Polars of Eight

BY PAUL BIKLE

Level flight performance polars have recently been measured on eight sailplanes as a part of a rather comprehensive flight-testing activity now under way by volunteers and individual members of the SSA Flight Test Committee. Results of this series of comparative tests were to be covered as one of the later articles in a series on flight testing planned for *Soaring*. However, the inclusion in the test program of five modern fiberglass sailplanes likely to play significant roles in the World Championships makes it timely to report these results as the first of the series.

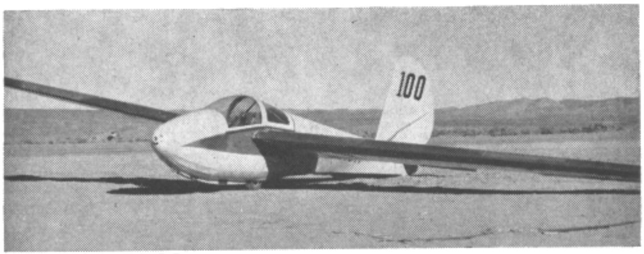
Completion of these tests at this time was as much a matter of a fortunate combination of circumstances as it was the result of good planning. Early in the fall, we had started tests to determine the level flight performance polar for the T-6, a modified HP-14T. At the same time Einar Enevoldson had started tests on his Phoebus A, concentrating on flying quality tests with particular emphasis on the P.I.O. tendencies of full-flying, slab-type horizontal tails. As the Christmas holidays approached some three months later, the T-6 polar had been measured and we had a high level of confidence in its accuracy. Work on the Phoebus A had progressed to the point where Einar needed a good airspeed system calibration and was ready for comparison tests to get both airspeed errors and level flight performance. We were both interested in using the holiday period to perfect our equipment and techniques for comparison tests, with the hope that we could organize a "workshop" later in the spring where we could obtain data for a number of sailplanes.

Relatively stable air and poor soaring weather had developed at El Mirage; the weather was cooperating! Earlier experiments with comparison tests had demonstrated that tests in air associated with any degree of convection yielded uncertain and generally unsatisfactory results. Interest of other pilots developed as tests progressed; Kurt Horn volunteered the use of his Phoebus C. Gus Briegleb wanted to take advantage of the opportunity to evaluate his modified BG-12, #67C. While we were at it, the Antelope Valley Soaring Club 1-26 was available, and members Floyd Finberg and Alan Bikle were willing to do the work involved. The first day of the new year found us pretty well finished with the work on these sailplanes. George Uveges then showed up with his 16.5-meter Diamant; Jack Nees came up from Laguna Beach with his Kestrel, and Dave Nees came along to fly it. Ross Briegleb persuaded Al Leffler to join in with his new Cirrus, and finally Mike Adams arrived with his standard, kit-built BG-12, which was included as being a more representative BG-12 than the modified 67C. We had the final essential ingredient with a number of volunteers with sailplanes of interest and a desire to participate to an extent which included paying for the towing. The year 1970 was certainly off to a good start as far as this part of the Flight Test Committee was concerned.

It was fortunate that only one or two sailplanes were available on any given day. The limited number of experienced flight-test people were able to give close attention to each sailplane and every detail of the testing. Pilot experience varied widely from that of Einar, a research pilot for NASA in between his soaring activities, and Ross Briegleb, with more than 6000 hours of glider time, down to the less than 200 hours of 16-year-old Alan Bikle, who flew the 1-26. Testing techniques on the comparison flights were adjusted to suit so that the less experienced pilots had nothing to do but hold their aircraft at a series of steady speeds. In addition to having a chance to fly in the tests, each participant received a copy of the test results on his sailplane including instrument calibrations, weighing, airspeed system errors, and a level flight performance polar. Results of the tests are listed in Table I and summarized as level flight performance curves in Figure 1 and Figure 2.

Each sailplane was weighed, as flown, on calibrated platform scales which we were able to place in the hangar at El Mirage to avoid any effects of wind. Most weighings were close to the weights on the A/C weight forms, but all were a few pounds heavier and one was found to be 79 pounds heavier than listed. Wing surface waviness measurements were made for the forward 50% chord at six chordwise stations on the wings of the higher-performance sailplanes; these measurements indicated wave heights in thousandths of an inch using a 2-in. gage spacing. A representative plot showing the data for the Cirrus is included as Figure 11. Maximum values for each sailplane are listed in Table I. Airspeed systems were checked and any leaks were corrected. Airspeed indicators were calibrated against the T-6 indicator and also against a standard indicator borrowed from a local government laboratory. Each sailplane was carefully sealed and checked for the tests.

