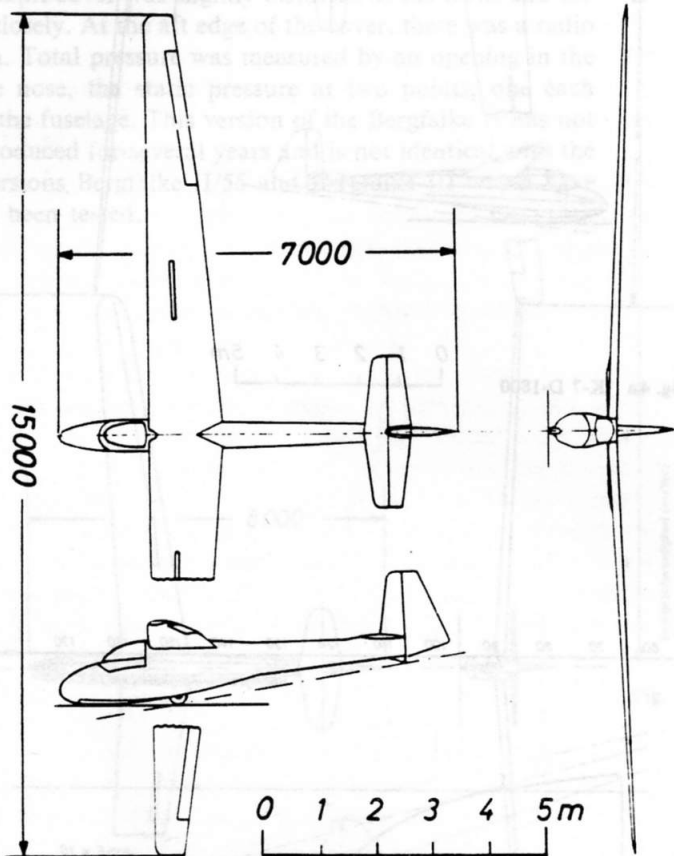


Fig. 5a K-8 D-1590

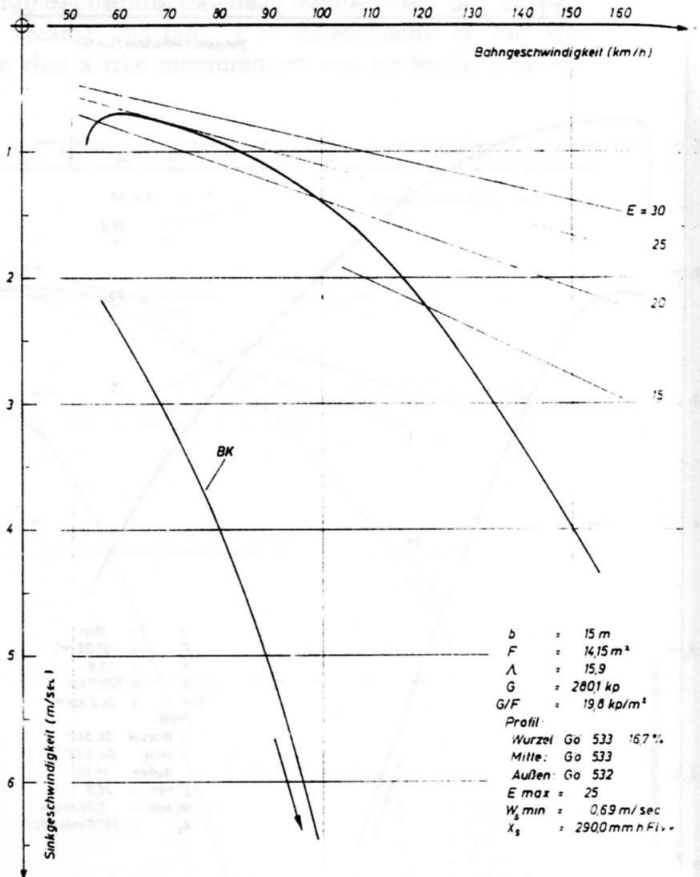


Fig. 5b K-8 D-1590, speed polar

6. Ka 6 CR, D-4390

This was a brand new production machine, with the extended stiff wing covering from the spar to the ailerons. Total pressure tube in fuselage nose; static openings each side of fuselage nose.

