N. A. E. Library

NATIONAL AERONAUTICAL ESTABLISHMENT
LIBRARY

C.P. No. 43
13259
A.R.C. Technical Report

MINISTRY OF SUPPLY

AERONAUTICAL RESEARCH COUNCIL
CURRENT PAPERS

Further Wind Tunnel Tests on the Effects of Ice Accretion on Control Characteristics

By

A. Spence, B.Sc.

Crown Copyright Reserved

LONDON: HIS MAJESTY'S STATIONERY OFFICE

1951

Price 1s. 6d. net.

C.P. No.43

Technical Note No. Aero.2048

May, 1950

ROYAL AIRCRAFT ESTABLISHMENT

Further Wind Tunnel Tests on the Effects of Ice Accretion on Control Characteristics

by

A. Spence, B.Sc.

SUMMARY

R.A.E. Technical Note No. Aero.1878[3] gave recommendations on values of b_1 and b_2 to allow for icing effects on the leading edge of the main surface. These were based on tests of a Viking tailplane (T.N.1875)[1] with 22° trailing edge angle and t/c = 16%. Further measurements at the N.P.L.[2] for a range of trailing edge angle with thickness-chord ratio constant at 15% showed that reduction of trailing edge angle gave no relief.

The present note describes tests on a tailplane with a thickness-chord ratio of 9% and trailing edge angle 12°. They show that reduction of thickness has little effect and that the recommendations of Tech.Note Aero 1878[3] still apply. It is emphasised, however, that the effects of transition movement on b_2 are of great importance, especially at large trailing edge angles.

LIST OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

---

1 Introduction

R.A.E. Technical Note No. Aero.1875[1] gave results of measurements on the effect of simulated ice accretion on control hinge moments for a Viking tailplane. The thickness-chord ratio was 16%, the trailing edge angle 22° and the aspect ratio 5. The tests did not distinguish between the effects of ice and of transition movement, nor was the transition point fixed during the tests.

The question arose whether the ice effects would be smaller on controls with smaller trailing edge angles. Tests in two dimensional flow were made at the National Physical Laboratory on a 15% thick wing with a series of controls of various trailing edge angles. These tests are described in "Current Paper No 42".

In addition, a further test has been made at R.A.E. on an existing model tailplane with 9% thick section, 12° trailing edge angle and aspect ratio 3 to find the effect of reducing the thickness-chord ratio as well as the trailing edge angle.

The results of these latest tests are given in this note and compared with those from the two earlier series.

2 Details of model and tests

Relevant details of the model are given in Table I and a general arrangement drawing in Fig.1. The two parts of the elevator were joined by a torque rod, freely hinged on ball bearings, the hinge moment being measured by the tension in a wire attached to the elevator by a sting.

Two types of ice accretion were represented, called 'A' and 'B' as in Ref.1. These are illustrated in Fig.2. The extent of ice 'A', the chordwise position of ice 'B', and the thickness of ice 'A' and ice 'B' medium measured from the tailplane surface were made the same fractions of local wing chord as in Ref.1. In addition, two other sizes of ice 'B' were tested.

The tests were made in the No.1 $11\frac{1}{2} \times 8\frac{1}{2}$ ft tunnel at the Royal Aircraft Establishment during August 1948. The wind speed was 120 ft/sec giving a Reynolds number of 1.8×10^6 based on the mean chord of the tailplane. The measurements consisted of readings of lift and hinge moment for a range of control angles (1° intervals) at zero incidence and for a range of incidence (1° intervals) at zero control setting. These tests were made with the four ice representations and also for two conditions without 'ice', the transition point being fixed by means of a wire at 10% and 30% chord respectively.

3 Results and discussion

The hinge moment coefficients are shown in Fig.3 and the changes caused by 'ice' compared with a datum with transition at 10% chord are given in Figs.4 and 5. Values of a_1, a_2, b_1, and b_2 are summarised in Table II.

The following table gives the changes of b_1 and b_2 caused by transition movement and by ice.

