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Plascott, R. H.

Aerodynamics (2)

Wings and Airfoils (6)

Airfoils - Drag (08200); 11 Z.3657

(08421.7) Airplanes - Drag Reduction (08421.7);

20344

AERO-2153

Profile drag measurements on hurricane 11 Z.3657 fitted with "Low Drag" section wings

Royal Aircraft Establishment, Farnborough, Hants

Ot.Brit.

Eng.

Restr.

Restr.

Sep'46

15

tables, graphs, dwgs

Tests were conducted to determine the improvement obtained by reducing the surface waviness on the experimental "low drag" wings fitted to the Hurricane II Z. 3657, to one thousandth of an inch variation from the mean curve deflection on a two inch gauge length. Results show that the drag coefficient has been reduced to 0.0044 over a range of lift coefficients from 0.1 to 0.5. This corresponds to transition at 50-60% chord. Laminar flow was maintained up to Reynolds Numbers of nearly twenty millions.

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ROYAL AIRCRAFT ESTABLISHMENT

Farnborough, Hants.

PROFILE DRAG MEASUREMENTS ON HURRICANE II Z. 3687 FITTED WITH "LOW DRAG" SECTION WINGS

by

R. H. PLASCOTT, B.Sc.(Eng.)

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Report No. Aero. 2153.

September, 1946.

ROYAL AIRCRAFT ESTABLISHMENT, FARNBOROUGH

Profile Drag Measurements on Hurricane II Z.3687
fitted with Special Wings of "Low Drag" Section built by
Armstrong Whitworth Aircraft Ltd.

by

R.H. Plascott, B.Sc. (Eng.)

SUMMARY

This report describes flight tests to determine the improvement obtained by reducing the surface waviness on the experimental "low drag" wings fitted to this aircraft to $\pm$ one thousandth of an inch variation from the mean deflection curve on a two inch gauge length.

Provided no flies or other insects were picked up during the flight, the drag coefficient has been reduced to 0.004 over a range of lift coefficient from 0.1 to 0.5. This corresponds to transition at 50-60% chord. With the reduced surface waviness it was possible to maintain laminar flow up to Reynolds Numbers of nearly twenty millions. The slight rise in drag coefficient at Reynolds Numbers above fifteen millions probably arises because the surface did not meet the above requirements at all points on the surface.

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1 Introduction

A new type of construction thought to be suitable for the maintenance of laminar flow on a wing of "low drag" section has been designed by Armstrong Whitworth Ltd. In order to determine the characteristics of such a wing in flight, special wings of this construction have been fitted out-board of the wing joint at the undercarriage to a Hurricane II Z.3687.

During the previous flight tests on this aircraft (Ref.1), it was found that the waviness of the surface was large enough to prevent full laminar flow being established, especially at the higher Reynolds Numbers. The aircraft was therefore returned to Armstrong Whitworth Ltd. for reduction of the surface waviness, by use of an appropriate filler and careful rubbing down.

The present tests were undertaken to determine the improvement obtained by reducing the surface waviness to $\pm$ one thousandth of an inch variation from the mean deflection curve on a two inch gauge length.

2 Description of the Aircraft

The aircraft is fitted with a Merlin XX engine (Fig.1). The wings are made to a design by Armstrong Whitworth Ltd. There is no spar, the stresses being taken in a thick skin (18 S.W.G.) stiffened by sparwise stringers of 3 inches spacing. The top and bottom surfaces are connected by ribs 15 inches apart. The leading and trailing edges are constructed in a normal manner and are connected to the "low drag" construction, which extends from 5% to 62% of the chord on both surfaces.

The wing profile was designed by the N.P.L. to give a peak suction at 50% chord. The root thickness is 17.9% and tip thickness 14.8%. The junction of the "low drag" wing with the "conventional section" wing root was covered by a fairing panel to blend the different profiles into each other.

The test section was 9 feet from the fuselage centre line on the port wing (Fig.1). The detail of the test section, together with its profile, is shown in Fig.2.

A leading-edge pitot-static head was fitted to the port wing tip.

3 Description of the Tests

The profile drag of the section was measured by a pitot-static comb mounted 8.17 inches (9.94% chord) behind the trailing edge (Fig.2). The loss in total head in the wake was measured by connecting the tubes to airspeed indicators in the automatic observer. An altimeter, aircraft A.S.I. and accelerometer for normal "g" were included in the observer.

