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# Calculated Lift Distributions in Incompressible Flow on Some Sweptback Wings

*By*

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# CALCULATED LIFT DISTRIBUTIONS IN INCOMPRESSIBLE FLOW ON SOME SWEPTBACK WINGS

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## SUMMARY

In the course of a larger survey of some aerodynamic characteristics of a family of sweptback wings, the low-speed lift distributions were calculated. The 35 planforms considered cover a range of leading-edge sweep angles from 55° to 70°, and aspect ratios from 2 to 3·9. The results are given here, together with a comparison with other calculations and with experimental results on one particular wing.

Replaces R.A.E. Tech. Note No. Aero. 2836 - A.R.C. 24 437.

## LIST OF CONTENTS

## LIST OF TABLES

## LIST OF ILLUSTRATIONS

# LIST OF SYMBOLS

| | |
|---|---|
| $a_o$ | two-dimensional lift slope |
| $A$ | aspect ratio |
| $c_o$ | root chord |
| $c_t$ | projected tip chord (see Fig.2) |
| $C_L(y)$ | local lift coefficient |
| $\bar{C}_L$ | overall lift coefficient |
| $\ell$ | overall length of wing |
| $m_o$ | $= \tan \varphi_o$ |
| $m_1$ | $= \tan \varphi_1$ |
| $M_o$ | free stream Mach number |
| $n$ | chordwise loading parameter |
| $s$ | semi-span |
| $T$ | "taper ratio", $c_t/c_o$ |
| $x,y,z$ | cartesian coordinates, x streamwise, y spanwise; origin at wing apex |
| $x_L$ | wing leading-edge ordinate |
| $x_T$ | wing trailing-edge ordinate |
| $\bar{x}_{ac}$ | distance of overall aerodynamic centre behind wing apex |
| $X_{ac}$ | local aerodynamic centre position, measured in terms of local chord from leading edge |
| $\alpha$ | wing incidence |
| $\eta$ | $= \lvert y \rvert / s$ |
| $\xi$ | $= (x - x_L(y))/c(y)$ |
| $\varphi_o$ | wing leading-edge sweepback |
| $\varphi_1$ | wing trailing-edge sweepback |
| $\varphi_{c/2}$ | sweepback of mid-chord line |

## 1 DETAILS OF THE WINGS CONSIDERED

The wing planforms which were first dealt with are shown in Fig.1. This family of planforms were considered by Bagley and Beasley[1] in a general survey of wing shapes designed for operation at $M_0 = 1{\cdot}2$; each member of the family has a straight swept trailing edge and a leading edge which is straight over the inner half and parabolically curved over the outer half, fairing into a streamwise tip. The planform can be defined by three parameters: the aspect ratio, A, and the sweepback angles of the inner part of the leading edge, $\varphi_0$, and of the trailing edge, $\varphi_1$. Other geometrical parameters of interest are the semi-span, s, the overall length (in the streamwise direction), $\ell$, the root chord, $c_0$, and the "projected tip chord", $c_t$, defined by extending the inner part of the leading edge as indicated in Fig.2.

Taking x,y,z as right handed Cartesian coordinates with x measured streamwise and y spanwise, with the origin at the wing apex, the leading edge of any planform in this family is given by

$$x_L = m_0|y| \qquad \text{for } 0 < |y| < \tfrac{1}{2}s$$

$$x_L = m_0|y| + c_t\{1 - 2\sqrt{2(1-\eta)} + 2(1-\eta)\} \text{ for } \tfrac{1}{2}s < |y| < s$$

and the trailing edge is given by

$$x_T = c_0 + m_1|y|$$

where $m_0 = \tan\varphi_0$, $m_1 = \tan\varphi_1$, and $\eta = \frac{|y|}{s}$ .

It can be deduced that

$$A = \frac{24(s/c_0)}{11 - 5(s/c_0)(m_0 - m_1)}$$

$$(c_0/s) = \frac{1}{11}\left\{\frac{24}{A} + 5(m_0 - m_1)\right\}$$

$$(s/\ell) = 11\Big/\left\{\frac{24}{A} + 5m_0 + 6m_1\right\}$$

$$(c_t/c_0) = \left\{\frac{24}{A} - 6(m_0 - m_1)\right\}\Big/\left\{\frac{24}{A} + 5(m_0 - m_1)\right\}$$

Values of these parameters for the various wings of the family are given in Table 1

Calculations have also been made for the wing planform tested by Garner and Walshe[2], here referred to as "Garner's wing", which is shown in Fig.3. This has a shape rather similar to the other wings considered, with sweepback of 60° on the trailing edge and on the inboard part of the leading edge. Outboard of $\eta = 0{\cdot}616$ the leading edge is curved, and is given by the expression

$$x_L = |y|\sqrt{3} + c_o\left[1 - \sqrt{\left(\frac{1 - \eta}{0\cdot 383}\right)}\right]^2 .$$

The aspect ratio of this wing is 3·899; the root chord of the model was 36 inches, the semi-span 65·7 inches, and the overall length 149·8 inches.

## 2 CALCULATION OF THE LIFT DISTRIBUTIONS

All the calculations were made using Küchemann's method[3], assuming incompressible flow without separations. Thus no account has been taken of leading-edge vortices or other viscous effects. The two-dimensional lift slope parameter $a_o$ was assumed equal to $2\pi$ throughout; past experience suggests that this is a sensible value for wings of about 6% thickness-chord ratio and moderate sweep. (The choice of a particular value for $a_o$ affects the overall value of the calculated lift slope $\bar{C}_L/\alpha$, but has little effect on the spanwise distribution of lift.)

For Garner's wing and for wing 31 of the original family, the calculations were made using the complete Küchemann theory, so that the correct variation of mid-chord sweep, $\varphi_{c/2}$, across the outer part of the wing was taken into account. Calculations were also made for these two wings using a constant value of $\varphi_{c/2}$ throughout (equal to the value over the inner part of the wing), and the results are compared in Fig.4 with those from the full theory. Calculations for the remaining wings were made using the simpler method with a constant value of $\varphi_{c/2}$ across the whole wing.

