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The Development of a Static Tube which is Insensitive to Incidence at Supersonic Speeds

By

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LONDON: HER MAJESTY'S STATIONERY OFFICE

1961

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The Development of a Static Tube which is
Insensitive to Incidence at Supersonic Speeds

- By -
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February, 1960

SUMMARY

A static tube of conventional type with holes on the windward side only and at about 35° from the plane of symmetry was found to be almost insensitive to incidence for incidences of up to 14°, the limit of the tests. Of the symmetrical configurations tested, the one least sensitive to incidences up to about 10° appeared to be that with holes at about 25° from the plane of symmetry. The tests were carried out at a Mach number of 2.

Notation

C_p	pressure coefficient
C_{po}	pressure coefficient at zero incidence
ϕ	angle between pressure hole and the incidence plane
α	angle of incidence

1. Introduction

The experiments described below were done in conjunction with a project for which it was necessary to design a flat-nosed static pressure probe which would be as insensitive as possible to changes of incidence up to 10°. Two configurations were investigated (c.f. Fig.3), an asymmmetric one, suitable for cases where only positive incidence is encountered, and a symmetric one.

Some previous work is reported by Gracey[1] and in Fig.39 of his report, it is shown that at a point on the surface of a parabolic body of revolution, in the region of 35° to 40° from the incidence plane, the measured static pressure was insensitive to incidence in the range from 0° to 20°. A similar result can be obtained on a flat nosed circular cylinder as shown in Fig.1, drawn from the results of Ref.2, although not to such a high incidence. Gracey also gives results for cylindrical probes, with hemispherical, conical and truncated cone noses in which the static pressure measurements were insensitive to changes of incidence up to 15°, when the static holes were on the windward side at angles of 30°, 33° and 37½° respectively to the incidence plane.

The results obtained by Hall, Rogers, and Davis[2] are more easily related to the present investigation if they are replotted as the variation of pressure measured at some hole, against incidence. The static pressures measured at about 12 diameters from the nose are

plotted/

Previously issued as A.R.C.21,644

plotted in this way in Fig.2; they show that a hole at an angle, ϕ, of about 35° to the incidence plane gives the minimum sensitivity to incidence.

It is assumed throughout that the incidence is in one plane.

2. Experimental Details

The model, which is shown in Fig.3, consisted of a flat-ended cylindrical pitot-static tube. The pitot hole was not used in the present investigation. The tube was 9" long and 0.5" diameter, with a static hole drilled at 4.5" (9 diameters) from the nose. This one hole is equivalent to two holes placed symmetrically on either side of the plane of incidence and was on the pressure side of the tube at positive incidences.

The tests were carried out in the N.P.L. 14" x 11" supersonic wind tunnel at a Mach number of 2.0. The static pressure was measured at incidences in the range 0° to 14° for values of ϕ of 30°, 35°, and 40°. The body was held in a cradle attached to the incidence changing gear which allowed the incidence to be altered while the tunnel was running. When changing incidence the model rotated about the position of the static hole.

In order to produce a probe which would be insensitive to incidence in the range -10° to 10° it was necessary to use a symmetrical distribution of pressure holes. Another static hole was drilled diametrically opposite to the original one; these two holes may then be considered equivalent to a tube with four holes. The static pressure was measured with the plane of the pressure holes at three angles to the incidence plane, ϕ = 20°, 30°, and 40°.

The measured static pressure at zero incidence differed slightly from the true local static pressure but this is unimportant in the present context since it can be included in the instrument calibration. The results are presented in terms of the difference between C_p and its value at zero incidence, C_{po}.

3. Results

3.1 Asymmetric configuration

The variation of measured static pressure with incidence is shown in Fig.4 for values of ϕ of 30°, 35°, and 40°. At roll angles greater than 35° the pressure falls with increase of incidence from zero (as, for example is usual for a static tube with four equally spaced holes). On the other hand for roll angles less than 35° the pressure increases with increase of incidence in the range of incidence investigated.

