C.P. No. 1133

C.P. No. 1133

MINISTRY OF TECHNOLOGY

AERONAUTICAL RESEARCH COUNCIL
CURRENT PAPERS

Interference Effects at $M=8.5$ of Wires and Probes on the Wake of a Magnetically Suspended Rounded Base Cone

by

J. F. W. Crane

Aerodynamics Dept., R.A.E., Farnborough

LONDON: HER MAJESTY'S STATIONERY OFFICE

1970

PRICE *7s 0d* [*35p*] NET

U.D.C. 533.6.071.4 : 533.6.071.32 : 533.6.082.3 :
533.6.048.3 : 533.696.4 : 533.6.011.55

C.P. No. 1133*
February 1970

INTERFERENCE EFFECTS AT M = 8.5 OF WIRES AND PROBES ON THE WAKE OF A MAGNETICALLY SUSPENDED ROUNDED BASE CONE

by

J. F. W. Crane

SUMMARY

Transverse and axial probes and wires in the wake produced two types of interference with the wake. With transverse probes and wires the effect is to narrow the wake shock diameter and move its source downstream. With axial probes and wires there is an opposite effect. The former is apparent when the probe is within three base diameters of the model, and the latter is apparent when the edge of the viscous core is approached from within.

---

*Replaces R.A.E. Technical Report 70023 - A.R.C. 32287

CONTENTS

1 INTRODUCTION

The reason for magnetic suspension of wind tunnel models is the avoidance of support interference with the flow. The principle use of the R.A.E. system[1,2] is the study of wakes of axisymmetric shapes, and for this it is required to insert probes into the flow. When temperature and pressure measurements are required from the model it becomes necessary to attach wires to it to relay this information, but if telemetry can be fitted within the model the use of wires may be avoided. The following tests, using a cone model with a rounded base, describe the effects of flow interference caused by stings, probes and wires. The model was 5.7 inches long.

2 TEST CONDITIONS

The tests were made in the 7 in × 7 in hypersonic wind tunnel at $M = 8.52$ and at a free stream Reynolds number based on cone length of 0.8 million. At this Reynolds number the boundary layer was expected to be laminar and this was supported by schlieren pictures of the flow. The temperature at the base and half way along the model was measured by thermocouples in one series of runs, (Fig.15). From these we can deduce that for the tests described, which were made in single run or two-run lots with the model cooled to room temperature in between, the wall to stagnation temperature ratios were 0.45 to 0.5 for the base and 0.51 to 0.56 half way along the model. Stagnation temperature was about 700°K and was sufficient to avoid air condensation effects[3,4]. It is assumed that the small variation in wall temperature has no effect on the flow. In all tests the model was at zero incidence[2].

3 TECHNIQUES

Flow visualization by schlieren was used to detect interference with the wake by measuring the variation in position of the wake shock source, defined in Fig.1, from the undisturbed position (Fig.2).

Axial stings were mounted from wires at the diffuser entry to be within the viscous core of the near wake, leaving just sufficient room behind the model to allow operation of the model launcher[1].

The transverse probe, which had a sharp leading edge of 18° included angle and a thickness of 0.186 in, was mounted on the traversing sting at the side of the working section, by means of which it was rotated into the centre of the flow. The pitot tube and static pressure probes were mounted similarly and pressure measurements were made along the arc of rotation. For comparison some measurements were made along a radius through the flow, Fig.1. A Midwood absolute manometer with a vacuum reference to zero was used to measure these pressures. Comparison with a mercury barometer showed agreement with the Midwood to better than 0.01 in Hg. For the measured static pressure of 0.03 in Hg the accuracy is probably within 30 per cent of the true value, but pitot pressure, which was always more than twice static pressure, had proportionally greater accuracy of measurement.

Temperature measurements on the model were made with Chromel/Alumel thermocouple wires of 0.01 in diameter overall (see Fig.15).

Drag measurements were obtained from the drag coil current. The probes and stings were made of brass and should not have affected the calibration of the drag coil.

4 RESULTS

4.1 With attached wires

Fig.3 shows that with wires welded and cemented to the model (Fig.15) and suspended at a small angle through the wake, the wake shock source is contracted in diameter and moved downstream of the undisturbed position of Fig.2. (With the wires the drag was increased by 50 per cent.) Fig.4 shows that with the wires removed but retaining the strip of cement which held the wires onto the cone surface the flow was undisturbed. The disturbance was therefore caused by the wires and not by tripping of the boundary layer by the cement strip.

Fig.5 shows that with a wire attached to the base at $2r/d = 0.45$ and running within the viscous core of the wake, no interference was observed.

4.2 With axial stings in the viscous core of the wake

Fig.6 shows that a 0.12 in diameter sting produces no interference and furthermore oil flow on the sting showed that the flow was in the mainstream direction and therefore the sting was downstream of the rear stagnation point.

Fig.7 shows that stings of 0.49 in diameter produce no interference and it is noticeable that no bow shockwave from the sting is visible. The flow is indeed supersonic in this region, see Fig.14, so that it appears that the density gradients are too weak to affect the schlieren picture.

Fig.8, however, shows interference with a sting of diameter nearly equal to that of the viscous core of the wake. The wake shock source is dilated and closer to the model. The bow shock is not visible within the viscous core but it is just visible in the outer flow bounded by the wake shock. (With this interference, drag decreased by one per cent.)

Fig.9 shows that a 0.49 in sting canted to 2y/d = 0.64 produces interference, and a disturbance from the sting tip is visible in the outer flow.

4.3 With a transverse probe

Fig.10 shows interference with a transverse probe close to the base of the model. The wake shock source is narrower and is moved further downstream. (Drag was increased by two per cent.)

4.4 Correlation of transverse probe interference

Fig.11 shows that for a transverse probe the wake shock source diameter, a, decreases and its distance from the model, b, increases as the probe is brought nearer to the model. There is more scatter in the results for b/d than for a/d, because the former is more difficult to locate exactly. Maximum interference is about ten per cent and at x/d greater than three, interference is small.

4.5 Correlation of axial probe interference

Fig.12 shows that interference from an axial probe causes the wake shock source to increase in diameter and to move nearer to the model. No interference occurs when 2y/d is less than 0.45.

4.6 Comparison of radial and arc pitot traverses

Fig.13 shows pitot traverses at two axial positions. The radial traverse shows the peak in the profile more distinctly and the comparison with the schlieren interpretation of the flow characteristics shows reasonably good agreement (Fig.14). It would seem that the radial traverse is to be preferred to the arc but more data points are required for full confirmation of this.

5 CONCLUSIONS

From the analysis of interference tests the following conclusions are drawn.

(1) For the transverse probe inserted into the centre of the wake, interference becomes noticeable within three diameters of the model, and the diameter and distance of the wake shock source downstream of the model base

were changed by about ten per cent when the probe was very near to the model base. The effect on the flow is shown as a narrowing of the wake shock source and its movement to a position further downstream.

(2) Axial probes mounted within the viscous core of the wake produced no interference when 2y/d was less than 0.45, but as the edge of the viscous core was approached from within, the wake shock source dilated and moved upstream towards the model. Wires attached to the model within this limit did not disturb the flow.

SYMBOLS

a	diameter of wake shock source
b	axial distance from model base to wake shock source
d	base diameter of model
M	free stream Mach number
p	pressure
r	radius
Re	Reynolds number
x	axial distance from model base
y	distance from wake axis to outer edge of sting
$\delta\rho/\delta r$	radial density gradient

Subscripts

s	sting or static
o	stagnation

Superscript

$'$	pitot

REFERENCES

No.	Author	Title, etc.
1	A. Wilson B. Luff	The development, design and construction of a magnetic suspension system for the R.A.E. 7 in × 7 in hypersonic wind tunnel. R.A.E. Technical Report 66248 (1966)
2	J. F. W. Crane	Performance aspects of the R.A.E. magnetic suspension system for wind tunnel models. R.A.E. Technical Report 68274 (A.R.C. 31072) (1968)
3	J. F. W. Crane R. J. Marshall	Air condensation effects measured in the R.A.E. 7 in × 7 in hypersonic wind tunnel. A.R.C. R & M 3511 (1966)
4	J. F. W. Crane	Air condensation effects at $M = 8.5$ measured on the drag and the wake of a magnetically suspended 20° cone. R.A.E. Technical Report 70022(A.R.C. 32246) (1970)

