AD NUMBER
ADA800698
CLASSIFICATION CHANGES
TO: **unclassified**
FROM: **restricted**
LIMITATION CHANGES
TO: **Approved for public release; distribution is unlimited.**
FROM: **Distribution authorized to DoD only; Foreign Government Information; JUL 1946. Other requests shall be referred to British Embassy, 3100 Massachusetts Avenue, NW, Washington, DC 20008.**
AUTHORITY
DSTL, DSIR 23/15846, 15 Oct 2009; DSTL, DSIR 23/15846, 15 Oct 2009

The U.S. GOVERNMENT

IS ABSOLVED

FROM ANY LITIGATION WHICH MAY ENSUE FROM THE CONTRACTORS IN-FRINGING ON THE FOREIGN PATENT RIGHTS WHICH MAY BE INVOLVED.

REEL
354
FRAME

9048

REPORT No: AERO. 2143.

ROYAL AIRCRAFT ESTABLISHMENT

Farnborough, Hants.

A PRELIMINARY EXAMINATION OF HULL AFTERBODY VENTILATION

by

K. M. TOMASZEWSKI, Inz.Lotn.(Warsaw),

A. G. SMITH, B.Sc., D.I.C.

and

G. F. CHALMERS

RESTRICTED

Class No: 532.582.4.001.57

R.A.E. Report No. Aero. 2143.

July, 1946.

ROYAL AIRCRAFT ESTABLISHMENT, FARNBOROUGH

A Preliminary Examination of Hull Afterbody Ventilation

by

K.M. Tomaszewski, Inz. lotn. (Warsaw)
A.G. Smith, B.Sc., D.I.C.
and
G.F. Chalmers

SUMMARY

Reason for Enquiry

Information was required on the effect on the water forces of ventilating the afterbody of a stepped hull, and also on what improvement could be obtained by utilising the dynamic head of the air stream.

Range of Investigation

Examination of the available information showed that a reduction of ten per cent in resistance might be expected by the efficient supply of enough air in the region of maximum air suction on a hull afterbody. Ducts were designed for a Shetland hull to feed air from the dynamic head pressure in the region of the bows. Measurements of the air and water forces and of the air flow passing through the ducts were made for a range of attitudes and drafts in the planing region, with the model:

(1) screened from any air flow,
(2) in normal air flow conditions, no dynamic head ventilation,
(3) in normal air flow conditions with dynamic head ventilation.

Conclusions

Over the planing region there is a general decrease due to the dynamic head ventilation of about ten per cent in resistance/load on water ratio and draft. There is some reduction of pitching moment compared with the unventilated hull in the normal air flow. The volume air flow through the ducts is about 500 cu.ft./sec. full scale at 62 knots, which corresponds to an energy content of about 8 H.P.

The unducted hull in the correct air flow is in turn better than the screened hull by about the same amount, although when corrected for air forces these differences can become very large. These air forces are however measured with the hull just clear of the water and are of doubtful value.

The tests in air flow and with dynamic head ventilation demonstrate the beneficial effects of ventilation and further tests are required with increased ventilation.

To examine the interference between air and water flow it is recommended that tests be made

(1) to measure the pressure distribution on the hull in stability and force tests with different degrees of ventilation,

(2) to measure the air forces acting on a hull at different drafts.

LIST OF CONTENTS

LIST OF APPENDICES

LIST OF TABLES

LIST OF ILLUSTRATIONS

List of Illustrations (cont'd) Fig.

1 Introduction

A major design problem in the design of stepped hulls for seaplanes is the efficient ventilation of the afterbody. The supply of sufficient air to the afterbody bottom in the planing region, when the afterbody is clear of the wake from the forebody, has customarily been obtained by suitable design of the step and afterbody geometry.[1] However the demand for greater efficiency and the movement towards high water speeds and drafts, has made the problem more severe.[2] The presence of air suctions under the afterbody is thought to be the primary factor in interaction between the water and air flow assuming that the water flow has just been efficiently separated from the hull bottom by the main step. These air suctions lead to upper limit porpoising instability on disturbance and low drag/lift efficiency at both small and large drafts.

In the last few years several experiments have been made model and full scale to find whether any improvement in ventilation efficiency can be obtained by supplying air direct to the afterbody. These experiments have however been made empirically without examining the nature of the air and water flow over the hull bottom, and had very little success.[3,4,5]

It was therefore decided to explore more efficient methods of ventilating the afterbody, and in the first place to obtain the air supply from the dynamic head of the free air stream. The design of an effective ducting system was considered to depend on:

(a) the position of the duct exits on the afterbody bottom,

(b) the direction in which the air supplied should be ejected relative to the boat,

(c) the dimensions of the ducts,

(d) the volume and pressure of air flow at the duct exits,

(e) the position of the air intake to the ducts when using the dynamic head of the free stream for the air supply.

From theoretical considerations of air lubrication[6] it was considered that the separation of water flow from the afterbody bottom and reduction of drag is greatest when the air leaves the duct exits in an aft direction parallel to the hull bottom. The tests on the Sea-Otter[5] showed that the improvement of porpoising stability with ventilation occurs when the duct exits are about 30 per cent of the beam aft of the step and the attitude exceeds 8° on the forebody keel datum. For positions nearer the step there was very little improvement in the stability limits.

The pressure distribution on the afterbody of a model "Empire" flying boat has been measured in the R.A.E. tank.[7,8] An analysis of these results given in Appendix I, shows that if the suctions on the afterbody bottom were removed by efficient ventilation then at 57 knots full scale the resistance would be reduced as follows:

Attitude degrees	Percentage Reduction
5	6
7	10
9	11

The maximum suctions were shown to be present at from 30 to 60 per cent of the beam aft of the main step and about 25 per cent of the beam out transversely from the keel.

The hull of the Shetland was considered to be a useful form for the experiments to determine whether improvements of the above order could be obtained by ventilation. It was representative of contemporary design, having a straight V step moderately faired in elevation. Such steps, when sufficiently faired, have a very low air drag. Full scale water pressure measurements had shown that with such a step suctions could occur on the afterbody bottom.[9] Duct exits were chosen on the bases of the Empire boat and Sea-Otter results.

The air was to be ejected aft at 5° downwards with respect to the afterbody keel. The position of the duct intakes would ideally be put in the upper part of the bow, at the stagnation position, so that the air ventilation ducts could also produce some reduction of air drag and increase of air lift as well as reduction of water drag. Since however insufficient data was available on the pressure distribution on the bows the intakes were put at the highest part of the forebody planing bottom. The ducts were designed for minimum losses of head in the passage from intakes to exits.

The general purpose of this dynamic head ventilation was to show that afterbody ventilation could be considerably improved by the simple introduction of air in a reasonably efficient manner without undue expenditure of energy. The details of practical applications of the results and the effects on stability are left to further investigations.

2 Range of Investigation

It was customary at the time of writing, to measure water forces on a partial block model behind a screen, so as to eliminate air interference difficulties.[8] Tests have therefore been made in three conditions:-

(a) screened
(b) unscreened, without ventilation
(c) unscreened, with ventilation.

The screened results form part of the general investigation of the effect of air flow on the ventilation of the afterbody. All tests were made on a standard partial model, Fig.1.

The investigation consisted in finding the effect of ventilation, by air flow and duct ventilation, on the resistance, lift, pitching moment and spray characteristics over a range of drafts and attitudes. Tests were made by the generalised method[10] for the planing range only, i.e. Froude's law was neglected.

The air flow under the carriages was modified by means of flaps to give reasonably 'correct' air flow conditions.[11] Measurements were made on both carriages, Nos. 1 and 2, but only the results on No.1 carriage are given in this report. Results on No.2 carriage confirmed the effect of ventilation but were otherwise unreliable in absolute value because of drag balance difficulties.

Measurements of air lift and drag were made in air flow with the model just clear of the water.

Measurements of the air flow through the ducts were made with pitot static tubes, Fig.5, for different drafts and attitudes over a range of speeds.

Spray conditions were photographed for the condition of zero applied moment for the take-off planing range.

3 Description of model

Tests were made on a 1 : 19 scale flat topped resistance model of the Shetland hull. The hull lines and position and dimensions of the ducts are given in Fig.1. Photographs showing a general view and an exploded view of the model are given in Fig.2.

4 Results

The results are presented on a generalised basis in terms of:-

R/Δ = Resistance/Load on water
$M/\Delta b$ = Moment about C.G./Load on water x beam
$\sqrt{C_\Delta}/C_V$ = $\left[\Delta/wV^2b^2\right]^{\frac{1}{2}}$ = Lift coefficient
d/b = draft/beam
α_K = attitude of keel at main step.

It is assumed that

$$R/\Delta,\ M/\Delta b,\ d/b = f(\sqrt{C_\Delta}/C_V, \alpha_K)$$

i.e. independent of Froude and Reynold's Numbers. The lift efficiency is defined in terms of the relationship between d/b and $\sqrt{C_\Delta}/C_V$, which is usually linear at constant attitude. On a simple wedge one would expect the lift to be zero when the draft is zero. Generally $\sqrt{C_\Delta}/C_V$ is taken to define draft at any given attitude.

The results for the model in the unscreened condition will include both air and water forces. In the first instance the results have been presented as total forces i.e. air + water. Later, in paragraph 6, an attempt is made to separate out the air forces.

4.1 Air Drag and Lift

The results of measurements of the air drag and lift forces on the 1 : 19 scale model held just clear of the water surface are given in Table II. Figs.3 and 4 represent the change in air drag and lift over a range of attitudes and speed for the model hull respectively with and without ventilation. They show that for the model without ventilation there is a change of air flow conditions in the attitude range $\alpha_{hull} = 4^o$ to 6^o. This suggests that between these two angles there exists an attitude at which the air flow separated from the forebody bottom at the step rejoins the afterbody bottom.

Ventilation improves the air flow conditions, smoothing out the lift/attitude curves and reducing the model drag.

4.2 Air flow through the ducts

The results of measurements of air flow through the ducts are tabulated in Table III for a range of attitudes speed and load on water. Figs.6 and 7 represent the variation of air flow with draft and attitude.

The volume of air passing through the ducts may be conveniently expressed as follows:-

If D_d = diameter of duct
b = beam at main step
V_a = mean speed of air flow over the cross section of the duct
V_c = carriage speed or speed of aircraft,

the volume of air passing through two ducts per second is:-

$$2 \times \pi \times \frac{D_d^2}{4} \times V_a \; .$$

In practice it is convenient to express this volume in non-dimensional units, :-

$$C_{vol} = \frac{\text{volume of air passing through 2 ducts per sec.}}{b^2 \times V_c}$$

$$C_{vol} = \frac{\pi}{2} \cdot \left(\frac{D_d}{b}\right)^2 \cdot \frac{V_a}{V_c}$$

which for the hull as tested is:-

$$C_{vol} = 0.0364 \; . \; {}^{V_a}/V_c .$$

The energy in the air-stream passing through the ducts may be expressed in H.P. by the formula:-

$$\text{H.P.} = (\text{Volume of air per sec.}) \; \rho \; . \; \frac{V_a^2}{2} \; . \; \frac{1}{550}$$

where ρ = 0.002378 slugs/ft.^{3}
V_a = mean speed of air flow in ft./sec.

For the Shetland at 62 knots full scale

$$\text{H.P.} = 0.01678 \; . \; \left(\frac{V_a}{V_c}\right)^2 \; . \; (\text{volume of air per sec.})$$

In Table IV values of ${}^{V_a}/V_c$, ${}^{d}/b$, C_{vol} and the volume flow of air and energy at N.T.P. are tabulated for a range of attitudes at 62 knots (full scale). The variation of the volume coefficient with draft and attitude for the same speed is represented in fig.8. It is shown that there is a rapid decrease in the rate of volume flow between $\alpha_{hull} = 4^o$ and 6^o. This result is in accordance with the earlier suggested change of air flow conditions in the attitude range.

The volume of air flowing through the two ducts at 62 knots full scale is of the order 500 cu.ft. per second and the corresponding energy in the air stream 6 H.P.

4.3 Total Resistance Characteristics

The results of measurements of resistance of the Shetland hull model, with and without ventilation, in "correct" air flow conditions on No.1 carriage, and for a screened model without ventilation over a range of attitudes, speed, and load on water, are tabulated in Table V as a ratio ${}^{R}/\Delta$ together with corresponding lift coefficients ${}^{\sqrt{C_\Delta}}/C_v$. Figs.9a, 10a, 11a and 12a represent the variation of the resistance coefficient (${}^{R}/\Delta$) with attitude and lift coefficient (${}^{\sqrt{C_\Delta}}/C_v$).

Comparison of these resistance characteristics for the model with and without ventilation shows that:-

(a) the resistance coefficient ${}^{R}/\Delta$ of a model with ventilation, is smaller than for a model without ventilation over the complete range of attitudes and ${}^{\sqrt{C_\Delta}}/C_v$ from the hump speed, to the take-off speed,

(b) the reduction of resistance coefficient and draft is less at large values of ${}^{\sqrt{C_\Delta}}/C_v$,

(c) the reduction of resistance coefficients is higher in the range of attitudes $\alpha_K = 4^o38'$ to $8^o38'$ than at the extreme attitude $\alpha_K = 10^o38'$.

Comparison of resistance characteristics for a model without ventilation in "correct" air flow conditions and in screened conditions shows that:-

(a) for $\alpha_K = 4^o38'$ the difference between resistance coefficients is very small,

(b) for attitudes at and above $\alpha_K = 8^o38'$, the resistance coefficients of a screened model are smaller than unscreened, but at $\alpha_K = 6^o38'$ the reverse is the case.

4.4 Total Lift Characteristics

The results of measurements of drafts of the Shetland hull model with and without ventilation in "correct" air flow conditions, and for screened conditions over a range of attitudes, speed, and load on water are tabulated in Table V. Figs.13, 14, 15 and 16 represent the change of draft coefficient $^d/b$ with lift coefficient $\sqrt{C_\Delta}/C_V$, and attitude.

In Table VII the variation of draft with lift coefficient is represented algebraically by:-

$$^d/b = m \,.\, (\sqrt{C_\Delta}/C_V) + n$$

where m and n are constants at constant attitude. The range of $\sqrt{C_\Delta}/C_V$ for which this relationship holds is also given.

Comparison of the draft characteristics $^d/b$ for the model with and without ventilation in "correct" air flow conditions, shows that:-

(a) the smallest drafts are for a ventilated model, and the biggest for a screened model over the complete range of attitudes and $\sqrt{C_\Delta}/C_V$ in Table VII,

(b) over these ranges of $\sqrt{C_\Delta}/C_V$ the draft characteristics may be represented by parallel straight lines for α_K constant,

(c) for the ventilated model these lines pass through $\sqrt{C_\Delta}/C_V = 0$ for $\alpha_K = 4^o38'$, $6^o38'$ and $10^o38'$, but at $\alpha_K = 8^o38'$ $^d/b = 0$ occurs at $\sqrt{C_\Delta}/C_V \simeq 0.024$,

(d) over the range of $\sqrt{C_\Delta}/C_V$ given in Table VII the slopes of the lines decrease with increase of attitude, except when $\alpha_K = 8^o38'$.

4.5 Total Moment Characteristics

The results of measurements of pitching moment about the centre of gravity are tabulated in Table V and represented in Figs.17 and 18 in terms of the pitching moment coefficient $^M/\Delta.b$, attitude, speed, and load on water.

Comparison of the results shows that:-

(a) the model with ventilation will run at smaller attitudes than the model without ventilation in the high speed planing range, but at higher attitudes on the low speed range when the rear step is immersed,

(b) the model without ventilation in unscreened conditions will run at smaller attitudes than the model in screened conditions for the whole planing range.

(c) the change of pitching moment characteristics which occurs when the aft step just becomes immersed ($\alpha_K = 10°38'$) is altered by ventilation.

5 Attitude, Draft and Total Resistance for zero applied moment

From the results for pitching moment, draft, and resistance of the Shetland hull model the attitudes, drafts, and resistance characteristics over the range of speed from just before hump speed to take-off speed were estimated for the zero applied moment case. The attitudes for zero applied moment are plotted in Fig. 19, and corresponding draft and resistance coefficients in Fig. 20 as a function of speed or speed coefficient

$$(C_V = \frac{V}{\sqrt{g.b}}) .$$

Fig. 21 represents the change of draft and resistance coefficients with lift coefficient $\sqrt{C_\Delta}/C_V$ in the planing region.

Comparison of the results shows that:-

(a) from $C_V = 3.5$ (hump speed) to $C_V = 7$ the attitudes for a model with ventilation are smaller than without ventilation,

(b) above $C_V = 7$ there exist two values of the attitude at which $M = 0$ for a model with and without ventilation,

(c) from $C_V = 3.5$ (hump speed) to $C_V = 6.1$, the screened model runs at higher attitudes than when unscreened,

(d) above $C_V = 6.1$ the screened model has two values of the attitude at which $M = 0$ and in the region of $C_V = 7$ the smaller is lower than that for the model with ventilation,

(e) in the range of $\sqrt{C_\Delta}/C_V \simeq 0.08$ to $\sqrt{C_\Delta}/C_V \simeq 0.24$, the resistance coefficient (R/Δ) is smallest for a model with ventilation,

(f) in this range of $\sqrt{C_\Delta}/C_V$, below 0.155, the resistance coefficient for an unscreened model without ventilation is smaller than for a screened model, but above $\sqrt{C_\Delta}/C_V = 0.155$ the reverse is the case,

(g) over the range of $\sqrt{C_\Delta}/C_V \simeq 0.09$ to $\sqrt{C_\Delta}/C_V \simeq 0.24$ the draft characteristics may be represented by parallel straight lines

$$d/b = m . (\sqrt{C_\Delta}/C_V) + n$$

where m and n are constants (tabulated in Table VII).

(h) over this range of $\sqrt{C_\Delta}/C_V$ the smallest drafts are for a ventilated model, and the highest for a screened model.

5.1 Spray conditions for zero applied moment

Comparative spray photographs, for the model of the Shetland hull with and without ventilation for zero applied moment, are given in Fig. 22.

Examination of these photographs shows that in the planing region the spray is cleaner for a model with ventilation - probably because of the smaller drafts.

6 Separation of air and water forces

Gott showed that it is not possible to consider the water flow as independent of the air flow,[6] but made a suggestion that, if a dynamic model is very stable, the resistance tests on a screened model are not likely to be much in error.

In order to check this conclusion in the case of the model of the Shetland hull, the force characteristics as measured behind the screen, have been compared with those measured in air flow, corrected for air lift and air drag as measured for the model just above the surface of the water.

If R_s = resistance of a screened model
Δ = load on the water for a screened model
D = air drag of the model just above the water surface
L = air lift of the model just above the water surface
R = total resistance of an unscreened model
Δ_w = load on the water for an unscreened model
R_w = water resistance of an unscreened model for the normal routine of water resistance measurements
$R_w = R - D$
$\Delta_w = \Delta - L$.

In Table VI values are tabulated of R_w/Δ_w for a model of the Shetland hull with and without ventilation over a range of attitudes, together with the corresponding lift coefficients $\sqrt{C_\Delta}/C_V$. Figs. 9b, 10b, 11b and 12b represent water resistance coefficients over a range of attitudes and lift coefficients $\sqrt{C_\Delta}/C_V$ for an unscreened model with and without ventilation, and for a model in screened conditions.