/Table

	Change of b_1	Change of b_2
Change due to movement of transition point 0.3c to 0.1c	+0.013	+0.020
Additional change due to Ice A	+0.047	+0.035
" " " " Ice B (small)	+0.050	+0.020
" " " " Ice B (medium)	+0.087	+0.023
" " " " Ice B (large)	+0.101	+0.032

The effects of Ice 'A' are plotted in Fig.6 and compared with the Viking tests (Ref.1) and the N.P.L. tests converted to an aspect ratio of 3 (Ref.2) for comparison with the present tests. No attempt has been made to correct the Viking results for aspect ratio, since neither the lift slope nor the transition position is known. Fig.6 shows that the change of b_2 on the present tailplane (9% thick) agrees with the N.P.L. results (15% thick) whilst the present change of b_1 is somewhat larger.

As far as can be seen, the Viking test results fit in reasonably well if it is assumed that the transition point without ice was at about 20% chord.

Fig.6 also shows that the safety allowance of 0.055 on b_2 suggested by Morris[3] should still apply at any rate for trailing edge angles down to 10°.

Allowance should, however, be made for possible movement of transition point, especially at large trailing edge angles where the effect of transition movement on b_2 may be even greater than that of ice accretion.

As in the Viking tests, the change of b_1 caused by ice 'B' is greater than that caused by ice 'A', whilst the change of b_2 is rather less. The effect of varying the size of ice 'B' is to change Δb_1 almost linearly with the ice dimension, but Δb_2 is much less affected.

4 Conclusions

The combined results of the present tests and the N.P.L. results in Ref.2 show that the recommended values of b_1 and b_2 to allow for icing effects (see Ref.3) still apply when the trailing edge angle is reduced (down to 10° at least) and for tailplanes of thickness-chord ratio down to 9%. The results also show that at large trailing edge angles, the effects of transition movement on b_2 are more important than those of ice accretion.

LIST OF REFERENCES

No.	Author	Title, etc.
1	Worrall and Cole	Wind Tunnel Measurements of the Effect of Ice Formations on the Hinge-moment Characteristics of an Elevator. R.A.E. Tech. Note No. Aero.1875, March, 1947. A.R.C. 10,691.
2	Halliday, Batson and Cox	Wind tunnel tests on the Effect of Accretion of Ice on Control Characteristics in Two-dimensional Flow. Current Paper No.42. May 1950.
3	Morris	Designing to avoid Dangerous Behaviour of an Aircraft due to the Effects on Control Hinge Moments of Ice on the Leading Edge of the Fixed Surface. R.A.E. Tech. Note No. Aero.1878, March 1947. A.R.C. 10,670.

TABLE I

Details of model tailplane

Tailplane:-

Area	17.3 sq.ft.
Span	7.25 ft
Mean chord	2.39 ft
Chord at centre line	3.33 ft
Chord at tip	1.46 ft
Aspect ratio	3.04
Section	9% thick at 40% chord

Elevators (total both sides):-

Area (aft of hinge line)	3.65 sq.ft
Span	5.50 ft
Mean chord (aft of hinge line)	0.663 ft
Elevator chord + local tailplane chord	31%
Area forward of hinge + area aft of hinge	31.7%
Trailing edge angle	12°

Ice:-

For details see Fig.2.