The results of these calculations are given in Tables 2, 3 and 4, in the form of sectional lift slopes and aerodynamic centre positions, while the overall values of lift slope and aerodynamic centre position are given in Table 1. Küchemann's method[3] specifies that the chordwise loading at any station is approximated by

$$\Delta C_p(\xi,y) = -C_L(y)\ \frac{\sin \pi n}{\pi n}\left(\frac{1 - \xi}{\xi}\right)^n$$

where $\xi = (x - x_L(y))/\ c(y)$

and the parameter n (a function of y) is related to the local aerodynamic centre position by

$$X_{a.c.}(y) = \frac{x_{a.c.}(y) - x_L(y)}{c(y)} = \frac{1}{2}\,(1 - n(y))$$

The comparisons between the two sets of results using constant or varying value of $\varphi_{c/2}$ on the outer part of the wing show that the variation in sweep does not have a large influence on either the lift or the aerodynamic centre position. The majority of the wings considered will have a smaller variation of sweep over the tip region than either of these two, so it is probable that the effects of taking $\varphi_{c/2}$ constant will also be smaller.

## 3 COMPARISON WITH OTHER RESULTS

The results calculated for Garner's wing are compared in Fig.5 with experimental values taken from Garner and Walshe[2], and also with values calculated by Garner from Multhopp's[4] lifting-surface theory using 15 × 3 pivotal points. Over the inner part of the wing the experimental points agree reasonably well with either theory, although Küchemann's method appears to predict the aerodynamic centre positions more accurately, but over the tip region it is clear that there is a considerable difference between experiment and both theories. This is an effect which has been observed in several experiments on highly swept wings with curved tips: the reason for it has not been convincingly explained as yet, but it probably indicates a departure from the assumed attached inviscid flow in the immediate neighbourhood of the wing tip even at this small incidence of 2°. Similar effects have been discussed in Refs.3, 5 and 6.

## 4 OVERALL LIFT SLOPES AND AERODYNAMIC CENTRE POSITIONS

From the calculated lift distributions, values of the overall lift slope, $\bar{C}_L/\alpha$, and the aerodynamic centre positions were obtained by graphical integration, and these are quoted in Table 1.

The lift slope values are plotted in Fig.6 against $\varphi_{c/2}$, the mid-chord sweep of the inner part of the wing. For comparison, values obtained from Helmbold's approximate relation which is quoted in Ref.3 are also shown. This is:

$$\frac{\bar{C}_L}{\alpha} = \frac{a_o \cos\varphi}{\sqrt{1 + \left(\frac{a_o \cos\varphi}{\pi A}\right)^2} + \frac{a_o \cos\varphi}{\pi A}} .$$

In these computations, the values of $\varphi_{c/2}$ have been used for $\varphi$.

Within this range of sweep angles and aspect ratios, the results given by Helmbold's formula are within about 5% of those given by Küchemann's method[3].

Another approximate method for calculating the lift slopes of swept wings is given in Royal Aeronautical Society Data Sheet "Wings 01.01.01" and is probably more generally used than Helmbold's formula. The values given by this method also agree with those calculated in Table 1 within about 5%.

## 5 CONCLUSIONS

The comparison shown in Tables 2 and 3 and in Fig.4 indicates that in many cases it is adequate to calculate the spanwise lift distribution for a wing with a curved tip shape by using a constant value for the effective sweep, instead of taking the exact variation of $\varphi_{c/2}$ in the tip region. The chordwise loading parameter n is even less affected by this simplification.

The experimental results quoted in Fig.5 suggest that any lifting-surface theory which assumes attached inviscid flow over the whole wing will not adequately predict either the spanwise lift distribution or the chordwise loading close to the wing tip.

## LIST OF REFERENCES

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## TABLE 1

## Geometric details and results

$\varphi_o$ = leading edge sweep (inner part of wing)

$\varphi_1$ = trailing edge

$\varphi_{c/2}$ = mid-chord sweep (inner part of wing)

$c_o$ = root chord

s = semi-span

$\ell$ = overall length

$T = \frac{\text{projected tip chord}}{\text{root chord}}$

$\bar{x}_{ac}$ = distance of aerodynamic centre behind wing apex

| Wing No. | A | $\varphi_o$ | $\varphi_1$ | $\varphi_{c/2}$ | $c_o/s$ | T | $s/\ell$ | $\bar{C}_L/a$ | $\bar{x}_{ac}/\ell$ |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 3·5 | 55° | 35° | 46·73° | 0·954 | 0·24 | 0·604 | 2·876 | 0·474 |
| 2 | 3·5 | 55° | 45° | 50·52° | 0·818 | 0·48 | 0·550 | 2·780 | 0·445 |
| 3 | 3·5 | 55° | 55° | 55° | 0·623 | 1·00 | 0·487 | 2·605 | 0·412 |
| 4 | 3·5 | 60° | 35° | 50·57° | 1·092 | 0·06 | 0·558 | 2·637 | 0·491 |
| 5 | 3·5 | 60° | 45° | 53·80° | 0·956 | 0·23 | 0·511 | 2·594 | 0·470 |
| 6 | 3·5 | 60° | 55° | 57·67° | 0·762 | 0·60 | 0·457 | 2·470 | 0·441 |
| 7 | 2·75 | 55° | 35° | 46·78° | 1·124 | 0·35 | 0·548 | 2·695 | 0·463 |
| 8 | 2·75 | 55° | 45° | 50·52° | 0·988 | 0·57 | 0·503 | 2·608 | 0·436 |
| 9 | 2·75 | 55° | 55° | 55° | 0·793 | 1·00 | 0·450 | 2·433 | 0·403 |
| 10 | 2·75 | 60° | 35° | 50·57° | 1·262 | 0·18 | 0·510 | 2·499 | 0·489 |
| 11 | 2·75 | 60° | 45° | 53·80° | 1·126 | 0·35 | 0·470 | 2·462 | 0·463 |
| 12 | 2·75 | 60° | 55° | 57·67° | 0·932 | 0·67 | 0·424 | 2·338 | 0·432 |
| 13 | 2·0 | 55° | 35° | 46·78° | 1·422 | 0·49 | 0·471 | 2·345 | 0·440 |
| 14 | 2·0 | 55° | 45° | 50·52° | 1·286 | 0·67 | 0·438 | 2·300 | 0·413 |
| 15 | 2·0 | 55° | 55° | 55° | 1·091 | 1·00 | 0·397 | 2·183 | 0·383 |
| 16 | 2·0 | 60° | 35° | 50·57° | 1·560 | 0·34 | 0·442 | 2·297 | 0·467 |
| 17 | 2·0 | 60° | 45° | 53·80° | 1·424 | 0·49 | 0·413 | 2·232 | 0·444 |
| 18 | 2·0 | 60° | 55° | 57·67° | 1·229 | 0·75 | 0·376 | 2·116 | 0·413 |
| 19 | 3·5 | 65° | 55° | 60·76° | 0·949 | 0·25 | 0·421 | 2·246 | 0·461 |
| 20 | 3·5 | 65° | 65° | 65° | 0·623 | 1·00 | 0·361 | 2·088 | 0·435 |
| 21 | 3·5 | 70° | 65° | 67·76° | 0·897 | 0·33 | 0·329 | 1·854 | 0·454 |
| 22 | 2·75 | 65° | 35° | 54·89° | 1·450 | 0·00 | 0·465 | 2·269 | 0·509 |
| 23 | 2·75 | 65° | 45° | 57·54° | 1·314 | 0·13 | 0·432 | 2·255 | 0·487 |
| 24 | 2·75 | 65° | 55° | 60·76° | 1·119 | 0·36 | 0·393 | 2·172 | 0·462 |
| 25 | 2·75 | 65° | 65° | 65° | 0·793 | 1·00 | 0·340 | 1·986 | 0·427 |
| 26 | 2·75 | 70° | 55° | 64·41° | 1·393 | 0·05 | 0·354 | 1·879 | 0·480 |
| 27 | 2·75 | 70° | 65° | 67·76° | 1·067 | 0·44 | 0·311 | 1·806 | 0·457 |
| 28 | 2·0 | 65° | 35° | 54·89° | 1·747 | 0·17 | 0·409 | 2·156 | 0·501 |
| 29 | 2·0 | 65° | 45° | 57·54° | 1·611 | 0·29 | 0·383 | 2·111 | 0·477 |
| 30 | 2·0 | 65° | 55° | 60·76° | 1·417 | 0·49 | 0·352 | 2·019 | 0·448 |
| 31 | 2·0 | 65° | 65° | 65° | 1·091 | 1·00 | 0·309 | 1·842 | 0·410 |
| 32 | 2·0 | 70° | 45° | 61·91° | 1·885 | 0·07 | 0·347 | 1·887 | 0·507 |
| 33 | 2·0 | 70° | 55° | 64·41° | 1·691 | 0·22 | 0·321 | 1·845 | 0·483 |
| 34 | 2·0 | 70° | 65° | 67·76° | 1·365 | 0·56 | 0·285 | 1·722 | 0·451 |