No attempt was made to standardize loadings or pilot weights. The five fiberglass sailplanes and the T-6 were all contest sailplanes with normal contest equipment and in generally excellent condition. The condition of the Phoebus C was outstanding, the Phoebus A almost as good. The wing of the Diamant had accumulated a number of small scratches and patches. The Cirrus was nearly new, with no sanding done on



Opposite page: Kestrel and T-6. Above left: BG-12.

Above right: 1-26.

FIG. 1

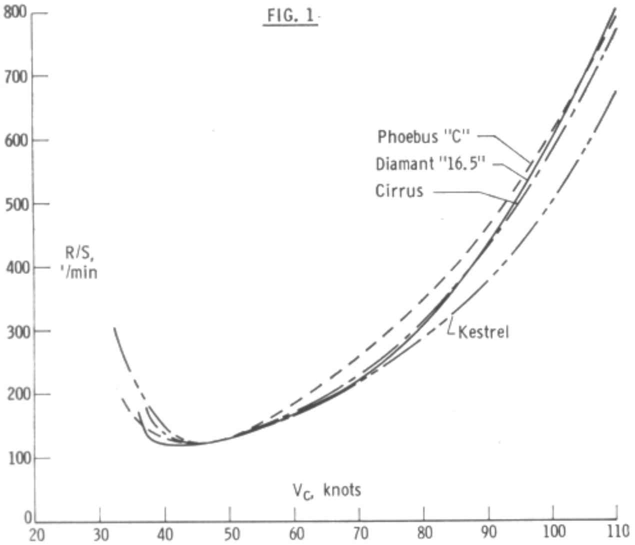


FIG. 2

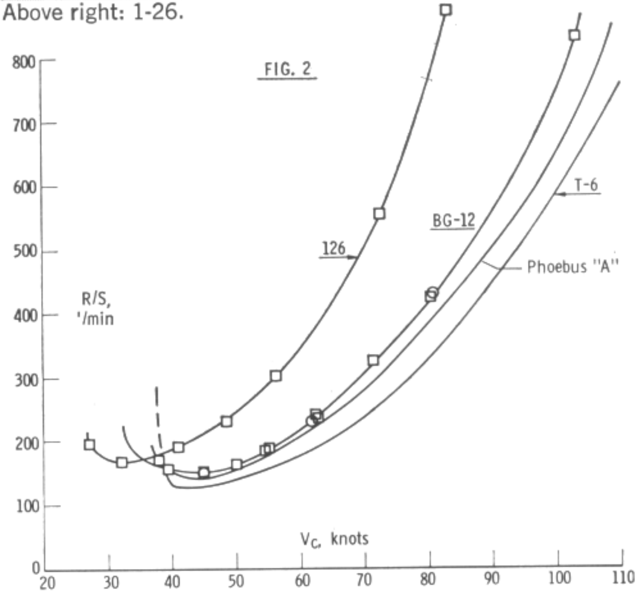


TABLE I

A/C	Kestrel	16.5 Diamant	Phoebus C	Cirrus	Cirrus	T-6	Phoebus A	BG-12	1-26
Factory No.	Apr. '68	042	833	65	Same but with 215 lb of water	6	41	113	100
Span, ft	55.7	54.2	55.8	58.2		57	49.2	50	40
Area, ft^2	123.7	143	151.2	135.6		142.5	139.7	141	160
Aspect ratio	25.1	20.5	20.6	25		22.8	17.3	17.7	10
Flap	As spec.	As spec.	None	None		0°	None	0°	None
Gear	Up	Up	Up	Up		Up	Fixed	Fixed	Fixed
Gross wt., lb	803	864	769	878	1093	810	711	828	593
Pilot wt., lb	165	175	165	218	218	200	200	155	160
W/S, lb/ft^2	6.5	6.04	5.08	6.5	8.06	5.7	5.08	5.9	3.7
Airfoil	-----	-----	E403	-----	-----	Mod-FX 61-163	E403	4415R 4406R	-----
Wave factor*	6	8	3	6	6	10	2.5	10$^+$	Very
Min. V_c, kt	32	36	33	37	41	37.5	32.5	37	27
At R/S, '/min	-----	170	200	180	200	-----	200	190	220
Min. R/S, '/min	124	120	124	127	140	125	139	151	165
At V_c, kt	45	43	43.5	44	49	43	45	43	32.5
Best L/D	38	38.5	37.5	37	37	36.3	34	31	21.5
V_c at best L/D, kt	52	51	49	50	55	48	48	50	42
V_c, 394 '/min, kt	92	87	84	87	93	86	81	78	64
'/min at 35 kt	N/A	N/A	170	N/A	N/A	N/A	177	N/A	171
'/min at 40 kt	148	122	134	138	N/A	130	151	154	186
'/min at 50 kt	132	131	134	136	141	140	152	162	243
'/min at 60 kt	168	168	184	173	168	179	207	217	343
'/min at 70 kt	219	219	257	230	213	236	282	307	500
'/min at 80 kt	287	307	347	319	278	326	380	419	760
'/min at 90 kt	372	435	458	430	362	450	497	562	-----
'/min at 100 kt	495	598	609	577	472	590	655	746	-----
'/min at 110 kt	672	803	790	766	624	758	890	-----	-----

