C.P. No. 395
(20,297)
A.R.C. Technical Report

C.P. No. 395
(20,297)
A.R.C. Technical Report

MINISTRY OF SUPPLY

AERONAUTICAL RESEARCH COUNCIL
CURRENT PAPERS

The Influence of a Model on Plenum Chamber Indication of Mach Number in a Slotted Wall Wind Tunnel

By

L.C.Squire and A. Stanbrook

LONDON: HER MAJESTY'S STATIONERY OFFICE

1958

PRICE 2s. 6d. NET

C.P. No. 395

U.D.C. No. 533.6.011.35 : 533.6.071

Technical Note No. Aero. 2541

February, 1958

ROYAL AIRCRAFT ESTABLISHMENT

THE INFLUENCE OF A MODEL ON PLENUM CHAMBER INDICATION OF MACH NUMBER IN A SLOTTED WALL WIND TUNNEL

by

L.C. Squire, and A. Stanbrook

SUMMARY

In many transonic tunnels the Mach number in the working section is determined from a pressure measured in the plenum chamber, on the assumption that this pressure is uniquely related to the free stream static pressure. The effect of a number of different sting-mounted models of solid blockage up to about $\frac{1}{2}$ per cent on this relationship has been investigated in the 3 ft tunnel at RAE Bedford. The results show that the Mach number determined from the pressure in the plenum chamber is not affected by the presence of any of the models in the working section, provided that the pressure is not measured near the downstream end of the plenum chamber.

LIST OF CONTENTS

LIST OF ILLUSTRATIONS

1 INTRODUCTION

In many transonic tunnels the Mach number in the working section is determined from a pressure measured in the plenum chamber[3], on the assumption that this pressure is uniquely related to the free stream static pressure at any Mach number. This relationship is found by calibration in the empty tunnel.

Some uncertainty exists as to the effect of the presence of a model in the working section on this relationship and an investigation of this effect has been made in the 3 ft tunnel at RAE, Bedford. A basic difficulty in this type of investigation is that the free stream conditions cannot be readily specified with a model in position; however, since the transonic working section of the 3 ft tunnel is relatively long there are points (on the wall) sufficiently far upstream of the model position to justify the assumption that the effect there of the presence of the model is negligible. The most suitable of these points has been chosen (as described in section 3) to define the Mach number of the flow.

2 DETAILS OF TESTS

2.1 Description of the transonic working section

Figure 1 shows the arrangement of the transonic working section in which the tests were carried out. The section is 3 feet square, with all four walls slotted, and is surrounded by a plenum chamber approximately one foot deep. The section open-area ratio is 10% and there are four slots, one at the centre of each wall, and four half slots at the sides of the top and bottom walls. The total length of the slotted section is 3.6 working section heights, the slots beginning 2.5 working section heights ahead of the model centre of rotation. Full details of this section and its calibration are given in reference 1.

Pressures were measured at ten points in the plenum chamber and at 38 points along one of the slotted walls of the tunnel. The positions of all these points are shown in figure 1.

2.2 Details of the models

The various shapes of models used in this investigation are shown in figure 2 together with their relative positions in the working section. Models A to D were intended to provide a wide range of body shapes and sizes and model E was intended to show the effect of lift.

Blockage ratios obtained by dividing the maximum cross-sectional area of the models by the cross-sectional area of the working section are also given in figure 2. It should be noted that these blockage ratios are determined by the geometry of the model and that they do not necessarily define the scale of the disturbance in the tunnel. For instance, the flow on model A separates at the edge of the front face and a wake is produced with a cross-sectional area at least twice that of the model.

2.3 Experimental technique

Models A to D were tested at zero incidence at Mach numbers from 0.7 to 1.2. Model E was tested at incidences of 0, 5° and 10° over the same Mach number range. The total pressure was kept constant at 33 inches of mercury throughout the tests giving Reynolds numbers/inch of 0.36×10^6 at $M = 0.7$ and 0.43×10^6 at $M = 1.2$.

In all cases the pressures in the plenum chamber and along the wall of the working section were recorded. These pressures were also recorded without a model in the tunnel (with the model support rig faired over).

The pressures were measured on self-balancing capsule manometers[2], the dials of which were photographed. During the analysis it was found that the manometer connected to the plenum chamber hole D (at station* 92 in the row of holes along the plenum chamber) was defective. Consequently, no readings are presented for this hole.

2.4 Accuracy

The readings obtained are subject to two separate sources of error, one due to the accuracy of the pressure measuring equipment and the other due to the condition of the pressure holes. This second source of error is of no consequence since the analysis is only concerned with comparison of the pressures at individual holes under different conditions.

In the measurement of Mach number at any point the first of the sources produces an error in the individual pressure reading together with corresponding errors in the initial and final zero readings of the instrument; similar errors occur in the measurement of total pressure. Combining all these errors it is estimated that the standard deviation of the error in the derived Mach number at any point is 0.0008 throughout the Mach number range.

3 PRESENTATION AND DISCUSSION OF THE RESULTS

Figure 3 shows typical Mach number distributions measured at the tunnel wall in the empty tunnel. Figures 4 and 5 show comparable Mach number distributions obtained with the model considered to have the largest effective blockage (model A at zero incidence) and the model with the largest lift (model E at 10° incidence) in the tunnel.