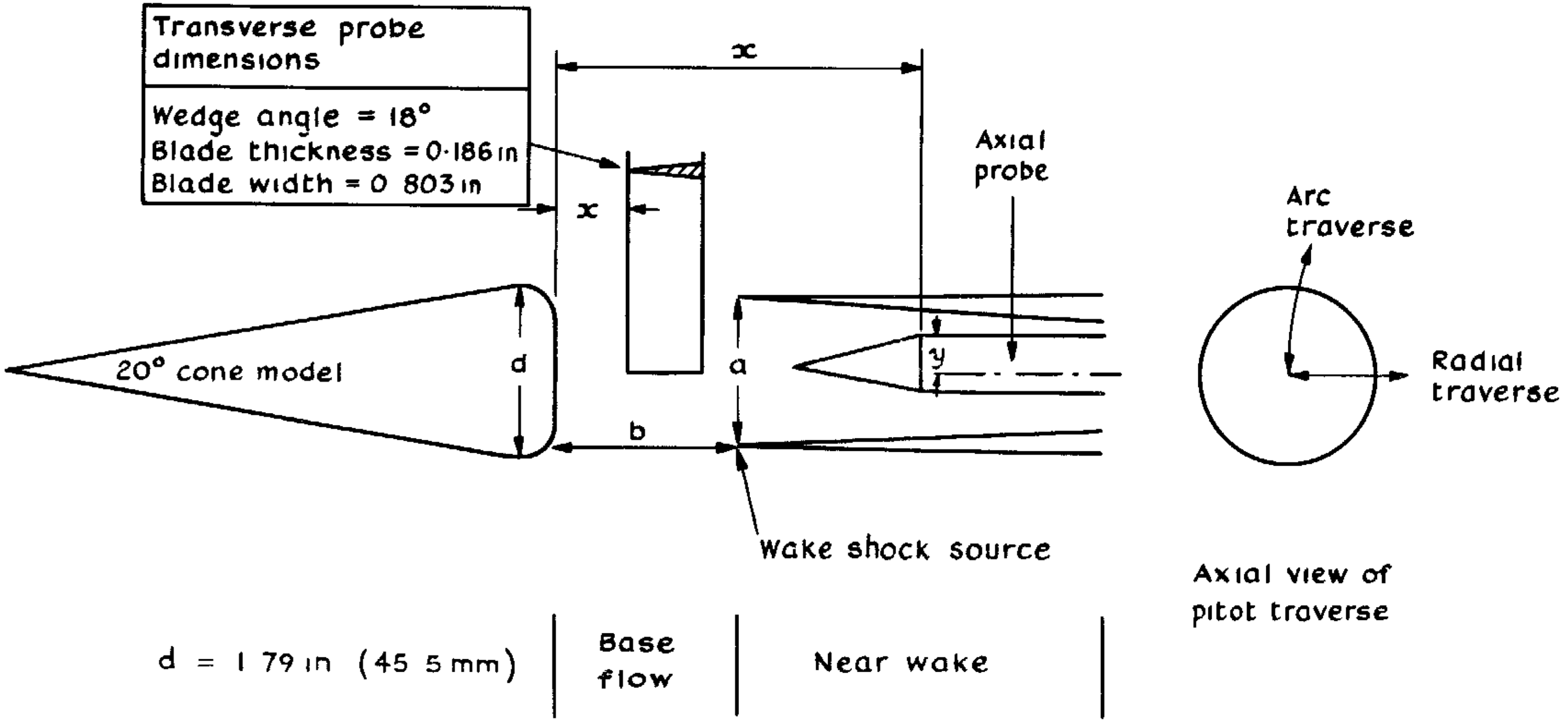


Fig. 1 Details of notation

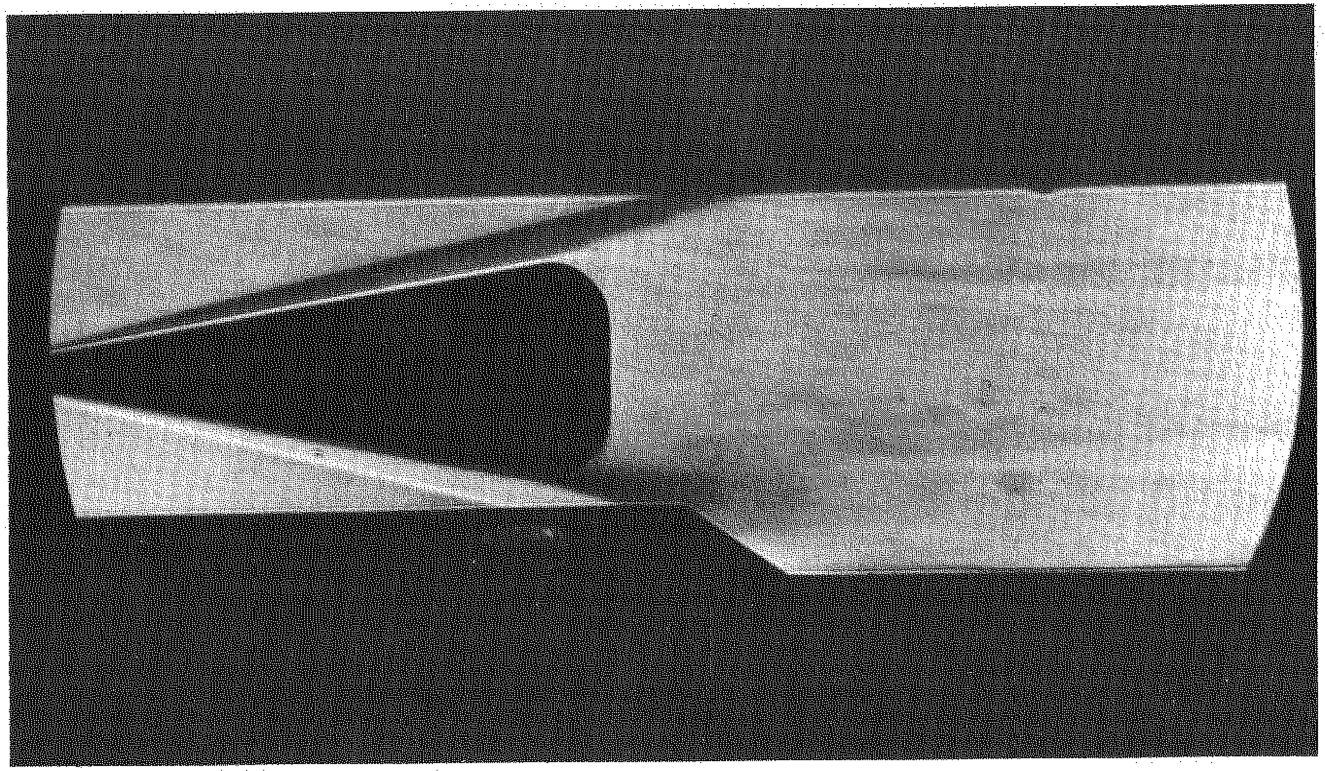


Fig.2. Flow without interference

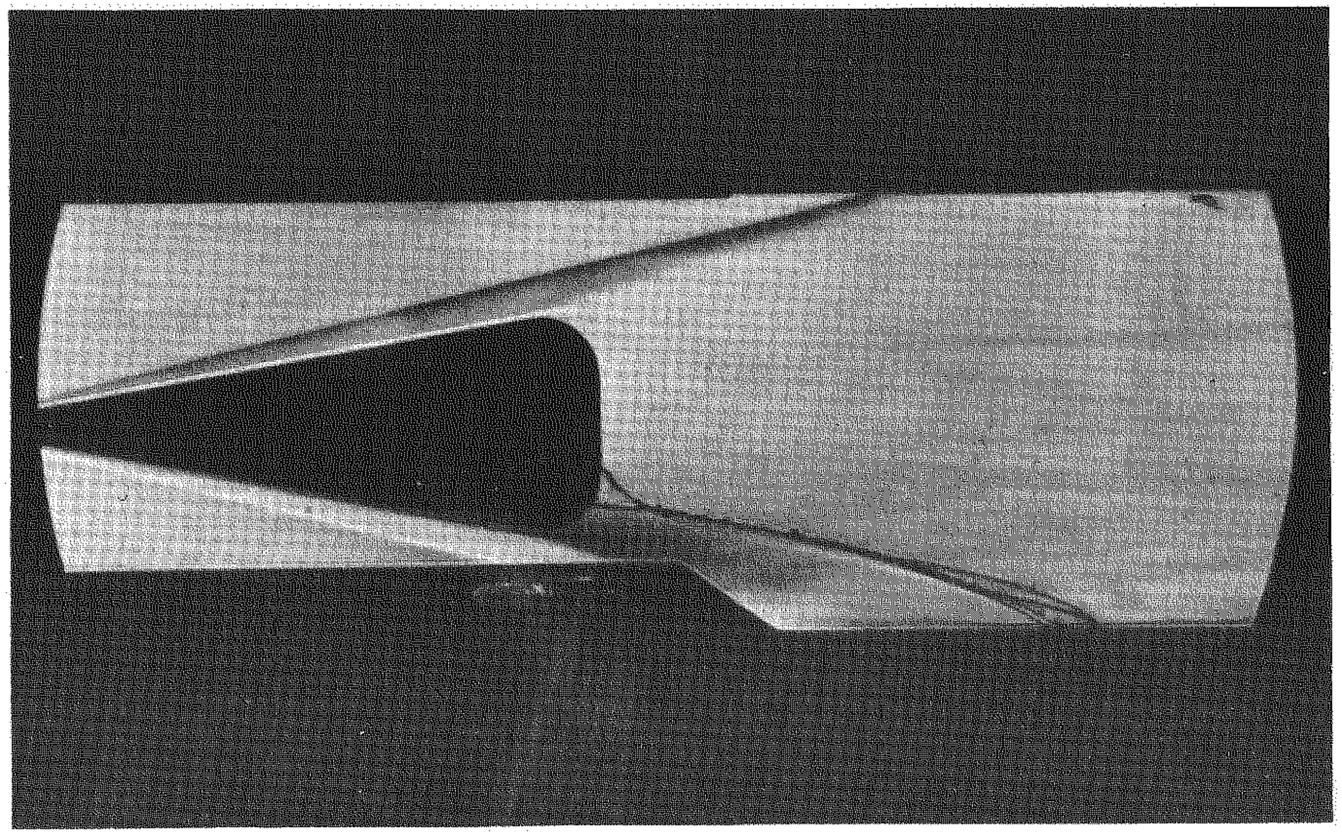


Fig.3. Flow interference from wires attached to base

