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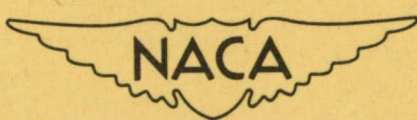
TECHNICAL NOTE 1968

FLIGHT TESTS OF THE HYDRODYNAMIC CHARACTERISTICS
OF A JAPANESE "EMILY" FLYING BOAT

By J. A. Ferguson, R. E. Seibels, Jr., and R. J. Corber

Naval Air Test Center

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SUMMARY

The results of quantitative and qualitative flight tests of the hydrodynamic characteristics of a Japanese "Emily" flying boat are presented. The tests on this airplane were conducted at the Naval Air Test Center at Patuxent River, Maryland.

The flight tests showed that the airplane had very little longitudinal hydrodynamic stability during take-off and was definitely inferior in this respect to contemporary U. S. Navy flying boats. The directional stability of the "Emily" was about average, though the airplane was responsive to small asymmetric power adjustments. The main-spray characteristics of this airplane during taxiing were superior to those of other existing flying boats.

Model spray tests undertaken at the Experimental Towing Tank in Hoboken, New Jersey, showed that the excellent spray characteristics of the "Emily" were attributable to the inboard spray strips on the forebody.

INTRODUCTION

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The Japanese "Emily" flying boat used in the tests described in this report was obtained at the Yokosuka Naval Station. It was shipped to the United States for inspection and tests under the cognizance of the Bureau of Aeronautics as part of a general evaluation of foreign aircraft.

Examination of the aircraft upon arrival disclosed that the material conditions of the engines, accessories, fuel system, and hull bottom were such that extensive reconditioning was necessary prior to tests. This reconditioning was accomplished at the Naval Air Station, Norfolk, Virginia. A more detailed examination, made possible during overhaul, indicated that the condition of the structure and equipment was such that extensive flight testing was not advisable. Consequently, the decision was made to conduct only an abbreviated test program.

At the initiation of the tests, it was intended to obtain complete information on the hydrodynamic characteristics of the "Emily." However, failure of two of the Kasei engines, signs of imminent failure of two additional engines, and lack of serviceable replacements forced termination of the hydrodynamic tests early in the program. Nevertheless, it is felt that the information obtained may be of general interest.

During the course of the tests it became apparent that the inboard spray strips on the forebody of the "Emily" were effective in reducing the height of the spray. It was not possible to run spray tests without the inboard spray strips, because of the extensive reworking of the hull bottom that would have been required to remove them and because of termination of the test program due to engine failures. Instead, it was recommended that model tests be conducted to determine the extent to which the excellent spray characteristics of the "Emily" could be attributed to the inboard spray strips. Such tests were undertaken in the Experimental Towing Tank, with the financial assistance of the Bureau of Aeronautics, and the results are presented in the appendix. Appreciation is expressed to Mr. W. C. Hugli, Jr., for the preparation of the appendix.

NOTATION

The following notation and nondimensional coefficients have been used throughout this report:

C_{Δ_0}	gross-load coefficient	$\left(\frac{\Delta_0}{wb^3}\right)$
C_{Δ}	load coefficient	$\left(\frac{\Delta}{wb^3}\right)$
C_V	speed coefficient	$\left(\frac{V}{\sqrt{gb}}\right)$
C_M	trimming-moment coefficient	$\left(\frac{M}{wb^4}\right)$
C_X	longitudinal spray coefficient	(X/b)
C_Z	vertical spray coefficient	(Z/b)
C_d	draft coefficient	(d/b)

where

Δ_0	gross load, pounds
Δ	load on water, pounds
w	specific weight of water (62.3 for Stevens Tank and 63.0 for Patuxent River), pounds per cubic foot
b	beam of hull at step, feet
d	draft at step, feet
V	speed, feet per second
S	acceleration of gravity (32.2 ft/sec ²)
M	water trimming moment, pound-feet
X	longitudinal position of main-spray point of tangency to the blister envelope, measured fore or aft of the main step, feet
Z	vertical position of main-spray point of tangency to the blister envelope, measured from the line tangent to the forebody keel at the main step and in the plane of symmetry, feet

Other symbols used are:

V_k	speed, knots
δ_f	flap deflection, degrees
δ_e	elevator deflection, degrees
τ	trim, that is, the angle between the tangent to the forebody keel and the horizontal
ϕ	heel, that is, the angle between the plane of symmetry and the vertical

All moments are measured about the center of gravity, and water trimming moments tending to raise the bow are considered positive.

DESCRIPTION OF AIRPLANE

The Japanese "Emily" type 2, model 12 aircraft, serial no. 426, is a four-engine high-wing monoplane flying boat constructed by the Kawanishi Aircraft Company. The airplane is powered by four Kasei model 22 aircraft engines, with power ratings as follows, according to the pilot's manual:

Power condition	Engine speed (rpm)	Boost (mm Hg)	Brake horsepower	Altitude (ft)
Take-off ¹	2600	450	1850	Sea level
Normal rated				
Low supercharger ratio	2500	300	1680	6,890
High supercharger ratio	2500	300	1540	18,050

¹With water injection.

During overhaul, lack of suitable replacement parts necessitated removal of the provisions for water injection. Therefore, the full take-off power rating was not available during the tests. The estimated maximum power ratings and power loadings used were:

Engine speed (rpm)	Boost (mm Hg)	Brake horsepower per engine	Gross weight (lb)	Power loading (lb/bhp)
2350	325	1525	49,900	8.2
2350	325	1525	60,400	9.9

The heavier loading is quite comparable to the unit loading (9.7 lb/bhp) which occurs at the maximum overload gross weight (71,700 lb) and the maximum rated take-off power of the engines.

This aircraft was equipped with 12.8-foot-diameter, four-blade, constant-speed, non-feathering, model H₀K₂ propellers, with pitch stops set at 27° and 47°.

A descriptive arrangement drawing of the airplane is given in figure 1. Three photographic views of the airplane may be found in figure 2. Certain of the interesting external features are shown in figure 3, and attention is invited to the very awkward means for reaching the beaching gear when the aircraft is afloat. Figure 4

shows the lines of the hull, which were prepared from measured offsets. The general particulars and specifications of the "Emily" are given in table I.

METHODS OF TEST

Longitudinal stability during take-off.— Hydrodynamic stability data for the preparation of the curves of high and low elevator limits for satisfactory take-off characteristics were obtained by making simulated take-off runs at constant power, flap, and elevator-angle settings. Porpoising oscillations of a double amplitude in excess of 2° in trim angle, or skipping at high trim angles prior to get-away, were considered unsatisfactory characteristics.

Trim-angle oscillations were determined by an NACA visual trim-angle indicator. Elevator positions were measured with a Selsyn type control-position indicator. All test runs were made in smooth water and in winds of 10 knots or less. When the wind velocity was in excess of 5 knots, identical runs were made both upwind and downwind to observe the effect of airspeed on the results.

Initial tests of hydrodynamic stability characteristics were conducted at a gross weight of 49,900 pounds. During take-off at this weight, the acceleration rate through the critical speed range was too rapid to permit ready observation of a porpoising oscillation. The take-off time was about 12 seconds.

The tests were subsequently conducted at a gross weight of 60,400 pounds. At this weight and the slightly reduced rate of acceleration associated therewith, the take-off, although only approximately 30 seconds in a calm, was sufficiently prolonged to permit adequate observation of the hydrodynamic stability characteristics. The tests were conducted over a range of center-of-gravity positions from 24 to 31 percent mean aerodynamic chord. The changes in center-of-gravity position were made by moving ballast and crew.

Spray characteristics.— The aircraft was taxied at a stabilized speed past a crash boat dead in the water, from which photographs were taken. Two views, three-quarters front and beam, were photographed during runs at each taxi speed. The tests were conducted on a calm day. Water-speed values were based upon airspeed indications and visual estimates by experienced pilots. While believed to be reasonably accurate, the precise values of the water speeds are open to some question. Zero flap deflection and neutral elevator were used throughout.

The taxi tests were conducted and photographs of the spray characteristics taken at a gross weight of 49,900 pounds with the center of gravity at 28.9 percent mean aerodynamic chord. Engine failures prevented completion of plans to conduct taxi tests for photographs of spray characteristics at the heavier test weight.