## TABLE 2

### Calculated spanwise distributions of lift and aerodynamic centre on Garner's wing

$A = 3{\cdot}9,\ \varphi_0 = \varphi_1 = 60°$

| (a) Full method of R&M 2935 | | | (b) Using constant $\varphi_{c/2}$ | |
|---|---|---|---|---|
| $\eta$ | $C_L/\alpha$ | $X_{a.c.}$ | $C_L/\alpha$ | $X_{a.c.}$ |
| 0 | 2·17 | 0·410 | 2·18 | 0·410 |
| 0·195 | 2·39 | 0·283 | 2·40 | 0·283 |
| 0·383 | 2·50 | 0·254 | 2·52 | 0·254 |
| 0·556 | 2·47 | 0·245 | 2·50 | 0·245 |
| 0·707 | 2·33 | 0·232 | 2·41 | 0·232 |
| 0·832 | 2·19 | 0·209 | 2·36 | 0·211 |
| 0·924 | 2·03 | 0·169 | 2·31 | 0·181 |
| 0·981 | 1·93 | 0·108 | 2·24 | 0·140 |
| Overall $\bar{C}_L/\alpha$ = 2·36 | | | $\bar{C}_L/\alpha$ = 2·42 | |

## TABLE 3

### Calculated spanwise distributions of lift and aerodynamic centre on Wing 31

$A = 2,\ \ \varphi_0 = \varphi_1 = 65°$

| (a) Full method of R&M 2935 | | | (b) Using constant $\varphi_{c/2}$ | |
|---|---|---|---|---|
| $\eta$ | $C_L/\alpha$ | $X_{a.c.}$ | $C_L/\alpha$ | $X_{a.c.}$ |
| 0 | 1·73 | 0·411 | 1·74 | 0·411 |
| 0·195 | 1·80 | 0·313 | 1·82 | 0·313 |
| 0·383 | 1·86 | 0·266 | 1·88 | 0·266 |
| 0·556 | 1·84 | 0·232 | 1·88 | 0·232 |
| 0·707 | 1·79 | 0·200 | 1·86 | 0·201 |
| 0·832 | 1·72 | 0·164 | 1·84 | 0·170 |
| 0·924 | 1·65 | 0·126 | 1·79 | 0·143 |
| 0·981 | 1·56 | 0·074 | 1·71 | 0·111 |
| Overall $\bar{C}_L/\alpha$ = 1·80 | | | $\bar{C}_L/\alpha$ = 1·84 | |

# TABLE 4

## Calculated lift distributions for 34 wings

(Using constant value of $\varphi_{c/2}$ across the span)

| Wing No. | 1 | | 2 | | 3 | |
|---|---|---|---|---|---|---|
| $\eta$ | $C_L/\alpha$ | $X_{a.c.}$ | $C_L/\alpha$ | $X_{a.c.}$ | $C_L/\alpha$ | $X_{a.c.}$ |
| 0 | 2·24 | 0·366 | 2·31 | 0·376 | 2·43 | 0·392 |
| 0·1951 | 2·60 | 0·287 | 2·60 | 0·286 | 2·61 | 0·284 |
| 0·3827 | 2·92 | 0·254 | 2·83 | 0·255 | 2·70 | 0·255 |
| 0·5556 | 3·16 | 0·243 | 2·94 | 0·242 | 2·65 | 0·241 |
| 0·7071 | 3·34 | 0·239 | 3·00 | 0·234 | 2·59 | 0·228 |
| 0·8315 | 3·53 | 0·232 | 3·05 | 0·223 | 2·54 | 0·210 |
| 0·9239 | 3·75 | 0·220 | 3·10 | 0·204 | 2·48 | 0·184 |
| 0·9808 | 4·04 | 0·195 | 3·17 | 0·172 | 2·41 | 0·149 |
| $\bar{C}_L/\alpha$ | 2·88 | | 2.78 | | 2·60 | |

| Wing No. | 4 | | 5 | | 6 | |
|---|---|---|---|---|---|---|
| $\eta$ | $C_L/\alpha$ | $X_{a.c.}$ | $C_L/\alpha$ | $X_{a.c.}$ | $C_L/\alpha$ | $X_{a.c.}$ |
| 0 | 1·94 | 0·378 | 2·00 | 0·388 | 2·08 | 0·401 |
| 0·1951 | 2·31 | 0·296 | 2·33 | 0·296 | 2·33 | 0·293 |
| 0·3827 | 2·69 | 0·257 | 2·63 | 0·258 | 2·52 | 0·258 |
| 0·5556 | 3·03 | 0·245 | 2·86 | 0·243 | 2·59 | 0·242 |
| 0·7071 | 3·35 | 0·243 | 3·02 | 0·239 | 2·62 | 0·233 |
| 0·8315 | 3·70 | 0·242 | 3·21 | 0·232 | 2·65 | 0·217 |
| 0·9239 | 4·16 | 0·238 | 3·44 | 0·218 | 2·69 | 0·193 |
| 0·9808 | 4·95 | 0·226 | 3·99 | 0·188 | 2·72 | 0·156 |
| $\bar{C}_L/\alpha$ | 2·64 | | 2·59 | | 2·47 | |