A preliminary step in the analysis of the results was to choose one station on the wall at which the pressure conditions at any Mach number are suitable for use as a reference datum for the pressures at the other stations. The selected station must be (a) downstream of the region of accelerating flow so that the pressures there will be indicative of the general level of Mach number at the model position and (b) upstream of the influence of the model.

A comparison between the variation of the Mach number at each individual hole in the wall with the variation of the mean Mach number near the model position (from the original calibration data in the empty tunnel, reference 1) has shown that station 48 would satisfy the first requirement.

Strictly, the measurements obtained cannot show the limit of the upstream influence of the model. However, in practice the disturbance caused by the model decreases as the distance from the model increases, until the point is reached at which the effect of the model becomes less than the accuracy of the measurements. The wall distributions for model A (which had the largest apparent upstream influence) in figure 4 indicates that, in this sense, the hole at station 48 is sufficiently far upstream to be unaffected by the presence of the model.

Station 48 is, therefore, a suitable choice for a reference hole, and the Mach number, M_W, measured there is used as a datum in the following analysis.

---

* The "station" refers to the distance downstream of the beginning of the slots in inches.

The Mach number, M_p, indicated by the pressures in the plenum chamber are plotted in figures 6 and 7 in the form $(M_p - M_w)$. In figure 6 this difference is plotted against Mach number for the various stations along the plenum chamber with and without the models in the tunnel. Figure 7 shows this difference for the various stations around the plenum chamber at station 92.

Except at station 108, in figure 6, the results lie scattered within a band of width approximately 2 standard deviations of the error in the Mach number (see paragraph 2.4) as indicated for station 0 in figure 6. It will be noted that the results for model E were obtained at slightly lower Mach numbers than those for the other models; this was due to an incorrect zero setting of the reference manometer.

Within the limits of accuracy of the experimental measurements the results in figures 6 and 7 show that the variation of $(M_p - M_w)$ with Mach number is independent of the presence of a model in the tunnel except near the downstream end of the plenum chamber (as at station 108). Hence the assumption (mentioned in the introduction) that the plenum chamber pressure is uniquely related to the free stream static pressure at any Mach number is justified (for the range of models tested).

The larger scatter in the results at station 108 compared with the other stations may be explained by the displacement effect of the model and wake causing large changes in the diffuser flow which, in turn, penetrate the downstream end of the plenum chamber. However, although the results for any one model are systematically high or low, the variation from model to model does not follow any obvious pattern.

The results of this investigation may strictly only be applied to tunnels of similar layout. In particular, the effect of the presence of a model could be different in a tunnel with perforated walls or in a tunnel using auxiliary suction.

4 CONCLUSIONS

The results obtained show that the relationship between the Mach number measured at the wall sufficiently far upstream of the model position and a Mach number indicated by a pressure in the plenum chamber is unaltered by the presence of a model in the tunnel provided that the plenum chamber pressure is not measured near the downstream end of the plenum chamber.

The conclusions may not necessarily apply to ventilated working sections of other design or to larger models.

LIST OF SYMBOLS

M_p Mach number indicated by plenum chamber pressure

M_w Mach number measurod at hole in slotted wall 48 inches from beginning of slots

α Angle of incidence

LIST OF REFERENCES

Ref. No.	Author	Title, etc.
1	Sutton, E.P. Stanbrook, A. Caiger, M.T.	Performance of the 36" x 35" transonic working section of the RAE Bedford 3 ft wind tunnel. R.A.E. Report in preparation.
2	Midwood, G.F. Hayward, R.W.	An automatic self-balancing capsule manometer. C.P. 231. July, 1955.
3	-	Transonic wind tunnel testing techniques Jour. R.Ae.S. Vol.62, No.565 pp.1-31 January, 1958.

