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An Investigation of the Disturbances Caused by a Reflection Plate in the Working-Section of a Supersonic Wind Tunnel

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COMMUNICATED BY THE PRINCIPAL DIRECTOR OF SCIENTIFIC RESEARCH (AIR), MINISTRY OF SUPPLY.

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Summary.—An investigation has been made of the disturbances caused by a reflection plate, mounted clear of the boundary layer in a supersonic tunnel. Static traverses were made, mainly at a Mach number of 1·4 above four reflection plates having different plan forms, with various conditions in the passage between the plate and the tunnel wall.

In the region above the plate two main disturbances were found; there was a small disturbance from the leading edge and a disturbance further downstream which had originated beneath the plate. Between the two there was a region of approximately constant pressure in which a model could be located. The forward disturbance seemed unavoidable. Increasing the area of the passage beneath the plate by a recess in the tunnel wall, was the most effective way of moving back and reducing the magnitude of the disturbance at the rear. With the best arrangement, at a Mach number of 1·4, it was found possible to obtain a region of approximately constant pressure, extending downstream from the apex of the plate for a distance of about 0·66 times the height of the tunnel.

A plate spanning the tunnel was found to be unsuitable because of disturbances originating at the extremities of the leading edge, in or near the tunnel boundary layer.

1. *Introduction.*—Half-model technique has been used for some time in both subsonic and supersonic wind tunnels. It is applicable to models which are symmetrical about a plane parallel to the wind direction, and consists, in effect, of substituting a flat plate for this plane of symmetry. It is supposed that the flow appropriate to the complete model is simulated correctly by the half-model, together with its image in the plate.

At subsonic speeds, the plate should extend large distances upstream and downstream of the model, whereas in a supersonic tunnel the plate may be much smaller since it need not extend upstream further than disturbances produced by the model. This note is concerned exclusively with the latter application.

The technique has the advantages that for a given size of tunnel a larger Reynolds number can generally be achieved than with a complete model, and extraneous supports may be dispensed with since the model is fixed at its root to the plate. The reflection plate technique is, moreover, attractive mechanically since it simplifies considerably the problem of leading pressure tubes through the model and out of the tunnel.

* R.A.E. Technical Note Aero 2084, received 16th April, 1951.

Half-model tests have occasionally been made with the model mounted so that the tunnel wall acts as the reflection plane (Current Paper 7[1]). Such tests are not entirely satisfactory because of the comparatively thick boundary layer on the tunnel wall, which leads to an uncertainty in defining the exact position of the reflection plane, and also interferes with the flow over the model. The boundary layer on the tunnel wall could be reduced in thickness by using a suction slot ahead of the model, but such a method would require a specially designed working-section and special pumping equipment ; moreover, the suction slot might, itself, be expected to introduce a disturbance to the flow similar to that found in tests on a reflection plate spanning the tunnel (*cf.* section 3). An alternative and more usual method is to install a separate reflection plate some distance from one of the tunnel walls, so that the passage between it and this wall forms a by-pass for the wall boundary layer. One possible arrangement is to have a fixed plate completely spanning the tunnel, with a model free to rotate in pitch relative to it, but this scheme is not convenient mechanically. A more satisfactory mechanical arrangement is to have the model rigidly connected to a plate which only partly spans the tunnel, and which is free to rotate in its own plane. Such an arrangement is shown in Fig. 2.

The tests described in this Note have been made with the object of developing a reflection plate which would be suitable for use with existing models of swept-back wings. The property required of the plate was that it should introduce negligibly small disturbances into the flow about the model. One plate spanning the tunnel, together with three different plates which were free to rotate with the model, were examined.

Emphasis was placed on the lower Mach number range (*i.e.*, in the neighbourhood of 1·4, the lowest practicable Mach number which can be attained in the Royal Aircraft Establishment 9 in. × 9 in. Tunnel), since it was found that it became progressively more difficult to avoid disturbances from the plate as the Mach number was reduced.

The work was carried out in the R.A.E. 9 in. × 9 in. Supersonic Tunnel, during the period from March to December, 1949.

2. *Design Considerations*.—2.1. *Aerodynamic*.—The minimum size of reflection plate is determined by the condition that the plate should behave strictly as a reflecting surface to the flow over the model. At supersonic speeds and in an inviscid flow this condition requires an area of plate bounded upstream by the shock-wave from the nose of the model, and downstream by the trace in the plane of the plate of the rearmost forward facing Mach cone from the model surface. The area of the plate determined in this manner is shown in Figs. 3 and 6, for constant-chord swept-back and delta-wing models.

In a real fluid the type of idealised reflections from the plate assumed above may not be realised, owing to the presence of a boundary layer on the plate. Thus a disturbance originating at the model may, on striking the plate, be partially propagated upstream through the plate boundary layer[2], and on this account the reflected disturbance may be more diffuse than that predicted from inviscid-flow considerations. The effects of this diffusion near the leading edge of the model can be minimised by arranging the front of the reflection plate to be as close as possible to the nose of the model (*see* for example, Fig. 6), so as to ensure that the plate boundary layer is of minimum thickness.

Interaction between the flow about the model and the plate boundary layer is likely to be most pronounced towards the rear of the model and is probably an essential feature of the half-model technique. It can only be eliminated by applying continuous boundary-layer suction to the plate. However, it is not yet known whether such interactions seriously distort the flow about the model.

In this Note, only the disturbances which are introduced to the flow by the reflection plate, in the absence of a model, are considered. The various ways in which these disturbances may arise are discussed below.

2.1.1. *Disturbances due to misalignment of the plate.*—The upper surface of the plate may be not quite in line with the free-stream direction. The air passing over it will then be deflected and a change in pressure will result. In the present tests the plates were always set so that their upper surfaces were as near as possible parallel to the side walls of the tunnel. However, slight bending under aerodynamic loads occurred with plates having a large overhang relative to their support (*cf.* Fig. 9).

2.1.2. *Leading-edge disturbance.*—With ideal conditions at the leading edge, the air flowing above the plane containing the upper surface of the plate should be unaffected by the edge, while the air stream below this plane is deflected by the bevel (*see* for example, Figs. 2 and 3), through an attached shock-wave. These ideal conditions will not be achieved if the velocity component perpendicular to the edge is subsonic, or if it is supersonic, but too small for an attached shock-wave to deflect the flow through the angle of the bevelled edge. The theoretical two-dimensional wedge angles through which an air stream may be deflected by an attached shock-wave are given below.

Mach number component perpendicular to the edge	Maximum angle (deg)
1·0	0
1·1	1·5
1·2	3·8
1·3	6·6
1·4	9·4

In practice it was found desirable to restrict the maximum angle to about 0·8 of that given in the table.

