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Draft Corrections for Water Surface Deflection under No. 1. Carriage of the R.A.E. Seaplane Tank

By

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SUMMARY

The running draft and attitude of hulls under test are measured relative to the undisturbed water level, but at normal running speeds an appreciable deflection of the water surface is produced at the model testing position by the aerodynamic pressure field of the carriage. These deflections have been measured and data is given for the correction of measured draft and attitude values covering the normal range of model positions and conditions. When testing models screened from airflow there is an inclination of the surface of -0.4 degrees at 10 ft/sec and a deflection of -0.23 inches at 12 ft/sec. It is therefore recommended that planing tests on hulls should be confined to speeds above 16 ft/sec where the surface inclination is small and the deflection decreases steadily from -0.09 inches at 16 ft/sec to -0.03 inches at 36 ft/sec. When testing models in airflow there is no appreciable inclination of the water surface and the peak deflection of -0.06 inches at 12 ft/sec decreases to -0.02 inches at 16 ft/sec and remains at this value up to 38 ft/sec.

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1 Introduction

When any analysis of forces on planing hulls is required, for the more accurate estimation of scale effect or research on basic shapes, the main parameters are draft and attitude. In the R.A.E. Seaplane Tank the running draft and attitude of a model are measured relative to the undisturbed water level using the carriage as a datum. The track was accurately relevelled[1] in September, 1946 and with regular checks and minor adjustments it is claimed that the carriage runs parallel to the undisturbed water surface to within $\pm$ 0.003 in. However it was suspected that at normal running speeds the aerodynamic pressure field of the carriage was producing a deflection of the water surface at the testing position of the model, and preliminary wetted surface measurements on hulls showed that the deflection was appreciable. This report describes the method adopted to determine this deflection and gives data for the correction of measured draft and attitude values.

2 Model testing technique

A sketch of the carriage arrangement is shown in Fig.1. The tank is 9 ft wide and the carriage runs along with a clearance of 2 ft 9 in. from the water surface. The carriage is floored except for a well 10 ft x 4 ft in the centre in which the balance is mounted. The model is attached about two thirds of the way back under the carriage and it was found that the airflow at this position was very unsteady and about 40% faster than the carriage speed. A series of experiments[2] was made in 1944 to improve the airflow, and the system of flaps adopted is shown in Fig.1. With the front flap raised to the horizontal position indicated and the rear flap as shown the air velocity at the balance suspension - corresponding to the C.G. of the model - is equal to the carriage speed, but there is a pressure gradient giving a velocity ratio of 1.1 at the nose of the model and 0.9 at the tail. This arrangement - referred to hereafter as 'correct airflow' condition - was used for some preliminary tests on afterbody ventilation[3] but is not used for general hull force measurements as the aerodynamic components are falsified by the pressure gradient.

Hull force measurements are usually made in the screened condition with the flaps as shown in Fig.1. The front flap is lowered to within one inch of the water surface and the model runs in a pocket of air carried along with the carriage, so enabling the measurement of almost pure* hydrodynamic forces. The rear flap in this case does not affect the airflow but is normally lowered to the 'correct airflow' position to protect the rails from spray thrown up from the model.

3 Measurement of water surface deflection

The water surface deflection was determined by comparing the indicated draft of a small wedge relative to the undisturbed water surface with the actual draft deduced from corresponding measurements of the keel wetted length.

3.1 Measurement of wetted length

A small black wedge about $4\frac{1}{2}$ in. long and of 45° deadrise was attached to the balance rise mechanism at 16° incidence as indicated in Fig.2. One side of the wedge was sprayed with a 5% solution of hydroquinone diacetate in acetone, the acetone evaporating almost immediately

* There is a slight boundary layer airflow at the water surface which can become important during tests at very low draft values.

leaving a thin coating of the solute on the wedge. Hydroquinone diacetate though readily soluble in acetone is only sparingly soluble in water and it has been found[4,5] that when a thin layer of such a substance is being dissolved off a surface, it dissolves more rapidly in flow regions where there is a high pressure gradient or a turbulent boundary layer than in laminar flow regions with small gradients. In particular the stagnation line and keel wetted length on a wedge shape are clearly shown.

The procedure used in the present tests was, after spraying, to hold the wedge clear of the water till the carriage reached its steady speed and then immerse the wedge quickly to a preset draft value. After about 200 ft at the steady speed the wedge was quickly lifted clear of the water again and on return to dock was dried with an air jet. Fig.3 shows a typical result. The thickness of the solute was chosen to show the keel wetted length accurately rather than the whole stagnation line which was not required for these tests.