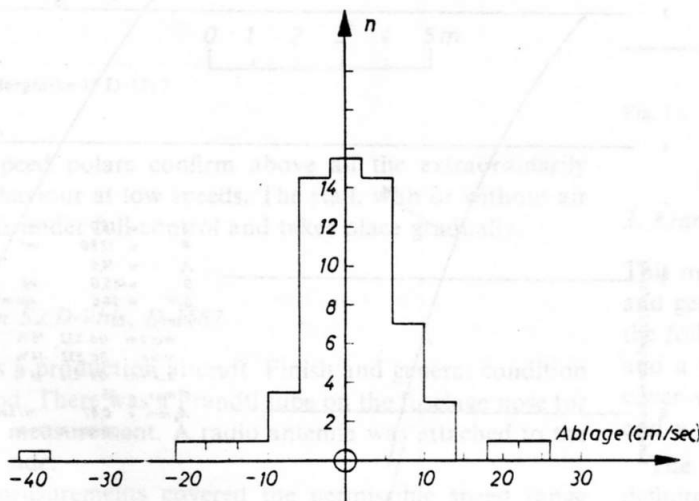


Fig. 5c K-8 D-1590, error diagram

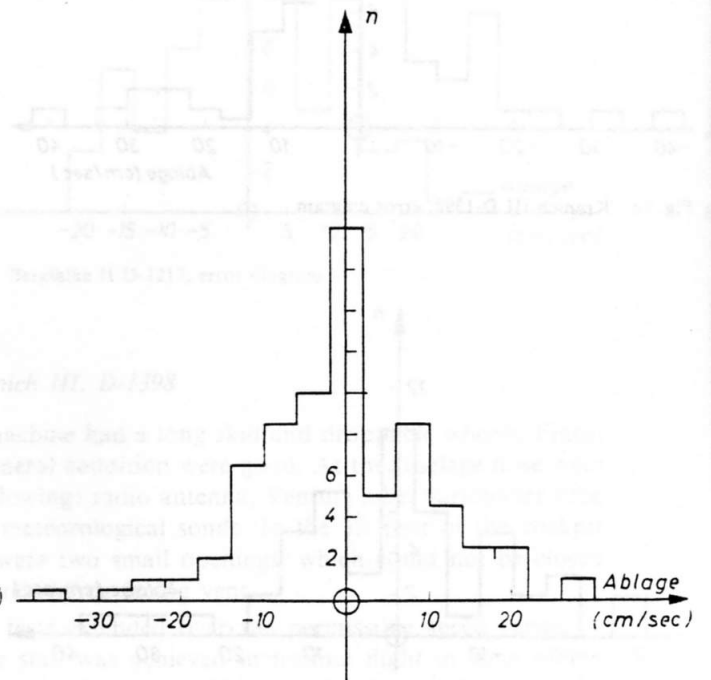


Fig. 6c Ka-6 CR D-4390, error diagram

◀ Fig. 6a Ka-6 CR D-4390

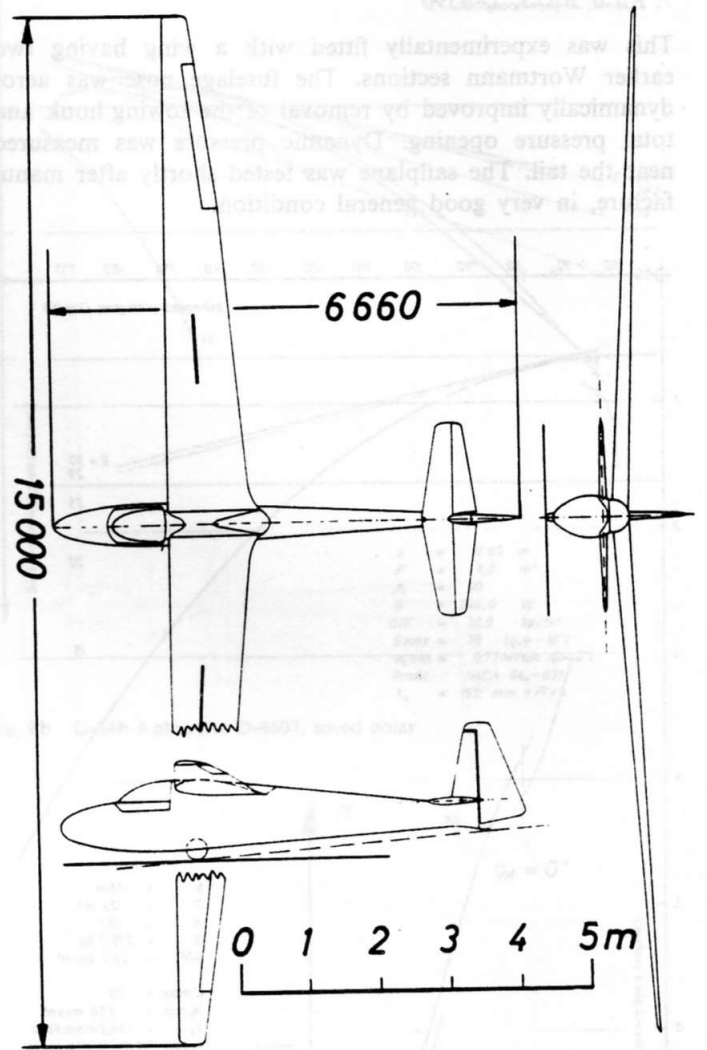


Fig. 7a Ka-6 BR/S D-8390

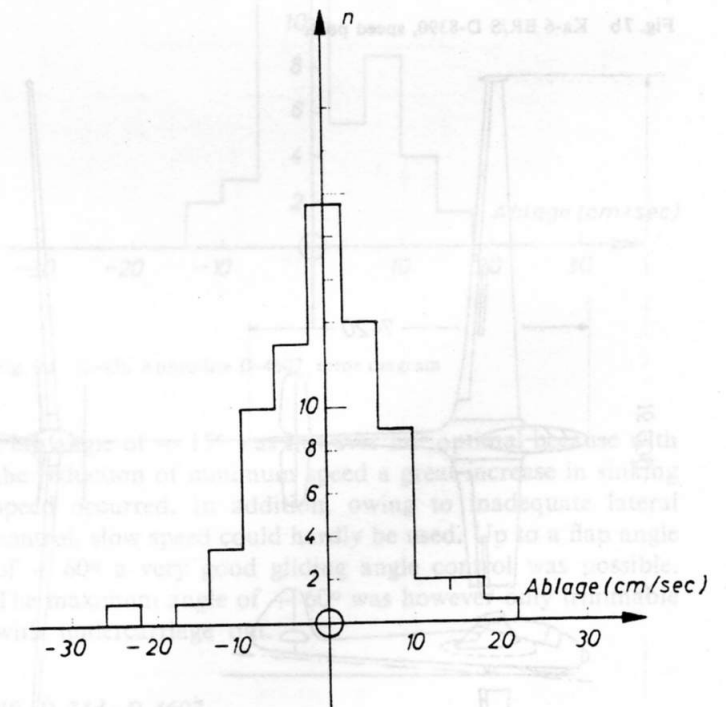
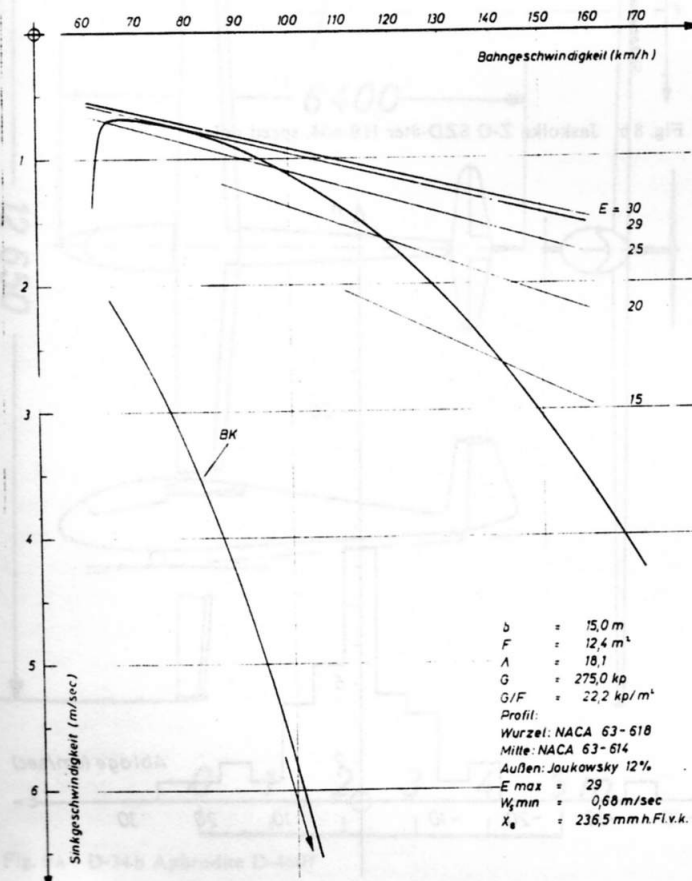
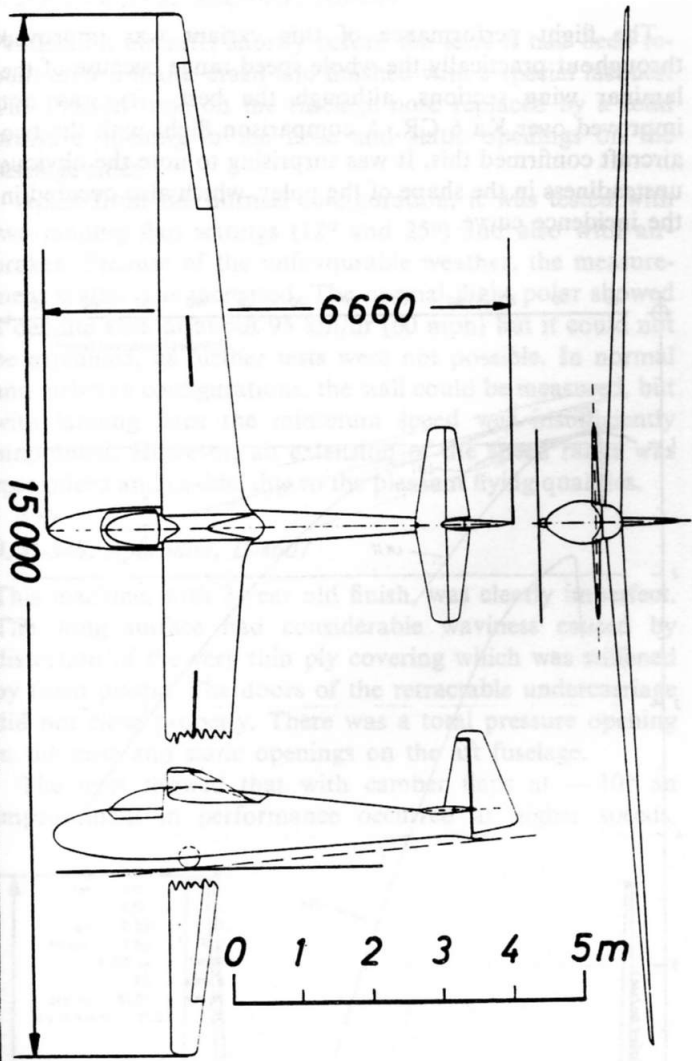


