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NAVY DEPARTMENT

THE DAVID W. TAYLOR MODEL BASIN

AERODYNAMICS LABORATORY

WASHINGTON 7, D.C.

(6) WIND-TUNNEL TESTS TO DETERMINE THE AIR-FLOW CHARACTERISTICS IN THE WAKES OF THREE AIRCRAFT CARRIER MODELS

PART I - TESTS OF THE ATTACK CARRIER CVA 65

~~(Title Unclassified)~~

by

(10) Herbert E. White. (14) Aero-955-Pt-1

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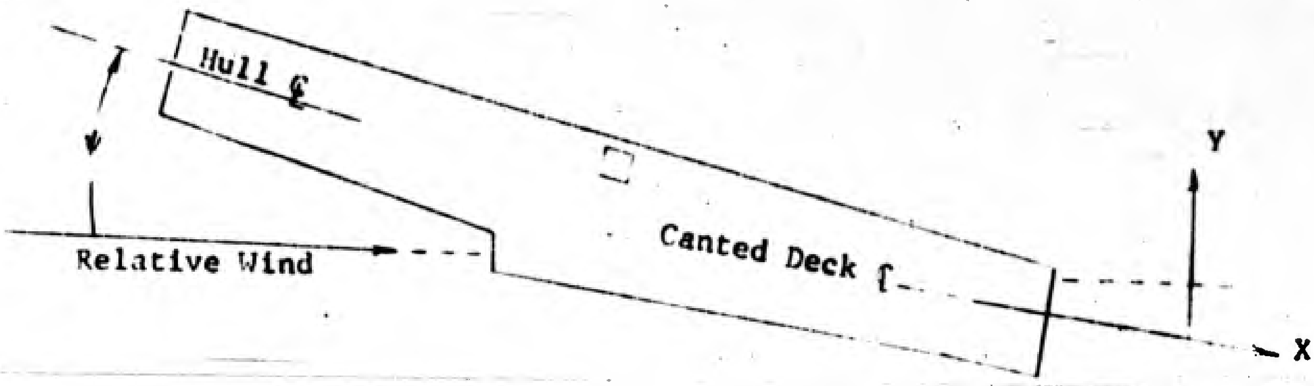
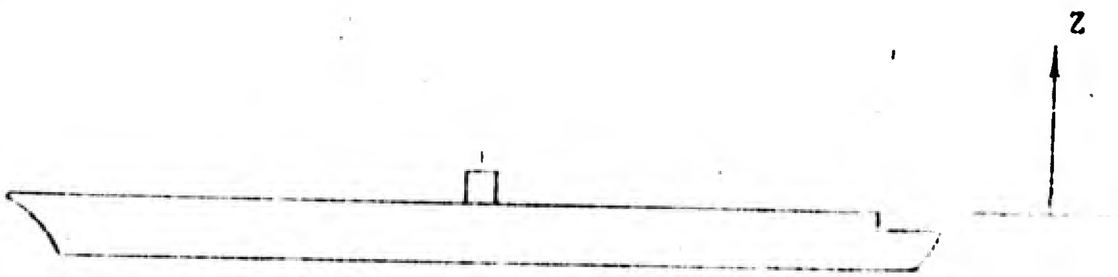
NOTATION

Arrows indicate positive directions of coordinates and yaw angle





Axis	Positive Direction –	Along –	From –
X	Aft	℄ of canted deck	T.E. of canted deck
Y	Starboard	Perpendicular to relative wind	℄ of canted deck
Z	Up	Vertical line	Deck level

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Symbols

q/q_r	dynamic pressure ratio
q	local dynamic pressure ($\rho V^2/2$) in pounds per square foot
q_r	reference (free stream) dynamic pressure ($\rho V_r^2/2$) in pounds per square foot
q_a	local dynamic pressure referred to airplane
q_o	initial airplane dynamic pressure at approach air-speed
V	local airspeed at any point in feet per second
V_r	reference (free stream) airspeed in feet per second
ρ	mass density of air in slugs per cubic foot
R	Reynolds number ($\rho V_r \ell/\mu$)
ℓ	length of flight deck in feet
μ	absolute coefficient of viscosity in pound-second per square foot
ψ	angle of yaw in degrees (angle between relative wind vector and the hull axial center line)

[redacted]

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AERODYNAMICS LABORATORY
DAVID TAYLOR MODEL BASIN
UNITED STATES NAVY
WASHINGTON, D. C.