When the incidence is increased in the opposite direction, the pressure falls rapidly, the shape of the curve being almost independent of the roll angle, ϕ. This suggested that a roll angle smaller than 35° would prove the least sensitive configuration in the symmetrical case. This is because a comparatively high pressure is required on the pressure side of the body to balance the low pressure on the suction side.

3.2 Symmetric configuration

It did not prove possible to find a roll angle for which the measured static pressure was as insensitive to incidence as it

was/

was for $\phi = 35^\circ$ in the asymmetric case. However the results for $\phi = 20^\circ$, 30°, and 40° which are shown in Fig.5, show that for some value of ϕ between 20° and 30°, the maximum value of, C_p could be kept below about 0.01 in the incidence range from -10° to $+10^\circ$.

4. Conclusion

A flat-nosed cylindrical static tube was found to be reasonably insensitive to incidence if the static holes were at particular stations around the circumference when the holes were drilled on the pressure side only, at about 35° to the incidence plane, there was no significant variation in the measured static pressure at positive incidences up to 14°. The best symmetrical configuration was found to be when the holes were drilled at about 25° to the incidence plane. In this case C_p was always less than 0.01 in the incidence range from -10° to $+10^\circ$.

References

No.	Author(s)	Title, etc.
1	W. Gracey	The measurement of static pressure on aircraft. N.A.C.A. Report 1364. Supersedes TN 4184. 1958.
2	I. M. Hall, E. W. E. Rogers and Miss B. M. Davis	Experiments with inclinded blunt-nosed bodies at $M_0 = 2.45$. A.R.C. R. & M.3128. August, 1957.

Table I/

Table I

C_p at M_o = 2.0. Asymmetric configuration

α	$C_p - C_{po}$		
	ϕ = 30°	ϕ = 35°	ϕ = 40°
-14°		-0.0648	
-12°		-0.0478	
-10°		-0.0313	
- 8°		-0.0248	
- 6°		-0.0113	
- 4°		-0.0056	
- 2°		-0.0008	
- 1°		-0.0002	
0°	0	0	0
1°	+0.0046	+0.0016	+0.0019
2°	+0.0046	+0.0022	+0.0035
3°	-0.0005		+0.0016
4°	+0.0006	-0.0027	-0.0005
5°	+0.0033		-0.0003
6°	+0.0060	+0.0003	+0.0008
8°	+0.0115	+0.0008	-0.0019
10°	+0.0166	+0.0006	-0.0054
12°	+0.0188	+0.0019	-0.0122
14°	+0.0251	+0.0019	-0.0142

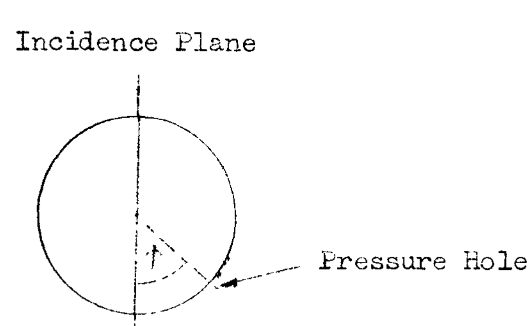
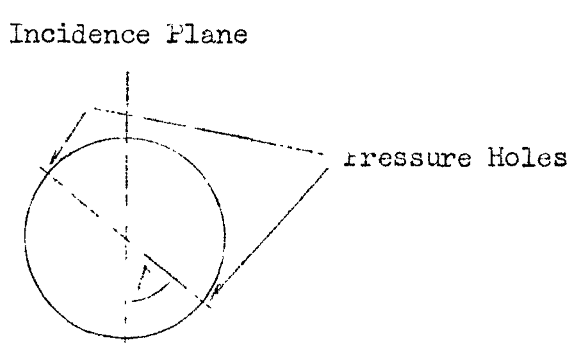