RESULTS OF TESTS

Longitudinal stability during take-off.— The original test directive called for determination of the take-off characteristics with the flaps at 20° . A study of the pilot's manual indicated the advisability of making a preliminary check of the hydrodynamic characteristics at lesser flap deflections. During the course of this investigation, it was determined that an increase in take-off flap deflection from 7° to 12° resulted in a marked decrease of hydrodynamic stability and a deterioration of longitudinal control. Porpoising during take-off at the higher flap deflection and most favorable center-of-gravity position was in excess of 2° double amplitude with elevator settings outside the range of 12° to 15° up, and the longitudinal control was inadequate for satisfactory damping of the oscillation. For this reason, the flap deflection was limited to 7° during take-off stability tests, and this is the same flap angle recommended in the pilot's manual.

The results of the tests are presented graphically in figure 5, wherein the high and low limiting elevator angles are shown as a function of the center-of-gravity position. This type of plot was originally suggested by the presentation used for some unpublished NACA model tests of the JRM-1 flying boat. From its use with this and other flying boats, the plot has been developed into its present form. The plot and type of test represent a continuing development of the methods used by Stout (reference 1) for studying the longitudinal stability of full-scale and model flying boats.

Spray characteristics.— Photographs of the results of the spray tests at a gross weight of 49,900 pounds are presented as figures 6, 7, 8, 9, 10, and 11. It will be seen that there is a fairly large change in the character of the main spray when the speed is increased from 20 to 25 knots. This change is probably due to the fact that above about 20 knots the inboard spray strips come clear of the water and no longer can control the main spray. Attention is particularly invited to figure 11 which clearly shows the effectiveness of the inboard spray strips in suppressing the main spray.

In figure 12(a) will be seen the results of an analysis of all the available photographs of the main spray taken when the aircraft was taxiing. This analysis was done in the same manner as that developed for model tests in reference 2. A method is given in reference 3 for collapsing the results of model main-spray tests made at different loads to a single curve. This method depends in part on knowing the load on the water at the given speed. It is difficult to estimate the load on the water that occurred at different speeds during the taxi tests of the "Emily." However, at any given actual speed on the water, the total lift would remain approximately constant regardless of the gross weight. Hence, it would appear permissible to substitute C_{Δ_0} for C_{Δ} in the main-spray relations developed in reference 3. This is what has been done in figure 12(b). The curve in figure 12(b) appears to be quite suitable for estimating the main-spray characteristics of the "Emily" at any gross weight other than that at which the tests were made.

The bow-spray characteristics of the "Emily" were determined by taxiing through the wake of a crash boat. No bow spray reached the pilot's windshield when taxiing through waves 2 to $2\frac{1}{2}$ feet high at a speed of 10 to 15 knots.

The principal hydrodynamic characteristics determined in the flight tests of the "Emily" at a gross weight of 60,000 pounds are summarized in figure 13. The spray envelope shown therein was interpolated from figure 12(b).

Directional stability.— Observations were made concerning the directional stability and the adequacy of directional control during take-off. The airplane appeared to be directionally unstable during the take-off run, particularly at the higher trim angles in the vicinity of the hump, and there was a tendency to turn to the left. However, the aircraft was very responsive to asymmetric power and angle of heel. The take-off course could be satisfactorily maintained by a slight reduction of power on the starboard outer engine, or by banking to the right and dragging the wing-tip float if necessary. The asymmetric power adjustments were sufficiently small so that take-off performance was not appreciably affected.

Lateral control was possible early in the take-off run at an airspeed estimated to be between 20 and 25 knots. On the other hand, the rudder control was inadequate during take-off prior to the hump speed.

Maneuvering on the water could be satisfactorily accomplished in winds having a velocity up to 20 knots. The buoyancy of the wing-tip

floats was adequate in crosswind taxiing at both loading conditions tested. No undesirable features of the wing-tip floats were noted during the taxi tests.

DISCUSSION

The longitudinal stability characteristics of the "Emily" during take-off are very unsatisfactory. There appear to be at least two major factors which make the porpoising behavior so undesirable. As previously mentioned, the stability during take-off is very sensitive to the flap angle. The longitudinal controllability deteriorates rapidly with increasing flap angle. A critical condition is approached at only 12° flap deflection. The usual flap arrangement is, therefore, possibly the most obvious factor contributing to the unfavorable porpoising characteristics.

When the flaps are deflected to 12° during take-off, about 12° of up-elevator represent the minimum that can be used to avoid large-amplitude, low-angle porpoising at the aft center-of-gravity positions. As may be seen in figure 5, about 7° of up-elevator are required for the same conditions during take-off at a 7° flap deflection. By making a linear extrapolation, it may be estimated with reasonable assurance that neutral elevator would be similarly just acceptable for a zero-flap take-off. From this, it is inferred that the location of the main step relative to the rest of the airplane would have been quite satisfactory, provided that some other type of flap which did not introduce large moments when deflected had been used. On the other hand, presumably the main step could have been located to allow reasonable elevator angles during take-off with any one predetermined deflection of the complicated "Emily" flap. However, it actually appears that the location selected for the main step would be satisfactory, with regard to the low-angle porpoising characteristics, only in combination with zero flap deflection. The fact that the longitudinal stability during take-off does become increasingly critical with increasing flap angle may be taken, therefore, as a very strong indication that the flaps are introducing excessive nose-down pitching moments. Wind-tunnel tests on a somewhat similar flap arrangement (reference 4) show large pitching moments even at relatively small deflections and thus tend to confirm one of the indications of the "Emily" flight tests.

On the basis of the discussion in the preceding paragraphs, it seems reasonably clear that the forebody cannot be directly blamed for the stability difficulties encountered with the "Emily." The design of the afterbody, however, is considered to be the other major factor responsible for the very unfavorable porpoising characteristics.

A study made by Parkinson of American and British flying boats (reference 5) indicates that the afterbody length is related to the initial load coefficient. The results of this study show that any flying boat having as high an initial load coefficient as the "Emily" should have an afterbody length-beam ratio of about 4.0, whereas it actually has an afterbody length-beam ratio of only 2.06. The afterbody of the "Emily" is very short, therefore, in comparison with those usually incorporated in American or British flying boats.

The trim angles over the entire speed range up to the hump are ordinarily inclined to be too high to permit good spray or resistance characteristics for hulls with short afterbodies. The simplest way to overcome the high trim angles found on a hull with a short afterbody is to reduce the afterbody angle. Further, a short afterbody with a low sternpost angle introduces no particularly undesirable effects at speeds up to the hump. This, then, may be the explanation of why the sternpost angle of the "Emily" is only 5.5° .

At planing speeds, however, very harmful effects can be introduced into the porpoising characteristics of a hull by a short afterbody at a low sternpost angle. Unpublished model tests of such a configuration show that the upper trim limit of stability may actually intersect the lower trim limit. This effect can result in wide ranges of speed in which there is no trim region of stability. The flight tests of the "Emily" did not show quite so critical a condition, and this is attributed primarily to the rapid take-off. It is believed that there was insufficient time for the inherent instability to manifest itself fully, and that the critical porpoising characteristics may be partially attributed to the short afterbody with the low sternpost angle.

Although the power loading of the "Emily," even at maximum patrol overload gross weight, is less than that of various U. S. Naval flying boats at normal design gross weight, its hydrodynamic stability is considered to be definitely inferior. This comparison is based upon a qualitative evaluation by pilots who have flown the "Emily" and such types of U. S. Naval flying boats as the PB2Y-5, the PBM-5, and the JRM-1. The latter flying boats have power loadings ranging from 13 to 15 pounds per horsepower at the design gross weight. It is felt that if the available power of the "Emily" were reduced to make a similar high power loading, the airplane would be completely unmanageable because of violence of the porpoising.

The spray characteristics of the "Emily" are as good as its stability characteristics are bad. Since an envelope of the spray was determined for this airplane, it is possible to make a quantitative comparison with other flying boats for which information is available in reference 6.

The comparison of the heights of the heavy main-spray blisters given in reference 6 is based on the reduction of the full-scale data by the relations developed in reference 3 for handling model main-spray data in the displacement range. Because the longitudinal location of the propeller plane is at a value of C_X/C_{Δ_0} of about 1.50 for most flying boats, it is permissible to make direct comparisons between the values of C_Z/C_{Δ_0} determined for individual flying boats. In the case of the "Emily," the value of C_X/C_{Δ_0} at the propeller plane is about 1.25 at a gross weight of 60,000 pounds. Since the spray envelope of the "Emily" is given in figure 12(b), spray comparisons can be made at the particular value of C_X/C_{Δ_0} of the propeller plane of any of the other individual flying boats. However, for the sake of expediency and in order to make a reasonably fair comparison with other flying boats, C_Z/C_{Δ_0} for the "Emily" will be taken at $C_X/C_{\Delta_0} = 1.50$. Figure 12(b) shows that this results in $C_Z/C_{\Delta_0} = 0.66$.