3.2 Measurement of indicated draft

The balance rise mechanism carries a direct reading scale indicating the draft of a model relative to a datum which for these tests was set at zero with the point of the wedge keel just touching the undisturbed water surface. Before each run a stop was set to determine the approximate depth to which the wedge could be lowered, and during the test run the indicated draft was read off the scale while the wetted length was being recorded as described in the previous paragraph. At each carriage speed about three runs were made with the stop set to give a range of wetted lengths between 0.2 in. and 1.5 in.

3.3 Deduction of water surface deflection

Fig.2 shows the quantities involved. The wedge is set at an angle τ to the undisturbed water surface and makes an angle $\tau + \delta\tau$ to the water surface behind the screen. Due to pile up of the water at the wedge the wetted length ℓ is greater than the projected intersection of the wedge with the water surface ℓ'. The water surface deflection δd, measured negative downwards is obtained as the difference between the indicated draft d and the actual draft d' as follows

$$d' = \ell' \sin(\tau + \delta\tau)$$

$$\delta d = \ell' \sin(\tau + \delta\tau) - d \qquad (1)$$

The only quantities known are d, ℓ and τ. Equation (1) can be re-written as:

$$\delta d = \ell \sin\tau - d - \ell\sin\tau + \ell' \sin\tau \cos\delta\tau + \ell' \cos\tau \sin\delta\tau$$

$$\delta d = (\ell \sin\tau - d) - (\ell - \ell' \cos\delta\tau) \sin\tau + \ell' \cos\tau \sin\delta\tau \qquad (2)$$

Writing the quantity $(\ell \sin\tau - d)$, in which all the quantities are known, as $\delta d'$,

$$\delta d = \delta d' - (\ell - \ell' \cos\delta\tau) \sin\tau + \ell' \cos\tau \sin\delta\tau \qquad (3)$$

As ℓ tends to 0, ℓ' tends to 0 and so $\delta d'$ tends to δd. The value of δd can therefore be obtained by plotting $\delta d'$ against ℓ for several values of ℓ and extrapolating the curve to $\ell = 0$. This method is shown in fig.4 for one longitudinal position of the wedge in the screened condition. The results of this series of tests and preliminary tests in a second longitudinal position showed that the method of determining δd could be simplified as follows:

(a) Except for a small speed range in the screened condition the water surface inclination $\delta\tau$ was small enough to be neglected and equation (3) reduced to

$$\delta d = \delta d' - (\ell - \ell') \sin \tau \qquad (4)$$

(b) As shown in Fig.4 the measured points can be satisfied with a series of straight lines of equal slopes. This means that ℓ' is proportional to ℓ. If ℓ' is written as $(^1/k).\ell$ and $\delta d'$ as $(\ell \sin \tau - d)$ equation (4) becomes,

$$\delta d = (^1/k)\, \ell \sin \tau - d \qquad (5)$$

The value* of k deduced from Fig.4 is 1.091 and since for these tests τ was 16° equation (5) becomes

$$\delta d = 0.2525\, \ell - d \qquad (6)$$

Apart from tests at about 8 ft/sec in the screened condition where a slight correction for $\delta\tau$ had to be applied, the whole of the tests were calculated using equation (6), an arithmetical mean being taken of the values of δd obtained at any one condition.

4 Results

The measured values of wetted length and indicated draft with the corresponding deduced values of the water surface deflection are given in Tables I and II. The deflection was measured in two longitudinal positions to cover the normal range of model locations and to determine the local water surface inclination.

4.1 Screened condition

The variation of water surface deflection with carriage speed is shown in Fig.5a. There is a peak deflection of -0.23 in. at 12 ft/sec which is the resonant speed for long waves in the tank**, decreasing to -0.09 in. at 16 ft/sec and -0.05 in. at 30 ft/sec. Above 12 ft/sec the measurements at the two longitudinal positions agree in general to within 0.02 in. which means that the surface inclination is less than

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* Tests on hulls and large wedges using wetted lengths up to 3 ft confirm that there is a forward splash factor k which is independent of forward speed and depends only on the attitude and deadrise of the planing bottom.

** The velocity of propagation of long waves is $\sqrt{g \times \text{depth of water}}$ and the depth of water is 4 ft 6 in.

-0.05°. Below 12 ft/sec however the two sets of measurements differ considerably, the maximum difference being 0.17 in. at 10 ft/sec corresponding to an effective increase in model attitude of 0.4°. The variation of water surface inclination with carriage speed is shown in Fig.6.

