R. & M. No. 2666
(11,496)
A.R.C. Technical Report

MINISTRY OF SUPPLY

AERONAUTICAL RESEARCH COUNCIL
REPORTS AND MEMORANDA

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LONDON: HER MAJESTY'S STATIONERY OFFICE
1953
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Summary.—The stalling properties of an 8 per cent thick symmetrical aerofoil with large leading-edge radius of curvature and continuous (distributed) suction over the nose have been tested in the 4-ft No. 2 Wind Tunnel of the National Physical Laboratory.

It was found that suction postponed the stall to higher angles of incidence by suppressing separation at the leading edge. The suction also produced beneficial effects in delaying transition. Moreover it prevented the development of boundary-layer turbulence behind a single excrescence or spanwise corrugation, provided the suction was applied over a sufficient chordwise extent of the aerofoil surface.

The quantity requirements are remarkably small. For example, even at the low Reynolds number of $0{\cdot}3 \times 10^6$ a quantity coefficient C_Q (Q/Uc) of only $0{\cdot}0036$ is sufficient to increase the lift coefficient at 15 deg inc. by $0{\cdot}6$ (from $0{\cdot}7$ to $1{\cdot}3$), and it is to be expected that C_Q will become even less as the Reynolds number is increased. It is not yet possible to estimate the probable power requirements, because the potentialities of the best methods of porous construction are not known.

1. *Introduction.*—Theory has shown[1, 2] that suction through porous material over the nose of an aerofoil should be an effective means of preventing the separation which occurs at high incidence, and thus of delaying the stall and increasing the maximum lift of the section. Its primary application would be to the improvement of the stalling characteristics of the thin sections used for high-speed flight. Wind-tunnel tests were required in order to check the theoretical predictions.

2. *Experimental Arrangement.*—The tests were made in the National Physical Laboratory 4-ft No. 2 Wind Tunnel, on an 8 per cent thick symmetrical aerofoil H.S.A.V. designed[2] as a high-speed section with a critical Mach number of $0{\cdot}8$ at a lift coefficient of $0{\cdot}1$. With a view to increasing the maximum lift, the leading-edge radius of curvature was large ($0{\cdot}03c$), with a sharp velocity peak at the nose, where distributed suction was applied. The maximum thickness occurred at $0{\cdot}42c$ from the leading edge. The ordinates are given in Table 1.

The nose of the aerofoil (Fig. 1) was constructed in the form of a cap of porous metal (sintered bronze, 'Porosint' grade C) built over a series of brass ribs. The suction chamber thus constituted was divided into three separate compartments along the span; the middle compartment formed the test section, the outer sections serving to ensure approximately two-dimensional flow conditions. The two outer sections were connected together by copper tubing of $\frac{5}{8}$-in. bore. The porous nose extended to $0{\cdot}15c$ from the leading edge; the rest of the aerofoil was constructed of wood. Owing to manufacturing difficulties, imperfections and unevenness in the aerofoil contour could not be avoided over the nose. Pressure-plotting holes were fitted to both the porous and the wooden parts of the aerofoil.

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The pipework connecting the aerofoil to the pump outside the tunnel (Fig. 2) was similar to that previously used for the tests of nose slot-suction aerofoils[3, 4]. Some trouble was at first experienced with leaks; the resulting errors in quantity measurements would have been serious because the suction quantities are themselves low. The measurement of the suction flow should preferably be made as close to the aerofoil as possible, in order to avoid spurious readings due to leaks at joints in the pipework between the aerofoil and the measuring instrument. It is suggested that greased ground conical joints might prove to be more satisfactory for this type of work than flanges with rubber washers, particularly where (at the tunnel walls) provision has to be made for rotating the aerofoil with respect to the main pipework in order to cover a range of incidence.

The pressure difference required across the porous material (Porosint grade C) was about 10 in. water per ft/sec normal velocity into the surface.

The suction flow into the centre compartment was measured in the calibration pipe (Fig. 2) by means of a ' quarter-radius meter '* which had previously been calibrated. The uniformity of flow through each section of the porous material was checked, at zero tunnel speed, by means of an instrument incorporating a hot wire of the type described in Ref. 5, and was found to be satisfactory for present purposes.

3. *Range of Tests, and Reduction of Observations.*—The tests without suction extended from zero incidence to 15 deg, which was well beyond the stall. They were done mainly at 40 and 60 ft/sec. Scale effect was investigated, at incidences of 10 deg and 15 deg, over the range of wind speed from 25 to 60 ft/sec.

When suction was applied, it was found convenient usually to allow the pump to run full out, variations in the suction parameter $(v_0/U)\sqrt{R}$ (*see* section 5) being obtained by altering the tunnel speed. Control of the suction flow was attempted in only a few runs. In all cases the valves V, V (Fig. 2) were set to ensure the same suction flow per unit area over the outer sections of the aerofoil as over the middle section. A range of suction quantity was covered at each incidence above 10 deg, at which the lift reached its maximum without suction. With the existing experimental set-up, the aerofoil could not be tested at incidences above 15 deg. In this region, cross-flow (indicated by wool tufts) began to be troublesome.

The separation was observed by means of wool tufts and also by carefully using the chemical method. The latter was also used for determining the transition point. Since the surface of the model had not been suitably finished for this type of measurement, the lead spray was not applied to the surface directly. Instead, strips of ' Lasolastic ' self-adhesive tape were first coated; short lengths were then cut off as required and applied to the aerofoil surface just behind the hole from which the reactive gas was to be exuded. This technique was found to be both satisfactory and convenient.

Several determinations of profile drag were made by wake traverse, and a few tests were made with excrescences attached to the nose near the leading edge.

Further tests were made with parts of the porous surface rendered impermeable by means of spanwise strips of Lasolastic adhesive tape. Incidental investigations, of a crude nature, were conducted to gain some idea of the effect of rain on a sample of the porous material: these are described in the Appendix.

The results have been reduced to lift coefficients (C_L) rather than normal-force coefficients (C_N). No corrections were applied for tunnel interference, as their numerical values in the neighbourhood of maximum lift are not known with certainty. At low angles of incidence the correction for lift constraint would have reduced the lift coefficients, at constant incidence, by about 6 per cent.

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* Designed by J. H. Preston[6], the quarter-radius meter consists of four pitot-tubes within the pipe, spaced at 90 deg intervals and fixed at a distance from the wall equal to a quarter of the pipe radius. A static-pressure hole is provided in the wall opposite each pitot-tube.

4. *Results with Zero Suction.*—The lift curves obtained with zero suction are shown in Fig. 3. The slope $\partial C_L/\partial \alpha$ is initially 0·97 per deg (5·6 per radn),* and decreases above an incidence† of 7 deg. The lift coefficient reaches a maximum of 0·87 at an incidence of 10·5 deg, beyond which it falls steadily.