A disturbance originating from the leading edge of the plate was present with all the plates tested. The pressure variation is limited approximately to the region of the Mach sheet spreading backwards from the leading edge of the plate, and is of comparatively small magnitude. In all cases, the bevel angle was 5·7 deg, measured perpendicular to the edges. Of the four plates tested, only the one spanning the tunnel, with its leading edge perpendicular to the free-stream direction, complied with the requirements for an attached leading-edge shock-wave. Nevertheless, a disturbance was found to be present in this case, of the same order of magnitude as that occurring with the other plates.

The cause of this leading-edge disturbance is not fully understood, but it is possible that, in spite of the efforts made to obtain a razor-sharp leading edge, some small rounding existed, which presumably would produce a weak detached shock-wave, followed by an expansion around the leading edge. The form of the pressure disturbance, as shown for example in Fig. 8, is indicative of this type of flow. Another possible cause of the disturbance is the rapid growth of the boundary layer on the surface of the plate near its leading edge ; on this basis, a disturbance may be expected even when the leading edge is perfectly sharp.

2.1.3. *Disturbances originating beneath the plate.*—The air flowing through the passage beneath the plate suffers changes of pressure which may be propagated round the side edges of the plate, thereby affecting the flow in the region occupied by the model. The cross-section of the stream-tube containing this air is reduced from its area ahead of the plate, firstly by the bevelled edge, and then by the presence of the support. If the contraction is too great, choking will occur, and the higher pressure in the subsonic region will cause the air to spill round the side edges of the plate. In order to prevent choking, the passage area was increased by making a recess in the tunnel wall beneath the reflection plate.

In the 9 in. × 9 in. Tunnel this was most conveniently carried out by putting a packing ring round the edge of the turret plate in which the model support is fixed, so that its surface was no longer flush with the side of the tunnel (*see* Fig. 4). The plan area of the recess so provided was in general too large for the reflection plates ; that is, the expansion associated with it would have been propagated across the working-section instead of being confined to the passage beneath the plate. The recess area was therefore adjusted by brass blanking plates of the appropriate thickness.

For the present tests, recess depths of 0, 0·2, 0·3 and 0·5 in. were used. The ratios of the minimum cross-sectional area of the passage beneath the plate to the cross-sectional area of a free-stream tube containing the same mass flow are given below.

Recess depth (inches)	0	0·2	0·3	0·5
$\dfrac{\text{Passage area}}{\text{Free-stream area}}$	0·90	1·00	1·06	1·20

These figures apply to all the reflection plates tested. It will be seen that recesses of 0·3 and 0·5 in. provided an expansion of the flow beneath the plate.

The minimum value of the above ratio to achieve supersonic flow in a tunnel at a Mach number of 1·4, as given by one-dimensional theory, is 0·936. It would be expected, therefore, that with no recess the flow would be unsatisfactory.

If the disturbances transmitted round the edges of the plate are small, it can be assumed that they are propagated along Mach lines. The only area of the reflection plate from which such disturbances can affect the model is that included in the rearmost forward-facing Mach cone from the model. If the free stream has a supersonic velocity component perpendicular to an edge of the plate, with an attached shock-wave on the undersurface, no small pressure change can be propagated round this edge. It is advantageous therefore to arrange the shape of the reflection plate so that these conditions exist along the whole edge of the plate within the rearmost forward-facing Mach cone from the model. In the present tests only type 3 reflection plate had a supersonic component along the whole length of the edges in this region. It was not possible however to reduce the bevel angle sufficiently to ensure an attached shock-wave on the under-surface.

2.1.4. *Disturbances propagated upstream in the plate boundary layer.*—Pressure disturbances produced at the trailing edge of the reflection plate may be propagated upstream through the plate boundary layer and so affect the flow about the model. It is therefore advisable to extend the plate some distance downstream of the rearmost forward-facing Mach cone from the model.

2.1.5. *Disturbances caused by the tunnel boundary layer.*—There is evidence of a further disturbance arising from the region where the plate enters the boundary layer on the tunnel wall.

2.2. *Mechanical.*—One of the main problems in the use of half-model technique at low Mach numbers is that of securing adequate strength and stiffness of the plate and its support and, at the same time, keeping the components slender. It is desirable to have the reflection plate and its support as thin as possible in order to reduce the blockage area to the flow in the tunnel. In all the arrangements of the present series of tests, the thicknesses of these components were unchanged.

The thickness of the reflection plate was limited by the difficulty of preventing the plate from warping during manufacture and under aerodynamic loading. It was considered that for plates with an approximate diameter of 9 in., a minimum thickness of 0·1 in. was necessary. Even so, the plates tested were warped to an extent of about 0·006 in. in 9 in., and there was some evidence from the pressure measurements of bending under aerodynamic loads.

The plan form of the reflection plate is restricted by the condition that the plate should not foul the tunnel liners when it is rotated so as to alter the model incidence. This is an important consideration, especially for models to be tested at high angles of incidence.

The front bevels on the under-surface of the plates were all made with an angle of $5 \cdot 7$ deg measured in a plane perpendicular to the edge. It was considered that this angle was near to the minimum which could be made by hand filing, without appreciable distortion of the upper surface of the plate.

The pressure tubes from the model must pass through the support. The minimum practical size of tubing is 1 mm overall diameter. If about 15 tubes are to pass through a single passage in the support, a hole $0 \cdot 25$ in. diameter is necessary. To accommodate such a hole, the thickness of the support has been taken as $0 \cdot 4$ in. The high bending loads carried by the support also require a thickness of this order.

3. *Description of the Plates Tested.*—3.1. *Type* 1 *Reflection Plate* (*Fig.* 3).—Type 1 plate was made for a half-model of a 50 deg swept-back wing. This wing has a constant chord of 3 in. with pressure holes across a chordwise section $2 \cdot 5$ in. from the centre-line. The various design considerations are illustrated in Fig. 3.

The model was to be tested at Mach numbers between $1 \cdot 4$ and $2 \cdot 0$. When the model and reflection plate were designed it was appreciated that there would be a slight disturbance from the leading edge of the reflection plate. The distance of the leading edge in front of the apex of the wing was fixed so that this disturbance would be in front of the pressure-plotting section at the highest Mach number. The incidence of the model was changed by rotating it about an axis through the middle of the pressure-plotting section. The rear edge of the plate was made as an arc of a circle with its centre on the axis of rotation of the model, and with such a radius that there was $0 \cdot 2$ in. clearance between the plate and the tunnel liners. Since it was hoped to measure pressures at incidences up to 20 deg, the upper and lower edges of the plate were made tangential to the rear circle at an angle of 20 deg to the free-stream direction. The front edge of the plate was a curve joining the tangents to the most forward point, in the plane of the wing. The requirements that no disturbances from the leading edge should cross the pressure-plotting section, and that the model should have an incidence range of $\pm$ 20 deg made it impossible to arrange a supersonic component perpendicular to those edges from which a disturbance could affect the wing pressure-holes.