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SUMMARY

Wind-tunnel tests of a 1/144-scale model of the CVA 65 aircraft carrier were conducted to determine the local dynamic pressures in that portion of the air wake of the carrier normally traversed by an airplane approaching for a landing. The wake surveys were conducted with a pitot-static rake, for winds directly over the bow of the ship, and at yaw angles of 10° and 20°.

Plots are presented showing the local dynamic pressure as a fraction of the free-stream dynamic pressure. One plot presents the dynamic pressure ratios encountered by an airplane flying a typical approach.

As might be expected, the effect of the island of this carrier is somewhat larger and more pronounced than it is on a carrier with a conventional island. Sharp differences in the dynamic pressure patterns are seen between yaw angles of 10° and 20°.

INTRODUCTION

Aircraft approaching a carrier for landing sometimes encounter difficulty in holding a glide path because of variation of air flow downwind of the carrier. The variations are caused principally by the hull, the flight deck overhang, and the island.

The Bureau of Ships, in anticipation of the problem, requested wind-tunnel tests of three new carrier designs, the CVA 62, CVA 64, and CVA 65, to determine the air-flow characteristics downwind (Reference 1). The resulting data are in the form of ratios of dynamic pressures at various local points in the approach zone (1 1/2 carrier lengths downwind) to the free-stream dynamic pressure. A plot showing conditions encountered in a typical approach is also presented.

An understanding of the data presented should be of value in determining areas of extreme flow variation and in evaluating possible shape modifications of the carrier.

Tests were conducted in May 1957. Preliminary data were given to the Bureau of Ships as soon as they were available.

MODEL AND APPARATUS

A 1/144-scale waterline model of the CVA 65 was constructed at the Taylor Model Basin. Principal dimensions are shown in Figure 1. Photographs are shown in Figures 2 and 3. A mirror image (mirror on the waterline) of the real model was constructed to the same scale and the two models were attached to each other at the waterline. Sufficient details were included in the models to assure a reasonable simulation of the full-scale flow conditions. A fitting and streamlined strut were provided, which permitted installing the models at several yaw angles. Figures 4 and 5 show the models the models installed in the wind tunnel.

To determine the relationship between the local dynamic pressure at various points and the free-stream dynamic pressure, a rake containing forty-three pitot-static tubes was used. Forty-two of these tubes measured local dynamic pressures at various points within the wake, while one was a reference tube, measuring the free-stream dynamic pressure.

This rake was mounted on a track and could be located in the wind tunnel on a three-axis coordinate system. It was provided with numbered holes and pins for the more frequently changed settings. Figures 6 and 7 illustrate the rake setup.

The rake was connected to two multiple-tube manometer boards, and Recordak cameras were used to record the manometer readings on film.

TEST CONDITIONS AND PROCEDURES

Tests were conducted in the Aerodynamics Laboratory 8- by 10-Foot Atmospheric Wind Tunnel 1. The model was installed with the "real" model inverted and the image erect. A strut from the tunnel ceiling, fastened into the image model, supported the models.

The image-model method of testing was used because it provides simulation of the effects of a water surface, without requiring the presence of a very large ground board in the test section. Having the test section free of the ground board facilitates adjustments of the rake and model changes.

The pitot-static rake used to survey the wake was mounted on tracks which permitted rapid and accurate positioning within the wake of the model. With the model fixed at a certain yaw angle, a dynamic pressure of six inches of alcohol, corresponding to an airspeed of approximately 84 knots, was generated in the tunnel. The pressures on the various tubes of the rake were then recorded by photographing the manometer board. By repeating this procedure for predetermined model positions, with model both in and out, it was possible to record the dynamic pressures throughout the wake of the model. Repeating the process, model in and out, nullifies the effects of pitot-tube calibration errors and local variations of dynamic pressure in the tunnel.

