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Summary.—Tests on NACA 0020 sections of 1·2 and 2·0-in. chord completely spanning the tunnel showed that there was no appreciable difference in compressibility drag rise due to wind-tunnel interference. This was the case both with the aerofoil yawed (40 deg) and straight across the tunnel.

The results, and further measurements on a Piercy aerofoil previously tested, showed also that the gain in Mach number has been increased from 65 to about 80 per cent of the theoretical value that assumes infinite span and no boundary-layer effects, now that the air is dried to a large extent by use of return ducts.

Some explorations of the flow behind the aerofoil are considered to justify these conclusions at Mach numbers up to at least 0·92.

In Ref. 1 the results of a single series of measurements on a yawed aerofoil were compared with the improvements due to yaw to be expected on a highly idealized theory. It was found that giving an angle of yaw 40·5 deg to a symmetrical Piercy section, maximum thickness 20 per cent at 40 per cent of the chord, increased the Mach number at which the drag coefficient at zero incidence reached 0·015 from $M = 0{\cdot}72$ to 0·89. Theory, for an infinite span and neglecting boundary-layer effects, would have predicted a rise to $M = 0{\cdot}98$.

The further tests described in the present report were made to see whether there was any error due to tunnel interference and also to take advantage of the recent improvement in the tunnel-flow conditions due to installation of return ducts and the consequent reduction of humidity.

For the latter purpose the tests of Ref. 1 were repeated under the new conditions but with the same Piercy aerofoil. The results are compared in Fig. 1 (experimental points in Fig. 5) and it may be seen that there is an even greater improvement, the Mach number for a drag coefficient of 0·15 being raised to 0·93. This change with reduction of humidity, in this case from well above 50 per cent relative humidity to about 15 per cent, is not unexpected at very high Mach numbers[2]. The reduction in "low speed" drag, that is, before the steep rise begins, is probably due to a contemporary reduction of wind-tunnel turbulence.

For the interference tests use was made of two available models of NACA 0020, of chord 1·2 and 2·0 in. The results obtained at zero incidence and zero and 40 deg yaw are shown in Fig. 2 (experimental points in Figs. 3 and 4). It is clear that the change in aerofoil chord/tunnel size in the ratio 2·0/1·2 has made little difference to the drag variation. The same proportion of the theoretical gain has been achieved in this case as with the Piercy aerofoil.

It must be remarked that there is considerable difficulty in making the tests at the very highest wind-tunnel speeds, which were obtained by setting the flexible walls for constant speed along them. Some degree of doubt must be held to apply to the values of the Mach number above approximately 0·92 (*cf.* the second set of results in Fig. 3, with the speed too high ahead of the aerofoil).

Further experiments relating to the flow around the aerofoil are described in Appendices I and II.

Conclusions.

1. Observations of drag rise on a 2-in. chord aerofoil 8-in. long unyawed and approximately $10\frac{1}{2}$-in. yawed at 40 deg in a rectangular wind-tunnel 8-in. by 17·5-in. correspond with sufficient accuracy to true two-dimensional conditions.

2. The increase of the Mach number at which the drag rise commences for a two-dimensional aerofoil yawed at 40 deg. is 80 per cent of the theoretical improvement to be expected if boundary-layer effects are ignored.

REFERENCES.

No.	*Author.*	*Title, etc.*
1.	C. N. H. Lock *and* R. G. Fowler	Yaw and Sweepback at High Mach Number. A.R.C. 8718 (May, 1945).
2.	H. H. Pearcey	The Effect of Condensation of Atmospheric Water Vapour on Total Head and Other Measurements in the N.P.L. High-speed Tunnels. R. & M. 2249 (February, 1944).

APPENDIX I.

Pitot Traverse at Different Positions Behind the Aerofoil.

(1) *At Different Distances Behind the Trailing Edge Down the Middle of the Wind-Tunnel.*—Pitot traverses were made at ½, 1, 2 (the standard distance) and 4 in. behind the trailing edge of the Piercy aerofoil (chord at right angles to the leading edge 2 in.) at the 40 deg angle of yaw and a Mach number 0·80. The results shown in Fig. 6 indicate a definite fall with increased distance downstream. Previous to this set of readings another series, nominally under the same conditions, gave the values plotted in Fig. 6 as circles o o, which for some unknown reason are considerably higher than the normal set. They, however, also indicate a fall with distance downstream.

The above were taken at $M = 0{\cdot}80$ which is below the speed at which the drag rises (for this yawed case). Similar results (Fig. 7) were obtained on the NACA 0020 aerofoil at $M = 0{\cdot}81$, and also at $M = 0{\cdot}92$, which according to previous results as shown in Fig. 2 should have been a high enough speed to give a very much higher drag. However, Fig. 7 shows that the drag was only about 20 per cent higher than the value at $M = 0{\cdot}81$, which can hardly be explained as a speed error since in all cases the speed was taken as the average over the walls facing the whole length covered by the yawed aerofoil, and this varied very similarly in the two cases.