| Wing No. | 7 | | 8 | | 9 | |
|---|---|---|---|---|---|---|
| $\eta$ | $C_L/\alpha$ | $X_{a.c.}$ | $C_L/\alpha$ | $X_{a.c.}$ | $C_L/\alpha$ | $X_{a.c.}$ |
| 0 | 2·18 | 0·358 | 2·27 | 0·371 | 2·34 | 0·386 |
| 0·1951 | 2·46 | 0·288 | 2·48 | 0·291 | 2·46 | 0·292 |
| 0·3827 | 2·72 | 0·254 | 2·65 | 0·256 | 2·51 | 0·258 |
| 0·5556 | 2·90 | 0·235 | 2·73 | 0·236 | 2·47 | 0·236 |
| 0·7071 | 3·02 | 0·226 | 2·76 | 0·222 | 2·42 | 0·216 |
| 0·8315 | 3·13 | 0·216 | 2·77 | 0·208 | 2·35 | 0·197 |
| 0·9239 | 3·23 | 0·200 | 2·77 | 0·188 | 2·27 | 0·172 |
| 0·9808 | 3·35 | 0·174 | 2·74 | 0·159 | 2·18 | 0·140 |
| $\bar{C}_L/\alpha$ | 2·70 | | 2·61 | | 2·43 | |

## TABLE 4 (Contd.)

| Wing No. | 10 | | 11 | | 12 | |
|---|---|---|---|---|---|---|
| $\eta$ | $C_L/a$ | $X_{a.c.}$ | $C_L/a$ | $X_{a.c.}$ | $C_L/a$ | $X_{a.c.}$ |
| 0 | 1·90 | 0·364 | 1·96 | 0·382 | 2·03 | 0·395 |
| 0·1951 | 2·21 | 0·291 | 2·23 | 0·299 | 2·22 | 0·300 |
| 0·3827 | 2·51 | 0·254 | 2·48 | 0·259 | 2·38 | 0·261 |
| 0·5556 | 2·78 | 0·233 | 2·66 | 0·237 | 2·44 | 0·237 |
| 0·7071 | 3·01 | 0·227 | 2·79 | 0·226 | 2·45 | 0·219 |
| 0·8315 | 3·25 | 0·221 | 2·90 | 0·215 | 2·46 | 0·202 |
| 0·9239 | 3·55 | 0·208 | 3·02 | 0·196 | 2·45 | 0·178 |
| 0·9808 | 3·95 | 0·183 | 3·16 | 0·165 | 2·44 | 0·143 |
| $\bar{C}_L/a$ | 2·50 | | 2·46 | | 2·34 | |

| Wing No. | 13 | | 14 | | 15 | |
|---|---|---|---|---|---|---|
| $\eta$ | $C_L/a$ | $X_{a.c.}$ | $C_L/a$ | $X_{a.c.}$ | $C_L/a$ | $X_{a.c.}$ |
| 0 | 2·01 | 0·344 | 2·10 | 0·353 | 2·18 | 0·372 |
| 0·1951 | 2·20 | 0·284 | 2·25 | 0·287 | 2·24 | 0·291 |
| 0·3827 | 2·37 | 0·250 | 2·35 | 0·251 | 2·26 | 0·256 |
| 0·5556 | 2·46 | 0·226 | 2·38 | 0·227 | 2·20 | 0·229 |
| 0·7071 | 2·52 | 0·208 | 2·36 | 0·206 | 2·12 | 0·204 |
| 0·8315 | 2·54 | 0·194 | 2·33 | 0·188 | 2·04 | 0·179 |
| 0·9239 | 2·55 | 0·177 | 2·28 | 0·169 | 1·95 | 0·157 |
| 0·9808 | 2·53 | 0·153 | 2·20 | 0·145 | 1·84 | 0·131 |
| $\bar{C}_L/a$ | 2·34 | | 2·30 | | 2·18 | |

| Wing No. | 16 | | 17 | | 18 | |
|---|---|---|---|---|---|---|
| $\eta$ | $C_L/a$ | $X_{a.c.}$ | $C_L/a$ | $X_{a.c.}$ | $C_L/a$ | $X_{a.c.}$ |
| 0 | 1·85 | 0·349 | 1·88 | 0·363 | 1·94 | 0·381 |
| 0·1951 | 2·09 | 0·288 | 2·08 | 0·294 | 2·06 | 0·300 |
| 0·3827 | 2·30 | 0·252 | 2·25 | 0·255 | 2·15 | 0·259 |
| 0·5556 | 2·48 | 0·227 | 2·35 | 0·228 | 2·18 | 0·230 |
| 0·7071 | 2·62 | 0·209 | 2·42 | 0·207 | 2·17 | 0·205 |
| 0·8315 | 2·73 | 0·198 | 2·46 | 0·191 | 2·14 | 0·181 |
| 0·9239 | 2·83 | 0·182 | 2·48 | 0·172 | 2·09 | 0·158 |
| 0·9808 | 2·92 | 0·157 | 2·48 | 0·145 | 2·01 | 0·144 |
| $\bar{C}_L/a$ | 2·30 | | 2·23 | | 2·12 | |

TABLE 4 (Contd.)

| Wing No. | 19 | | 20 | | 21 | |
|---|---|---|---|---|---|---|
| $\eta$ | $C_L/a$ | $X_{a.c.}$ | $C_L/a$ | $X_{a.c.}$ | $C_L/a$ | $X_{a.c.}$ |
| 0 | 1·72 | 0·411 | 1·83 | 0·424 | 1·41 | 0·433 |
| 0·1951 | 2·00 | 0·304 | 2·02 | 0·294 | 1·65 | 0·310 |
| 0·3827 | 2·28 | 0·261 | 2·13 | 0·259 | 1·87 | 0·263 |
| 0·5556 | 2·47 | 0·244 | 2·14 | 0·242 | 2·02 | 0·244 |
| 0·7071 | 2·62 | 0·240 | 2·13 | 0·226 | 2·11 | 0·238 |
| 0·8315 | 2·77 | 0·231 | 2·13 | 0·204 | 2·22 | 0·225 |
| 0·9239 | 2·97 | 0·214 | 2·15 | 0·173 | 2·37 | 0·203 |
| 0·9808 | 3·25 | 0·180 | 2·14 | 0·131 | 2·63 | 0·161 |
| $\bar{C}_L/a$ | 2·25 | | 2·09 | | 1·85 | |