The model was tested in the manner described, at yaw angles of 0°, 10°, and 20°. These angles correspond to angles of relative wind with respect to the canted deck of -10°, 0°, and 10°. The test conditions resulted in a Reynolds number of 6,510,000, based on standard atmospheric conditions and a hull length of 7.2 feet.

RESULTS

The basic results of the test are presented in Figure 8 as ratios of local dynamic pressure in the wake to free-stream dynamic pressure, for various locations above and aft of the flight deck. While it would be possible to present the results as velocity ratios, dynamic pressure ratios are more significant. This is because the aerodynamic forces on a body are directly proportional to the dynamic pressure of the air stream. For example, the lift of an airplane may be expressed thus:

$$L = \rho V^2 S C_L / 2$$

or

$$L = q S C_L$$

where S and C_L may be considered constants.

From this it will be seen that lift is directly proportional to q, the dynamic pressure, which the aircraft feels.

The conditions encountered by an airplane on a 4° path are presented in Figure 9 and the various altitudes of this approach path are listed in Table 1.

Symbols, notation, and orientation of axes are shown in the preface. No corrections were necessary.

It will be noted that there are areas of the plots where considerable scatter is in evidence. This is probably due to errors in film readings. Because of the large volume of data, only those regions of the wake considered to be of practical significance were checked.

DISCUSSION

In analyzing the dynamic pressure ratios referred to the carrier (as presented in Figure 8) in terms of the effect on an airplane approaching to land, it is important to remember that the airspeed of the airplane is much greater than that of the carrier.

Suppose, for example, that the carrier is moving at an airspeed of 30 knots and that at some point in the approach path the local airspeed is 15 knots. This will be a loss in airspeed of 50 percent. (The loss in q/q_r will be 75 percent.) Now suppose that an airplane approaches the carrier at an airspeed of 130 knots. As the airplane enters that portion of the wake where the local airspeed is 15 knots lower, it will experience a loss of airspeed of 15 knots, but this will be a loss of only 12 percent. The corresponding loss in q_a/q_o will be 23 percent. It will be seen that a given decrease, in either airspeed or dynamic pressure, is much less, in percentage, for the airplane than for the carrier.

The factor that makes this relatively small decrease in airspeed so important is, of course, the fact that the airplane is already at a speed not very far above the stall.

A simple formula has been developed by which one may go from the form of dynamic pressure ratio q/q_r in which the data are presented to the more significant dynamic pressure ratio

q_a/q_o. The results of this equation are presented for a set of assumed approach conditions in Figure 9. For the usual conditions, where airplane speed is greater than carrier speed:

$$\frac{q_a}{q_o} = \left[1 - \frac{V_r}{V_a}\left(1 - \sqrt{\frac{q}{q_r}}\right)\right]^2$$

where:

q_a = local dynamic pressure experienced by airplane

q_o = initial airplane dynamic pressure at approach air speed

V_r = carrier airspeed (wind over the deck - W.O.D.)

V_o = airplane approach airspeed when free of wake effects

q/q_r = local dynamic pressure ratio (as given in Figure 8)

A study of Figure 9 may help the reader in understanding the effect of the speed difference between the airplane and carrier. It will be seen that the general shape of the curves in Figure 9 is the same as those of the corresponding stations and heights in Figure 8b. However, in Figure 9 the curves are "flatter"; that is, the peaks are lower and the valleys not as deep. It can be said, then, that the airplane's higher airspeed tends to "flatten out" the disturbances shown in Figure 8.

The island and the overhanging forward edge of the canted deck probably are responsible for the two main areas of dynamic pressure decay in the wake of the carrier. The "blockhouse" island of this carrier produces a wide wake with considerable dynamic pressure decay. This wake is larger in its lateral extent than the wake of a conventional island, and tends to blend in with the hull wake, causing a carrier wake wherein the depression of dynamic pressure is relatively uniform across the wake.

With the W.O.D. alined with the center line of the ship, some effects of the hull and island are seen in the wake at 1546 feet, the aftmost station surveyed. However, aft of about 400 feet the disturbances are not of severe consequence. At the trailing edge of the flight deck, disturbances due to the hull extend upward to about 40 feet. The effects of the island extend considerably higher, but are not very large and are well above the approach path.