(2) *At Different Spanwise Positions.*—A few pitot traverses were made at positions off the central plane of the tunnel. The values of C_D obtained are shown diagrammatically in Fig. 8, which also includes the results of Fig. 7.

It will be noticed that the drag is higher behind the sweptback end of the aerofoil, where also Fig. 9 shows that the shock wave is larger.

Although the observations were too few to draw reliable conclusions, it is thought that the comparative value of the main series of results (Figs. 1 and 2) of this report is fairly well established, but absolute values are open to considerable doubt.

APPENDIX II.

Static Explorations Around the Aerofoil.

An attempt was made to obtain a rough idea of the velocity field around the yawed aerofoil (NACA 0020 2-in. chord). The experiments took the form of traverses of a static tube at right-angles to the aerofoil along lines through the trailing edge, 2-in. behind it, and 2 and 4-in. ahead of it. These were done in the centre plane of the tunnel and 1·3 in. from each wall.

The readings were reduced to Mach number on the assumption that despite the presence of shocks total-head loss was negligible. They are shown plotted in Figs. 9, 10 and 11 for three free-stream speeds, each partial diagram corresponding to a plane parallel to the side tunnel walls, *i.e.* perpendicular to the aerofoil span and chord. Very approximate contour lines have been dotted in for $M = 1$ in the lowest speed case (M at walls $= 0{\cdot}91$), being made solid where a shock wave is likely.

It will be seen that up to $M = 0{\cdot}92$ at least, it should be quite safe to use the pitot-traverse method of measuring the drag, but at $M = 0{\cdot}97$ (mean speed at tunnel walls opposite the aerofoil) the pitot tube may have been in supersonic regions of flow. However the top speed value of C_D (at mean $M = 0{\cdot}97$) given in Fig. 4 is possibly not in much error, since, as shown there, a uniform speed was achieved at the walls, whereas in the later exploratory tests described above the speed of sound was exceeded over part of the walls (Figs. 10 and 11).

The high readings in Figs. 10 and 11 ahead, but slightly to the side of, the sweptback end of the aerofoil seem very anomalous, but there seems little doubt as to their actually being read.

An attempt to portray the whole velocity field at once is made in Fig. 12, for the case $M = 0{\cdot}91$.