Study of table I in reference 6 reveals that the lowest full-scale value of C_Z/C_{Δ_0} previously determined is 0.73 in the case of the Martin PBM-1 flying boat. This is 10 percent higher than the value of 0.66 for the "Emily." This comparison does not take into account the fact that there is a difference in size between the two flying boats or the fact that other flying boats having a different forebody length-beam ratio might have relatively better spray-height characteristics.

Figure 4 of reference 6 contains the available full-scale data on the spray height of various flying boats, adjusted to a common 10-foot beam, as a function of the forebody length-beam ratio. Figure 3 of that reference indicates that 0.02 should be added to the value of C_Z/C_{Δ_0} of the "Emily" to put it on the standard 10-foot beam for purposes of comparison. The adjusted value of C_Z/C_{Δ_0} at $C_X/C_{\Delta_0} = 1.50$ therefore becomes 0.68. The forebody length-beam ratio of the "Emily" is 3.69, and the adjusted value of C_Z/C_{Δ_0} may be compared directly with the values for the other flying boats shown in figure 4 of reference 6. On this basis the "Emily" still has the lowest value of C_Z/C_{Δ_0} yet determined. Also, the value of C_Z/C_{Δ_0} of the "Emily" falls farther below the mean-spray-height curve at its forebody length-beam ratio than the value of C_Z/C_{Δ_0} of any other American, British, or German flying boat at their own forebody length-beam ratios. This means that, regardless

of the forebody length-beam ratio, the "Emily" has outstandingly low spray-height characteristics. Observations made during the taxi tests attributed the truly excellent spray control to the inboard spray strips on the forebody and these observations are confirmed by the model spray tests reported in the appendix.

CONCLUSIONS

The following conclusions are drawn from the results of flight tests conducted on the Japanese "Emily" flying boat:

1. The longitudinal hydrodynamic stability characteristics during take-off are inferior to those of comparable U. S. Navy flying boats. The inferiority is attributed to the effect of (a) the type of wing flap used and (b) the afterbody of the hull.

2. The main-spray characteristics during taxiing are superior to those of American, British, and German flying boats for which quantitative information is available. The superiority is attributed primarily to the effect of the inboard spray strips on the forebody.

3. The directional stability characteristics during take-off are about average compared with those of contemporary U. S. Navy flying boats.

Naval Air Test Center
Patuxent River, Md., June 10, 1947

APPENDIX

MODEL SPRAY TESTS ON THE EFFECTIVENESS OF THE INBOARD SPRAY STRIPS
ON THE JAPANESE "EMILY" FLYING BOAT

By W. C. Hugli, Jr.

Flight tests of a captured Japanese "Emily" flying boat indicated that it had exceptionally good spray characteristics. The Naval Air Test Center recommended that suitable tank tests be undertaken to determine whether the excellent spray characteristics were attributable to the inboard spray strips used on the forebody of the "Emily." Simple spray tests of a $\frac{1}{21}$ -scale model of the "Emily" were therefore undertaken at the Experimental Towing Tank. The lines of the $\frac{1}{21}$ -scale model shown in figure 4 (ETT model no. 1019) were prepared from offsets of the hull bottom measured by the NATC.

For the sake of simplicity, the tests were limited to two constant loads which did not vary with speed. Over the entire speed range investigated, and at both loads, the model was tested in both the upright and heeled condition with and without the inboard spray strips on the forebody. The conditions of the tests were as follows:

Loads, pounds	48,740 and 58,490
C_{Δ}	1.00 and 1.20
Speed range, knots	12.8 to 31.9
C_V	1.27 to 3.14

Most of the tests were made with a nose-down applied moment corresponding to the thrust generated by 1525 brake horsepower per engine. The thrust moment used was $C_M = 0.17$ in the standard coefficient form. A few tests were run without the thrust moment.

The results of the spray tests are shown in the form of a nondimensional spray envelope in figure 14. It is quite similar to figure 12(b) showing the results of the full-scale tests, except that the load on the water at each speed is used instead of the initial gross weight. The model results are in generally good agreement with the full-scale tests. A detailed comparison, however, would require knowledge of the full-scale water-borne loads at the various speeds and is outside of the scope of this paper.

As may be seen from figure 14, the inboard spray strips used on the "Emily" constitute a powerful means for lowering the spray height. In the vicinity of the propeller plane (roughly $C_X/C_\Delta = 1.4$), the reduction in spray height attributable to the inboard spray strips is about 30 percent. In the heeled condition, the spray height is somewhat higher with respect to the airplane, but the inboard spray strips remain equally effective in suppressing the spray. Figure 15 shows photographs of the model with and without the inboard spray strips, taken at about the speed where the inboard spray strips have their greatest influence. The speed at which the inboard spray strips cease to be effective in controlling the spray depends upon the waterborne load. At a gross weight of 48,740 pounds the inboard spray strips become clear of the water at a speed of 29 knots ($C_V = 2.85$), while at a gross weight of 58,490 pounds the inboard spray strips become clear of the water at a speed of 32 knots ($C_V = 3.15$).

The trim angles are very nearly the same for the hull with and without the inboard spray strips. When the crest of the spray is at the propeller plane, removing the inboard spray strips decreases the trim angle only $1/2^\circ$. The few tests made without the thrust moment gave almost the identical spray heights obtained when the thrust moment was present. The small difference in hull trim angles found with and without the inboard spray strips is not believed to have been even partially responsible for the large difference in spray heights.

In comparison with conventional hulls of about the same forebody length-beam ratio, the "Emily" hull without inboard spray strips has slightly lower spray at low speeds and slightly higher spray at the higher speeds. The "Emily" and the British Short "Shetland" have somewhat similar forebodies, and a comparison of the results of spray tests made at the Experimental Towing Tank on both hulls shows that the "Emily" without inboard spray strips and the "Shetland" have approximately the same spray heights. On the other hand, when the inboard spray strips are installed on the "Emily," its spray height at the propeller plane is 35 percent lower than that of the "Shetland."

When towing a model fixed in yaw through the prehump speed region of violent directional instability, the experience has been that the model and the apparatus will frequently go through noticeable lateral oscillations. In the case of the "Emily," these lateral oscillations did not occur. It may be inferred, then, that the "Emily" is probably free from any violent directional instability. This agrees with the flight experience that, although the aircraft appeared to be directionally unstable, it was very responsive to slight asymmetric power. This apparent lack of violent directional instability may be due to the afterbody skeg and the general concavity of the afterbody plan form.

Inboard spray strips, such as are used on the "Emily," appear to be a powerful method for decreasing the spray height of a hull which has bad spray characteristics. Inboard spray strips might be worth considering for any existing hull which has undesirable spray characteristics.

Experimental Towing Tank
Stevens Institute of Technology
Hoboken, N. J., November 7, 1947