*Wave factor is the maximum wave height in thousandths of an inch measured on the forward 50 percent of the wing surface with a 2 inch gage at six chordwise stations.

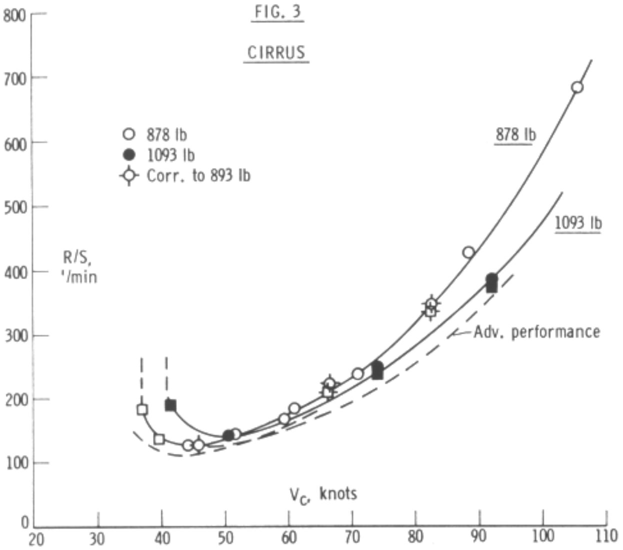


FIG. 3

CIRRUS

the factory wing finish. Condition of the Kestrel was outstanding except for a leaking forward canopy seal which was not discovered until the tests were completed. Except for an inherent waviness in the metal wing surface greater than the fiberglass sailplanes, the T-6 was in first-class condition. The BG-12 was in generally good condition, while the 1-26 was representative of the average club trainer which it was. Obviously the results of the tests pertain to these eight individual sailplanes as flown and should be applied to other sailplanes of the same type with some degree of caution.

Testing of individual sailplanes involved one flight with either the swivel-head wing boom, as shown in the photograph of the Phoebus A, or a trailing static cone, as shown in the flight photo of the T-6, to obtain a complete airspeed error calibration. A cross-check on this calibration was also obtained from the T-6 airspeed readings during side-by-side comparative sink tests made on later flights. Airspeed system correction curves and data points are plotted in Figure 9. Errors for the Kestrel, Diamant, and T-6 were found to be negligible. On the other hand, neglect of these corrections in the case of the Phoebus C, Phoebus A, and BG-12 would result in serious errors in the high-speed performance measurements. There is a tendency to lose sight of the fact that a polar represents both rate of sink and speed. One knot may not seem like much, but it is equivalent to about 15 or 20 feet per minute in R/C at 100 knots; at 50 knots, one knot is equivalent to 2% in L/D or nearly 1 point in L/D on the higher performance sailplanes.

At least two flights, and in some cases three or four flights, were then made on each sailplane for comparison tests with the T-6. All flights in this series were made from tows to the neighborhood of 10,000 feet, with the first flights each day made at about nine in the morning. Temperature data was taken in the climb and tests were discontinued if the lapse rate was not stable. On several of the flights the air was smooth enough for absolute, timed rate-of-sink measurements, and these were made when the opportunity presented itself. However, the bulk of the data was obtained when the air was not completely smooth and not suitable for absolute measurements. Tests were discontinued at lower altitudes whenever convection was encountered.