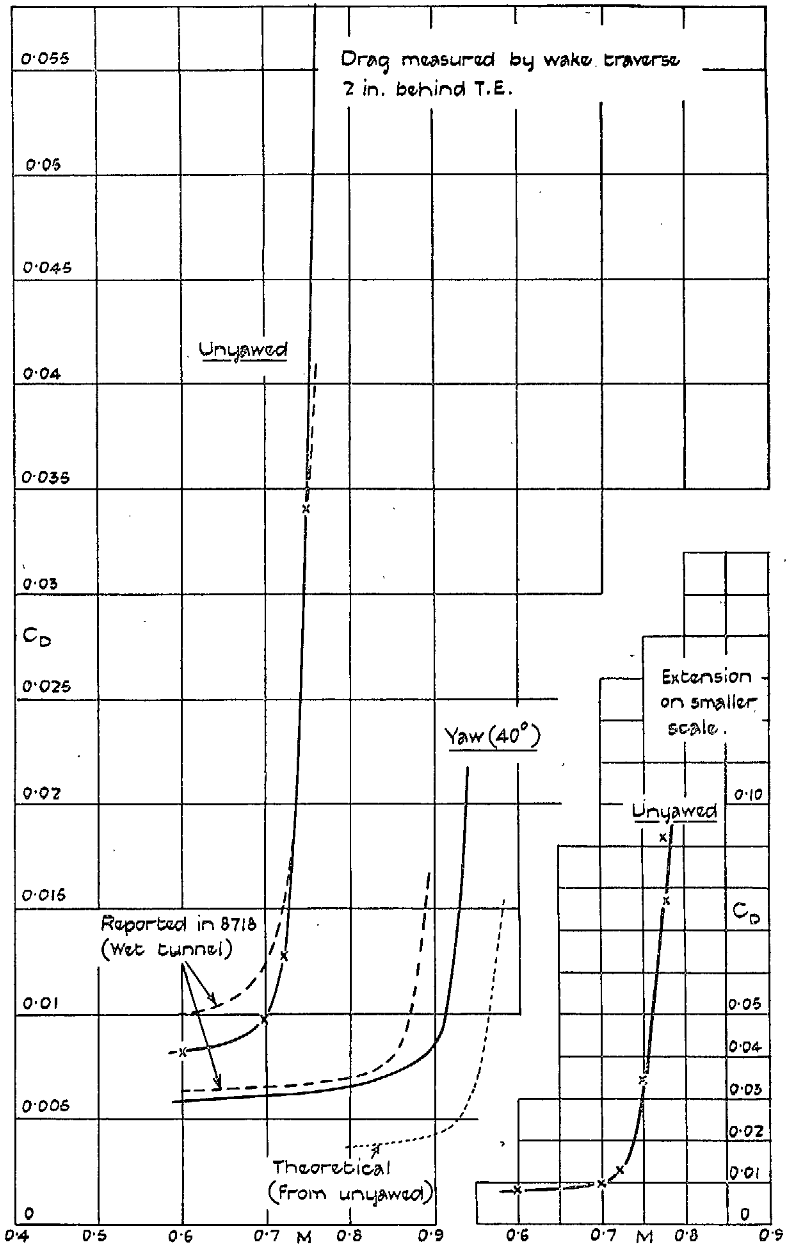


Fig. 1. Effect of yaw on drag of Piercy 20 per cent t/c aerofoil, 2·0-in. chord.

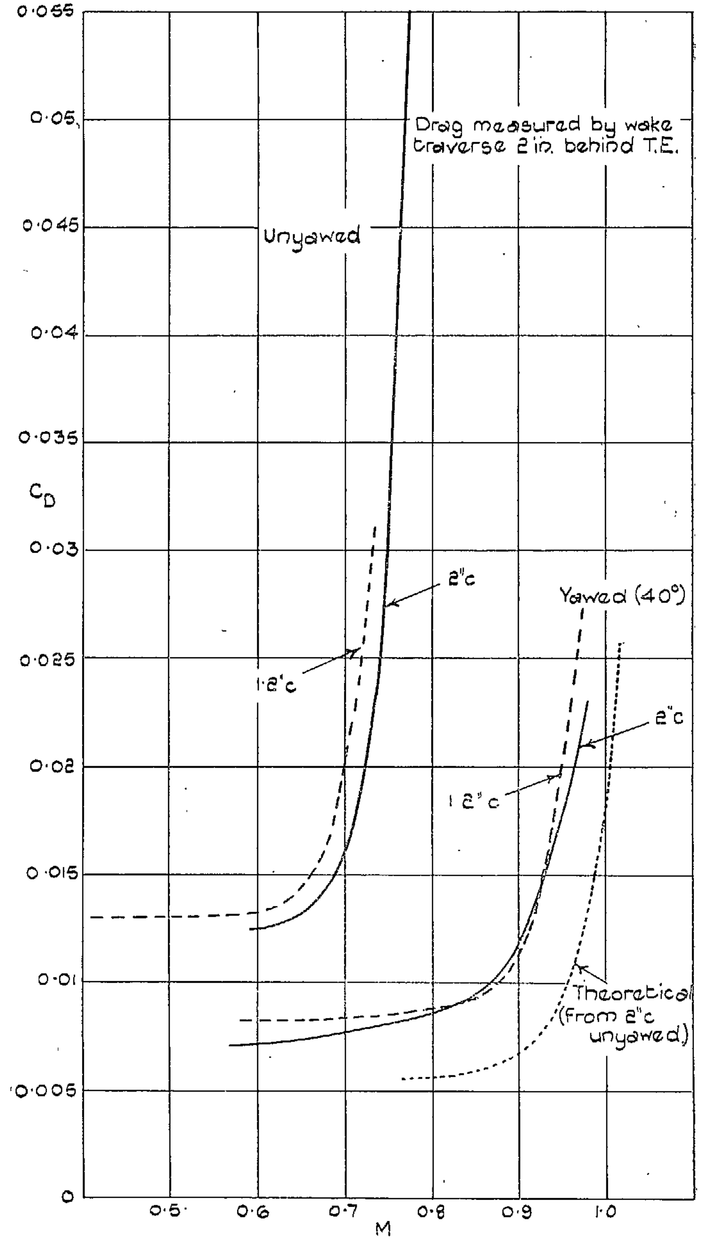


Fig. 2. Effect of yaw on drag of NACA 0020 aerofoils 2·0 and 1·2-in. chord.