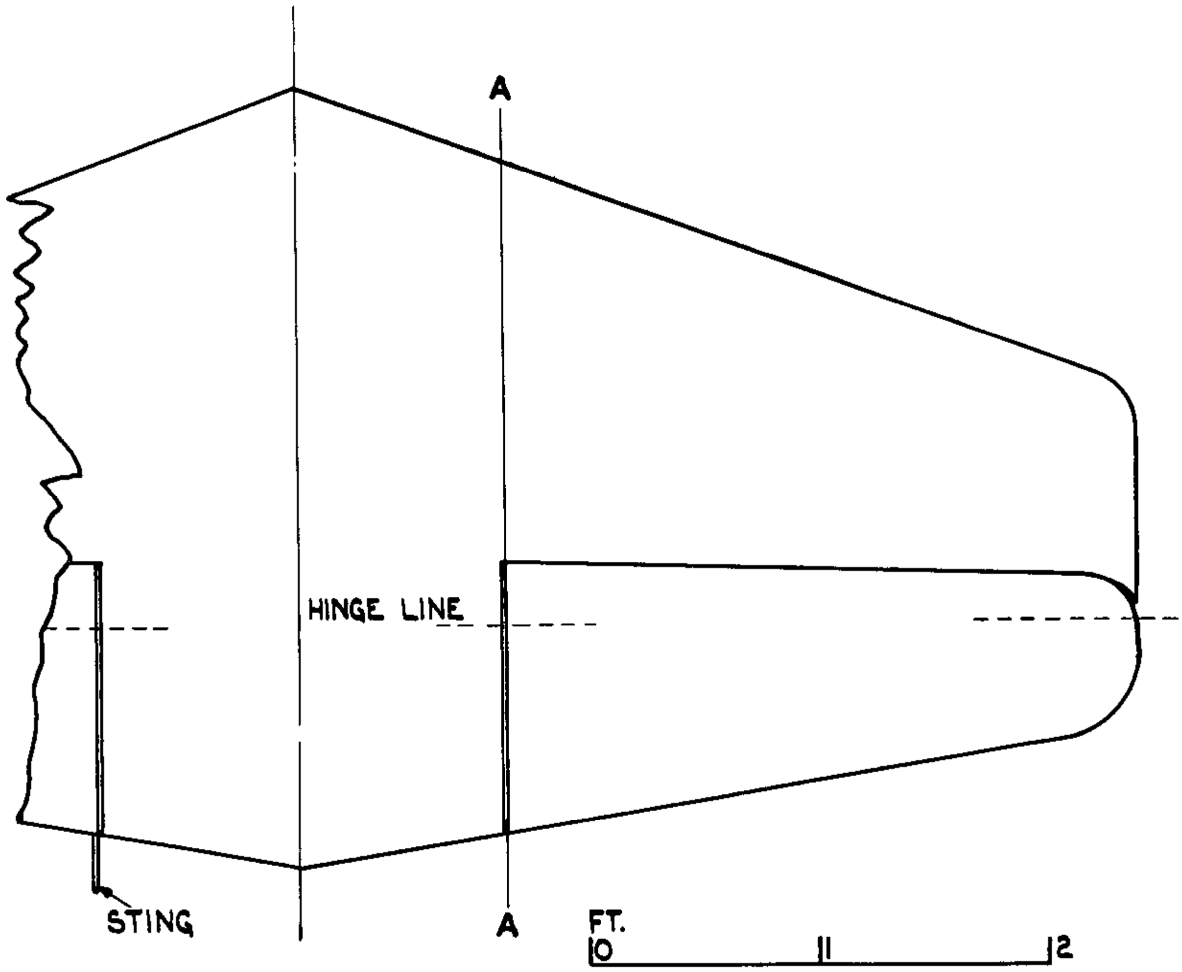
TABLE II

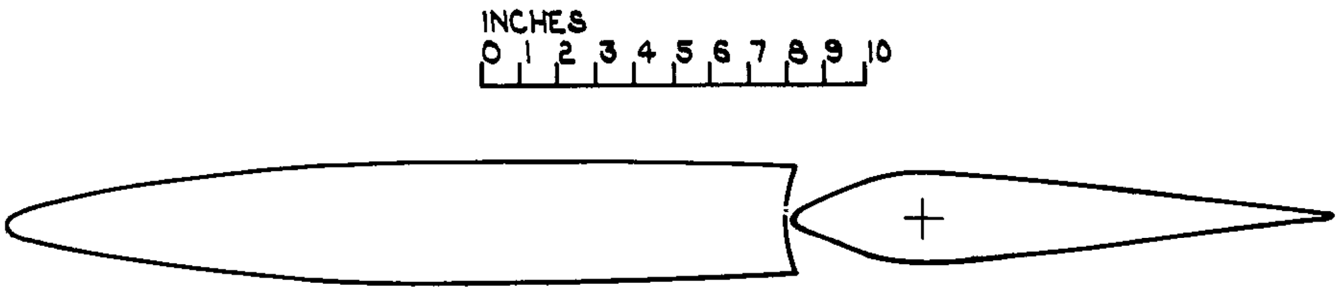
Measured values of lift and hinge moment derivatives

(Values of a_1, a_2 and b_2 defined over 0°-5°; b_1 over 0°-2°)

Condition	a_1	a_2	b_1	b_2
No ice. Transition wires at 0.3c	3.21	1.61	-0.100	-0.340
No ice. Transition wires at 0.1c	3.48	1.38	-0.087	-0.320
Ice A	3.15	1.28	-0.040	-0.285
Ice B - small	2.99	1.26	-0.037	-0.300
Ice B - medium	2.98	1.26	0	-0.297
Ice B - large	2.94	1.10	+0.014	-0.288

Wt.2078. CP43.K3. Printed in Great Britain





SECTION A-A

FIG. 1. G.A. OF MODEL TAILPLANE.