Table II

C_p at M_o = 2.0. Symmetric Configuration

α	$C_p - C_{po}$		
	$\phi = 20^\circ$	$\phi = 30^\circ$	$\phi = 40^\circ$
0°	0	0	0
1°	+0.0018	+0.0027	-0.0008
2°	+0.0013	+0.0011	-0.0016
4°		-0.0030	-0.0071
6°	+0.0073	-0.0038	-0.0114
8°	+0.0097	-0.0101	-0.0253
10°	+0.0010	-0.0141	-0.0346
12°	-0.0063	-0.0210	-0.0422
14°	-0.0168	-0.0359	-0.0503



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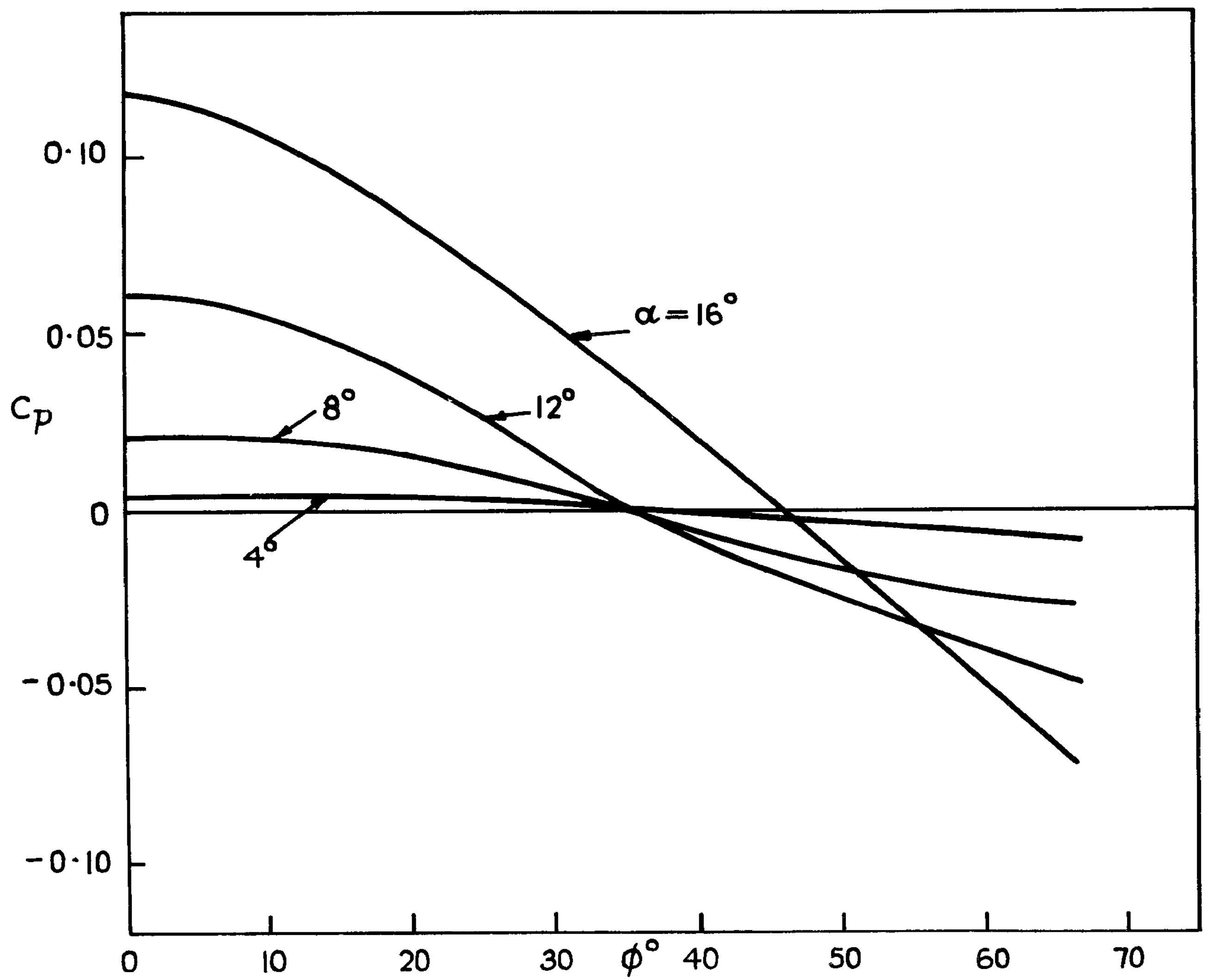


The pressure distribution around a flat-ended body of revolution at 12 diameters from the nose. $M_0 = 2 \cdot 45$.