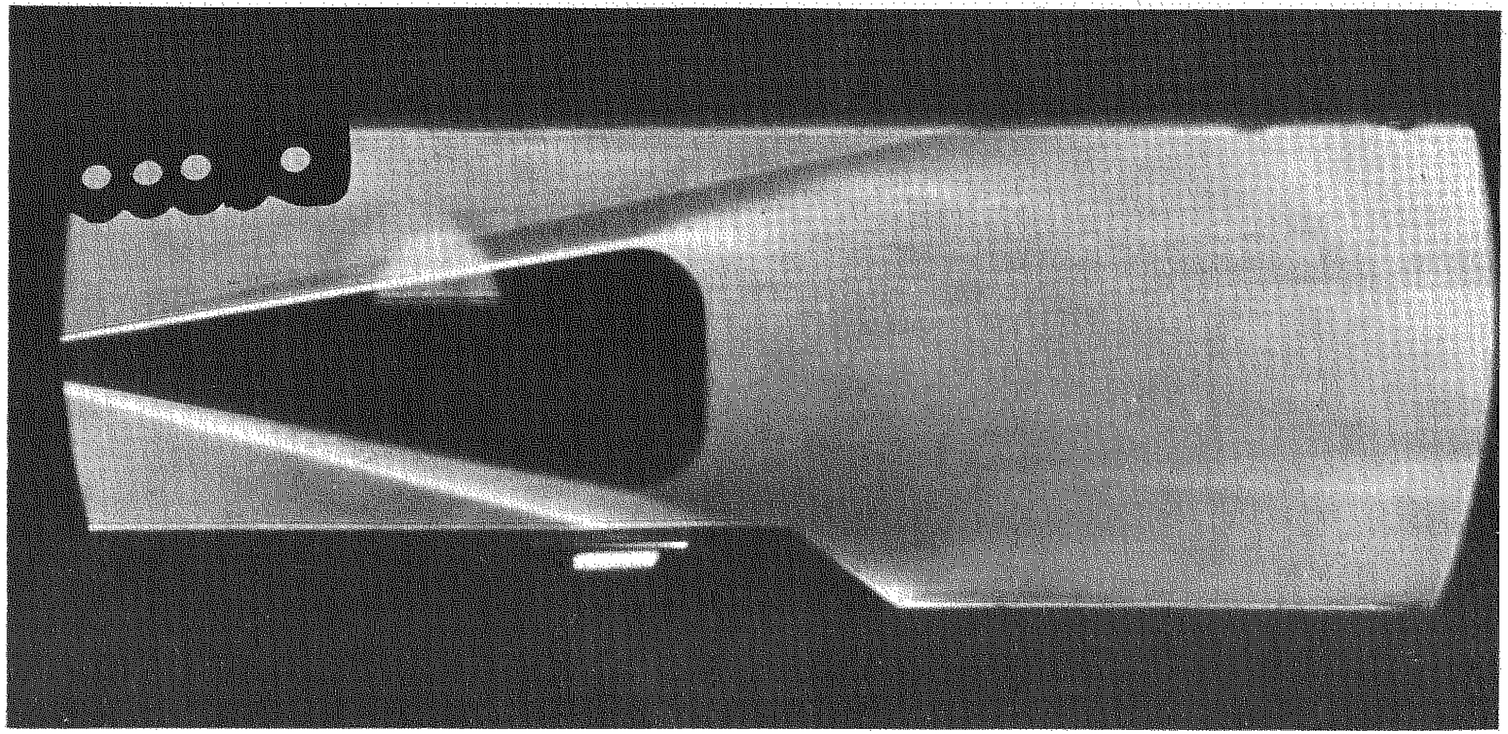
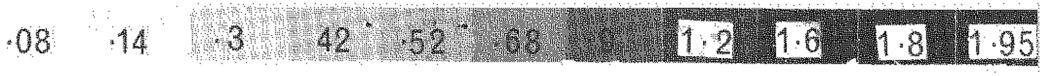


Fig.4. No interference from cement fixing for wires



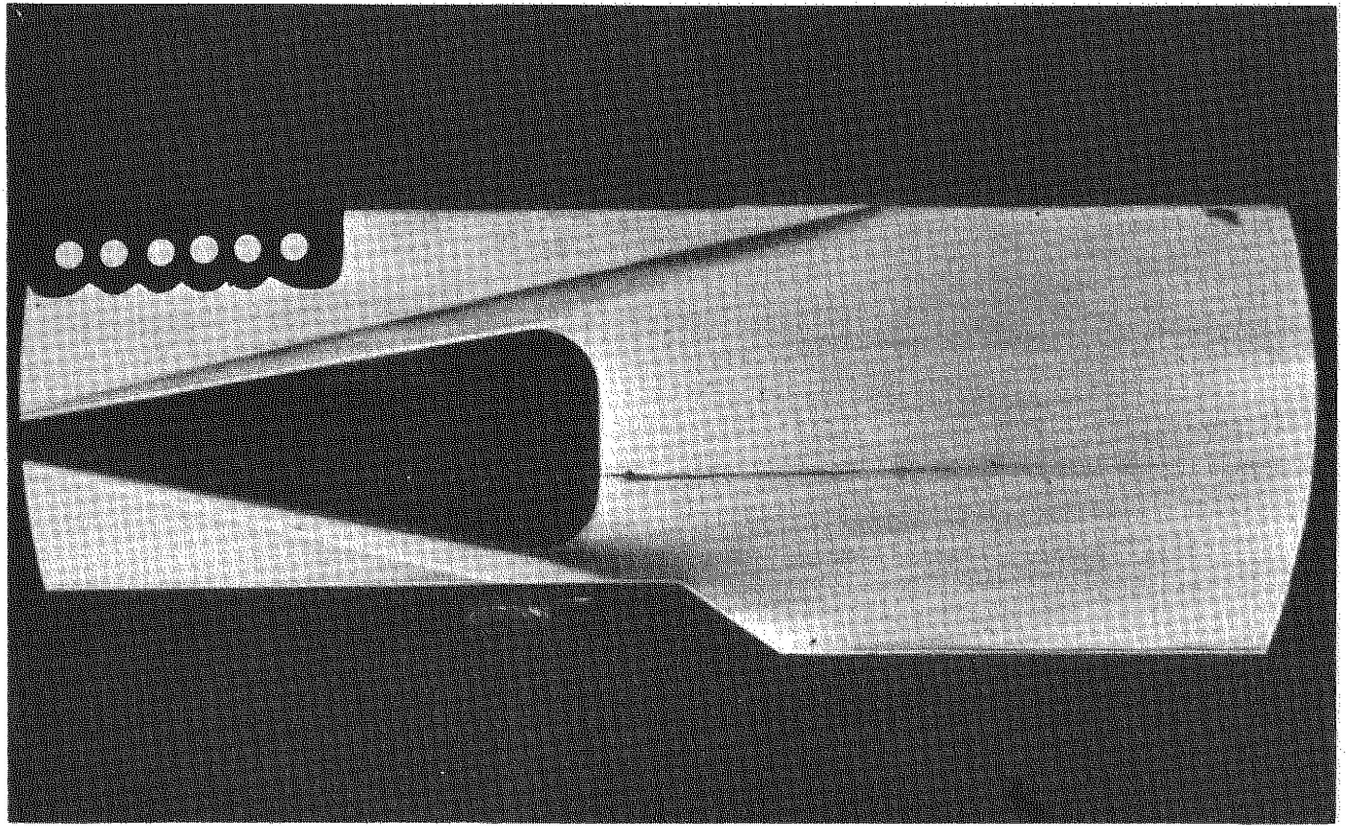


Fig.5. No interference from wire within viscous core of wake attached to model at 2r/d=0.45