FIG. 2.

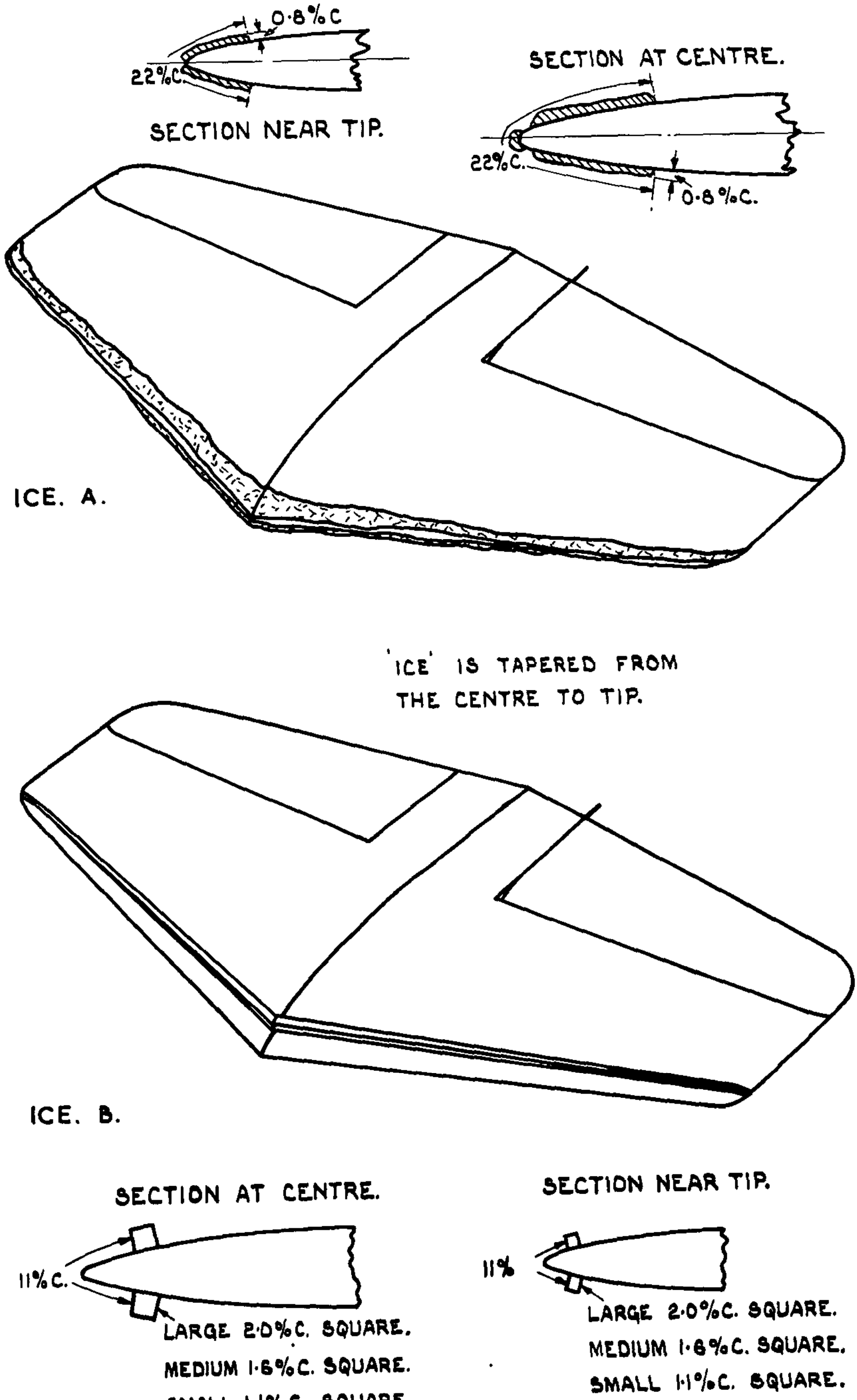


FIG. 2. ICE FORMATIONS TESTED ON MODEL TAILPLANE.

FIG. 3.

