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Tests on a 'Lighthill' Nose-suction Aerofoil in the N.P.L. 4-ft. No. 2 Wind Tunnel

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TWO SHILLINGS NET

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Summary.—A series of tests on an 8·6 per cent thick nose-suction aerofoil designed by Lighthill has been made in the 4-ft No. 2 Wind Tunnel at the National Physical Laboratory at Reynolds numbers of 0·385 and 0·577 $\times$ 10^6. The results show that the wing stalls at $\alpha \doteqdot 13$ deg ($C_L = 1 \cdot 12$) without suction, the lift coefficient at the stall increasing approximately linearly with suction quantity and reaching 1·93 at $C_Q = 0 \cdot 019$ and 23 deg incidence.*

1. *Introduction*.—Goldstein and Richards suggested that, by applying suction near the nose of an aerofoil, separation of the boundary layer from the upper surface at high incidences may be suppressed, and the $C_{L\,\max.}$ increased. Lighthill[1] gives the profiles of several aerofoils designed for this purpose, and one of these, 8·6 per cent thick, has now been tested in the N.P.L. 4-ft No. 2. Wind Tunnel.

2. *The Aerofoil*.—A section of the aerofoil is shown in Fig. 1, with an enlarged drawing of the nose showing the position of the slot. The model had a chord of 18 in. and spanned the tunnel horizontally. The roof and floor of the tunnel were set for zero static-pressure drop down the centre. The slot ran along the whole span of the wing; with suction applied, it had the designed width of 0·10 in., but without suction the wood sprang, owing to the impossibility of screwing near the lips, and the width increased to 0·12 in.

The ducting inside the wing (Fig. 2) followed Rawcliffe's design[2] and was divided at the centre, the air being exhausted by a double system of pipes (Fig. 3). Calibration tubes were fitted in both sides, with valves to ensure equal flow through the two halves, and further control of the total quantity was obtained through shutters on the collector box before the pump, by means of which air could be bled in to the pump intake, and by a shutter in the pump exit.

The pressure and velocity distributions over the wing were determined from readings taken at surface holes. The lift was obtained by integration of normal pressure.

3. *Results*.—3.1 *Suction Distribution*.—The spanwise distribution of the suction flow was measured by means of a backward-facing open tube inserted a short distance into the slot. The distribution of the velocity, shown in Fig. 4, indicates that the flow was reasonably uniform.

*Throughout this report no correction has been applied for tunnel interference. At low incidence the lift constraint correction would reduce the lift coefficients by about 6 per cent.

3.2 *Tests without Suction.*—The wing was tested at 40 and 60 ft/sec ($R = 0{\cdot}385$ and $0{\cdot}577 \times 10^6$) over a range of incidence from no-lift to beyond the stall. The lift curves are shown in Fig. 5. The section stalls at $C_L = 1{\cdot}12$, at an incidence of approximately 13 deg.

3.3 *Tests with Suction.*—The wing was tested at four suction quantities, $C_Q \left(= \dfrac{Q/\text{unit span}}{\text{Tunnel speed} \times c}\right) = 0{\cdot}010$ and $0{\cdot}0125$ at 60 ft/sec, and $C_Q = 0{\cdot}015$ and $0{\cdot}019$ at 40 ft/sec. The slope of the lift curve (Fig. 5) is the same as without suction, but the stall is delayed until 15 deg ($C_L = 1{\cdot}46$) at $C_Q = 0{\cdot}010$, and 23 deg ($C_L = 1{\cdot}93$) at $C_Q = 0{\cdot}019$. In Fig. 6 it is shown that the increase of C_L at the stall is approximately linear with C_Q.

3.4 *Velocity Distribution.*—The velocity distribution over the aerofoil (not corrected for tunnel interference) is shown in Figs. 7 to 10. Fair agreement is shown with the shape of the theoretical curves near zero lift.

3.5 *Tests with Slot Faired.*—Results of tests with the slot closed and faired in showed no appreciable difference from the no-suction results.

3.6 *Surface Flow Patterns.*—Figs. 11 to 14 show the results of an investigation of the flow patterns on the upper surface made by the lead-carbonate method[3]. The arrows indicate the holes used for emission of the gas. It will be seen (Fig. 11) that even at 6 deg incidence the flow separates close behind the slot, and rejoins later. With increasing incidence the separated region grows. Fig. 14 shows that a small régime of laminar flow (about $0{\cdot}03\ c$) is possible on the upper surface at 20 deg incidence with suction sufficient to prevent stalling.