At 10° of yaw, at which angle the W.O.D. is alined with the center line of the canted deck, the reductions in dynamic pressure are rather large, but are somewhat symmetrical about the center line of the approach. Of the three yaw angles tested, this is probably the most favorable for approach, from the wake disturbance viewpoint.

As might be expected, the wake of the carrier at 20° relative wind angle (with reference to ship center line) is rather extensive. At the trailing edge of the flight deck the wake is about 450 feet wide. The dynamic pressure pattern at that angle is characterized near the hull by high q/q_r along the center line of approach path with sharp reductions approximately 40 feet each side of the center line. At 250 feet aft, the pattern of q/q_r has shifted to the side (relative to the approach center line) so that a drop in q/q_r occurs across the center line of the glide path.

The most important factor here, especially from the standpoint of crosswind landings, is the sharp change in the dynamic pressure pattern between 10° and 20° of cross wind. It is suspected that this change occurs rather suddenly at some angle between 10° and 20°, but the scope of these tests did not permit a determination of this angle.

It is evident that accurate instrumentation for determining the direction of W.O.D. is especially important when dealing with wake conditions that are so strongly affected by the wind direction. Even a small error in determining W.O.D. could mean a great difference between what the approaching pilot would expect and what he will actually experience.

A final report will be published, presenting a comparison of the CVA 65 and the other carriers of the series.

Aerodynamics Laboratory
David Taylor Model Basin
Washington, D. C.
May 1959

REFERENCE

1. BUSHIPS CONF ltr C-All/NS-715-103 Ser 420-0179 of 30 Jul 1956.

Table 1

Altitudes at Various Stations for a

Typical Approach Path

Carrier Yaw Angle in degrees	Survey Station	Distance Aft of T.E. of Deck, feet	Distance Aft of Touchdown, feet	Altitude Above Deck, feet
	1	-26	124	15
	2	11	161	17
	3	120	270	25
0	4	230	380	33
	5	523	673	53
	6	1034	1184	89
	7	1546	1696	125
	1	-30	120	14
	2	6	156	17
	3	114	264	25
10	4	222	372	32
	5	510	660	52
	6	1013	1163	87
	7	1518	1668	123
	1	-3	147	16
	2	30	183	19
	3	144	294	26
20	4	253	403	34
	5	546	696	55
	6	1058	1208	90
	7	1569	1719	126

Conditions:

Approach angle (glide angle), 4°.

Touchdown 150 feet forward of flight deck trailing edge.

Wing plane 6' above deck at touchdown.