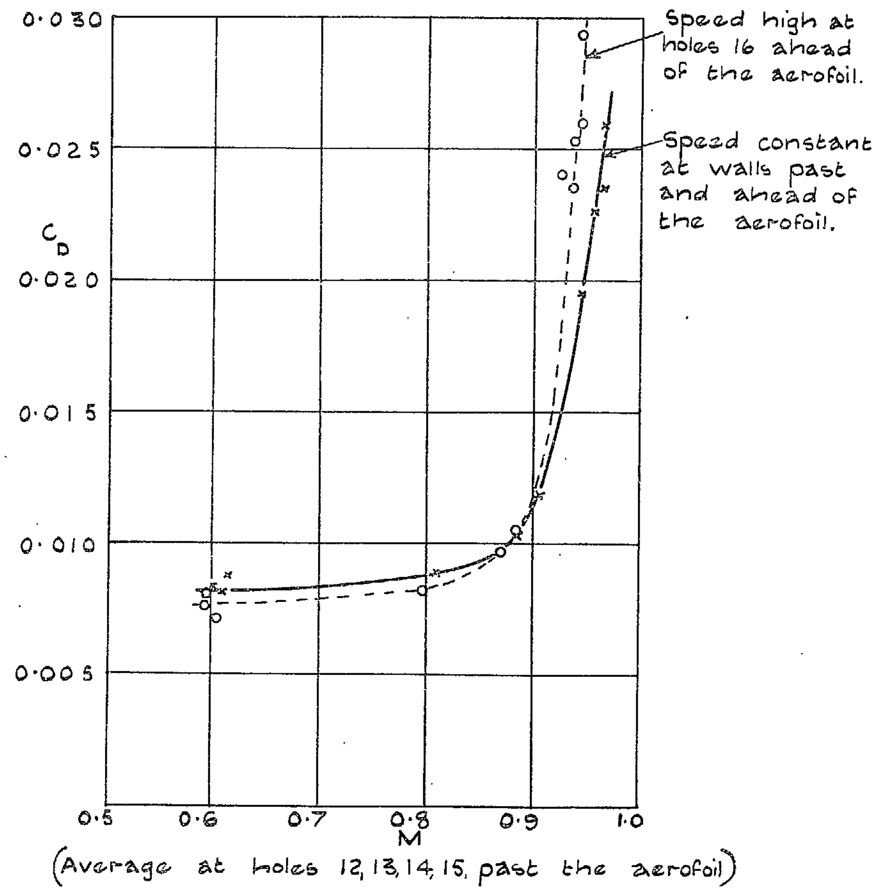


FIG. 3. Drag of NACA 0020 1·2-in. chord, yaw 40 deg.

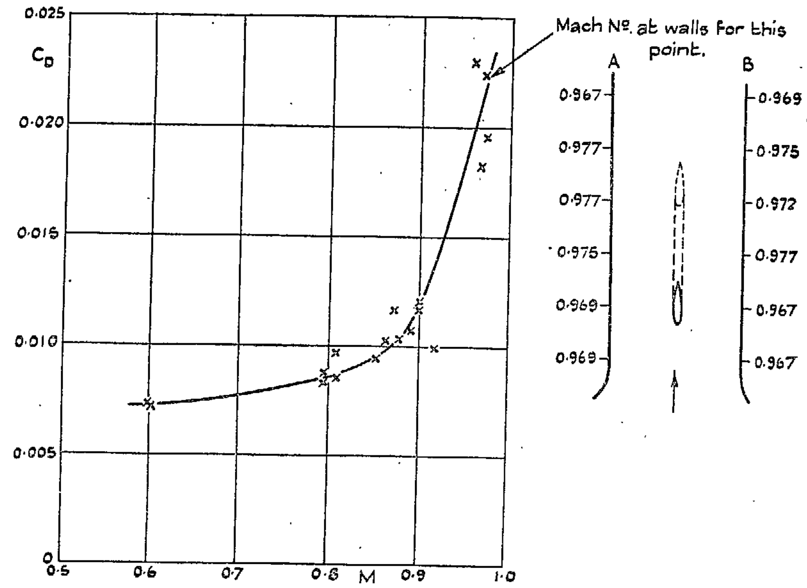


FIG. 4. Drag of NACA 0020 2-in. chord, yaw 40 deg.

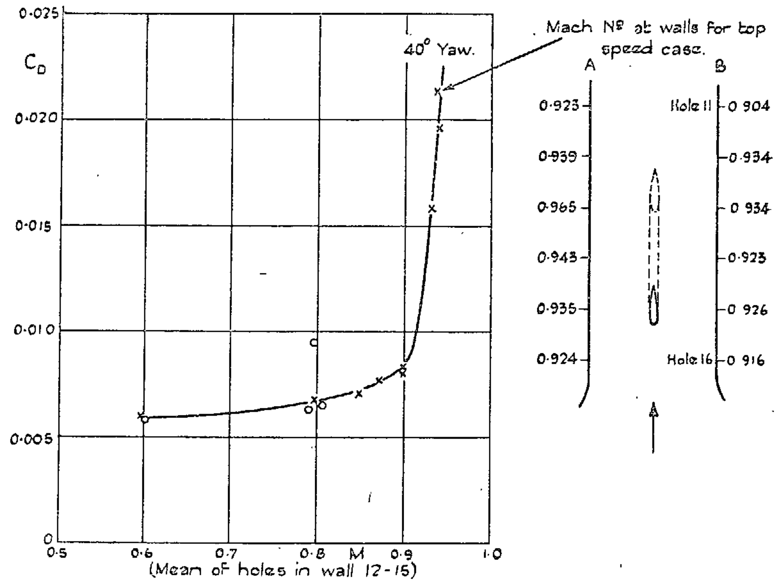


FIG. 5. Drag of Piercy 2040 2-in. chord, yawed 40 deg.