3.2. *Type* 2 *Reflection Plate* (*Fig.* 6).—The second plate was designed for a half-model wing of delta plan form with a semi-apex angle of 30 deg and a root chord of 7 in. (Fig. 6). Pressures over the whole surface of this wing were to be measured at Mach numbers ranging from $1 \cdot 4$ to $1 \cdot 8$. The apex of the wing was arranged to lie on the leading edge of the reflection plate. The rear edge was made a circular-arc with its centre on the axis of rotation of the model. The front edge of the plate was a curve passing through the point corresponding to the apex of the wing and joining the rear arc, in such a way that the plate would not foul the tunnel, at any incidence. The shape of the front curve gives supersonic flow perpendicular to that section of the edge from which disturbances can affect the forward 4 in. of the wing-root chord.

3.3. *Type* 3 *Reflection Plate* (*Fig.* 6).—Types 1 and 2 were designed before the importance of eliminating disturbances originating beneath the plates was fully appreciated. The pressure distribution above type 1 at $M = 1 \cdot 4$ showed a very large disturbance of this kind. It was found that the pressure variation could be reduced to what were then considered as acceptable limits, by recessing the tunnel wall beneath the reflection plate. Tests on the second plate showed that at $M = 1 \cdot 4$ comparatively large disturbances could not be eliminated from the region occupied by the model by further increasing the recess depth. Type 3 reflection plate was therefore designed for the delta wing, so that at $M = 1 \cdot 4$ there was the highest possible supersonic component perpendicular to the full length of edge from which disturbances could affect the flow over the wing. The leading edges were straight lines swept back from the apex and making angles of 58 deg with the free-stream direction, so that the normal Mach number component was $1 \cdot 2$. The bevel angle of $5 \cdot 7$ deg was greater than the maximum angle through which the air could be deflected by an attached shock-wave ($3 \cdot 8$ deg). In this design it was necessary to restrict the incidence range to about $\pm$ 2 deg.

It was found that the disturbance from the under-surface of the plate could be almost eliminated from the region occupied by the wing at $M = 1 \cdot 4$, by using a deep recess and by moving the support backwards relative to the plate leading edge. Moving the support backwards increased the over-hang of the plate. Since this caused the plate to distort under the air loads, the scheme was not satisfactory.

3.4. *Type 4 Reflection Plate* (*Fig.* 10).—Finally it was decided to test a plate completely spanning the tunnel. At $M = 1 \cdot 4$ there would be an attached shock-wave on the under-surface of the leading edge. Such a scheme would seem to be the most obvious way of eliminating the effects of disturbances from the under-surface, although it has the big disadvantage that the plate cannot be rotated as the incidence of the model is changed. It was found however that this scheme was unsatisfactory because of a disturbance originating at the ends of the leading edge, in or near the tunnel boundary layer.

4. *Test Details.*—The reflection plates tested were designed to be used with a series of swept-back and delta wings. These wings and their supports were manufactured in one piece from a single forging. In order to study the disturbances introduced into the air stream in the region to be occupied by the model, it was necessary to make a dummy support on which the reflection plate could be fixed.

The airflow over the plate was studied by traversing a static tube along lines parallel to the axis of the tunnel. The static tube used was made from stainless steel hypodermic tubing, $0 \cdot 08$ in. diameter. The nose was blocked up and rounded off. Four static holes $0 \cdot 02$ in. diameter were drilled round the circumference of the tube, $0 \cdot 6$ in. behind the nose. The pressures were read on a vertical mercury manometer. Fig. 1 shows a reflection plate with the traversing gear mounted in the tunnel.

It is considered that the pressure indicated by this static tube was within 1 per cent of the true static pressure. For this investigation however, a high accuracy in measuring the absolute pressure is not required. The pressure was read at half-inch intervals, with intermediate readings taken in regions of large pressure gradients.

All the tests were made with a stagnation pressure of one atmosphere corresponding to a Reynolds number of about $0 \cdot 4 \times 10^6$ per in.

5. *Results.*—In the main, the tests were carried out to find reflection plates suitable for existing models rather than as part of a general research programme. From the many static traverses that have been made, those presented have been selected to show as systematically as possible the properties of the arrangements tested. The results, given in graphical form, show the effect on the static-pressure distribution above the plate of the parameters set out below.

Figure	Reflection plate shape	Parameters varied
5	1 (Fig. 3)	Recess depth and model incidence
7	2 (Fig. 6)	Recess depth and area, and support section
8	2 (Fig. 6)	Mach number
9	3 (Fig. 6)	Recess depth and fore-and-aft position of the support
11	4 (Fig. 10)	The sealing of the gaps between the floor and roof for a plate spanning the tunnel.

Two scales are used in the figures. One gives the ratio of the measured static pressure to the tunnel settling chamber pressure. The other expresses the difference between the measured static pressure and the static pressure in the undisturbed stream just ahead of the reflection plate, in the form of the coefficient,

$$C_p = \frac{P - P_1}{\frac{1}{2}\rho V^2}$$

where P is static pressure measured above the plate
P_1 static pressure of the undisturbed stream
$\frac{1}{2}\rho V^2$ the dynamic head of the undisturbed stream.

When the pressures measured for different conditions of the model are equal or almost equal, the curves have been run together and drawn as a single line, for clarity in graphical presentation.

The incidence referred to in the figures gives the angle made by the plane of the support with the direction of the oncoming stream. This would correspond to the incidence of a model mounted on the reflection plate.

6. *Discussion.*—In order to provide a standard for judging the effect on the tunnel flow of introducing a reflection plate, Fig. 12 gives typical pressure distributions in the empty tunnel at a Mach number of 1·4. The maximum variation in static pressure shown by the two traverses given in Fig. 12 will be seen to be about $\pm 0 \cdot 2$ per cent of the stagnation pressure, corresponding to a variation of $\pm 0 \cdot 005$ in pressure coefficient and $\pm 0 \cdot 35$ per cent in Mach number.

6.1. *Type* 1 *Reflection Plate* (*Fig.* 3).—Fig. 5 shows the improvement produced by a recess in the tunnel wall behind the reflection plate, at a Mach number of 1·4. With no recess, the airflow in the passage beneath the plate was choked, and the large pressure rise was propagated round the edges of the plate. It caused a peak pressure coefficient of 0·25 in the region occupied by the model. By the provision of a recess, the largest pressure-coefficient peak was reduced to less than 0·03.

The small peak in the pressure distribution, 7 in. from the leading edge of the plate was unaffected by further increases of recess depth. This is a disturbance probably originating behind the plate from the compression of the supersonic stream by the presence of the support, and propagated round the subsonic edges of the plate. Disturbances from the subsonic edges of the plate can affect the pressures in line of traverse downstream of a point 3·8 in. from the leading edge of the plate. With the recess of 0·3 in. there was a fall in the measured pressure towards the back of the plate, indicating an over-expansion produced by the recess.

Fig. 5 gives the pressures measured with the plate set for a model incidence of zero and of 4 deg. At 4 deg incidence the pressure rise occurred slightly further forward than at zero incidence, presumably due to the larger effective blockage of the flow beneath the plate by the support. This effect was small compared with the variations caused by altering the recess depth.