Comparison of these resistance characteristics shows that:-

(a) the water resistance characteristics for an unscreened model in the range of attitudes $\alpha_K = 6°38'$ and $\alpha_K = 8°38'$ are much smaller than for a screened model,

(b) in this range of attitudes for small values of $\sqrt{C_\Delta}/C_V$ differences may be over 40% and for high values of $\sqrt{C_\Delta}/C_V$ over 6%,

(c) for attitudes $\alpha_K = 4°38'$ and $\alpha_K = 10°38'$ it is difficult to reach any definite conclusion because of the scattered nature of the points for the unscreened model.

In fact, D and L probably do not represent air drag and air lift for a model running on the surface of the water. These corrected results were therefore not used for discussing the duct ventilation characteristics.

7 Discussion

The test results recorded in this report may be considered from two points of view, (1) of practical importance, i.e. of how the characteristics of the hull may be improved by dynamic head ventilation, and (2) the general effect of air flow on the water forces.

Dynamic head ventilation has been shown effective in the following respects.

(a) It improves the air flow around the model in the region of the change of air flow conditions especially at high speeds (e.g. for the Shetland hull in the range of attitudes $\alpha_K = 6°38'$ to $\alpha_K = 8°38'$).

(b) It reduces the attitude for zero applied moment in the planing condition between the hump and take-off speed. For the Shetland hull the average value of reduction being about $\frac{1}{2}^{o}$.

(c) It reduces the resistance and draft of the model, i.e. increases lifting force at constant draft.

(d) The reduction of the resistance is particularly marked at high speed and in the range of attitudes where changes of air flow conditions occur.

(e) In the range of attitudes where changes of air flow conditions occur there is a rapid reduction in the volume of the air passing through the ventilating ducts, (for the model of Shetland hull over 20%). This is accompanied by a reduction in the energy of the duct stream of the air from the order of 6 to 3 H.P. at 62 knots full scale.

The general effect of air flow on water forces, based on the tests on screened and unscreened model of the Shetland hull shows that:-

(a) It is especially important in the range of attitudes where changes of air flow condition occur.

(b) The total resistance and draft for a screened model of the Shetland hull are greater than when unscreened.

(c) When corrections are made for air lift and drag forces the water resistance of an unscreened model becomes much smaller than that of the screened one and at high speeds the differences may amount to over 40% in the critical range of attitudes.

(d) The air flow reduces the attitudes for zero applied moment by about $\frac{1}{2}^{o}$.

Both the effect of the ventilation ducts and the effect of air flow would appear to correspond to different degrees of afterbody ventilation. Unfortunately there is as yet no data on what standard of ventilation is achieved under full scale conditions.

It is known however that porpoising stability is generally better full scale, although it is as yet not certain whether this is because of less severe disturbance conditions or better ventilation. The fact that both trim attitudes and stability limits tend to be lower full scale than model scale appears to point to better ventilation as at least part of the reason.

Model scale, the achieved efficiency of ventilation could be estimated by comparison of the draft characteristics with those of a forebody only. Proposed wedge measurements will provide systematic data on this aspect, but full scale generalised data on stability and force characteristics are essential for scale effects.[2]

8 Recommendations for further work

Results of the experiments described in this report show that even for the comparatively stable hull form of the Shetland there is considerable interaction between the air and water flow under the afterbody. It has been shown earlier that resistance measurements made on an unstable model behind a screen are of doubtful significance because of air-water interference[8], and it now appears that screened measurements on fairly stable hulls may also be doubtful. There is however little quantitative data on the nature of the air flow and its interaction with the water flow. This will be obviously dependent on both the air flow conditions and the hull form and in particular the degree of ventilation of the afterbody.

The following series of tests are recommended to measure and understand better the characteristics of ventilation and interference.

(1) Stability and trim tests with the dynamic model of the Shetland using (a) the same dynamic head ducting used on the resistance model (b) an external air supply in order to obtain comparison with model and full scale measurements.

(2) Repeat force measurements on the resistance model with a faired superstructure to reproduce more representative air flow conditions over the afterbody, and in addition tests with an external air supply. The effect of wings and slipstream might also be looked into and examined if found important.

(3) Measurements of the air pressure distribution on the hull for both selected dynamic and resistance model test conditions of (1) and (2).

(4) Wind tunnel measurements of the air forces acting on a hull in the presence of ground over a range of attitudes and drafts, and in the presence of wings and slipstream. This is to provide evidence on the validity of the air lift and drag corrections based upon measurements made just clear of the water.

9 Conclusions

It is concluded from these tests that at a given speed and load on water ventilation of the afterbody bottom of the Shetland hull by dynamic head pressure, reduces the resistance and draft of the hull approximately ten per cent (model tests) over the whole planing range. For zero applied moment there is a corresponding increase in the lifting force of the hull and a reduction in attitude of half a degree. This reduction of resistance and increase of lifting force is of the same order as calculated for the "Empire" boat, assuming that the measured air suctions on the afterbody bottom were removed. It was also found that natural ventilation due to the presence of normal air flow has a big but unknown influence on the water forces.

To understand better the nature of the air flow and its interaction with the water flow it is recommended that further experiments be made to measure,

(1) the pressure distribution, the total forces, porpoising stability and trim for different degrees of ventilation.

(2) air forces acting on a hull for different attitudes, drafts and speeds.

LIST OF SYMBOLS

Angles:

$\alpha_K{}^o$ = attitude relative to the forebody keel
$\alpha_a{}^o$ = afterkeel angle relative to the forebody keel

β^o = overall deadrise angle
$\theta_K{}^o$ = deadrise angle at keel
$\theta_c{}^o$ = deadrise angle at chine
$\theta_m{}^o$ = mean deadrise angle

Lengths:

b = beam
b' = local beam
d = draft
D_d = diameter of front part of ventilated duct
ℓa = distance aft from main step along datum line of hull
ℓy = distance beamwise from central line of hull

Forces:

R = total drag of hull
R_a = afterbody drag due to pressure distribution on bottom
D = air drag
L = air lift
Δ_o = load on the water at rest
Δ = load on the water
Δ_a = afterbody lifting force due to pressure distribution on afterbody
P = Force on afterbody bottom due to pressure distribution

Pressures:

p = local pressure
p_m = mean pressure

Moment: M = pitching moment about C.G.

Velocity:

V_c = speed of aircraft or towing carriage
V_a = speed of local air flow

Acceleration:

g = acceleration due to gravity

Density:

w = density of sea water = 64.4 lb./ft.^{3}
ρ = density of air = 0.002378 slugs/ft.^{3}

Energy: H.P. = energy in the air-stream passing through ducts in H.P.

Coefficients:

$C_v = \frac{V_c}{\sqrt{g.b}}$ = velocity coefficient (Froude Number)

$C_{\Delta_o} = \frac{\Delta_o}{w.b^3}$ = static beam loading coefficient

$C_\Delta = \frac{\Delta}{w.b^3}$ = beam loading coefficient

R/Δ = resistance coefficient
d/b = draft coefficient
$M/\Delta b$ = pitching moment coefficient

LIST OF SYMBOLS (Cont'd)

$\sqrt{C_\Delta}/C_v = \left(\frac{\Delta}{w.V^2.b^2}\right)^{\frac{1}{2}}$ = lift coefficient

$\eta = \left(\frac{R-R_a}{R}\right) . \left(\frac{\Delta-\Delta_a}{\Delta}\right) . 100$ = percentage reduction of drag due to removing suction on afterbody bottom

$C_{vol} = \frac{\text{Volume of air through 2 ducts per sec.}}{b^2.V_c}$

REFERENCES

No.	Author	Title, etc.
1	A.G. Smith H.G. White	A review of porpoising instability of seaplanes Report No. H/Res/173. A.R.C.7741. February, 1944.
2	A.G. Smith	An examination of some problems of large seaplane design and methods of investigation Tech.Note No. Aero.1748. A.R.C.9405. Jan., 1946.
3	I.W. McCaig W.M. Inverarity	The water stability of the "Coronado" flying boat Report No. H/Res/176. A.R.C.8063. May, 1944.
4	J.R. Dawson	Tank tests of two models of flying boat hulls to determine the effect of ventilating the step N.A.C.A. Tech.Note No. 594.
5	G.L. Fletcher	Tank test on the water stability of the supermarine Sea-Otter. Report No.Aero.1927. A.R.C.7851. March, 1944.
6	H.G. White	Note on Air lubrication of seaplane hulls Report No. H/Res/170. February, 1944.
7	C.B. Baker	Tank test on a model of the "Empire" flying boat Report No. B.A. 1678. A.R.C.5213. May, 1941.
8	G.P. Gott	Interference between Air Flow and Water Flow in Seaplane Tank Testing. Aero.Tech.Note 1460. A.R.C.7906. July, 1944.
9	E.J. Evans A.G. Smith R.A. Shaw W. Morris	Water performance of Sunderland K.4774 with step fairing. Report H/Res/140. December, 1940.
10	W.J. Reiners	A generalised method of examining the hydrodynamic force characteristics of seaplanes planing on the water surface Report No. Aero. (Unpublished).
11	K. Tomaszewski S. Raymond G.F. Chalmers	The Air Flow under the towing carriages in the R.A.E. Seaplane Tank Tech.Note No.Aero. 1743. June, 1946.

Attached:- Drgs. 19111 - 19130S
Negs. 69371 - 69374
Appendix I
Tables I - XI.

Circulation:- C.S.(A)
D.G.S.R.(A)
D.S.R.(A)
A.D.A.R.D.(Res.) (Action copy)
A.D.S.R. (Records)
S.D.D.A.R.D.
P.D.T.D.
R.T.P./T.I.B. (110 + 1)
D.D.A.R.D. (Serv.)
D.D.A.R.D. (Civ.)
D.D.R.D. (Perf.)
A.D.R.D.S.
A.D.R.D.N.
A. & A.E.E.
M.A.E.E. (2)
A.R.C. (40)

APPENDIX I

Calculation of the possible reduction of drag of the "Empire" boat at 57 knots full scale by removing air suctions from the afterbody bottom.

In research on afterbody bottom ventilation it is very useful to know the possible reduction of drag by removing the air suctions on the afterbody bottom. From work done in the R.A.E. seaplane tank[7,8] on the "Empire" boat calculations have been made for one speed (57 knots - full scale).

From reference 8 and unpublished data the pressure distribution was determined for attitudes 5^o, 7^o and 9^o on the afterbody bottom of the "Empire" boat. Fig. 23 represents the location of the pressure points and table VIII values of the pressure for the 1 : 16 model at 24 f.p.s. For each lateral section of the afterbody bottom the pressure distribution was plotted as shown in fig. 24. The mean values of the pressure for each section were found using a planimeter and are tabulated in Table IX. Table IX also gives the mean values of the pressure components, in the plane of symmetry of the hull, $p_m \cdot \sin\beta \cdot b'/b$, where b' is the local beam, and b the beam at the step. In fig. 25 the variation of these components along the afterbody keel line is plotted for attitudes 5^o, 7^o and 9^o. The resultant forces normal to the afterbody were then found by means of a planimeter. These forces and their horizontal and normal components to the water line are given in table X.

If R, Δ are drag and load on water for the "Empire" boat hull with suction on the afterbody bottom[7], and R_a and Δ_a drag and lifting force on afterbody bottom due to the suctions, as tabulated above, the drag of the hull without suctions will be:-

$$R' = (R-R_a) \cdot \left(\frac{\Delta-\Delta_a}{\Delta}\right)$$

and the percentage reduction of drag by removing suctions on the afterbody bottom:-

$$\eta = \frac{R'}{R} \cdot 100 = \left(1 - \frac{R_a}{R}\right) \cdot \left(1 - \frac{\Delta_a}{\Delta}\right) \cdot 100$$

The results given in table XI show that for the "Empire" boat at 57 knots the possible reductions of total drag are:-

$\alpha_K = 5^o$ more than 6%
$\alpha_K = 7^o$ more than 10%
$\alpha_K = 9^o$ more than 11%

TABLE I

Particulars of Ventilated Shetland Hull

Model Scale 1 : 19

All up Weight 120,000 lb.

Static Beam Loading Coefficient C_{Δ_o} = 0.96

Beam (at step) b = 12 ft. 6 ins.

Forebody ÷ Beam, Ratio 3.5 (reference to point of step)

Afterbody ÷ Beam, Ratio 3.3 "

Unfaired Step Depth 9% of Beam (at keel)

Centre of Gravity Position:

Above Datum at Main Step 16 ft.
Forward of Step Parallel to Datum Line 5 ft. 2 ins.

Keel Angle to Hull Datum $2°38'$

Afterkeel Angle to Forebody Keel $7°35'$

Step Included Angle in Plan $136°$

Deadrise Angle on Forebody at Main Step:

Deadrise Angle at Keel $\theta_K = 30°$

Deadrise Angle at Chine $\theta_c = 15°$

Mean Deadrise Angle $\theta_m = 25°$

The shape and position of ducts relative to the hull is given in Fig. 1.

TABLE II

Air Lift and Air Drag for 1 : 19 Scale Shetland Hull Measured just clear of the Water on No.1 R.A.E. Carriage.

Model Scale (b = 7.88")						
α_K^o Keel	Speed V_c (f.p.s.)	With Ventilation		Without Ventilation		$C_V = \frac{V_c}{\sqrt{gxb}}$
		Air Lift (lb.)	Air Drag (lb.)	Air Lift (lb.)	Air Drag (lb.)	
2°38'	16	-	0.02	0.14	-	3.49
4°38'		0.15	0.02	0.14	0.10	
6°38'		0.15	0.02	0.17	0.15	
8°38'		0.15	0.02	0.16	0.17	
10°38'		0.15	0.02	0.19	0.13	
2°38'	28	0.31	0.13	0.36	0.23	6.10
4°38'		0.35	0.13	0.36	0.28	
6°38'		0.41	0.13	0.46	0.42	
8°38'		0.43	0.13	0.41	0.35	
10°38'		0.45	0.13	0.50	0.37	
2°38'	36	0.43	0.43	0.53	0.35	7.85
4°38'		0.50	0.40	0.53	0.40	
6°38'		0.65	0.38	0.67	0.59	
8°38'		0.70	0.43	0.59	0.45	
10°38'		0.75	0.43	0.71	0.54	

TABLE III

Velocity Measurement of Air Flow through Duct with Different Drafts and Attitudes

α_K^o Keel	Model Scale (b = 7.88")		$\frac{\sqrt{C_\Delta}}{C_V}$	$\frac{V_a}{V_c} = \frac{\text{Air Flow Speed}}{\text{Carriage Speed}}$ for Pitot Position:				
	Speed V_c (f.p.s.)	Load on water Δ (lb.)		1	2	3	4	5
2°38'	16	5.5	0.172	0.92	1.03	1.01	-	-
4°38'		5.5	0.172	0.98	1.05	1.04	-	-
6°38'		5.5	0.172	0.97	1.03	1.02	-	-
8°38'		5.5	0.172	0.95	0.98	1.01	-	-
10°38'		5.5	0.172	0.92	0.92	0.96	-	-
4°38'	24	10.1	0.155	0.98	1.01	0.98	0.88	0.75
6°38'		8.9	0.146	0.95	0.90	0.88	0.86	0.71
8°38'		7.5	0.134	0.75	0.77	0.80	0.63	0.42
10°38'		6.2	0.122	0.78	0.74	0.81	0.70	0.46
2°38'	28	5.5	0.098	0.98	0.98	0.94	-	-
4°38'		5.5	0.098	0.89	0.91	0.88	-	-
6°38'		5.5	0.098	0.84	0.88	0.85	-	-
8°38'		5.5	0.098	0.85	0.86	0.80	-	-
10°38'		5.5	0.098	0.83	0.87	0.85	-	-
2°38'	36	5.5	0.076	0.99	0.98	0.96	-	-
4°38'		5.5	0.076	0.88	0.88	0.86	-	-
6°38'		5.5	0.076	0.85	0.84	0.82	-	-
8°38'		5.5	0.076	0.85	0.83	0.81	-	-
10°38'		5.5	0.076	0.90	0.91	0.89	-	-

TABLE IV

Volume and Energy of Air Flow through Ducts for Take-Off Conditions at 62 knots (Full Scale)

$C_{vol} = \frac{\text{Volume of Air through 2 Ducts per sec.}}{(\text{Beam})^2 \times \text{Carriage Speed}}$				Full Scale	
αK^{o} Keel	$\frac{V_a}{V_c} = \frac{\text{Air Flow Speed}}{\text{Carriage Speed}}$	$\frac{d}{b} = \frac{\text{Draft}}{\text{Beam}}$	$C_{vol} = 0.0364 \times \frac{V_a}{V_c}$	Volume of Air Per Sec. ($ft.^3$/sec.)	Power in Ducts Stream in H.P.
4°38'	0.918	0.165	0.0334	544	7.7
6°38'	0.855	0.127	0.0311	506	6.2
8°38'	0.681	0.108	0.0248	404	3.2
10°38'	0.703	0.095	0.0256	417	3.45

TABLE V

Total Resistance, Draft and Moment Characteristics of Shetland Hull With and Without Air Flow and Ventilation.