4.2 'Correct airflow' condition

In the 'correct airflow' condition there was no measurable inclination of the water surface and a single curve showing the variation of surface deflection with carriage speed for both longitudinal positions has been drawn in Fig.5b. The curve is the same general shape as for the screened condition but the peak value at 12 ft/sec is reduced to -0.06 in. while above 20 ft/sec the deflection is nearly constant at -0.02 in.

5 Conclusions

The water surface deflections produced by the aerodynamic pressure field of the carriage are appreciable, especially when testing models screened from airflow.

5.1 Screened condition

The surface deflection reaches -0.23 in at 12 ft/sec, the worst carriage speed which is the resonant speed for long waves in the tank, while at 10 ft/sec a surface inclination of nearly -0.4° is present at the model testing position. It is therefore recommended that planing tests on hulls should only be made at speeds above 16 ft/sec, where the surface inclination is small and the surface deflection is not varying sharply with carriage speed but decreases steadily from -0.09 in. at 16 ft/sec to -0.03 in. at 36 ft/sec. The interpolated values of the water surface deflection and inclination at the normal model step position, 2.1 in. behind the C.G. attachment, are given in Table III at 1 ft/sec intervals from 4 ft/sec to 40 ft/sec. The surface deflection and inclination at alternative positions can be interpolated from the results in Table I and the curves of Figs.5a and 6.

5.2 'Correct airflow' condition

There is no appreciable inclination of the water surface and the peak deflection is -0.06 in. at 12 ft/sec, decreasing to -0.02 in. at 16 ft/sec and remaining at this value up to 38 ft/sec. The interpolated values of water surface deflection are given in Table III at 1 ft/sec intervals from 4 ft/sec to 40 ft/sec and the corresponding curve is shown in Fig.5b.

REFERENCES

No.	Author	Title, etc.
1	Owen	Track levelling in the R.A.E. Seaplane Tank. A.R.C. 12,630, March, 1949
2	Tomaszewski, Raymond and Chalmers	The Air Flow under the Towing Carriages in the R.A.E. Seaplane Tank. Current Paper No.38, June, 1946
3	Tomaszewski, Smith and Chalmers	A Preliminary Examination of Hull Afterbody Ventilation. A.R.C. 10,009, July, 1946
4	Pringle and Main-Smith	Visualisation of the boundary layer transition in water. A.R.C.9151, September, 1945
5	Smith	5th International Conference of Ship Tank Superintendents, 1948, pages 70 - 72.

TABLE I

Water surface deflection measurements, screened condition

Carriage Speed (ft/sec)	Wedge 2.1 in. aft of balance attachment				Wedge 26.7 in. aft of balance attachment			
	ℓ	d	δd	Mean δd	ℓ	d	δd	Mean δd
5					0.48 0.85	0.10 0.20	+0.02 +0.015	+0.018
8	0.69 0.80 1.30	0.20 0.21 0.35	-0.025 -0.01 -0.02	-0.018	0.43 1.02	0.01 0.17	+0.10 +0.09	+0.095
10	0.83	0.32	-0.11	-0.11	0.93 1.91	0.185 0.42	+0.05 +0.06	+0.055
12	0.45 0.90 1.15	0.35 0.435 0.55	-0.235 -0.21 -0.26	-0.235	0.72 1.49	0.40 0.595	-0.22 -0.22	-0.22
14	0.25	0.19	-0.125	-0.125				
16	0.50 0.82 1.28	0.21 0.29 0.43	-0.085 -0.085 -0.105	-0.092	0.52 0.88 1.25	0.20 0.31 0.395	-0.07 -0.09 -0.08	-0.08
20	0.15 0.48 0.75 0.88	0.11 0.20 0.27 0.29	-0.07 -0.08 -0.08 -0.07	-0.075	0.55 0.61 1.59 1.67	0.19 0.20 0.45 0.48	-0.05 -0.045 -0.05 -0.06	-0.051
28	0.35 0.60 0.69 0.99	0.15 0.215 0.21 0.30	-0.06 -0.065 -0.035 -0.05	-0.053	0.65 1.35 1.38	0.205 0.40 0.40	-0.04 -0.06 -0.05	-0.05
36	0.31 0.72 1.50	0.105 0.21 0.40	-0.03 -0.03 -0.02	-0.027	0.57 1.25 1.36	0.18 0.35 0.375	-0.035 -0.035 -0.03	-0.033