The profile drag of the section was calculated by analysing the wake traverse by the method of Ref.2.

All the tests were made in level flight at 10,000 feet. In order to obtain the high speeds, the aircraft had to be dived from some height above 10,000 feet and then levelled out before taking readings. This of course meant that the aircraft was decelerating whilst the readings were being taken; but the deceleration was only about 1 ft./sec./sec., and the correction to drag coefficient due to this was negligible.

4 Measurement of Surface Waviness

The surface waviness was measured by means of a deflection gauge which consisted of an 11 inch dial mounted on an adjustable base. Traverses

of the wing were made with a three inch gauge length on the test section and on sections five inches and ten inches inboard and outboard of the test section. As the spacing of the spanwise stringers was three inches, these measurements tend to exaggerate the waviness for comparison with the flight tests on King Cobra FZ.440 (Ref.3), a traverse of the test section was made with a two inch gauge length.

5 Results

5.1 Surface Waviness

The results of the measurements with the deflection gauge are shown in Figs.3, 4 and 5. The improvement in the surface waviness is apparent on all the sections, the variation from the mean deflection curve being mostly less than one thousandth of an inch on the two inch gauge length. The bottom surface is the worse in this respect.

5.2 Profile Drag

The profile drag coefficients, calculated by the method of Ref.2 are plotted against aircraft lift coefficient in Fig.6, for all cases in which it appeared that no flies or other insects were picked up during the flight. It will be seen that the drag coefficient has been reduced over the whole "low drag" range, the greatest improvement being at the higher Reynolds Number end. The lowest lift coefficient recorded was 0.097 and the drag coefficient at this point was 0.0049. For comparison, the drag curve obtained in the previous flight tests is plotted on Fig.6 and it will be seen that the drag coefficient for a lift coefficient of 0.097 was then 0.0066, the present tests thus showing a reduction in drag of 26%. The "low drag" range now extends from 0.1 to 0.5 lift coefficient.

In Fig.7, are shown the results of all the flights made, including those during which flies and other insects were picked up. The increase in drag due to flies was quite large and it is clear that unless some means can be found to prevent the insects sticking to the surface, the full advantage of smooth low drag sections will not be achieved in practice.

6 Maintenance of the surface

Most of the surface held very well; however at two points on the port wing, chordwise cracks developed and extended from the leading edge to about 60% of the chord on the bottom surface, though on the top surface it only extended to about 4% back. One of the cracks was only two inches outboard of the test section and required filling and rubbing down after each flight.

No trouble was experienced with the drying out of the filler, though it was noticed that a substance, which presumably had been used in processing the wing, tended to ooze out of the skin joints and around the rivet heads.

7 Conclusions

The tests confirm the conclusions reached in previous flight tests on wings of "low drag" section. A great improvement has been achieved at the high Reynolds Numbers by reducing the surface waviness to $\pm$ one thousandth of an inch variation from the mean deflection curve on a two inch gauge length. It is essential for the maintenance of laminar flow at Reynolds Numbers of twenty millions that the surface waviness should not be larger than this. The same conclusion was reached during flight tests on King Cobra FZ.440 (Ref.3) when drag coefficients of the order of 0.0028 were measured after the surface waviness had been reduced to

this standard. The slight rise in drag coefficient at the high Reynolds Numbers is probably due to the fact that the surface waviness did not meet the above requirements at all points on the surface; particularly on the bottom surface which will be the more critical at high speeds due to decreasing incidence.

The drag coefficient has been reduced over the whole "low drag" range which now extends from 0.1 to 0.5 lift coefficient as compared with the 0.17 to 0.45 of the previous tests. The full reduction in drag was of course obtained only in those flights during which no flies or other insects were picked up by the wing.

REFERENCES

<u>Ref.No.</u>	<u>Author</u>	<u>Title etc.</u>
1	Smith, Higon & Bramwell	Flight tests on Hurricane II Z.3687 fitted with special wings of "low drag" design. R.A.E. Report No. Aero. 2090. October, 1945.
2	Thompson	A simple method of computing C_D from wake traverses at high speeds. R.A.E. Report No. Aero. 2005. 1944.
3	Smith & Higon	Flight tests on King Cobra FZ.440 to investigate the practical requirements for the achievement of low profile drag on a low drag aerofoil. R.A.E. Report No. Aero. 2078. 1945.
4	Winterbottom & Squire	Note on further wing profile drag calculations. R.A.E. Report No. B.1634. 1940.

attached:- 193778 - 193838.
Table I.