This figure also shows the disturbance associated with the leading edge of the plate. This appears as the small bump in the pressure distributions at about 2·5 in. behind the leading edge. Such a disturbance is present in all the pressure distributions and appears to be weak enough to be propagated across the tunnel along Mach lines.

The variation in static pressure is of the order of 1·2 per cent of the stagnation pressure, or about six times the pressure variation measured with the tunnel empty.

6.2. *Type* 2 *Reflection Plate* (*Fig.* 6).—Fig. 7 shows some pressure measurements above the second type of plate. The first point of note is that for the same recess depth there was a greater pressure rise above this plate than type 1, shown in Fig. 5. With recesses 0·2 in. deep, the peaks corresponded to pressure coefficients of 0·19 and 0·03 respectively. An increase in the recess depth to 0·3 in. (curve 2) reduced the peak, and moved it backwards. Curves 3 and 6 show that there was little improvement to be obtained from a further increase in the recess depth. A comparison of curves 3 and 4 indicates that there was little change in the pressure distribution when the shape of the recess in plan view was changed. On the other hand, curves 2 and 3 show that sharpening the support leading edge had a comparatively large beneficial effect; there was no improvement produced by sharpening the trailing edge of the support. The pressure peaks measured in a traverse 0·5 in. above the plate were slightly smaller than those measured 2·8 in. above the plate but occurred rather further upstream. With increase of Mach number, the pressure rise above the plate moved downstream and the pressure peaks were decreased. This effect is shown in Fig. 8.

6.3. *Type* 3 *Reflection Plate* (*Fig.* 6).—Curve 1 of Fig. 9 shows that the third shape of plate, with a recess of 0·3 in., produced a higher peak pressure than the second with the same recess. In this case however, an improvement was obtained by increasing the recess to 0·5 in. Traverses above this third plate were made with the support in three positions. The curves of Fig. 9 show that as the support was moved backwards relative to the leading edge of the plate the distance of the pressure rise from the leading edge of the plate became greater, and the pressure peaks were reduced.

This set of curves shows that the pressure behind the leading-edge disturbance changed appreciably as the position of the support was altered. It is considered that this effect was due to the distortion of the plate under the air loads. The higher pressure beneath the plate would cause it to bend upwards, the deflection increasing as the support was moved backwards. The estimated drop in pressure which would be produced by such bending is of the same order as that shown in Fig. 9.

6.4. *Type* 4 *Reflection Plate* (*Fig.* 10).—Fig. 11 shows the characteristics of a plate spanning the tunnel. The results are given for the small gaps between the edges of the plate and the top and bottom liners both sealed and unsealed. Besides the small disturbance associated with the leading edge, there was a disturbance arising near the junction of the plate leading edge with the liners. This was found to be unaffected by the depth of the recess beneath the plate. It was probably caused by an interaction between the flow over the plate and the tunnel boundary layer. The figure shows that the pressure behind the second disturbance was more uniform when the gaps were sealed.

7. *Conclusions.*—The introduction of a reflection plate into the working-section of the R.A.E. 9 in. × 9 in. Supersonic Tunnel was found to produce two main disturbances to the flow. One disturbance originated from the leading edge of the reflection plate ; some distance downstream, the other appeared to originate from the flow beneath the plate, that is to say, from the flow in the passage between the undersurface of the plate and the tunnel wall. It was found that the flow field between these two disturbances was reasonably uniform and could, therefore, be regarded as a suitable region for testing a model, provided that the trailing edge of the model nowhere approaches too closely the downstream disturbance.

It appeared from the tests that the disturbance produced by the leading edge of the plate was unavoidable, but the magnitude and position of the origin of the downstream disturbance could to some extent be controlled by the geometry of the reflection plate and the dimensions of the passage between its under surface and the tunnel wall ; the disturbance was not entirely eliminated in any of the tests.

Type 3 reflection plate (Fig. 6) seemed to be the most promising. It was designed so that the largest possible region above the plate could be affected only by conditions at the edge of the plate where the perpendicular velocity component was supersonic. Unfortunately, the results for this plate were rather inconclusive because of the distortion under the air loads. However, they indicated that, provided the large pressure changes occurring beneath the plate could be reduced sufficiently, most of the region influenced only by the supersonic edges had no large pressure peaks. The supersonic edges were not fully effective because their extremities were inside the liner boundary layer ; this gave a disturbance similar to that observed in the test on a plate spanning the tunnel.

The tests showed that the large pressure rise occurring beneath a given plate could be reduced or moved downstream by the following means : they are given in order of their effectiveness.

(*a*) Increasing the passage area beneath the plate by introducing a recess in the tunnel wall ;
(*b*) Moving the support downstream relative to the plate ;
(*c*) Sharpening the leading edge of the support.

At a Mach number of 1·4 it should be possible to obtain a region of approximately constant pressure just above the plate, extending downstream from its apex for a distance equal to roughly 0·66 of the height of the tunnel. At a Mach number of 1·6, the extent of this constant pressure region should be about 0·78 of the height of the tunnel.

Tests made on a plate spanning the tunnel showed that the model would have to be located behind the disturbance originating near the junction of the leading edge of the plate and the tunnel liners. A long plate, involving a comparatively thick boundary layer, would therefore be necessary.

LIST OF SYMBOLS

P	Pressure as measured by the static tube
P_0	Tunnel stagnation pressure
C_p	$= \dfrac{P - P_1}{\frac{1}{2}\rho V^2}$

where

P_1	Static pressure of the undisturbed stream
$\frac{1}{2}\rho V^2$	Dynamic head of the undisturbed stream

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2	J. Ackeret, F. Feldmann, and N. Rott	Investigations on Compression Shocks and Boundary Layers in Fast Moving Gases. Institut für Aerodynamik ETH, Zürich. No. 10, 1946. Translated as A.R.C. 10,044.

