Base Pressure on a Blunt Base in Transonic Flow—Some Effects of Base Geometry and Bleed Air

An experimental investigation has been carried out on an aerofoil-like body having a thick square-cut trailing edge. Measurements of base pressure have been made for a range of mainstream Mach numbers from 0.6 to 1.3. The results also include measurements of vortex shedding frequency and schlieren photographs. Bleed air was discharged through the blunt base using three different configurations: (i) A wide two-dimensional slot; (ii) A narrow two-dimensional slot; (iii) A series of accurately bored discrete holes, equal in total area to the narrow slot. As the rate of discharge of bleed air was increased from zero the base pressure was found to rise to a maximum value before falling again at higher rates of discharge. At zero incidence the three configurations gave similar results but when incidence was applied the results were markedly different for the wide and narrow slots.

NOMENCLATURE

- C: chord length
- $C_p$: base pressure coefficient ($= \frac{P_b - P_{\infty}}{\frac{1}{2} \rho U^2}$)
- $Q$: bleed air mass flow coefficient ($= \frac{m}{2 \rho_{\infty} U_{\infty}}$)
- $f$: vortex shedding frequency
- $h$: half base height
- $i$: angle of incidence
- $M$: Mach number
- $m$: bleed air mass flow rate per unit span
- $P$: pressure
- $S_H$: Strouhal number ($= \frac{2hf}{U_{\infty}}$)
- $U$: velocity
- $x$: chordwise distance from trailing edge
- $\delta, \delta^*, \Theta$: boundary layer thickness, displacement thickness, momentum thickness
- $\rho$: density

SUBSCRIPTS

- $b$: at the base
- $\infty$: in the mainstream

INTRODUCTION

The base pressure on an aerodynamic body is an important factor in a variety of applications. The present work arose from an interest in the base pressure and associated losses occurring in turbine blades having a discharge of cooling air from the trailing edge. It is particularly concerned with the effects of base bleed and the interaction with vortices shed from the trailing edge.

Investigations in this area have been carried out for low speed flows by Wood (1) and Bearman (2). Observations of vortex shedding from cascades of turbine blades have been made by Heinemann, Lawaczek and Böteflisch (3, 4, 5) and from a blunt-based body in compressible flow by Pollock (6). Sieverding, Stanislas and Snoeck (7) carried out experimental measurements of base pressure on a model simulating the trailing edge of a turbine blade in cascade. Other experimental work, for example that of Tanner (8), has been concerned with the effect of trailing edge geometry on base pressure and base drag.

The present work was part of a more complete programme which has so far been carried out on a single aerodynamic body with a square-cut base mounted in a transonic wind tunnel and in air streams up to a mainstream Mach number of 1.3. Kadir and Gibbings (9, 10) performed comprehensive experiments in which the bleed air was discharged through a slot in the trailing edge. In a later paper Motallebi and Norbury (11) investigated the nature of the vortex shedding from the trailing edge and its influence on the base pressure through interaction with the bleed flow.

The object of the present investigation was to perform comparative experiments for the same aerodynamic body but with additional base geometries. In the first of these trailing edge slot (now called the 'wide' slot) was replaced by another of half the width - the 'narrow' slot. In the second the bleed air was discharged through a series of holes of circular cross-section, equal in total area to the narrow slot. This was only used in the experiments...
at zero incidence. Some measurements were also made on the model with a solid base having no aperture.

EXPERIMENTAL APPARATUS

Wind Tunnel and Model

The transonic wind tunnel used for the experiments has a working section 102 mm square, the upper and lower boundaries having slotted walls. The internal form of the wind tunnel in the vicinity of the working section is shown in Fig. 1a, which also indicates the position of the model and the schlieren windows. Compressed air was supplied by a four-stage centrifugal compressor giving a stagnation pressure of 3 bar and a mass flow of 5 kg/s. The air may be cooled and its humidity may be controlled. The bleed air was supplied by a reciprocating compressor and passed to the model via a receiver, pressure control valve and orifice plate, the last being used to measure the mass flow rate.

Fig. 1a Wind tunnel working section and diffuser

The profile of the model and its principal dimensions are shown in Fig. 1b, which also shows the profile of the interior duct for the original wide slot. Bleed air was supplied to the interior of the model through two circular tubes, symmetrically placed on each side, which formed the mounting for the model. The air was distributed spanwise along the enlarged section and passed rearwards through the duct of uniform height. The narrow slot was obtained by placing a liner in the rearward 19 mm of this duct. For the set of discrete holes used in the present experiment, the rearward 15 mm of the blade was replaced by a separate piece having the same external form. The solid base was formed by placing a metal filler strip inside the wide slot. Details of the trailing edge configurations are given in Fig. 1b.