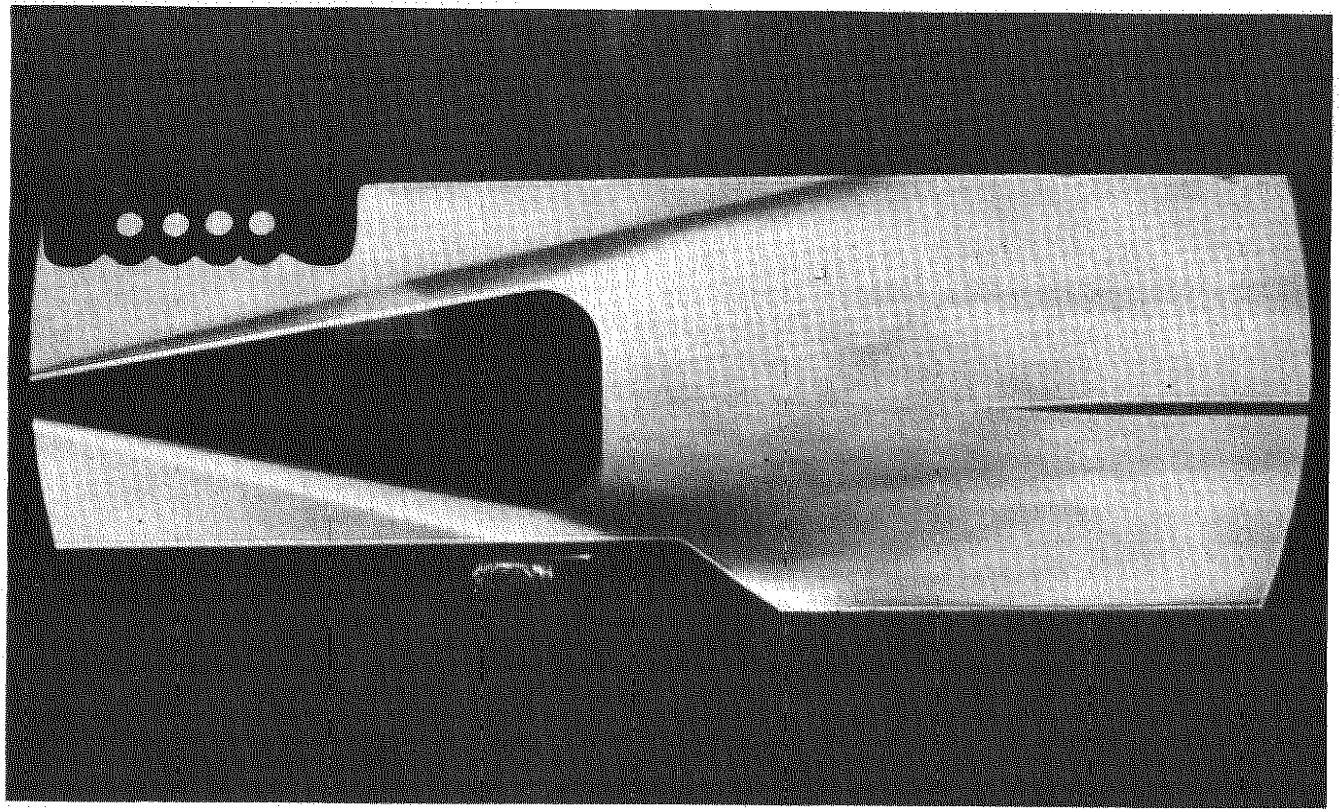


Fig.6. No interference from axial sting 0.12 inch dia.
Oil flowed on sting in mainstream direction

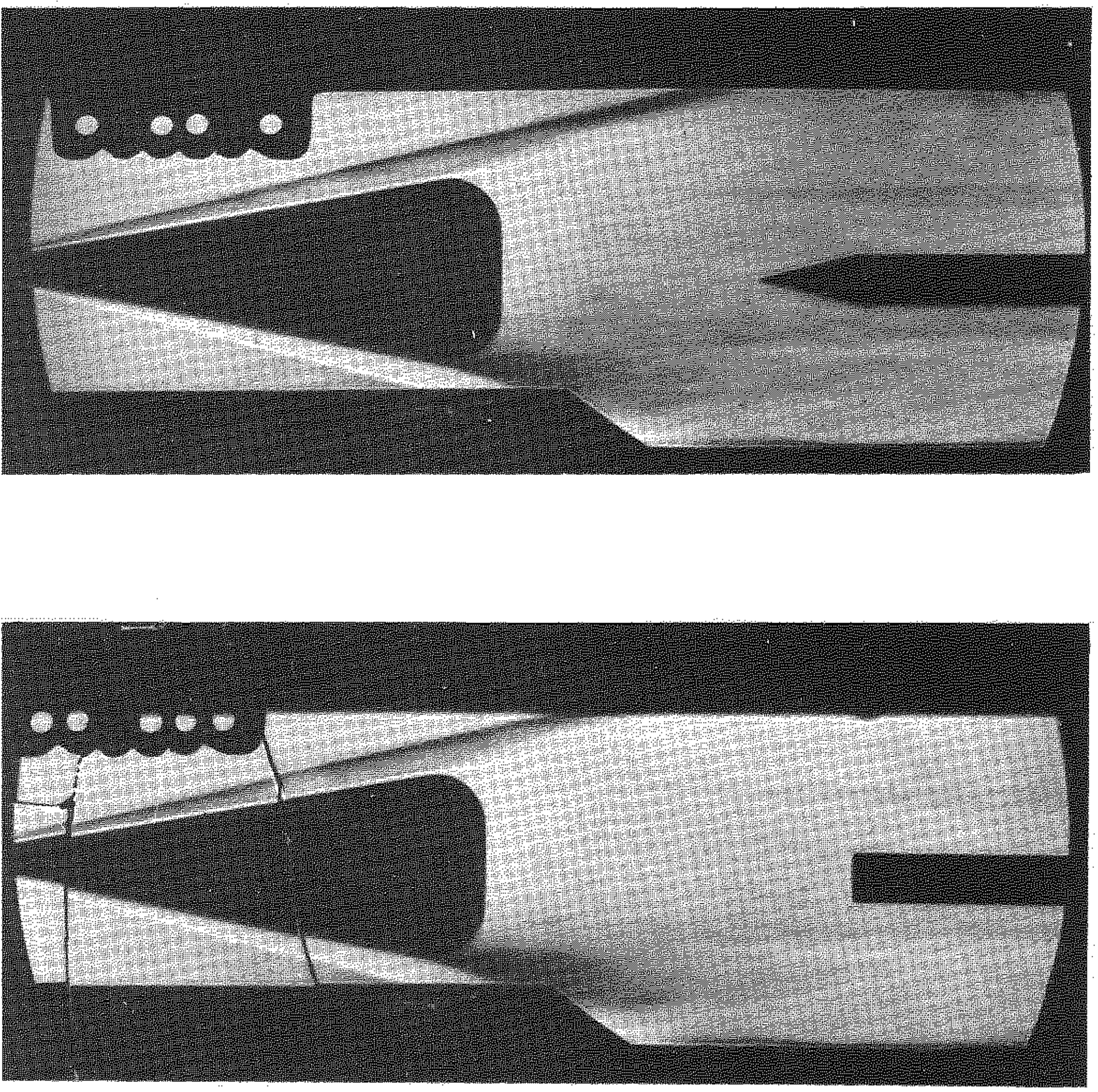


Fig.7. No interference from axial stings 0.49 inch dia.
N.B. No bow shockwave visible from stings

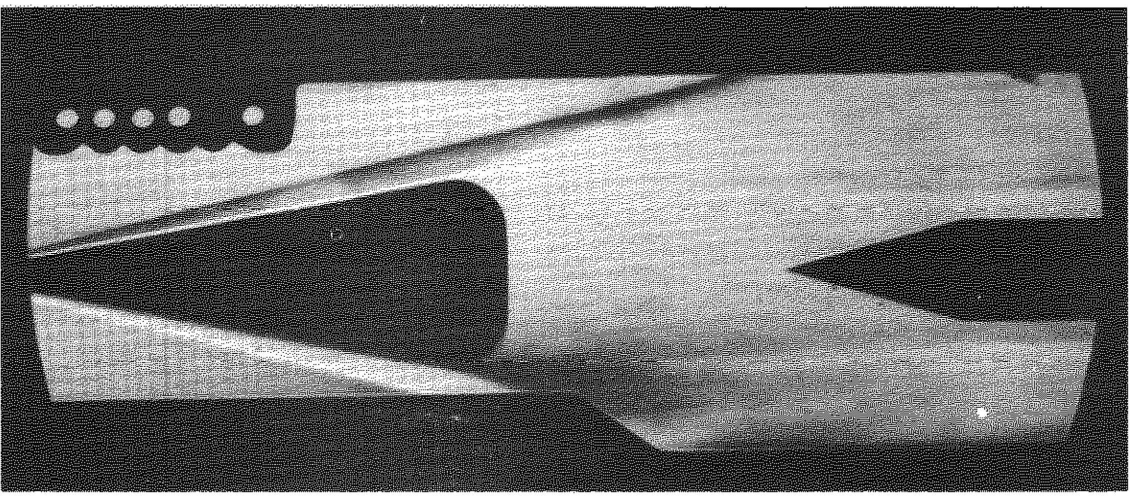


Fig.8. Interference with the wake from axial sting 0.98 inch dia. N.B. No bow shockwave visible in viscous core but there appears to be a shock in the external flow within the wake shock