Fig. 7c Ka-6 BR/S D-8390, error diagram

◀ Fig. 6b Ka-6 CR D-4390, speed polar



7. Ka 6 BR/S, D-8390

This was experimentally fitted with a wing having two earlier Wortmann sections. The fuselage nose was aerodynamically improved by removal of the towing hook and total pressure opening. Dynamic pressure was measured near the tail. The sailplane was tested shortly after manufacture, in very good general condition.

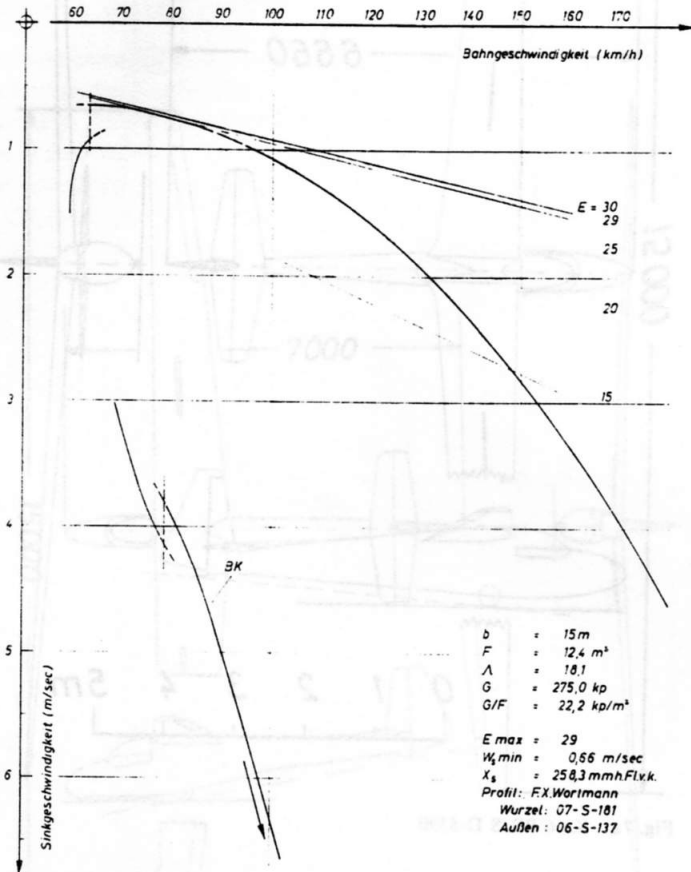


Fig. 7b Ka-6 BR/S D-8390, speed polar

The flight performance of this variant was improved throughout practically the whole speed range because of the laminar wing sections, although the best L/D was not improved over Ka 6 CR. A comparison flight with the two aircraft confirmed this. It was surprising to note the obvious unsteadiness in the shape of the polar, which also occurred in the incidence curve.