The aft part of the model had an external contour similar to that of a supersonic nozzle and was designed to give a uniform flow, parallel to the trailing edge at zero incidence, for a mainstream Mach number of 1.3. The model could be set at different angles of incidence with respect to the tunnel. In this way different Mach number distributions could be created on the upper and lower surfaces giving, in particular, differences of local Mach number and boundary layer thickness across the trailing edge.

Transition wires, of diameter 0.18 mm, were fixed to the upper and lower surfaces at a chordwise distance of 12 mm from the leading edge. The Reynolds number, based on chord length and mainstream speed, varied from \(1.6 \times 10^6\) at \(Ma = 0.6\) to \(4 \times 10^6\) at \(Ma = 1.3\). Corresponding values based on base height were therefore \(0.8 \times 10^5\) and \(2 \times 10^5\).

Instrumentation

The mainstream Mach number was determined from measurements of total pressure, obtained as the static pressure in the large upstream settling chamber, and working section static pressure, measured by a tapping in the upper plenum chamber outside the slotted wall. Static pressure tapping points were distributed around the profile of the model, most being placed in the rearward part of the upper surface. The tapping point for the measurement of base pressure was placed near the mid-plane of the model (Fig. 1b). The same reading may be obtained from a pitot tube with its mouth placed immediately behind the tapping point. Furthermore, by traversing the pitot tube in a spanwise direction behind the trailing edge the variation of base pressure across the span may be measured. Representative results under different conditions showed that the spanwise variation of base pressure was small - not more than 2% of the mainstream dynamic pressure. These results were considered to confirm a satisfactory two-dimensionality of the basic flow.

Observations of vortex shedding from the base were made using both hot-wire equipment and a schlieren system (11). A hot-wire reinforced by a bridge of Araldite was used to obtain periodic signals generated by shed vorticity. The output was fed to a storage oscilloscope and the frequency was determined from the stored signals on the oscilloscope screen. The vortices were observed using a spark-schlieren system, the light source being an argon arc having a time duration of about 1 microsecond.

RESULTS AT ZERO INCIDENCE

Measurements with Zero Bleed

The variation of Mach number along the surface of the model, set at zero incidence, is shown in Fig. 2 for a range of values of mainstream Mach number, \(Ma\). Towards the trailing edge each curve exhibits a marked
Fig. 2 Suction surface Mach number distribution -
i = 0°, C = 0°
upturn, indicating the upstream penetration of the low base pressure occurring behind the trailing edge. The distance of this upstream penetration is reduced as the mainstream Mach number is increased.

For values of mainstream Mach number equal to or greater than 0.8 there is a region of supersonic flow over the upstream part of the body. This is followed by a shock wave which moves downstream and weakens as the value of \( M_\infty \) approaches 1.3.

Measurements of the boundary layer profile were made at a point 10.2 mm upstream of the trailing edge, just at the beginning of the final acceleration. Values of boundary layer thickness, displacement thickness and momentum thickness measured for the slotted base are given in Table 1. There is a significant reduction in boundary layer thickness as the Mach number increases.

These values are not used specifically in the present paper but are given as an indication of the boundary layer thickness relative to the base height, which was 7.62 mm.

\[ M_\infty \quad \delta \quad \delta d \quad \theta \]

<table>
<thead>
<tr>
<th>( M_\infty )</th>
<th>0.6</th>
<th>1.00</th>
<th>1.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \delta )</td>
<td>5.1</td>
<td>3.6</td>
<td>3.0</td>
</tr>
<tr>
<td>( \delta d )</td>
<td>0.74</td>
<td>0.69</td>
<td>0.61</td>
</tr>
<tr>
<td>( \theta )</td>
<td>0.44</td>
<td>0.36</td>
<td>0.31</td>
</tr>
</tbody>
</table>

Table 1 Boundary layer measurements for zero incidence at 10.2 mm upstream of trailing edge - thicknesses in millimetres

The variation of base pressure with \( M_\infty \) is shown in Fig. 3 for the three principal base configurations, the base pressure, \( P_b \), being non-dimensionalised with respect to the mainstream static pressure, \( P_\infty \). The curves all have the same general configuration, falling from values of about 0.9 at \( M_\infty = 0.6 \) to minimum values in the range of \( M_\infty \) between 1.1 and 1.2 and then rising sharply again as \( M_\infty \) approaches 1.3. In terms of base pressure coefficient,

\[ C_{pb} = \frac{P_b - P_\infty}{\frac{1}{2} \rho \omega^2} \]

the results give values around -0.5 in the lower range of \( M_\infty \), changing to the range of -0.7 to -0.8 for \( M_\infty \) between 1.0 and 1.1. As \( M_\infty \) increases further the values of \( C_{pb} \) change rapidly to values about -0.4 at \( M_\infty = 1.3 \).