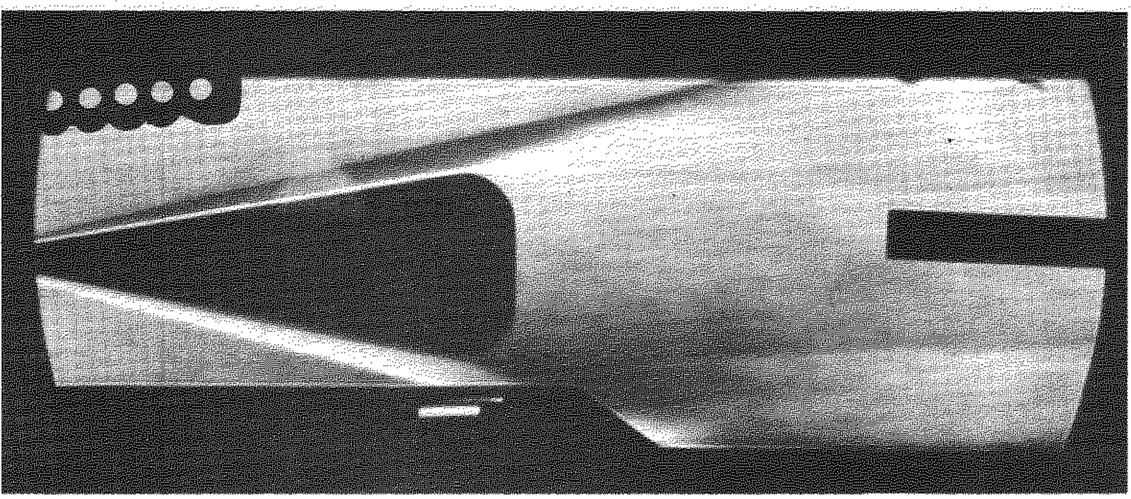
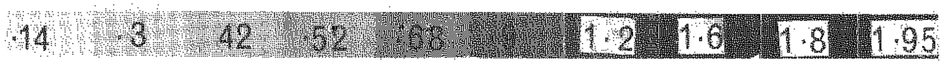


Fig.9. Interference with the wake from a canted sting at $2y/d=0.64$. N.B. Shockwave from sting disturbance visible in the external flow within the wave shock