4. *Conclusions and Discussion.*—The results show that the application of suction to this wing can increase the stalling C_L from $1{\cdot}12$ at $C_Q = 0$ to $1{\cdot}93$ at $C_Q = 0{\cdot}019$. The modification of the nose caused by fitting the slot (of width $0{\cdot}00556\ c$) makes little difference to the behaviour of the wing without suction. It may be doubted, however, whether the high suction quantity required for the increase in maximum lift will be acceptable to designers, unless a slot is fitted only near the wing tips.

Acknowledgments.—Grateful acknowledgments are due to the Engineering Division, N.P.L., for the loan of the pump and motor.

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No.	*Author.*	*Title, etc.*
1.	M. J. Lighthill	A Theoretical Discussion of Wings with Leading Edge Suction. R. & M. No. 2162 (May, 1945).
2.	A. G. Rawcliffe	Suction-slot Ducting Design. A.R.C. 9487 (March, 1946). (To be published).
3.	J. H. Preston *and* N. E. Sweeting	Experiments on the Measurement of Transition Points by Chemical Methods. R. & M. No. 2014 (March, 1945).

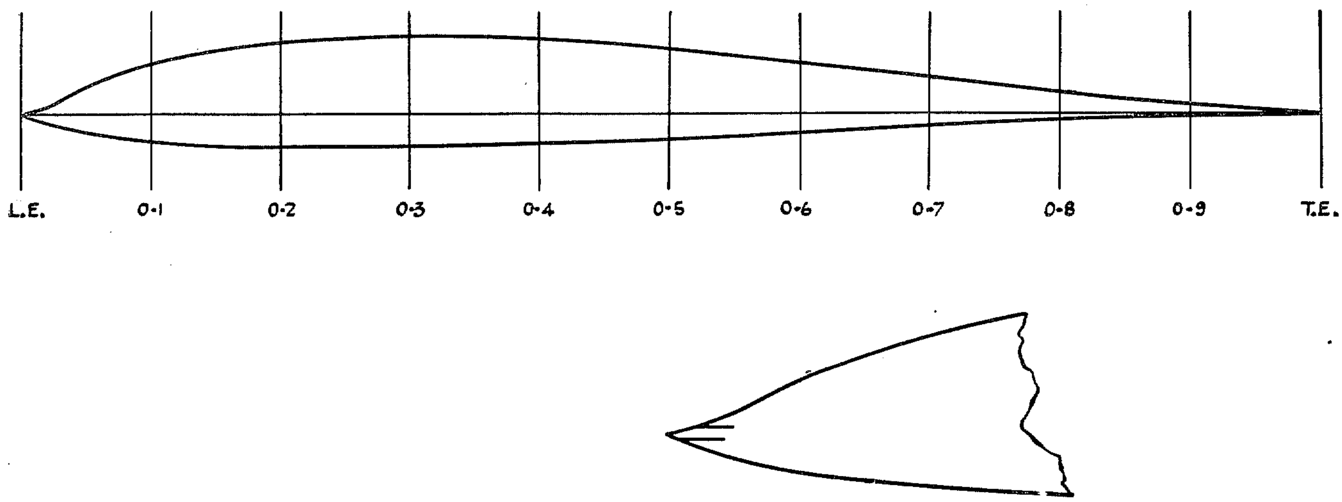


FIG. 1. Section of aerofoil with drawing of nose showing position of slot.