The results show close agreement in the range of \( M_\infty \) up to 1.0 and again for \( M_\infty > 1.2 \). Between these limits there are quite significant differences.

Fig. 3 also shows the variation of Strouhal number for the three base configurations. Again they exhibit the same general character, remaining constant at about 0.2 in the range of Mach number up to 0.9 and then rising to maximum values corresponding to the minimum values of base pressure. The maximum value of Strouhal number for the wide slot is significantly higher than for the other two cases, corresponding to the lower minimum value of base pressure.

In the previous work described in Ref. 11 it was shown that the increase in base pressure from the minimum value corresponded with a shift of the region of vortex formation away from the immediate vicinity of the trailing edge. At values of \( M_\infty > 1.2 \) the vortices are formed downstream in the region of confluence of the trailing edge shear layers and the trailing edge shocks.

The rather surprising disparities between the base pressure results around the minimum values must presumably reflect the effects of the base geometry on the mechanics of the vortex formation just before the downstream shift occurs.

Effect of Base Bleed

The variation of base pressure with the base bleed mass flow is given in Fig. 4 for three values of \( M_\infty \). The bleed mass flow rate is expressed as a coefficient, \( C_q \), defined as

\[ C_q = \frac{\dot{m}}{2h \rho \omega^2} \]

where \( \dot{m} \) = bleed mass flow rate per unit span

\( 2h \) = base height

The spanwise distribution of the bleed flow was very uniform both for the narrow slot and for the base with circular holes. In these cases the mass flow rate
over the centre span was only about 2% or 3% different from the spanwise mean value. For the wide slot the uniformity was not quite so good, the disparity between centre span and mean values being about 13% for low rates of bleed and about 6% or 7% at the other end of the bleed flow rate.

The results shown in Fig. 4 exhibit only relatively small differences between the three base configurations. As the bleed flow rate increases from zero the base pressure rises in each case to a maximum value. Beyond the maximum further increases in blowing rate produce a more or less monotonic reduction of base pressure as $C_q$ increases.

In Fig. 5a the base pressure curve for the wide slot at $M_\infty = 1.0$ is presented, along with corresponding measurements of the Strouhal number of the shed vorticity. The general effect of base bleed on the nature of vortex formation has been described in Ref. 11. Four different flow regimes have been identified, one of which has no vortex shedding. The others are illustrated in Fig. 5b and the ranges over which they occur are indicated in Fig. 5a and other subsequent figures.

The effect of a small amount of bleed flow is to produce a rearward shift in the zone of vortex formation but without changing the basic nature of the
vortex flow (Regime I). This is accompanied by a rise in the value of base pressure. In Regime II no vortex shedding can be identified. This occurs over a range of $C_{\alpha}$ near to the value that produces the maximum base pressure.

In Regime III a symmetrical train of vortices is formed behind the lips of the trailing edge, alternately drawing fluid from the shear layers on the outer surface of the model and the shear layers of the central jet of bleed air. The vortex shedding frequency is much higher than that occurring in Regime I. Finally, Regime IV occurs when the central jet penetrates along the centre plane of the wake and two separate vortex trains are formed behind the outer lips of the base. The mechanics of the vortex formation in this regime is presumed to be similar to that occurring in Regime I but with the shear layers of the central jet interacting with the outer shear layers. In this regime the vortex shedding frequency usually increases quite rapidly with $C_{\alpha}$.

The results for the narrow slot and the circular holes are presented in Figs. 5c and 5d. This last is perhaps the most interesting. In the first place it should be remarked that vortex shedding does occur even though the bleed flow is discharged through a series of discrete holes—it is clearly not inhibited by the three-dimensional character of the flow in the immediate vicinity of the trailing edge. Furthermore the four regimes of vortex flow may be identified. However, the values of Strouhal number in Regimes III and IV rise with $C_{\alpha}$ much more rapidly than for the slotted base configurations and attain very much higher values as $C_{\alpha}$ approaches 0.3. At this end of the range the frequencies measured are of the order of 50 kHz. The differences between these values and those obtained for the slotted base configurations are not reflected in a corresponding difference in base pressure, as is evident from Fig. 4.