FIG. 1.

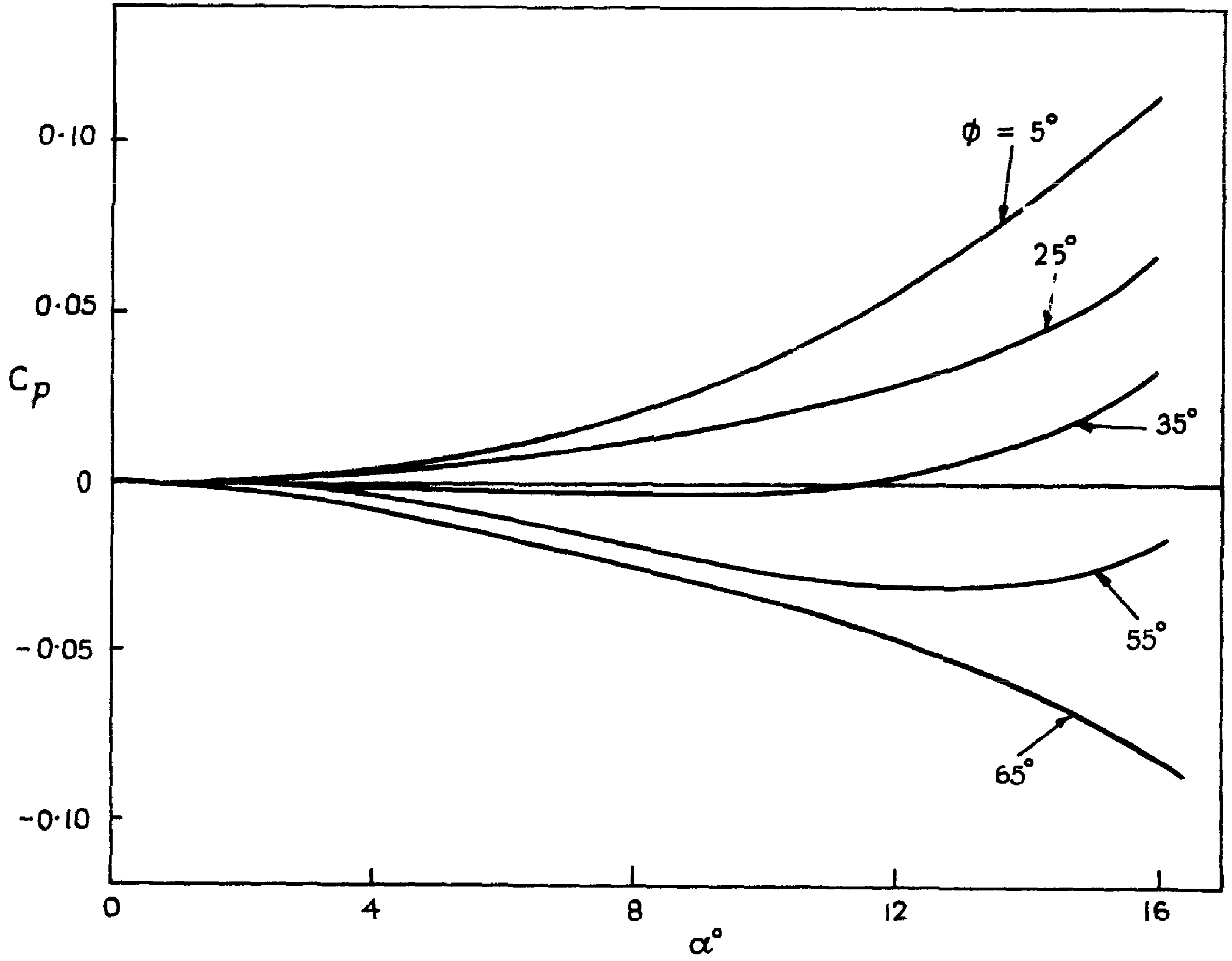