Circulation:- C.S.(u)
D.G.S.R.(u) (action copy)
D.S.R.(u)
A.D.S.R.D.(Res.)
A.D.S.R.(Records)
D.A.R.D.
P.D.T.D.
R.T.P./T.I.B. (110 + 1)
D.D.S.R.D.(Serv.)
A.R.C. (36)
Armstrong Whitworth per R.T.O. (2)

TABLE I

<u>% chord</u>	<u>% chord upper surface</u>	<u>% chord lower surface</u>
2½	3.04	2.29
5	4.42	3.09
7½	5.42	3.68
10	6.19	4.19
15	7.55	4.89
20	8.63	5.43
30	10.07	6.20
40	10.67	6.46
50	10.34	6.21
60	8.83	5.16
70	6.60	3.76
80	4.27	2.26
90	2.03	1.04
95	1.07	0.61
100	(0.21) 0	(0.21) 0

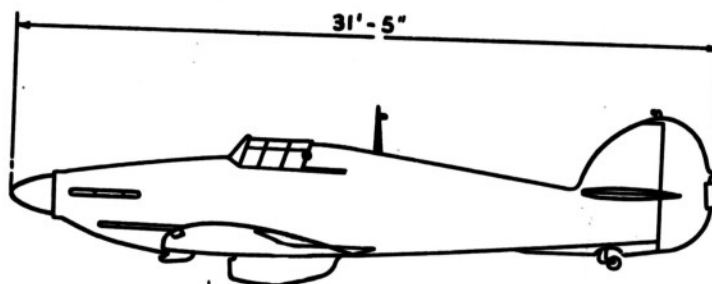
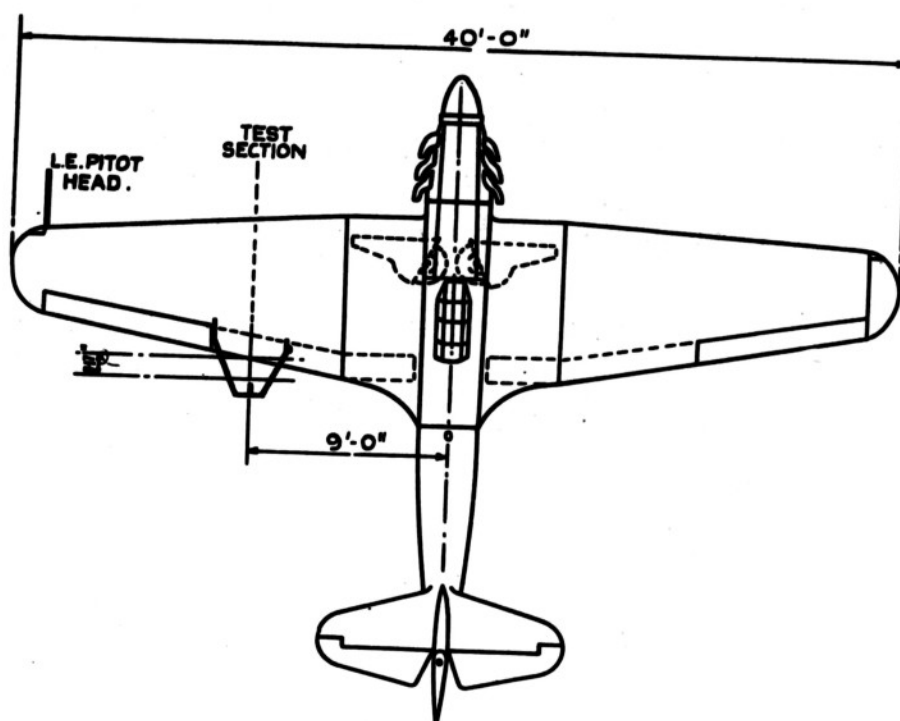
FIGURE 2. 3687.

Ordinates of Test Section.