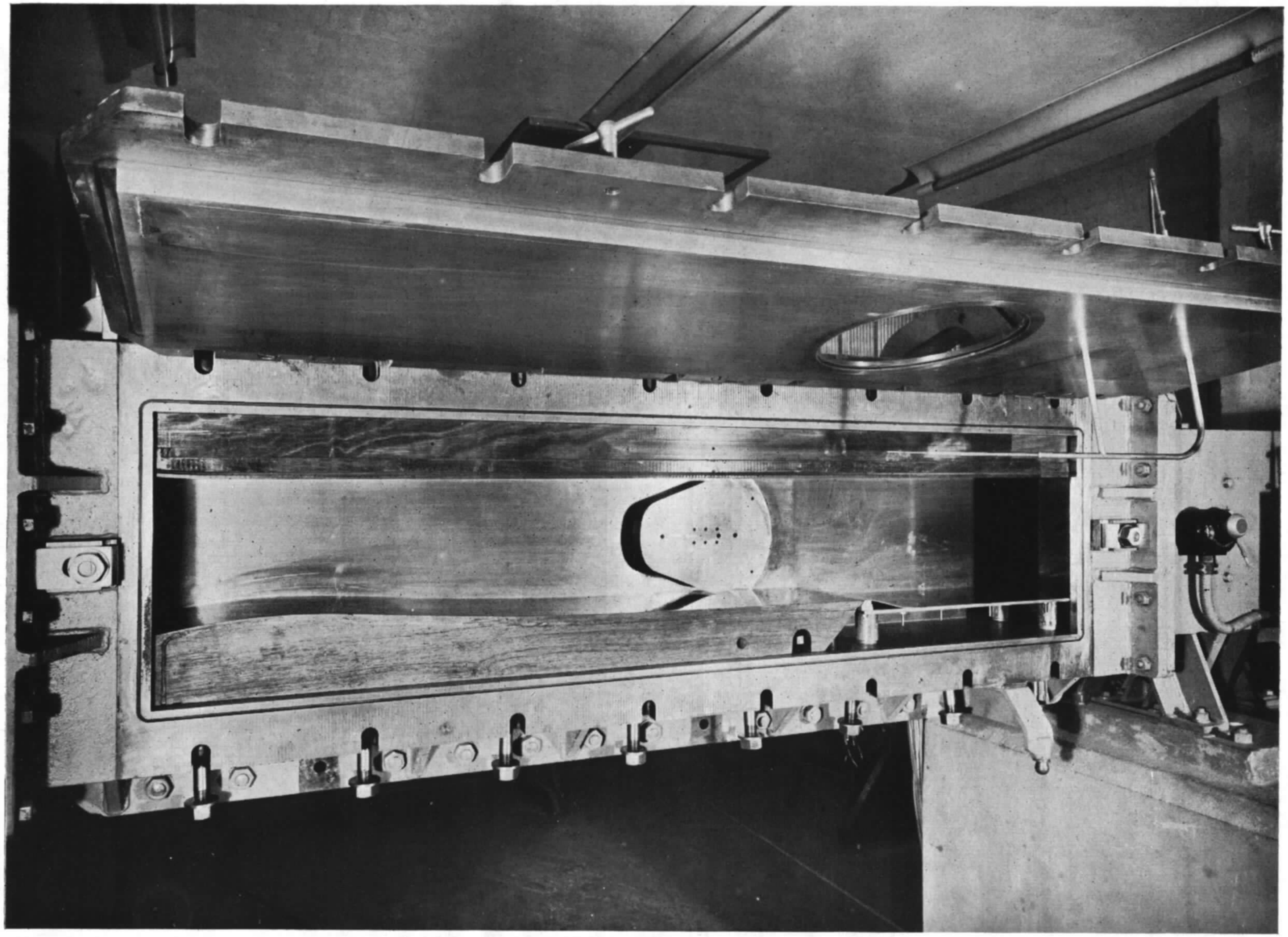

FIG. 1. A reflection plate, with the traversing static probe, in the 9 in. $\times$ 9 in. tunnel.

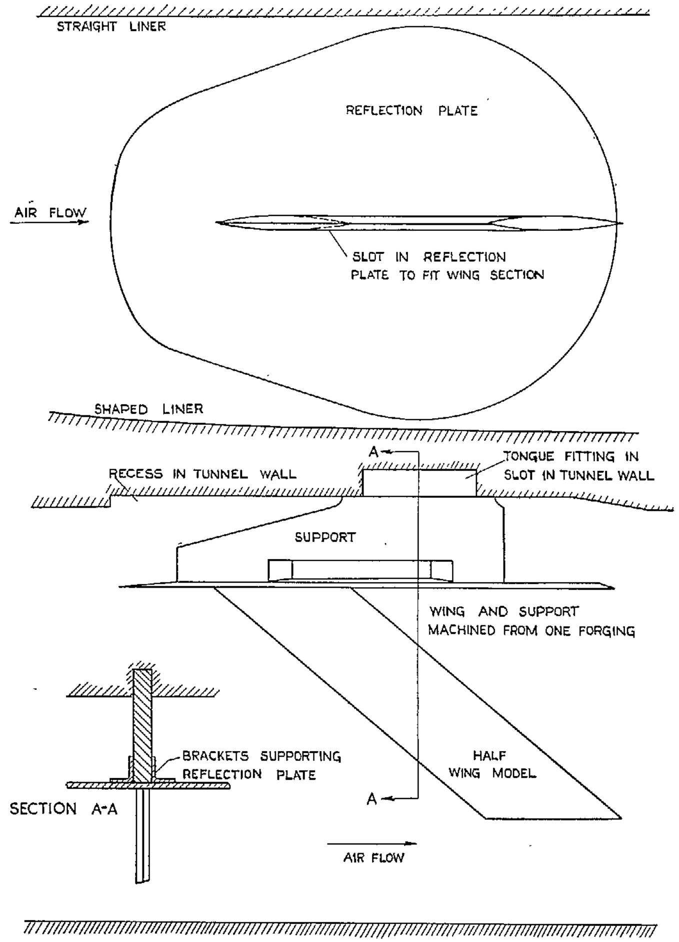

FIG. 2. Typical model wing with reflection plate.

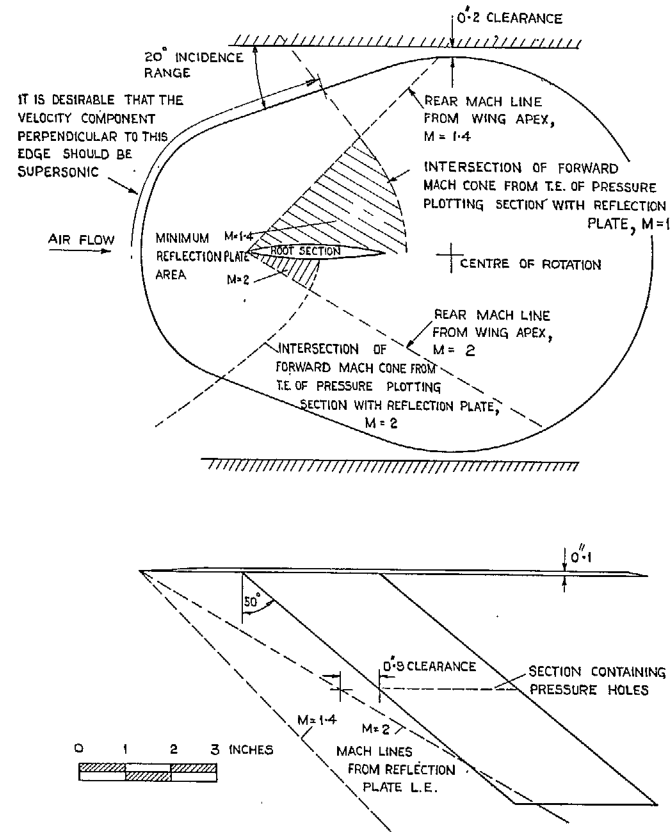

FIG. 3. Design of reflection plate plan form, illustrated by type 1 plate.