α_K^o Keel	Model Scale (b = 7.88")		$\frac{\sqrt{C_\Delta}}{C_V}$	With Ventilation			Without Ventilation			Without Ventilation Screened		
	Speed V_c (f.p.s.)	Load on water Δ (lb.)		$\frac{R}{\Delta}$	$\frac{d}{b}$	$\frac{M}{\Delta b}$	$\frac{R}{\Delta}$	$\frac{d}{b}$	$\frac{M}{\Delta b}$	$\frac{R}{\Delta}$	$\frac{d}{b}$	$\frac{M}{\Delta b}$
4°38'	12	14.1	0.342	0.215	0.396	0.879	0.236	0.403	0.556	0.234	0.424	0.571
6°38'		13.5	0.329	0.200	0.363	0.381	0.207	0.373	0.271	0.198	0.397	0.259
8°38'		13.0	0.328	0.200	0.330	0.070	0.204	0.335	0.029	0.192	0.359	-0.012
10°38'		12.6	0.323	0.220	0.275	-0.677	0.218	0.284	-0.364	0.210	0.294	-0.519
6°38'	16	12.2	0.239	0.184	0.274	1.118	0.192	0.283	0.784	0.197	0.297	0.833
8°38'		11.4	0.231	0.188	0.218	0.471	0.200	0.239	0.381	0.197	0.248	0.400
10°38'		10.6	0.222	0.218	0.184	-0.211	0.229	0.198	-0.151	0.223	0.205	-0.091
6°38'	20	10.5	0.177	0.162	0.172	0.169	0.174	0.191	0.260	0.177	0.198	0.312
8°38'		9.5	0.168	0.190	0.153	0.012	0.205	0.172	0.039	0.198	0.179	0,056
10°38'		8.5	0.159	0.224	0.133	-0.019	0.236	0.146	-0.102	0.229	0.156	-0.102
4°38'	24	10.1	0.145	0.193	0.165	0.466	0.218	0.174	0.303	0.215	0.180	0.414
6°38'		8.9	0.136	0.168	0.127	0.025	0.182	0.148	0.033	0.189	0.158	0.088
8°38'		7.5	0.125	0.200	0.108	-0.152	0.220	0.130	-0.085	0.206	0.137	-0.073
10°38'		6.2	0.113	0.236	0.095	-0.361	0.250	0.108	-0.225	0.242	0.115	-0.208
4°38'	28	8.5	0.114	0.214	0.130	0.169	0.232	0.140	0.179	0.235	0.147	0.223
6°38'		7.0	0.097	0.185	0.094	-0.130	0.207	0.109	-0.087	0.221	0.122	-0.032
8°38'		5.3	0.090	0.217	0.066	-0.310	0.240	0.090	-0.228	0.230	0.098	-0.158
10°38'		3.8	0.076	0.342	0.062	-0.745	0.421	0.075	-0.589	0.379	0.084	-0.469

TABLE V (Cont'd)

α_K^o Keel	Model Scale (b = 7.88")		$\frac{\sqrt{C_\Delta}}{C_V}$	With Ventilation			Without Ventilation			Without Ventilation Screened		
	Speed V_c (f.p.s.)	Load on water (lb.)		$\frac{R}{\Delta}$	$\frac{d}{b}$	$\frac{M}{\Delta b}$	$\frac{R}{\Delta}$	$\frac{d}{b}$	$\frac{M}{\Delta b}$	$\frac{R}{\Delta}$	$\frac{d}{b}$	$\frac{M}{\Delta b}$
4°38'	32	6.8	0.086	0.240	0.098	-0.033	0.279	0.110	0.000	0.279	0.118	0.067
6°38'		4.8	0.075	0.208	0.072	-0.309	0.242	0.093	-0.259	0.258	0.104	-0.126
8°38'		2.8	0.057	0.250	0.032	-0.683	0.411	0.058	-0.353	0.339	0.063	-0.298
10°38'		0.9	0.032	0.333	-0.040	-7.545	0.411	-0.214	-2.165	0.389	0.028	-4.009
4°38'	36	4.8	0.081	0.271	0.072	-0.210	0.344	0.086	-0.079	0.333	0.096	-0.219
6°38'		2.5	0.066	0.296	0.044	-0.457	0.380	0.061	-0.122	0.380	0.071	-0.122
8°38'		0.3	0.045	1.333	-0.044	-1.142	1.466	-0.082	0.862	-	0.043	-2.284

TABLE VI

Water Resistance Characteristics of Shetland Hull with and without Ventilation (Corrected for Air Drag and Air Lift Forces)

$\alpha_K{}^o$ Keel	Speed of Model (b = 7.88") V_c (f.p.s.)	With Ventilation		Without Ventilation	
		$\frac{R_W}{\Delta_W}$	$\frac{\sqrt{C_\Delta}}{C_V}$	$\frac{R_W}{\Delta_W}$	$\frac{\sqrt{C_\Delta}}{C_V}$
4°38'	12	0.218	0.338	0.234	0.341
6°38'		0.201	0.332	0.205	0.332
8°38'		0.202	0.324	0.197	0.327
10°38'		0.222	0.320	0.216	0.320
6°38'	16	0.185	0.237	0.182	0.236
8°38'		0.189	0.229	0.187	0.229
10°38'		0.219	0.220	0.221	0.220
6°38'	20	0.161	0.175	0.155	0.174
8°38'		0.195	0.166	0.185	0.166
10°38'		0.232	0.157	0.242	0.156
4°38'	24	0.190	0.143	0.208	0.143
6°38'		0.166	0.133	0.151	0.133
8°38'		0.198	0.122	0.189	0.121
10°38'		0.236	0.110	0.216	0.109
4°38'	28	0.207	0.111	0.208	0.111
6°38'		0.177	0.100	0.157	0.100
8°38'		0.209	0.086	0.188	0.082
10°38'		0.349	0.071	0.373	0.071
4°38'	32	0.262	0.076	0.291	0.079
6°38'		0.182	0.070	0.156	0.070
8°38'		0.214	0.051	0.305	0.052
4°38'	36	0.202	0.063	0.293	0.063
6°38'		0.167	0.041	0.196	0.041

TABLE VII

Algebraical Representation of Variation of Draft with Load on Water and Speed over a Range of Attitudes

$\alpha_K{}^o$ Keel	$\frac{d}{b} = m \times \frac{\sqrt{C_\Delta}}{C_V} + n$						The Range of $\frac{\sqrt{C_\Delta}}{C_V}$ Applicable
	With Ventilation		Without Ventilation		Without Ventilation Screened		
	m	n	m	n	m	n	
4°38'	0.0113	0.000	0.0113	0.010	0.0113	0.017	0.090-0.145
6°38'	0.0095	0.000	0.0095	0.018	0.0095	0.029	0.075-0.180
8°38'	0.0103	-0.022	0.0103	0.000	0.0103	0.009	0.055-0.230
10°38'	0.0083	0.000	0.0083	0.014	0.0083	0.021	0.075-0.220
Zero Applied Moment	0.0072	0.034	0.0072	0.047	0.0072	0.054	0.090-0.240

TABLE VIII

Air Pressure Distribution on Afterbody Bottom of 1 : 16 scale "Empire" boat, measured at 24 f.p.s.

Pressure Point No.	$\frac{\ell_y}{b}$	$\frac{\ell_a}{b}$	p = pressure (lb./ft.^{2})		
			$\alpha = 5^o$	$\alpha = 7^o$	$\alpha = 9^o$
1	0		-0.7224	-0.8056	-0.7224
19	0.478	0.275	-0.8004	-0.9303	-0.8264
10	0.840		-0.9044	-0.8836	-0.7380
2	0		-0.6185	-0.8056	-0.4781
20	0.464	0.869	-0.7796	-1.0083	-1.0707
11	0.783		-0.6757	-0.7588	-0.5093
3	0		-0.4796	-0.5977	-0.5041
21	0.435	1.420	-0.5925	-0.8004	-0.5509
12	0.739		-0.4574	-0.5509	-0.4262
4	0		-0.2390	-0.2806	-0.4366
22	0.466	2.017	-0.3742	-0.5405	-0.3690
13	0.681		-0.0259	-0.2703	-0.5200
5	0		-0.1351	-0.1559	-0.2806
23	0.377	2.580	-0.2599	-0.4366	-0.4678
14	0.638		+0.0208	-0.2599	-0.4262
6	0		-0.1455	-0.1871	-0.2806
24	0.333	3.119	-0.2027	-0.3014	-0.3846
15	0.579		+0.0416	-0.1871	-0.3950
7	0		-0.1351	-0.1871	-0.3326
25	0.319	3.739	-0.2287	-0.2910	-0.3534
16	0.522		+0.0520	-0.1871	-0.3742
8	0		-0.2080	-0.2599	-0.3638
26	0.304	4.334	-0.2495	-0.2495	-0.3534
17	0.493		-0.0104	-0.1871	-0.3118
9	0		-0.2183	-0.2390	-0.3599
27	0.275	4.869	-0.2599	-0.3014	-0.3326
18	0.420		-0.1663	-0.3534	-0.0000

TABLE IX

Variation of Mean Air Pressure Along the Afterbody of 1 : 16 Scale "Empire" Boat at 24 f.p.s.

Pressure Point No.	p_m (lb./ft.^{2})			p_m x sinβ x $\frac{b'}{b}$ (lb./ft.^{2})		
	$\alpha = 5^o$	$\alpha = 7^o$	$\alpha = 9^o$	$\alpha = 5^o$	$\alpha = 7^o$	$\alpha = 9^o$
1,19,10	-0.9317	-1.0349	-0.9526	-0.7814	-0.8680	-0.7986
2,20,11	-0.8165	-1.0775	-0.7499	-0.6727	-0.8878	-0.6179
3,21,12	-0.5118	-0.6680	-0.4932	-0.3939	-0.5141	-0.3795
4,22,13	-0.2634	-0.3894	-0.4884	-0.1884	-0.2785	-0.3493
5,23,14	-0.1944	-0.2874	-0.4110	-0.1282	-0.1893	-0.2706
6,24,15	-0.1590	-0.2600	-0.3900	-0.0936	-0.1530	-0.2226
7,25,16	-0.1736	-0.2789	-0.4200	-0.0938	-0.1508	-0.2271
8,26,17	-0.2175	-0.2828	-0.4279	-0.1032	-0.1342	-0.2030
9,27,18	-0.2340	-0.3233	-0.3006	-0.0972	-0.1344	-0.1249

TABLE X

Drag and Lift on Afterbody Bottom on 1 : 16 Scale "Empire" Boat at 24 f.p.s. Due to Air Pressure Distribution

α^o	$\alpha_K^o - \alpha_a^o$	P (lb.)	Δ_a = P x cos $(\alpha_K^o - \alpha_a^o)$ (lb.)	R_a = P x sin $(\alpha_K^o - \alpha_a^o)$ (lb.)
5°	2°30'	0.252	0.252	0.011
7°	0°30'	0.338	0.338	0.003
9°	-1°30'	0.319	0.319	-0.008

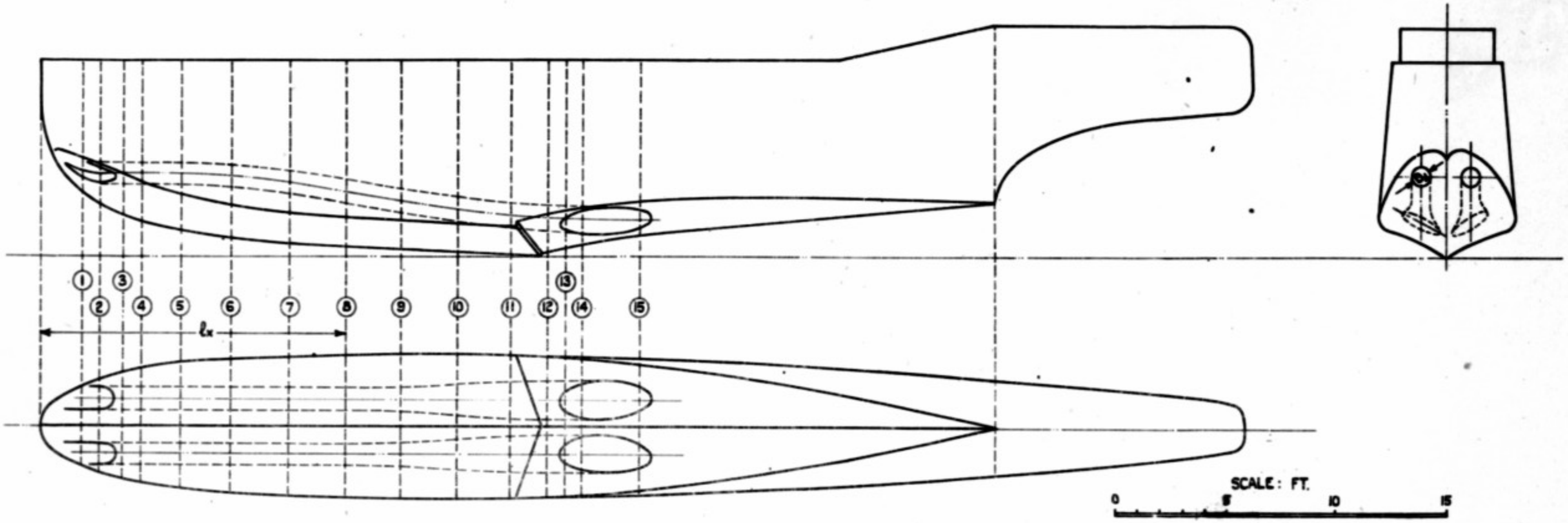
TABLE XI

Possible Reduction of Drag for Full Sale "Empire" Boat at 57 Knots by Removing Suction on Afterbody Bottom

α^o	R (lb.)	Δ (lb.)	R_a (lb.)	Δ_a (lb.)	$K = \frac{\Delta}{\Delta - \Delta_a}$	$R' = \frac{R - R_a}{K}$ (lb.)	$\eta = \frac{R'}{R}$ x 100%
5°	5570	17203	45	1033	1.064	5194	6.7
7°	3359	13926	12	1384	1.110	3014	10.2
9°	2867	10649	-34	1305	1.141	2543	11.3

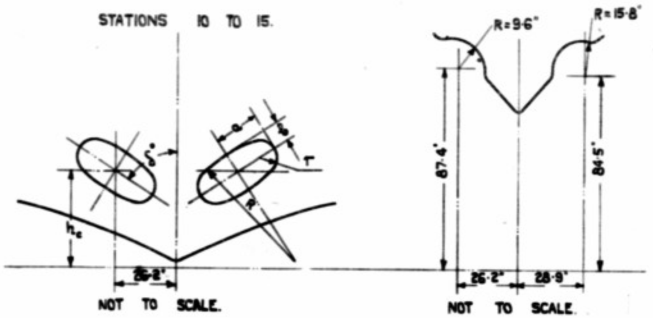
FIG. 1.

Nº 19111 B.



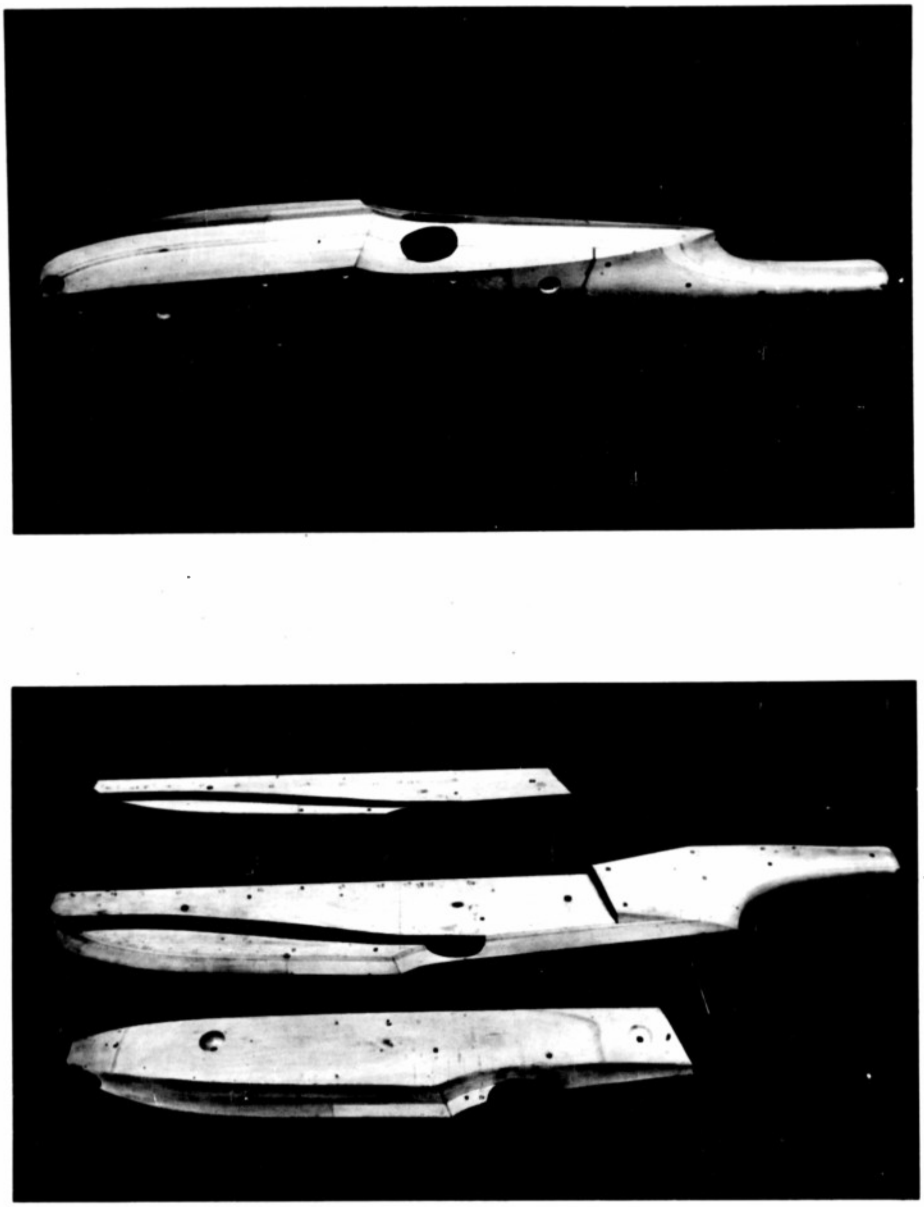
ALL DIMENSIONS IN INCHES

STATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
ℓ_x	43·5	61·6	85·5	107·5	147·5	204·6	257·5	327·75	387·2	484·4	505·3	546·0	566·2	582·7	645·0
h_e	87·4	87·4	87·4	87·4	87·4	83·6	76·75	68·4	58·9	49·6	40·8	37·0	36·1	36·1	36·1
D_d	22·8	22·8	22·8	22·8	22·8	22·8	22·8	22·8	22·8	—	—	—	—	—	—
a	—	—	—	—	—	—	—	—	—	13·9	19·4	23·6	24·7	24·7	—
b	—	—	—	—	—	—	—	—	—	9·3	6·5	5·5	5·3	5·3	5·3
R	—	—	—	—	—	—	—	—	—	18·6	47·5	72·2	84·1	87·0	87·0
r	—	—	—	—	—	—	—	—	—	6·8	3·6	2·5	2·5	2·5	—
$\delta°$	—	—	—	—	—	—	—	—	—	33°	33°	33°	33°	33°	33°



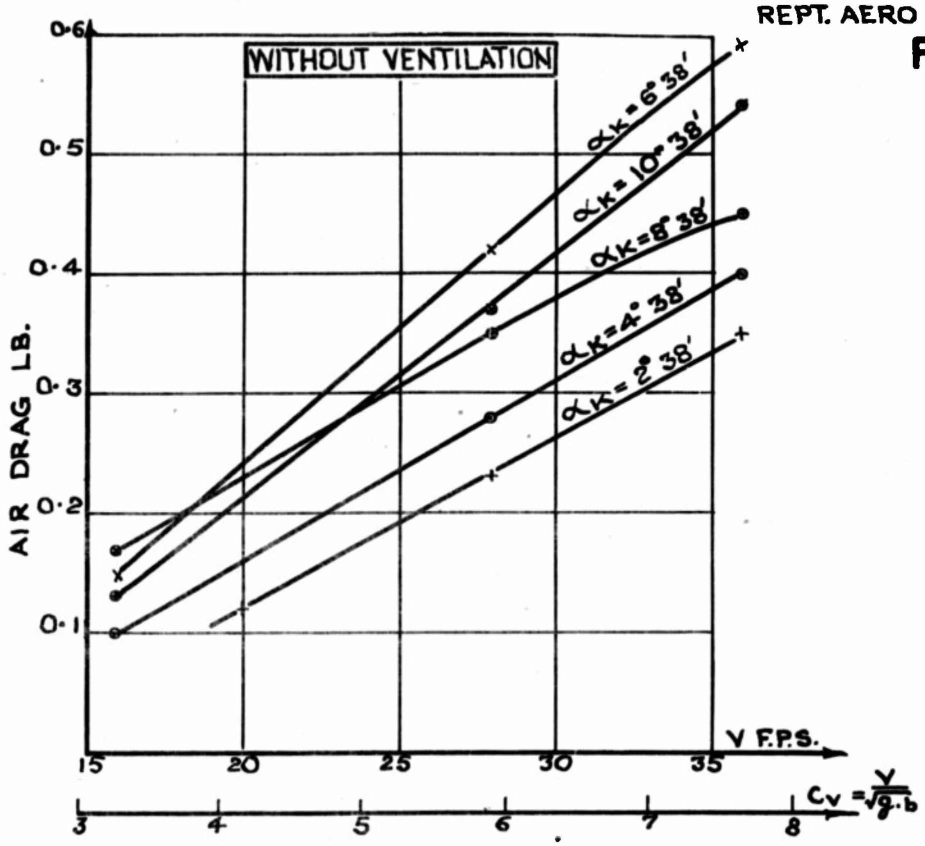
MODEL HULL LINES SHOWING POSITION OF VENTILATION DUCTS.