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TABLE I.- GENERAL DATA ON JAPANESE "EMILY" FLYING BOAT

General:	
Normal patrol gross weight, lb	54,022
Maximum overload gross weight, lb	71,660
Total take-off horsepower (four engines)	7400
Wing loading, normal patrol, lb/sq ft	31.4
Wing loading, maximum overload, lb/sq ft	41.6
Take-off power loading, normal patrol, lb/hp	7.30
Take-off power loading, maximum overload, lb/hp	9.68
Wing:	
Area, sq ft	1721
Span, ft	124.7
Root chord, ft	20.75
Tip chord, ft	7.75
Mean aerodynamic chord (M.A.C.), ft	14.27
Flaps, slotted with split trailing edge	
Semispan, ft	34.4
Chord (slotted), percent wing chord	24
Chord (split), percent wing chord	8
Take-off deflection (main flap), deg	7
Take-off deflection (auxiliary flap), deg approx.	21
Landing deflection (main flap), deg	25
Landing deflection (auxiliary flap), deg	52
Horizontal tail surfaces:	
Area, sq ft	245
Span, ft	33.0
Mean aerodynamic chord, ft	7.9
Tail length (measured between the 25-percent point of the M.A.C. of the wing and of the tail, ft)	48.0
Elevator area/horizontal tail area	0.41
Propellers:	
Number	4
Number of blades	4
Diameter, ft	12.80
Propeller clearance at rest on low side at normal patrol gross weight	
Inboard, ft	5.51
Outboard, ft	5.65
Distance from bottom of propeller arc to tangent to forebody keel at main step, inboard, ft	9.65
Hull:	
Over-all length, ft	92.30
Length of forebody (chines at bow to step), ft	33.88
Length of afterbody, ft	18.92
Beam at step, ft	9.18
Maximum beam, ft	9.95
Height at step, ft	16.41
Type of step	Transverse
Depth of step at keel, ft	0.35
Depth of step at chine, ft	0.40
Angle of forebody dead rise at step	
Excluding chine flare	25° 38'
Including chine flare	17° 32'
Angle of afterbody dead rise	27° 11'
Angle of afterbody keel to forebody keel, deg	3.5
Sternpost angle, deg	5.5
Center-of-gravity location at 27.5 percent M.A.C.	
Forward of step, ft	2.09
Above tangent to forebody keel at main step, ft	12.07
Miscellaneous:	
Average normal take-off speed, knots	75.6
Average normal landing speed (with flap), knots	70.5
Angle of heel to submerge tip float, normal patrol gross weight, deg	9

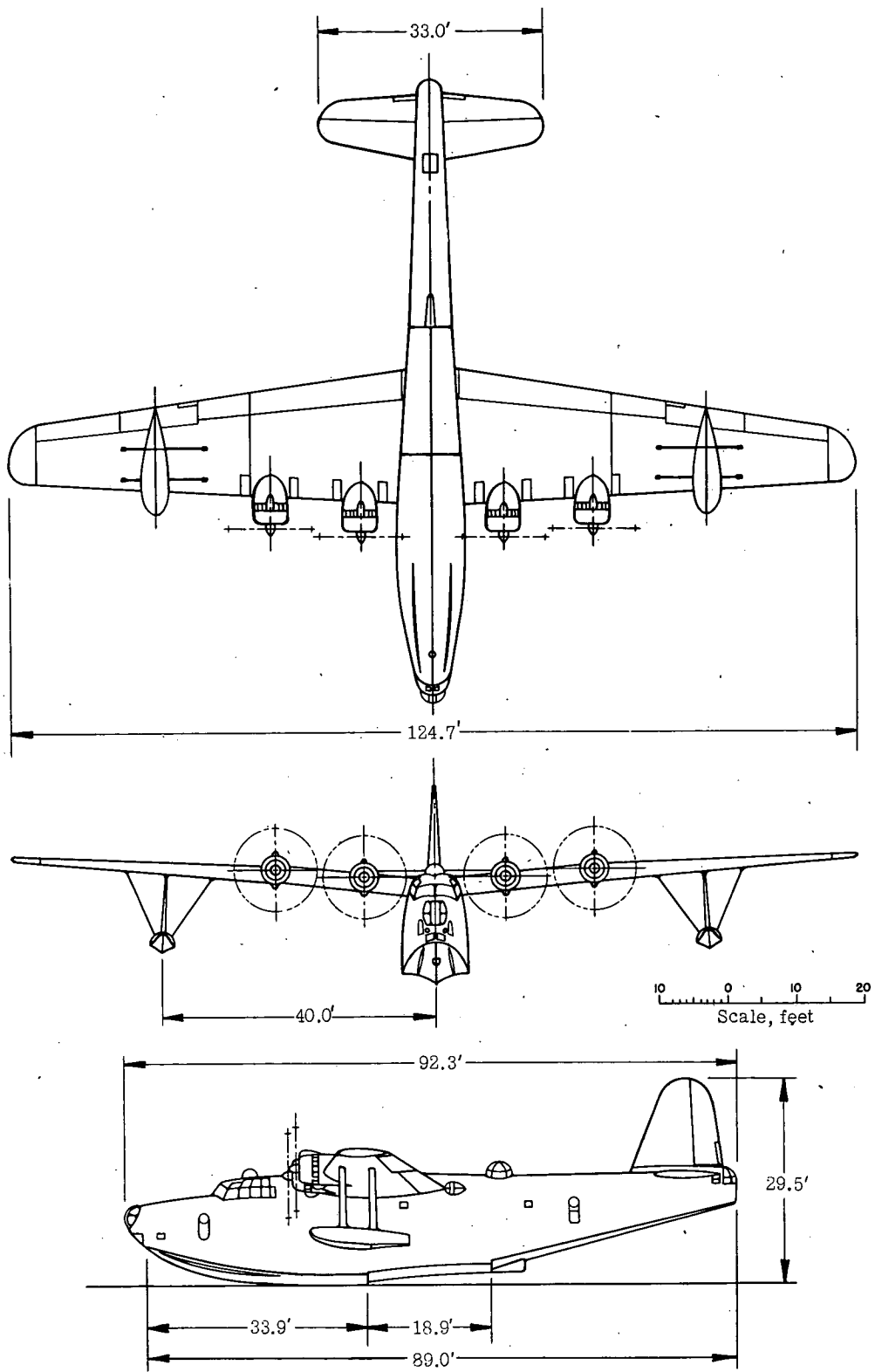


Figure 1.- Japanese flying boat "Emily." Descriptive arrangement.

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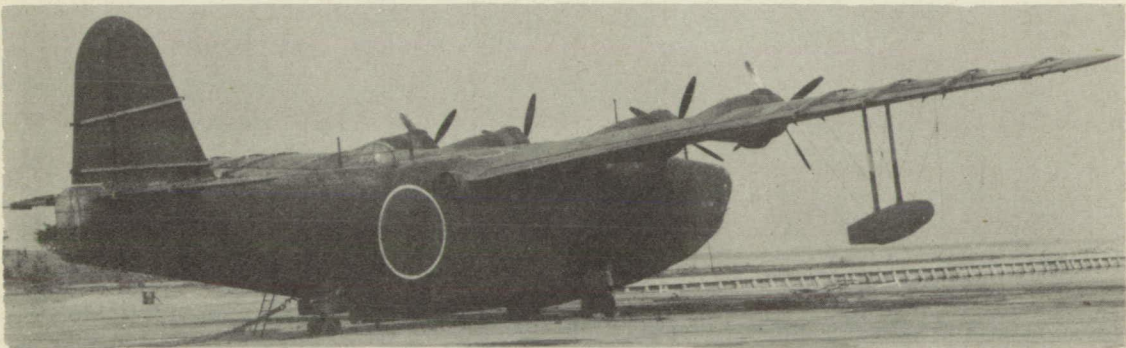
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(a) Left front view.



(b) Front view.

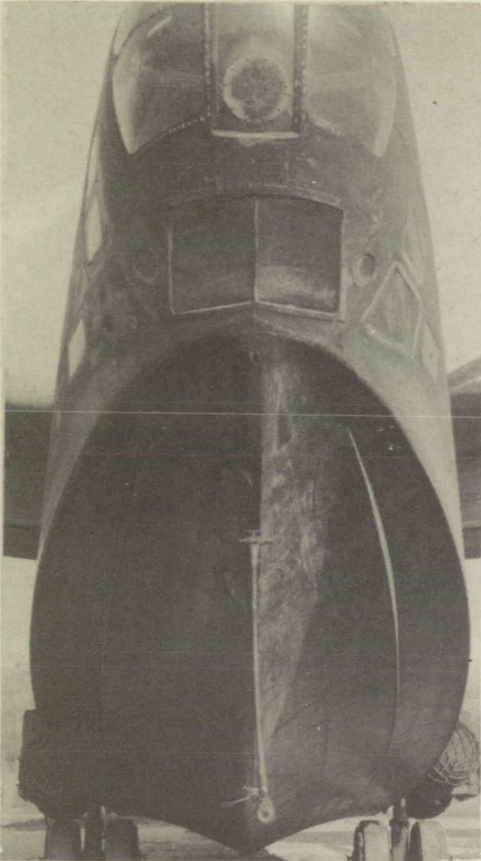


(c) Right rear view.