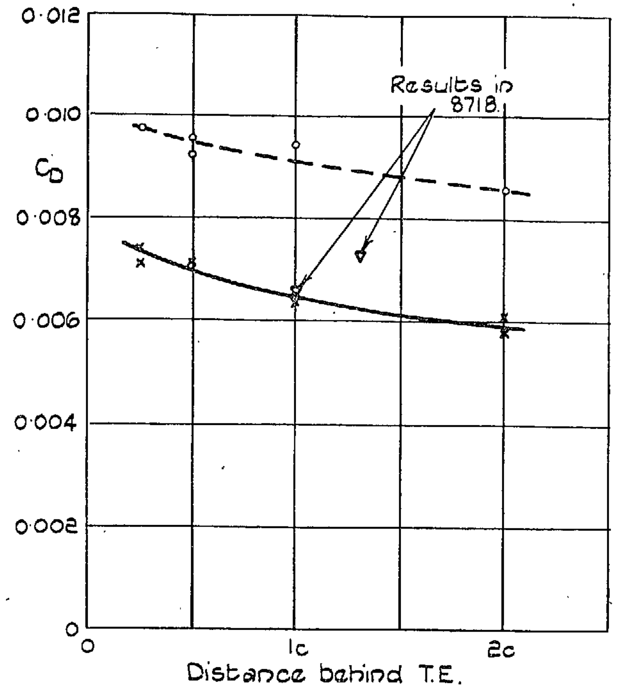


FIG. 6. Piercy 2040 at 40 deg yaw. $M = 0{\cdot}80$.

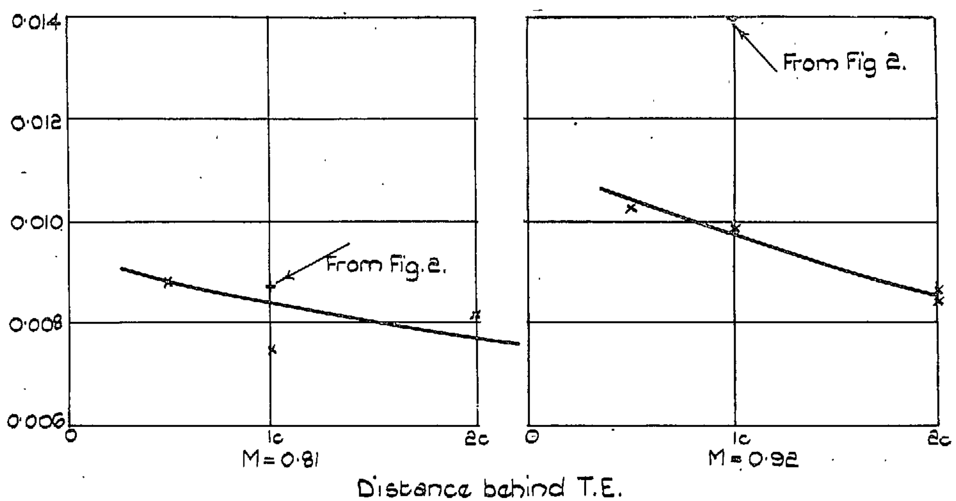


FIG. 7. NACA 0020 at 40 deg yaw.
Drag from wake traverse at different distances behind trailing edge.