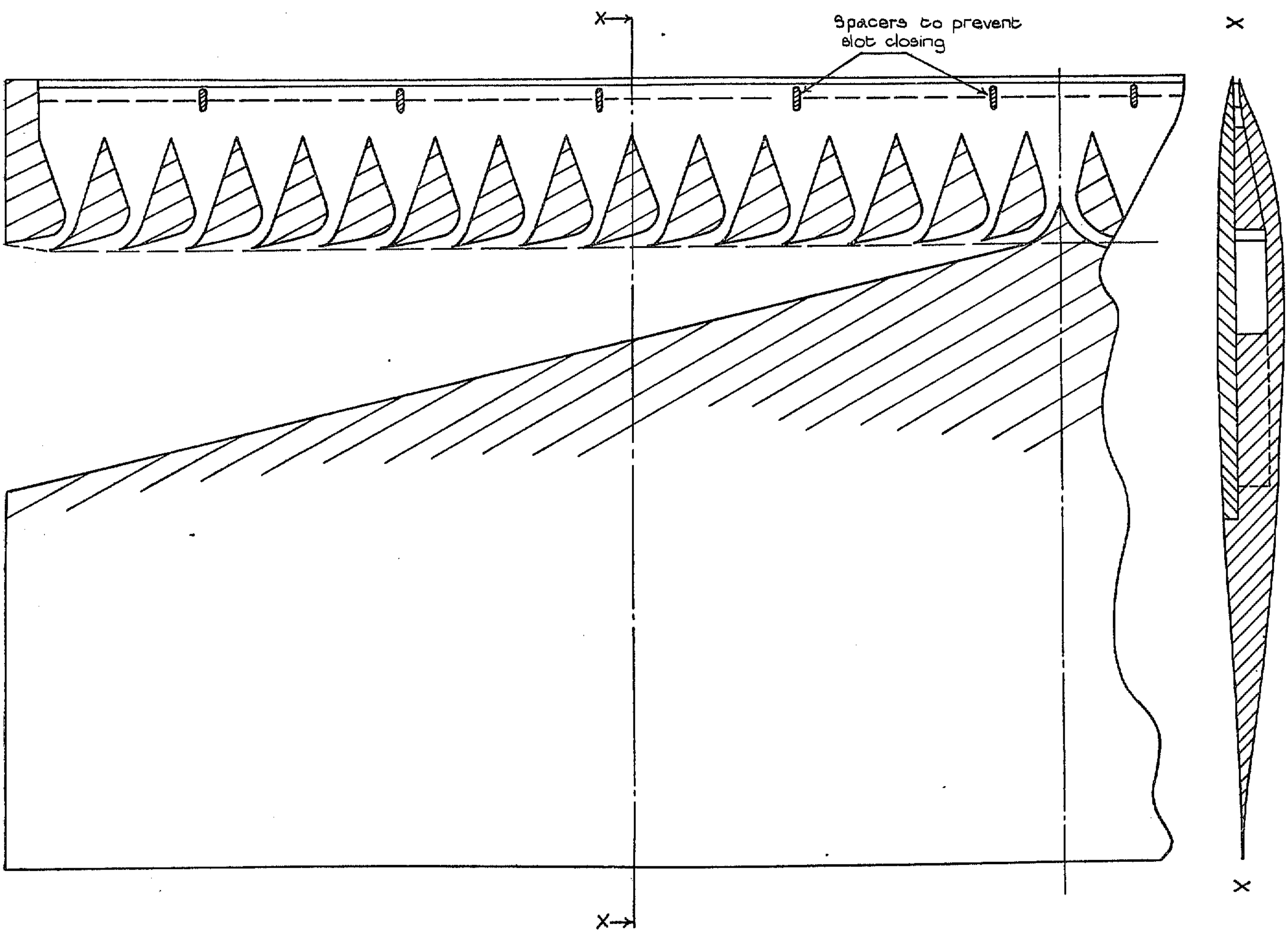


FIG. 2. Sketch of ducting in wing.