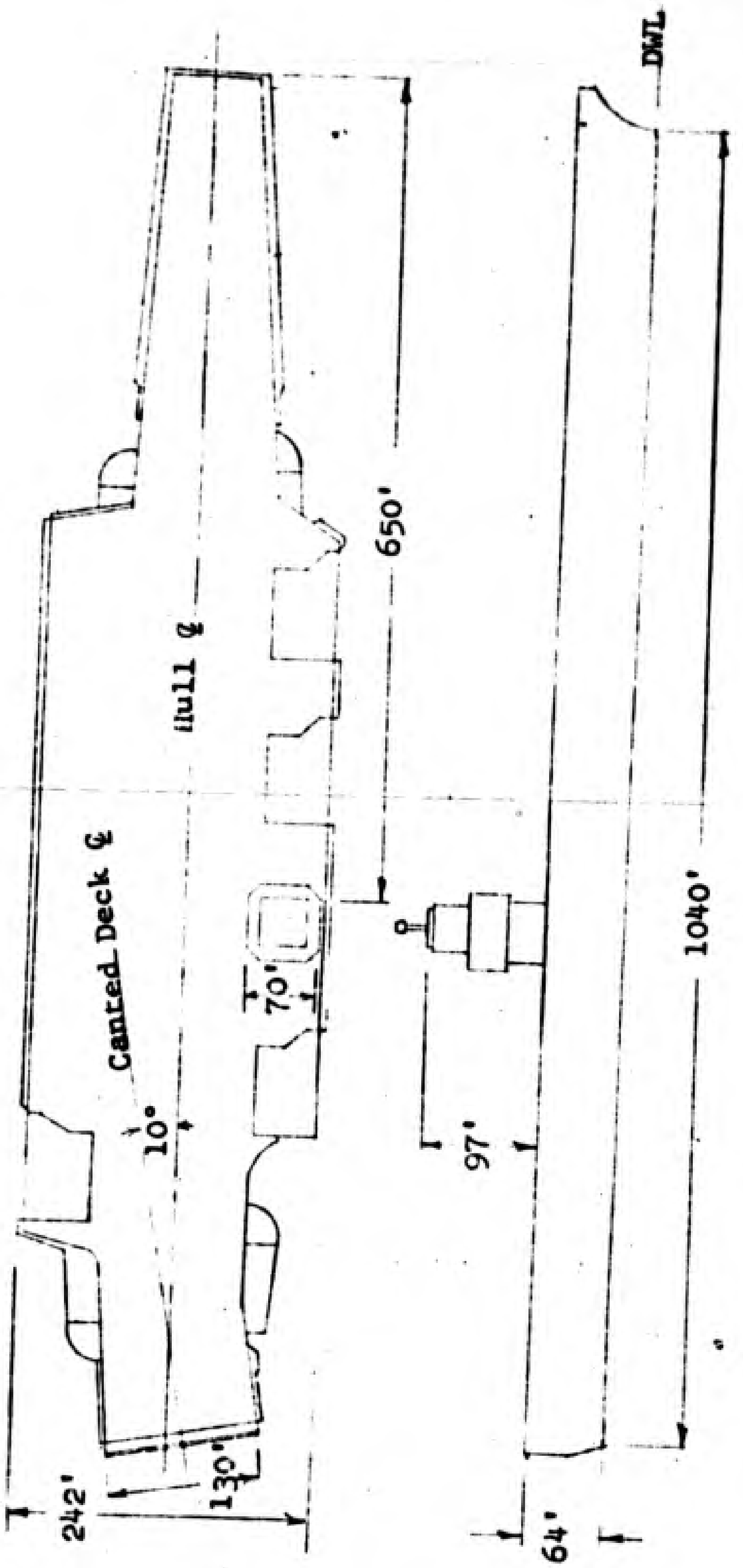
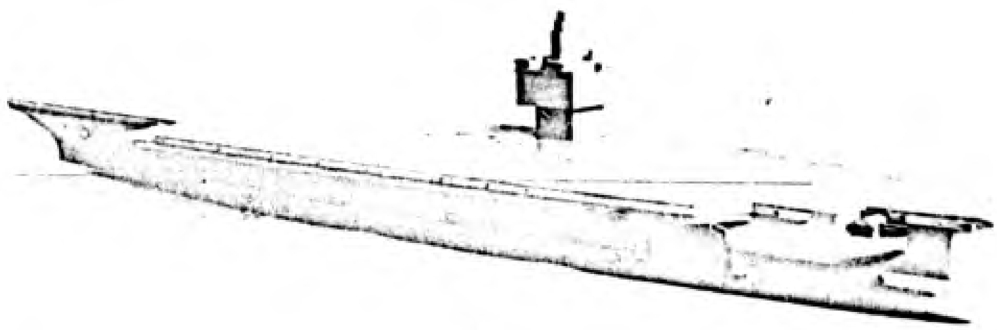