TABLE II

Water surface deflection measurements, 'correct airflow' condition

Carriage Speed (ft/sec)	Wedge 2.1 in. aft of balance attachment				Wedge 26.7 in. aft of balance attachment			
	ℓ	d	δd	Mean δd	ℓ	d	δd	Mean δd
5	0.80	0.20	0.00	0.00	0.38 0.79	0.10 0.21	-0.01 -0.01	-0.01
8	0.70 0.95	0.19 0.25	-0.015 -0.01	-0.013				
10	0.99	0.28	-0.03	-0.03	1.47	0.40	-0.03	-0.03
12	0.96 1.30	0.30 0.395	-0.06 -0.065	-0.063				
16	0.80 0.91 1.04	0.22 0.26 0.31	-0.02 -0.03 -0.035	-0.028				
20	0.32 0.70	0.105 0.20	-0.025 -0.02	-0.023	0.83 1.00 1.58	0.22 0.27 0.42	-0.01 -0.02 -0.02	-0.017
28	0.64 0.80 1.12 1.19	0.20 0.22 0.28 0.34	-0.04 -0.02 -0.00 -0.04	-0.025				
36	0.77 1.26	0.205 0.34	-0.01 -0.02	-0.015	0.83	0.23	-0.02	-0.02

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TABLE III

Water surface deflection and inclination calibration standard model position 2.1 in. behind balance attachment

Carriage Speed (ft/sec)	Screened Condition		'Correct Airflow' Condition*
	Water Surface Deflection (in.)	Water Surface Inclination (degrees)	Water surface Deflection (in.)
4	+0.01	+0.03	0.00
5	+0.01	-0.03	0.00
6	+0.01	-0.09	-0.01
7	0.00	-0.17	-0.01
8	-0.02	-0.26	-0.01
9	-0.06	-0.34	-0.02
10	-0.11	-0.38	-0.03
11	-0.20	-0.18	-0.05
12	-0.23	-0.04	-0.06
13	-0.20	-0.02	-0.05
14	-0.13	-0.02	-0.04
15	-0.10	-0.03	-0.03
16	-0.09	-0.03	-0.03
17	-0.09	-0.04	-0.02
18	-0.08	-0.05	-0.02
19	-0.08	-0.06	-0.02
20	-0.08	-0.06	-0.02
21	-0.07	-0.05	-0.02
22	-0.07	-0.05	-0.02
23	-0.07	-0.04	-0.02
24	-0.07	-0.03	-0.02
25	-0.06	-0.02	-0.02
26	-0.06	-0.02	-0.02
27	-0.06	-0.01	-0.02
28	-0.05	-0.01	-0.02
29	-0.05	-0.01	-0.02
30	-0.05	0.00	-0.02
31	-0.05	0.00	-0.02
32	-0.04	0.00	-0.02
33	-0.04	0.00	-0.02
34	-0.04	+0.01	-0.02
35	-0.03	+0.01	-0.02
36	-0.03	+0.01	-0.02
37	-0.03	+0.02	-0.02
38	-0.02	+0.02	-0.02
39	-0.02	+0.02	-0.01
40	-0.02	+0.02	-0.01

* There was no measurable water surface inclination in the 'correct airflow' condition.