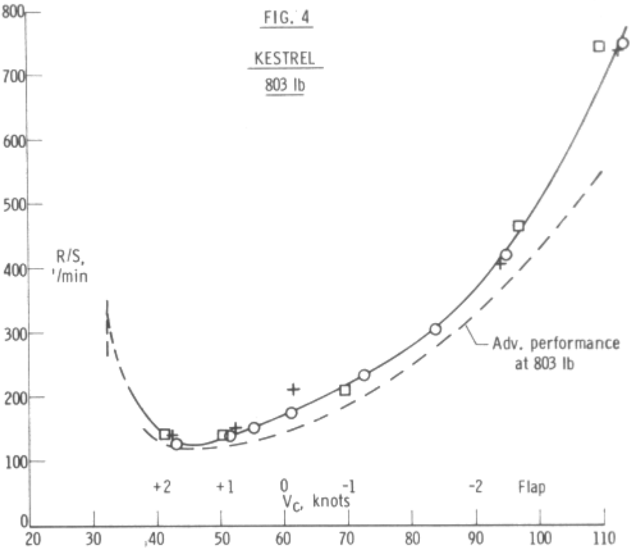


FIG. 4

KESTREL

803 lb

Basic comparisons were made in 5-minute, side-by-side glides. For each point, the lead sailplane would establish a steady glide at a constant indicated airspeed; the second sailplane would then take a position about 200 to 300 feet out from the wing tip of the lead sailplane. When both pilots were ready, the run would start, both pilots noting the altimeter and airspeed readings and estimating the difference in height between the sailplanes at this point. At the end of five minutes, the pilots took the same readings and the run was terminated. Where the performance of the two sailplanes was about the same, change in the relative heights of the two ships was determined most accurately from the estimates made by the pilots. For height differences in the neighborhood of 50 feet or less, the accuracy appeared to be about ±5 feet; when divided by five minutes, this would give an incremental rate of sink within about ±1 foot per minute.

Greater differences in performance resulted in relative height changes considerably in excess of 50 feet over a period of five minutes. In these cases, estimates were augmented with the use of transparent grids which could be used to gauge height differences in fuselage lengths, and the relative altimeter increments were also used as a source of data. For height differences approaching 150 feet, relative height differences were only accurate to about ±15 feet, and this would give an uncertainty of about ±3 feet per minute to measurements of difference in rate of sink. The differences were corrected to sea-level standard condition by the same methods used for reducing absolute rate-of-sink data to sea level. Corrected increments were then added to the standard rate of sink already determined for the T-6 at the specific calibrated airspeed at which the test was flown.

In cases where the difference in sink exceeded 30 feet per minute, comparisons were made by having the second sailplane start behind and to one side of the

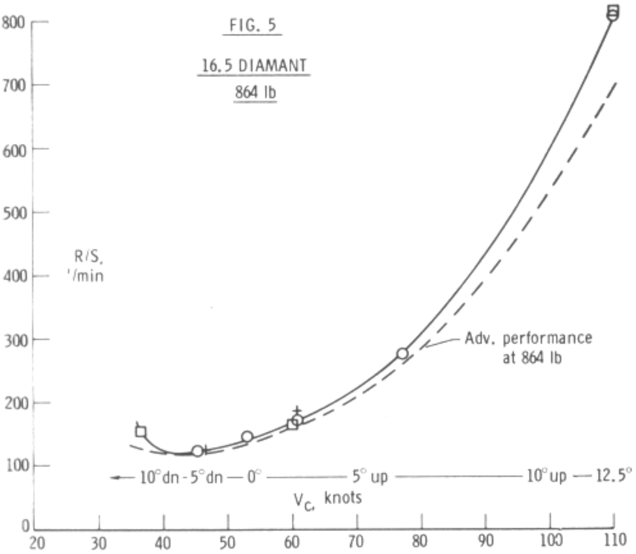


FIG. 5

16.5 DIAMANT

864 lb

lead sailplane, maintaining the same rate of sink by keeping the lead sailplane on an appropriate line of sight to the horizon, and noting the difference in calibrated airspeeds. The same technique was also used for points where the speed of the test airplane was outside the speed range of the T-6. This procedure required stable air, clear visibility, and a far-off horizon for reference, as well as a good understanding of the factors which might lead to a slight inclination of the line of sight; generally, any effect of an inclined line of sight can be minimized by selecting diverging flight paths so that the relative distance between the sailplanes remains about the same. The technique has been developed to a point where good results were obtained, and a number of points were checked using both techniques. It was then only necessary to read the rate of sink for both sailplanes from the standard-day, sea-level T-6 polar at the T-6 calibrated speed and to plot it at the calibrated speed of the test sailplane during the run.