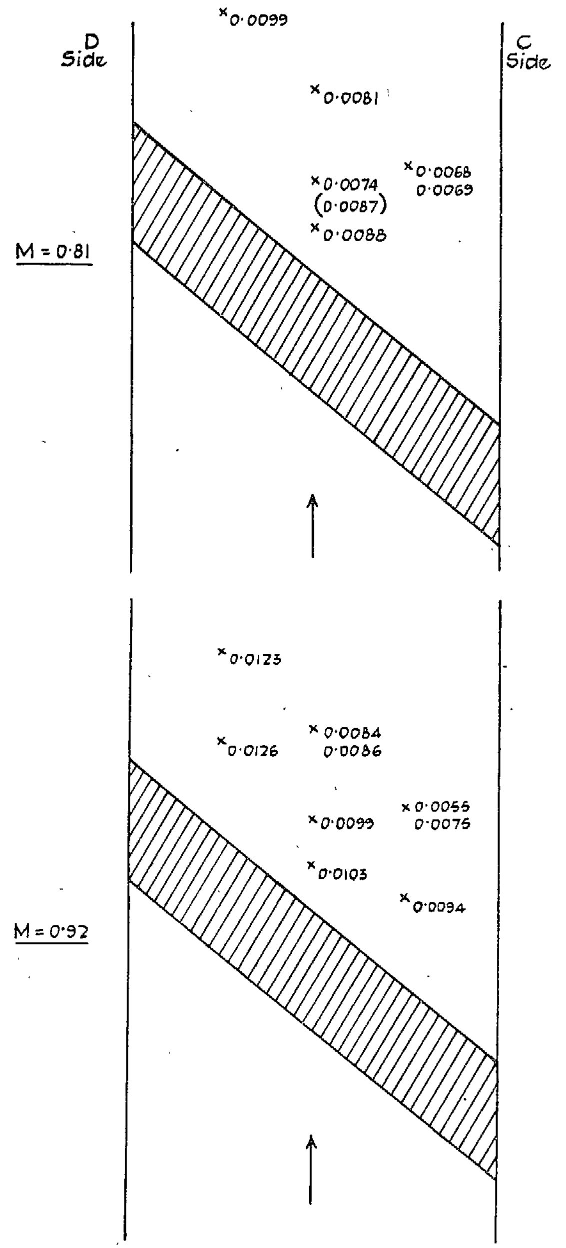


FIG. 8. C_D by wake traverse at various positions behind trailing edge—NACA 0020 2-in. chord.

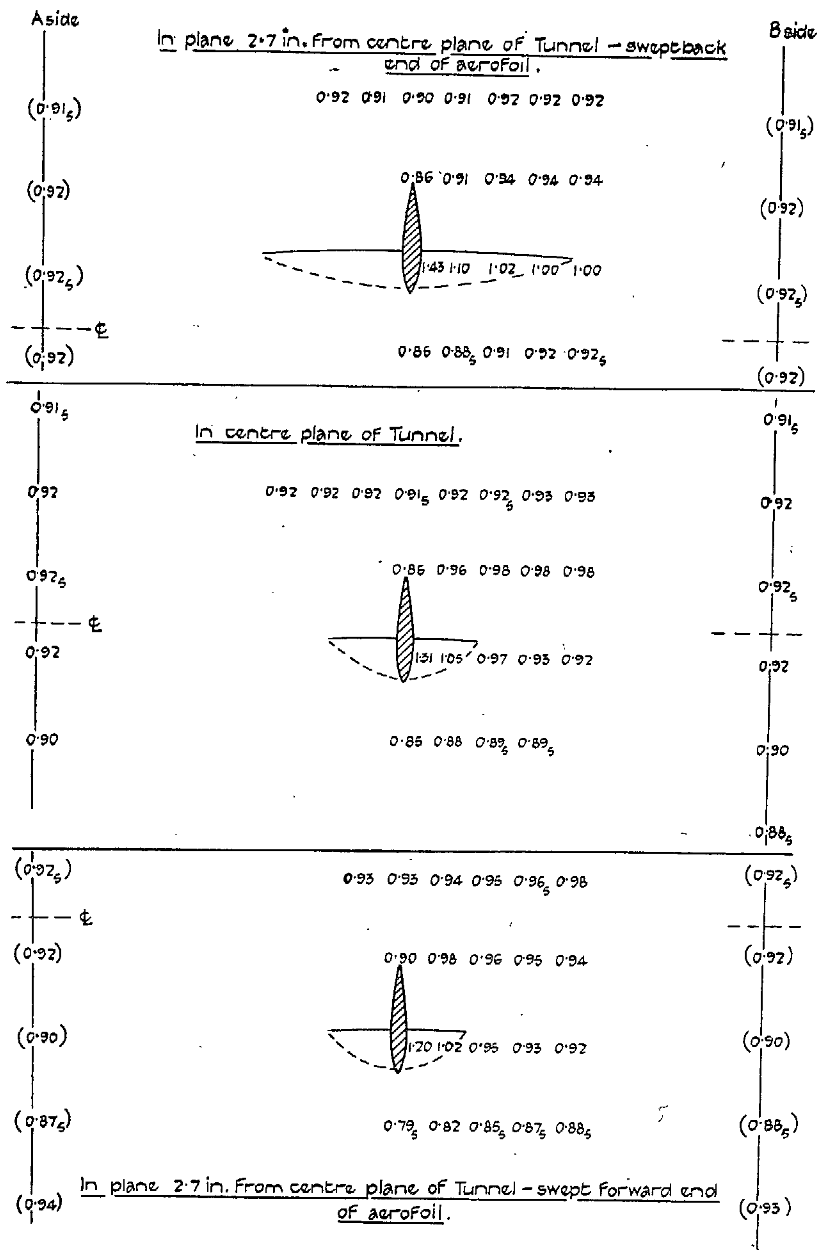


FIG. 9. Mach number around yawed aerofoil (NACA 0020 2-in. chord) $M_o = 0{\cdot}91$.