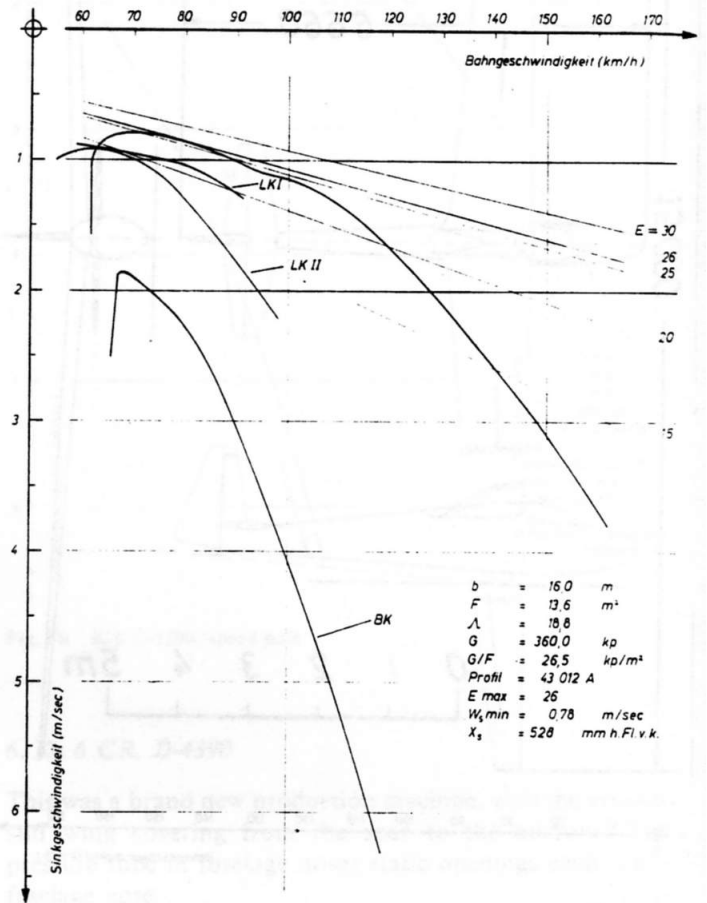


Fig. 8b Jaskolka Z-O SZD-8ter HB-604, speed polar

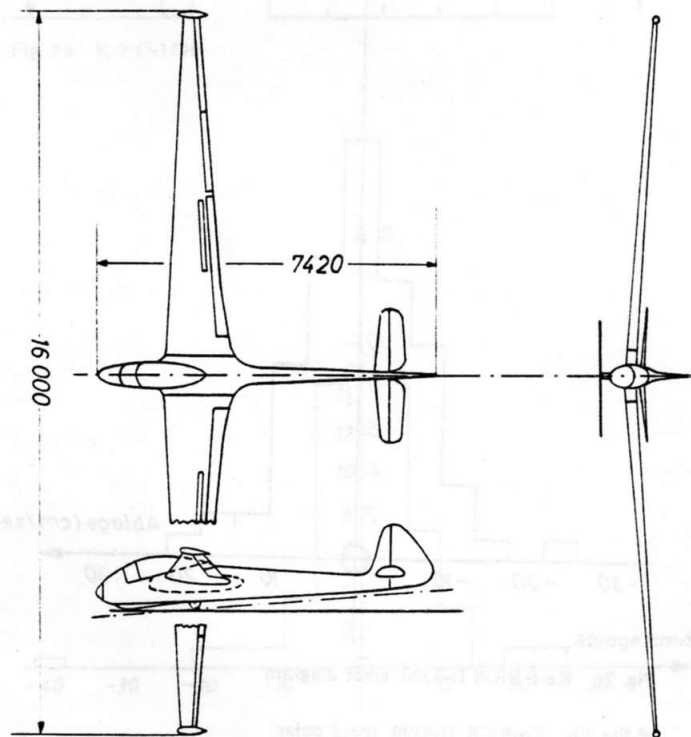


Fig. 8a Jaskolka Z-O SZD-8ter HB-604

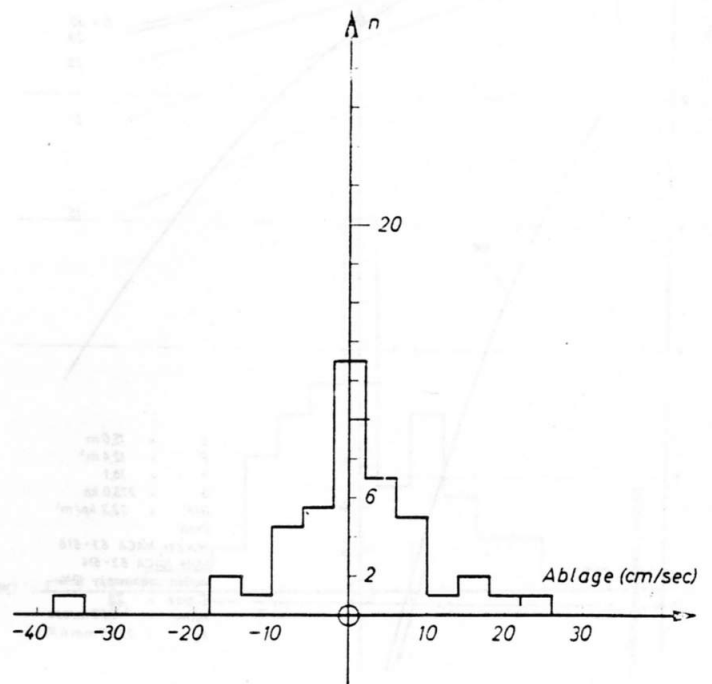


Fig. 8c Jaskolka Z-O SZD-8ter HB-604, error diagram

8. Jaskolka Z-O, SZD-8ter, HB-604

Production aircraft; shortly before the tests it had been rebuilt after a major crash and finished with a special lacquer. The Prandtl tube on the fuselage nose replaced by a total pressure opening in the nose and static openings on the fuselage sides.

Apart from the normal configuration, it was tested with two landing flap settings (12° and 25°) and also with airbrakes. Because of the unfavourable weather, the measurement scatter was increased. The normal flight polar showed a definite kink at about 95 km/hr (60 mph) but it could not be explained, as further tests were not possible. In normal and airbrake configurations, the stall could be measured, but with landing flaps the minimum speed was insufficiently pinpointed. However, an extension of the speed range was recognized and usable, due to the pleasant flying qualities.

9. D-34b, Aphrodite, D-4607

This machine, with 3-year old finish, was clearly imperfect. The wing surface had considerable waviness caused by distortion of the very thin ply covering which was stiffened by foam plastic. The doors of the retractable undercarriage did not close properly. There was a total pressure opening in the nose and static openings on the aft fuselage.

The tests showed that with camber flaps at -10° an improvement in performance occurred at higher speeds.