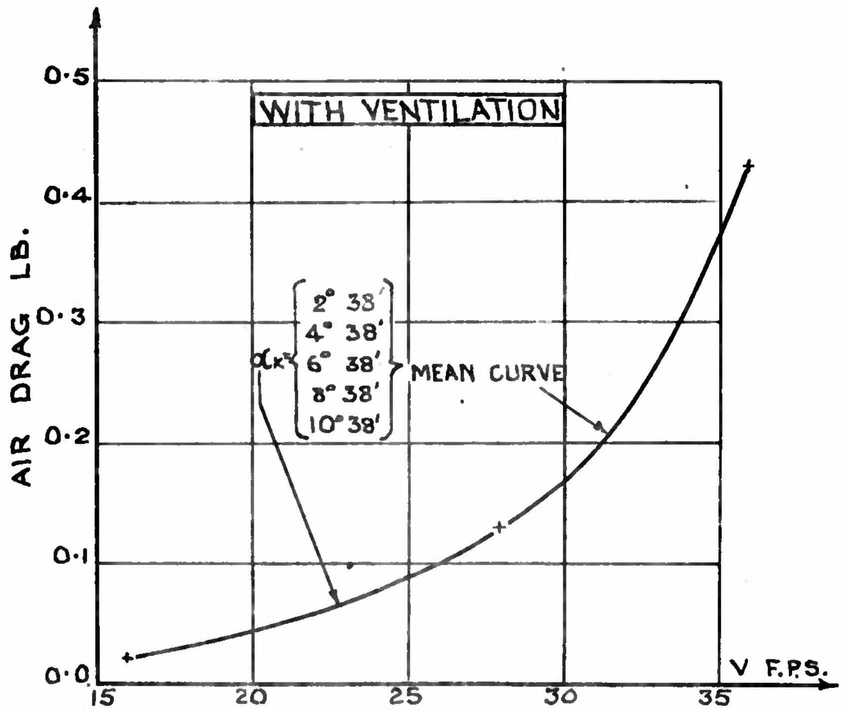
FIG. 2



GENERAL VIEW AND EXPLODED VIEW OF HULL WITH VENTILATION DUCTS

FIG. 3.



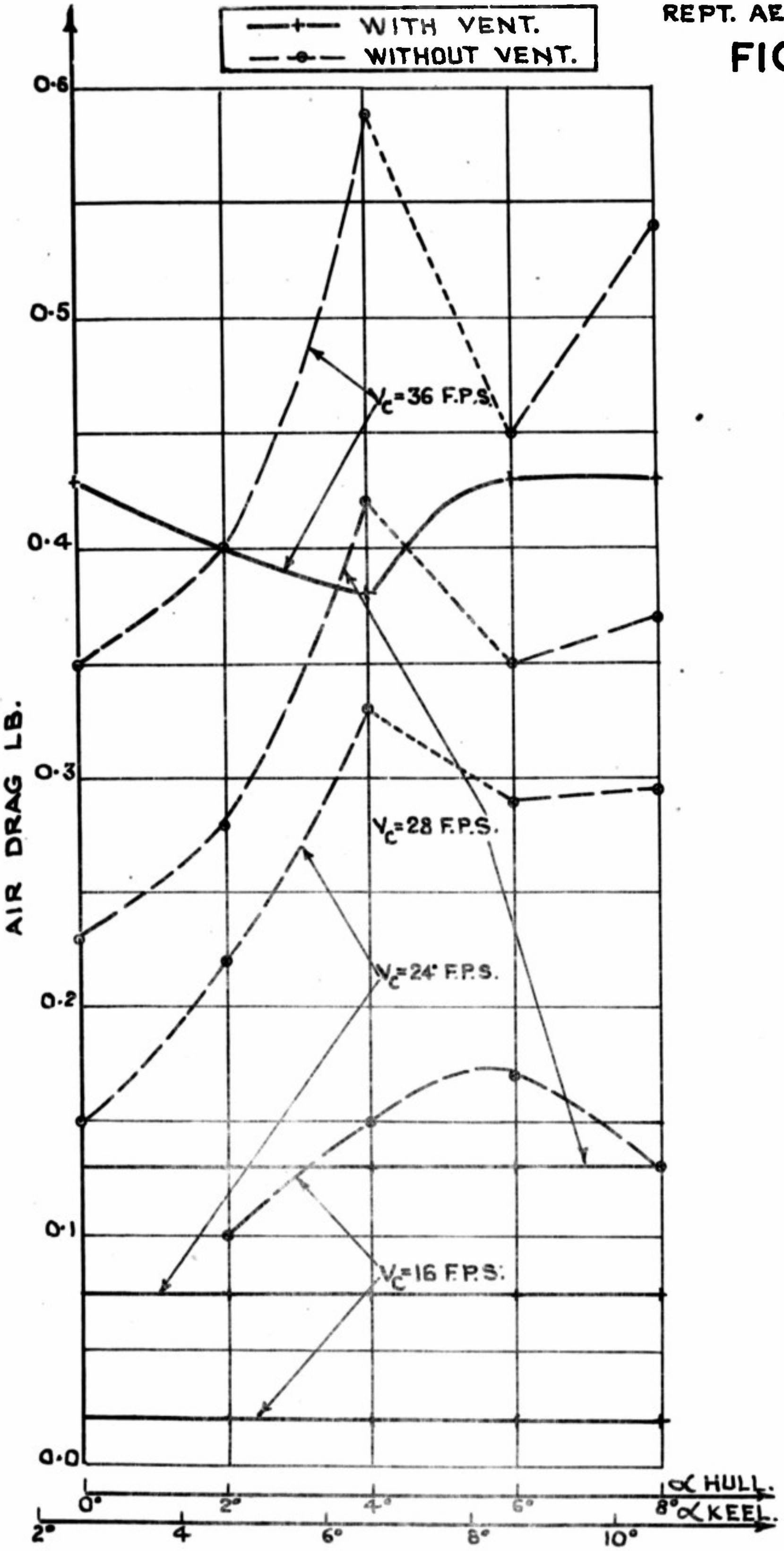


AIR DRAG OF MODEL SHETLAND HULL ON R.A.E. No.1 TOWING CARRIAGE. (MODEL JUST CLEAR OF WATER.)

N019113.S.

REPT. AERO 2143.

FIG.3. CONTD.

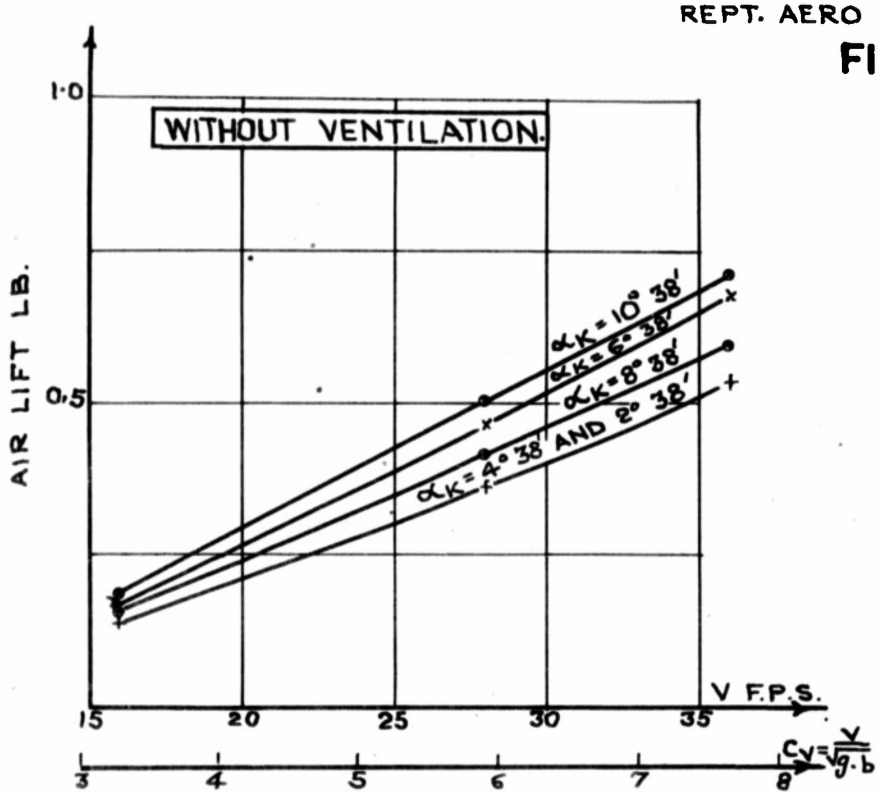


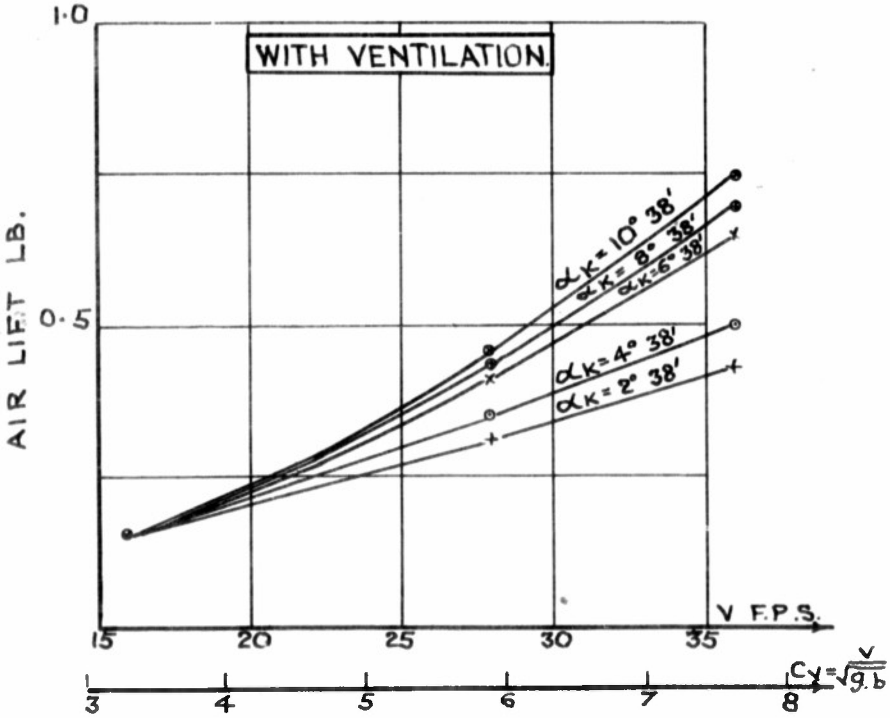
AIR DRAG OF MODEL SHETLAND HULL ON R.A.E. No.1 TOWING CARRIAGE. (MODEL JUST CLEAR OF WATER.)

No 19114. S.

REPT. AERO 2143.

FIG.4.



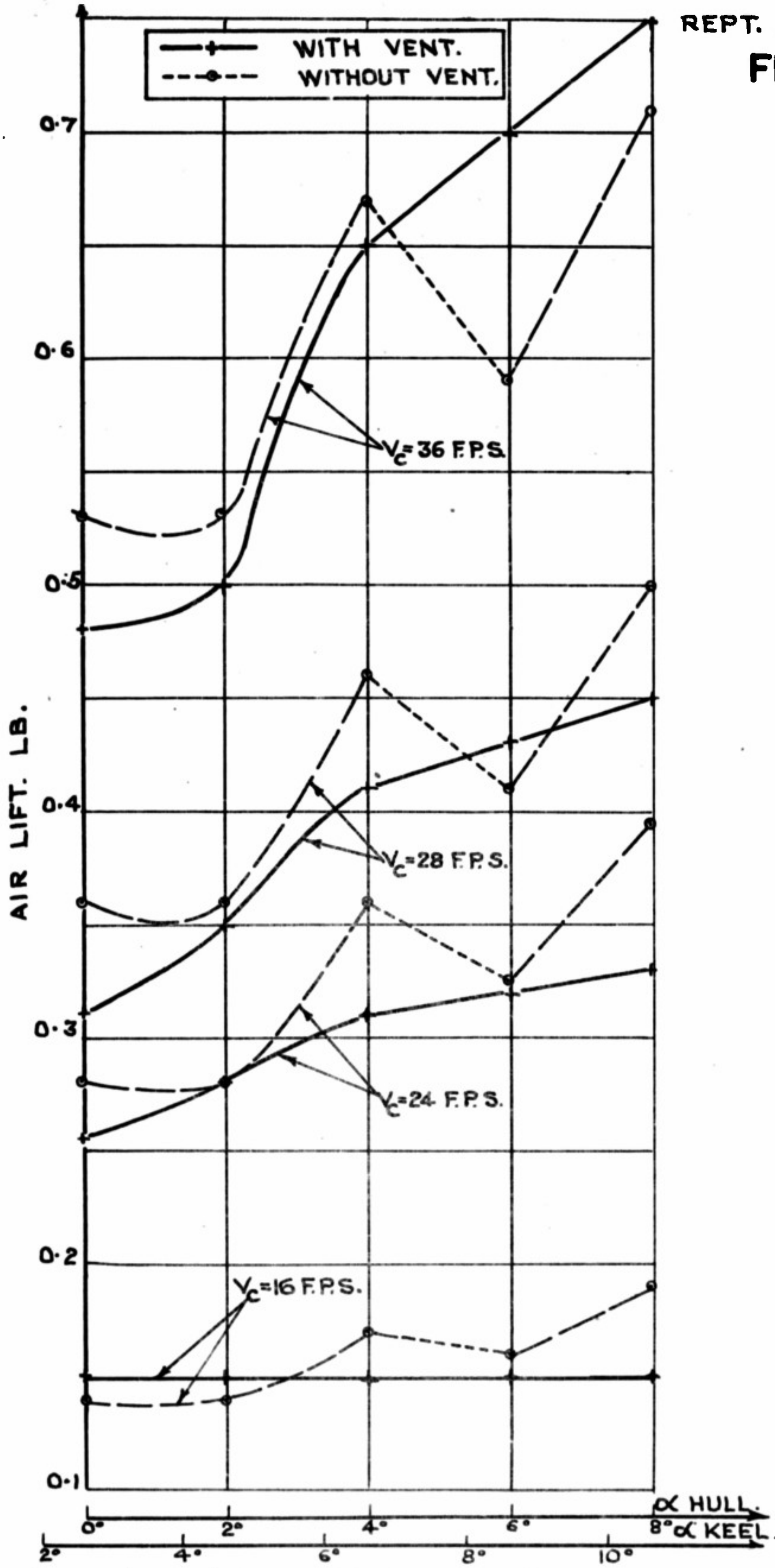


AIR LIFT OF MODEL SHETLAND HULL ON R.A.E. No.1 TOWING CARRIAGE.
(MODEL JUST CLEAR OF WATER.)

No. 19115. S.

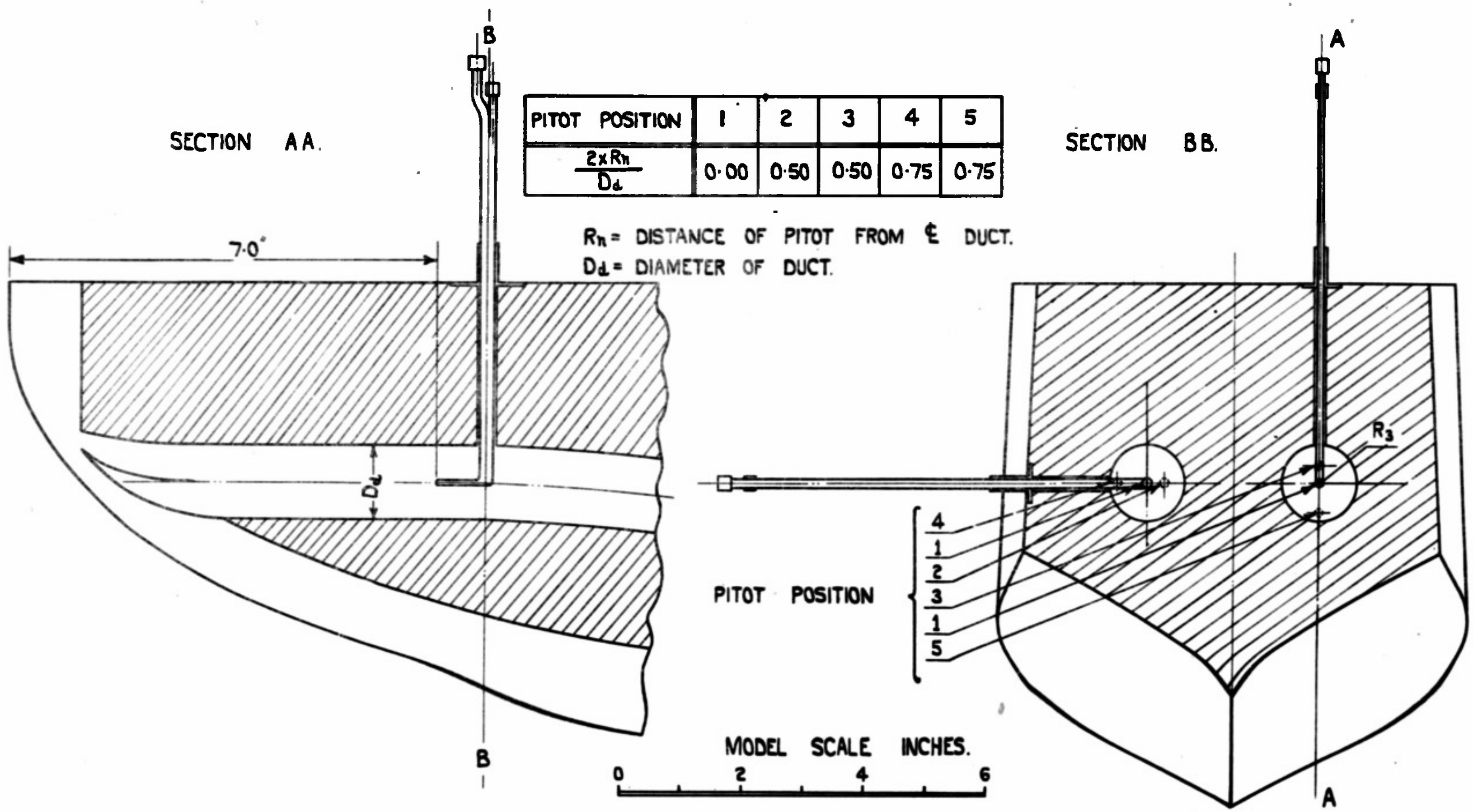
REPT. AERO 2143.

FIG. 4. CONTD.



AIR LIFT OF MODEL SHETLAND HULL ON R.A.E. No. 1 TOWING CARRIAGE. (MODEL JUST CLEAR OF WATER.)

FIG. 5.