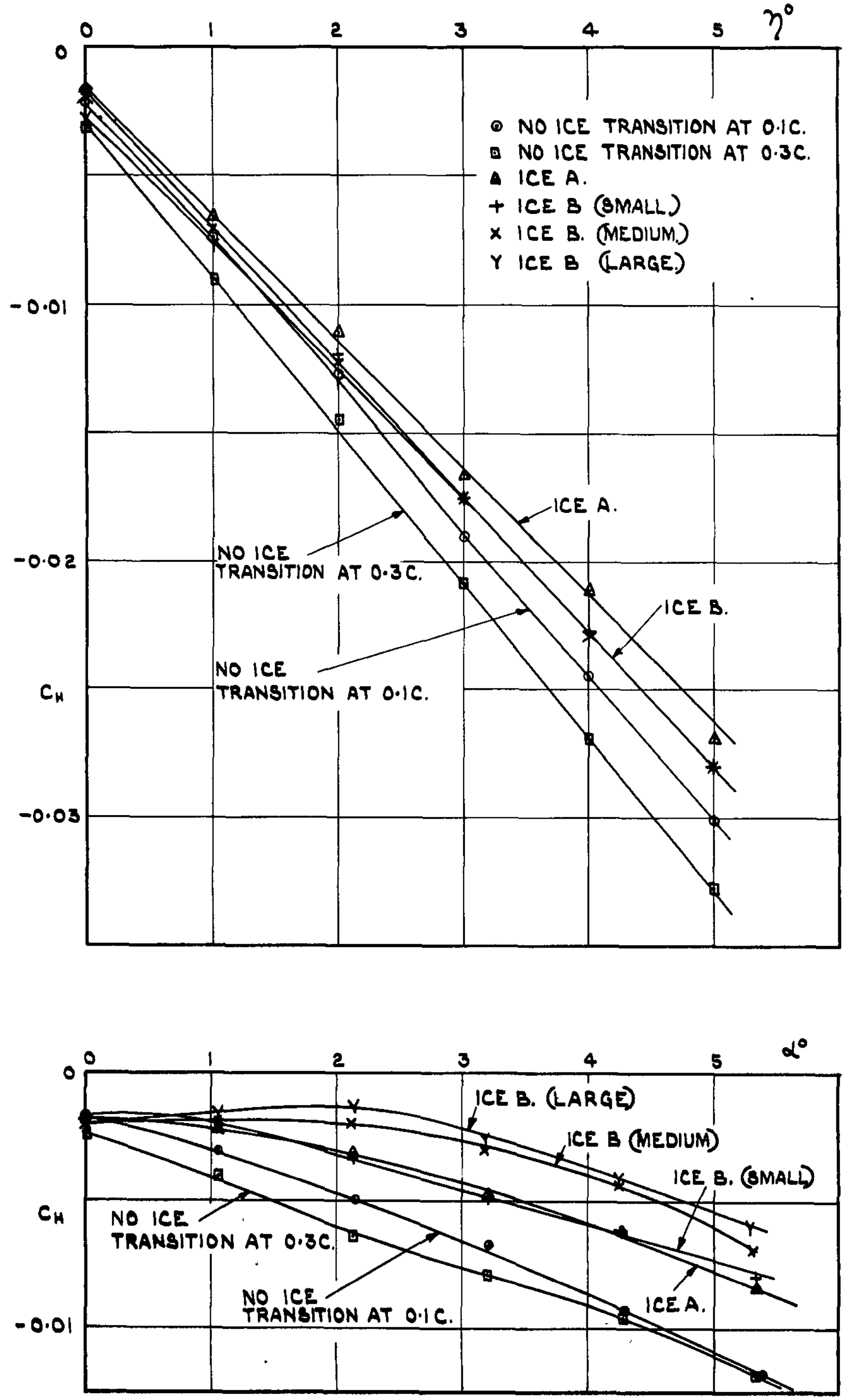


FIG. 3. HINGE MOMENTS OF MODEL TAILPLANE.

FIG. 4.