The lower of the two zero-suction curves A and B shown in Fig. 3 appears to be due to an alternative régime of flow. Points on both curves were obtained at each of the two wind speeds to which they refer (40 and 60 ft/sec). It is probable that the imperfections of construction of the porous nose makes the behaviour of the boundary layer sensitive to slight changes in external conditions in the neighbourhood of the stall, although the effect may possibly have been due to the abnormally large nose radius of curvature. Further research is needed to clarify this point, preferably at full-scale Reynolds numbers.

The mechanism of the stall, as indicated by the wool-tuft explorations, consists of a separation of the boundary layer from the upper surface near the leading edge, followed by reattachment at a position which gradually moves towards the trailing edge as the incidence is increased. Observations made at a tunnel speed of 40 ft/sec (Reynolds number $0 \cdot 38 \times 10^6$) are set out in the following table. It should be remembered, however, that the stall may occur differently at higher Reynolds numbers.

Angle of incidence (deg)	6	7	8	9	10 and above
Position of reattachment (fractions of aerofoil chord).	0·12	0·30	0·50	0·85	No attachment

The magnitude of the scale effect is shown in the inset of Fig. 3. The lift coefficient at a given incidence falls appreciably between 20 and 30 ft/sec (Reynolds number 0·19 and $0 \cdot 29 \times 10^6$) and becomes nearly constant between 40 and 60 ft/sec (Reynolds number 0·38 and $0 \cdot 58 \times 10^6$).

5. *Results with Suction Applied.*—The suction tests were conducted at incidences where the aerofoil would otherwise have stalled. Application of increasing amounts of suction gradually brought the lift coefficient up to the continuation of straight-line part of the lift curve without suction (Fig. 3). There was no evidence of hysteresis according as the wind speed was brought to the required value from below or from above.

The increases of lift at each incidence have been referred to the curve A of Fig. 3 as datum, with due allowance for scale effect so that the lift increment ΔC_L is the difference between that obtained with suction and that with zero suction at equal Reynolds numbers (R) in each case.

The lift increment is shown plotted against $(v_0/U)\sqrt{R}$ in Fig. 4 (Points marked A, corresponding to values of $(v_0/U)\sqrt{R}$ less than 8 to 9). Here v_0 denotes the mean‡ normal velocity through the porous surface, and U the tunnel speed; the total suction quantity coefficient is given by the equation

$$C_Q = \frac{Q}{Uc} = \frac{s}{c}\frac{v_0}{U}$$

where Q is the suction flow per unit span, c the aerofoil chord and s the extent of the porous surface (measured round the surface). For the points marked A, $s/c = 0 \cdot 314$. The normal-velocity parameter $(v_0/U)\sqrt{R}$ is the more convenient for the presentation of results for a specified

* The correction for tunnel constraint (lift effect) would reduce these figures by about 6 per cent.

† All incidences quoted are nominal values. As may be seen from Fig. 3, the nominal incidence at zero lift is $-0 \cdot 4$ deg instead of zero.

‡ The use of grade C Porosint was intended to ensure that chordwise variations of suction velocity would be negligibly small, the pressure difference across the porous material being large compared with the variations in static pressure over its outer surface. This condition was satisfied at low wind speeds (high values of $(v_0/U)\sqrt{R}$ and $C_Q\sqrt{R}$—*see* section 3). At the highest wind speeds (low values of the suction parameters) the larger dynamic head resulted in the suction velocity at the front stagnation point being considerably greater than the mean, while that at the position of minimum pressure on the upper surface was somewhat less than the mean.

extent of porous surface, whereas the quantity coefficient is the more convenient for comparing different extents. Results for a range of tunnel speeds at a given incidence confirmed that, over the limited speed range of the tests, ΔC_L does not vary greatly with Reynolds number provided $(v_0/U)\sqrt{R}$ (or $C_Q\sqrt{R}$) is maintained constant (Fig. 3, inset), but this conclusion must be regarded as provisional as it needs experimental verification over a wider range of Reynolds number before the results of the model tests can safely be extrapolated to full-scale conditions.

In view of the limited accuracy with which the differences ΔC_L can be determined, the apparent scatter in the results shown in Fig. 4 is not altogether surprising; but some of it may have been due to genuine changes in boundary-layer conditions. It is probable, for instance, that at high suction velocities the boundary layer would remain laminar further aft, with a greater tendency to separate than if it were turbulent.

The mechanism of the gradual increase in lift coefficient with increasing amounts of suction at given incidence is shown by the series of pressure distributions of Fig. 5. With zero suction (Fig. 5a), separation occurs on the upper surface at the nose; this separation is suppressed by the application of suction, until the negative pressure peak at the nose is fully developed (Fig. 5d). The effect of suction in suppressing separation is also illustrated by the following tabulated results from wool-tuft observations.

$\alpha = 10$ deg

$(v_0/U)\sqrt{R}$	0	3·0	5·5
Position of reattachment (fractions of aerofoil chord).	No reattachment	0·3	No separation

$\alpha = 13$ deg

$(v_0/U)\sqrt{R}$	0	4·5	5·5
Position of reattachment (fractions of aerofoil chord).	No reattachment		0·6

On several occasions an alternative value of ΔC_L was obtained for the same value of $(v_0/U)\sqrt{R}$ or a different value of $(v_0/U)\sqrt{R}$ for the same ΔC_L. This effect is ascribed to a different régime of flow, with consequently different types of pressure distribution, the higher lift coefficient being characterised by a negative-pressure peak at the nose. An example is given in Fig. 6, which shows the alternative pressure distributions which gave the same lift coefficient with different suction quantities.

There is little evidence that the alternative flow régimes with suction correspond to the zero-suction curves A and B of Fig. 3; the pressure distributions for these curves are similar in shape to each other, neither showing the development of the peak at the nose. It does appear that the flow over the porous nose is sensitive to slight changes in external conditions, probably owing to imperfections in construction which are unavoidable with a small-scale model.

The beneficial effect of suction in delaying transition is shown by the following observations on the upper surface at 30 ft/sec.

Transition Position (Fractions of Aerofoil Chord)

Reynolds Number $= 0 \cdot 29 \times 10^6$

$(v_0/U)\sqrt{R}$	$\alpha = -1$ deg	+2 deg	6 deg	9 deg	$\geqslant$10 deg
0	0·75	$\leqslant$0·15	$\leqslant$0·15	$\leqslant$0·15	$\leqslant$0·15
6·58	0·75	0·65	0·55	0·25	$\leqslant$0·15

The result of covering various amounts of the porous surface is shown in Figs. 7 and 8, for the highest incidence at which the aerofoil was tested (15 deg). As might be expected, it appears from Fig. 7 that the suction velocity required to produce a given lift increment is least when the greatest area of porous surface is exposed (Case A), but that covering the lower surface (Cases B and C) resulted in only slightly greater suction velocities. On the basis of suction *quantity*, however, the gradual increase in suction velocity (for a given lift increment) from Case A to Case D is offset by the decrease in area of porous material. The combined effect (Fig. 8) is that Case C requires the least suction *quantity*. The comparison between A, B and C shows that in practice the porous area on the lower surface need extend only to the proximity of the front stagnation point, while that between B and D suggests (again on the basis of suction quantity) that some economy may be effected by confining the extent of porous material on the upper surface to the vicinity of the peak velocity.