PITOT POSITION	1	2	3	4	5
$\frac{2 \times R_n}{D_d}$	0·00	0·50	0·50	0·75	0·75

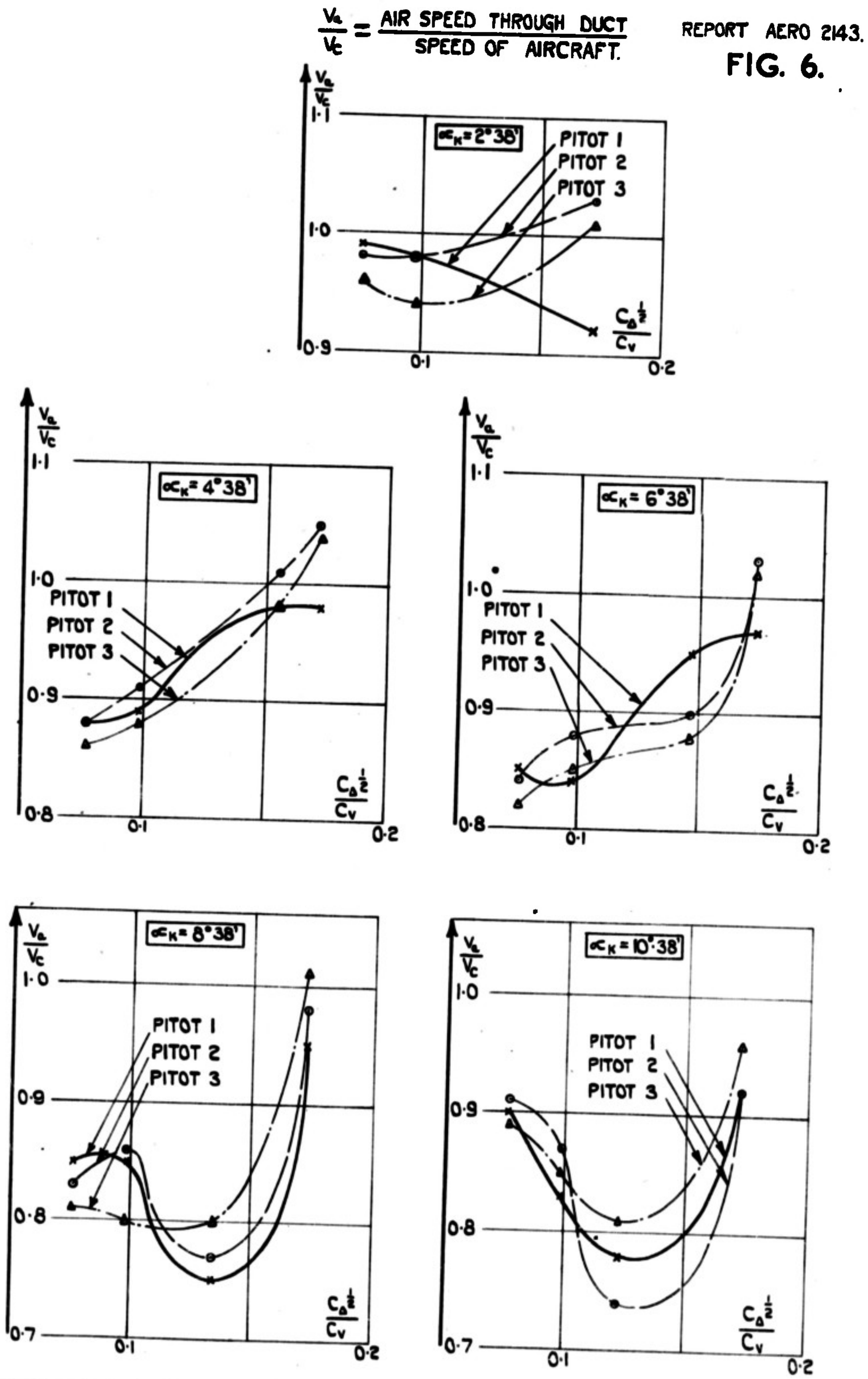
R_n = DISTANCE OF PITOT FROM ℄ DUCT.
D_d = DIAMETER OF DUCT.

MEASUREMENT OF AIR FLOW THROUGH DUCTS.

IN°. 19117. S.

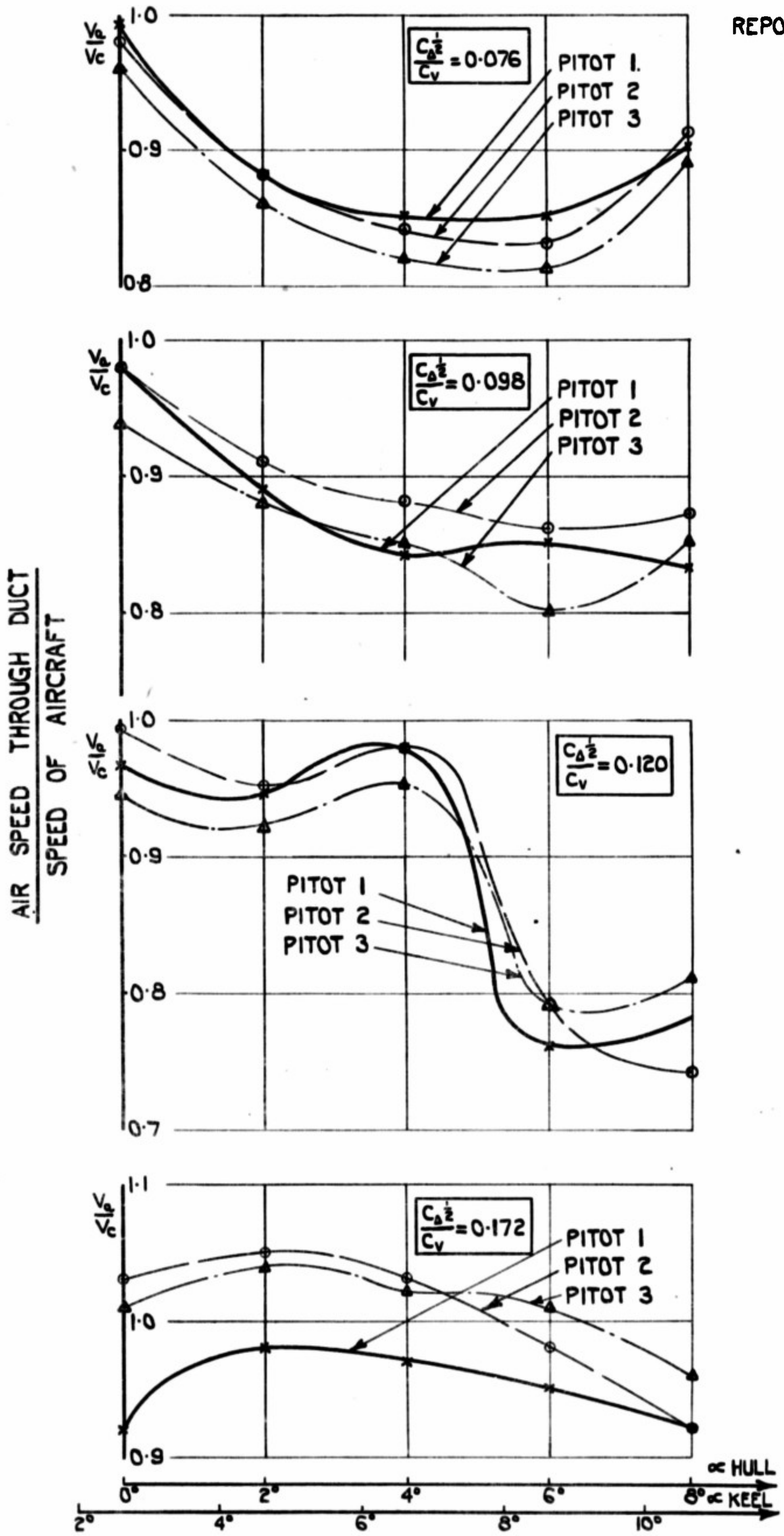
REPORT AERO 2143.

FIG. 6.



VARIATION OF AIR FLOW THROUGH DUCT WITH DRAFT AT CONSTANT ATTITUDE.

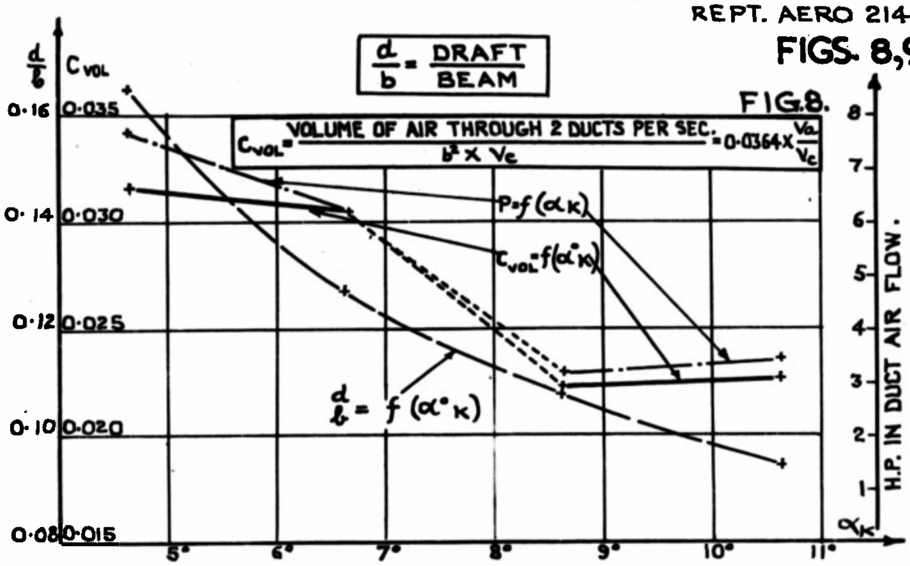
FIG. 7.



VARIATION OF AIR FLOW THROUGH DUCT WITH ATTITUDE AT CONSTANT LIFT COEFFICIENT.

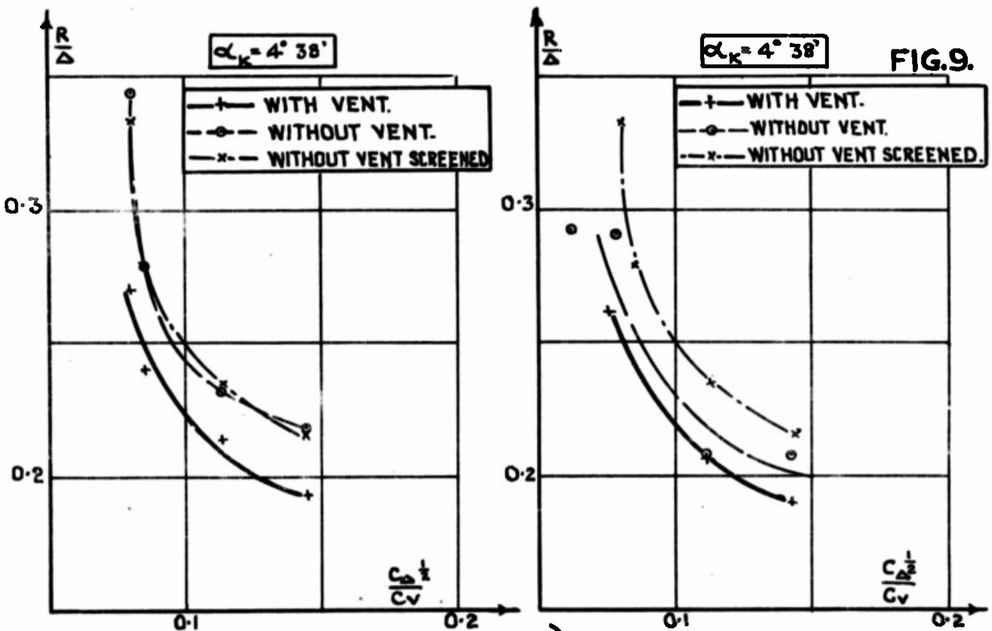
No 19119. S.

FIG.8.



VARIATION OF AIR FLOW FOR TAKE-OFF CONDITIONS AT 62° KNOTS (FULL SCALE.)

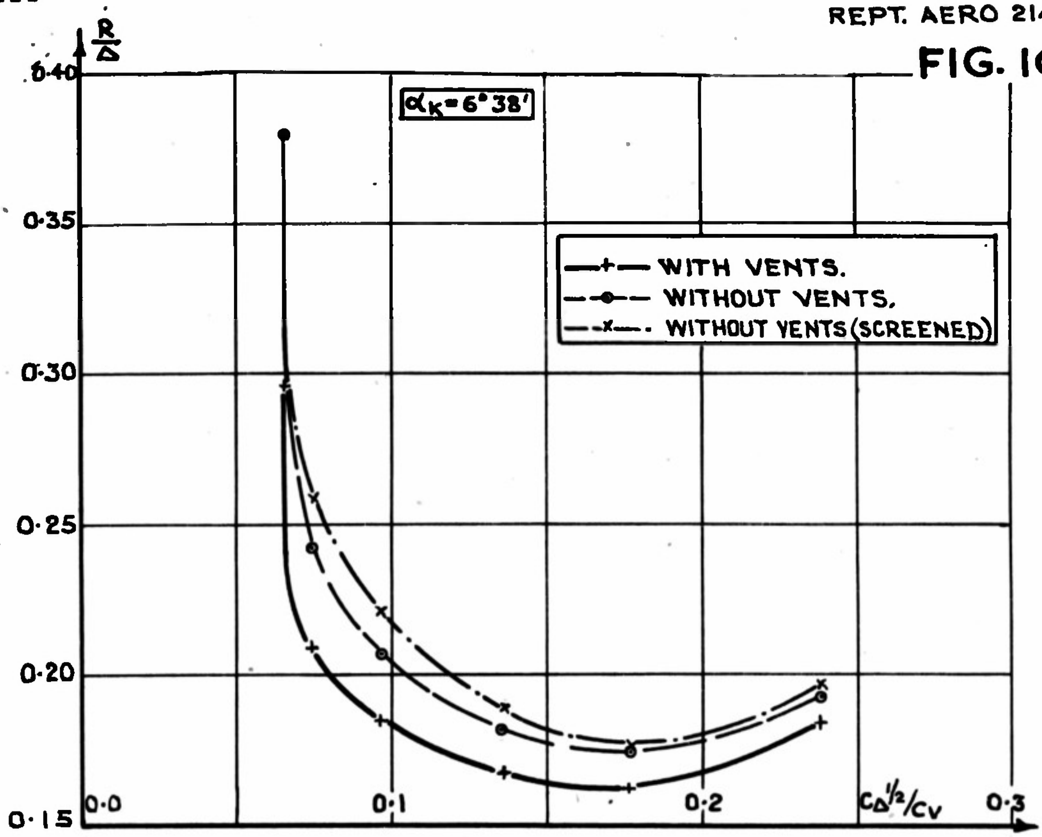
FIG.9.



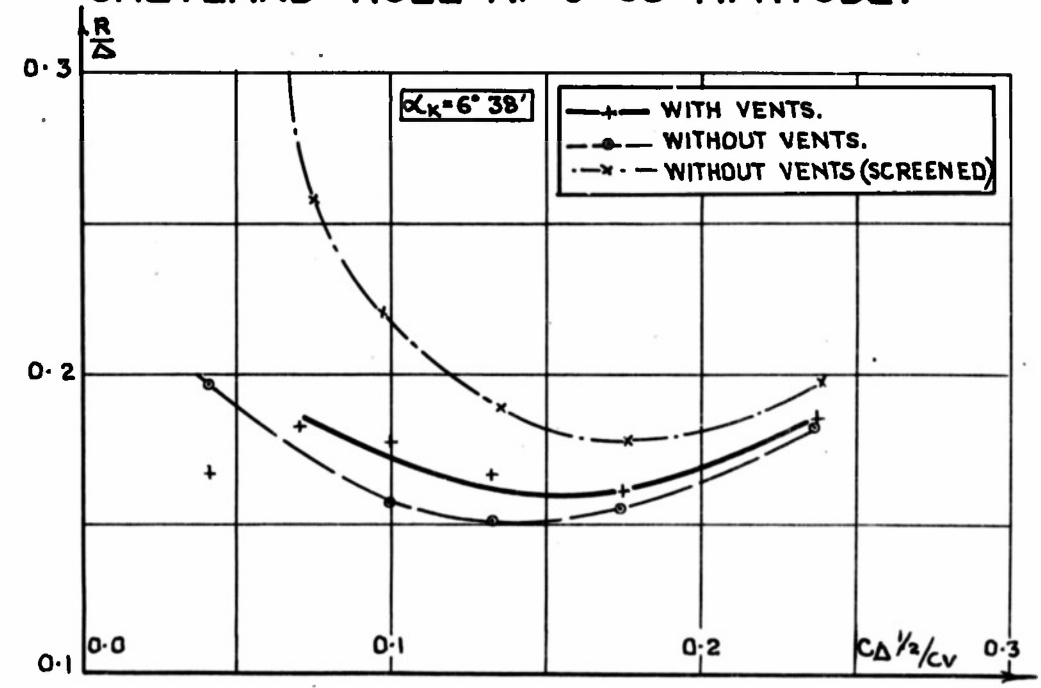
A) TOTAL RESISTANCE CHARACTERISTICS OF SHETLAND HULL AT 4° 38' ATTITUDE.

B) WATER RESISTANCE CHARACTERISTICS OF SHETLAND HULL AT 4° 38' ATTITUDE (WITH CORRECTION DUE TO AIR DRAG AND AIR LIFT FORCES.)

FIG. 10.

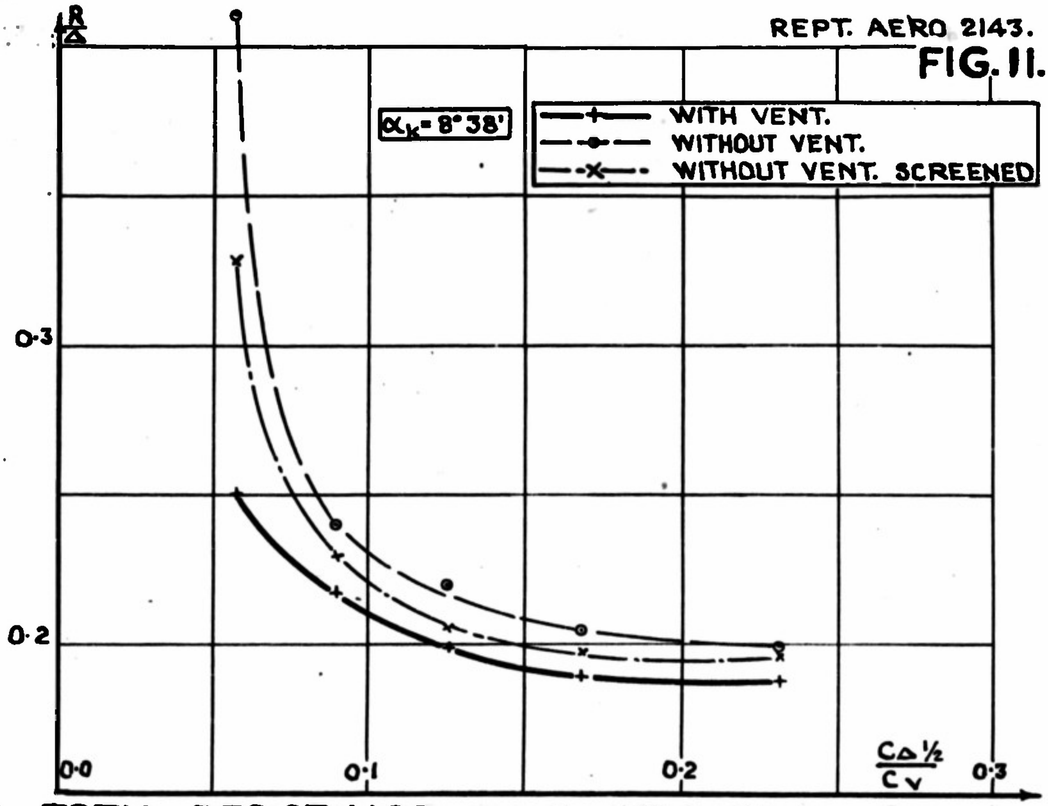


A) TOTAL RESISTANCE CHARACTERISTICS OF SHETLAND HULL AT 6° 38' ATTITUDE.