Corresponding results for a mainstream Mach number of 1.3 are presented in Figs. 6a, b and c. For the two slotted base configurations (Figs. 6a, 6b) the results are very similar to each other except for the highest measured value of Strouhal number in Fig. 6b. It appears that the effect of the difference in slot width is quite small. For the circular holes (Fig. 6c) the measurements of base pressure are very similar to those for the slotted bases except in the
Fig. 6c Variation of base pressure and Strouhal number with Cq for circular holes - θ = 0°, M∞ = 1.3

(Note that values of Strouhal number are presented as $\frac{1}{2} S_H$)

range of C between .02 and .08. There is no evident explanation of this disparity from the vortex frequency measurements. However in Regime III the Strouhal number starts at the very high value of 1.1 and increases to values around 1.7 at the upper end of the range of Cq.

Taking the results of Figs. 4, 5 and 6 together the general conclusion must be that at zero incidence the base pressure, for a given value of mainstream Mach number, is largely determined by the mass flow rate of the bleed air. For a given value of C the momentum flux of the jet from the wide slot is only about half that for the other two configurations but this difference in momentum flux appears to have little effect on the value of base pressure (except perhaps for $M_∞ = 0.6$ in the upper range of Cq). For the base with circular holes the vortex shedding frequency is much higher than for the two slotted configurations in the upper range of C but this again appears to have little effect on the values of base pressure.

RESULTS AT ANGLES OF INCIDENCE

Measurements with Zero Bleed

The variation of base pressure with mainstream Mach number for the wide slot is given in Fig. 7 for four angles of incidence ranging between 0° and 6°. The general form of the curves has been explained in Ref. 9 and may be considered in conjunction with the measurements of Mach number distribution on the suction surface which are given in Figs. 2, 8a, 8b and 8c.

At an incidence of 2° the values of base pressure are higher than those for zero incidence in the lowest range of Mach number (Fig. 7). This probably results from the thinner boundary layer produced at the trailing edge on the suction surface by the stronger adverse pressure gradients. In the middle range of Mach number the results correspond closely with those for zero incidence. However the increase in base pressure corresponding with the rearward shift of the zone of vortex formation occurs at a lower value of mainstream Mach number - about 1.14 compared with about 1.20 for zero incidence. This may be associated with the higher local values of surface Mach number occurring near the trailing edge at positive incidence.

When the angle of incidence is 4° the shock wave on the suction surface causes thickening of the boundary layer for values of $M_∞ < 0.9$ with a corresponding raising of the base pressure (Fig. 7). This effect disappears between $M_∞ = 0.9$ and 1.06. For higher values of $M_∞$ the base pressure rises again, corresponding with the change in the point of origin of the vortices. In fact the curve of Strouhal number against Mach number for this value of incidence is given in Fig. 7. The maximum value may be seen to correspond closely with the minimum value of base pressure.

By comparison with the values of Strouhal number for zero incidence (Fig. 3) the results for 4° incidence attain a higher maximum value, of 0.38, at a lower value of mainstream Mach number. For these two conditions the actual values of vortex shedding frequency are about equal at approximately 17 kHz. It was pointed out in Ref. 11 that this frequency is approximately that corresponding to the transverse travel of a pressure pulse at sonic speed if about half of each of the two trailing edge shear layers is traversed.

When the angle of incidence increases to 6° the suction surface boundary layer remains separated at
the trailing edge for values of $M_\infty$ up to about 1.0, with correspondingly higher values of base pressure (Fig. 7). The minimum value of base pressure is higher than that in the other cases but as the mainstream Mach number approaches 1.3 the value of base pressure appears to be almost independent of the angle of incidence.

Spark-schlieren photographs taken at $4^\circ$ incidence and for $M_\infty = 1.0$ and 1.3 are shown in Fig. 9.

At $M_\infty = 1.0$ the vortices are forming immediately behind the trailing edge whilst at $M_\infty = 1.3$ they form in the region where the free shear layers meet the trailing oblique shocks. In both photographs the zones of expansion near the trailing edge are evident and in Fig. 9b there is evidence of the separation shock springing from the lip of the trailing edge on the lower surface, as well as the trailing shocks. The trailing shock waves observed in Fig. 9a oscillate in correspondence with the shedding of the vortices.