No. 193775

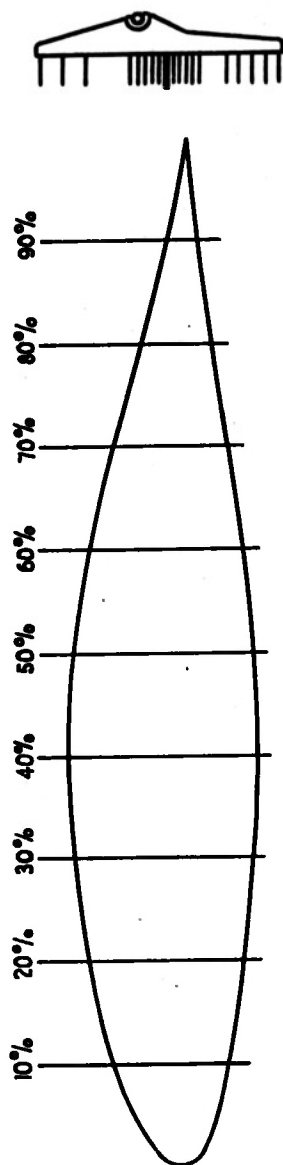
REPORT AERO 2153.

FIG. 1.



SCALE OF FEET.

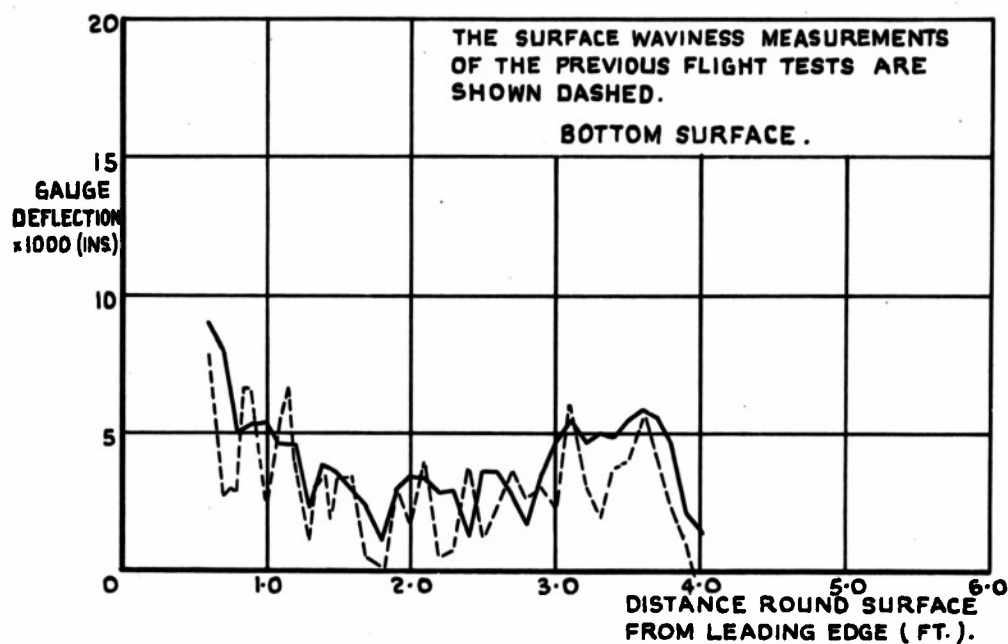
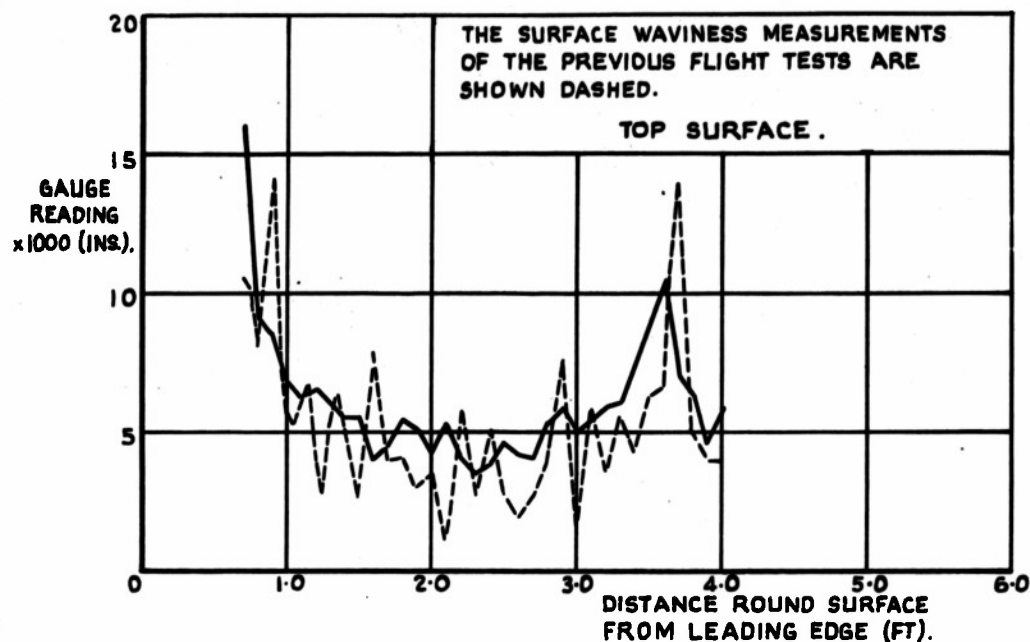
G.A. OF HURRICANE Z.3687.



