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Comparative Tests of Thick and Thin Turning Vanes in the Royal Aircraft Establishment 4 × 3-ft Wind Tunnel

By

K. G. Winter, B.Sc.

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COMMUNICATED BY THE PRINCIPAL DIRECTOR OF SCIENTIFIC RESEARCH (AIR),
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Summary.—The tests were made by replacing the existing centre six thick vanes at the first corner of the 4 × 3-ft wind tunnel by vanes of sheet metal.

The thin vanes reduced the corner loss, estimated from a wake traverse behind one vane, without any deterioration in outflow, and are therefore recommended for use in future wind tunnels.

1. *Introduction.*—The cascades fitted at the corners of return-circuit wind-tunnels are usually composed of vanes of an appreciable thickness, giving passages of approximately constant area round the corners. Such vanes, whilst quite satisfactory in operation, are difficult and expensive to construct. A need, therefore, was felt for further information on the use of thin vanes made of sheet metal, under actual operating conditions, tests[1, 2] at low Reynolds number having shown that there is little difference in the corner loss for thick and thin vanes.

Accordingly, comparative tests were made on thick and thin vanes fitted at the first corner of the 4 × 3-ft wind tunnel[3]. Originally, thick vanes (Fig. 1a) were fitted, there being fourteen vanes of gap: chord ratio 0·25. The six centre thick vanes were replaced by sheet metal vanes following the lines of the convex surface of the thick ones (Fig. 1b).

The tunnel section approaching the corner is circular and has a diameter of 6 ft.

2. *Measurement of Loss.*—To determine the overall loss at the corner, a very thorough traverse across the whole tunnel section would be required. This would have been difficult in the confined space between the first and second corners, and in order to obtain comparative results, would have involved replacing all the corner vanes. The comparison, therefore, was made on the basis of the drag computed from measurements in the wake of one turning vane by Jones' formula[4]:—

$$\text{Drag per unit length} = \tfrac{1}{2}\rho U_0^2 \int 2\left[g - \left(\frac{p_2 - p_0}{\frac{1}{2}\rho U_0^2}\right)\right]^{1/2}\left[1 - g^{1/2}\right] dz$$

where $g = 1 - \dfrac{h_2 - h_0}{\frac{1}{2}\rho U_0^2}$

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* R.A.E. Report Aero. 2217, received 17th November, 1947.

N.B. [illegible]

h total head

p static pressure

U_0 resultant stream velocity approaching turning vane

z distance normal to the direction of flow downstream of the turning vane and to the trailing edge of the vane

Suffix 0 applies before turning vane
,, 2 ,, after ,, ,,

The pitot static comb used was placed 5 in. above the tunnel centre-line and 12 in. downstream of the trailing edge of the seventh vane from the outside of the corner.

In order that calculated values of the loss coefficient could be compared with the measured values the surface pressures along the chord of the vanes were measured by means of creeper static tubes.

In addition to the profile drag measured by the wake traverse, there is an induced drag arising from the secondary flow in the passages of the cascade. A method of estimating this induced drag has been derived in a subsequent report[6].

3. *Results and Discussion.*—3.1. *Deflection.*—The direction of the outlet flow was checked with silk streamers, which showed that the deflection was roughly correct for the thick vanes but that the thin vanes produced an over-deflection of some 3 deg or 4 deg due to inaccuracies in construction and fitting. The static pressure measurements in the wake (Fig. 2) indicate a slight under-deflection for the thick vanes and an over-deflection for the thin ones.

3.2. *Loss.*—The loss coefficients calculated from the wake pressures (Fig. 2) are given in the table below, together with the losses estimated by the methods of R. & M. 1838[5] using the measured velocity distribution over the vanes (Fig. 3), and assuming transition near the leading edge. The results are given at the highest Reynolds number tested only, as the scale effect in the available speed range is within the experimental scatter.