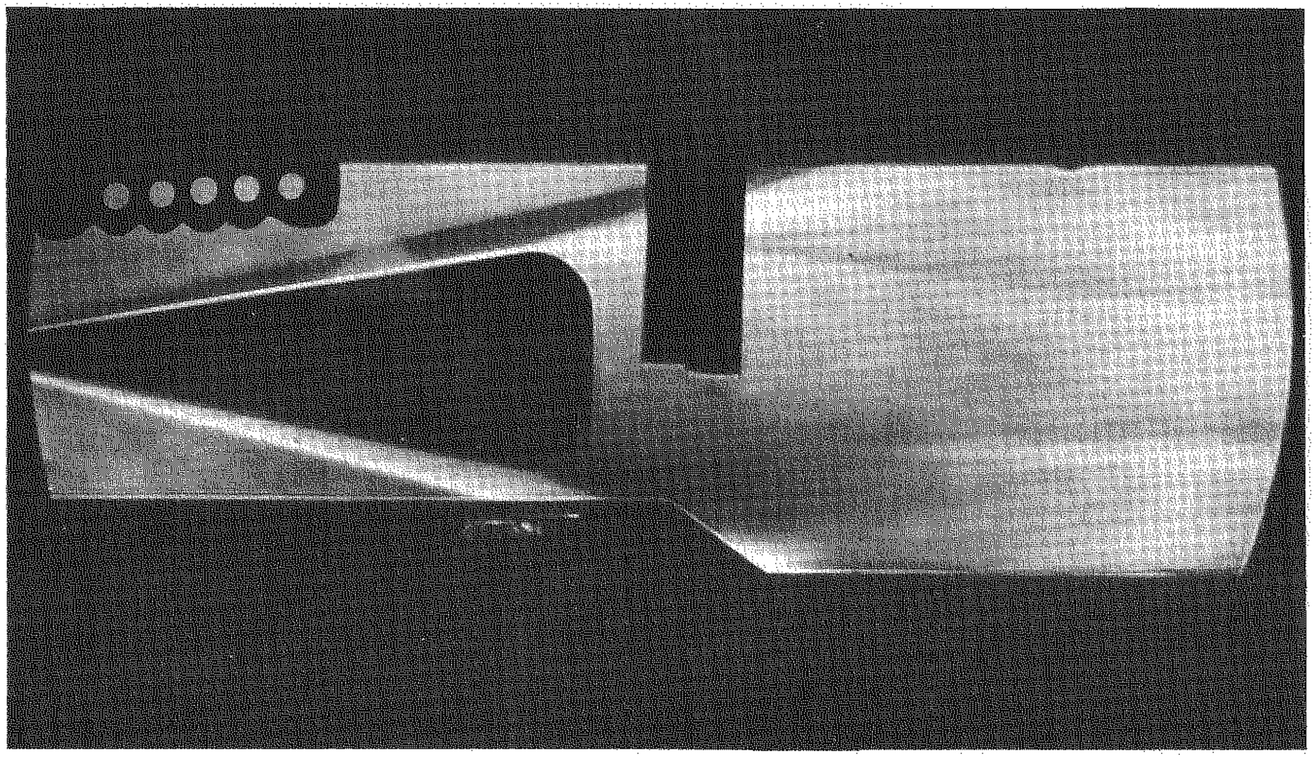


Fig.10. Interference with the wake from a transverse probe at $x/d=0.25$

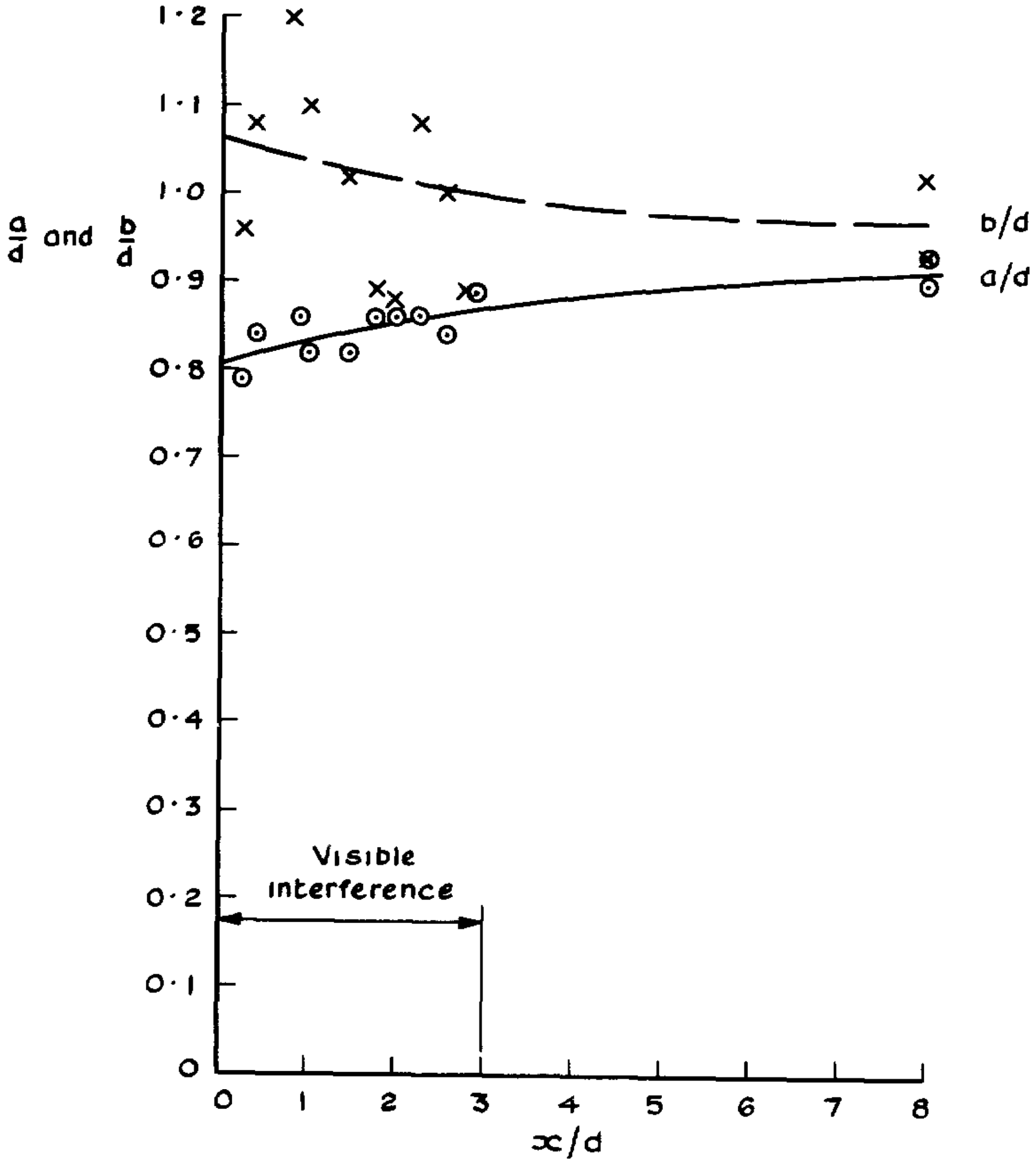