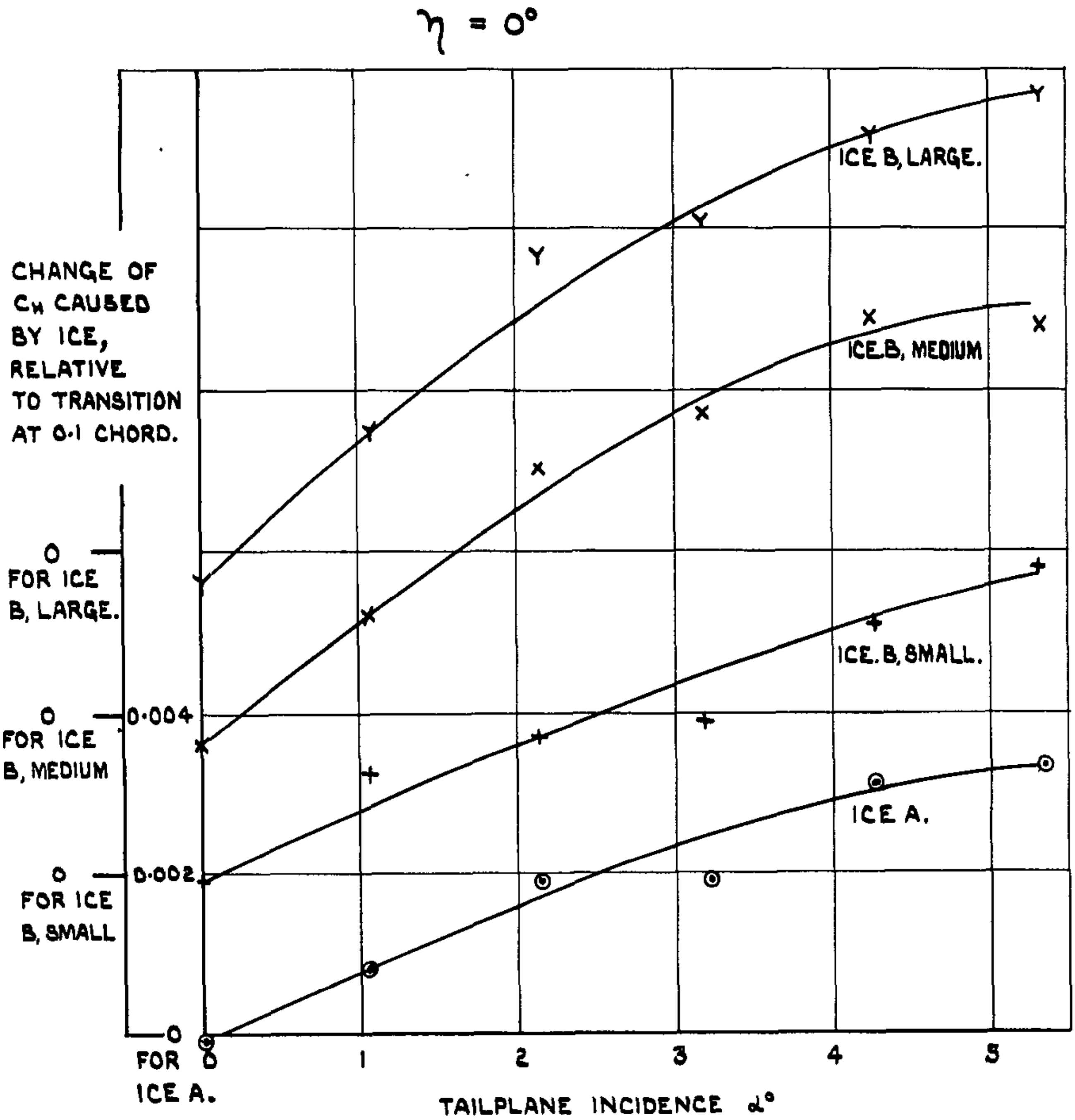


FIG. 4. CHANGES OF ELEVATOR HINGE MOMENT CAUSED BY ICE

I. EFFECTS ON b_1.

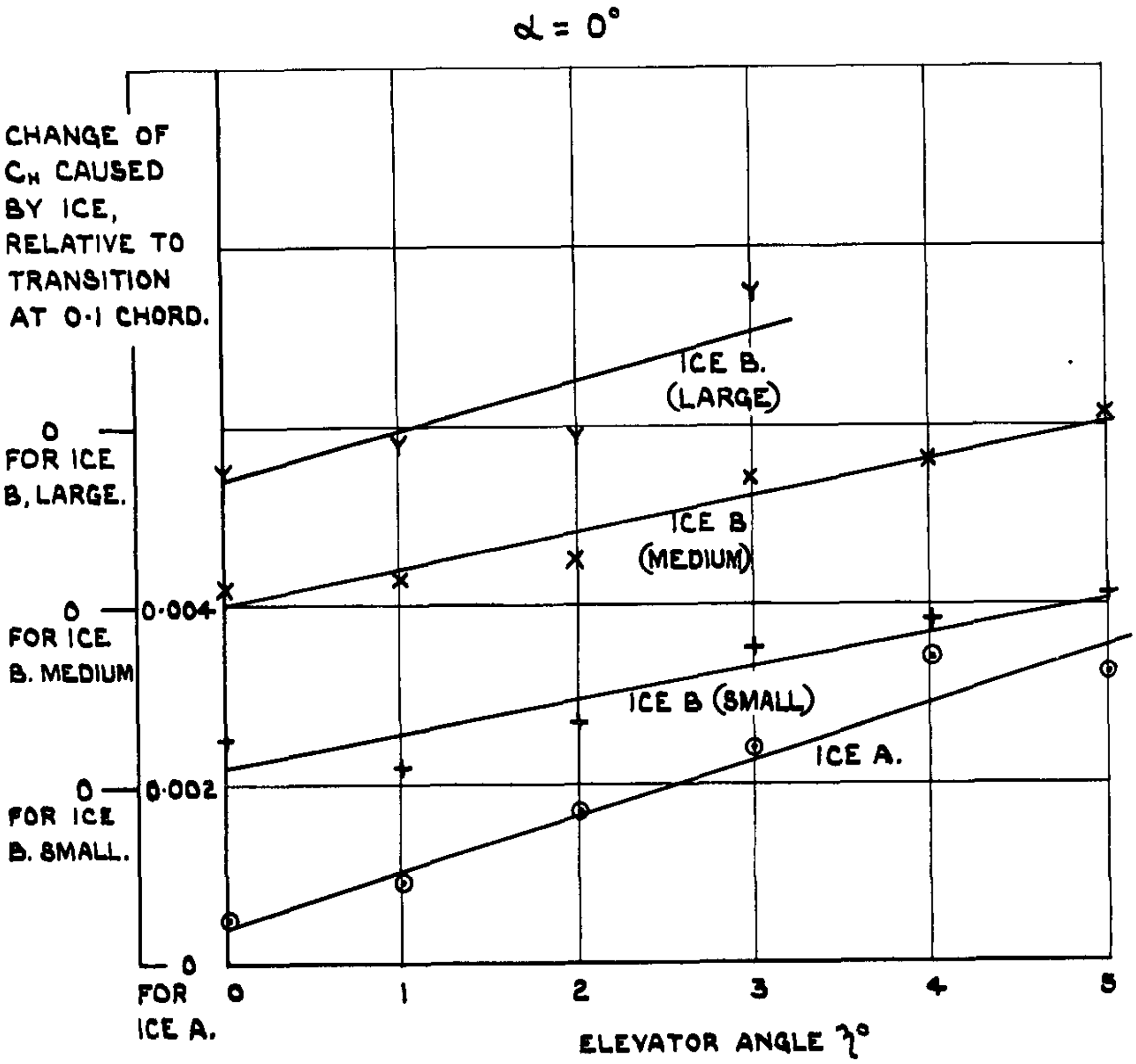


FIG. 5. CHANGES OF ELEVATOR HINGE MOMENT CAUSED BY ICE

II. EFFECTS ON b_2.

FIG. 6.

KEY:- ○ - CHANGE RELATIVE TO VALUE WITH TRANSITION AT 0·1C
△ - CHANGE RELATIVE TO VALUE WITH TRANSITION AT 0·3C
1 - N.P.L. TESTS (REF. 3) CORRECTED TO A = 3.
2 - PRESENT TESTS ON MODEL TAILPLANE A = 3.
V - RESULTS FROM REF. 1. - TRANSITION NOT FIXED; A = 5.

NOTE: EFFECT OF TRANSITION MOVEMENT IN 1 INTERPOLATED BETWEEN TESTS WITH FIXED AND FREE (ABOUT 0·6C) TRANSITION.