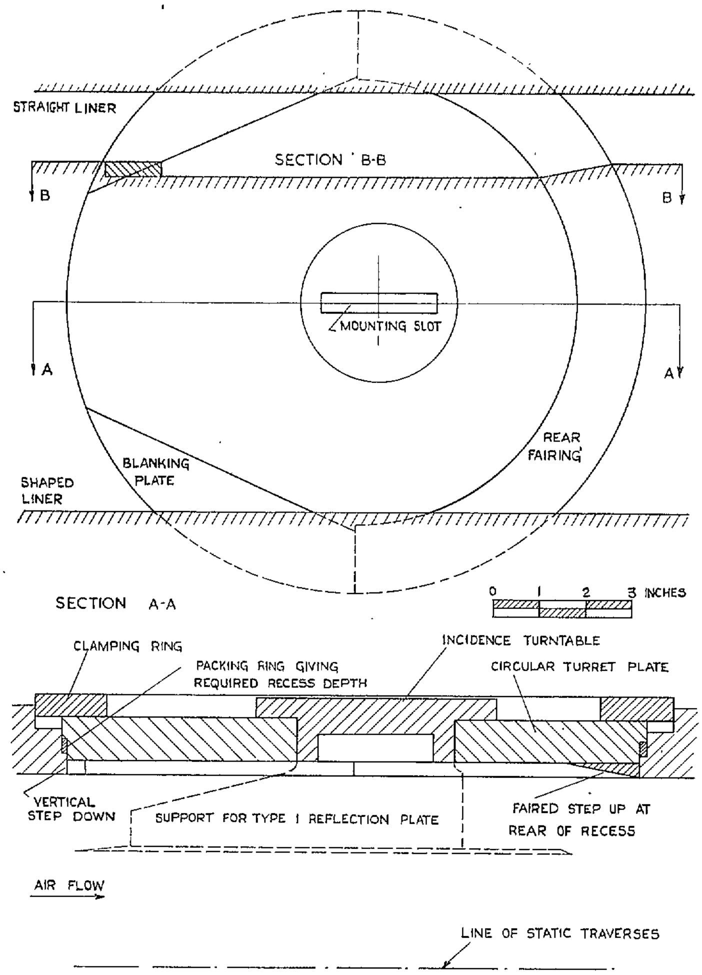

FIG. 4. Recess shape used with type 1 reflection plate showing the method of providing a recess.

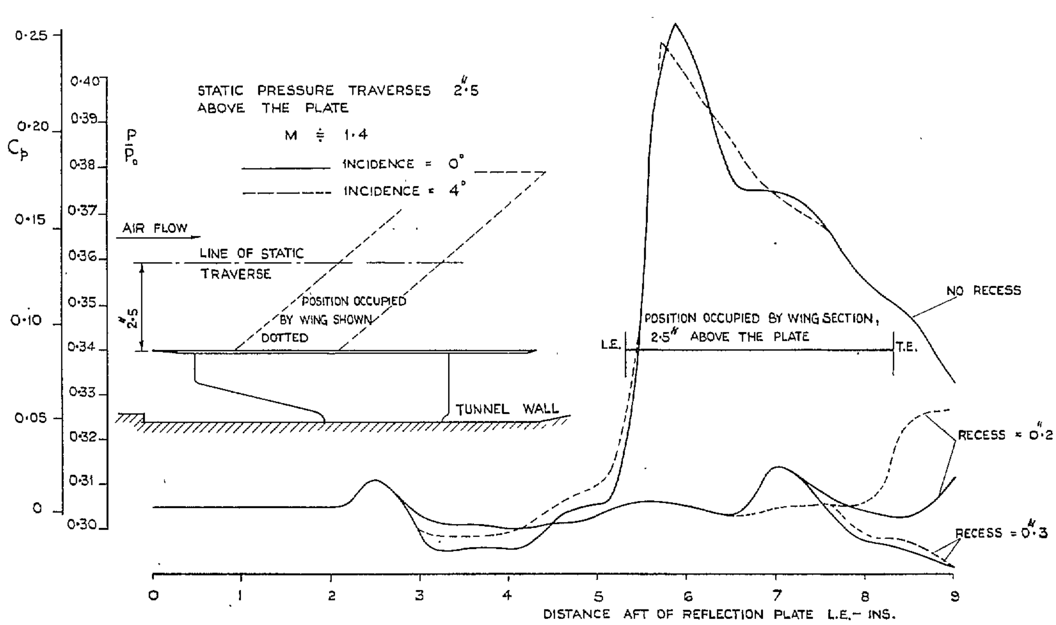

FIG. 5. Traverses over type 1 reflection plate. Effect of recess depth and incidence.

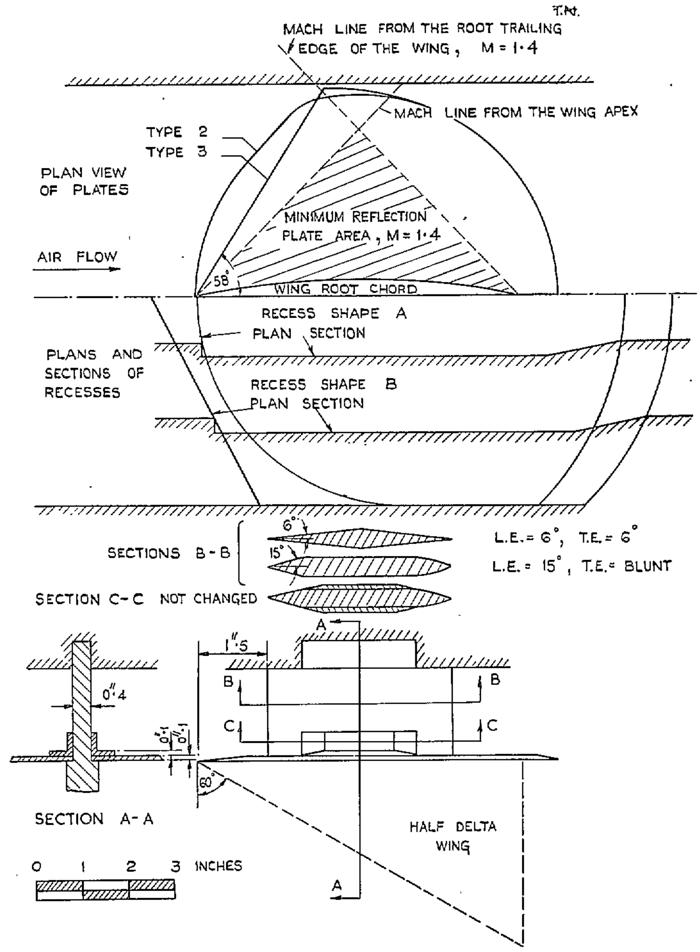

FIG. 6. Types 2 and 3 reflection plates, designed for a delta wing.