Test points for the 1-26 and BG-12 are plotted with the summary curves in Figure 2. Curves for the Cirrus, both with and without 215 pounds of water ballast, are shown in Figure 3 along with the test points for both conditions. The heavy weight points have also been corrected to the lighter weight and plotted on the light weight curve, showing full agreement with the theoretical effect of weight. Kestrel, Diamant, Phoebus C, and Phoebus A test data are shown in Figures 4, 5, 6, and 7. The points represented by circles are side-by-side comparisons, points portrayed by squares are from comparisons at the same rate of sink, while crosses indicate timed rate-of-sink measurements made in completely smooth air. Figure 8 is the reference curve for the T-6, with timed rate-of-sink points (crosses) obtained during the comparison tests plotted along with earlier test points (black dots) on which the curve was based. All data have been plotted in nondimensional form as lift coefficient squared vs. sailplane drag coefficient in Figure 10.

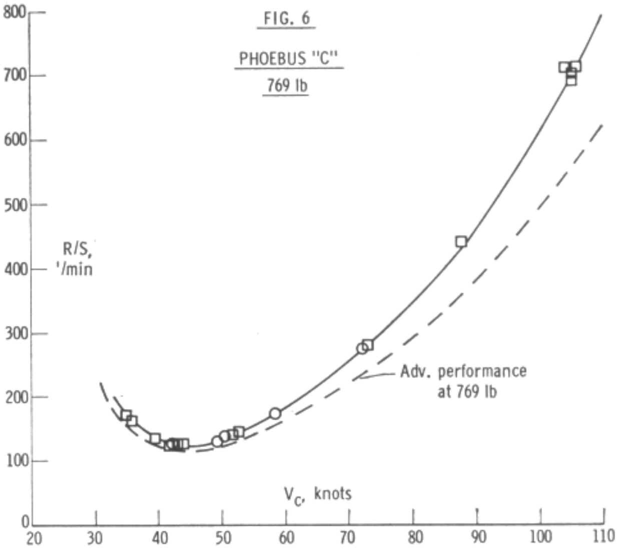
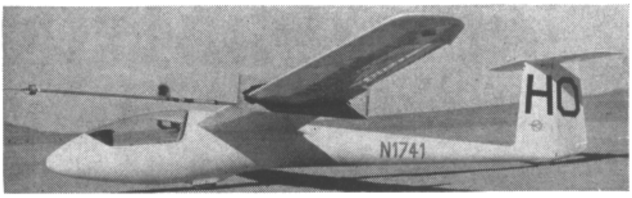


FIG. 6

PHOEBUS "C"

769 lb



The Phoebus A wearing the swivel airspeed head.

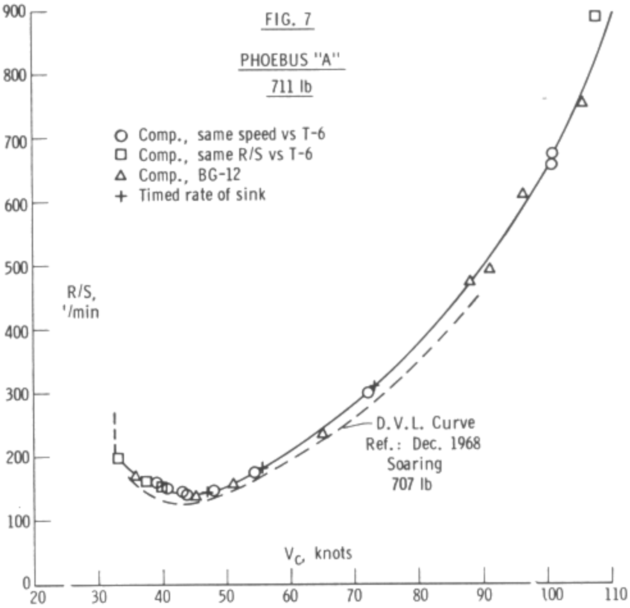
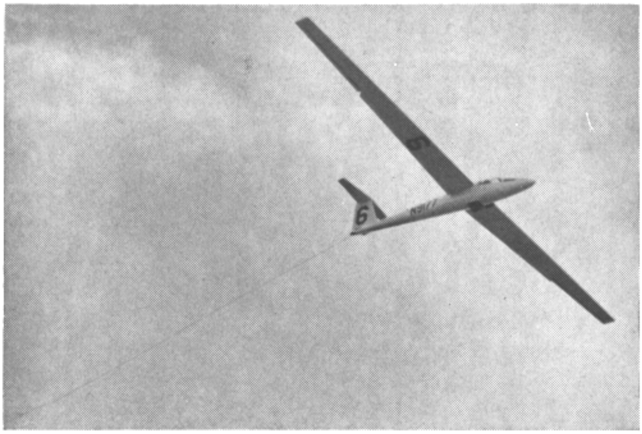