TABLE 1

Values of C_p = *Drag per Unit Length of Turning Vane divided by* $\frac{1}{2}\rho U_0^2 \,.\, 2b \cos E$

$$R = U_0 c/v = 1 \cdot 9 \times 10^6$$

	Measured	Calculated	Buoyancy* Correction
Thick Vanes	0·065	0·052	0·009
Thin Vanes	0·033	0·040	Negligible

For the thick vanes the agreement between experiment and calculation is as good as can be expected with the large adverse pressure gradient following the peak suction on the nose (Fig. 3). For the thin vanes it is difficult to account for the measured value being lower than that calculated. The obvious explanation of the existence of some laminar boundary layer must be

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* The buoyancy correction is the drag to be added to both measured and calculated values due to the pressure gradient across the vanes. Its significance in the present case is uncertain but the table shows that it is not large.

discounted as a wire guard net is fitted in the tunnel upstream of the corner and will produce a turbulent stream. This was confirmed by fitting transition wires on the vane which increased the drag only by the drag of the wires. A possible explanation is that there exists some form of cross flow in the boundary layer on the vanes, giving a reduced thickness near the centre of the vane, though a tuft exploration failed to find such flow in the region of the measurements.

However it is clear that the expanding passage, created over the first part of the corner by using thin vanes, does not cause any separation of the boundary layer. Consequently the corner loss is less for thin vanes than thick ones because the air velocity over the surface of the vanes is reduced.

4. *Conclusions.*—With a gap/chord ratio of $\frac{1}{4}$ as tested the use of thin turning vanes instead of the normal thick ones reduces the corner loss without any deterioration in the outflow and is therefore recommended for future wind-tunnels.

LIST OF SYMBOLS

ρ	Density
h	Total pressure
p	Static pressure
U_0	Resultant stream velocity approaching cascade
z	Distance measured normal to span of vanes and to direction of outlet flow
$2b$	Spacing of vanes measured along corner diagonal
c	Chord of vanes
$2E$	Stream deflection at corner
C_p	Loss coefficient = drag per unit length of turning vane divided by $\frac{1}{2}\rho U_0^2 . 2b \cos E$

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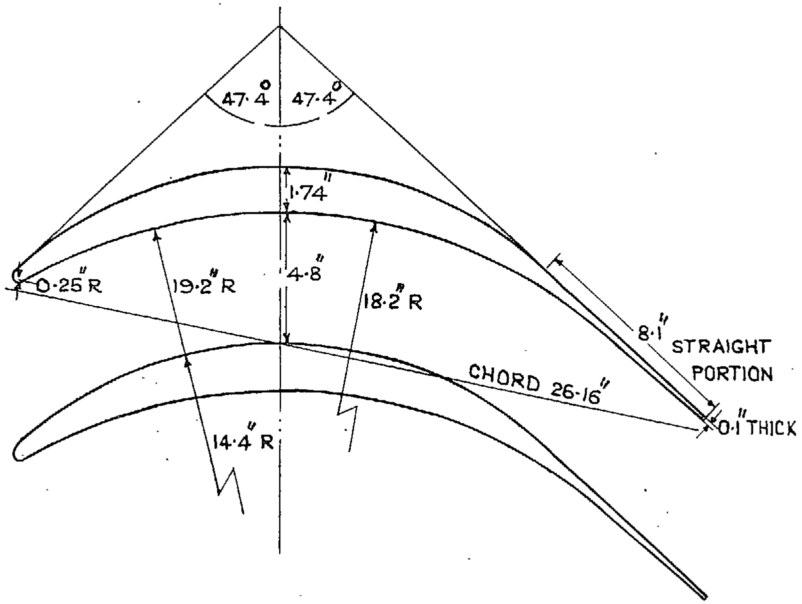
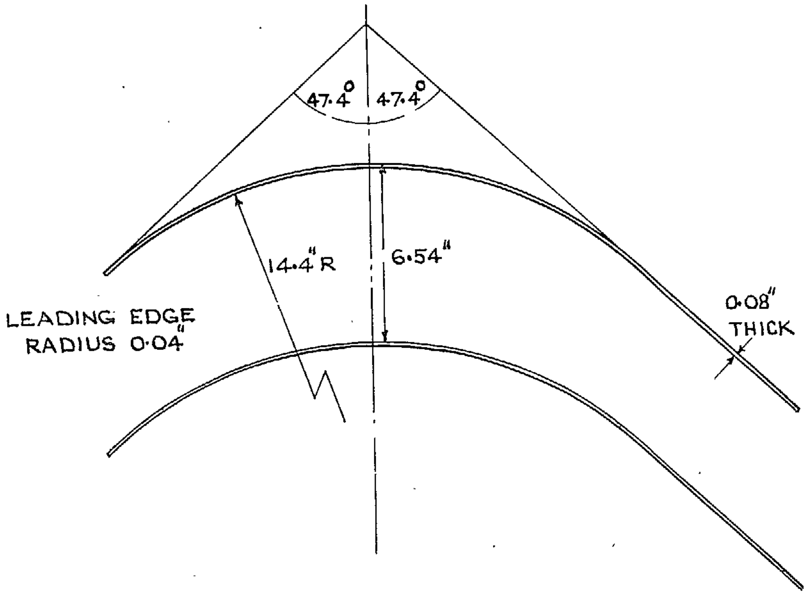