| Wing No. | 22 | | 23 | | 24 | |
|---|---|---|---|---|---|---|
| $\eta$ | $C_L/a$ | $X_{a.c.}$ | $C_L/a$ | $X_{a.c.}$ | $C_L/a$ | $X_{a.c.}$ |
| 0 | 1·64 | 0·379 | 1·67 | 0·391 | 1·71 | 0·406 |
| 0·1951 | 1·96 | 0·304 | 1·96 | 0·307 | 1·95 | 0·309 |
| 0·3827 | 2·31 | 0·260 | 2·27 | 0·262 | 2·18 | 0·263 |
| 0·5556 | 2·68 | 0·238 | 2·55 | 0·238 | 2·35 | 0·238 |
| 0·7071 | 3·05 | 0·236 | 2·80 | 0·233 | 2·51 | 0·226 |
| 0·8315 | 3·48 | 0·236 | 3·07 | 0·227 | 2·59 | 0·213 |
| 0·9239 | 4·09 | 0·236 | 3·41 | 0·216 | 2·72 | 0·190 |
| 0·9808 | 5·25 | 0·235 | 3·96 | 0·190 | 2·87 | 0·155 |
| $\bar{C}_L/a$ | 2·27 | | 2·26 | | 2·17 | |

| Wing No. | 25 | | 26 | | 27 | |
|---|---|---|---|---|---|---|
| $\eta$ | $C_L/a$ | $X_{a.c.}$ | $C_L/a$ | $X_{a.c.}$ | $C_L/a$ | $X_{a.c.}$ |
| 0 | 1·79 | 0·420 | 1·37 | 0·412 | 1·41 | 0·430 |
| 0·1951 | 1·92 | 0·306 | 1·63 | 0·319 | 1·60 | 0·322 |
| 0·3827 | 2·01 | 0·266 | 1·91 | 0·267 | 1·80 | 0·268 |
| 0·5556 | 2·04 | 0·238 | 2·19 | 0·240 | 1·95 | 0·239 |
| 0·7071 | 2·04 | 0·213 | 2·44 | 0·237 | 2·05 | 0·223 |
| 0·8315 | 2·03 | 0·190 | 2·70 | 0·234 | 2·15 | 0·205 |
| 0·9239 | 2·01 | 0·160 | 3·05 | 0·227 | 2·26 | 0·179 |
| 0·9808 | 1·97 | 0·121 | 3·74 | 0·211 | 2·41 | 0·138 |
| $\bar{C}_L/a$ | 1·99 | | 1·88 | | 1·81 | |

TABLE 4 (Contd.)

| Wing No. | 28 | | 29 | | 30 | |
|---|---|---|---|---|---|---|
| $\eta$ | $C_L/a$ | $X_{a.c.}$ | $C_L/a$ | $X_{a.c.}$ | $C_L/a$ | $X_{a.c.}$ |
| 0 | 1·62 | 0·361 | 1·64 | 0·373 | 1·68 | 0·389 |
| 0·1951 | 1·88 | 0·297 | 1·87 | 0·303 | 1·86 | 0·308 |
| 0·3827 | 2·15 | 0·256 | 2·10 | 0·259 | 2·02 | 0·262 |
| 0·5556 | 2·41 | 0·229 | 2·30 | 0·230 | 2·14 | 0·231 |
| 0·7071 | 2·67 | 0·214 | 2·48 | 0·210 | 2·22 | 0·206 |
| 0·8315 | 2·93 | 0·206 | 2·63 | 0·198 | 2·28 | 0·187 |
| 0·9239 | 3·24 | 0·193 | 2·79 | 0·180 | 2·32 | 0·164 |
| 0·9808 | 3·65 | 0·167 | 2·97 | 0·150 | 2·33 | 0·133 |
| $\bar{C}_L/a$ | 2·16 | | 2·11 | | 2·02 | |

| Wing No. | 31 | | 32 | | 33 | |
|---|---|---|---|---|---|---|
| $\eta$ | $C_L/a$ | $X_{a.c.}$ | $C_L/a$ | $X_{a.c.}$ | $C_L/a$ | $X_{a.c.}$ |
| 0 | 1·74 | 0·411 | 1·36 | 0·383 | 1·38 | 0·397 |
| 0·1951 | 1·82 | 0·313 | 1·61 | 0·312 | 1·60 | 0·317 |
| 0·3827 | 1·88 | 0·266 | 1·88 | 0·264 | 1·82 | 0·267 |
| 0·5556 | 1·88 | 0·232 | 2·18 | 0·232 | 2·05 | 0·232 |
| 0·7071 | 1·86 | 0·201 | 2·49 | 0·218 | 2·26 | 0·212 |
| 0·8315 | 1·84 | 0·170 | 2·82 | 0·214 | 2·45 | 0·200 |
| 0·9239 | 1·79 | 0·143 | 3·28 | 0·205 | 2·69 | 0·181 |
| 0·9808 | 1·71 | 0·111 | 4·03 | 0·184 | 2·99 | 0·148 |
| $\bar{C}_L/a$ | 1·84 | | 1·89 | | 1·84 | |

| Wing No. | 34 | |
|---|---|---|
| $\eta$ | $C_L/a$ | $X_{a.c.}$ |
| 0 | 1·41 | 0·417 |
| 0·1951 | 1·57 | 0·322 |
| 0·3827 | 1·71 | 0·270 |
| 0·5556 | 1·82 | 0·233 |
| 0·7071 | 1·91 | 0·204 |
| 0·8315 | 1·97 | 0·180 |
| 0·9239 | 2·02 | 0·152 |
| 0·9808 | 2·05 | 0·116 |
| $\bar{C}_L/a$ | 1·72 | |