FIG. 7

PHOEBUS "A"

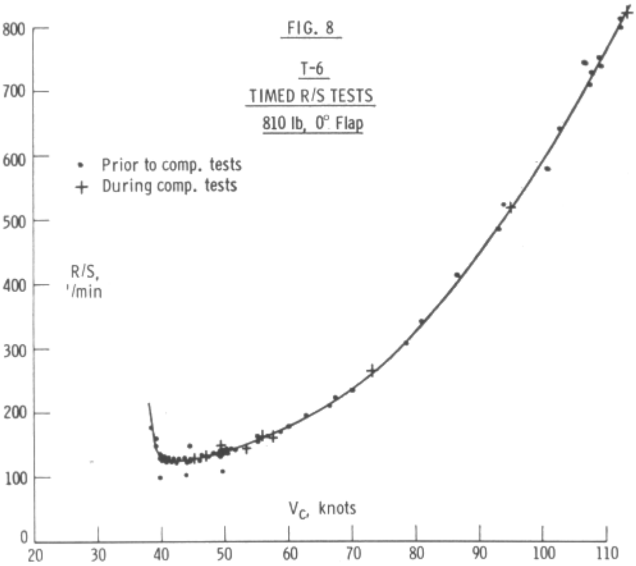
711 lb

Of course, the absolute level of the performances obtained for all eight sailplanes is entirely dependent on the validity of the reference T-6 data, which consist of 47 individual rate-of-sink measurements at various speeds. These were all timed runs at constant speed for a minimum of at least five minutes or 1000 feet; some were continued for as long as 15 minutes, and some for as much as 5000 feet of altitude. All were made on very early morning flights to altitudes in the neighborhood of 12,000 to 13,000 feet on days when the lapse rate was stable and wind velocities and wind shear was at a minimum. Temperatures were measured in flight; the aircraft had been weighed on several occasions during the flights; instruments were calibrated; and the configuration was carefully controlled



The T-6 trailing a static cone in order to calibrate the airspeed system.

FIG. 8

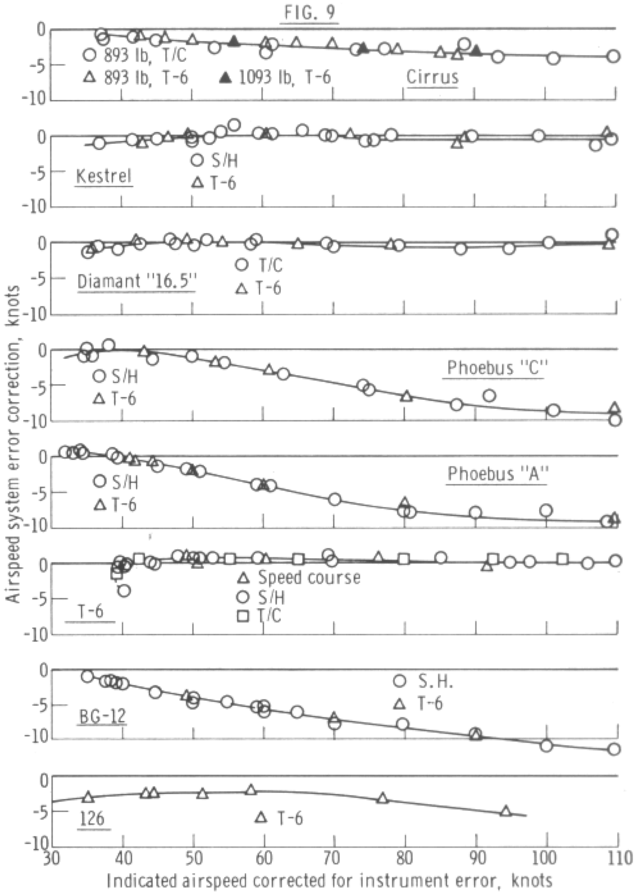


during the period of the tests. A rate-of-sink vs. speed polar has been determined for sea-level standard conditions using techniques essentially the same as those described by Dick Johnson in "Sailplane Flight Test Performance Measurement," published in the April 1968 issue of *Soaring* Magazine.