Thick turning vanes.



Thin turning vanes.

FIG. 1.

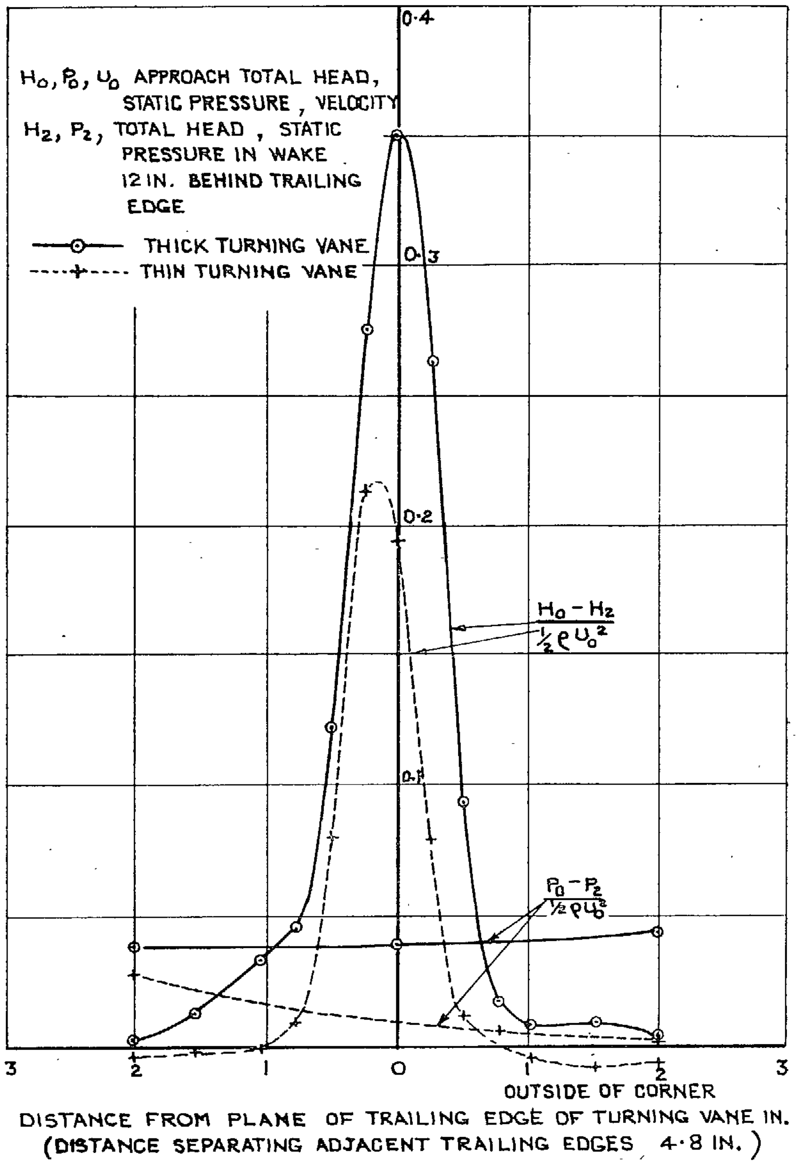


FIG. 2. Pressure distributions in wake of turning vane.