Fig. 11 Transverse probe interference on wake shock

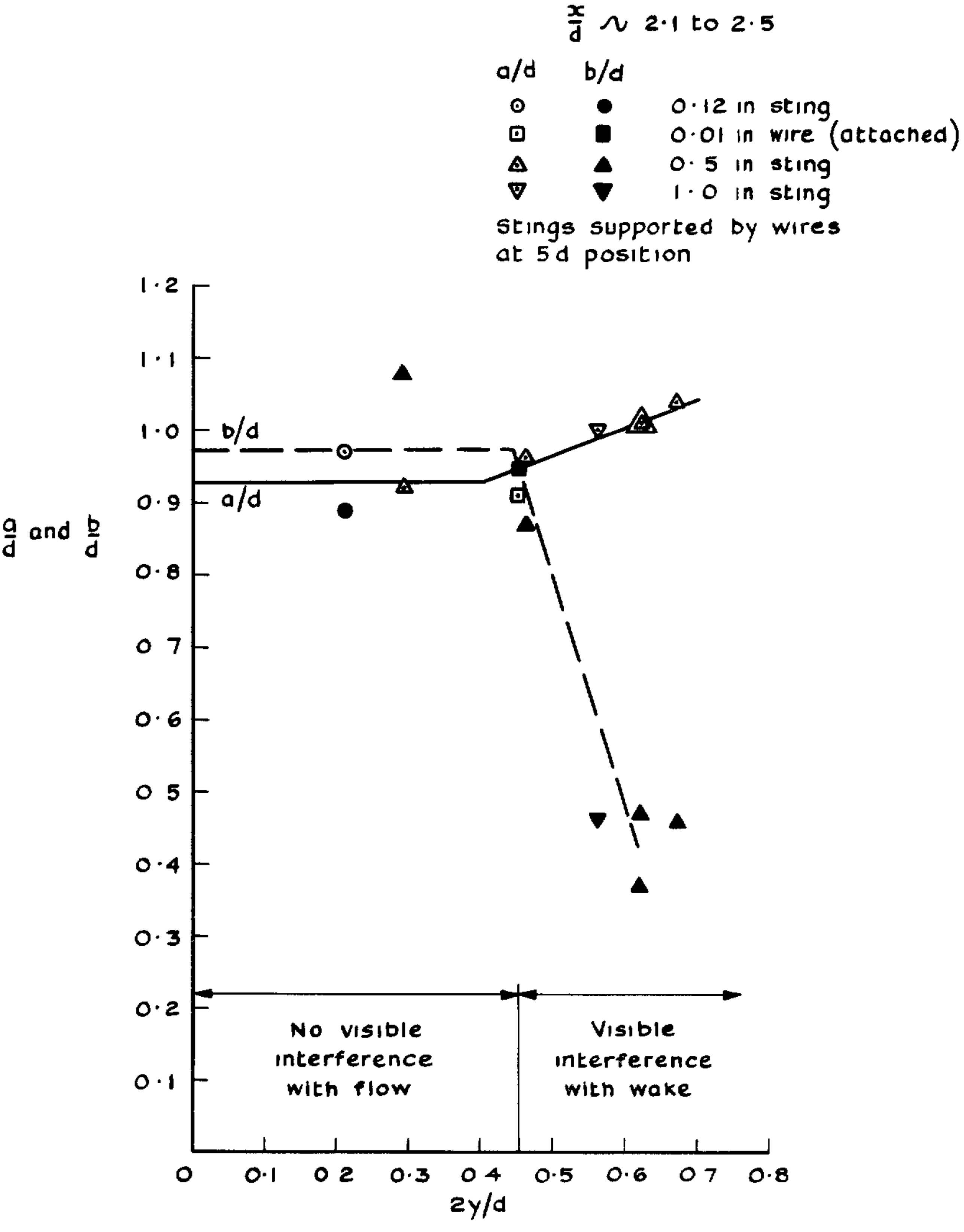
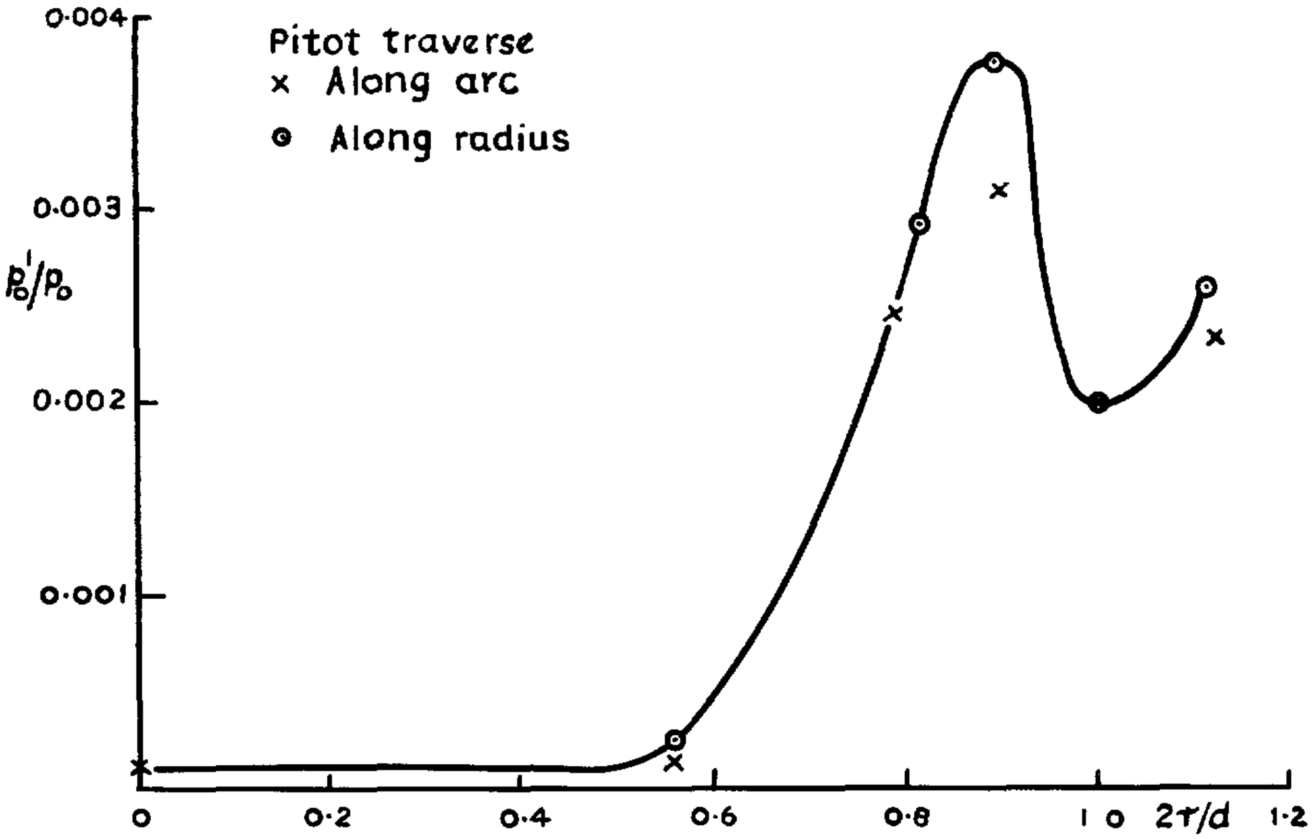
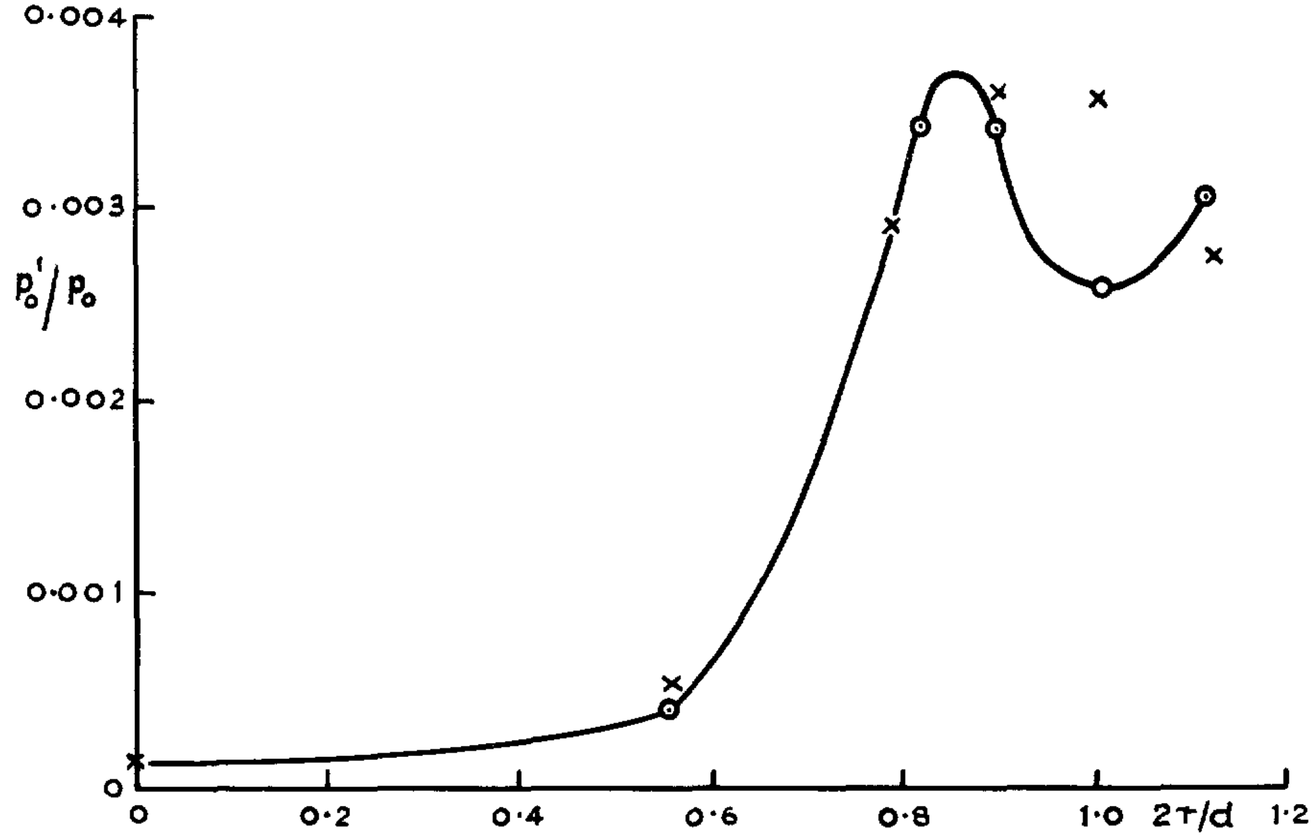