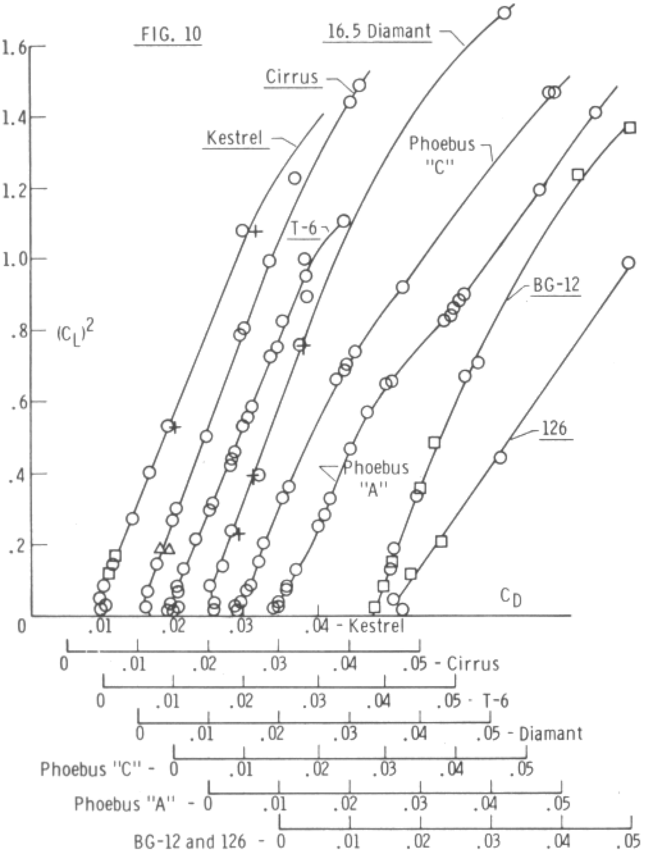
A great deal of attention had been given to the determination of the airspeed system errors to insure accurate calibrated airspeeds. Calibration flights were made on nine occasions; these included two series of runs with airplanes calibrated over a ground speed course, calibration against a separate airspeed system connected to a swivel airspeed head mounted 2.3 chord lengths ahead of the wing, calibration against a trailing static cone, and calibration against a previously calibrated SHK. All gave consistent results with a scatter of less than ± 1 knot. Check calibrations were also made during the comparison tests, and the agreement with earlier calibrations was excellent. This agreement, along with the consistent rate-of-sink data points obtained at this time, served to maintain our confidence in the accuracy of the reference polar.

There is always the possibility of some systematic error in procedure which has not been detected or the possibility that the average smooth air in the El Mirage area has some residual subsidence. The fact that the measured data presented here for the T-6 are almost identical to the data obtained by Dick Johnson in the flat lands of Texas with his quite similar HP-13 tends to indicate that this is not the case. What about the overall accuracy of the comparison tests? We ran additional tests on the Phoebus A flying with the BG-12; points obtained from comparisons with the BG-12 (represented by triangles) are plotted with the points from the T-6 in Figure 7 for the Phoebus A, with excellent agreement between the two sets of data. As a further check on the overall consistency of the test results, the BG-12 data of Figure 2 were compared with data obtained on the original BG-12 in 1956, with quite close agreement. The 1-26 points plotted in Figure 2 fell so close to the curve for a different 1-26 tested in 1960 that the curve drawn through the points is the same 1960 curve.

FIG. 9



Plots 3, 4, 5, and 6 also show dashed curves taken from the manufacturers' advertised curves. It is not too surprising that these range from 5% to 15% better performance than obtained in the tests. It is interesting to note that the Diamant performance curves almost agree at slow speed. Curves for other sailplanes are displaced about the same amount throughout the speed range, while some others differ more at slow speed than at high speed. Use of such advertised data for comparison purposes between sailplanes may introduce more differences than actually exist between the sailplanes tested. In several instances it was noted that maximum L/D, for example, was quoted as something like 44 in the tabulated performance, the curve in the same brochure showed 42, and the test results for the airplane tested showed something like 37 or 38. For another sailplane, the published L/D curve was 15% better than