Measurements of base pressure and Strouhal number are given in Fig. 10 for the narrow slot and for the model with solid base at $4^\circ$ incidence. The base pressure results for the narrow slot differ in some
Fig. 10 Variation of base pressure and Strouhal number for narrow slot and solid base - $\theta = 4^\circ$, $C_q = 0$

Fig. 11 Variation of base pressure with $M_x$ for narrow slot and solid base - $\theta = 6^\circ$, $C_q = 0$

Fig. 12 Variation of base pressure with $C_q$ for wide and narrow slots - $\theta = 4^\circ$

Fig. 13a shows the variation of Strouhal number (and base pressure) for the wide slot and may be compared with Fig. 5a which gives the corresponding results at zero incidence. The values of $S_H$ are lower in Regime I, while Regimes II and III occur over

Effects of Base Bleed

At $\theta = 4^\circ$ The variation of base pressure with base bleed flow rate is shown in Fig. 12 for the two slotted bases at $4^\circ$ incidence. The results are in notable contrast to those obtained at zero incidence. The wide slot gives consistently higher values of base pressure, although at $M_x = 0.6$ the difference is only appreciable at higher values of $C_q$.

At $M_x = 1.0$ the narrow slot gives measured values of base pressure lying below those occurring at zero incidence. On the other hand for the wide slot the results are generally higher. In fact after the initial increase as $C_q$ increases from zero the base pressure remains nearly constant over a range of $C_q$ up to 0.2 before a reduction which occurs as $C_q$ increases beyond this value.

At $M_x = 1.3$ the results for the narrow slot again have a well defined maximum, higher than that occurring at zero incidence. At values of $C_q > .06$ they are not very different from the results at zero incidence. For the wide slot the base pressure is again higher over the whole range of base bleed flows with a fairly flat maximum occurring at a value of $C_q$ of about .07.

Fig. 11 gives corresponding base pressure results for $6^\circ$ incidence. Again the measurements for the narrow slot differ to some extent from those observed for the wide slot, especially in the Mach number range between 1.0 and 1.1. There is a very close correspondence for the narrow slot and the solid base. No measurements of vortex shedding frequency have been made at this incidence.

respects from those obtained for the wide slot although, as may be seen from the figure, they correspond closely with measurements made for the solid base. The results again illustrate the effect of base geometry even in the absence of bleed flow. As in the case of zero incidence the measured values of Strouhal number lie significantly below those obtained for the wide slot.
only a small range of $C$. In Regime IV different frequencies were observed for the two vortex trains on either side of the central jet. Those plotted in the figure resulted from the vortex train originating from the suction surface shear layer and were about 50% higher than the values observed for the other vortex train. These results may reflect the difference in local Mach number of the flow approaching the trailing edge. At zero incidence this was about 1.16 (Fig. 2) whilst at $4^\circ$ incidence it was about 1.41 on the suction surface (Fig. 8b) and about 0.35 lower on the pressure surface.

The results given in Fig. 13a shows that the reduction in base pressure for $C > 0.2$ is associated with a sharp rise in the vortex shedding frequency. Corresponding results for $M_\infty = 1.3$ are presented in Fig. 13b which may be compared with Fig. 6a for zero incidence. The vortex shedding again exhibited asymmetry in Regimes III and IV, Regime III being initiated on the pressure side at a higher value of $C$ and the frequencies in Regime IV being lower on the pressure side than the values measured on the suction side, which are plotted. These values differ little from those for zero incidence, although the measured values of base pressure are very much higher for all values of $C > 0$.

Spark-schlieren photographs are shown in Fig. 14 to illustrate the three regimes of vortex shedding for $M_\infty = 1.0$. Fig. 14a, which may be compared with Fig. 9a, shows the rearward shift of the vortex origin produced by a very small amount of bleed air. In Fig. 14b the flow is in Regime III, the trailing shocks springing from points near to the corner of the trailing edge. At the higher value of $C$ shown in Fig. 14c the flow is in Regime IV. The shear layers of the internal flow and the expanding base bleed flow may be observed and the trailing shocks originate in the region where the shear layers combine and the vortex trains are formed.
Corresponding Spark-schlieren photographs are shown in Fig. 15 for $M_\infty = 1.3$. Fig. 15a shows the rearward shift of the vortex origin for a small value of $C_q$. Figs. 15b and 15c are not very clear near the trailing edge but there are visible differences in the nature of the wake.