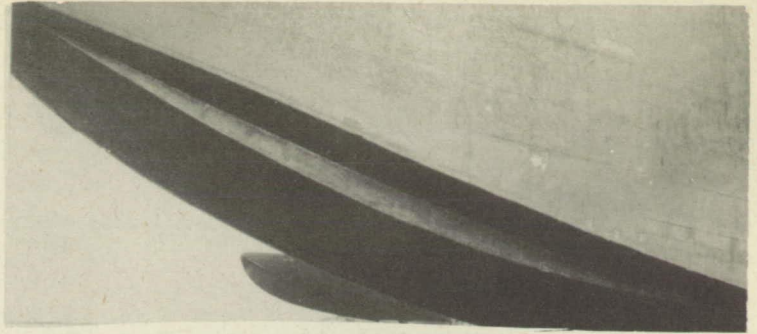
Figure 2.- Three views of the Japanese "Emily" flying boat.
(U. S. Navy official photographs.)

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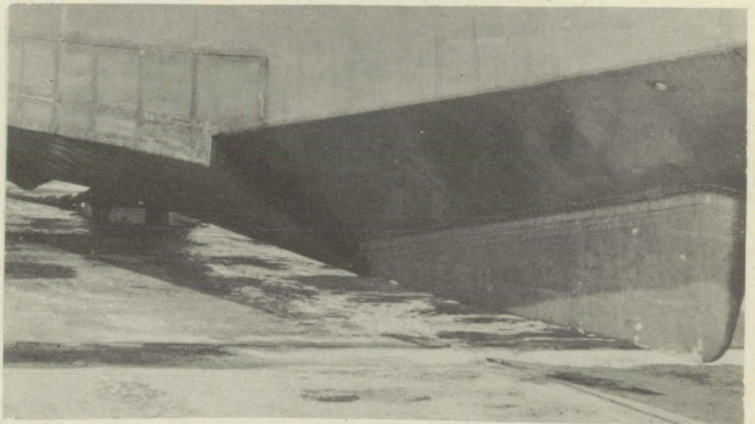
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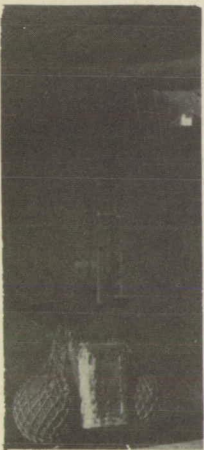
(a) Forebody showing inboard spray strip.



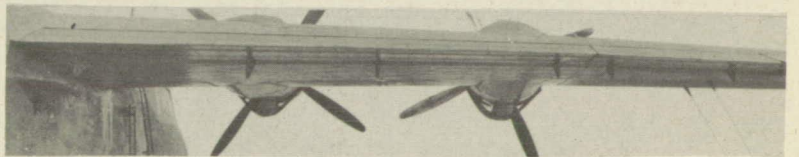
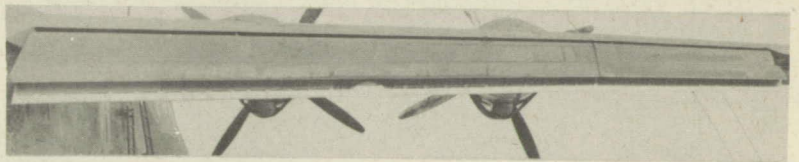
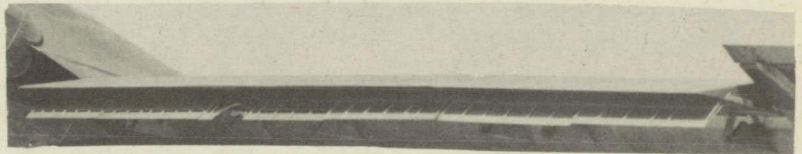
(c) Inboard spray strip.



(d) Skeg aft of second step.



(b) Ladders to reach beaching gear when afloat.



(e) Multiple flap.

Figure 3.- Unusual features of the Japanese "Emily" flying boat.
(U. S. Navy official photographs.)

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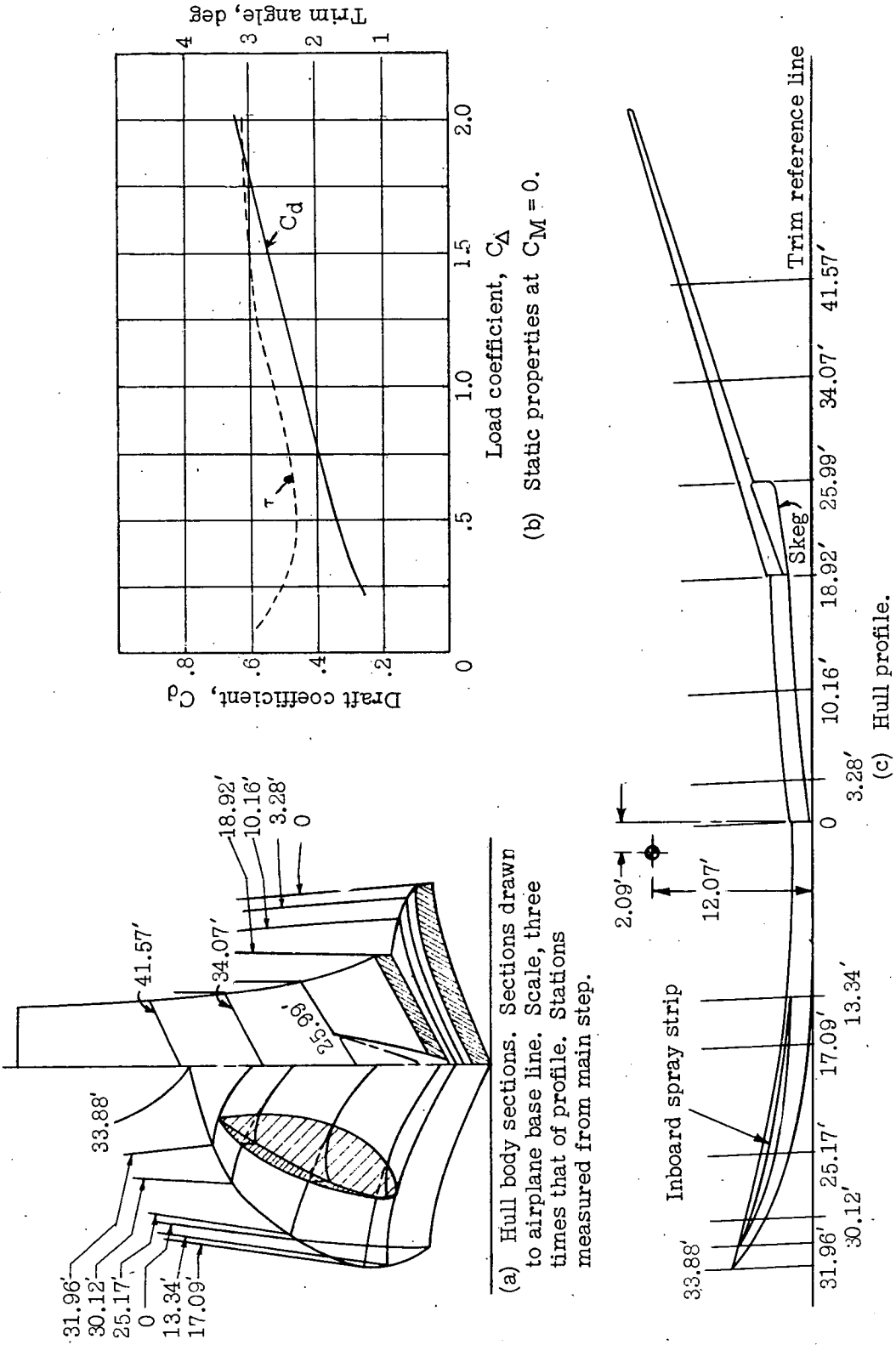


Figure 4.- Hull lines and static properties of the Japanese "Emily" flying boat.