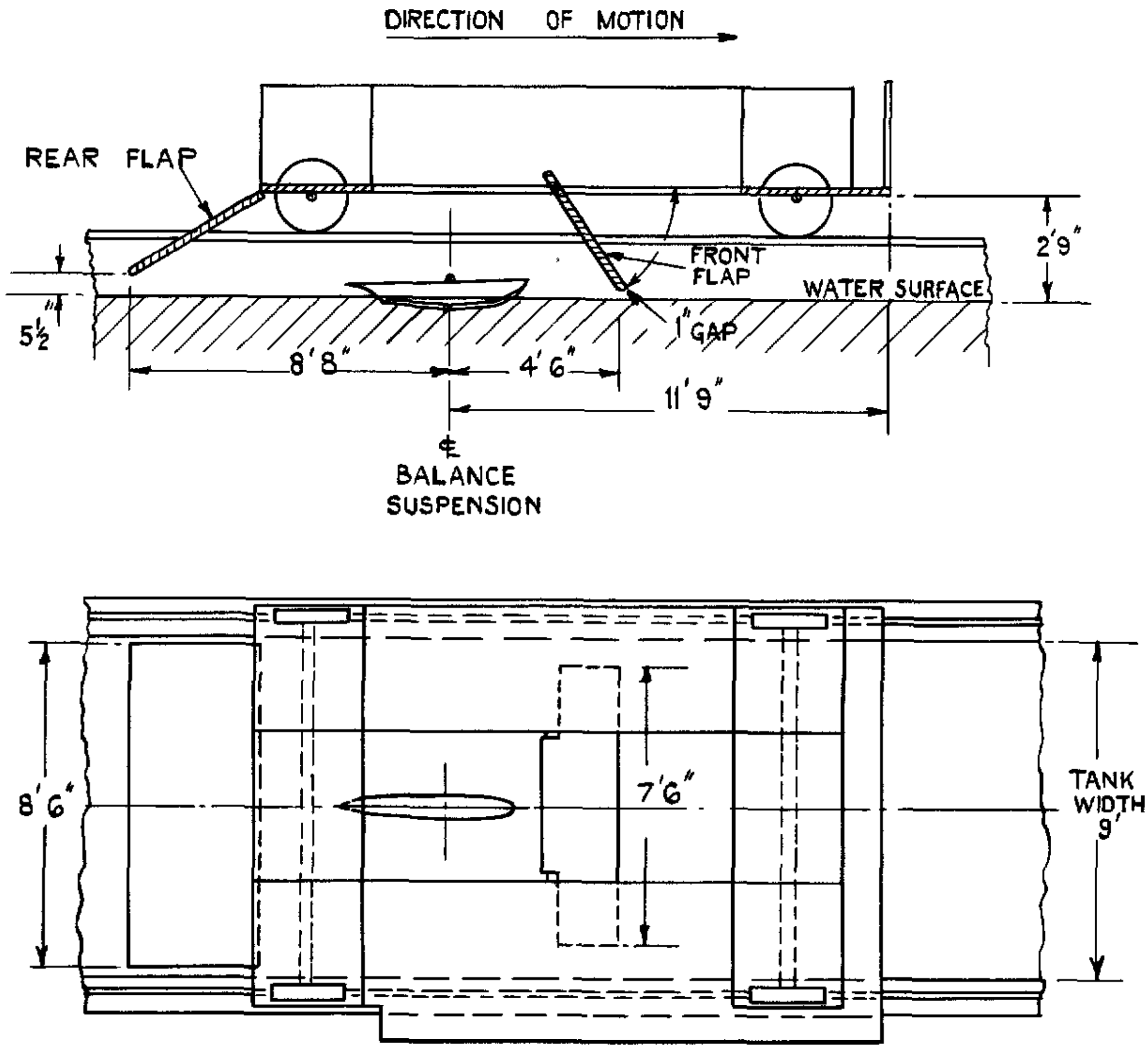

FIG. 1. SKETCH OF Nº 1 CARRIAGE SHOWING MODEL AND FLAP POSITIONS.

(FRONT FLAP SET FOR SCREENED TEST CONDITION).