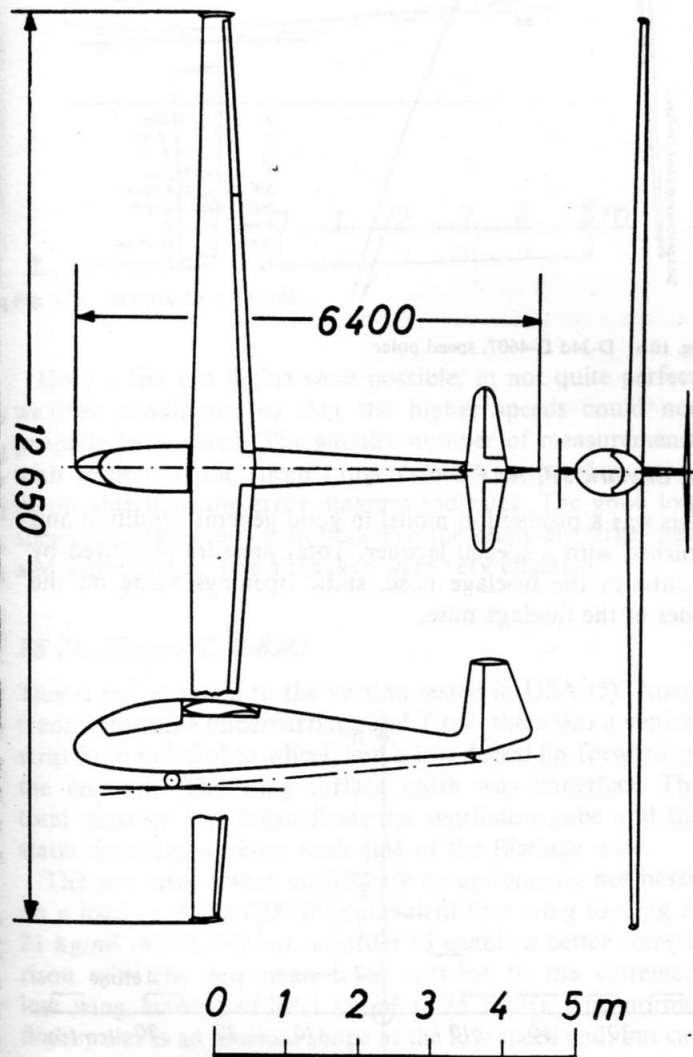


Fig. 9a D-34b Aphrodite D-4607

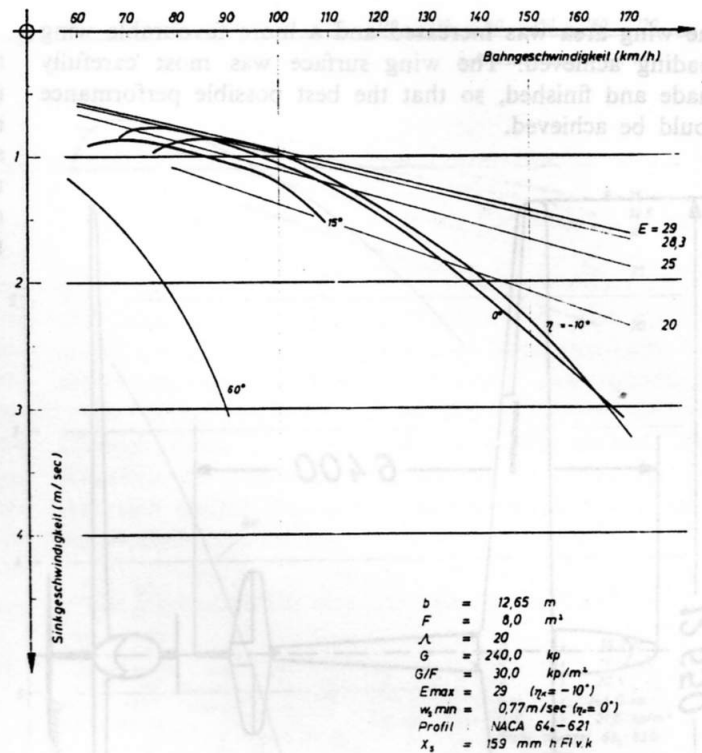


Fig. 9b D-34b Aphrodite D-4607, speed polar

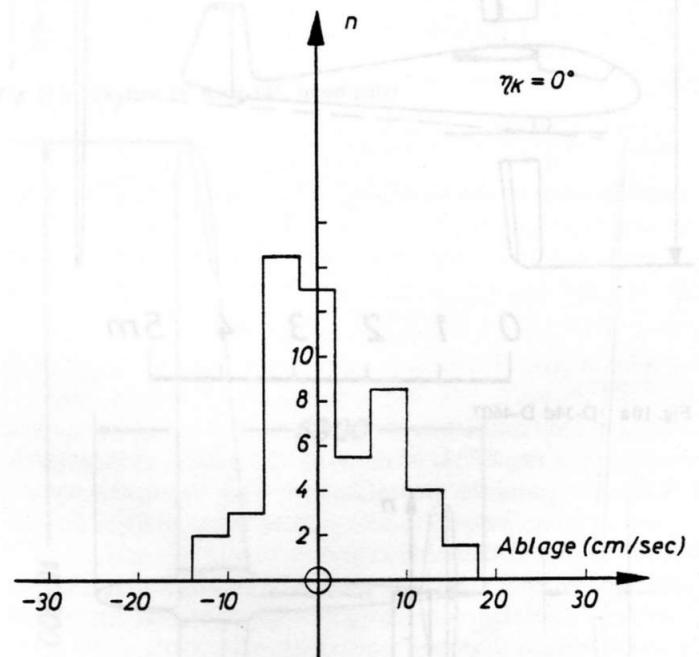


Fig. 9c D-34b Aphrodite D-4607, error diagram

Flap angle of $+15^\circ$ was however not optimal because with the reduction of minimum speed a great increase in sinking speed occurred. In addition, owing to inadequate lateral control, slow speed could hardly be used. Up to a flap angle of $+60^\circ$ a very good gliding angle control was possible. The maximum angle of $+60^\circ$ was however only trimmable with undercarriage out.

10. D-34d, D-4607

This aircraft used the same and unmodified fuselage of the D-34b, and a plastic wing. Although the span was the same,

the wing area was increased and a more favourable wing loading achieved. The wing surface was most carefully made and finished, so that the best possible performance could be achieved.

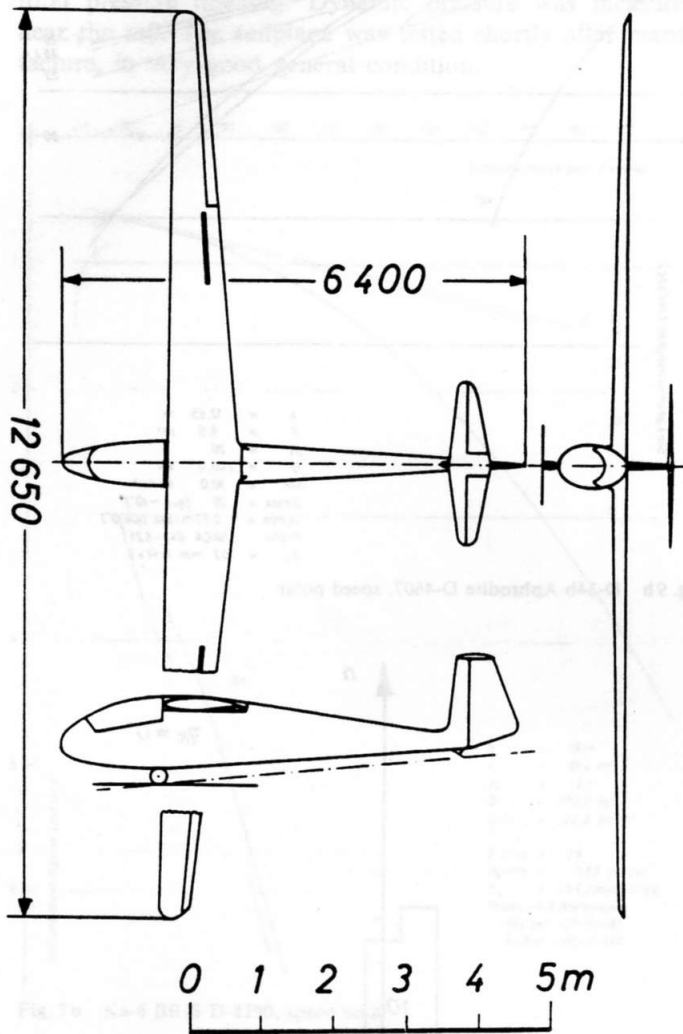


Fig. 10a D-34d D-4607

Considering the additional wing area at the same span, the improvement of the polar over that of the D-34b is remarkable. This showed, among other things, how very much the performance of laminar sections depends on the surface finish. During test flights extreme stalling could be measured distinctly, because the aircraft is still easily controllable at these high incidences. The effectiveness of the dive brakes was tested up to steady diving flight.