WT.2078.C.P.395.K3 - Printed in Great Britain

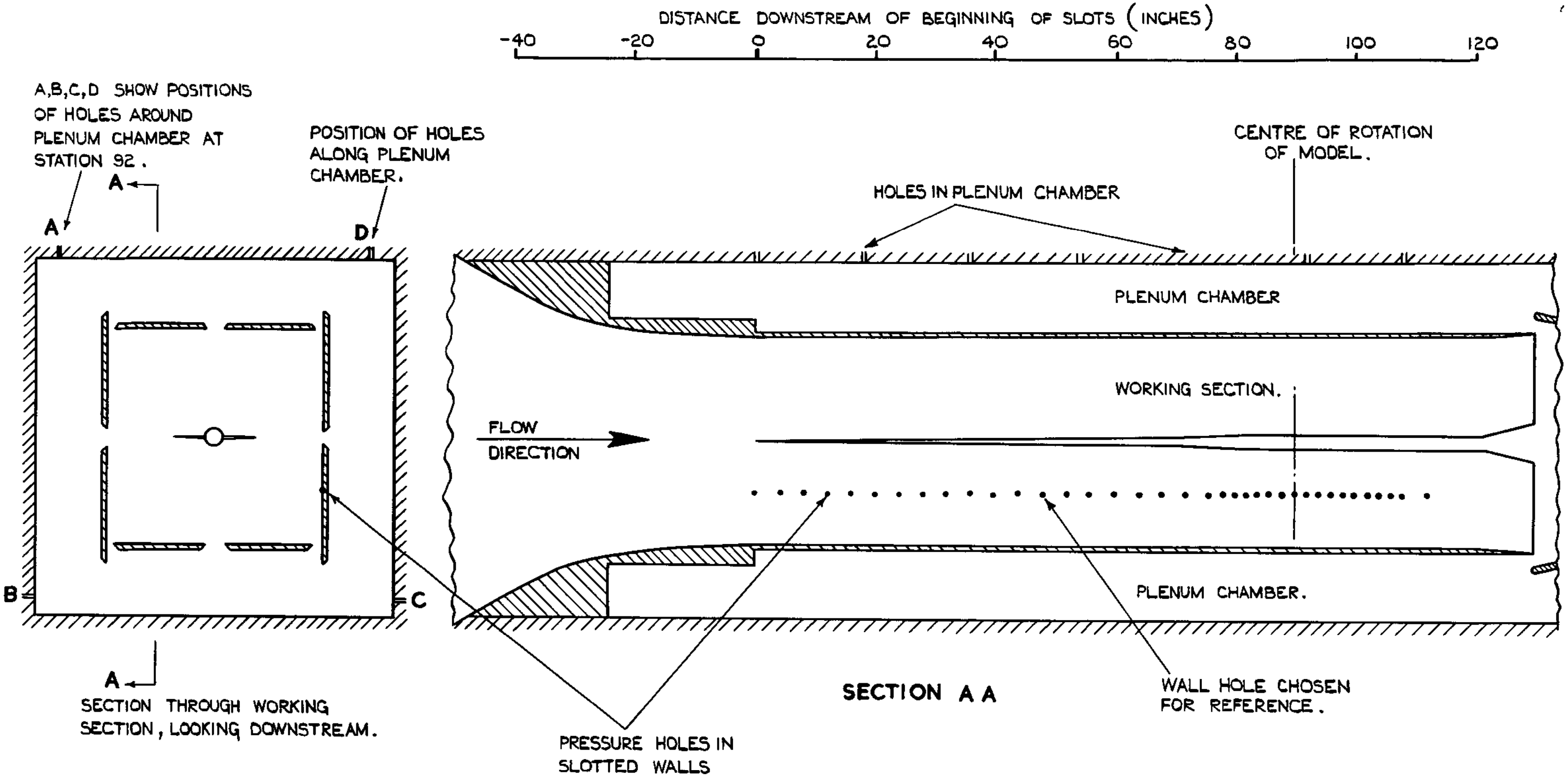

FIG. 1. RELATIVE POSITION OF SLOTTED WALLS WITHIN PLENUM CHAMBER AND POSITIONS OF PRESSURE HOLES.