The suction quantities for a lift coefficient increment of 0·6 (at 15 deg incidence) are set out below for Case C or D over a range of Reynolds number, assuming that the determining parameter is $C_Q\sqrt{R}$. This assumption needs experimental verification, especially as the extrapolation from model to full-scale conditions is rather extreme. Moreover, the mechanism of the stall may differ radically at high Reynolds numbers.

Values of C_Q to give $\Delta C_L = 0{\cdot}6$ (Case C of Fig. 7)

Based on the tentative assumption that the determining parameter is $C_Q\sqrt{R}$

R	8×10^6	10×10^6	15×10^6	20×10^6
C_Q	0·00069	0·00062	0·00050	0·00044

These quantity requirements might be reduced somewhat by further reducing the extent of porous surface on the upper surface, but they are already remarkably small.

The results for Case C at several angles of incidence are included in Fig. 4 (points marked C, $(v_0/U)\sqrt{R} > 8$ to 9). They link up surprisingly well with those for Case A and extend their range towards twice the suction velocity.* Case C is much more economical in suction *quantity*, however, owing to the smaller extent of porous surface. This is illustrated by Fig. 9, in which the curves of Fig. 4 have been converted to a base of $C_Q\sqrt{R}$ instead of $(v_0/U)\sqrt{R}$.

6. *Effect of Distributed Suction on Turbulent Wakes*.—Observations were made of the flow conditions behind a conical excrescence by means of the chemical method of transition indication, the reactive gas being allowed to exude from a hole at the downstream edge of the porous surface. The cone was fixed on the porous surface directly ahead of the hole and at various distances from it. These tests were all made at 30 ft/sec and zero incidence.

With a cone of height 0·1 in. and base diameter 0·1 in., the application of full suction did not succeed in preventing turbulence from developing when the excrescence was 0·75 in. ahead of the rear edge of the porous surface, but did succeed when this distance was increased to 2·1 in. A similar result was obtained with an excrescence of double the size, and with a wire of 0·048 in. diameter at the same distance (2·1 in.).

Thus it appears that distributed suction can prevent turbulence from spreading behind a single excrescence or spanwise corrugation, provided the suction is applied over a sufficient chordwise distance.

7. *Power Requirements and Equivalent Drag*.—A few measurements were made of the profile drag of the aerofoil by pitot traverse of the wake: to this we must add the equivalent drag corresponding to the power requirements of the suction pump.

* In consequence of the increased pressure drop across the porous material, the chordwise variations of suction velocity at high wind speed were less for Case C than for Case A.

If it is assumed that the pump efficiency is equal to that of the propulsive system of the aircraft, and duct losses are neglected, then the equivalent pump drag coefficient (corresponding to the power required to restore the total head of the sucked fluid) is approximately

$$\int \frac{H_0 - p_c}{\frac{1}{2}\rho U^2} \frac{v}{U} \frac{ds}{c} ,$$

where (Fig. 10) H_0 total head of the free stream,

p_c static pressure in the suction chamber,

v normal velocity of flow through the element ds of porous surface

U velocity of the free stream,

c aerofoil chord.

The equivalent pump drag is largely determined by the resistance which the porous material offers to the normal flow. If this ' porous resistance ' were zero, p_c would be equal to the static pressure p at the corresponding point on the aerofoil surface: the minimum pump drag coefficient is therefore

$$\int \frac{H_0 - p}{\frac{1}{2}\rho U^2} \frac{v}{U} \frac{ds}{c} .$$

The experimental results at 60 ft/sec ($R = 0 \cdot 58 \times 10^6$) and zero incidence, with suction applied to the whole of the porous surface, are as follows:

Aerofoil profile drag coefficient	=	0·0061
Minimum pump drag coefficient	=	0·0075
Minimum effective drag coefficient	=	0·0136

This figure (0·0136) is to be compared with the measured drag without suction, 0·0144. The profile drag when suction is used is thus about half the value obtained without suction, and the minimum effective drag is slightly less. As the Reynolds number is raised, the minimum pump drag coefficient will probably decrease more rapidly than the profile drag coefficient, making the comparison more favourable to suction in flight conditions.

The drag corresponding to the porous resistance (*i.e.*, to the power wasted in sucking the air through the surface) has not yet been examined. It was very large for the porous material used in the model tests, but it should be possible to reduce it considerably by appropriate choice of material, or by suitable alternative methods of constructing the porous surface. It is not possible to estimate the probable power requirements until the potentialities of the best methods of porous construction have been explored, but theoretical investigations have been initiated to determine the power wastage when various values are assumed for the resistance of the porous surface to the normal flow through it.

Conclusions.—From the research point of view these initial experiments have provided ample qualitative confirmation of the principle[1, 2] that distributed suction through porous material over the nose of the aerofoil prevents separation at high incidence and so delays the stall.

In order to anticipate practical applications, the next step is to estimate the power requirements when various values are assumed for the resistance of the porous surface to the normal flow through it. Tests at rather higher Reynolds numbers, and on other aerofoil sections, are also being planned, but a considerable further increase of scale is essential before the results can safely be extrapolated to full-scale conditions. Closer attention should then be paid to chordwise variations in suction velocity.

Acknowledgements.—Preparations for these tests were put in hand by B. Thwaites while on the staff of the National Physical Laboratory. The difficult task of constructing the porous nose was carried out by Mr. A. J. Hewson, of the Aerodynamics Division workshop.

APPENDIX

The Effect of Water on the Air Resistance of the Porous Material (Sintered Bronze)

It has often been asked whether rain would render porous material impermeable, as this would represent a serious difficulty in practical applications of distributed suction. As it was impracticable to simulate the effects of rain in the tunnel, the tests to date have been restricted to experiments in still air on a suction chamber with a porous surface on which water was sprayed from a height of about 18 in. at various rates up to that representing heavy rain (1·3 in. per hour) on a stationary wing.

The results (Fig. 11) showed that, with the given suction pump, the rate of 1·3 in. per hour reduced the suction flow to about a third. Drying out after the rain had ceased took a considerable time: after 15 minutes the suction flow had only risen to about 0·6 of its initial value (dry conditions).

It should be emphasised that these results relate to rain falling on a stationary wing, and that the effect of forward speed has not been considered. The volume of water impinging on the surface will be greatly increased by the forward speed. Rain does present a serious engineering problem in the practical application of distributed suction through the porous metal used in these experiments, but it is to be hoped that this trouble may be overcome, for example, by using a porous material of lower aerodynamic resistance to the normal flow. (This will also be necessary for reasons of power economy.) Alternatively, it might be possible to use other material, such as gauze, suitably supported.