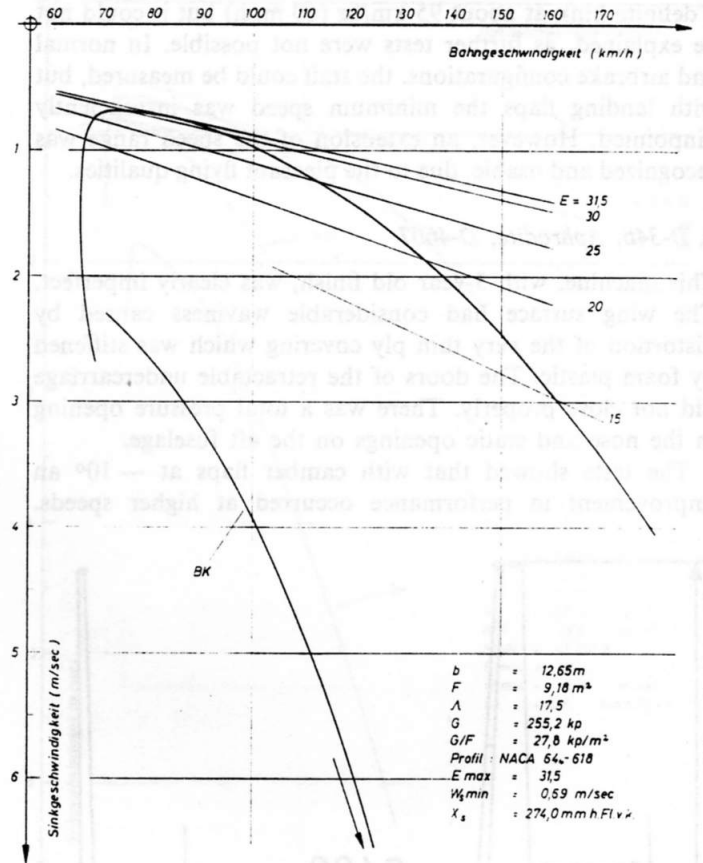


Fig. 10b D-34d D-4607, speed polar

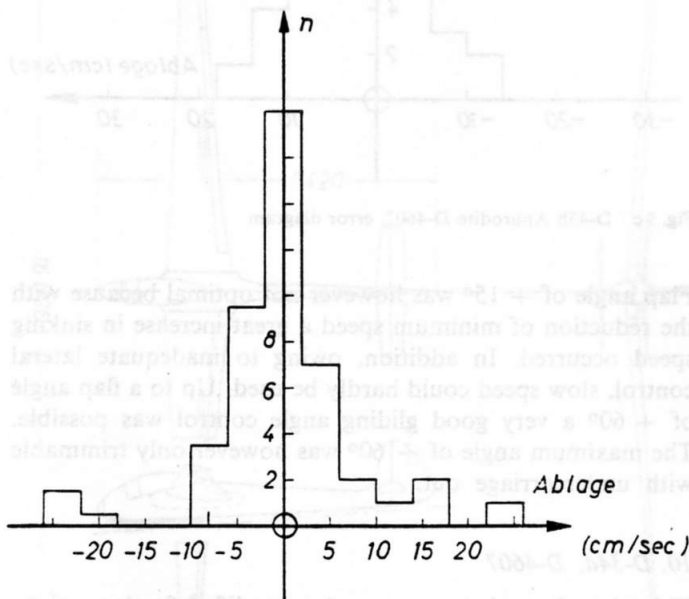


Fig. 10c D-34d D-4607, error diagram

11. Skylark 3F, RAF-146

This was a production model in good general condition and finished with a special lacquer. Total pressure measured by a tube in the fuselage nose, static openings being on the sides of the fuselage nose.