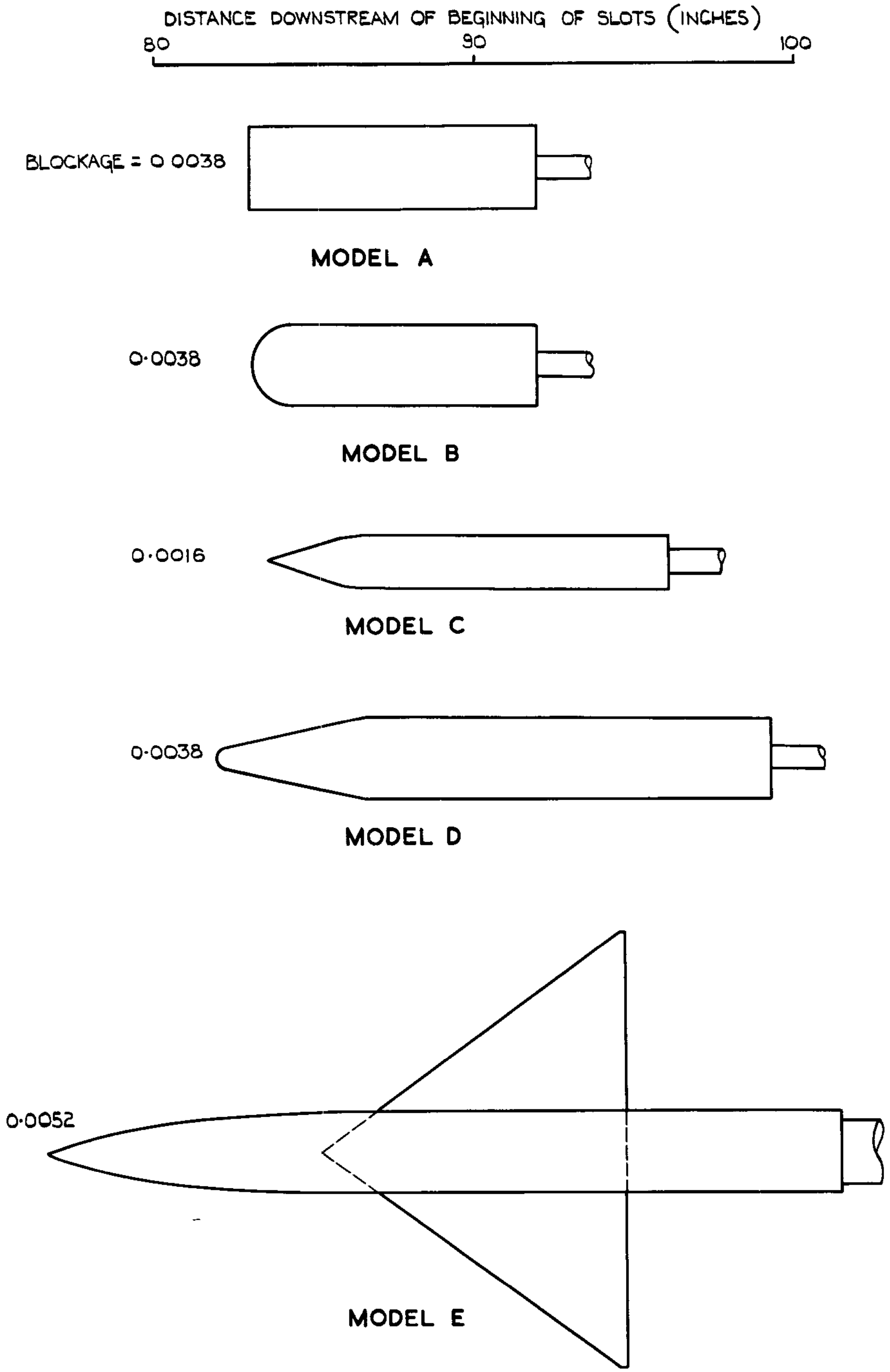

FIG.2. THE MODELS TESTED, SHOWING THEIR RELATIVE POSITION IN THE WORKING SECTION.