Fig. 12 Axial probe interference on wake shock

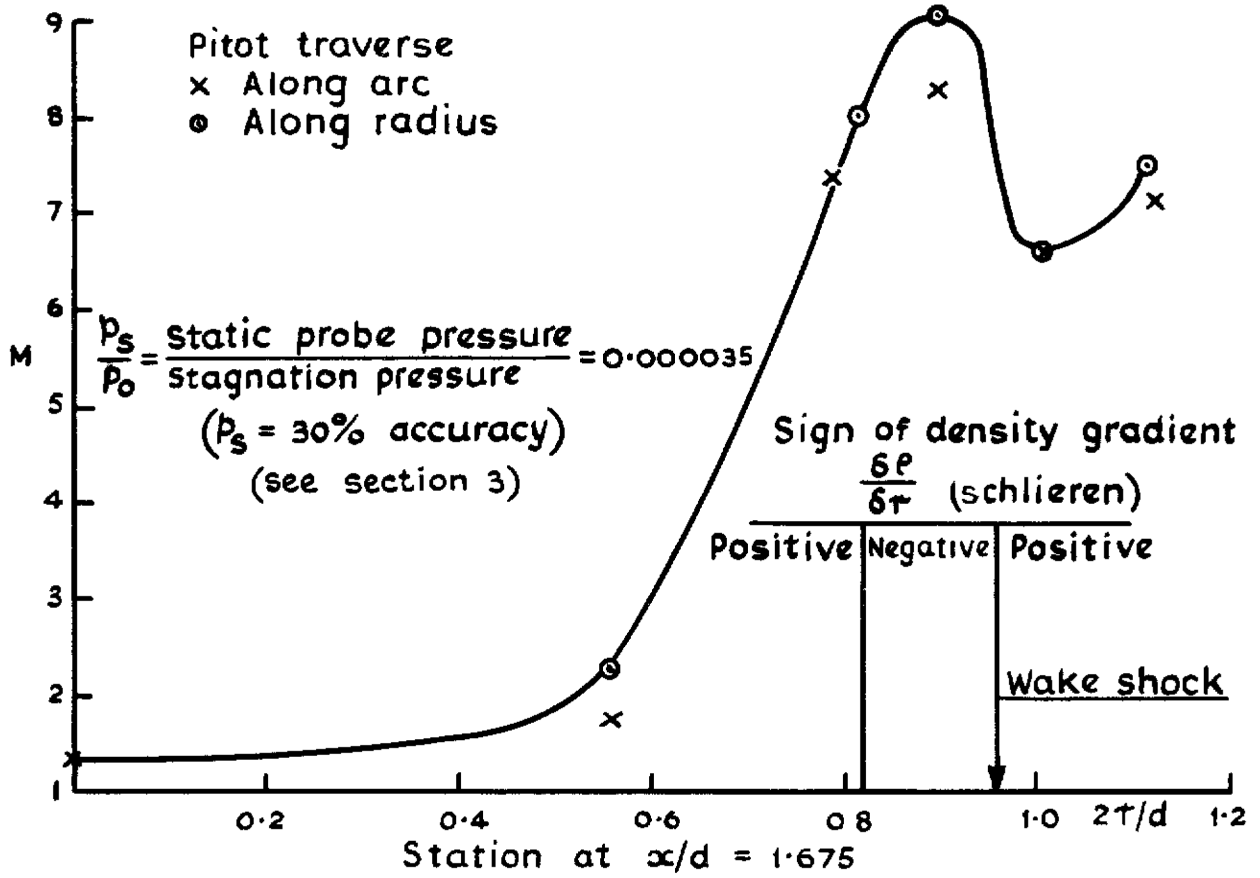


Station at $x/d = 1{\cdot}675$



Station at $x/d = 2{\cdot}237$

Fig. 13 Comparison of pitot traverse techniques



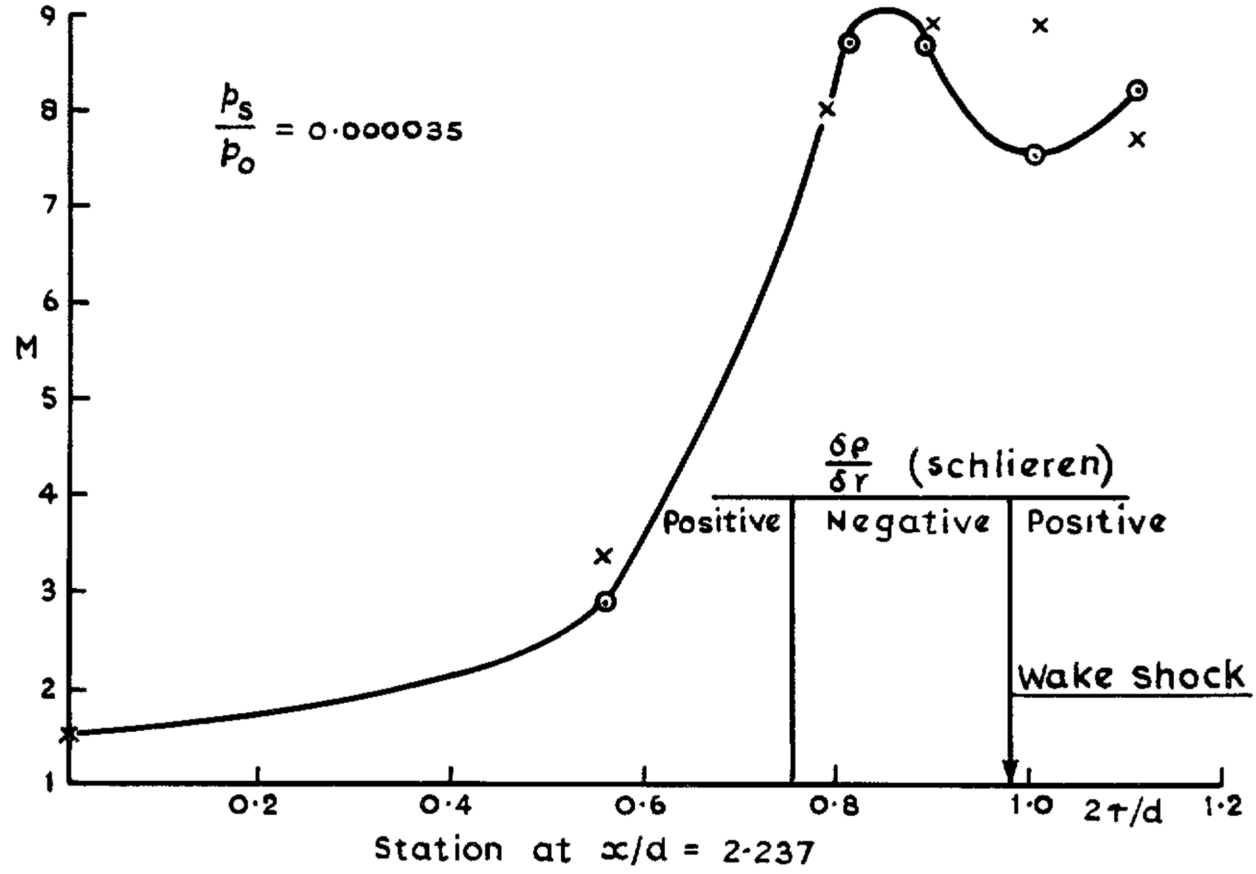


Fig. 14 Mach number profiles compared with schlieren details of flow field

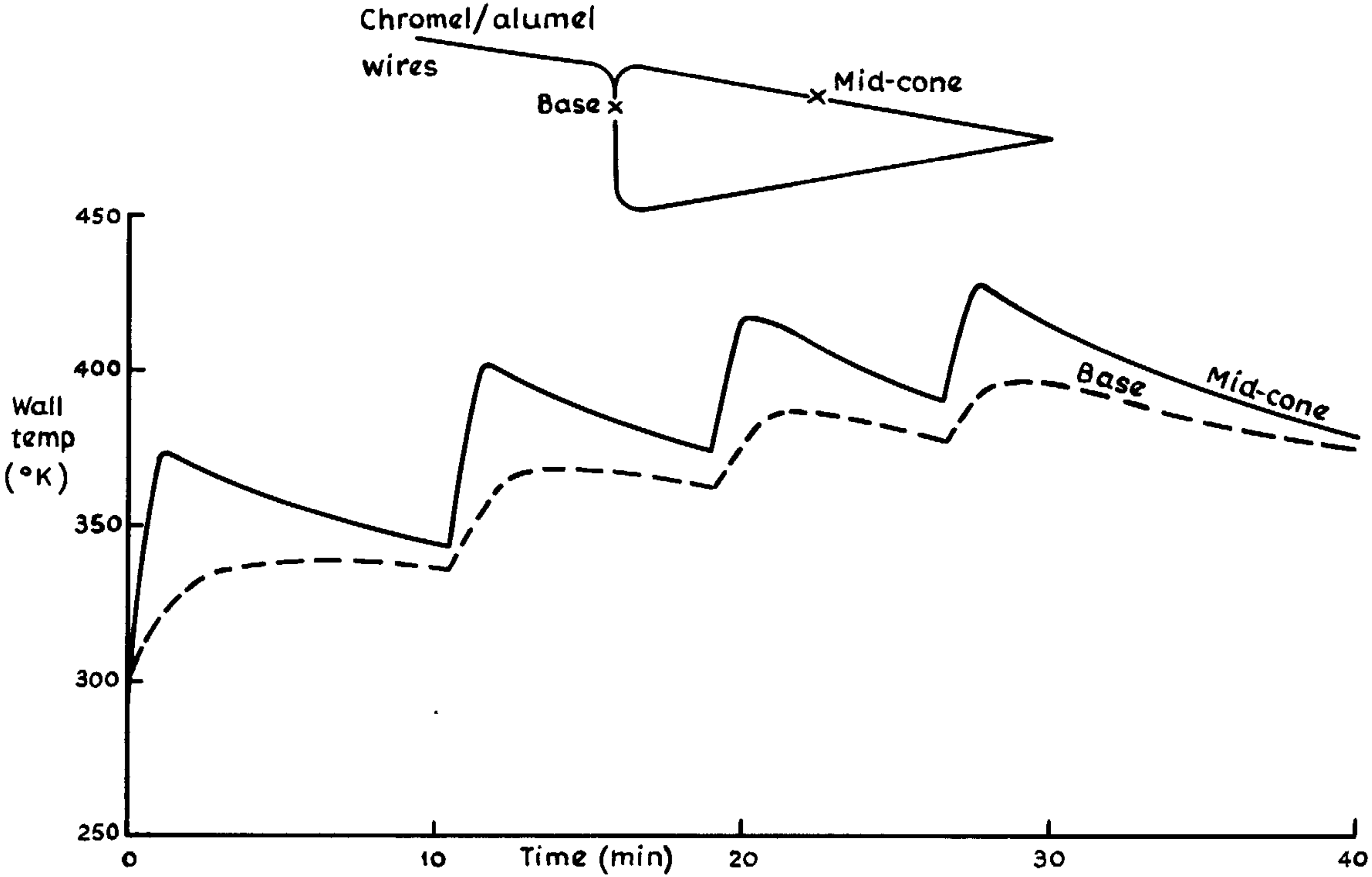


Fig 15 Base and mid-cone temperatures during a series of four one minute runs at $M_{\infty} = 8{\cdot}52$ $p_o = 400$ psi $T_o = 700°K$

Printed in England for Her Majesty's Stationery Office by the Royal Aircraft Establishment, Farnborough Dd 501371 K4

DETACHABLE ABSTRACT CARD

A.R.C. C.P. No. 1133
February 1970

Crane, J. F. W.

INTERFERENCE EFFECTS AT M = 8.5 OF WIRES AND PROBES ON
THE WAKE OF A MAGNETICALLY SUSPENDED ROUNDED BASE CONE

533.6.071.4:
533.6.071.32:
533.6.082.3:
533.6.048.3:
533.696.4:
533.6.011.55

Transverse and axial probes and wires in the wake produced two types of interference with the wake. With transverse probes and wires the effect is to narrow the wake shock diameter and move its source downstream. With axial probes and wires there is an opposite effect. The former is apparent when the probe is within three base diameters of the model, and the latter is apparent when the edge of the viscous core is approached from within.

A.R.C. C.P. No. 1133
February 1970

Crane, J. F. W.

INTERFERENCE EFFECTS AT M = 8.5 OF WIRES AND PROBES ON
THE WAKE OF A MAGNETICALLY SUSPENDED ROUNDED BASE CONE

533.6.071.4:
533.6.071.32:
533.6.082.3:
533.6.048.3:
533.696.4:
533.6.011.55

Transverse and axial probes and wires in the wake produced two types of interference with the wake. With transverse probes and wires the effect is to narrow the wake shock diameter and move its source downstream. With axial probes and wires there is an opposite effect. The former is apparent when the probe is within three base diameters of the model, and the latter is apparent when the edge of the viscous core is approached from within.

A.R.C. C.P. No. 1133
February 1970

Crane, J. F. W.

INTERFERENCE EFFECTS AT M = 8.5 OF WIRES AND PROBES ON
THE WAKE OF A MAGNETICALLY SUSPENDED ROUNDED BASE CONE

533.6.071.4:
533.6.071.32:
533.6.082.3:
533.6.048.3:
533.696.4:
533.6.011.55

Transverse and axial probes and wires in the wake produced two types of interference with the wake. With transverse probes and wires the effect is to narrow the wake shock diameter and move its source downstream. With axial probes and wires there is an opposite effect. The former is apparent when the probe is within three base diameters of the model, and the latter is apparent when the edge of the viscous core is approached from within.

C.P. No. 1133

Published by
HER MAJESTY'S STATIONERY OFFICE

To be purchased from
49 High Holborn, London w c.1
13a Castle Street, Edinburgh EH 2 3AR
109 St Mary Street, Cardiff CF1 1JW
Brazennose Street, Manchester 2
50 Fairfax Street, Bristol BS1 3DE
258 Broad Street, Birmingham 1
7 Linenhall Street, Belfast BT2 8AY
or through any bookseller

C.P. No. 1133

SBN 11 470381 7