Figure 1 - Principal Dimensions of the CVA 65 Attack Aircraft Carrier



Figu:e 2 - Three-Quarter Rear View of the 1/144-Scale Waterline Model CVA 65

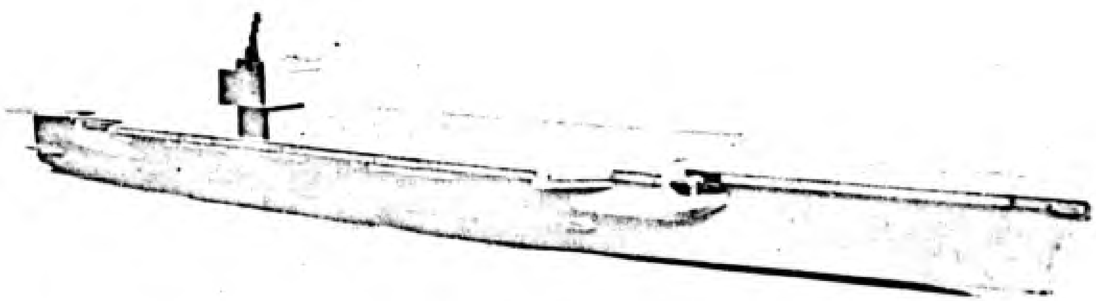


Figure 3 - Three-Quarter Front View of the 1/144-Scale Waterline Model CVA 65

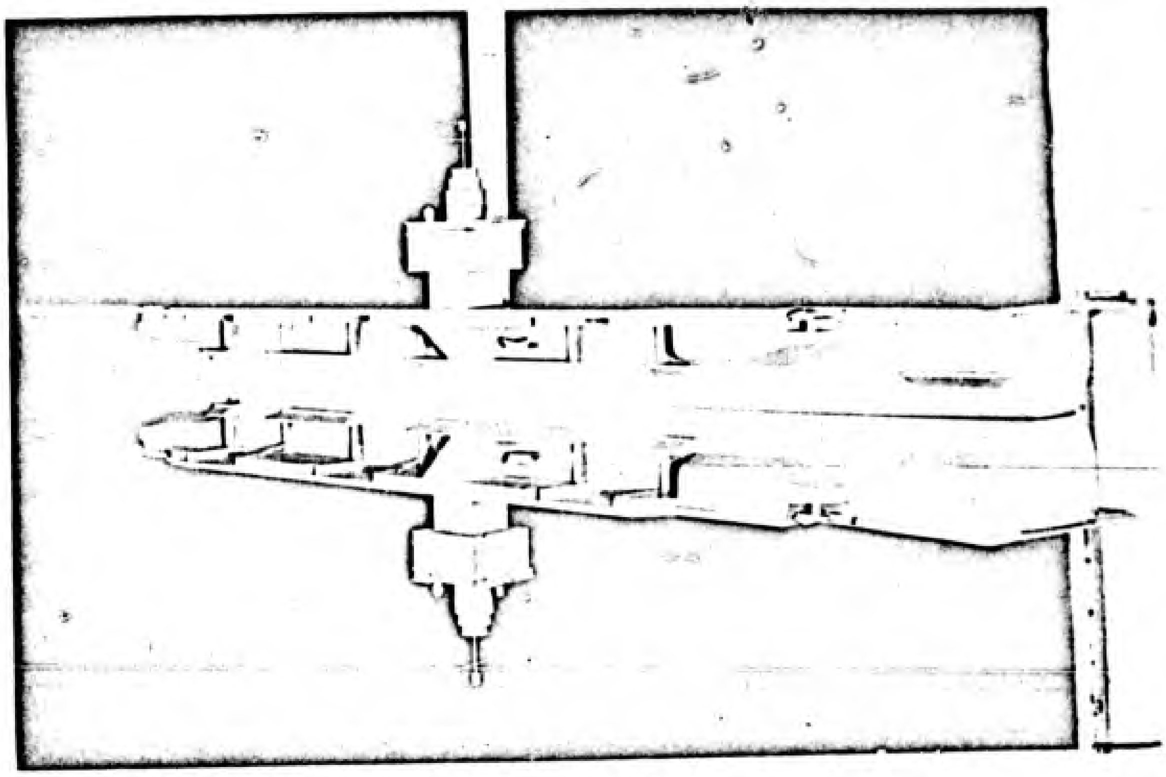


Figure 4 - Three-Quarter Rear View of the Real and Image Models Installed in the Wind Tunnel