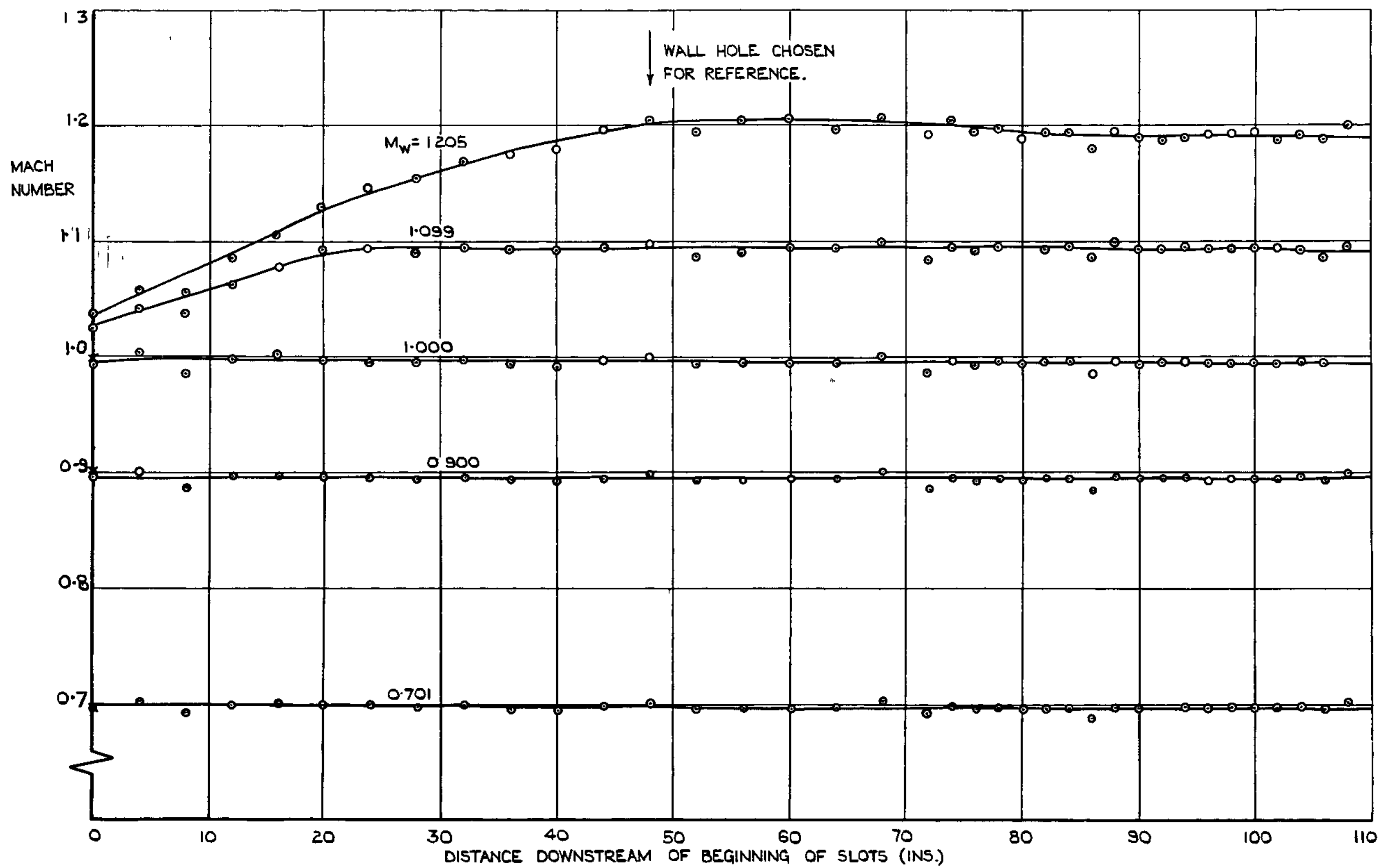

FIG.3. MACH NUMBER DISTRIBUTIONS ALONG SLOTTED WALLS IN THE EMPTY TUNNEL

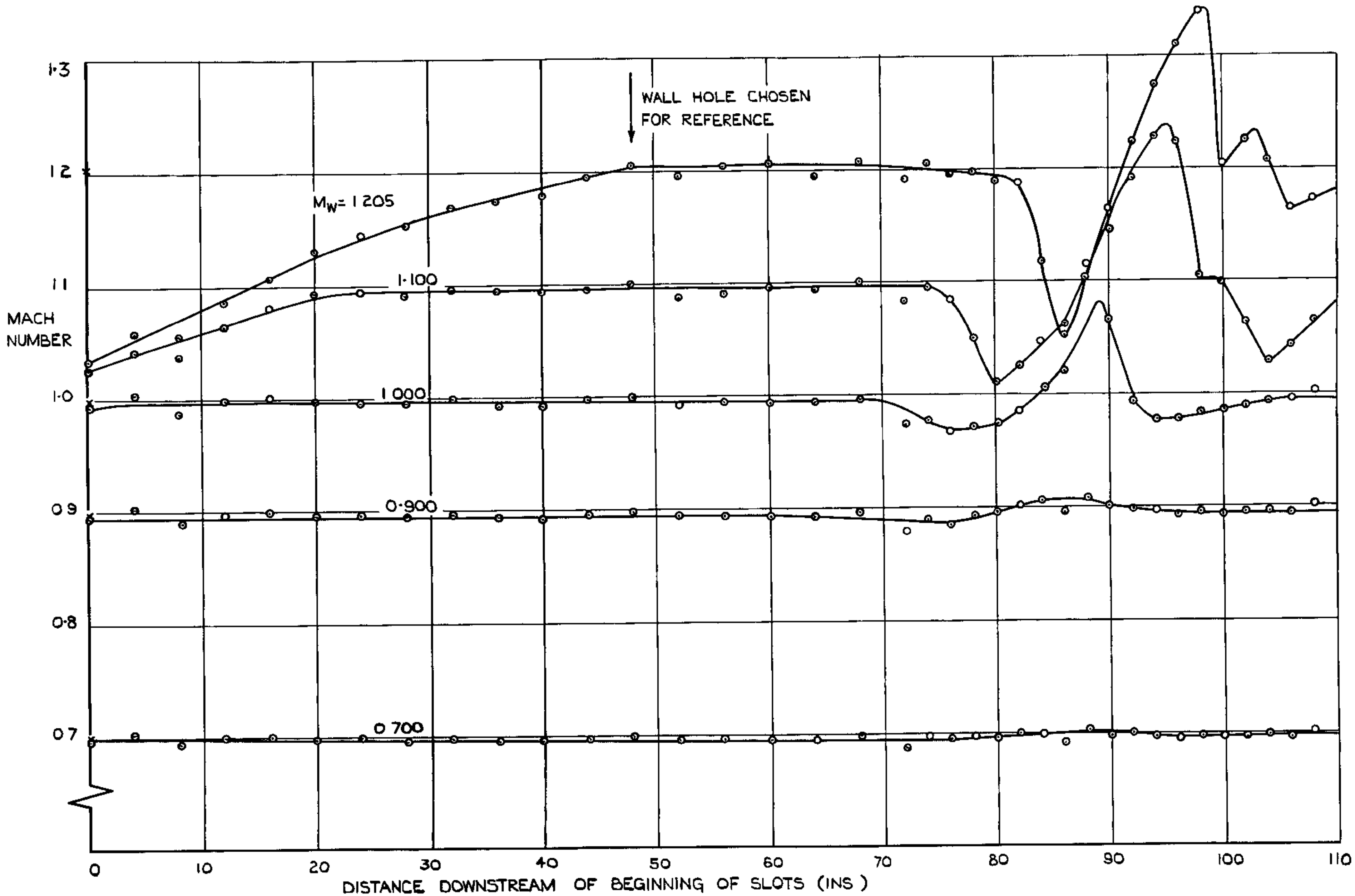

FIG. 4. MACH NUMBER DISTRIBUTION ALONG SLOTTED WALLS WITH MODEL A IN THE TUNNEL.