FIG. 2

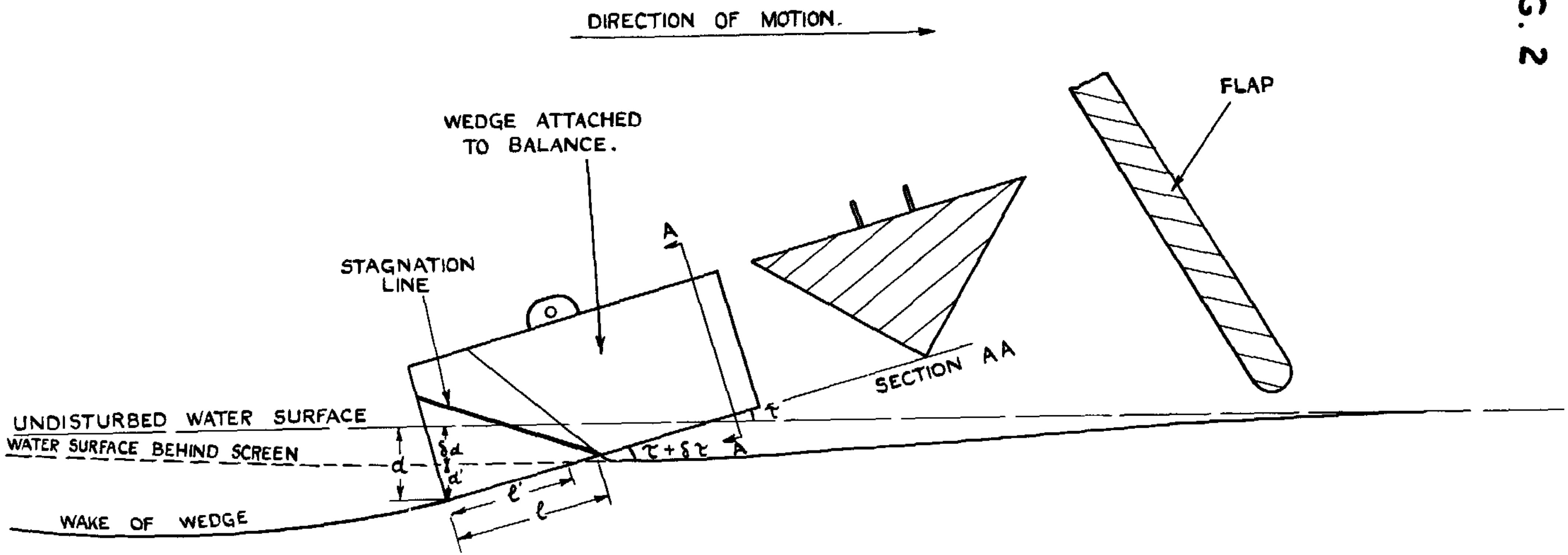

FIG. 2. WATER SURFACE DEFLECTION BEHIND SCREEN.