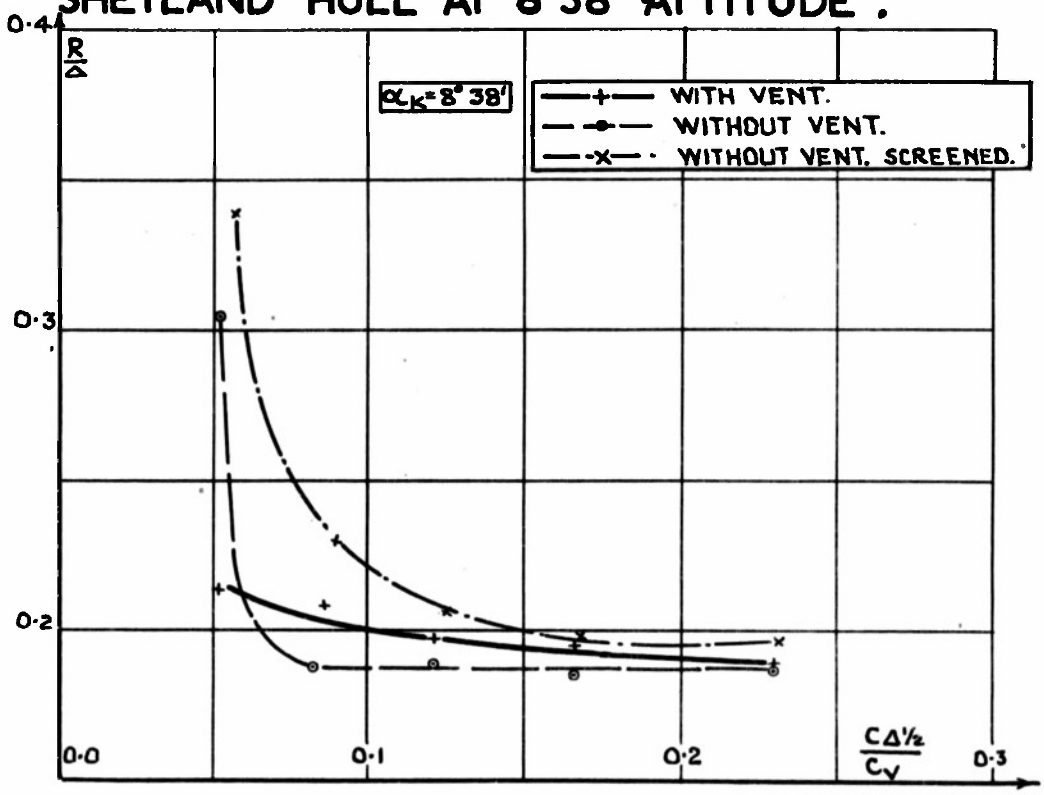


B) WATER RESISTANCE CHARACTERISTICS OF SHETLAND HULL AT 6° 38' ATTITUDE (WITH CORRECTION DUE TO AIR DRAG AND AIR LIFT FORCES.)

FIG. 11.



A) TOTAL RESISTANCE CHARACTERISTICS OF SHETLAND HULL AT 8° 38' ATTITUDE.



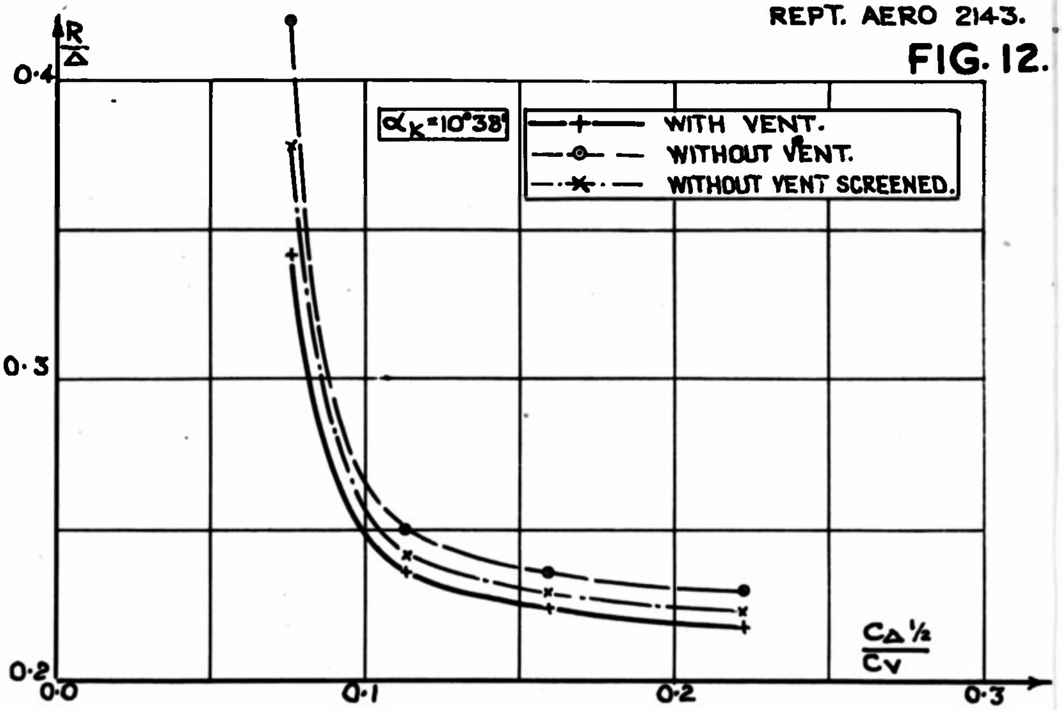
B) WATER RESISTANCE CHARACTERISTICS OF SHETLAND HULL AT 8° 38' ATTITUDE.

(WITH CORRECTION DUE TO AIR DRAG AND LIFT FORCES)

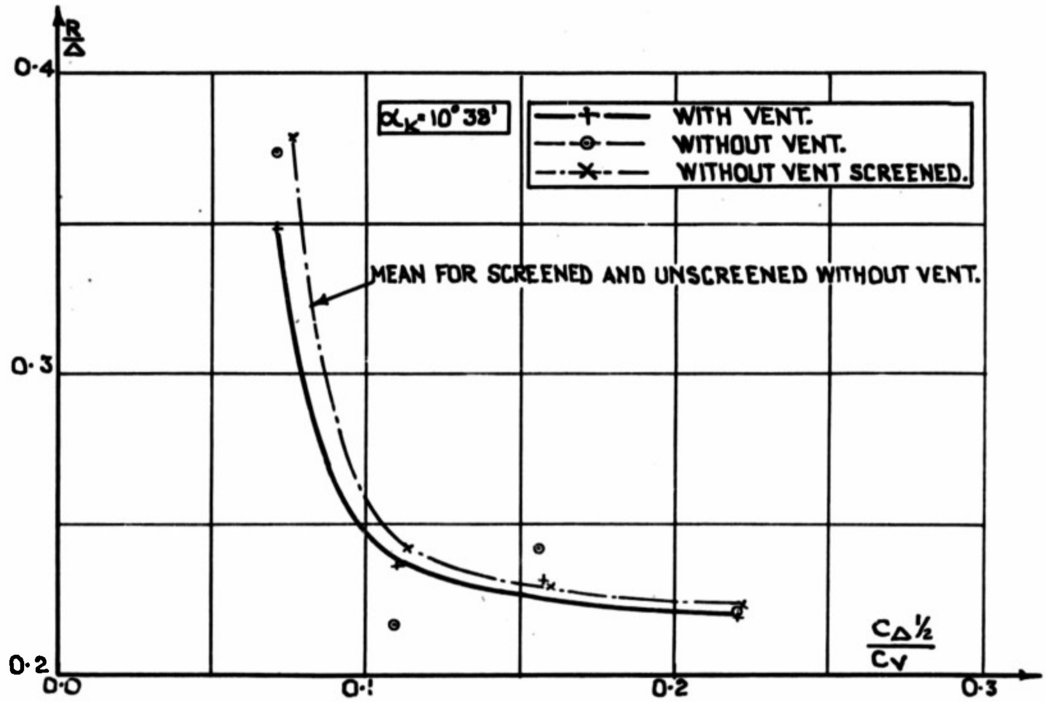
No. 19122.S.

REPT. AERO 2143.

FIG. 12.



A) TOTAL RESISTANCE CHARACTERISTICS OF SHETLAND HULL AT 10° 38′ ATTITUDE.



B) WATER RESISTANCE CHARACTERISTICS OF SHETLAND HULL AT 10° 38′ ATTITUDE (WITH CORRECTION DUE TO AIR DRAG AND LIFT FORCES).

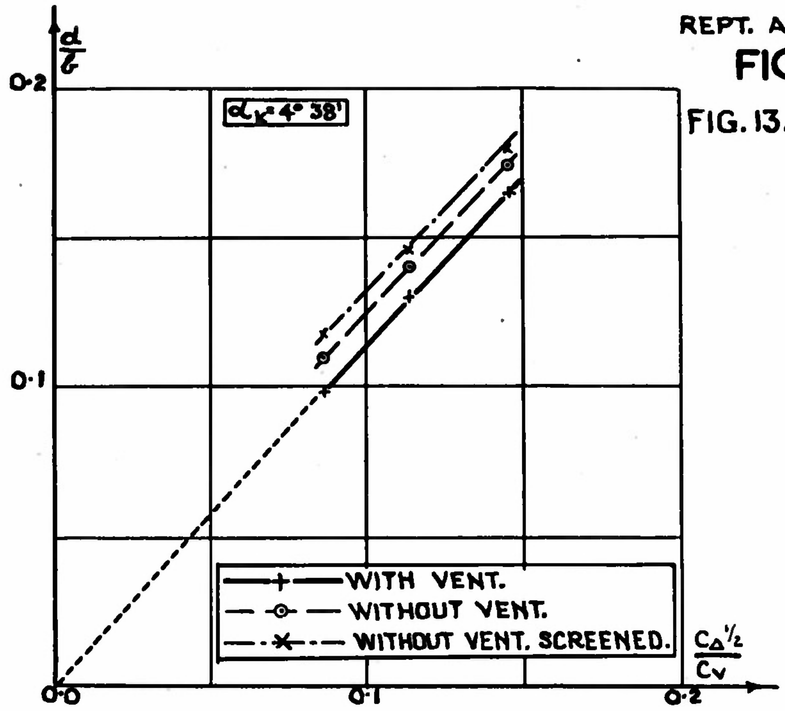


FIG. 13.

LIFT CHARACTERISTICS OF SHETLAND HULL AT 4° 38' ATTITUDE.

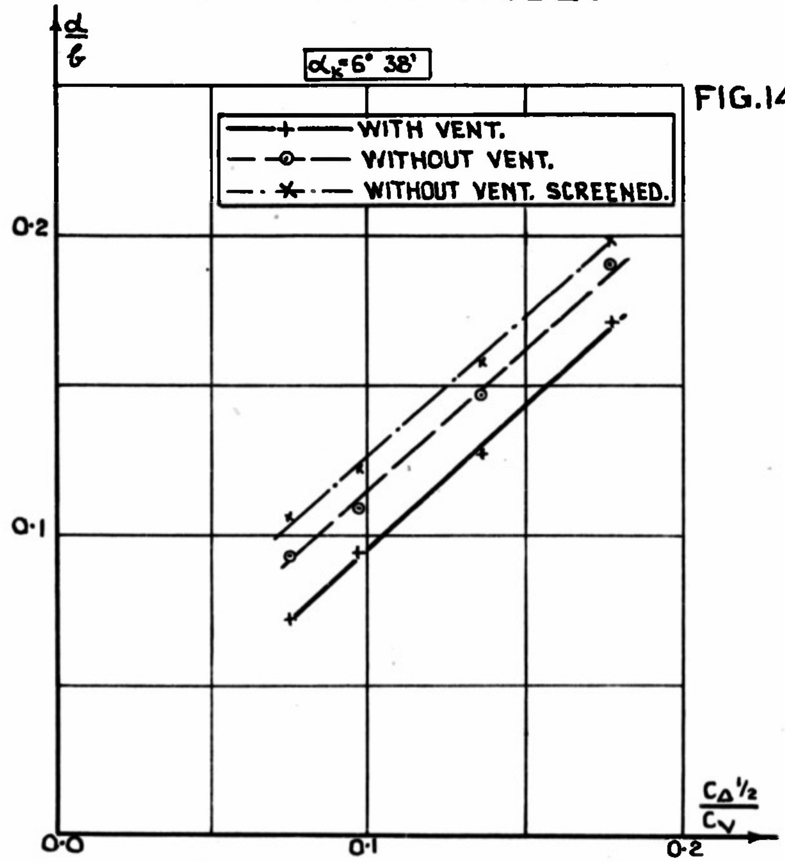
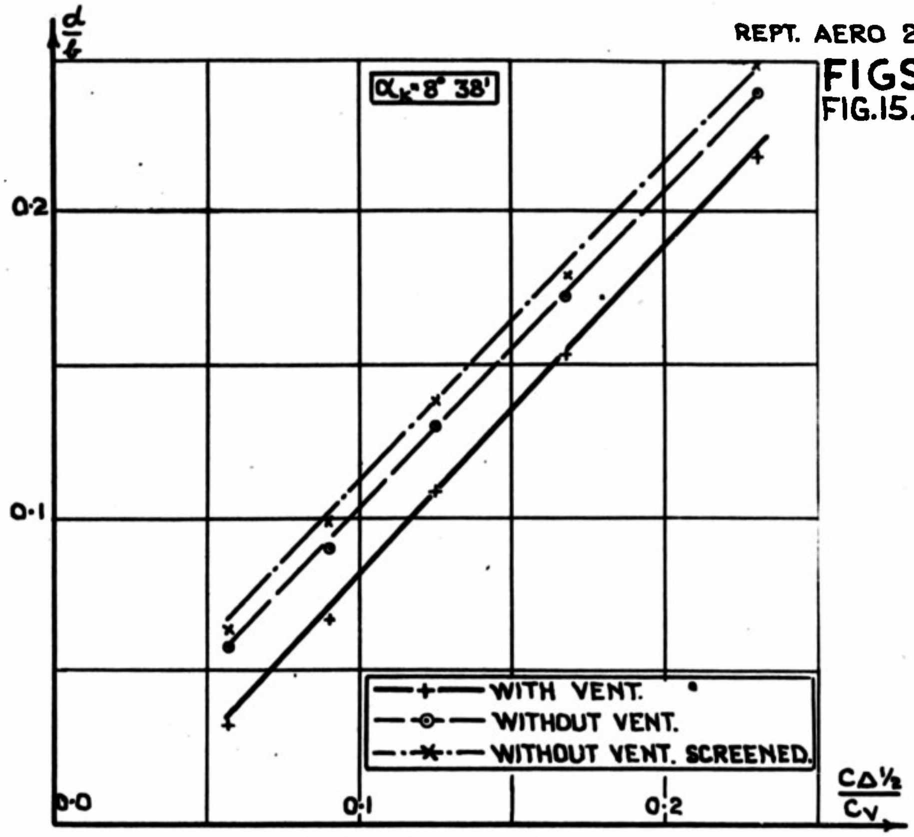


FIG. 14.

LIFT CHARACTERISTICS OF SHETLAND HULL AT 6° 38' ATTITUDE.

FIG. 15.



LIFT CHARACTERISTICS OF SHETLAND HULL AT 8° 38' ATTITUDE.