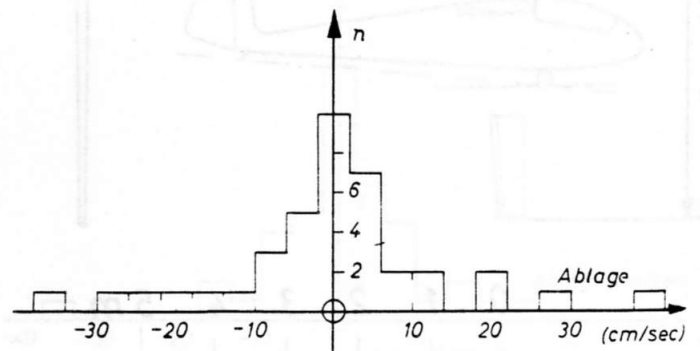


Fig. 11c Skylark 3F RAF-146, error diagram

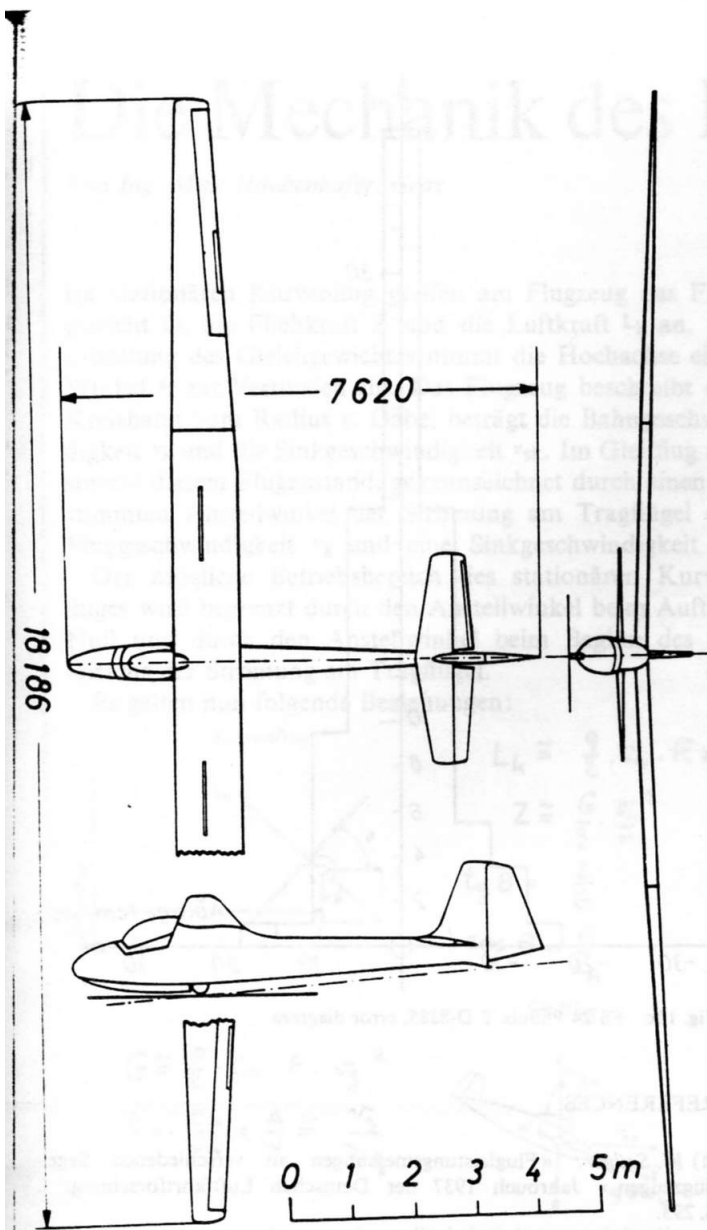


Fig. 11a Skylark 3F RAF-146

Only a few test flights were possible, in not quite perfect weather conditions, so that the higher speeds could not properly be covered. The smaller number of measurements with respect to the speed range covered is therefore more favourable than the error diagram indicates. The good low speed performance is mainly due to the relatively large span and aspect ratio. The airbrakes were very effective.

FS 24, Phoenix T, D-8385

This is not identical to the version tested in USA (5). Apart from retractable undercarriage and T tail, there was a ventral strip from tail skid to wheel, and a low dorsal fin forward of the tail unit. The wing surface finish was imperfect. The total pressure was taken from the ventilating tube and the static openings were on each side of the fuselage nose.

The test results were in this case exceptionnally not based on a load of 90 kg (200 lb) equivalent to a wing loading of 21 kg/m² (4.3 lb/ft²) but, in order to enable a better comparison with the American tests, reduced to the extremely low wing loading of 18.3 kg/m² (3.75 lb/ft²). The normal flight polar is an unusual shape at the low speed end, but can be explained by the special qualities of the Eppler laminar section used. The increase in sinking speed at low speeds is