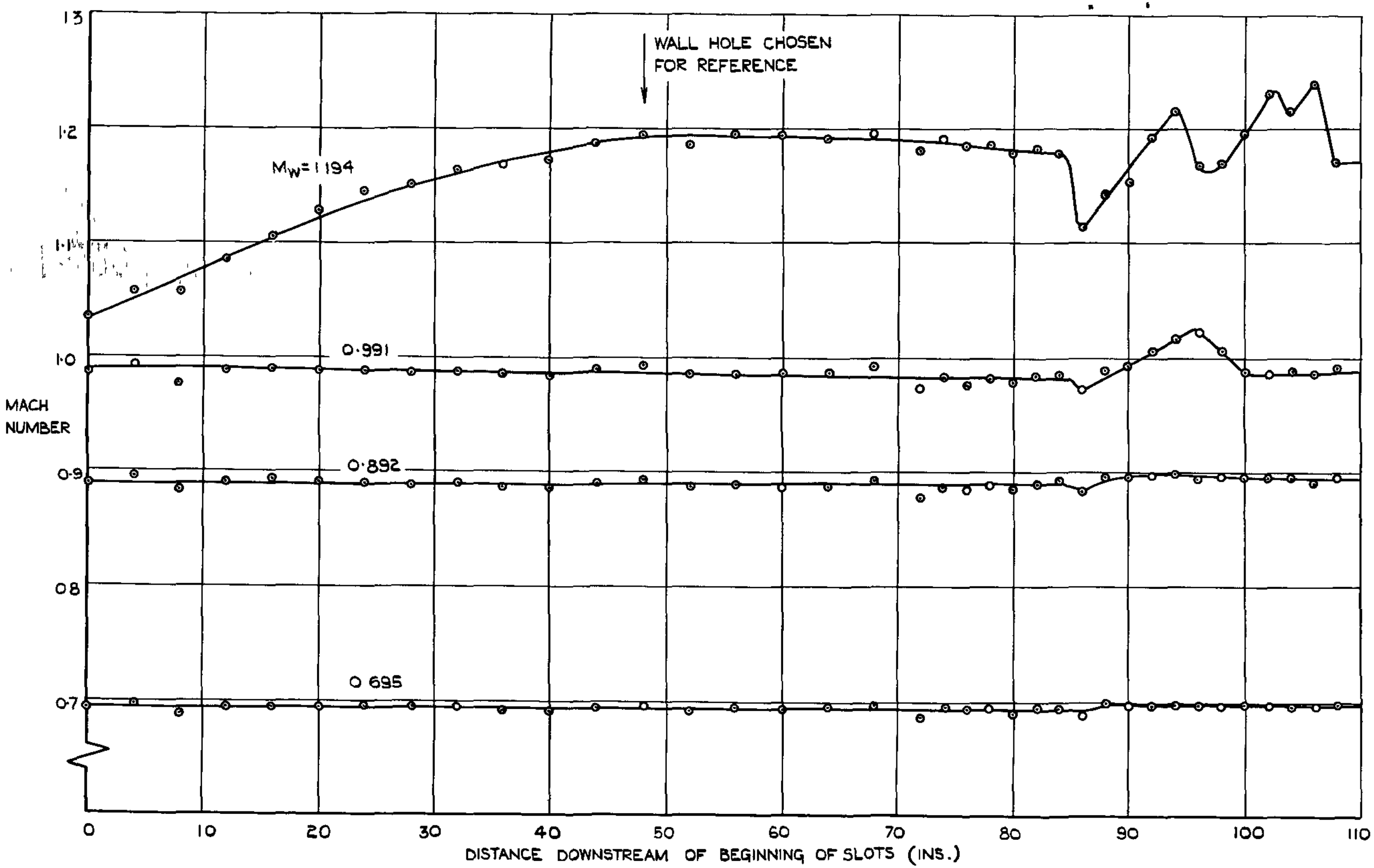

FIG. 5. MACH NUMBER DISTRIBUTIONS ALONG SLOTTED WALLS WITH MODEL E (AT 10° INCIDENCE) IN THE TUNNEL.