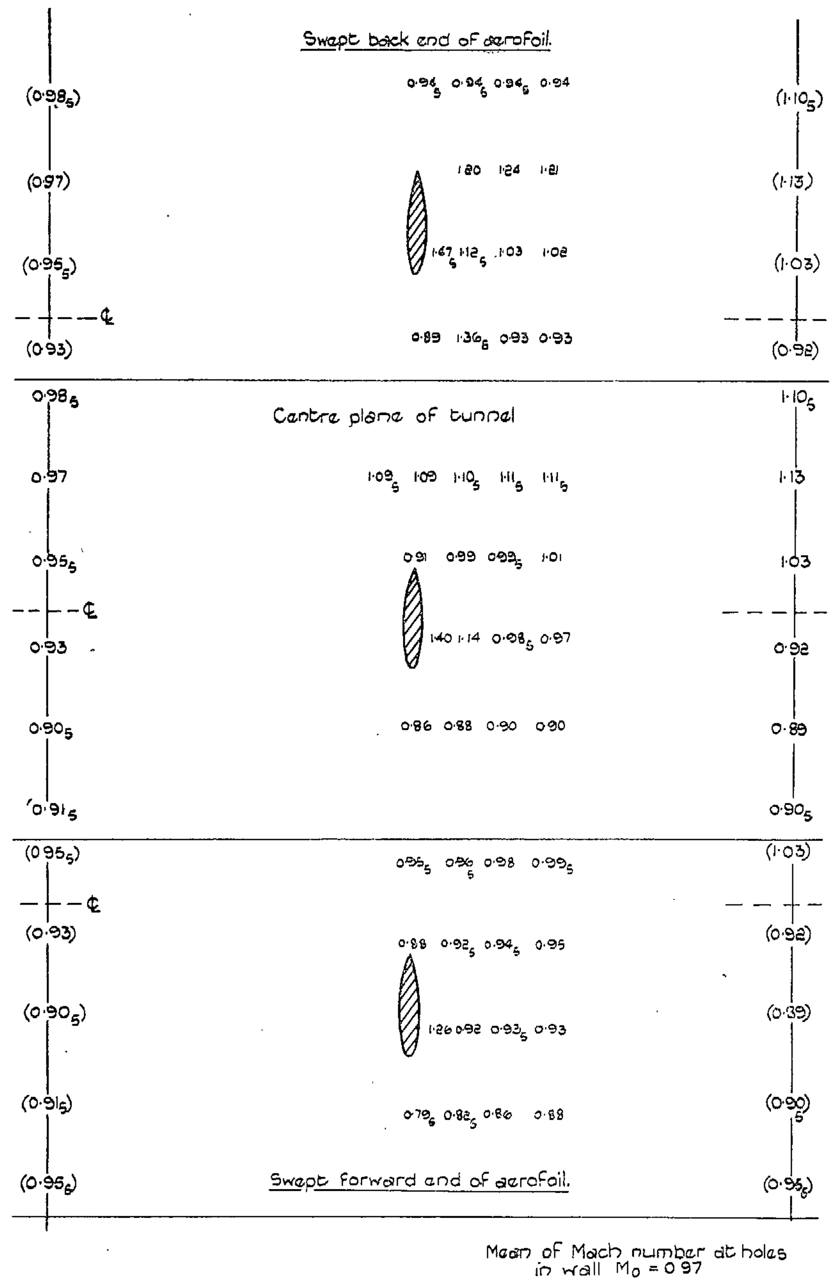


FIG. 10. Mach number around yawed aerofoil (NACA 0020 2-in. chord)