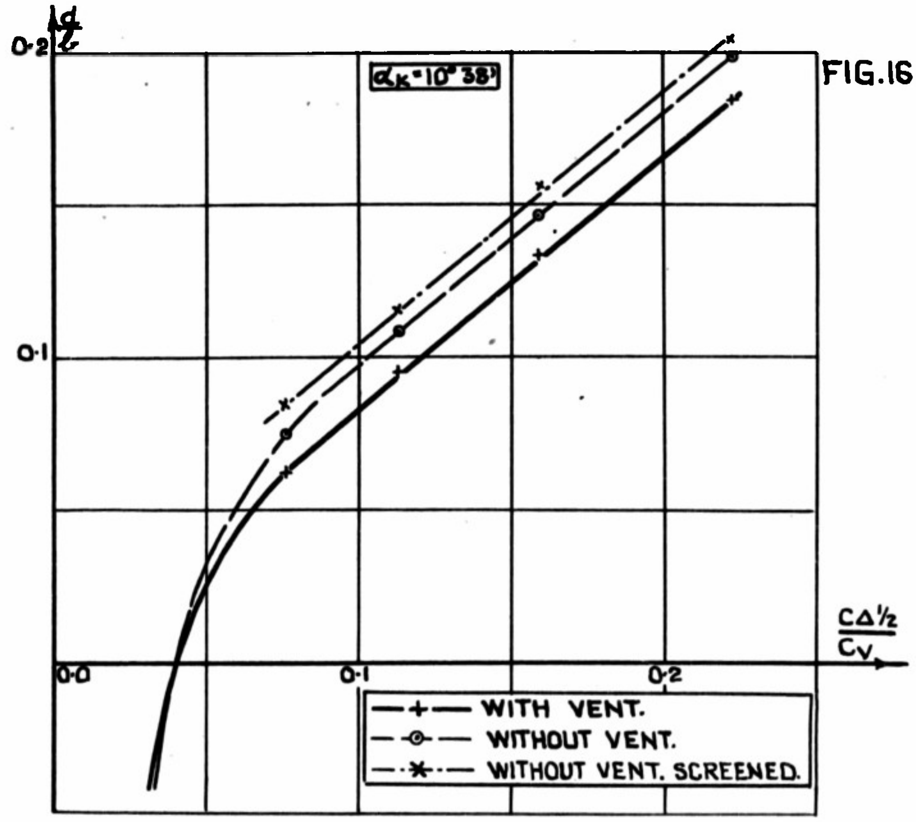


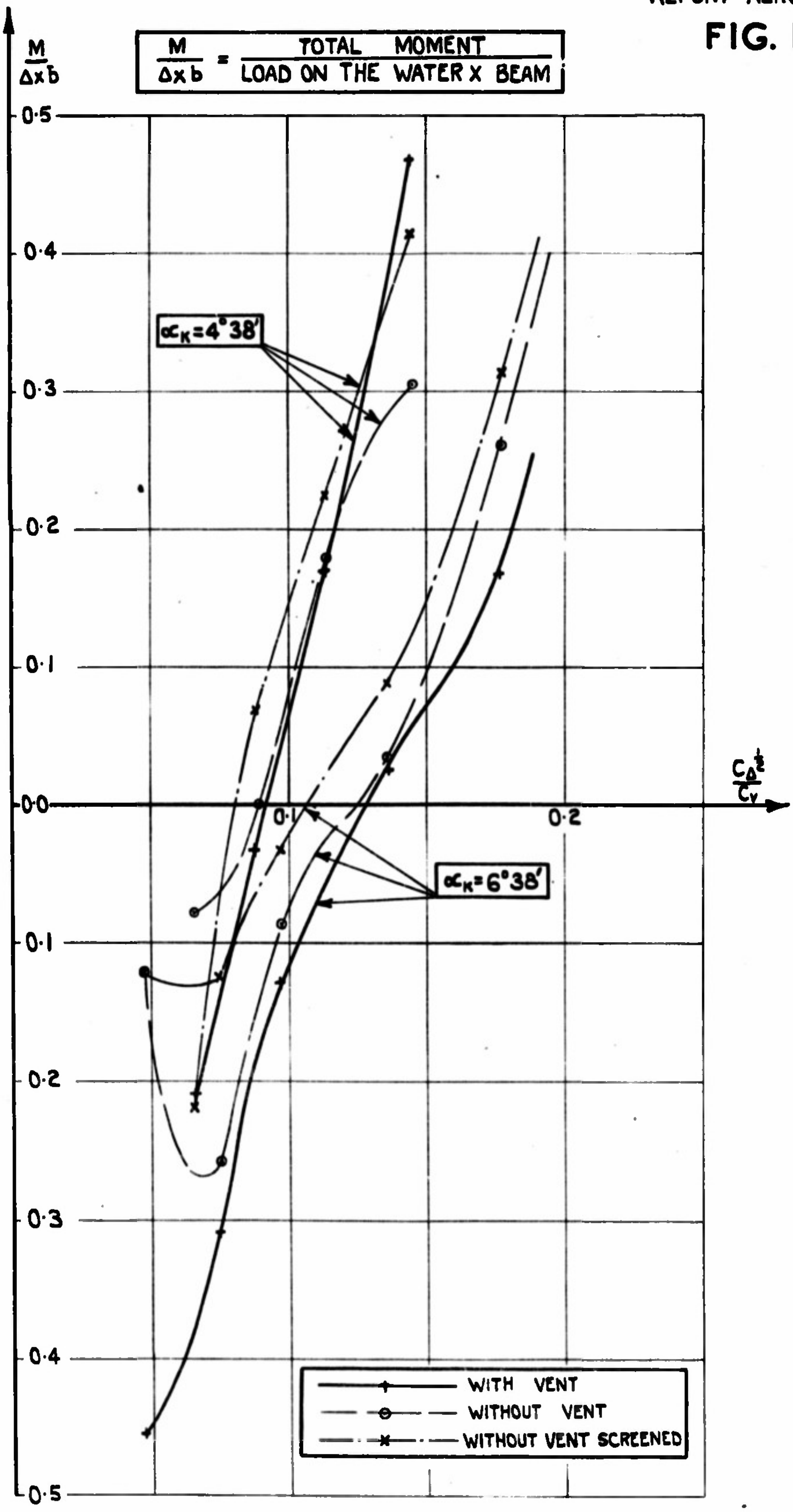
FIG. 16.

LIFT CHARACTERISTICS OF SHETLAND HULL AT 10° 38' ATTITUDE.

No. 19125. S.

REPORT AERO 2143.

FIG. 17.

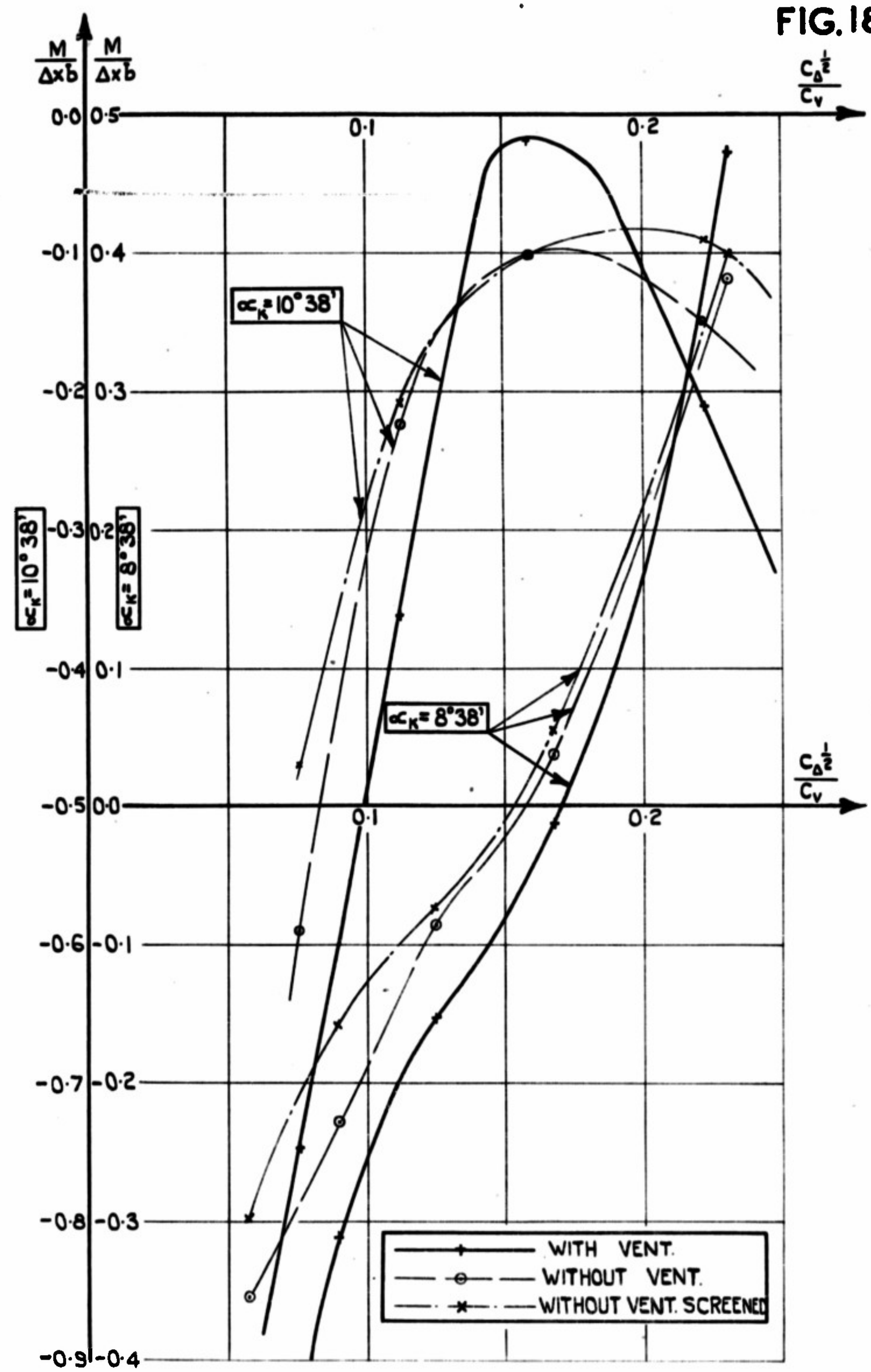


MOMENT CHARACTERISTICS OF SHETLAND HULL AT 4°38′ AND 6° 38′ ATTITUDE.

No. 19126. S.

REPORT AERO 2143

FIG. 18.



MOMENT CHARACTERISTICS OF SHETLAND HULL AT 8° 38' AND 10° 38' ATTITUDE.

No. 19127.S.

REPORT AERO 2143.

FIGS.19 & 20.

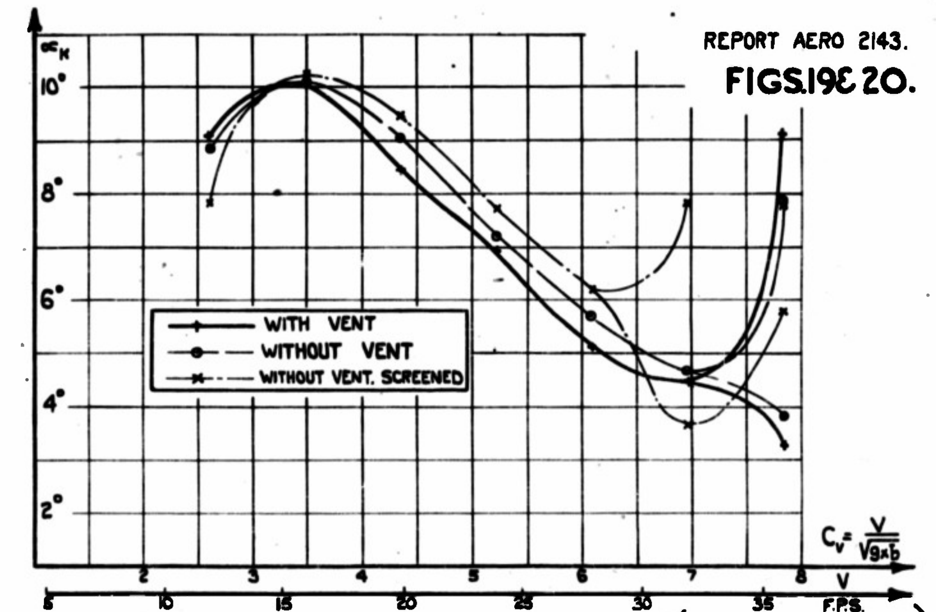


FIG.19. ATTITUDES FOR ZERO APPLIED MOMENT (No 1 CARRIAGE.)

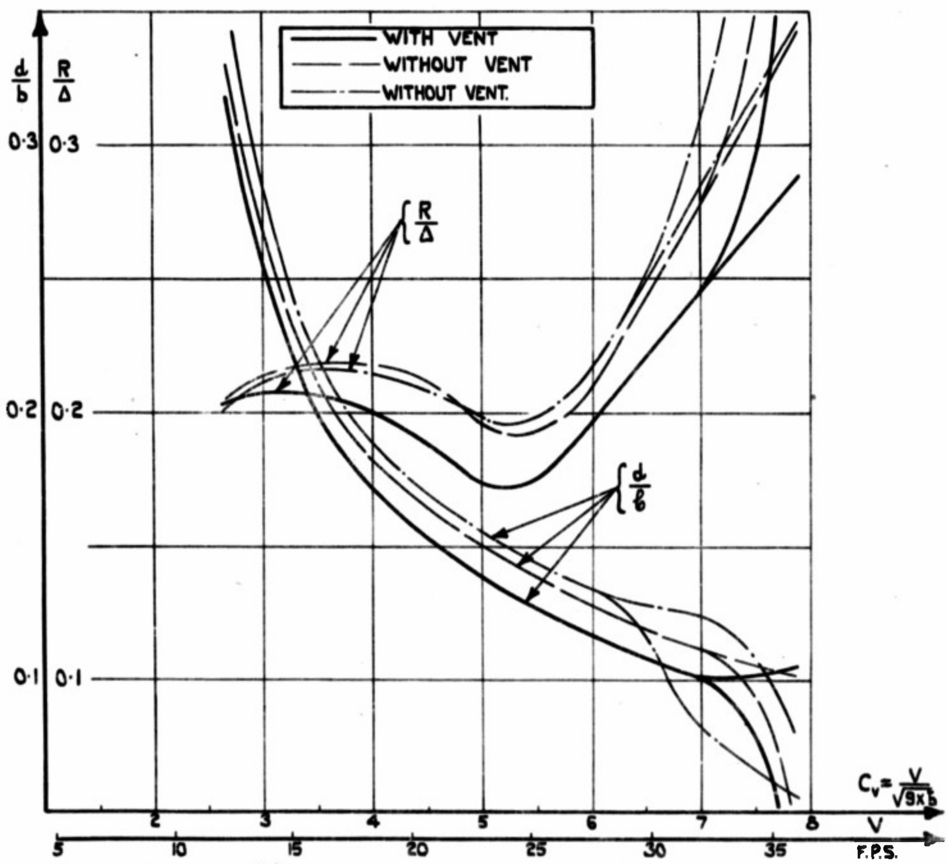
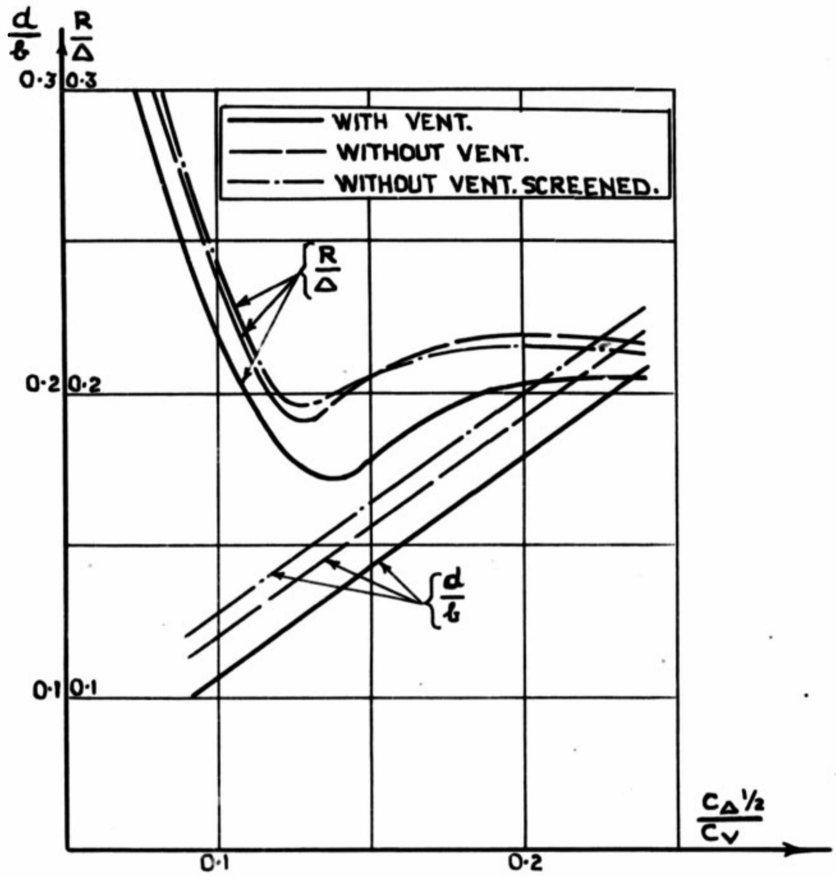


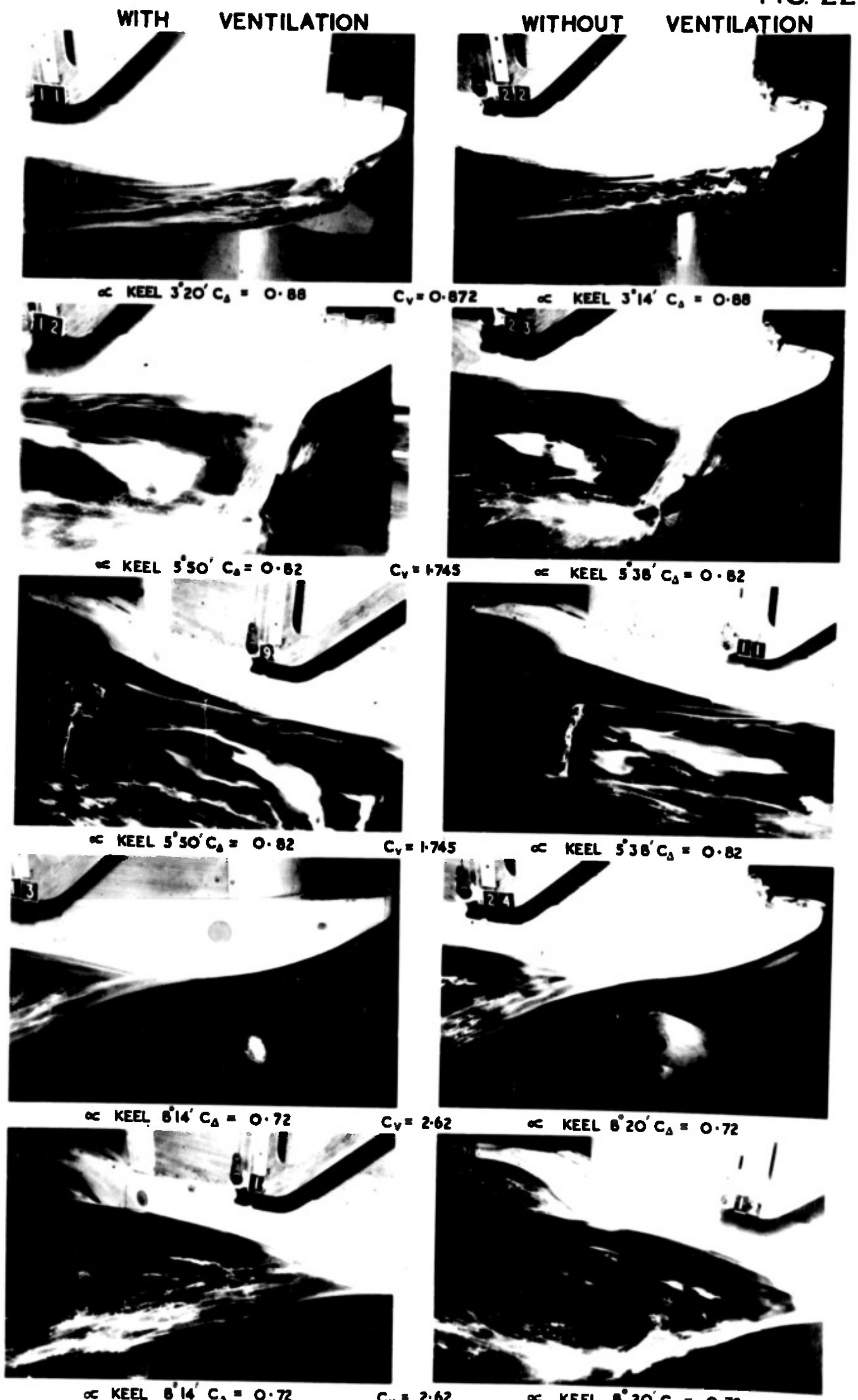
FIG.20. TOTAL RESISTANCE & LIFT CHARACTERISTICS OF SHETLAND HULL FOR TAKE OFF WITH ZERO APPLIED MOMENT (No 1 CARRIAGE.)

FIG.21.