REFERENCES

No.	*Author*	*Title, etc.*
1	B. Thwaites	Investigations into the Effect of Continuous Suction on Laminar Boundary-layer Flow under Adverse Pressure Gradients. R. & M. 2514. April, 1946.
2	B. Thwaites	A Theoretical Discussion of High-lift Aerofoils with Leading Edge Porous Section. R. & M. 2242. July, 1946.
3	F. Cheers, W. G. Raymer and Ola Douglas	Tests on a 'Lighthill' Nose-suction Aerofoil in the N.P.L. 4-ft No. 2 Wind Tunnel. R. & M. 2355. April, 1947.
4	F. Cheers and Ola Douglas	Tests on a 'Glauert' Nose-suction Aerofoil in the N.P.L. 4-ft No. 2 Wind Tunnel. R. & M. 2356. April, 1947.
5	L. F. G. Simmons	A Shielded Hot-wire Anemometer for Low Speeds. *J. S. I.* Vol. 26, p. 407 (1949).
6	J. H. Preston	The Three-Quarter Radius Pitot Tube Type of Flow Meter. *The Engineer.* Vol. 190, p. 400, 1950 and A.R.C. 12304

TABLE 1

Ordinates of H.S.A. V*

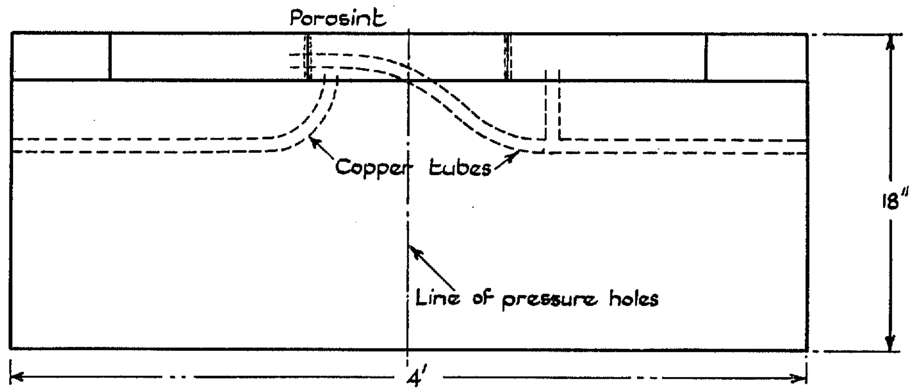
x/c	y/c	x/c	y/c
0	0	0·3455	0·04017
0·0016	0·00883	0·4218	0·04094
0·0062	0·01456	0·5000	0·04022
0·0138	0·01794	0·5782	0·03756
0·0244	0·02033	0·6545	0·03317
0·0381	0·02256	0·7270	0·02756
0·0545	0·02433	0·7939	0·02150
0·0737	0·02583	0·8536	0·01567
0·0955	0·02761	0·9045	0·01061
0·1198	0·02956	0·9455	0·00650
0·1464	0·03156	0·9756	0·00350
0·2061	0·03522	0·9938	0·00150
0·2730	0·03817	1	0

The section is symmetrical.

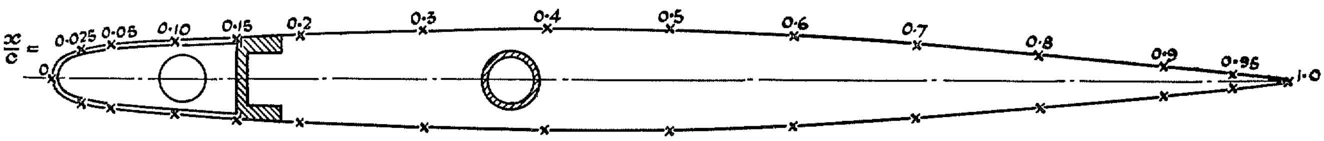
Leading-edge radius of curvature $= 0 \cdot 03c$.

Maximum thickness $= 0 \cdot 082c$, at $x/c = 0 \cdot 42$.

* N.P.L. 308 in the numbering system of the N.P.L. Aerofoil Catalogue (Current Paper No. 81, 1951).



Arrangement of internal ducting.



Section of aerofoil (showing positions of pressure holes).

FIG. 1. Model details.

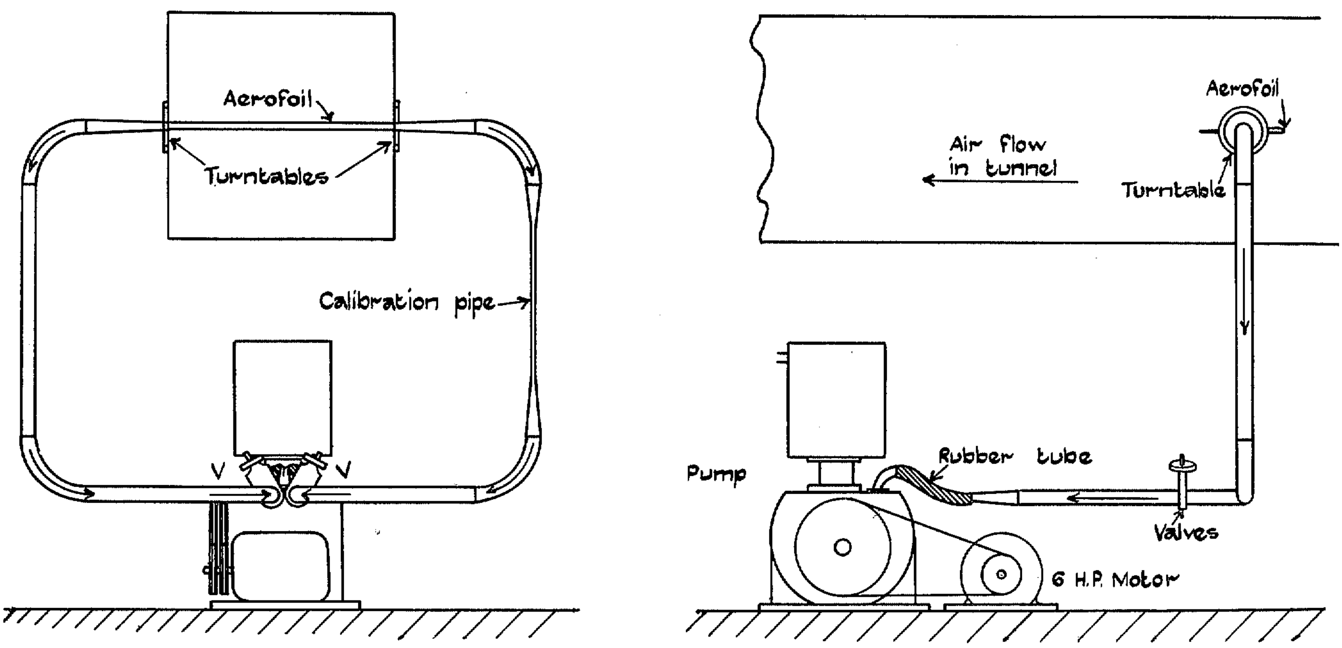


FIG. 2. Arrangement of ducting and pump.