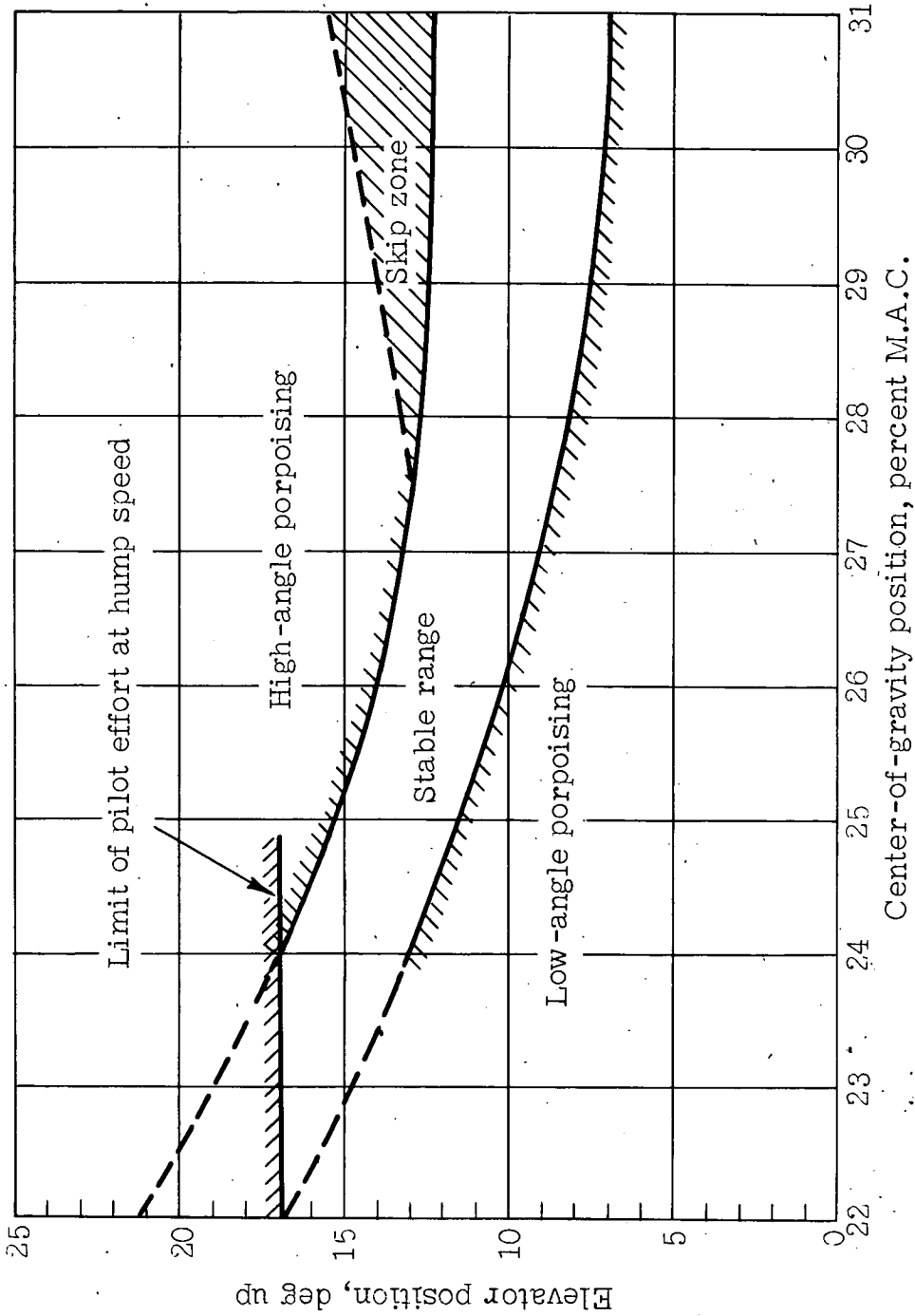


Figure 5.- Longitudinal hydrodynamic stability characteristics during take-off of Japanese "Emily" flying boat. Gross weight, 60,000 pounds; flap angle, 7°; brake horsepower, 1525 per engine.

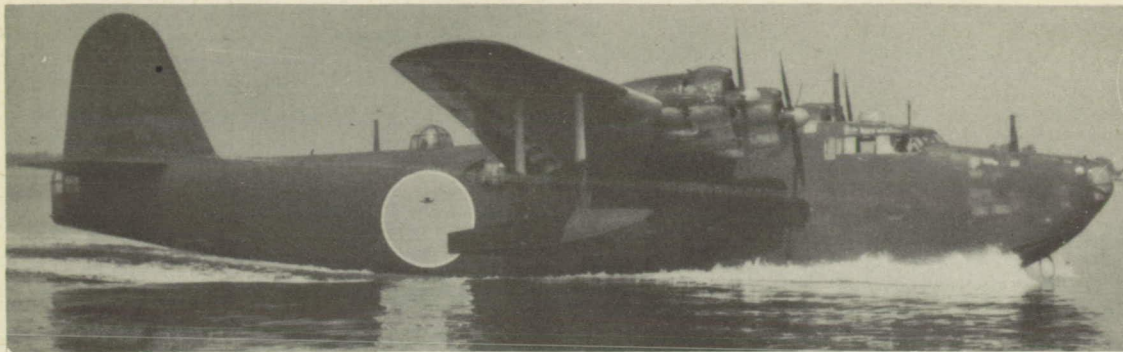


Figure 6.- Spray pattern when taxiing at 10 knots. $\Delta_0 = 49,900$ pounds;
 $\tau = 4.8^\circ$; $\phi = 1.9^\circ$ left.

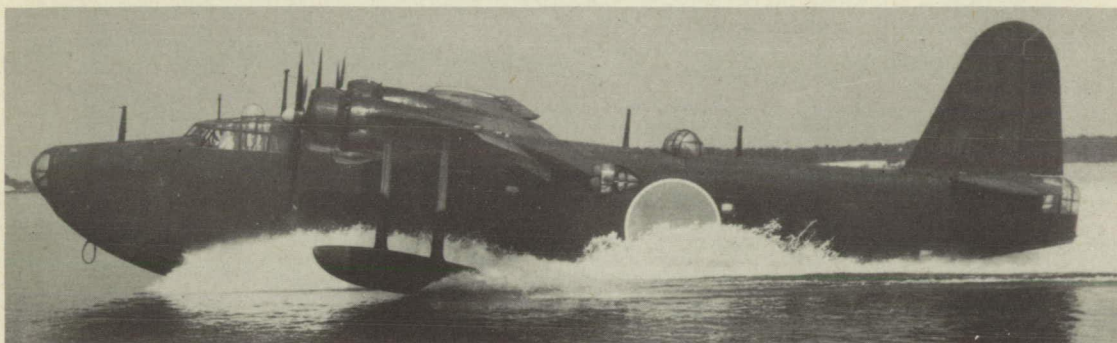


Figure 7.- Spray pattern when taxiing at 15 knots. $\Delta_0 = 49,900$ pounds;
 $\tau = 6.5^\circ$; $\phi = 2.2^\circ$ left.

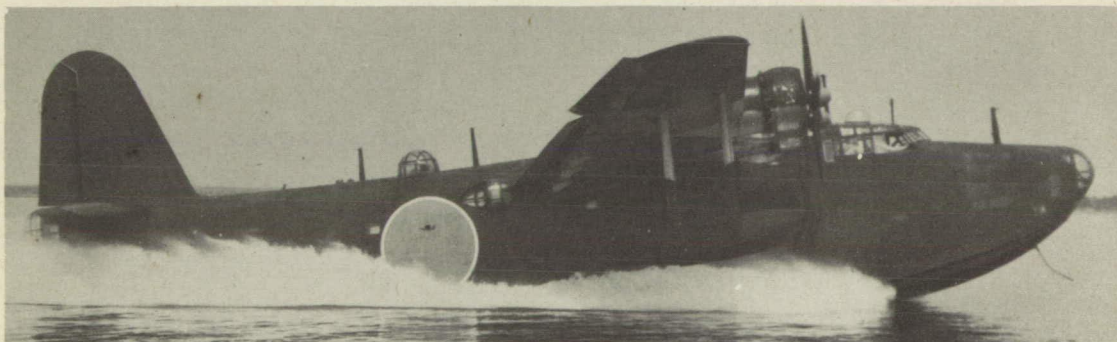


Figure 8.- Spray pattern when taxiing at 20 knots. $\Delta_0 = 49,900$ pounds;
 $\tau = 8.0^\circ$; $\phi = 2.5^\circ$ left.