TEST SECTION CHORD 82.3 INCHES — MAX. THICKNESS 17.2% AT 42.4% CHORD.

HURRICANE Z.3687.
PROFILE OF TEST SECTION SHOWING COMB.

FIG. 3.

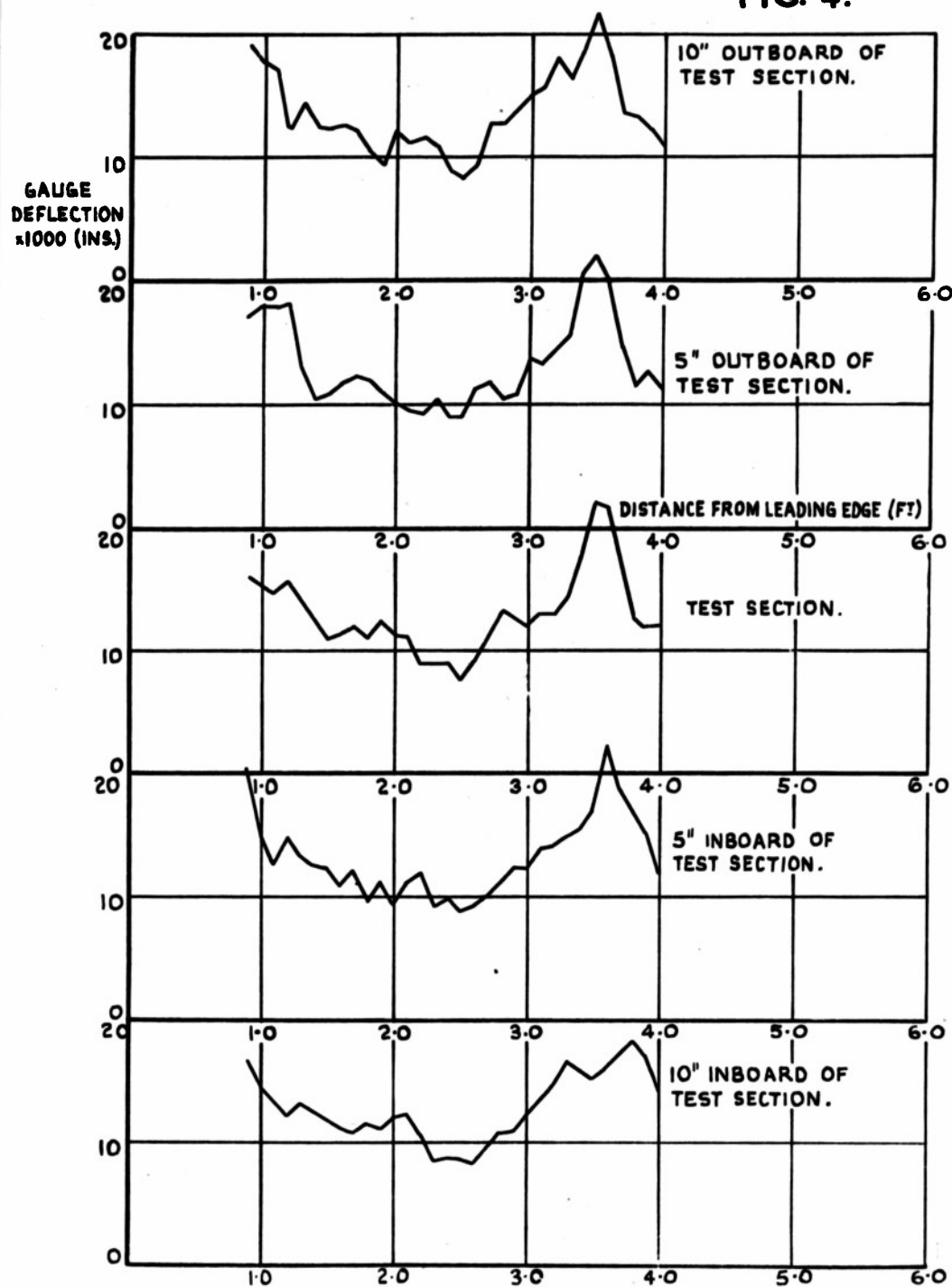