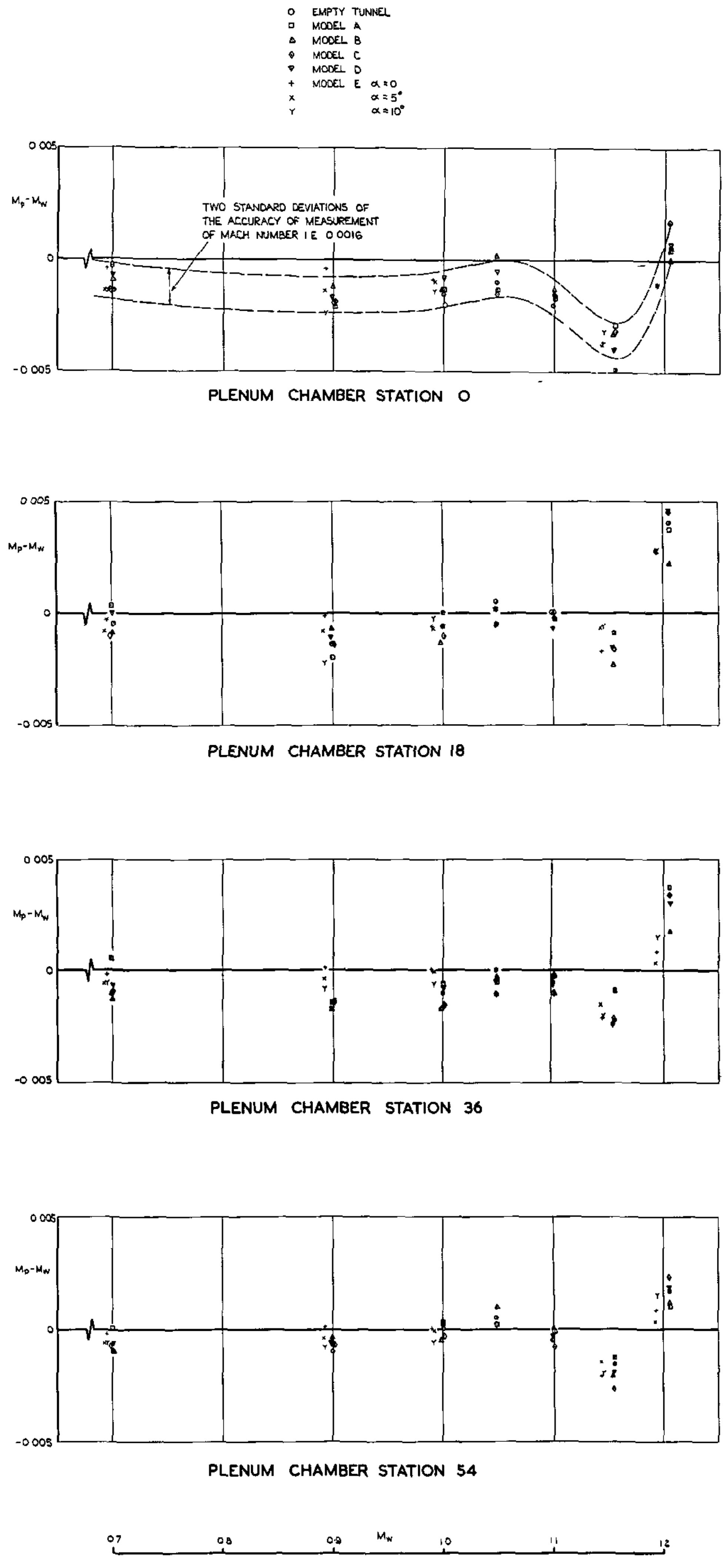

FIG.6. EFFECT OF PRESENCE OF MODEL ON MACH NUMBER INDICATED BY PLENUM CHAMBER PRESSURE. HOLES ALONG PLENUM CHAMBER.

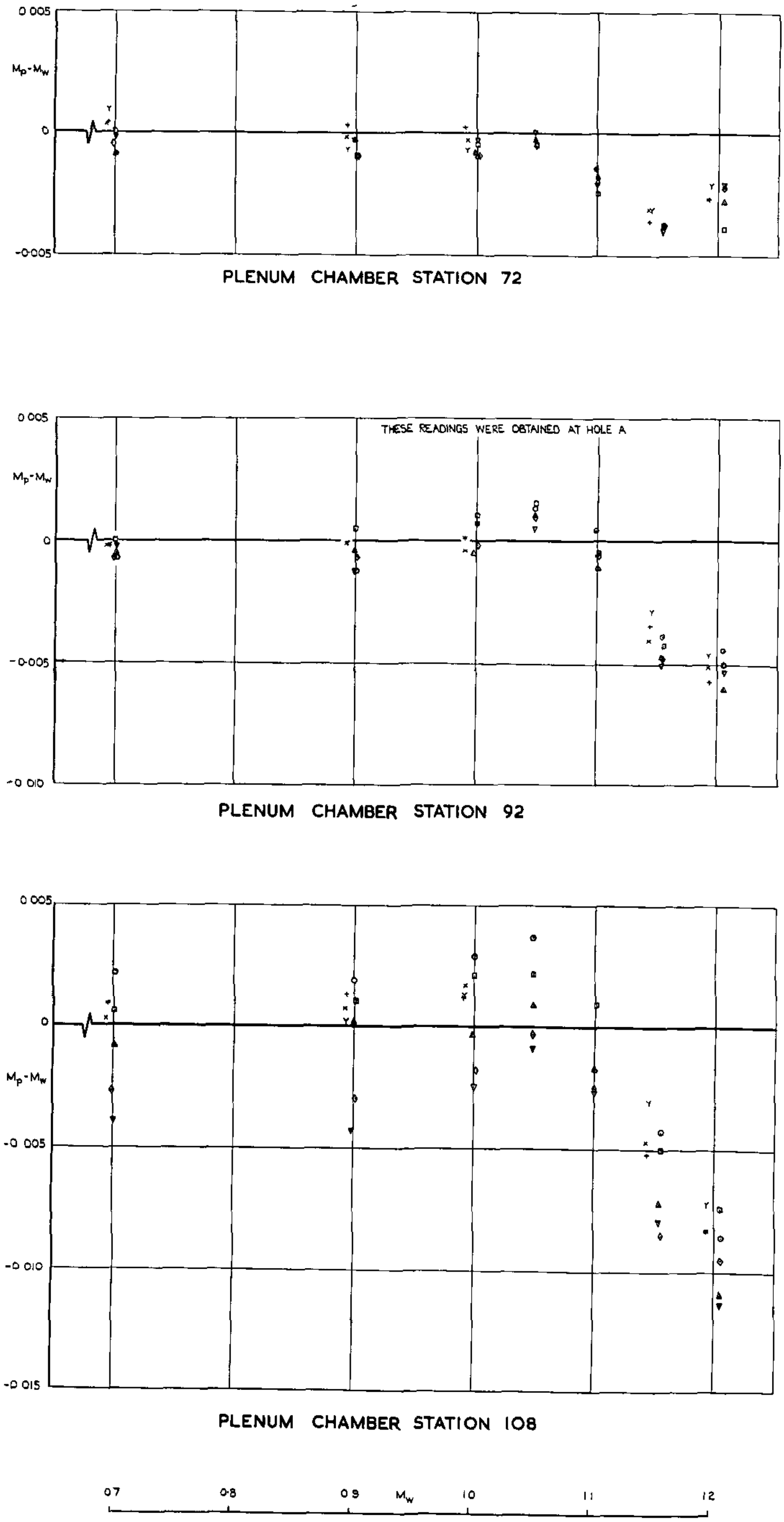

FIG. 6. (CONTD) EFFECT OF PRESENCE OF MODEL ON MACH NUMBER INDICATED BY PLENUM CHAMBER PRESSURE. HOLES ALONG PLENUM CHAMBER.