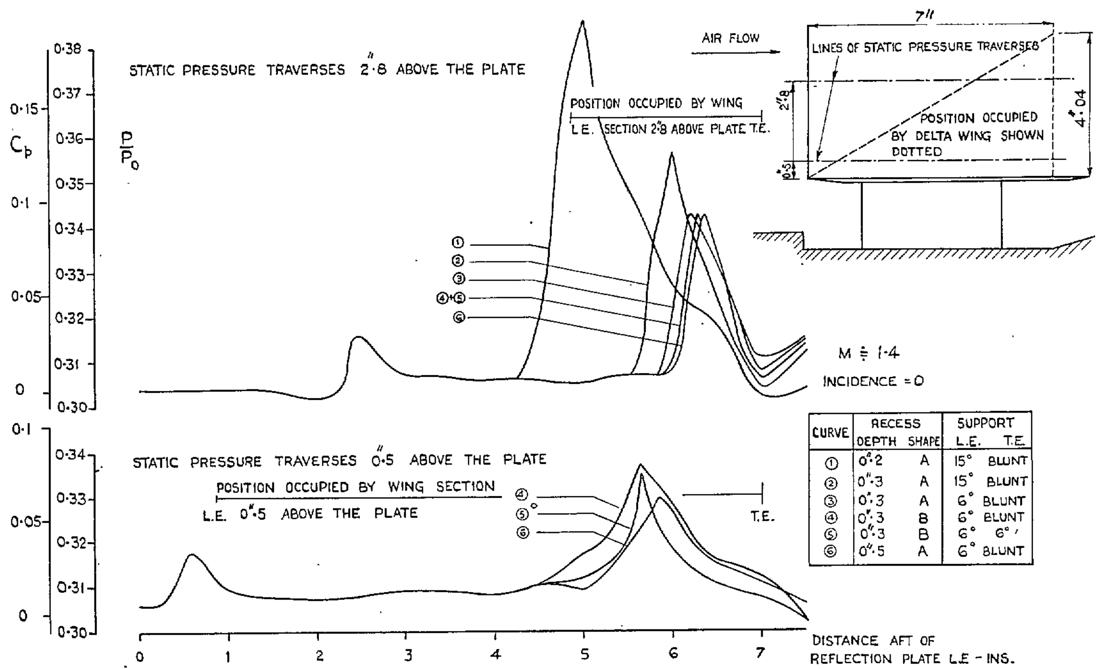

FIG. 7. Traverses over type 2 reflection plate. Effect of recess shape, depth and support shape.

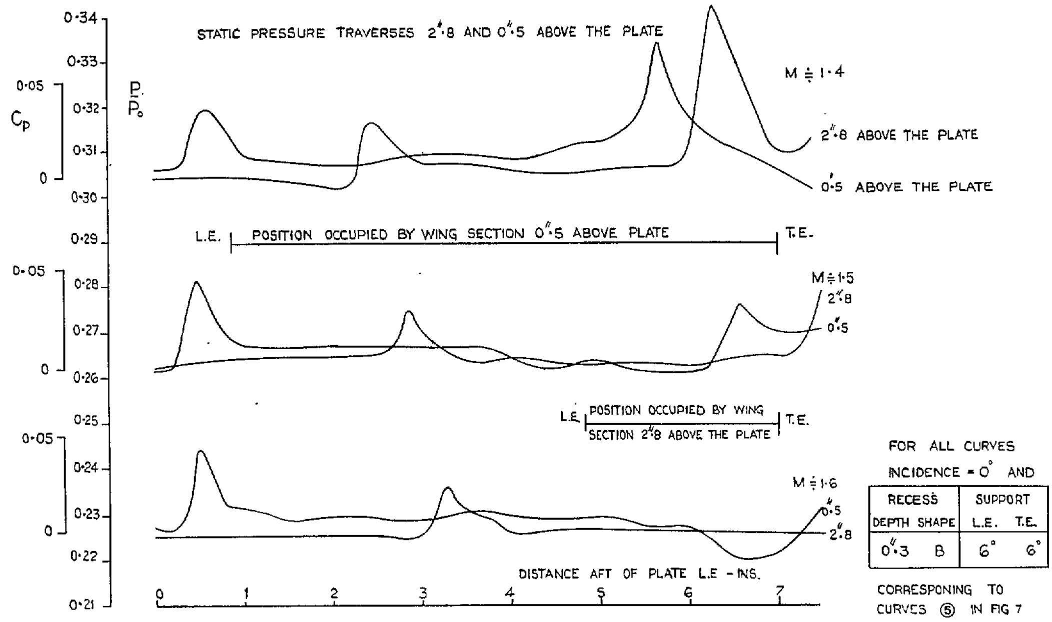

FIG. 8. Traverses over type 2 reflection plate at $M \simeq 1 \cdot 4$, $1 \cdot 5$ and $1 \cdot 6$.

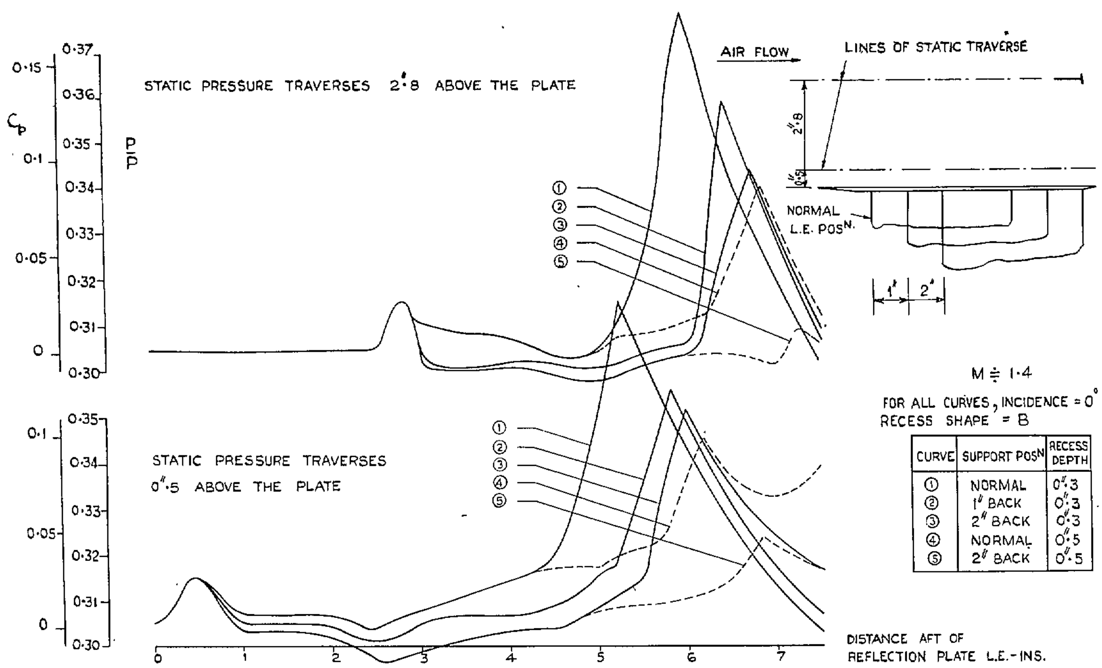

FIG. 9. Traverses over type 3 reflection plate. Effect of altering the support position.