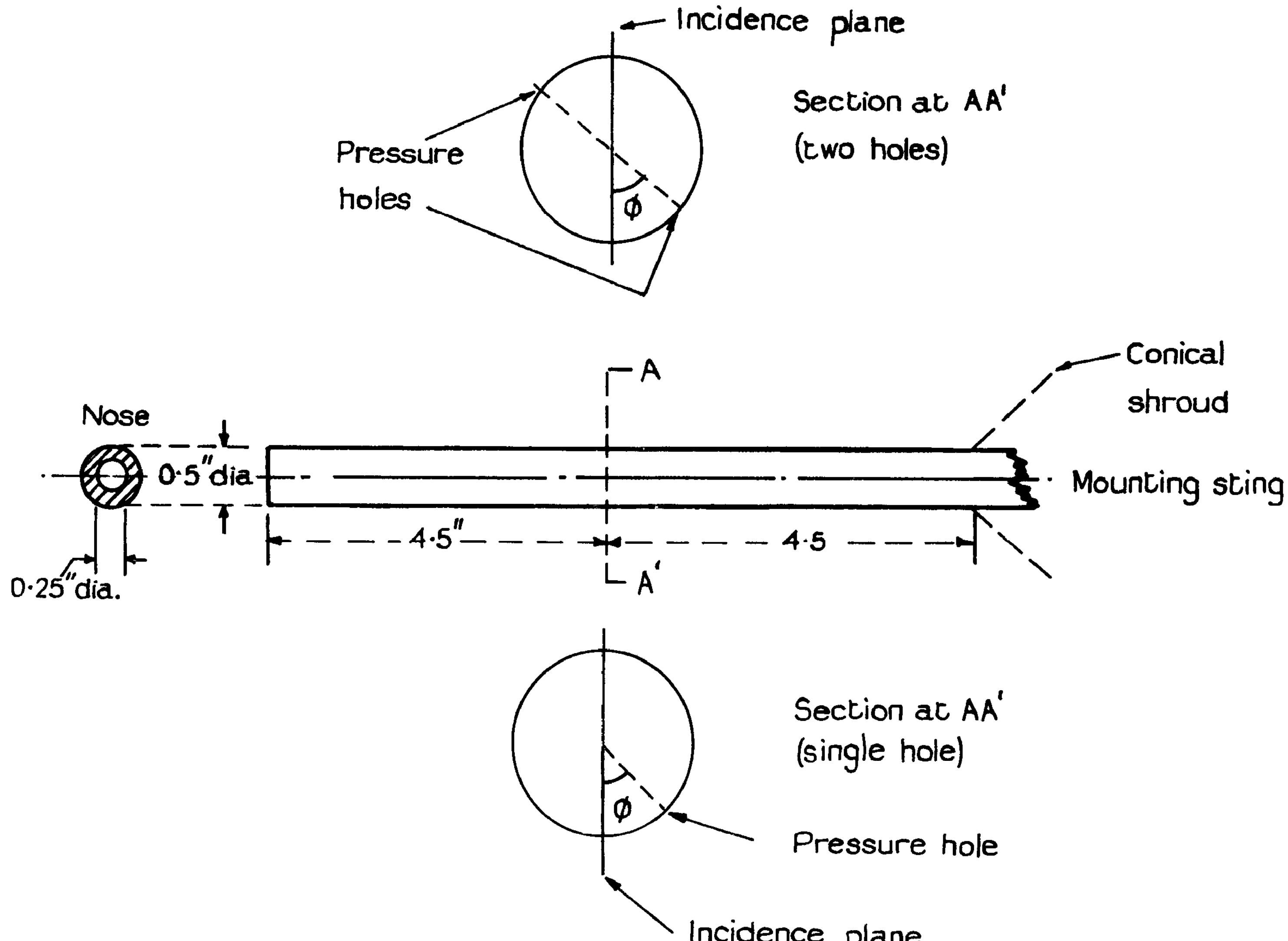