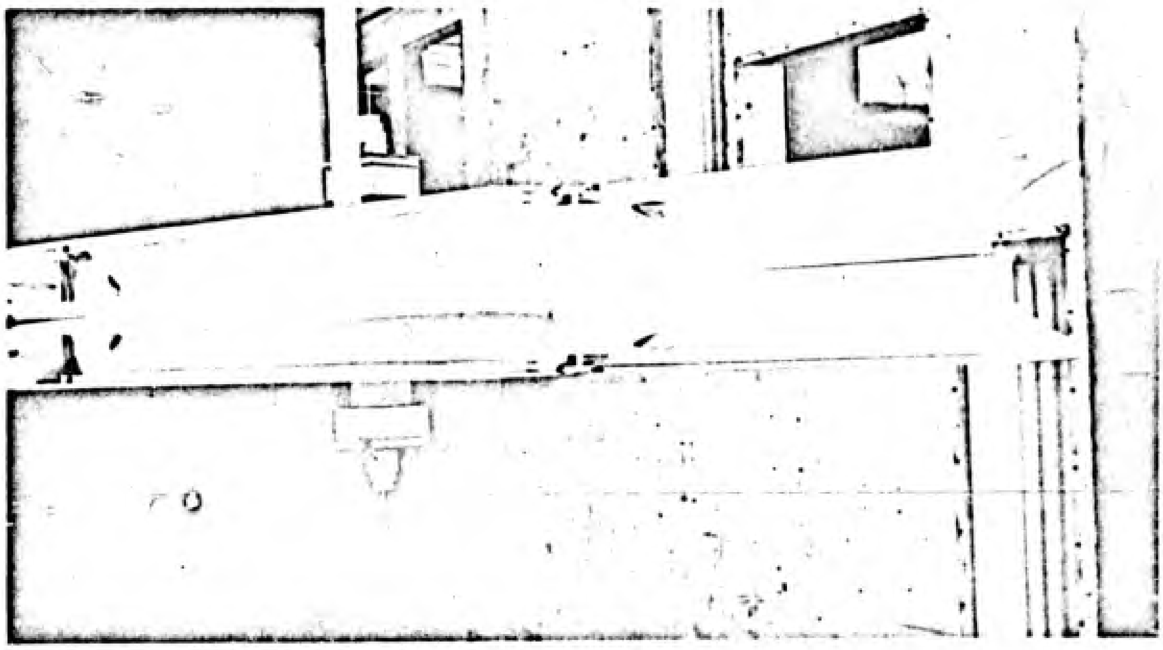


Figure 5 - Three-Quarter Front View of the Real and Image Models Installed in the Wind Tunnel