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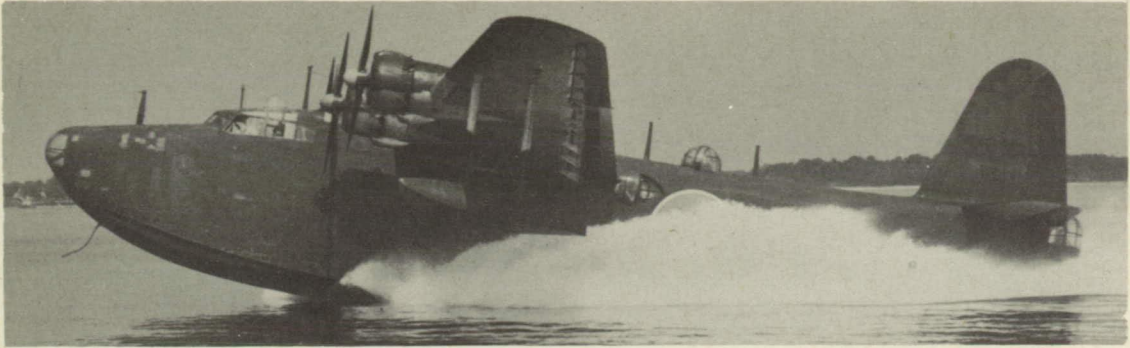


Figure 9.- Spray pattern when taxiing at 25 knots. $\Delta_O = 49,900$ pounds;
 $\tau = 9.0^\circ$; $\phi = 4.5^\circ$ right.

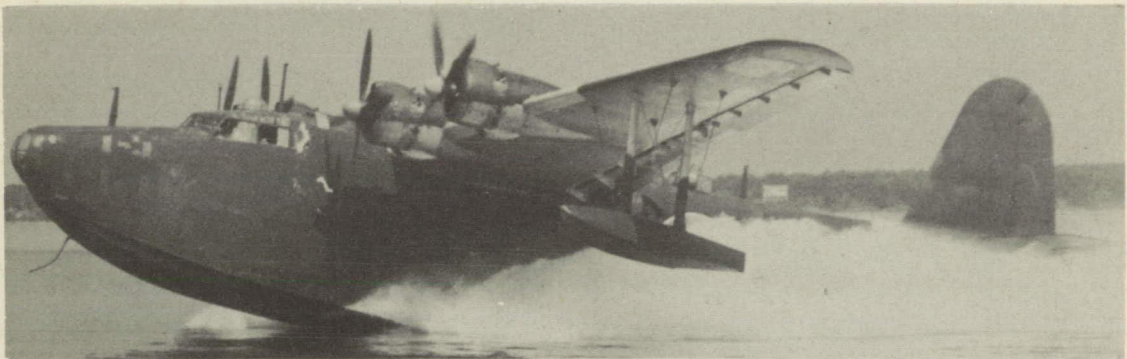


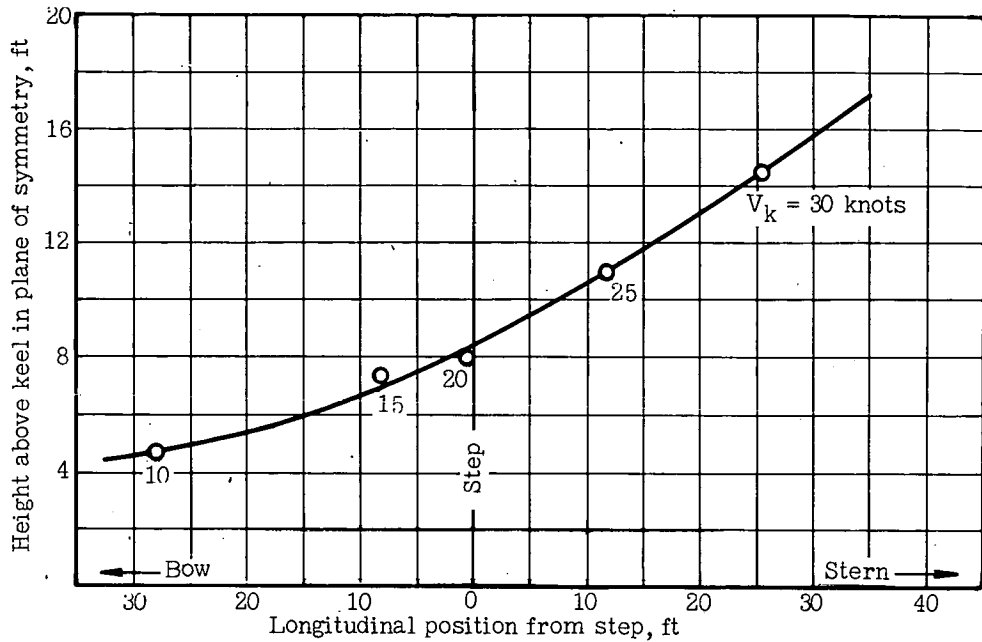
Figure 10.- Spray pattern when taxiing at 30 knots. $\Delta_O = 49,900$ pounds;
 $\tau = 11.0^\circ$; $\phi = 5.0^\circ$ right.



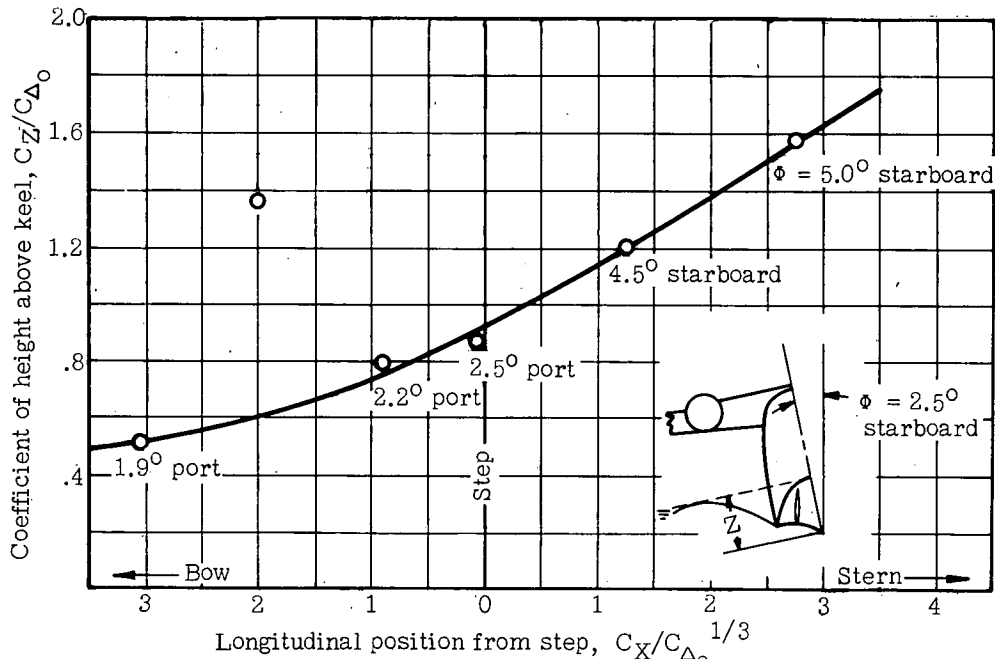
Figure 11.- Spray pattern when taxiing at 20 knots. Note action of inboard
 spray strips. $\Delta_O = 49,900$ pounds.

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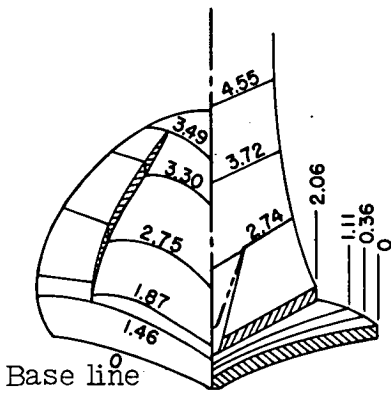


(a) Measured spray data at gross load of 49,900 pounds. From photographic analysis.

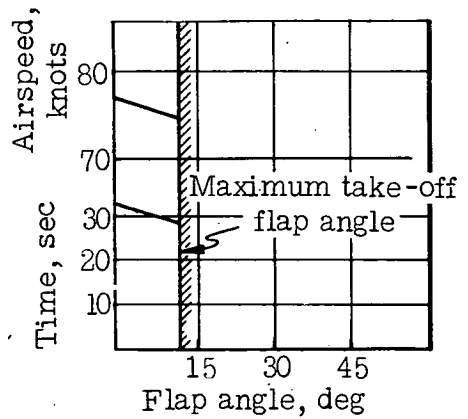


(b) Collapsed spray data. Gross-load coefficient, 1.02.