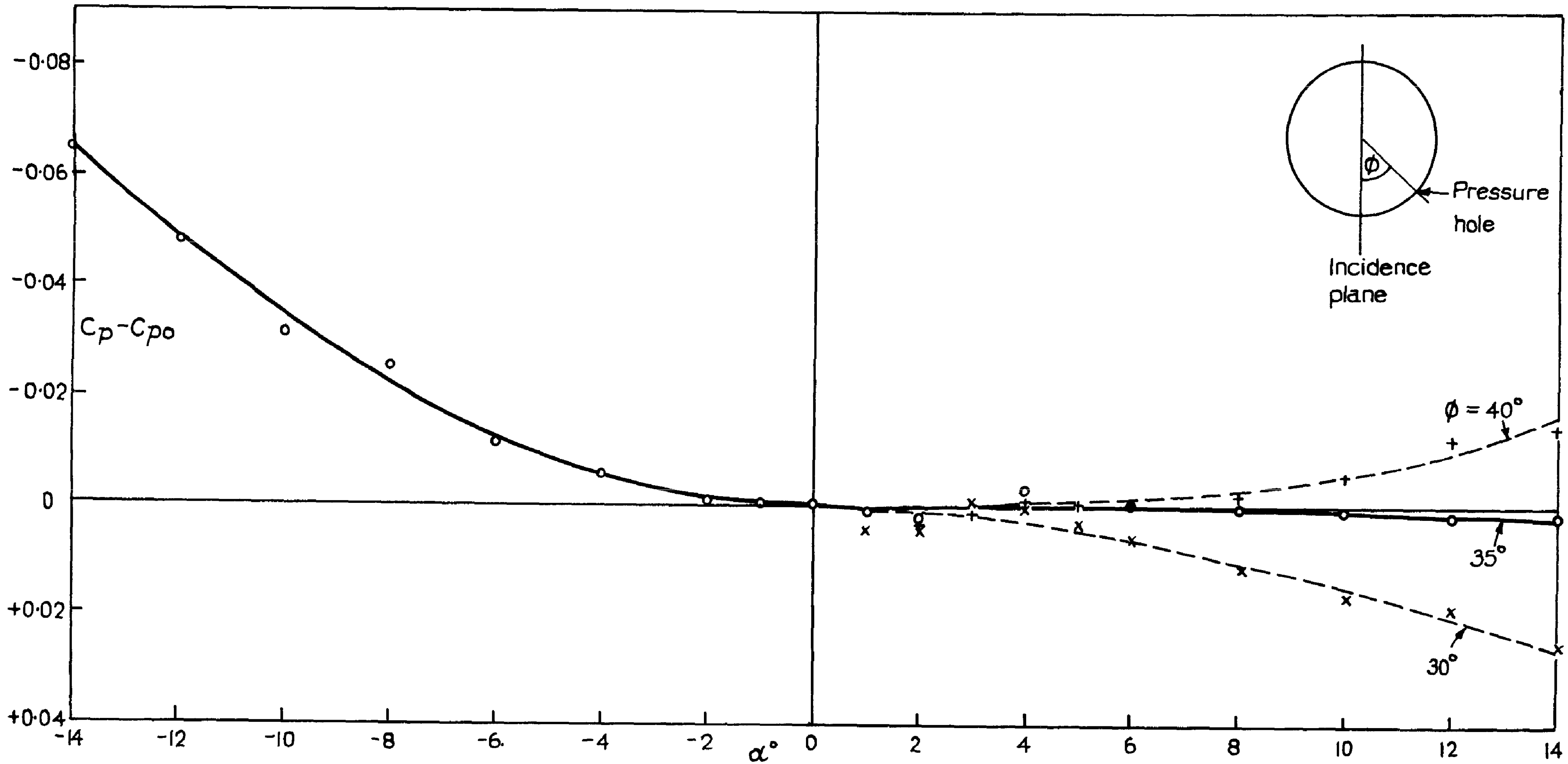
FIG. 2.