At $i = 6^\circ$ the variation of base pressure with base bleed is shown in Fig. 16 for $6^\circ$ incidence. The additional incidence produces little effect at $M = 0.6$ and $M_\infty = 1.3$ (compare Fig. 12). At $M_\infty = 1.0$ there is a very marked effect.

For $C_q = 0$ there is a considerable disparity between the measured values of base pressure for the wide slot and narrow slot. In this range of $M_\infty$ the base pressure is very sensitive both to incidence and Mach number (Fig. 7) and the results for zero bleed are markedly different for the wide slot from those for the narrow slot and the solid base (Figs. 10 and 11). This sensitivity arises from the separated or
For the narrow slot the initial effect of base bleed is the expected rise in base pressure, but beyond the maximum value an initial fall is followed by a region of constant values.

Discussion

In consideration of the experimental results at incidence, two striking features emerge.

First, in the absence of base bleed, all the results come quite close together at $M_\infty = 1.3$. Although the base pressure is strongly affected by incidence and to some extent by base geometry over almost the whole range of mainstream Mach number, all the values of $\frac{p_b}{p_{in}}$ come near to 0.55 as $M_\infty$ approaches 1.3. Furthermore, at this Mach number, the effect of the bleed flow through the narrow slot changes little with incidence.

Second, there is the contrast in the effect of bleed flow on base pressure for the two slot geometries. At zero incidence (Fig. 4) the base pressure varies with base bleed flow rate in a very similar manner for each of the three base configurations at each of the three values of Mach number. However, at both $\theta = 4^\circ$ and $6^\circ$ incidence, the wide and narrow slots give quite different results. The difference is not so marked at low values of $C_q$, where the effect of a small bleed flow in shifting the vortex origin is probably the governing factor. However, the differences are especially marked for higher values of $C_q > 0.06$. The base pressures resulting from blowing through the narrow slot are much lower than those for the wide slot. It is not easy to formulate the details of the interaction between the base bleed and the external flow, or the possible role of the shed vortices. However, for a given value of $C_q$ the momentum flux through the narrow slot is about twice as high as that through the wide slot and this may be the determining factor. It is not evident why it should be so much more important at the higher angles of incidence than it is at zero incidence.

Conclusions

Experimental results have been obtained for the base pressure occurring on the plane base of a symmetrical aerodynamic body in two-dimensional compressible flow taking account of the effects of a flow of bleed air through apertures in the base. Three different base aperture geometries have been investigated and special attention has been given to the role of vortices shed from the trailing edge.

At zero incidence and in the absence of base bleed, the different base geometries produce observable differences in base pressure over the range of mainstream Mach number between 1.0 and 1.2. Within this range, the zone of vortex formation shifted rearward from the immediate vicinity of the base to the region of confluence of the trailing edge shear layers and the trailing shock waves.

The effect of a base bleed flow was quite similar for the three different base geometries. Vortex shedding occurred even in the case of discharge through circular holes. Small amounts of bleed air moved the zone of vortex formation rearwards, giving an increase in base pressure. At higher rates of bleed flow, two additional regimes of vortex shedding were observed for each base geometry and the base pressure was reduced monotonically from its maximum value.

Experiments were also carried out at angles of incidence giving a difference in pressure distribution on the two surfaces of the model. At zero bleed the
effect of increasing incidence was to increase the base pressure over particular ranges of mainstream Mach number. The effect was greater for the base with the wide slot. In fact the results for the base with the narrow slot were virtually identical to those for the solid base in respect of both base pressure and of vortex shedding frequency.

The effect of base bleed flow was markedly different for the wide and narrow slots, by contrast with the zero incidence results. For the narrow slot the variation of base pressure with bleed mass flow was only slightly affected by the increase in incidence. For the wide slot the increase in incidence produced a substantial increase in base pressure over practically the whole range of bleed air mass flow coefficient.

ACKNOWLEDGEMENTS

The work represented part of a research programme being carried out with support by a Research Grant from the Science and Engineering Research Council of Great Britain (GR/A51174) and some of the earlier research was supported financially by Rolls-Royce Limited. This support is gratefully acknowledged.

Invaluable technical assistance, especially in the demanding task of running the transonic tunnel was given by Mr. John Paterson, Mr. Derek Smith and Mr. Andrew Davies.

REFERENCES


8. Tanner, M., "Experimental investigation of the drag of wings with a blunt trailing edge at transonic speeds", AGARD CP-83-71, pp. 8-1 and 8-6, 1971.