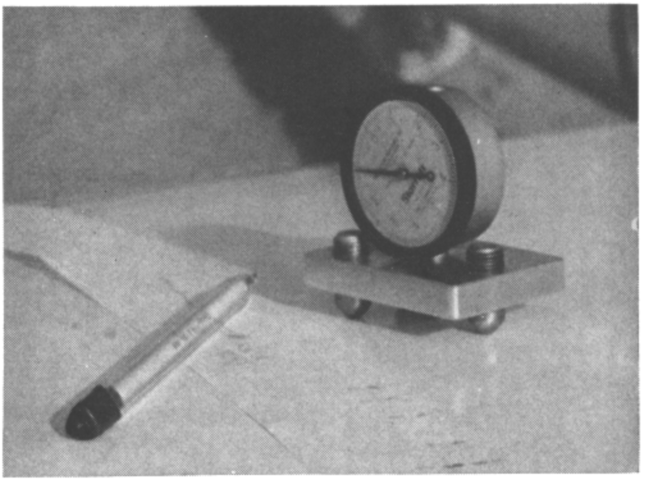


the rate-of-sink curve published on the same plot, in this case the rate-of-sink data agreeing with that obtained in these tests.

Of greater concern was the difference shown by the dashed curve in Figure 7 for the Phoebus A. This is the D.V.L. polar for the Phoebus A from the article by Hans Zacher which was reprinted in the December 1968 *Soaring*. The original data in the D.V.L. report have been checked and certainly appear to be correct. Earlier D.V.L. data obtained on a Ka-6CR was very close to the data obtained on a similar Ka-6CR in this country in 1961. We have been unable to account for this difference in Phoebus A performance except for a possible difference in the sailplanes.

Certainly the relative difference in performance for the eight sailplanes tested are valid within fairly close limits. The extent to which these sailplanes represent other sailplanes of the same type and the extent to which they represent the best of each type is, of course, unknown. It would be reasonable to assume that the performance of the sailplanes tested does indicate the general level of factory-built planes in the hands of the customer. Wing waviness measurements would indicate that the extent of laminar flow might be considerably less than claimed. Comparison of the lift-coefficient-squared vs. drag-coefficient plots, Figure 10, with claimed polars also indicates an incremental drag which could very easily be explained by a difference in the extent of laminar flow. This leaves open a very real question as to what extent laminar flow can be achieved in flight.

Closely examining the performance obtained and comparing it with experience in contests emphasizes a very real but hard to analyze and too often neglected consideration of the low-speed performance in comparing sailplanes. It would certainly appear that a combination of good performance and agility in maneuvering at very low speeds and rapid roll accelerations could combine to make up for a considerable difficiency in high-speed performance under many soaring conditions. At best, level flight polar data of the type reported here is only one piece of the puzzle of what makes a good sailplane. Even so, people do seem to be interested in such data and should benefit from a realistic assessment of its value.



The gage above measures the smoothness of wing surfaces.

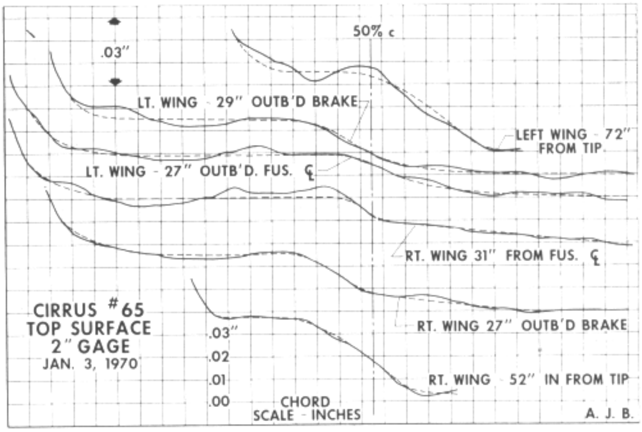


FIGURE 11

No attempt has been made to explain in detail much of what has been covered in this report. Future reports will address themselves to many aspects of interest. These will include new techniques, airspeed system error as related to type and design of airspeed systems, complete results of the T-6 tests, data obtained with simple hinged flaps including loads and hinge moments as well as lift and drag effectiveness, flight-test performance of 10 more sailplanes, profile drag measured on several airfoils in flight, and several articles devoted to stability and control testing.

In the coming months we plan to obtain data on the AS-W 12; preliminary data indicate that the AS-W 12 may well have a maximum L/D of about 44. Of great interest would be the opportunity to fly comparison tests with the new family of Standard Class sailplanes, but these will not be available until next fall for tests of this type.