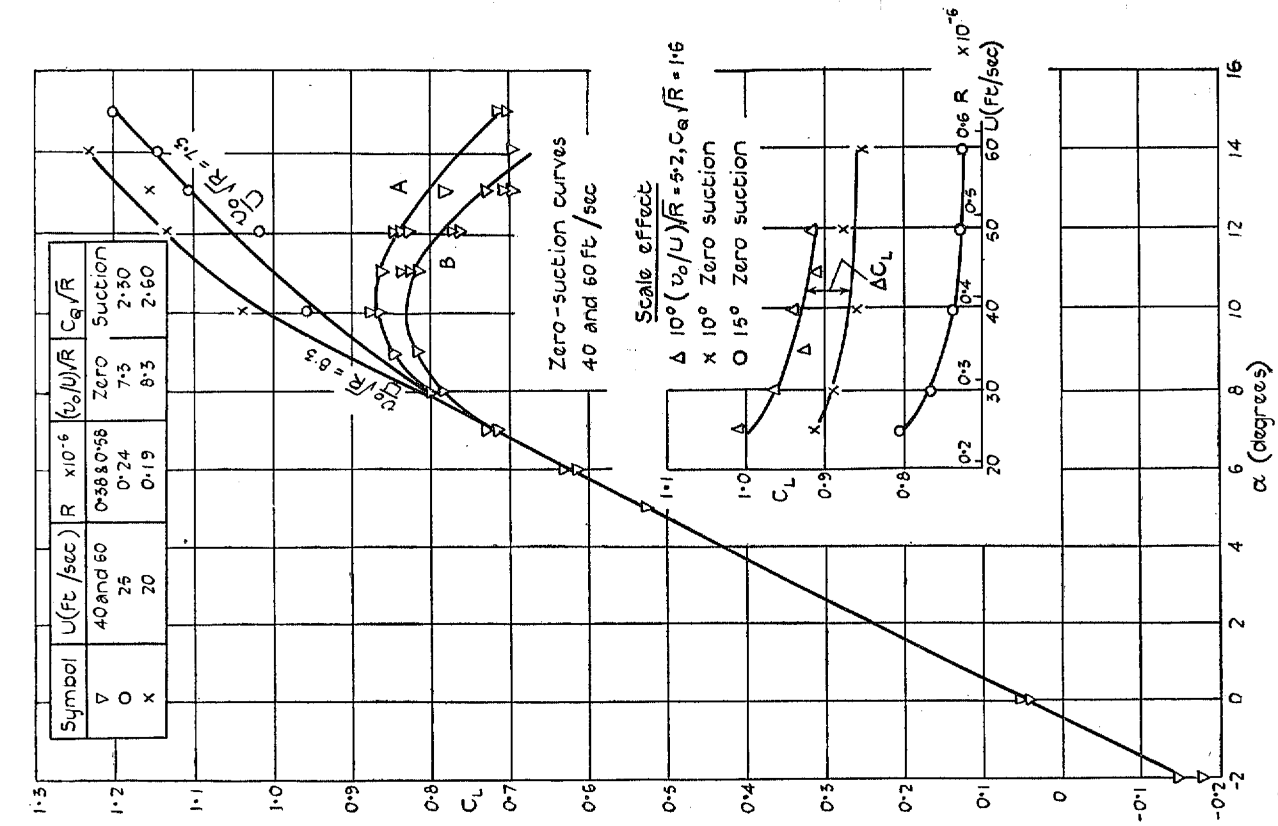


FIG. 3. Variation of lift coefficient with incidence, with and without suction. Note.—The inset (scale effect) corresponds to curve A of the main figure.

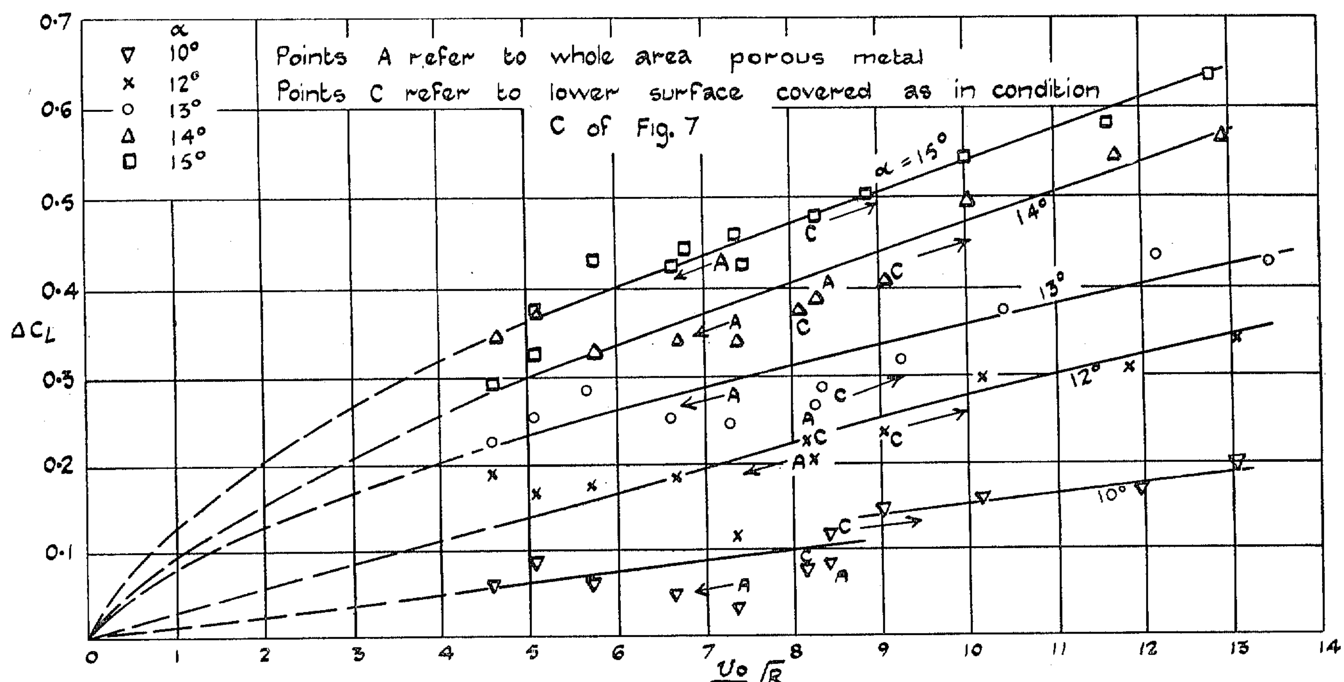
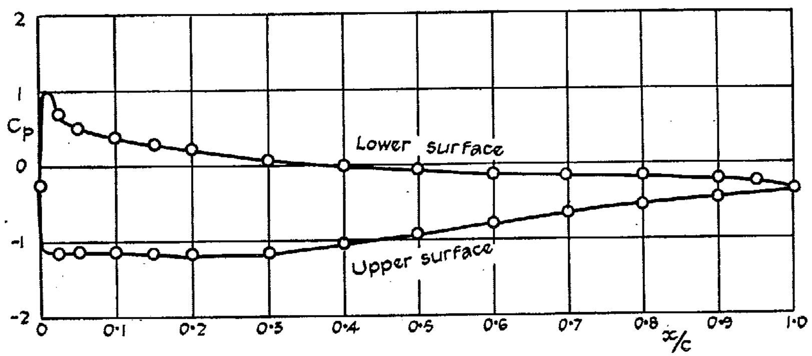