The variation of pressure with incidence at several points on a flat-ended body of revolution at 12 diameters from the nose. $M_o = 2 \cdot 45$.



The model

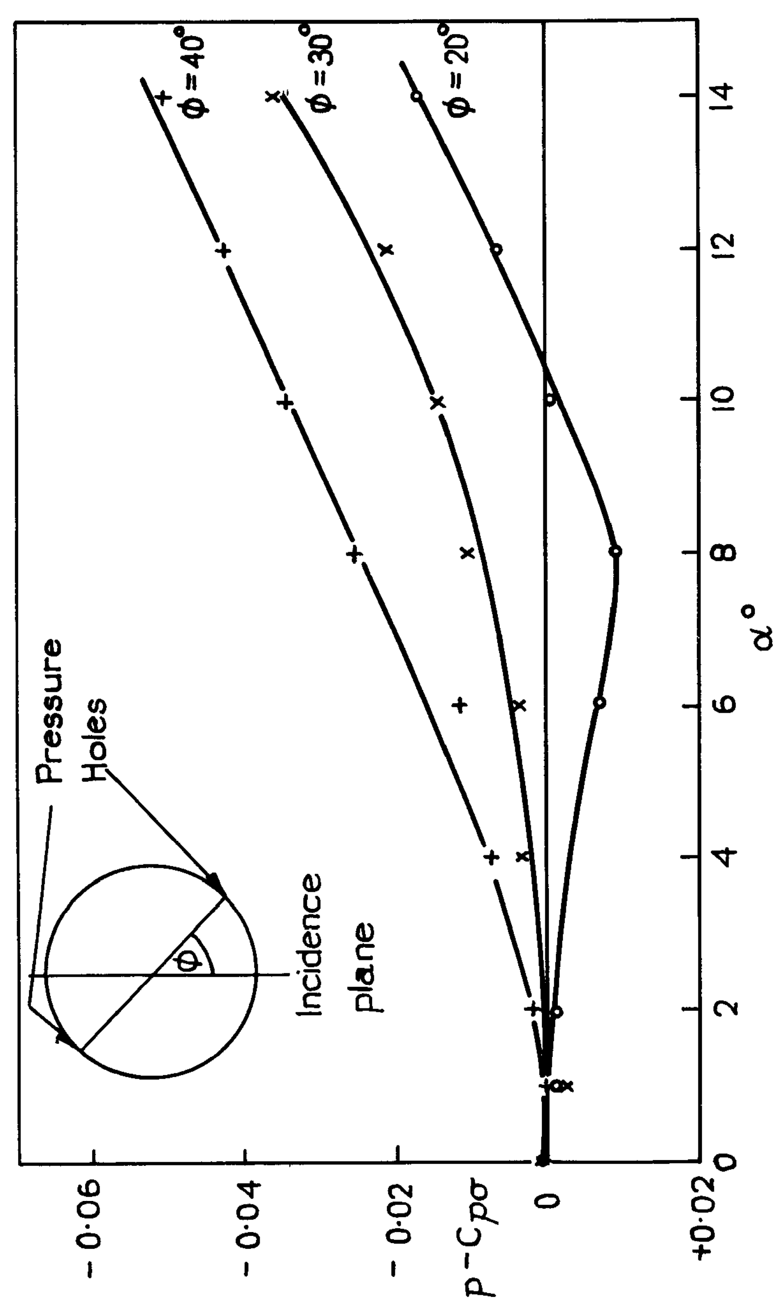
FIG. 3.



The variation of Cp with incidence – Asymmetric configurations.

FIG. 4.

FIG. 5.



The variation of C_p with incidence — Symmetric configurations.

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1.2.60
Townsend, J.E.G. - Nat. Phys. Lab.

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