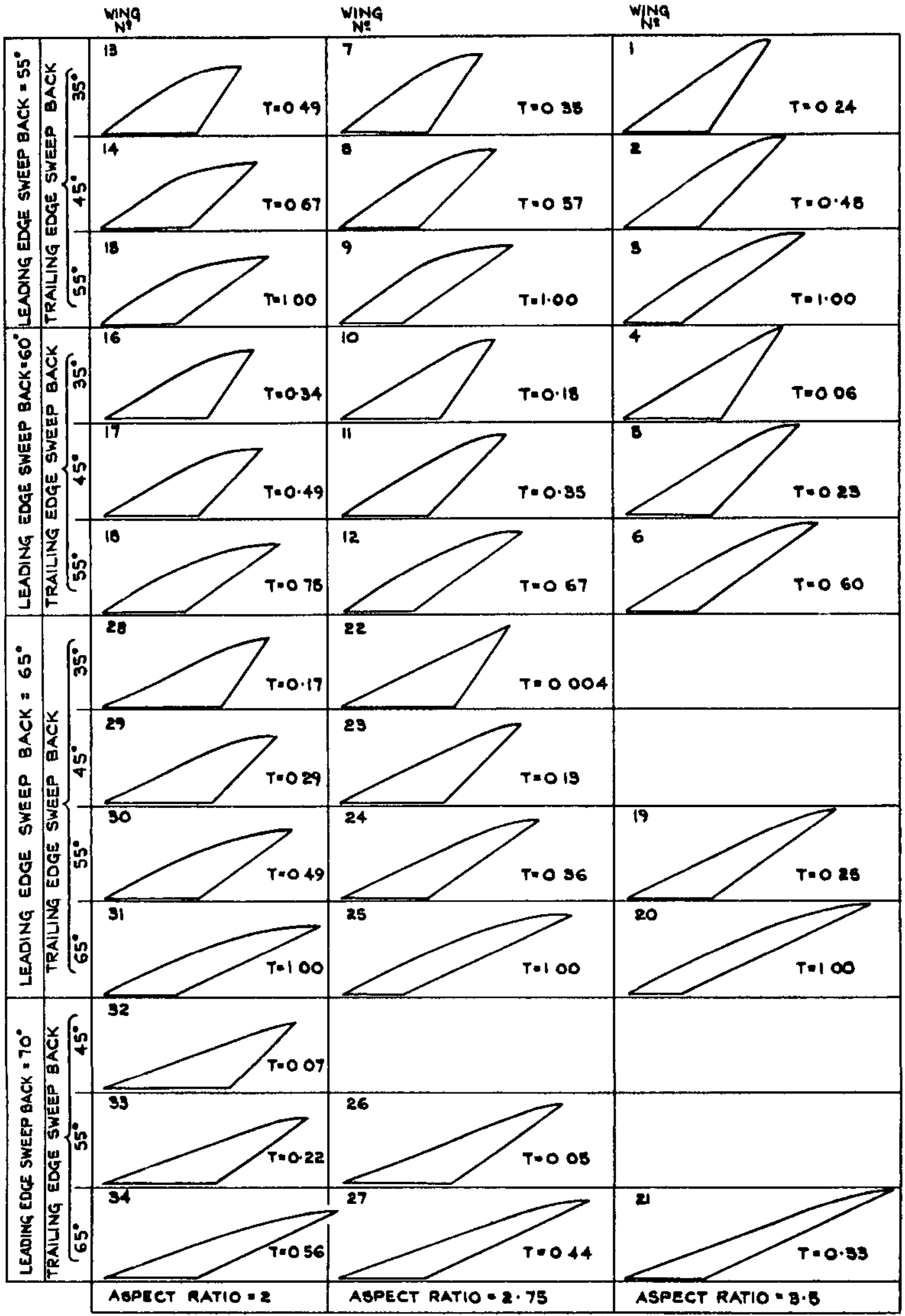

FIG. 1. PLANFORMS OF WINGS CONSIDERED.

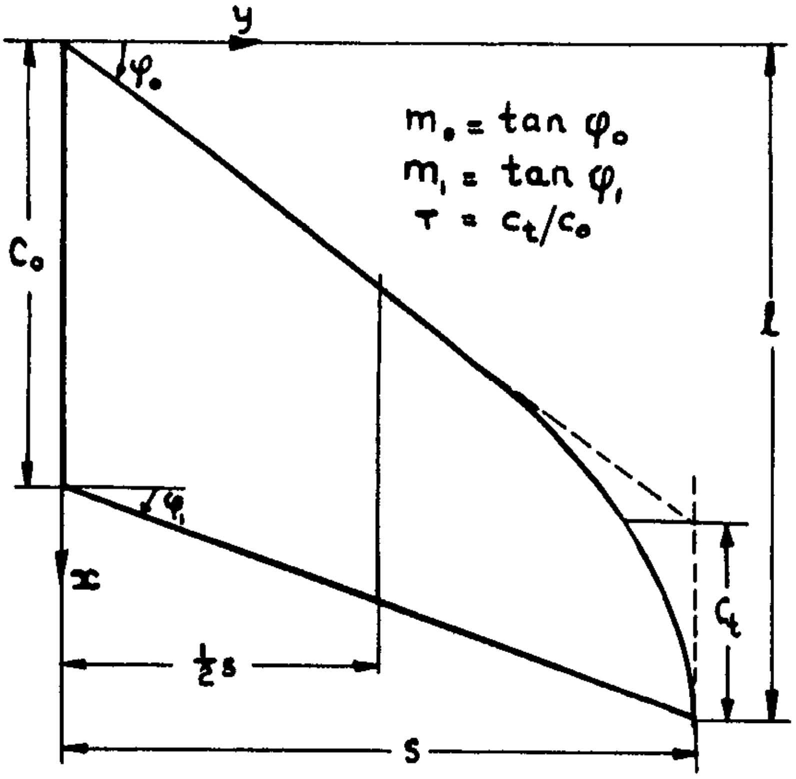

FIG.2. TYPICAL PLANFORM & NOMENCLATURE.

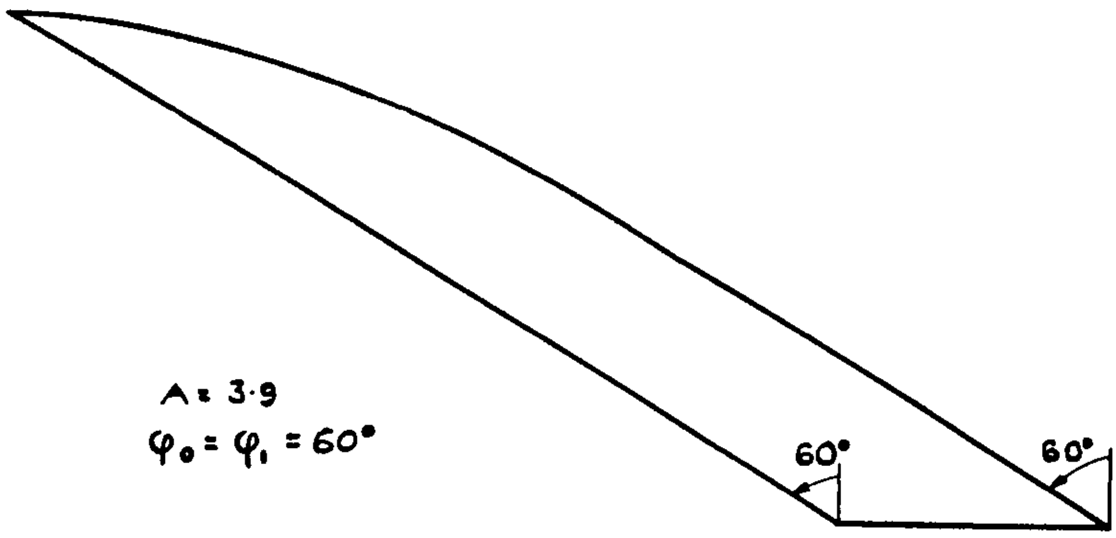

FIG.3. GARNER'S WING (R.& M. 3244).