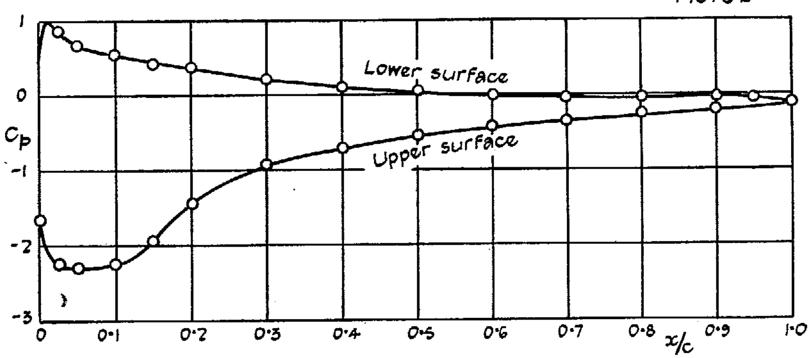
FIG. 4. Lift increment due to suction : variation with normal velocity through surface.

FIG. 5a



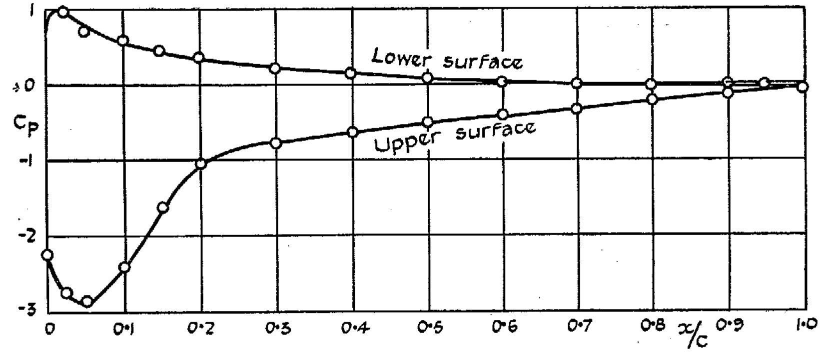
$\frac{v_0}{U}\sqrt{R}$	$C_Q\sqrt{R}$	R	C_L
Zero		0·38×10⁶	0·84

FIG. 5b



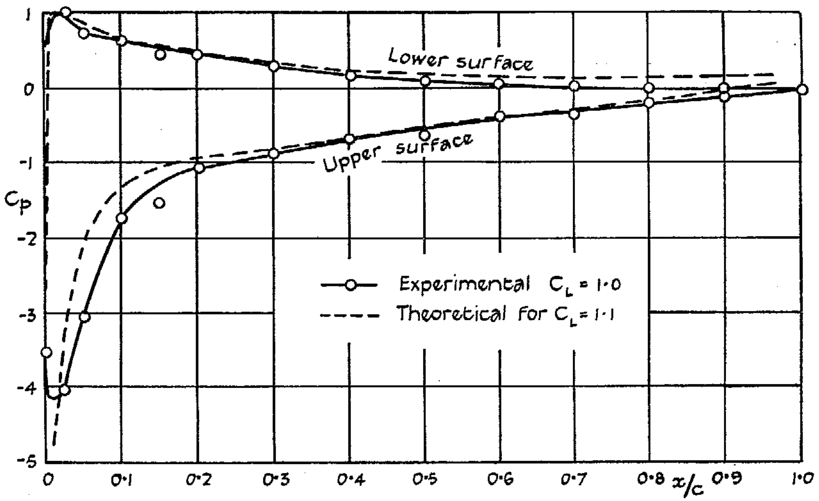
$\frac{v_0}{U}\sqrt{R}$	$C_Q\sqrt{R}$	R	C_L
6·64	2·09	$0{\cdot}29 \times 10^6$	0·94

FIG. 5c



$\frac{v_0}{U}\sqrt{R}$	$C_Q\sqrt{R}$	R	C_L
7·34	2·30	$0{\cdot}24 \times 10^6$	0·96

FIG. 5d



$\frac{v_0}{U}\sqrt{R}$	$C_Q\sqrt{R}$	R	C_L
8·40	2·63	$0{\cdot}19 \times 10^6$	1·04

FIG. 5. Variation of Pressure distribution with suction quantity. $\alpha = 10$ deg.