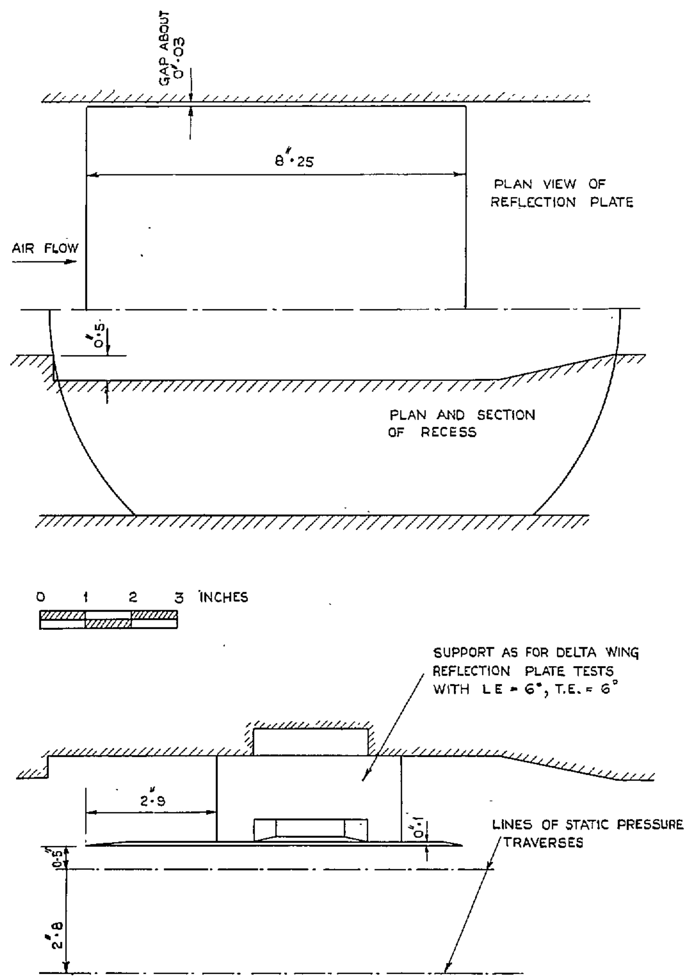

FIG. 10. Type 4 reflection plate spanning the tunnel.

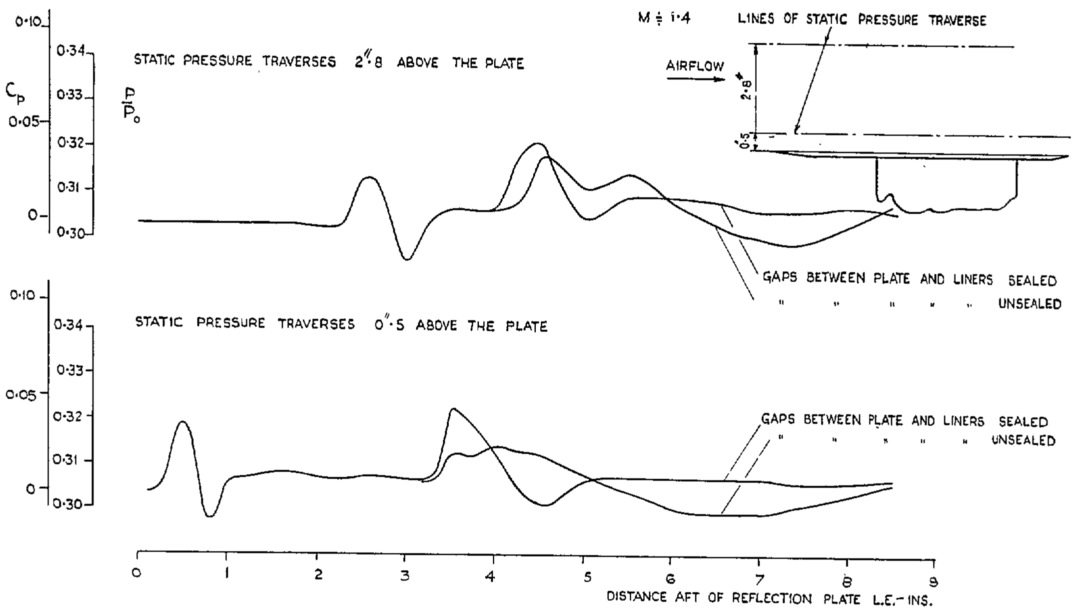

FIG. 11. Traverses over type 4 reflection plate.

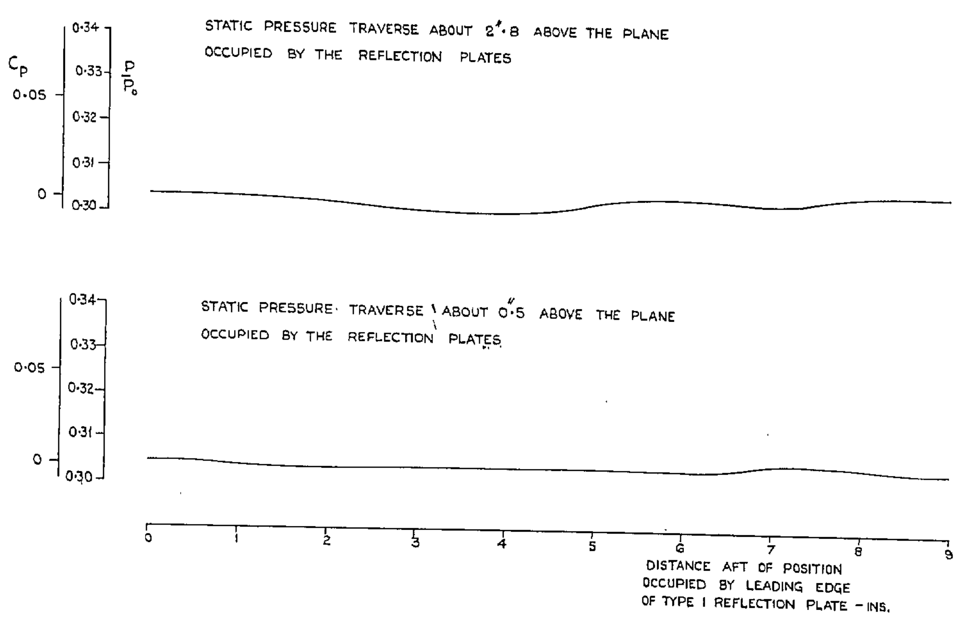

FIG. 12. Traverses in the empty tunnel.

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