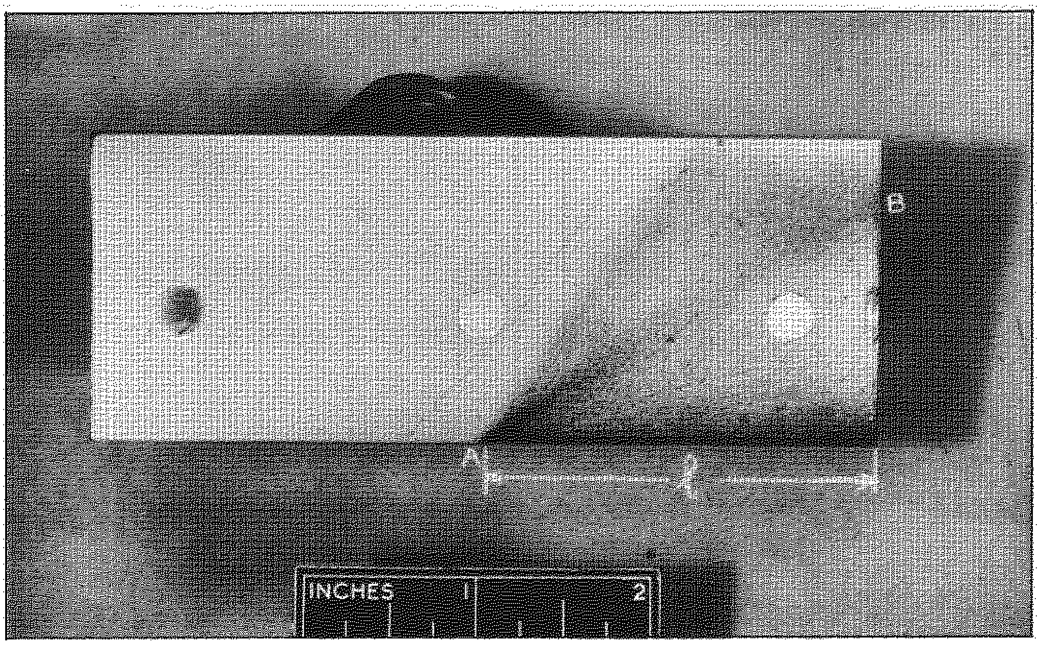

FIG.3. TYPICAL TEST RESULTS SHOWING STAGNATION LINE A B AND WETTED LENGTH ℓ

FIG. 4

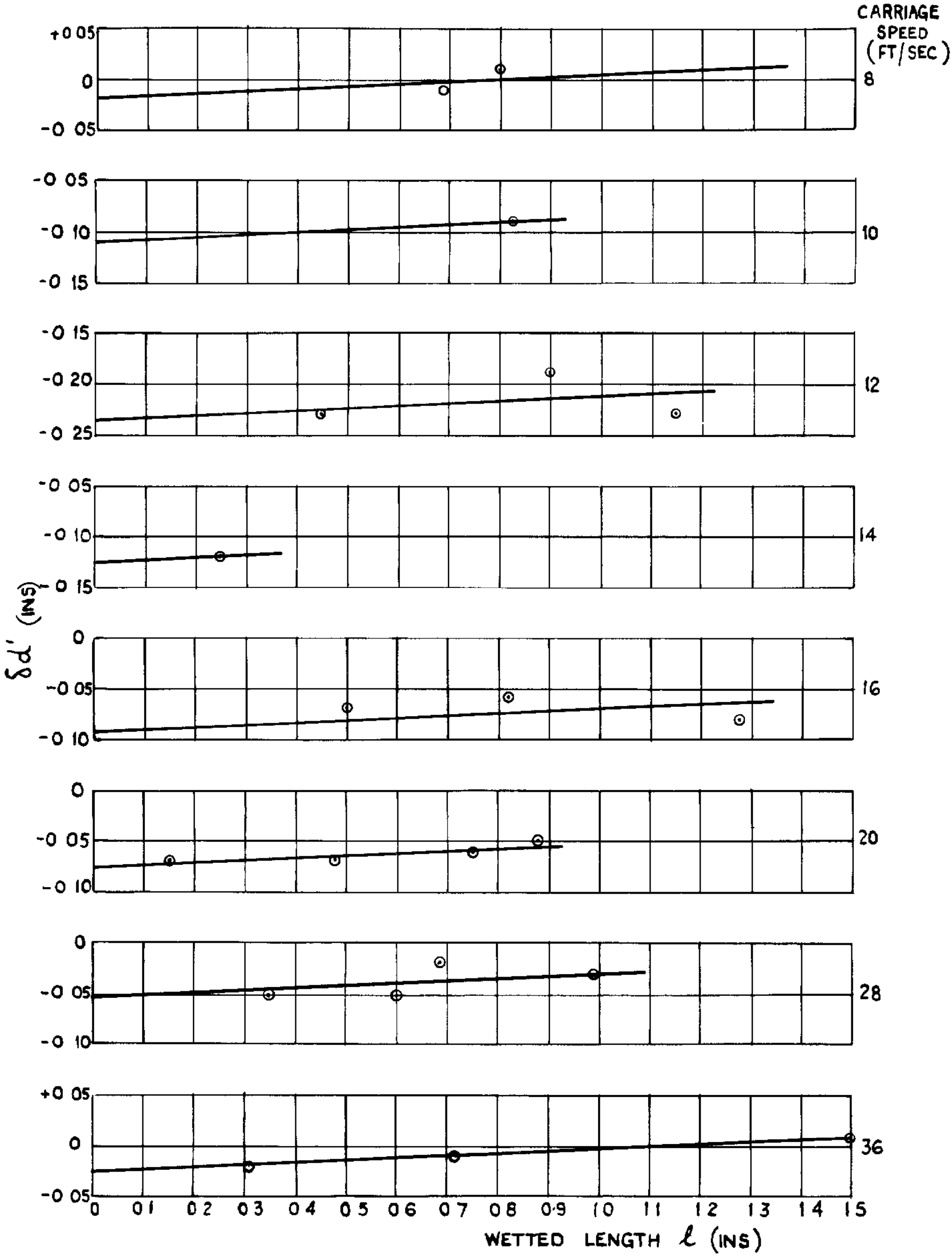

FIG. 4. WETTED LENGTH & DRAFT MEASUREMENTS, SCREENED CONDITION, WEDGE 2·1 INS. AFT OF BALANCE ATTACHMENT.

$\delta d' = \ell \sin \tau - d$ (SEE PARA 3·3)

FIG. 5.(a & b) & 6.