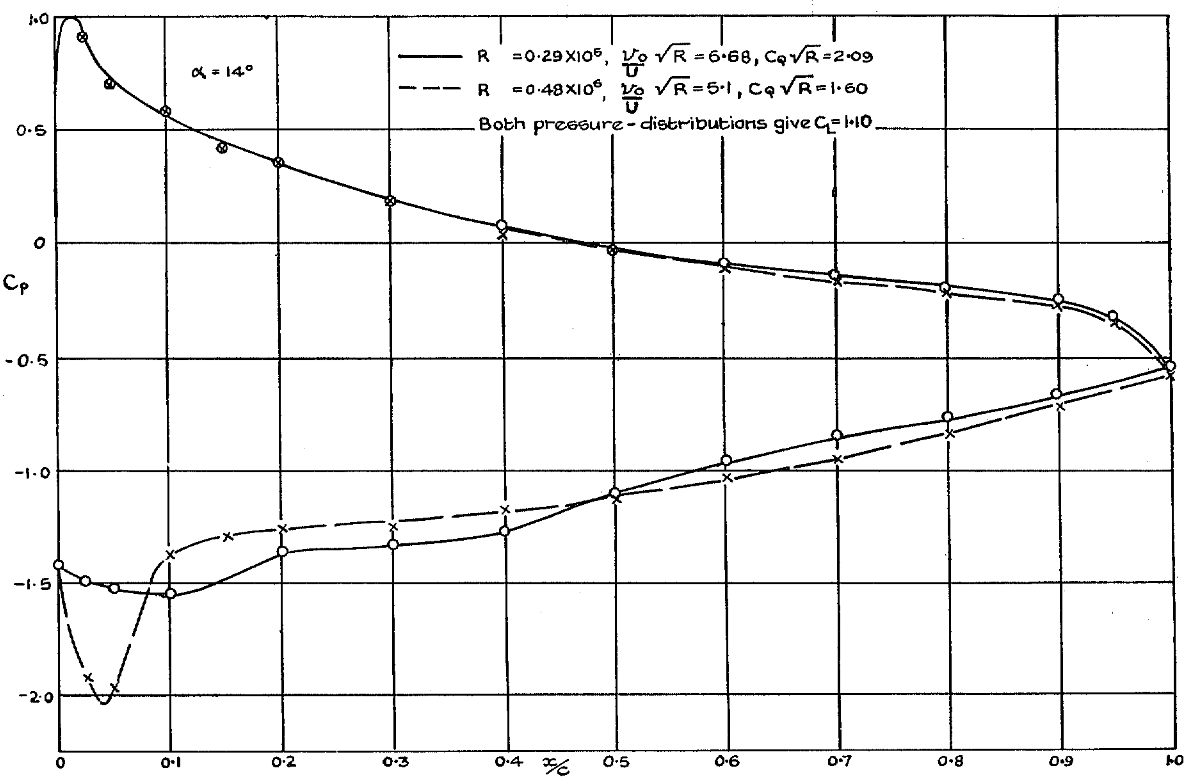


FIG. 6. Pressure distribution curves associated with two régimes of flow giving the same lift.

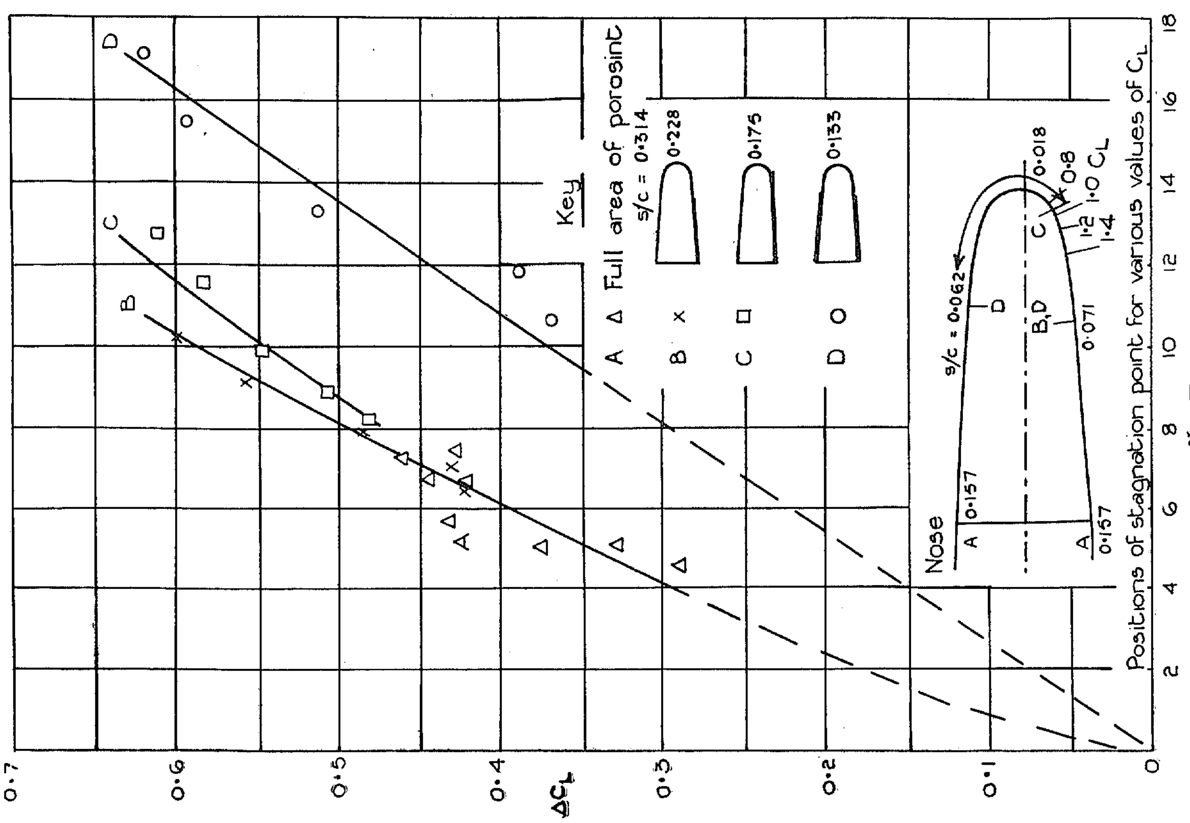


FIG. 7. Lift increment with various extents of porous surface, at 15 deg incidence: variation with normal velocity through surface.

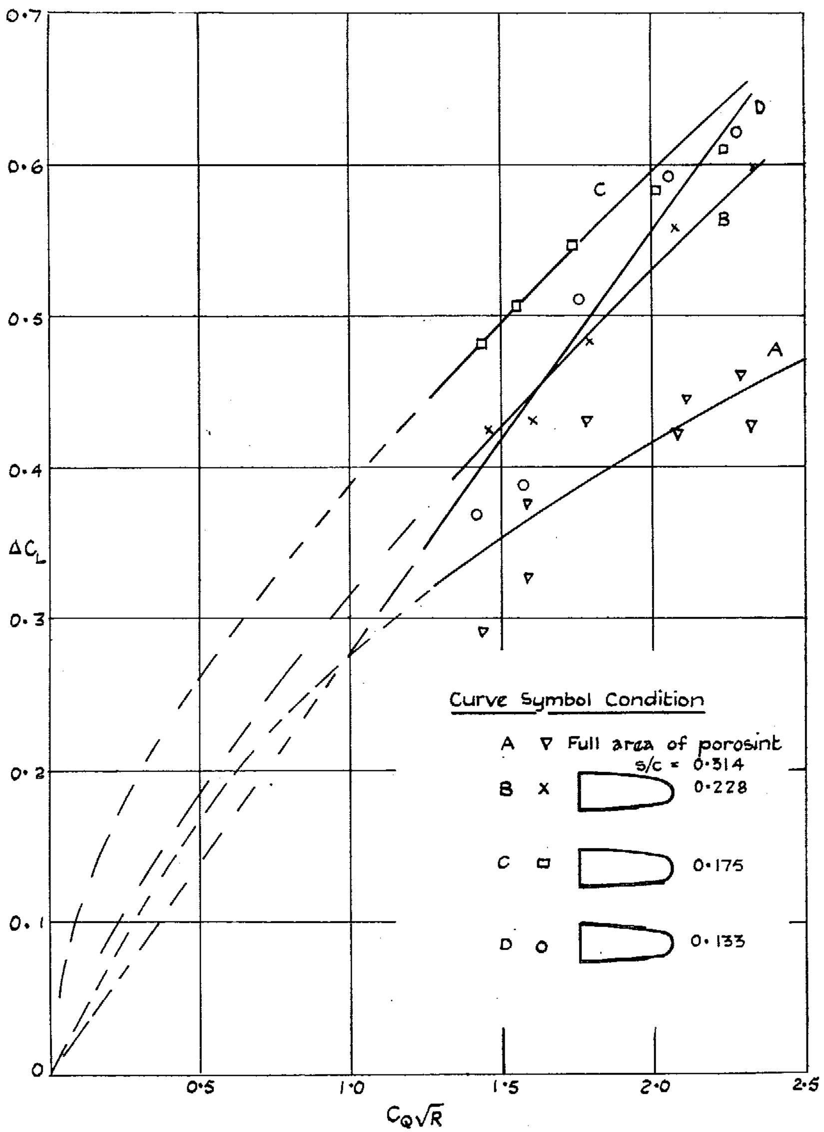


FIG. 8. Lift increment with various extents of porous surface at 15 deg incidence: variation with total suction quantity.