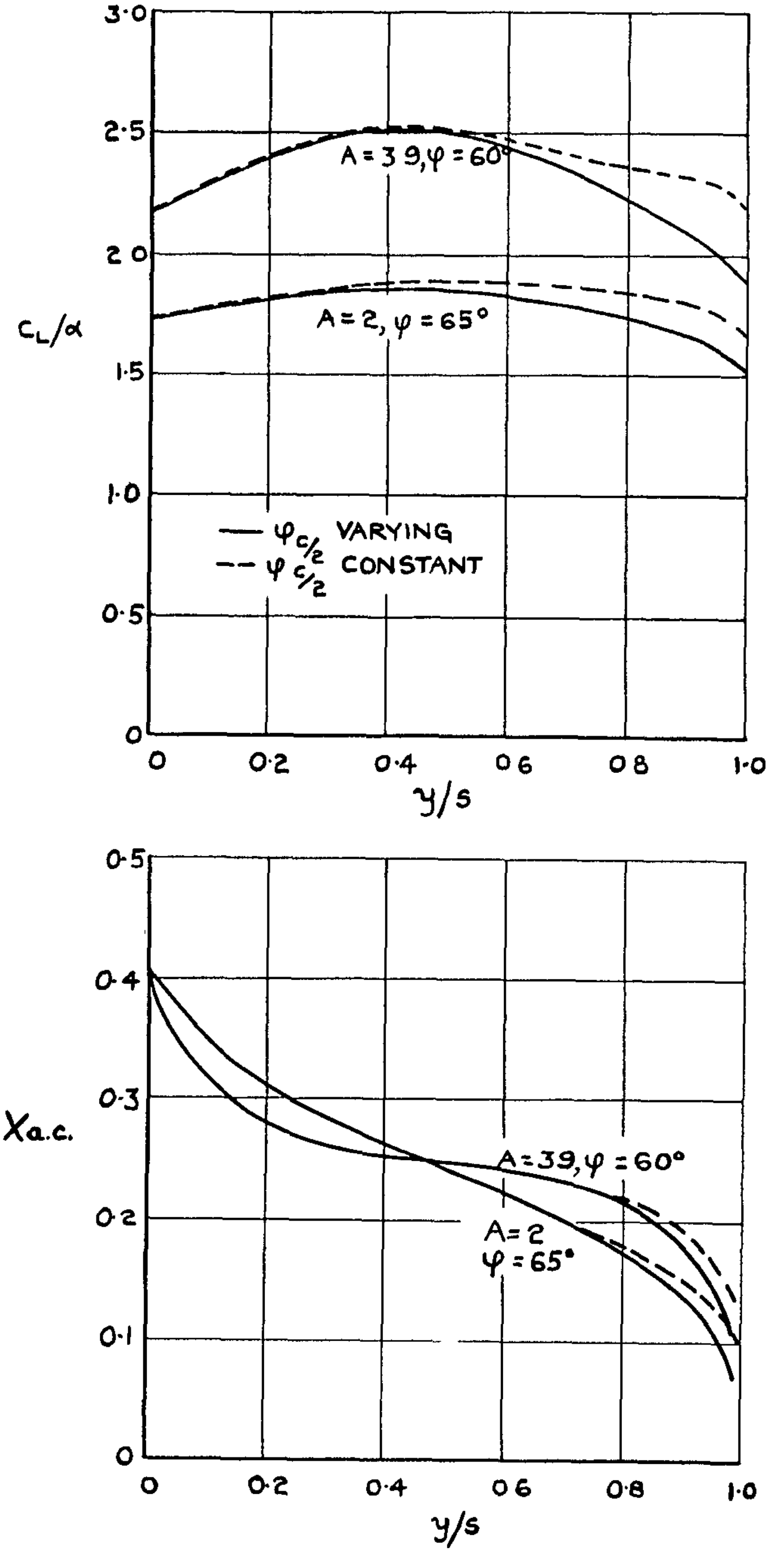

FIG. 4. EFFECT OF CURVED LEADING EDGE ON CALCULATED LOADINGS.