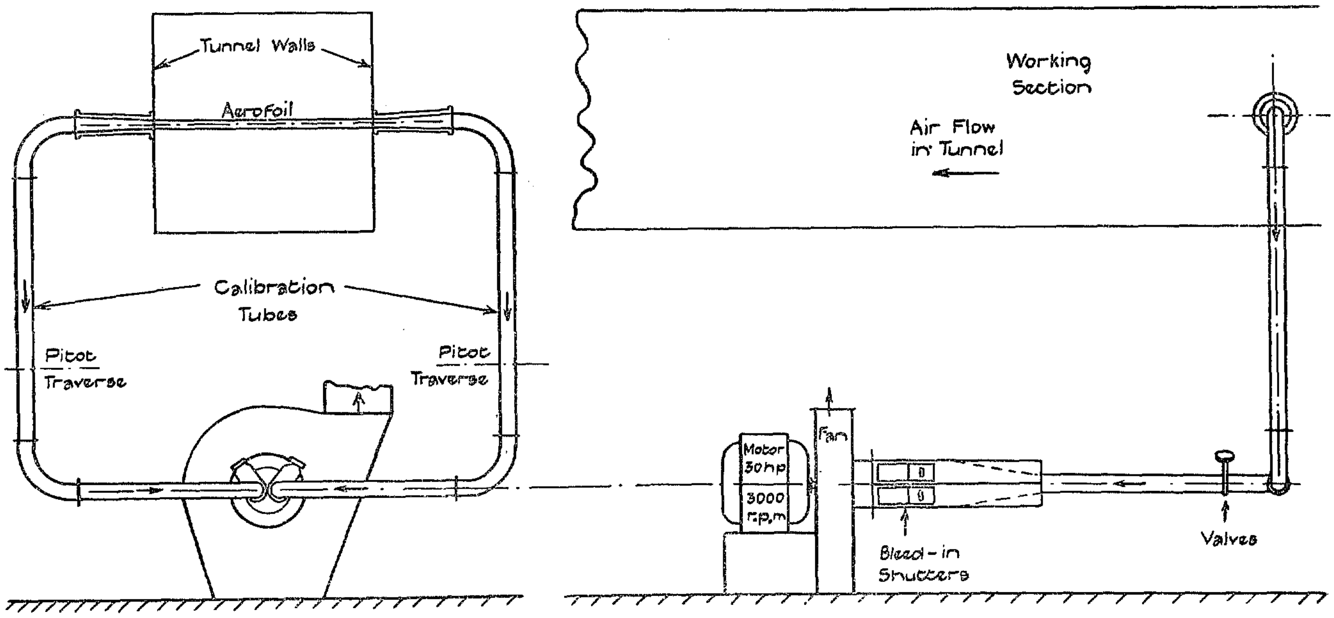


FIG. 3. Arrangement of ducting and fan.