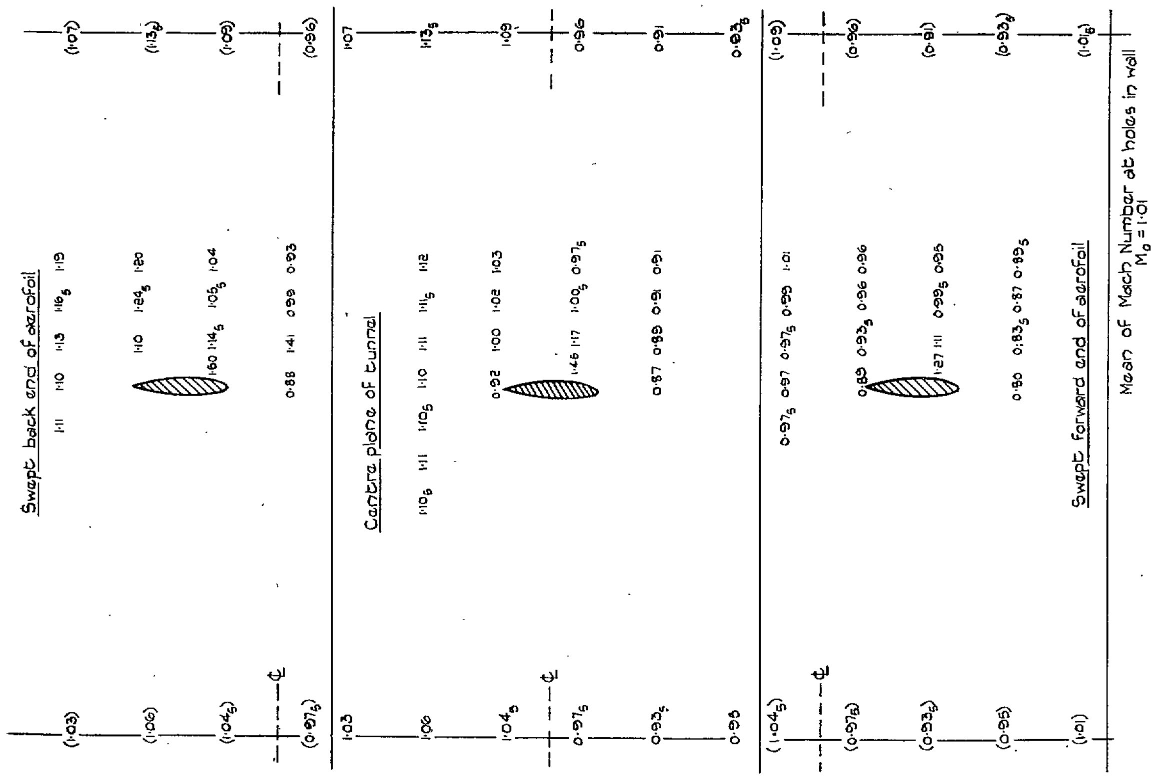
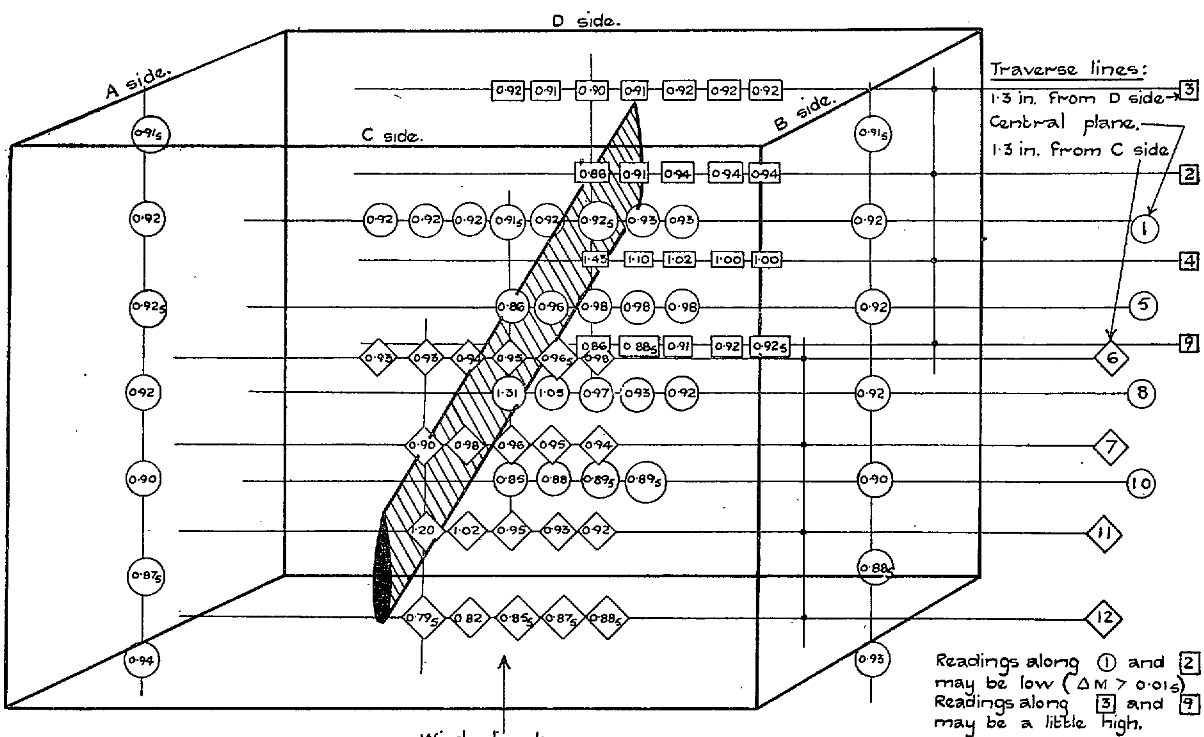


FIG. 11. Mach number around yawed aerofoil (NACA 0020 2-in. chord).



Mean T.S. (holes 12-15 A and B) M_0 = 0·910 C_D = 0·012 (From P.T. along ①)

FIG. 12. Mach number around yawed aerofoil.

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