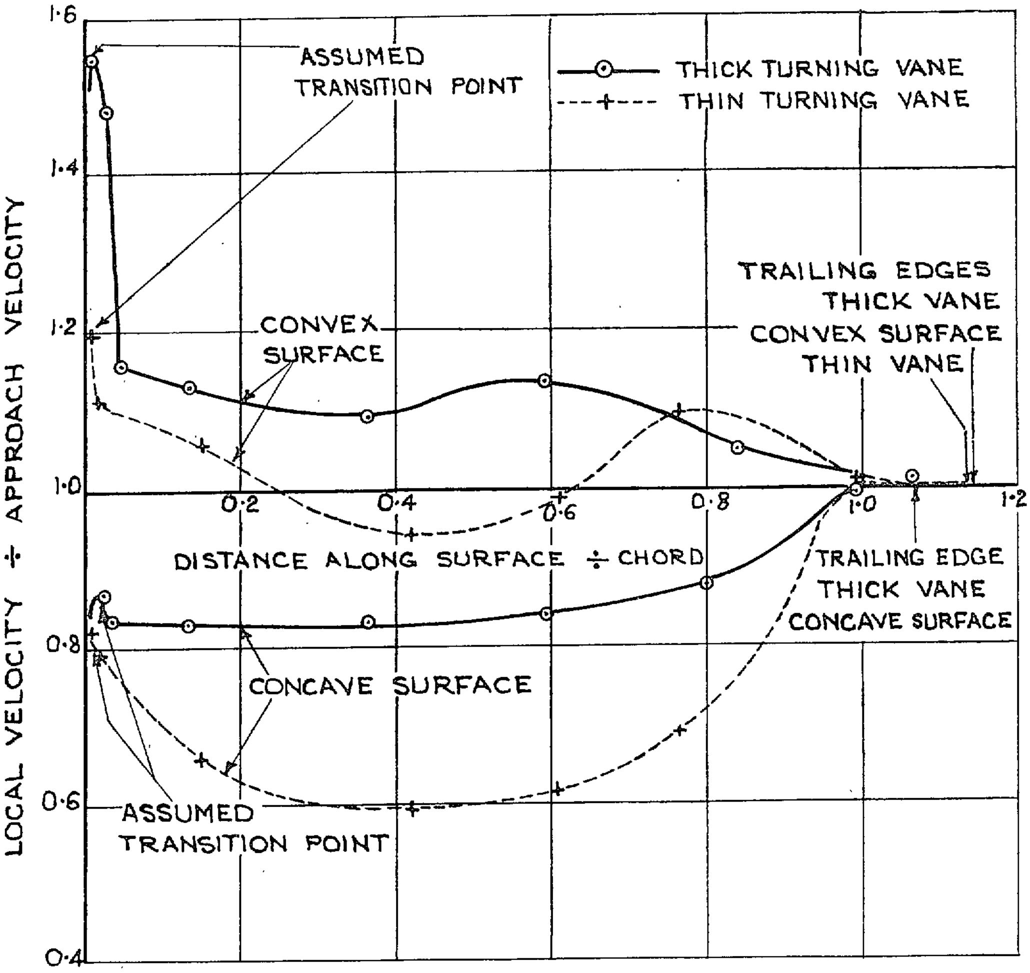


Fig. 3. Velocity distribution over turning vanes.

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