TEST SECTION SURFACE WAVINESS AS MEASURED
BY CURVATURE GAUGE WITH 2" BASE.
HURRICANE Z.3687.

19380S.

REPORT AERO 2153

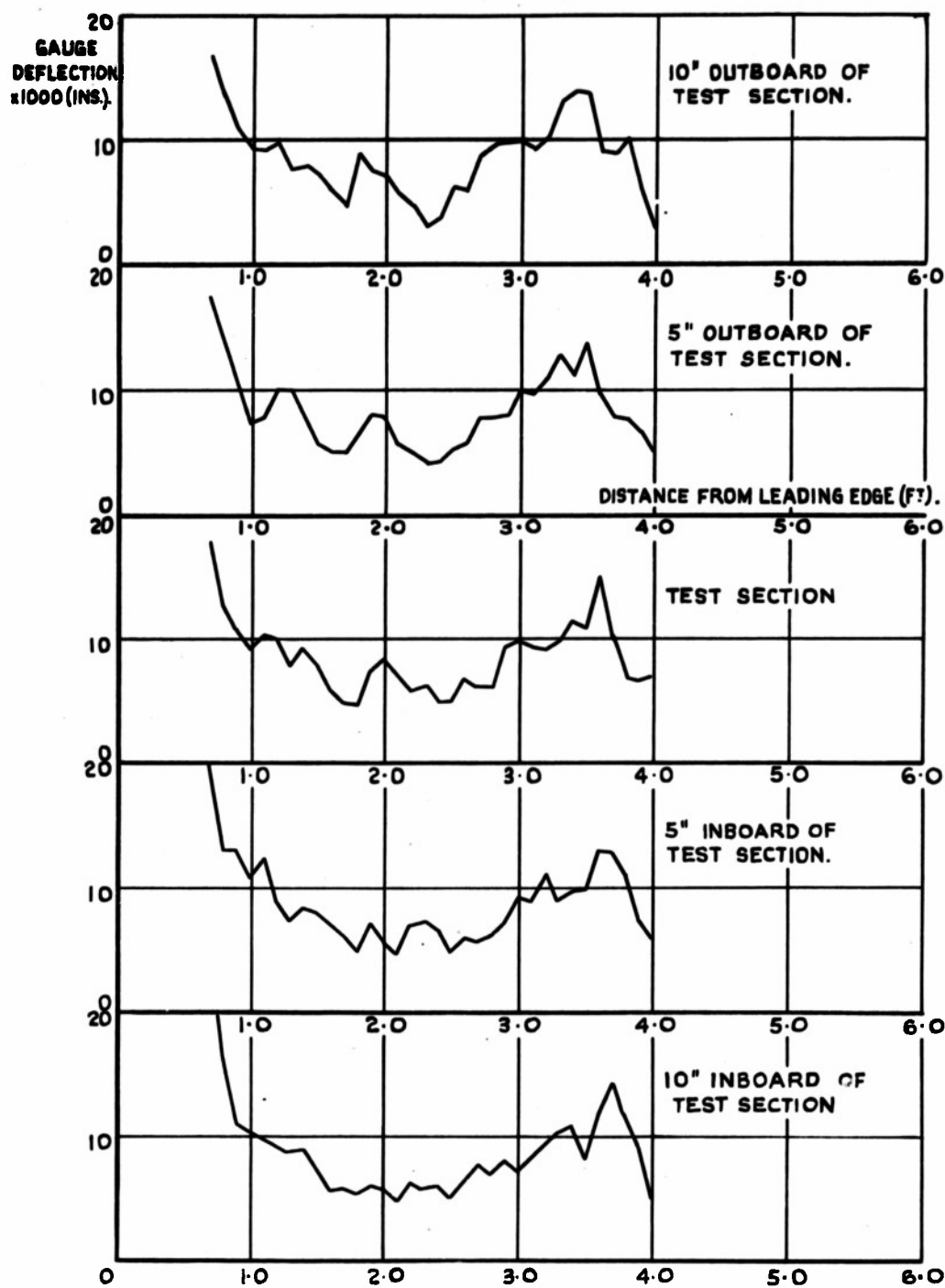
FIG. 4.