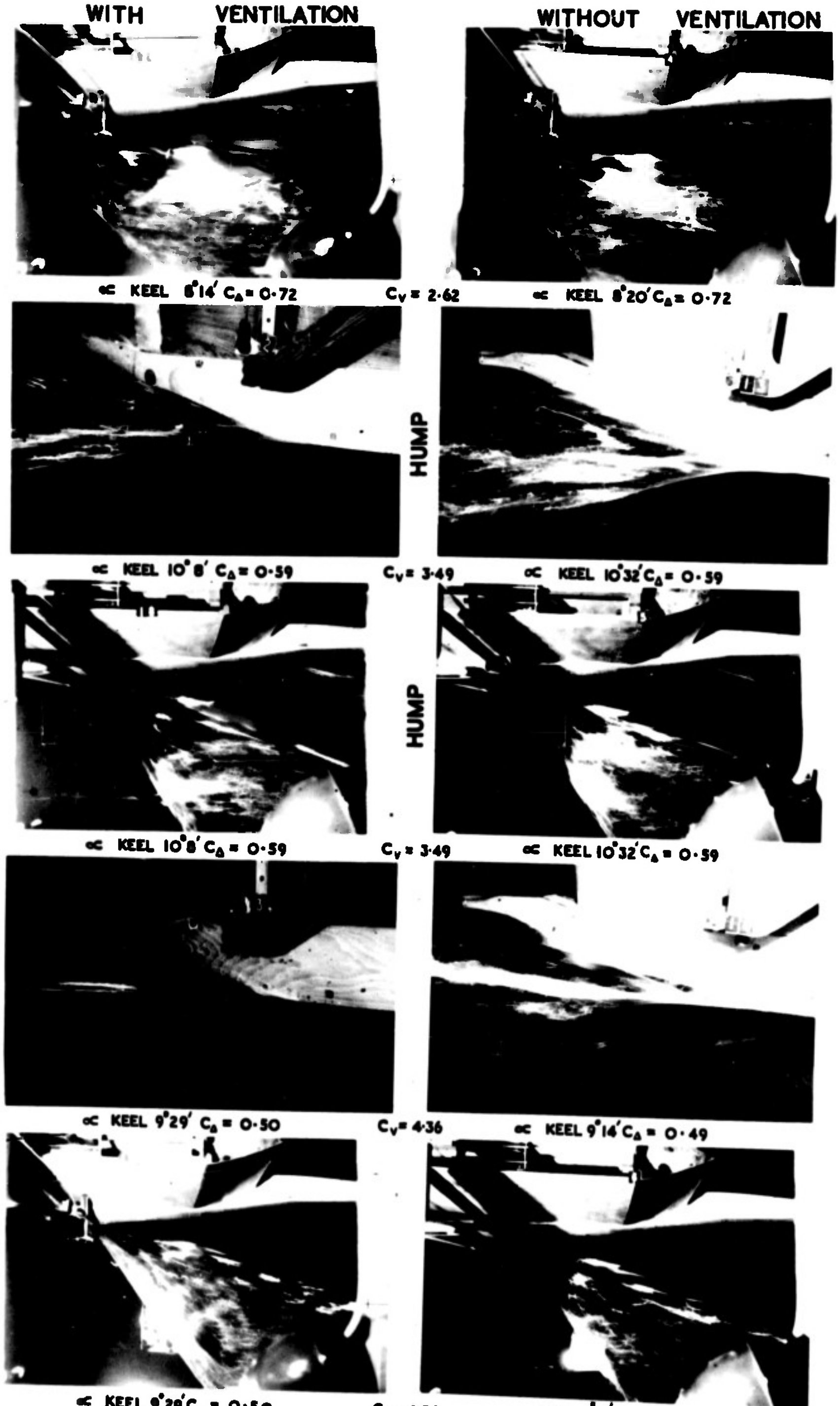
TOTAL RESISTANCE AND LIFT CHARACTERISTICS OF SHETLAND HULL FOR TAKE OFF WITH ZERO APPLIED MOMENT. (No. 1 CARRIAGE.)

FIG. 22.



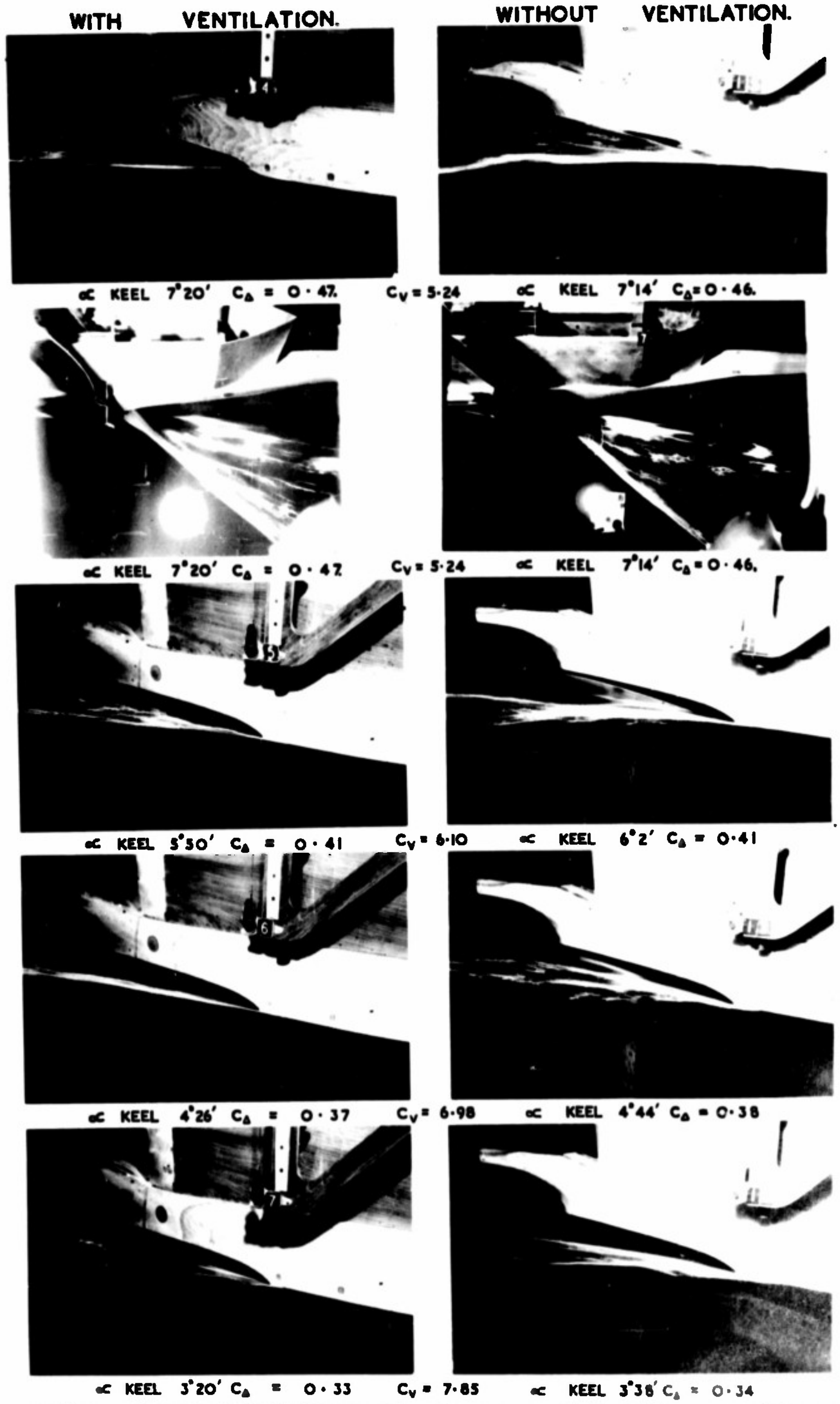
SPRAY CHARACTERISTICS ON CALM WATER WITH & WITHOUT VENTILATION FOR ZERO APPLIED MOMENT (No 2 CARRIAGE)

FIG. 22. CONT.



SPRAY CHARACTERISTICS ON CALM WATER WITH & WITHOUT VENTILATION FOR ZERO APPLIED MOMENT (No 2 CARRIAGE.)

FIG. 22. CONT.



SPRAY CHARACTERISTICS ON CALM WATER WITH & WITHOUT VENTILATION FOR ZERO APPLIED MOMENT (No 2 CARRIAGE.)

No. 19129. S.

REPORT AERO 2143.

FIGS. 23 & 24.

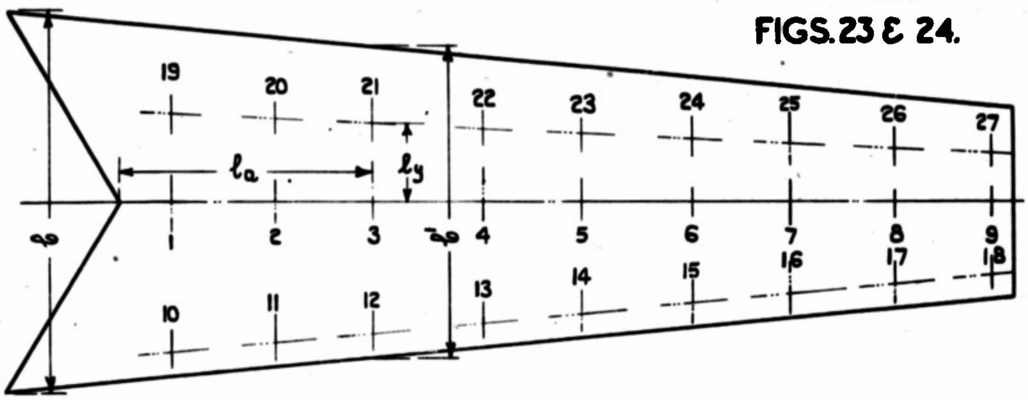


FIG. 23 LOCATION OF PRESSURE PLOTTING POINTS ON AFTERBODY BOTTOM OF "EMPIRE" BOAT.

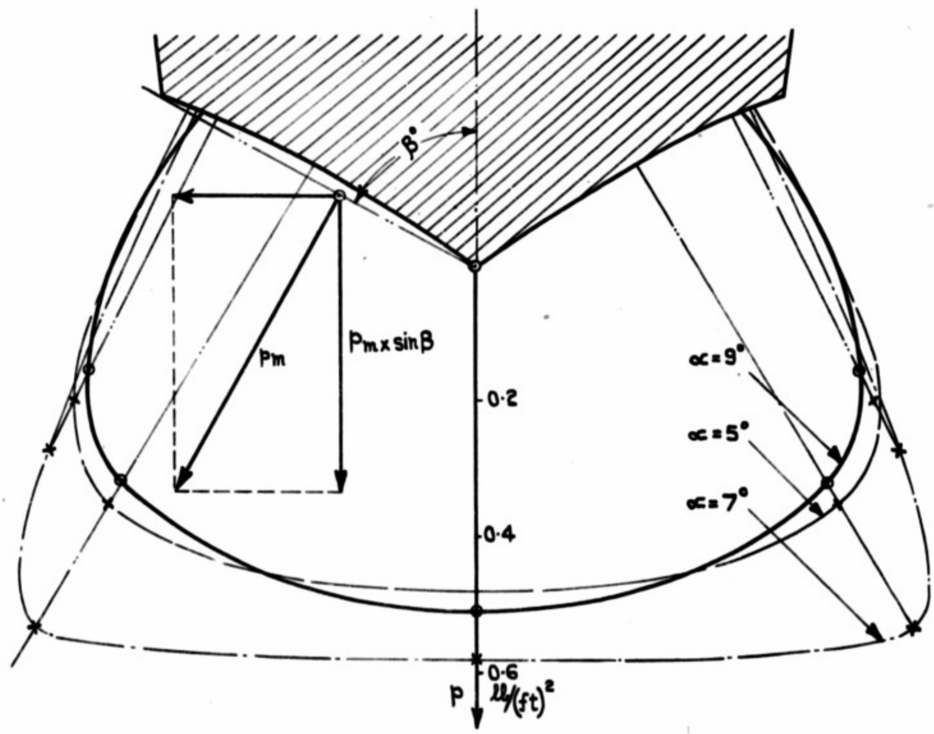
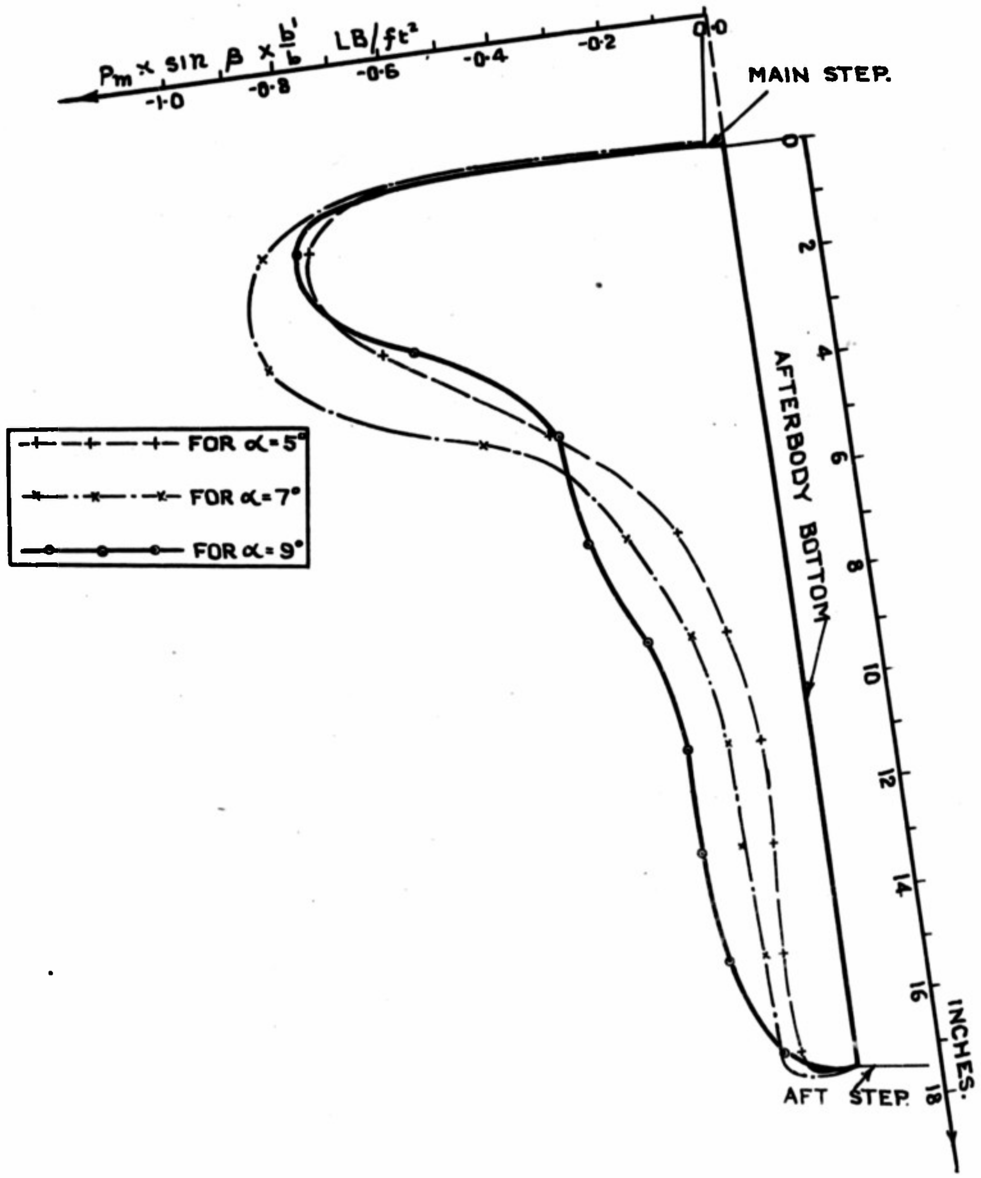


FIG. 24 TRANSVERSE PRESSURE DISTRIBUTION ON AFTERBODY BOTTOM AT STATION CORRESPONDING TO POINTS 12, 3 AND 21 AT 24 F.P.S. ON 1:16 SCALE "EMPIRE" BOAT.

No. 19130.S.

REPT. AERO 2143.

FIG. 25.



LONGITUDINAL PRESSURE DISTRIBUTION ON AFTERBODY BOTTOM OF 1:16 SCALE MODEL OF "EMPIRE" BOAT AT SPEED OF 24 F.P.S.

REEL
354
FRAME

9048

RESTRICTED

TITLE: A Preliminary Examination of Hull Afterbody Venttiation

AUTHOR(S): Tomaszewski, K. M.; Smith, A. G.; Chalmers, G. F.
ORIGINATING AGENCY: Royal Aircraft Establishment, Farnborough, Hants
PUBLISHED BY: (Same)

ATI- 9048

REVISION (None)

ORIG. AGENCY NO. AERO-2143

PUBLISHING AGENCY NO. (Same)

DATE	DOC. CLASS.	COUNTRY	LANGUAGE	PAGES	ILLUSTRATIONS
July '46	Restr.	Gt. Brit.	Eng.	49	photos, tables, graphs

ABSTRACT:

Measurements of air and water forces and air flow through hull venttlating ducts were made for a range of attitudes and drafts in the planing region wtth model under various air flow conditions. Tests indicated that for given speed and load conditions, ventilation of afterbody bottom of the Shetland hull by dynamic head pressure reduces resistance and draft of hull approximately 10% over whole planing range.

DISTRIBUTION: Copies of this report may be obtatned only by U.S. Military Organizations

DIVISION: Water-borne Aircraft (21)
SECTION: Planing (4)

ATI SHEET NO.: R-21-4-1

SUBJECT HEADINGS: Hulls - Afterbody - Ventilation (49698.72)

Air Documents Division, Intelligence Department
Air Materiel Command

AIR TECHNICAL INDEX

Wright-Patterson Air Force Base
Dayton, Ohio

RESTRICTED

RESTRICTED

ATI-	9048
REVISION	(None)
ORIG. AGENCY NO.	AERO-2143
PUBLISHING AGENCY NO.	(Same)

TITLE: A Preliminary Examination of Hull Afterbody Ventilation

AUTHOR(S): Tomaszewski, K. M.; Smith, A. G.; Chalmers, G. F.
ORIGINATING AGENCY: Royal Aircraft Establishment, Farnborough, Hants
PUBLISHED BY: (Same)

DATE	DOC. CLASS.	COUNTRY	LANGUAGE	PAGES	ILLUSTRATIONS
July '46	Restr.	Gt. Brit.	Eng.	49	photos, tables, graphs

ABSTRACT:

Measurements of air and water forces and air flow through hull ventilating ducts were made for a range of attitudes and drafts in the planing region with model under various air flow conditions. Tests indicated that for given speed and load conditions, ventilation of afterbody bottom of the Shetland hull by dynamic head pressure reduces resistance and draft of hull approximately 10% over whole planing range.

C

EO 10501 dd 5 NOV 1953

DISTRIBUTION: Copies of this report may be obtained only by U.S. Military Organizations

DIVISION: Water-borne Aircraft (21)
SECTION: Planing (4)

SUBJECT HEADINGS: Hulls - Afterbody - Ventilation (49698.72)

ATI SHEET NO.: R-21-4-1

[dstl]

Defense Technical Information Center (DTIC)
8725 John J. Kingman Road, Suit 0944
Fort Belvoir, VA 22060-6218
U.S.A.

AD#: ADA800698

Date of Search: 15 Oct 2009

Record Summary: DSIR 23/15846
Title: Examination of hull, afterbody ventilation of flying boats (RAE Rep AERO 2143)
Availability Open Document, Open Description, Normal Closure before FOI Act: 30 years
Former reference (Department): ARC 10009
Held by The National Archives, Kew

This document is now available at the National Archives, Kew, Surrey, United Kingdom.

DTIC has checked the National Archives Catalogue website (http://www.nationalarchives.gov.uk) and found the document is available and releasable to the public.

Access to UK public records is governed by statute, namely the Public Records Act, 1958, and the Public Records Act, 1967.
The document has been released under the 30 year rule.
(The vast majority of records selected for permanent preservation are made available to the public when they are 30 years old. This is commonly referred to as the 30 year rule and was established by the Public Records Act of 1967).

This document may be treated as UNLIMITED.