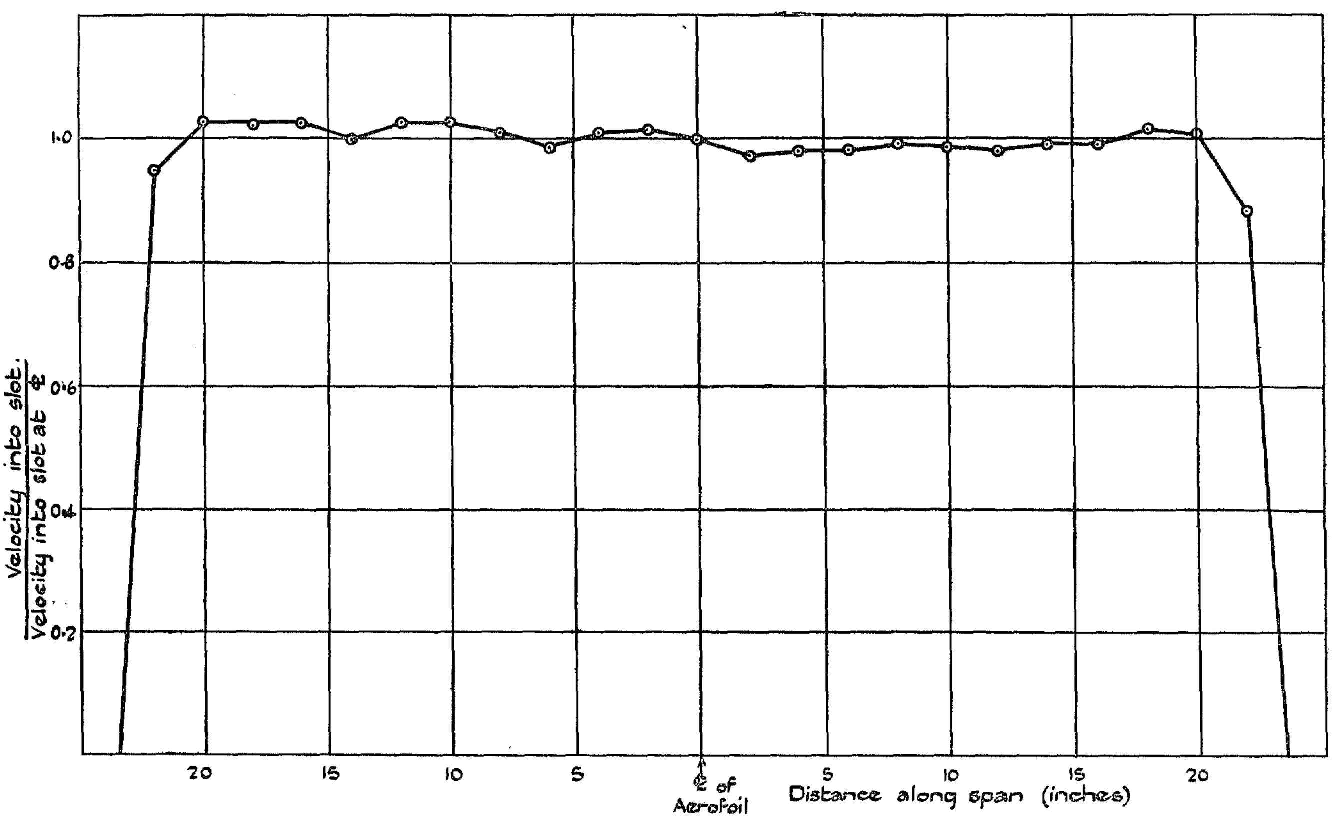


FIG. 4. Distribution of velocity into slot along span. Tunnel at rest; approximately maximum suction conditions.

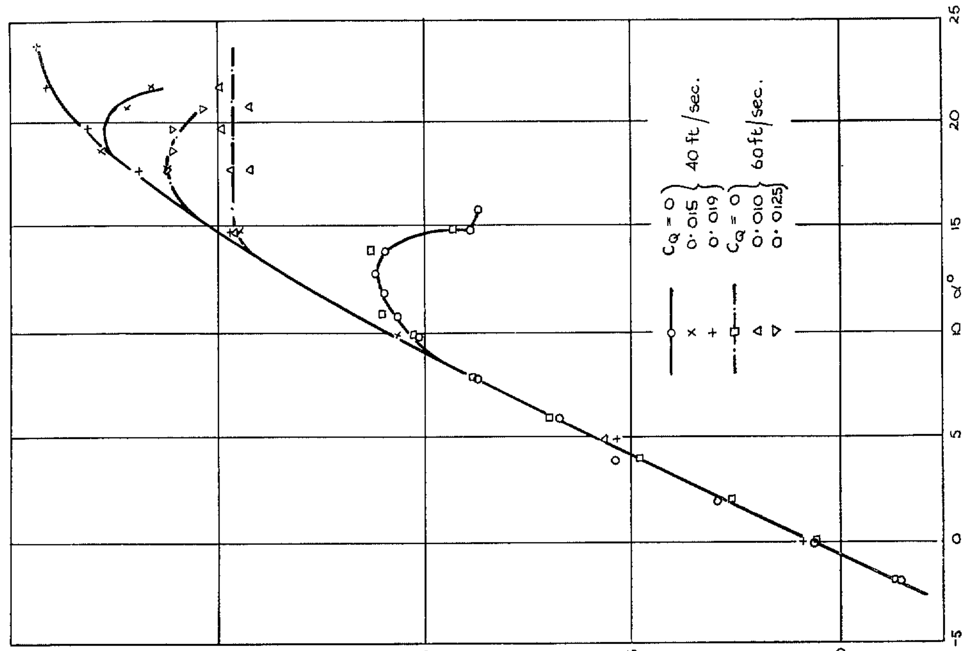


FIG. 5. Variation of lift coefficient with and without suction.

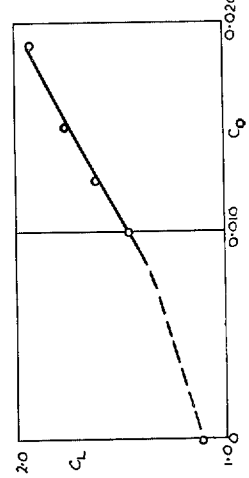


FIG. 6. Variation of stalling C_L with suction quantity.

