CRITICAL MACH NUMBER FOR HIGH SPEED AEROFOIL SECTIONS

1. NOTATION AND UNITS

		SI	*British*
a	speed of sound in undisturbed air	m/s	ft/s
C_L	section lift coefficient at Mach number, M_c		
M	Mach number, V/a		
M_c	critical Mach number, V_c/a		
V	velocity of undisturbed air relative to aerofoil section	m/s	m/s
V_c	value of V for which speed of sound is first reached somewhere on aerofoil section	m/s	ft/s

2. NOTES

Figure 1 shows the critical Mach number, M_c, plotted against thickness/chord ratio for high speed aerofoils over a range of lift coefficients, C_L, and for elliptic cylinders at zero lift.

When designing a high speed aeroplane it is desirable so to proportion it that shock stalls are avoided or at least postponed to a speed outside the normal flight range. At some Mach number a little greater than the critical, shock stalling may be expected. Existing data are not comprehensive enough for the prediction of the margin between the critical and shock stalling Mach numbers in any particular case; for aerofoils it is known that this margin varies with such factors as Reynolds number, section shape and incidence and may range from 0 to 0.1 or even more in special cases. This margin is often greater for sections or flight conditions giving low critical Mach numbers than for those giving high critical Mach numbers. The critical Mach number can therefore only be regarded as providing a warning or limit which it is generally inadvisable to exceed under normal flight conditions.

For a thickness/chord ratio the highest critical Mach number will be given by an aerofoil with the lowest suction peak; at zero lift, this is given by an elliptic cylinder. The elliptic cylinder, however, is unsatisfactory as an aerofoil.

Aerofoils designed for lift coefficients other than zero will be cambered. For other reasons, where flight at Mach numbers beyond the critical is contemplated, uncambered sections may be used. Such sections will have lower critical Mach numbers than those given by this Item.

The curves in Figure 1 are representative of aerofoil sections which have been designed to have the highest critical Mach numbers at the lift coefficients quoted. The desired form of pressure distribution is, however, only obtainable over a small range of lift coefficients on either side of C_L. An aerofoil operating at a lift coefficient other than that for which it is designed may have a lower critical Mach number than that indicated; in such cases the critical Mach number will have to be obtained from the pressure distributions derived either by experiment or theory.

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The curves may be regarded as representative of sections of careful design for high speed flight. Sections commonly used in the past had high suction peaks and considerably lower critical Mach numbers.

To obtain these curves an approximate theory for the pressure distribution on an aerofoil has been used. For the types of section considered it is believed, however, that the error in M_c involved in the use of the approximate theory is of the order of 0.01.

3. DERIVATION

The Derivation lists selected sources of information that have been used in the preparation of this Item.

1. ZAHM, A.F. — Flow and drag formulas for simple quadrics. NACA Rep. 253, 1926.

2. OWEN, P.R. — Generalised curves for use in designing low drag wing sections. RAE tech. Note aero. 1073, 1942.

4. EXAMPLE

Find the maximum permissible thickness/chord ratio for a high speed section which is designed not to exceed the critical Mach number at a true airspeed of 200 m/s (390 knots) at a pressure height of 12 000 m in the International Standard Atmosphere, and a section lift coefficient, C_L, of 0.3.

From Item No. 78017, for a true airspeed of 200 m/s at 12 000 m, $M = 0.68$. Hence from Figure 1, with $C_L = 0.3$, the maximum permissible thickness/chord ratio is 0.15.

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