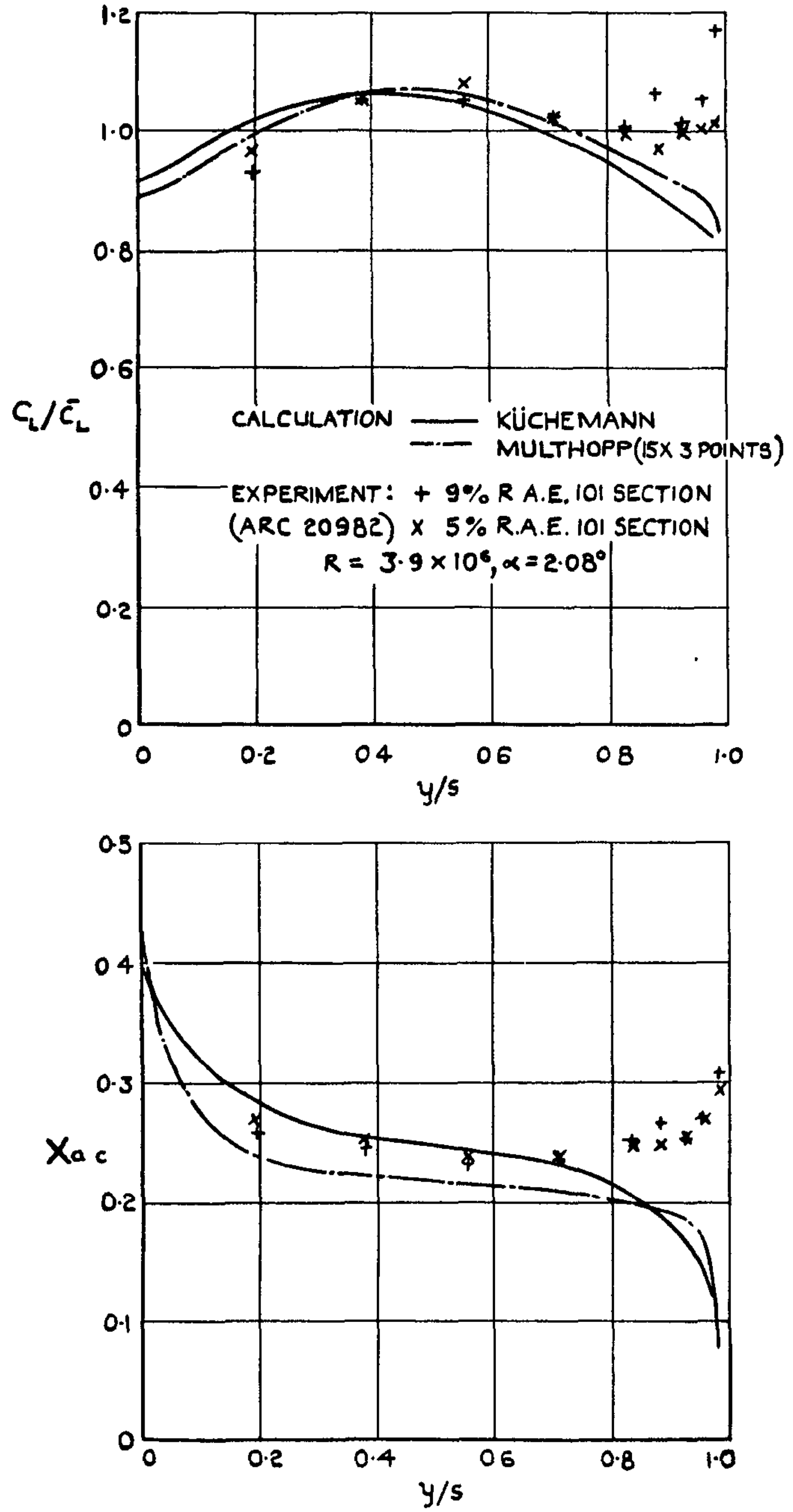

FIG.5. CALCULATED & EXPERIMENTAL LOADINGS ON GARNER'S WING ($A = 3 \cdot 9, \varphi = 60^\circ$)

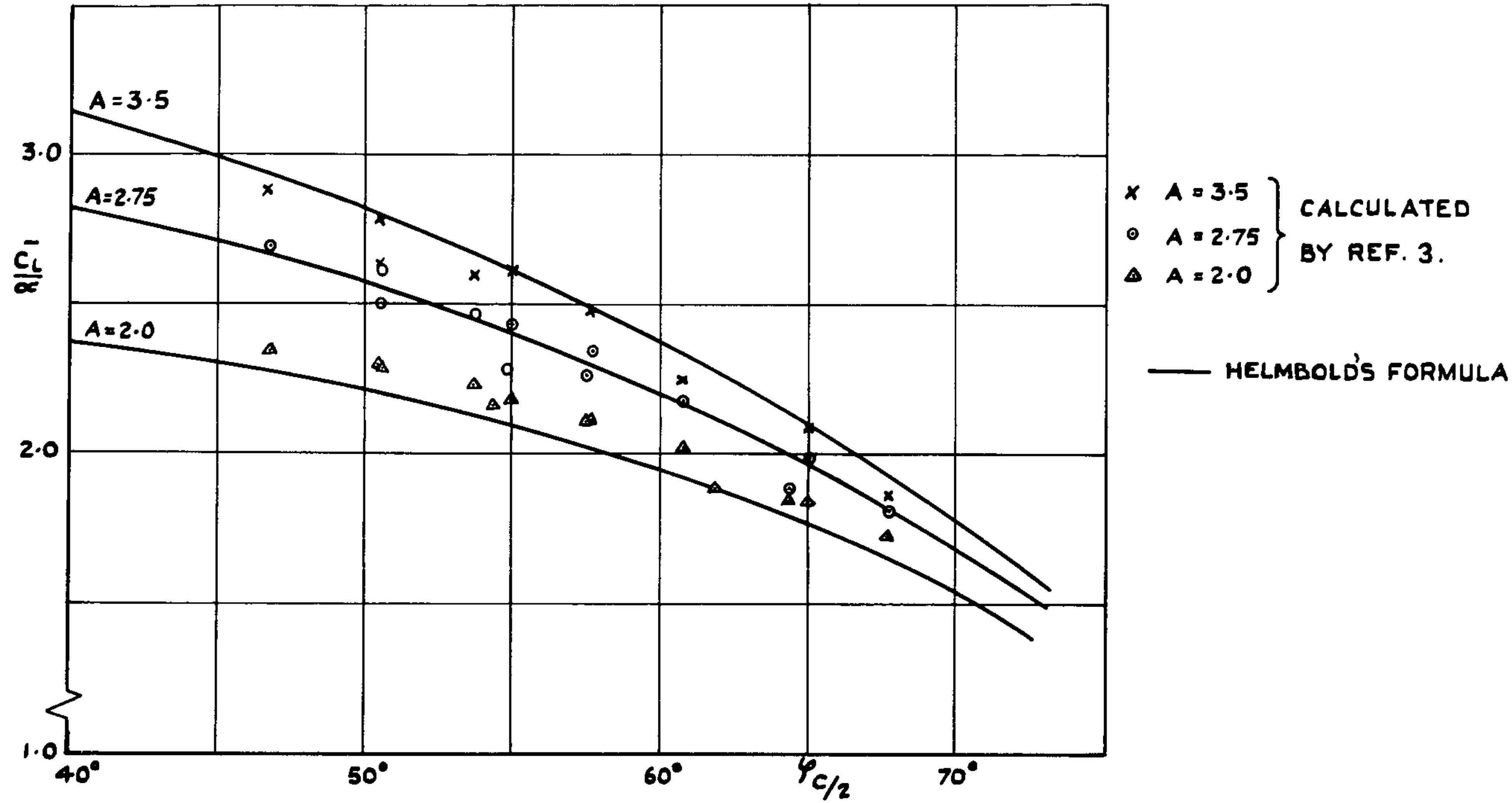

FIG. 6. VARIATION OF LIFT SLOPE WITH WING SWEEP AND ASPECT RATIO.

A.R.C. C.P. No. 675

533.693.1:
533.6.013.13·
533.6.011.32

CALCULATED LIFT DISTRIBUTIONS IN INCOMPRESSIBLE FLOW ON SOME SWEPTBACK WINGS. Bagley, J.A. and Joyce, G.M. August, 1962.

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