TOP SURFACE WAVINESS AS MEASURED BY
CURVATURE GAUGE WITH 3" BASE.

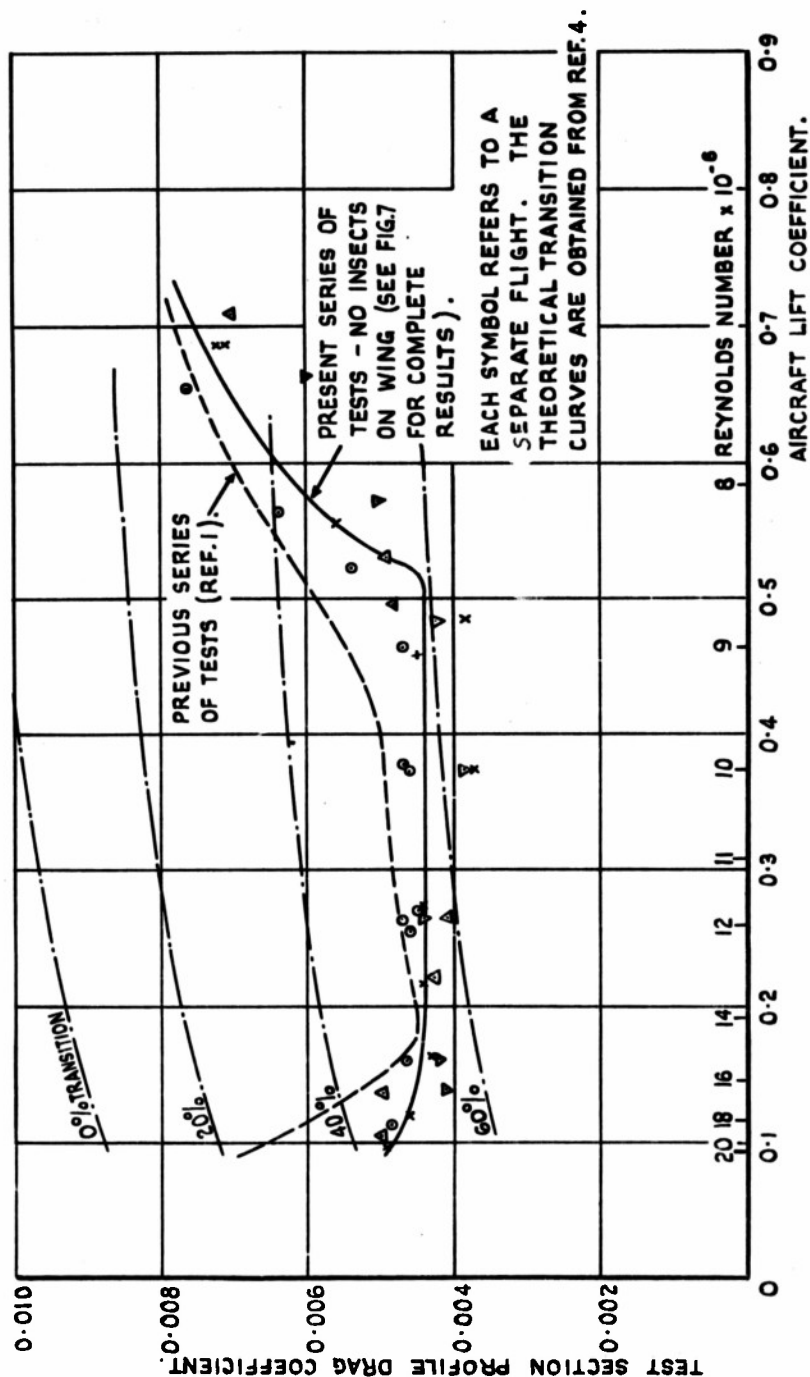
HURRICANE Z.3687.

FIG. 5.