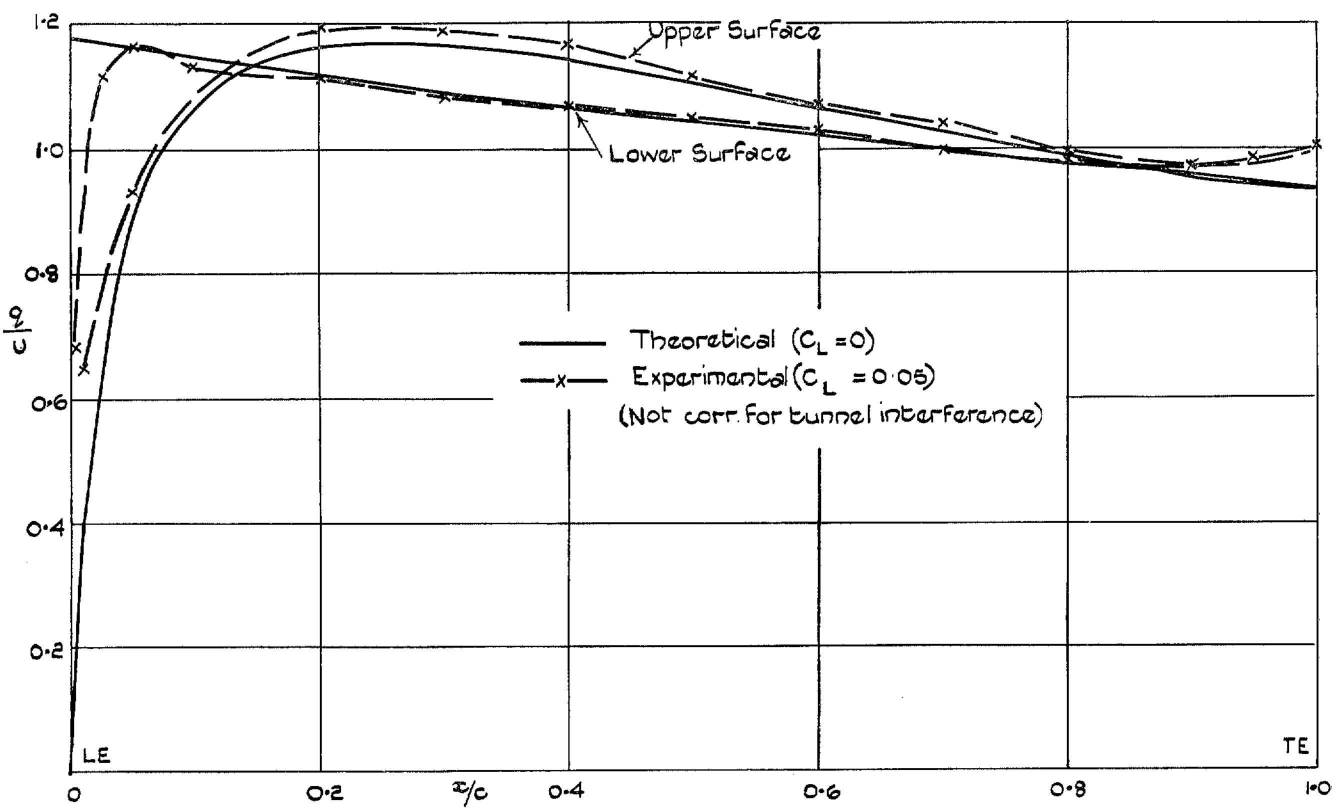


FIG. 7. Velocity distribution over aerofoil at approximately zero lift (60 ft/sec).