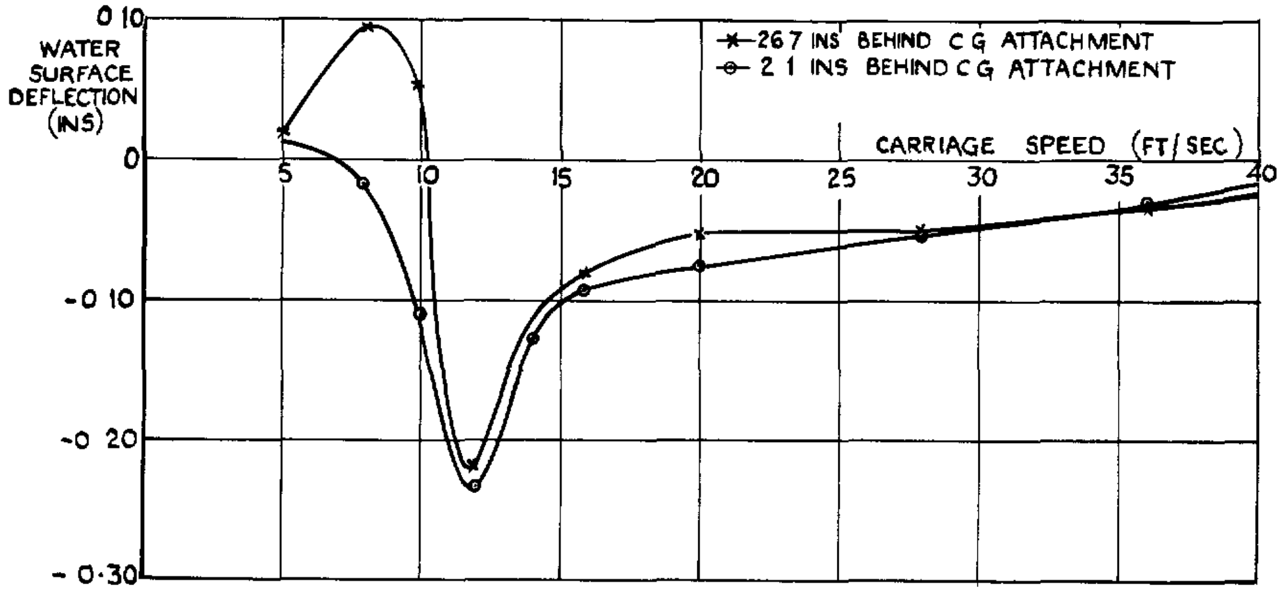

FIG. 5(a) WATER SURFACE DEFLECTION SCREENED CONDITION.

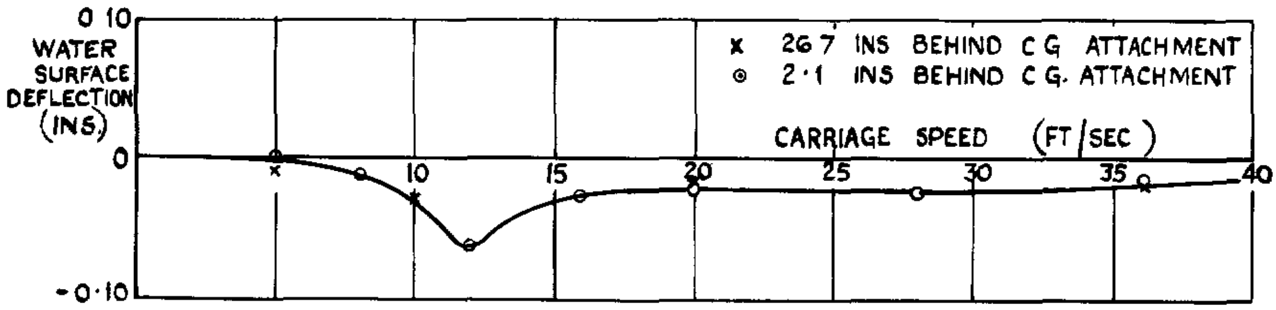

FIG. 5 (b) WATER SURFACE DEFLECTION CORRECT AIR-FLOW CONDITION.

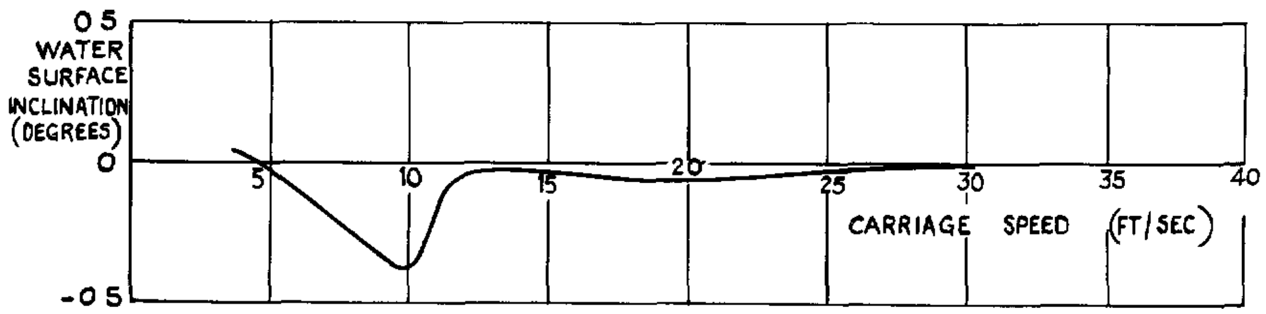

FIG. 6. WATER SURFACE INCLINATION, SCREENED CONDITION.

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