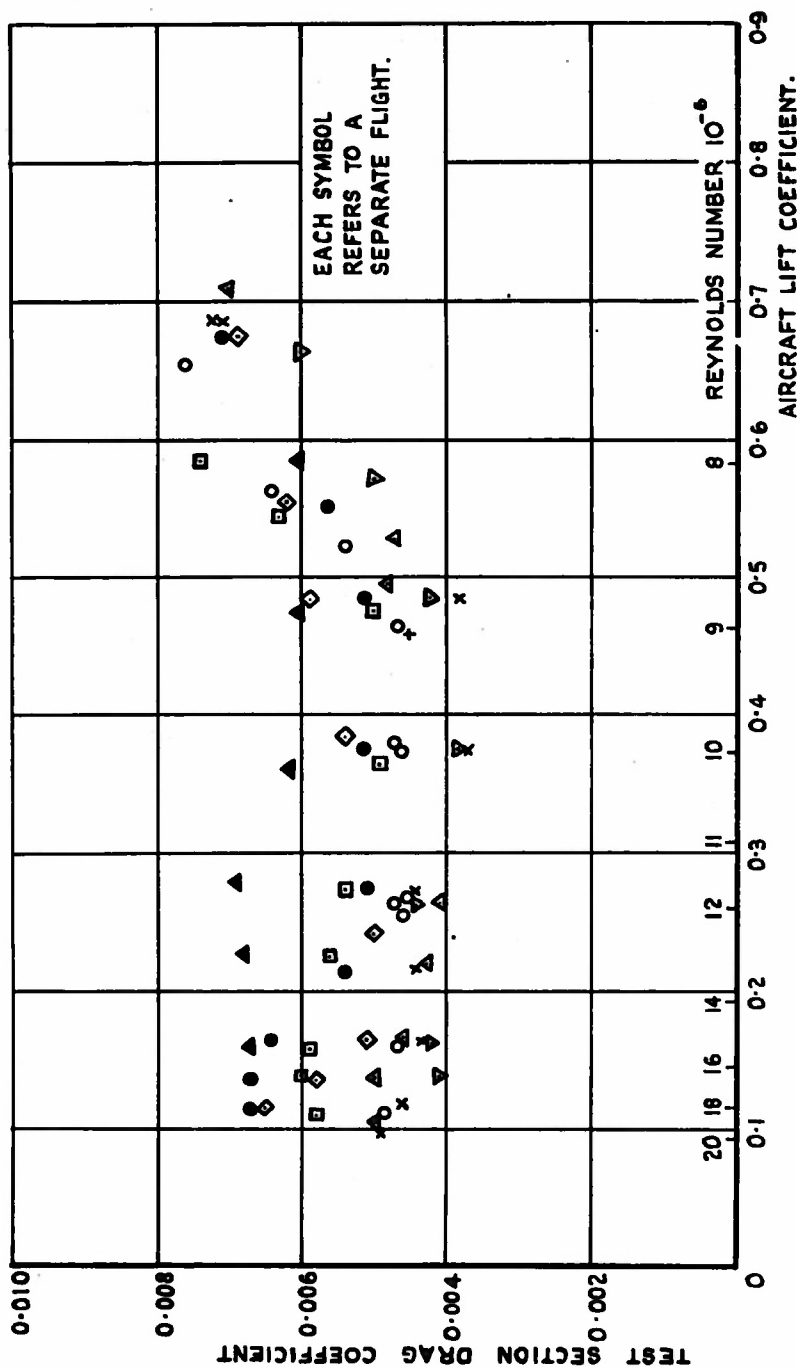
BOTTOM SURFACE WAVINESS AS MEASURED BY CURVATURE GAUGE WITH 3" BASE.
HURRICANE Z.3687.

FIG. 6.



HURRICANE Z.3687.
SECTION PROFILE DRAG OBTAINED FROM FLIGHT TESTS.

FIG. 7.



HURRICANE Z.3687.

RESULTS FROM ALL FLIGHTS-INCLUDING THOSE DURING WHICH FLIES OR OTHER INSECTS WERE PICKED UP.

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Plascott, R. H.

DIVISION: Aerodynamics (2)

SECTION: Wings and Airfoils (6)

CROSS REFERENCES: Airfoils - Drag (08200); 11 Z.3687
(08421.7) Airplanes - Drag Reduction (08421.7);

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AMER. TITLE: Profile drag measurements on hurricane 11 Z.3687 fitted with "Low Drag" section wings

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COUNTRY	LANGUAGE	FORG'N. CLASS.	U. S. CLASS.	DATE	PAGES	ILLUS.	FEATURES
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