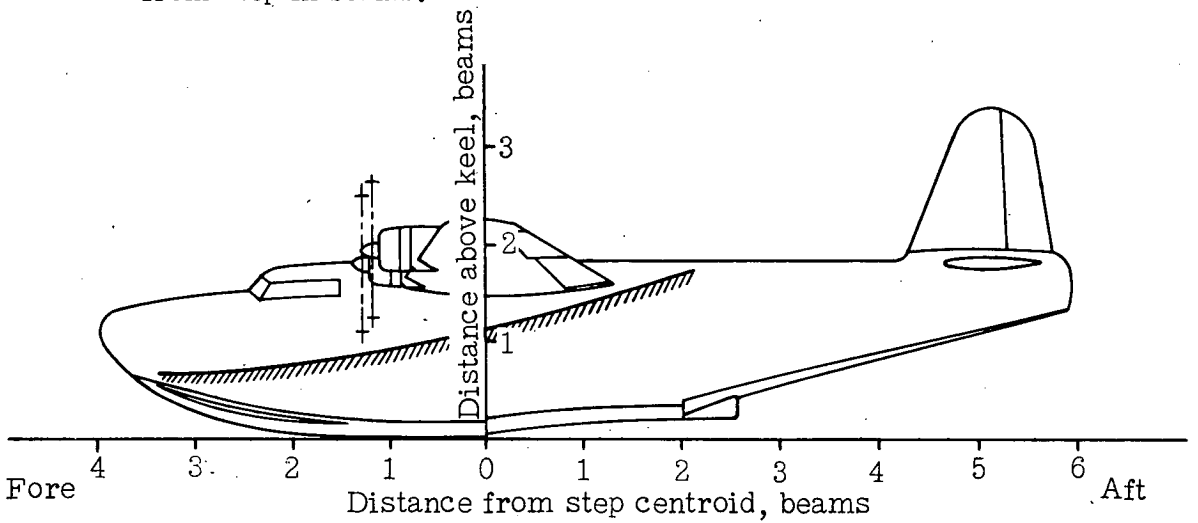
Figure 12.- Spray characteristics of Japanese "Emily" flying boat during taxiing. Flap angle, 0° ; elevator angle, 0° ; center-of-gravity position, 28.9 percent mean aerodynamic chord.



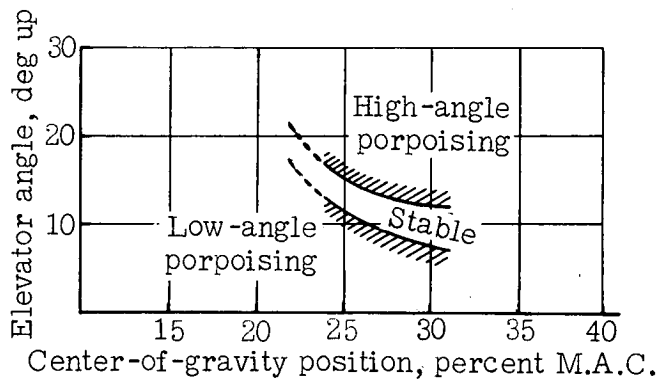
(a) Body plan: Stations measured from step in beams.



(b) Take-off time.

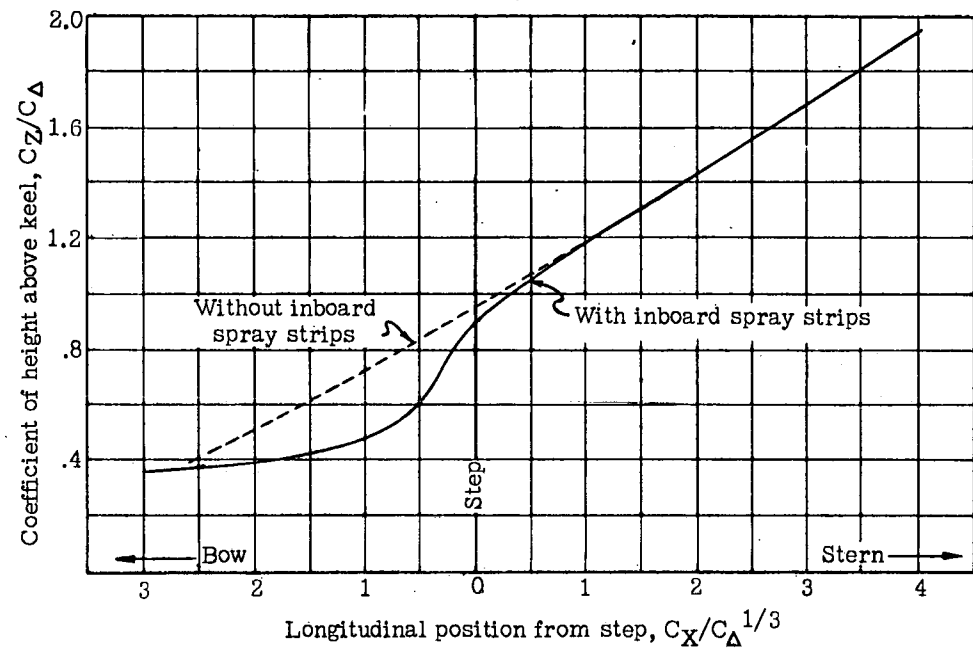


(c) Main-spray envelope. $\delta_f = 0^\circ$; $\delta_e = 0^\circ$.

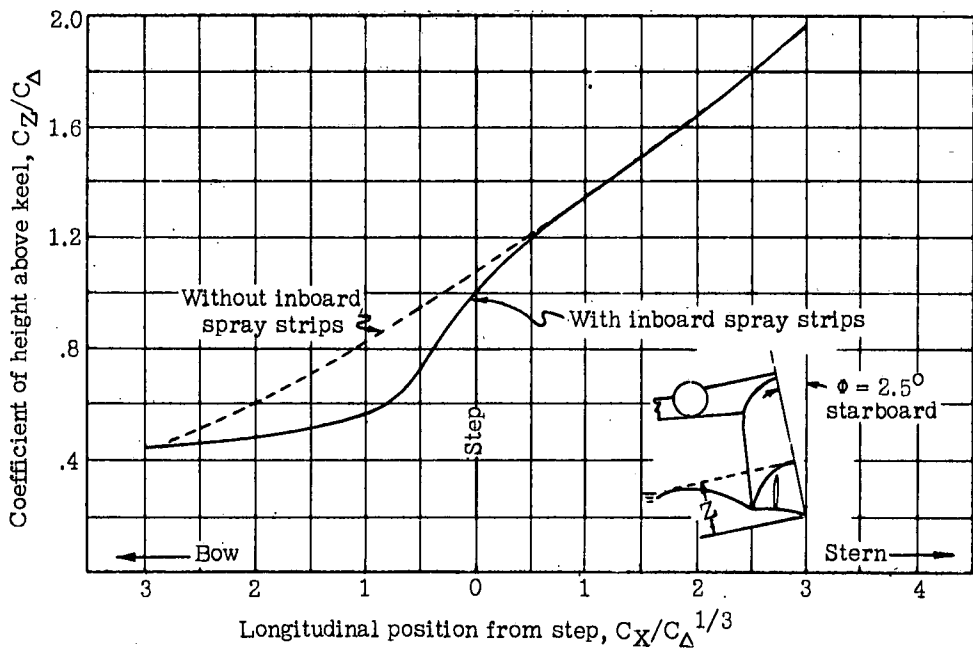


(d) Take-off stability. $\delta_f = 7^\circ$.

Figure 13.- Summary of principal hydrodynamic characteristics of Japanese "Emily" flying boat. Wind, 5 to 10 knots; water, calm.



(a) $\phi = 0^\circ$.



(b) $\phi = 2.5^\circ$ starboard.

Figure 14.- Model spray tests of the effectiveness of the inboard spray strips on the hull of the Japanese "Emily" flying boat. Free-to-trim tests at $C_\Delta = 1.20$ and $C_\Delta' = 1.00$. Center of gravity, $0.23b$ forward of step and $1.31b$ above keel. $C_M = 0.17$. Spray heights measured in plane of symmetry.

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(a) Spray pattern of the "Emily" without inboard spray strips.



(b) Spray pattern of the "Emily" with inboard spray strips.

Figure 15.- Effect of the inboard spray strips on the spray characteristics of a $\frac{1}{21}$ -scale model of the "Emily." $C_{\Delta} = 1.20$ (58,500 lb); $C_V = 1.89$ (19.2 knots); $C_M = 0.17$ (thrust moment).