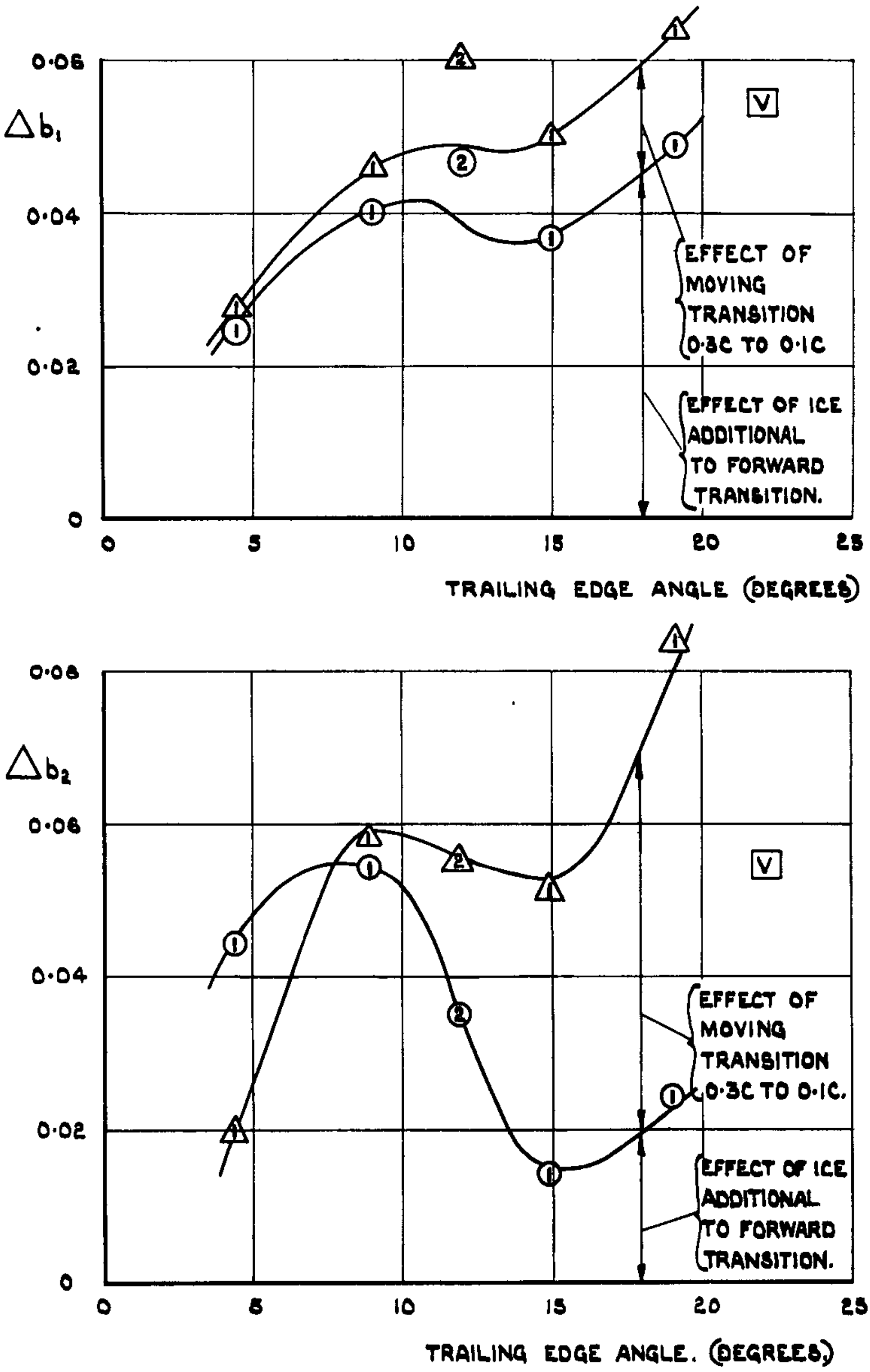


FIG. 6. CHANGES OF b_1 AND b_2 CAUSED BY ICE 'A'.

(ASPECT RATIO ≈ 3)

C.P. No. 43
13259
A.R.C. Technical Report

PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE
To be purchased from
York House, Kingsway, LONDON, W C 2, 429 Oxford Street, LONDON, W 1,
P O Box 569, LONDON, S E 1,
13a Castle Street, EDINBURGH, 2 | 1 St Andrew's Crescent, CARDIFF
39 King Street, MANCHESTER, 2 | 1 Tower Lane, BRISTOL, 1
2 Edmund Street, BIRMINGHAM, 3 | 80 Chichester Street, BELFAST,
or from any Bookseller
1951
Price 1s. 6d. net
PRINTED IN GREAT BRITAIN

S.O. Code No. 23-9006-43