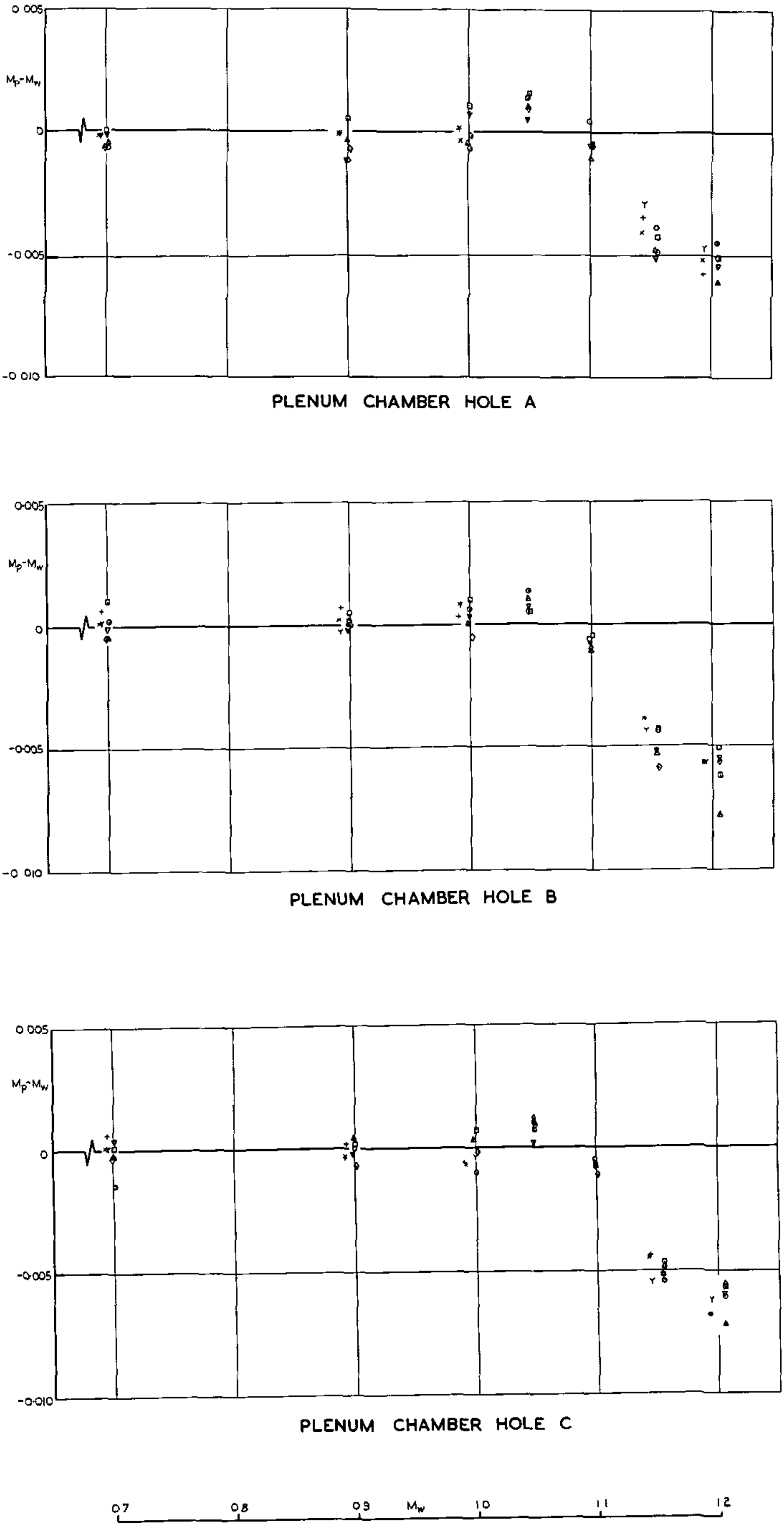

FIG. 7. EFFECT OF PRESENCE OF MODEL ON MACH NUMBER INDICATED BY PLENUM CHAMBER PRESSURE. HOLES AROUND PLENUM CHAMBER AT STATION 92.

C.P. No. 395
(20,297)
A.R C. Technical Report

Published by
HER MAJESTY'S STATIONERY OFFICE

To be purchased from
York House, Kingsway, London W C 2
423 Oxford Street, London W.1
13A Castle Street, Edinburgh 2
109 St Mary Street, Cardiff
39 King Street, Manchester 2
Tower Lane, Bristol 1
2 Edmund Street, Birmingham 3
80 Chichester Street, Belfast
or through any bookseller

PRINTED IN GREAT BRITAIN

S.O. Code No. 23-9010-95

C.P. No. 395