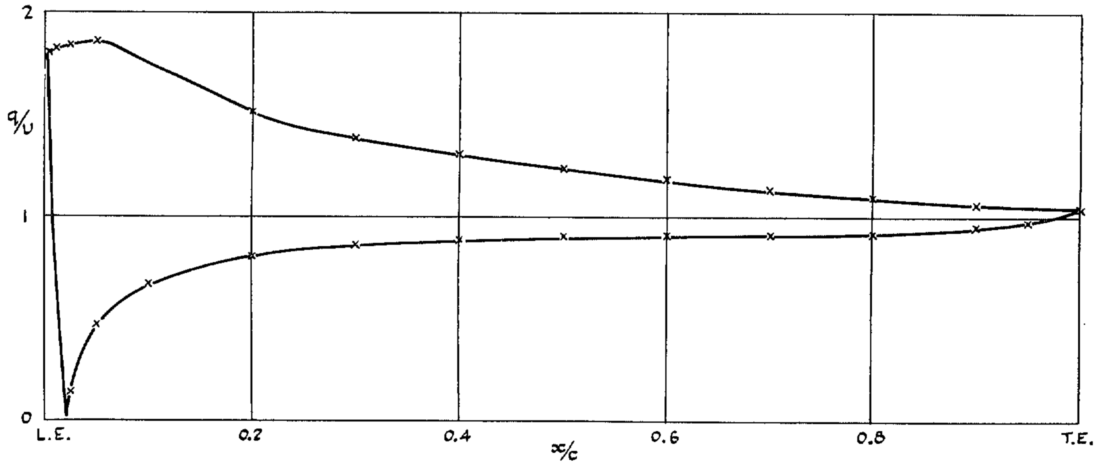


FIG. 8. Velocity distribution round aerofoil. $\alpha = 10$ deg. No suction. $C_L = 1{\cdot}03$. (60 ft/sec).

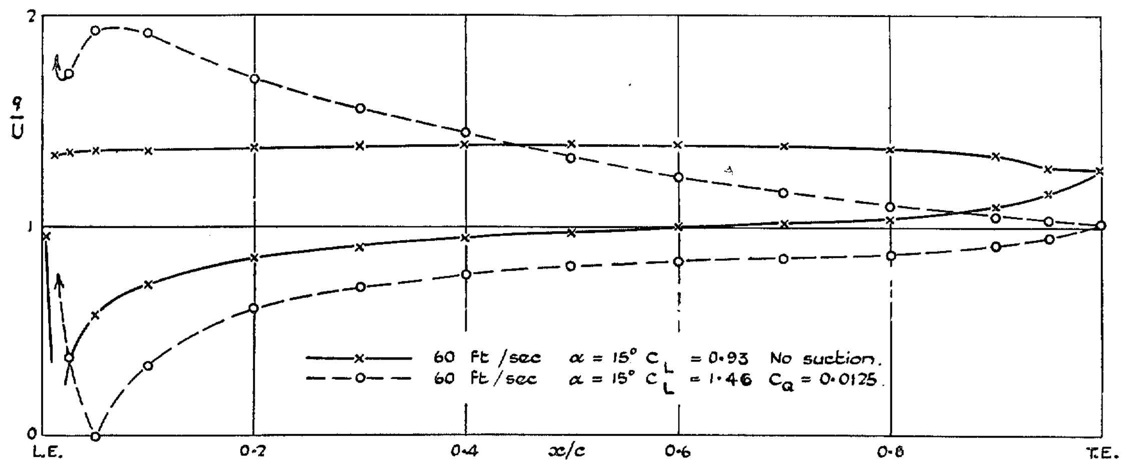


FIG. 9. Velocity distribution over aerofoil (above no-suction stall).