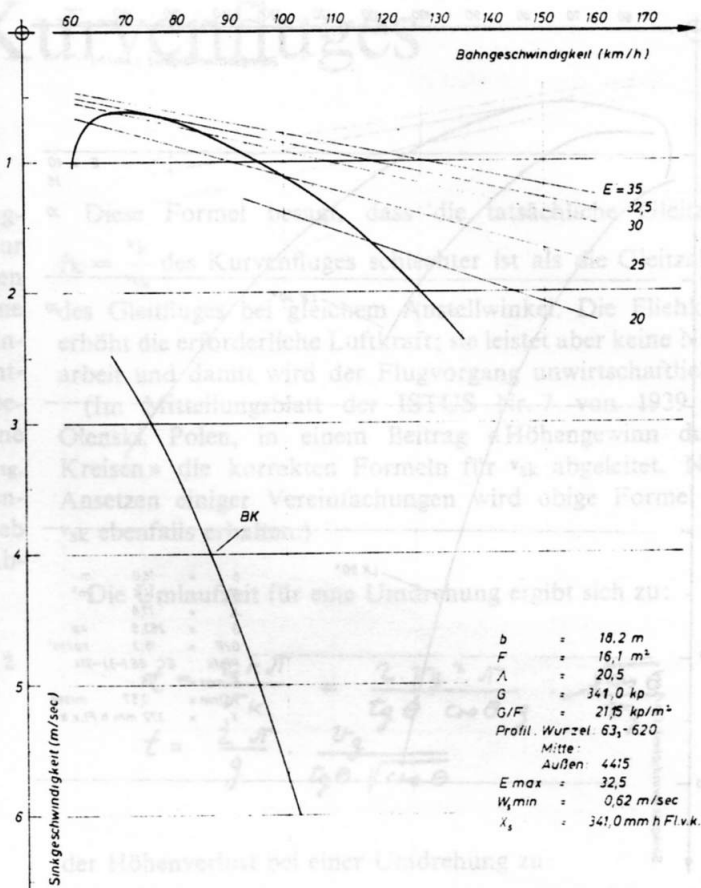


Fig. 11b Skylark 3F RAF-146, speed polar

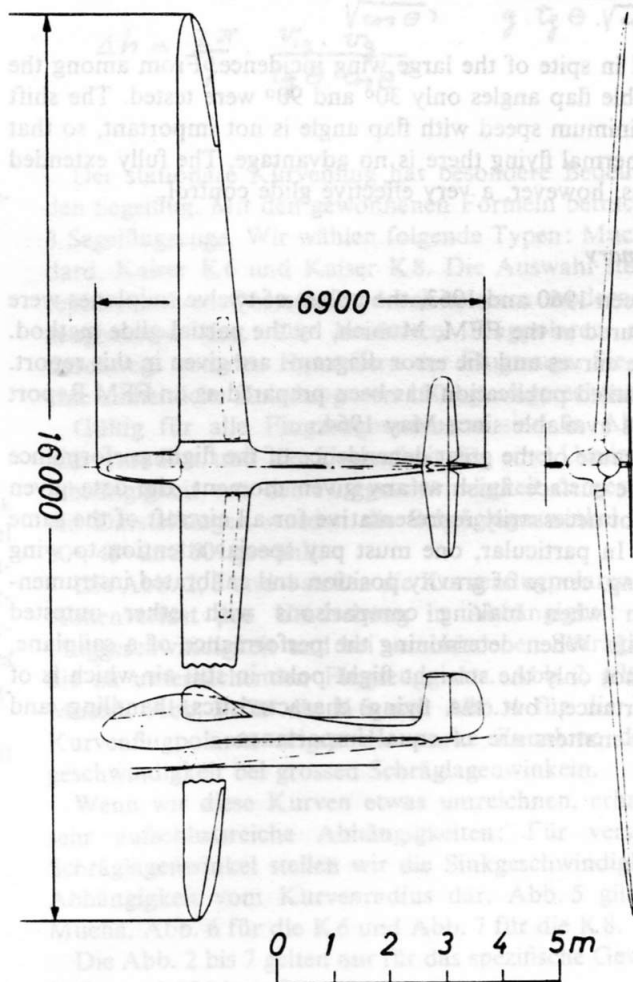


Fig. 12a FS 24 Phönix T D-8385

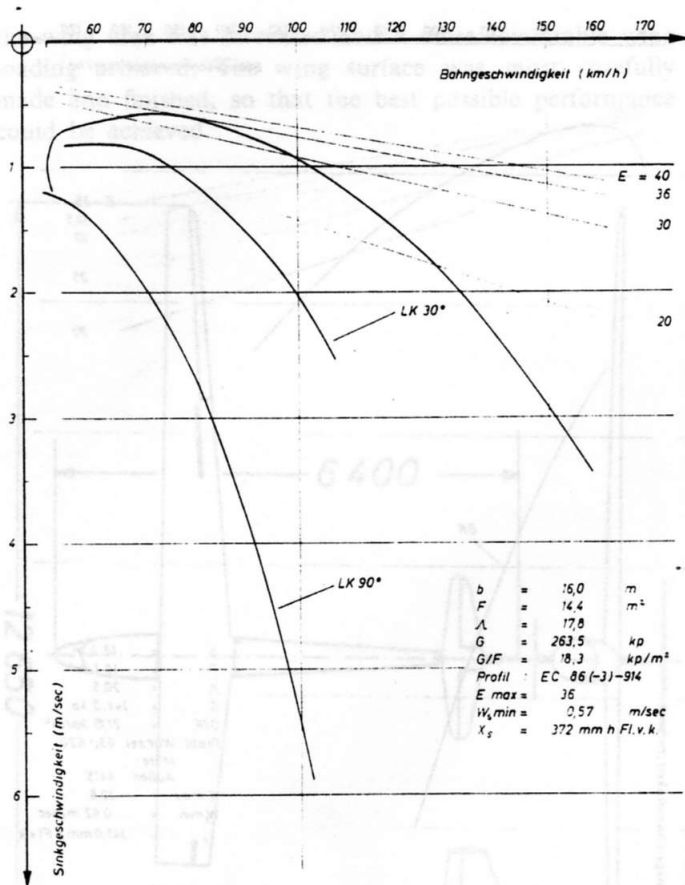


Fig. 12b FS 24 Phönix T D-8385, speed polar

small in spite of the large wing incidence. From among the possible flap angles only 30° and 90° were tested. The shift of minimum speed with flap angle is not important, so that for thermal flying there is no advantage. The fully extended flap is, however, a very effective glide control.

Summary

Between 1960 and 1963, the polars of twelve sailplanes were measured at the FFM, Munich, by the partial glide method. These curves and the error diagrams are given in this report. A detailed publication has been prepared as an FFM Report and is available since May 1964.

Because of the great dependence of the flight performance on the surface finish at any given moment, the data given are not necessarily representative for all aircraft of the same type. In particular, one must pay special attention to wing loading, centre of gravity position and calibrated instrumentation when making comparisons with other untested aircraft. When determining the performance of a sailplane, it is not only the straight flight polar in still air which is of importance, but the flying characteristics, handling and other matters are of equal importance.

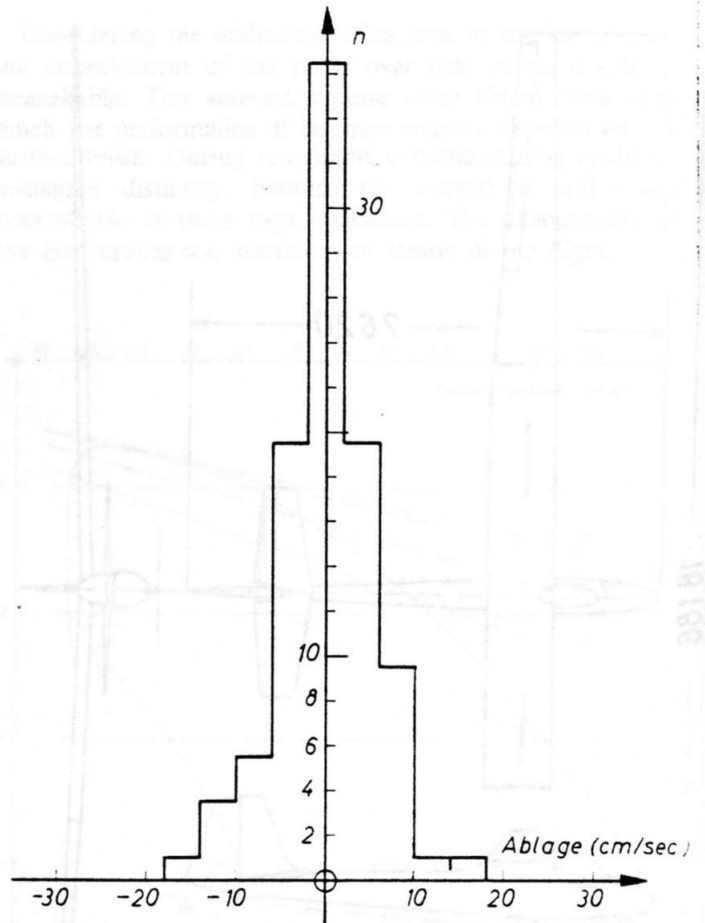


Fig. 12c FS 24 Phönix T D-8385, error diagram

REFERENCES

- (1) *W. Spilger*: «Flugleistungsmessungen an verschiedenen Segelflugzeugen.» Jahrbuch 1937 der Deutschen Luftfahrtforschung, I, S. 293.
- (2) *W. Spilger*: «Weitere Flugleistungsmessungen an Segelflugzeugen.» Jahrbuch 1938 der Deutschen Luftfahrtforschung, I, S. 319.
- (3) *H. Zacher*: «Ergebnisse der Leistungsmessungen und Flugeigenschaftsprüfung des Segelflugzeuges D 30 'Cirrus'.» Mitteilungen der Flugtechnischen Fachgruppen und Arbeitsgemeinschaften, I, Heft 1944.
- (4) *K. E. Machin*: «The Performance Testing of the Slingsby 'Sky'.» Journal of the Royal Aeronautical Society, July 1954.
- (5) *A. Raspert and D. Györgyfalvy*: «Boundary Layer Studies on the Phoenix Sailplane», Swiss Aero-Review, March 1961.
- (6) *M. Rade*: «Leistungsmessungen am L-Spatz 55 'Moritz'.» Thermik July 1959 and January 1960.
- (7) *H. Zacher*: «Flugeigenschaftsuntersuchungen an 14 Segelflugzeugen.» Bericht Nr. 40 der Flugwissenschaftlichen Forschungsanstalt E V, München, Dezember 1960.
- (8) *H. J. Merklein*: «Schleppsondeneichungen mit 12 Segelflugzeugen.» Bericht Nr. 60 der Flugwissenschaftlichen Forschungsanstalt EV, München, August 1963.
- (9) *H. J. Merklein*: «Maschinelle Datenverarbeitung bei Flugleistungsmessungen.» OSTIV - Publication VI 1960.

)Swiss Aero-Review 1964. 10/11)