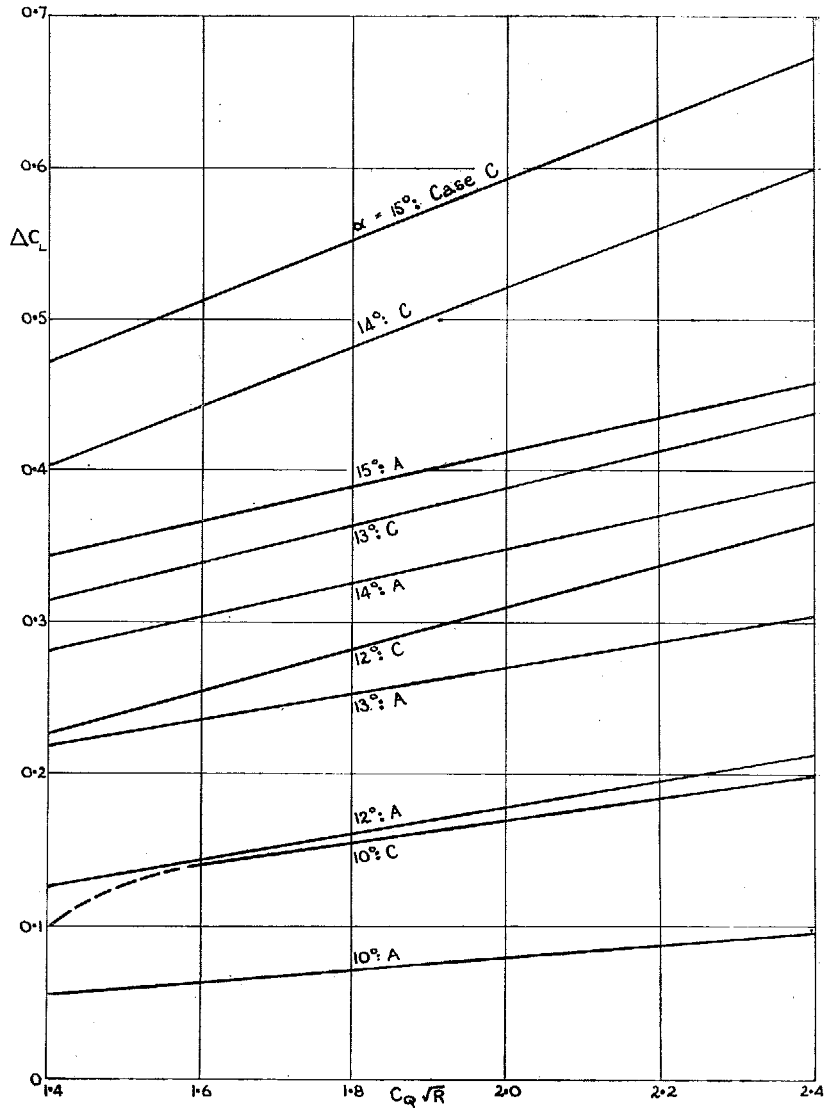


FIG. 9. Lift increment due to suction: variation with total suction quantity for cases A and C.

(51766)

(51766) Wt. 15/680 K.9 4/53 Hw.

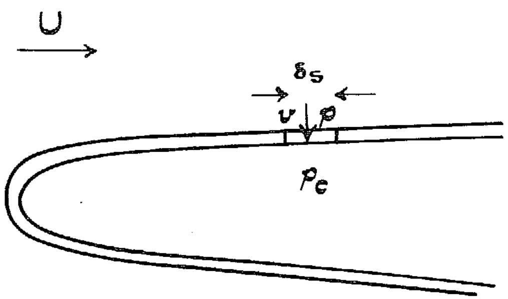


FIG. 10. Estimation of power requirements and equivalent drag.

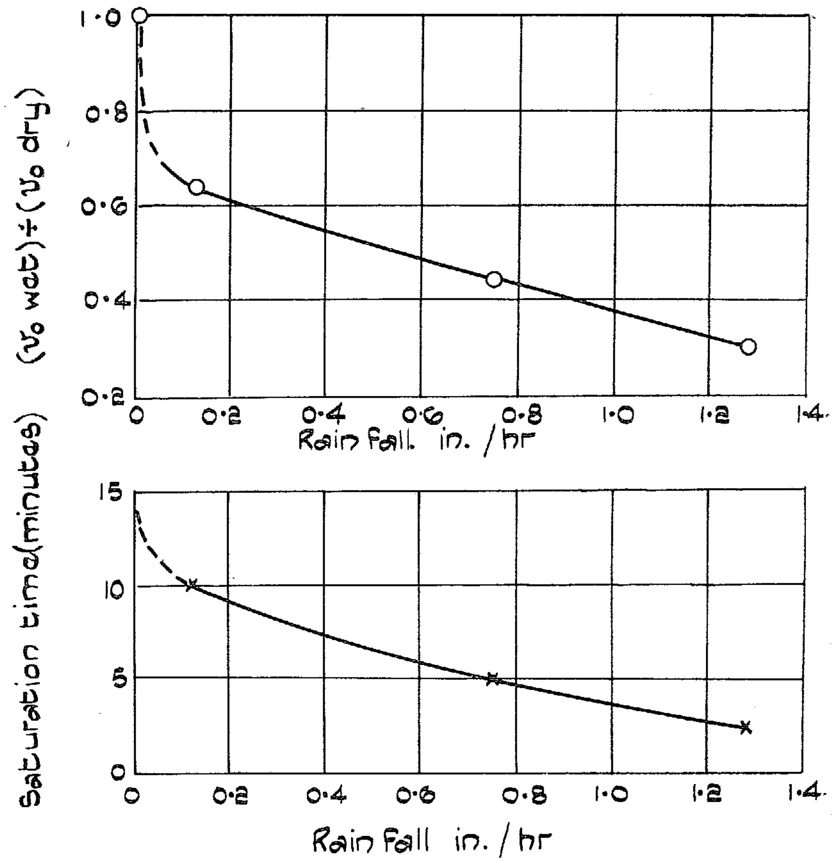


FIG. 11. Effect of rain on suction through sintered bronze (' Porosint ', grade C) : static condition only.

PRINTED IN GREAT BRITAIN

R. & M. No. 2666
(11,496)
A.R.C. Technical Report

Publications of the Aeronautical Research Council

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