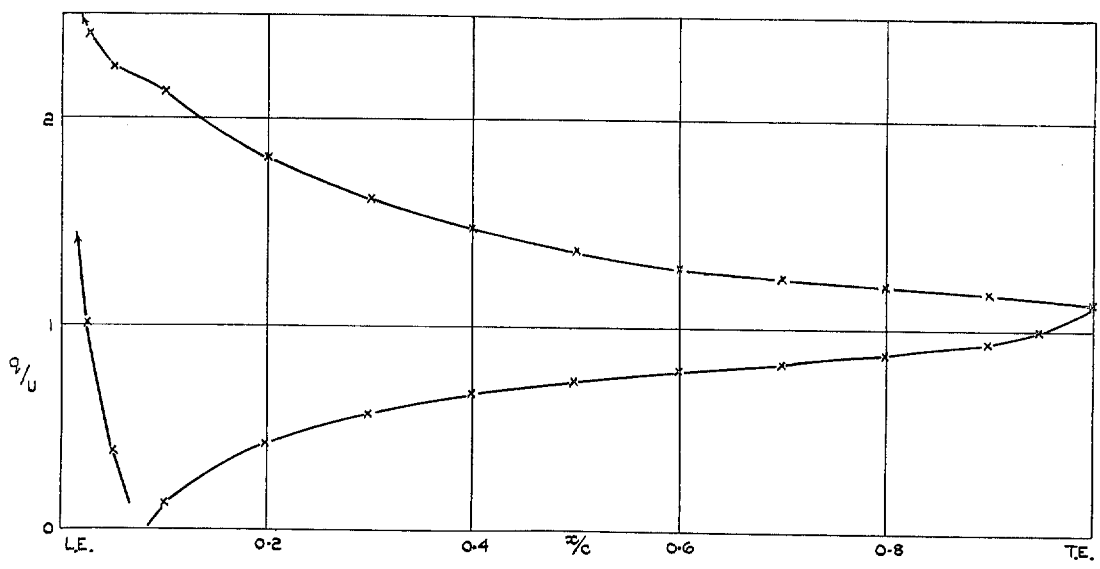
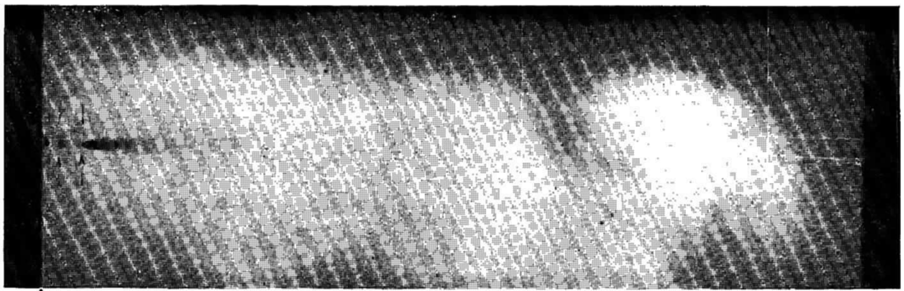


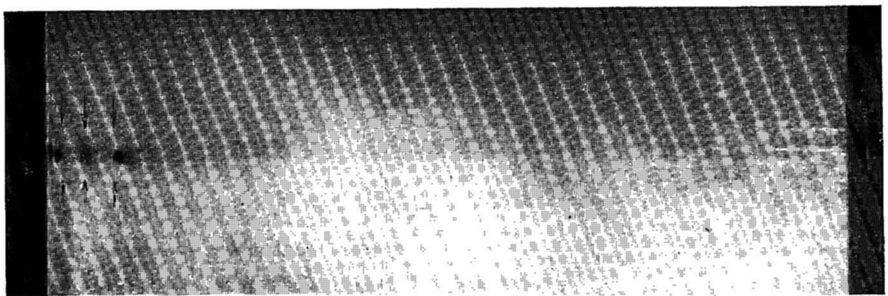
FIG. 10. Velocity distribution round aerofoil. $\alpha = 23$ deg. $C_Q = 0{\cdot}019$; $C_L = 1{\cdot}92$. (40 ft/sec).

FIG. 11.



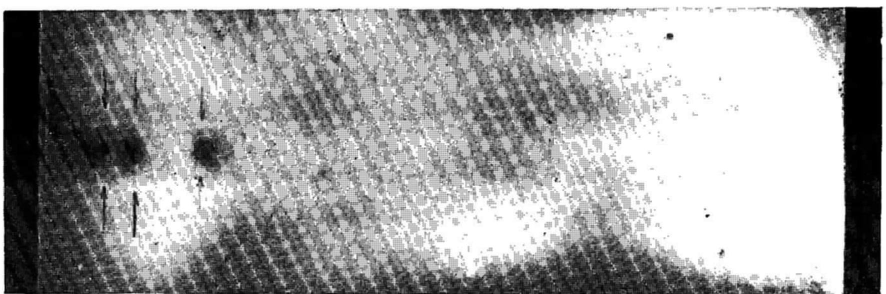
L.E. $\alpha = 6°$ No suction V = 40 ft/sec T.E.

FIG. 12.



L.E. $\alpha = 8°$ No suction V = 40 ft/sec T.E.

FIG. 13.



L.E. $\alpha = 10°$ No suction V = 40 ft/sec T.E.

FIG. 14.

L.E. $\alpha = 20°$ $C_Q = 0{\cdot}019$ V = 40 ft/sec T.E.

Flow patterns on upper surface.

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