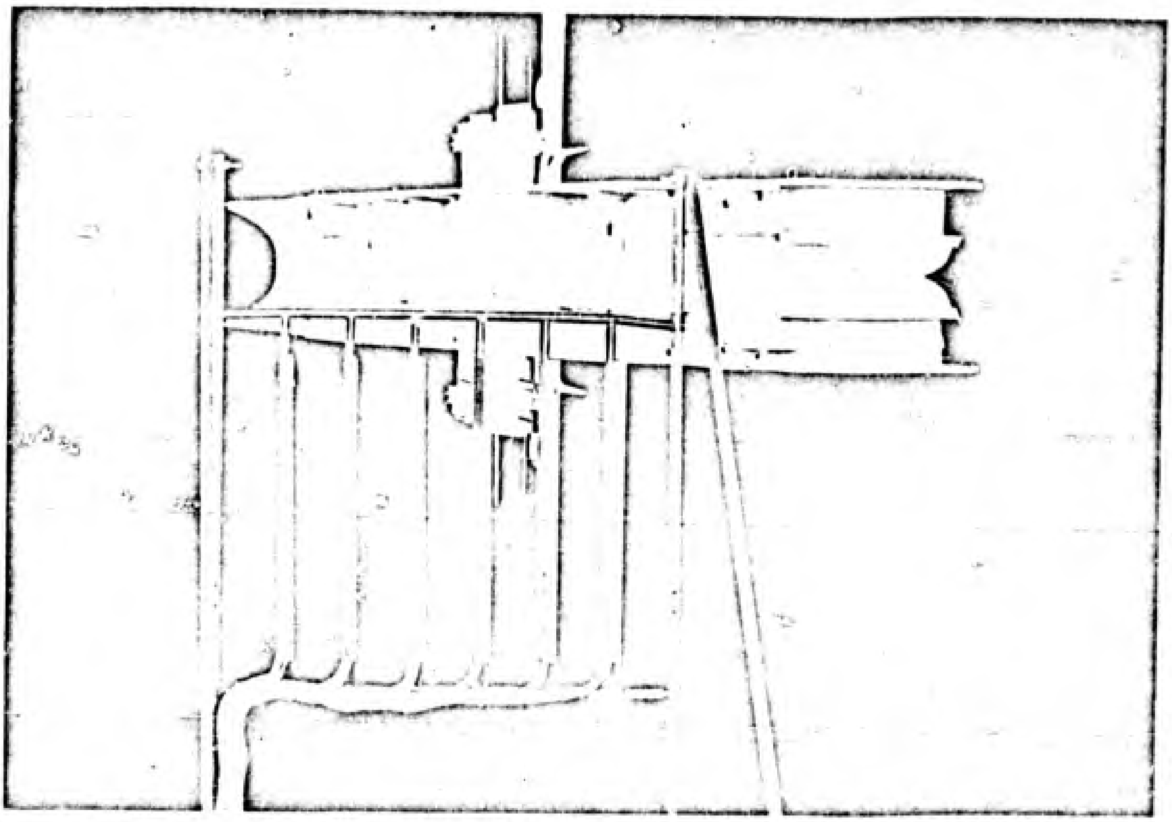


Figure 6 - Three-Quarter Rear View of the Survey Rake Installed in the Wind Tunnel With a CVA 64 Model

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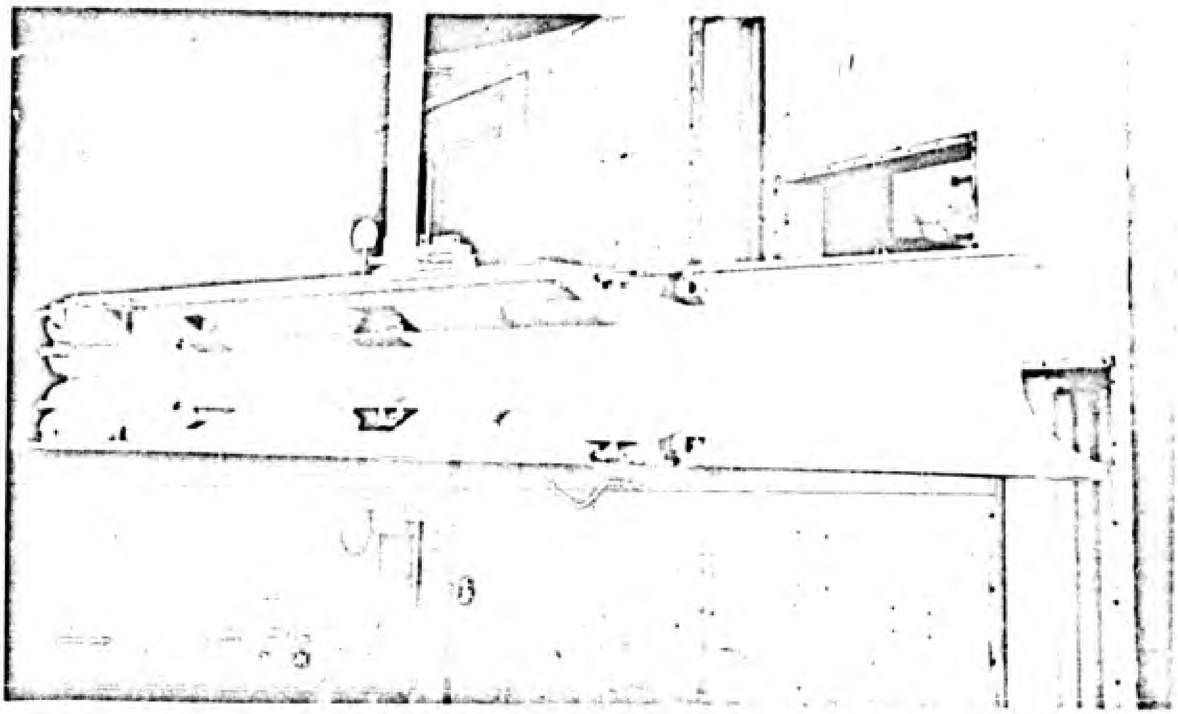

Figure 7 - Three-Quarter Front View of the Survey Rake Installed in the Wind Tunnel With a CVA 64 Model

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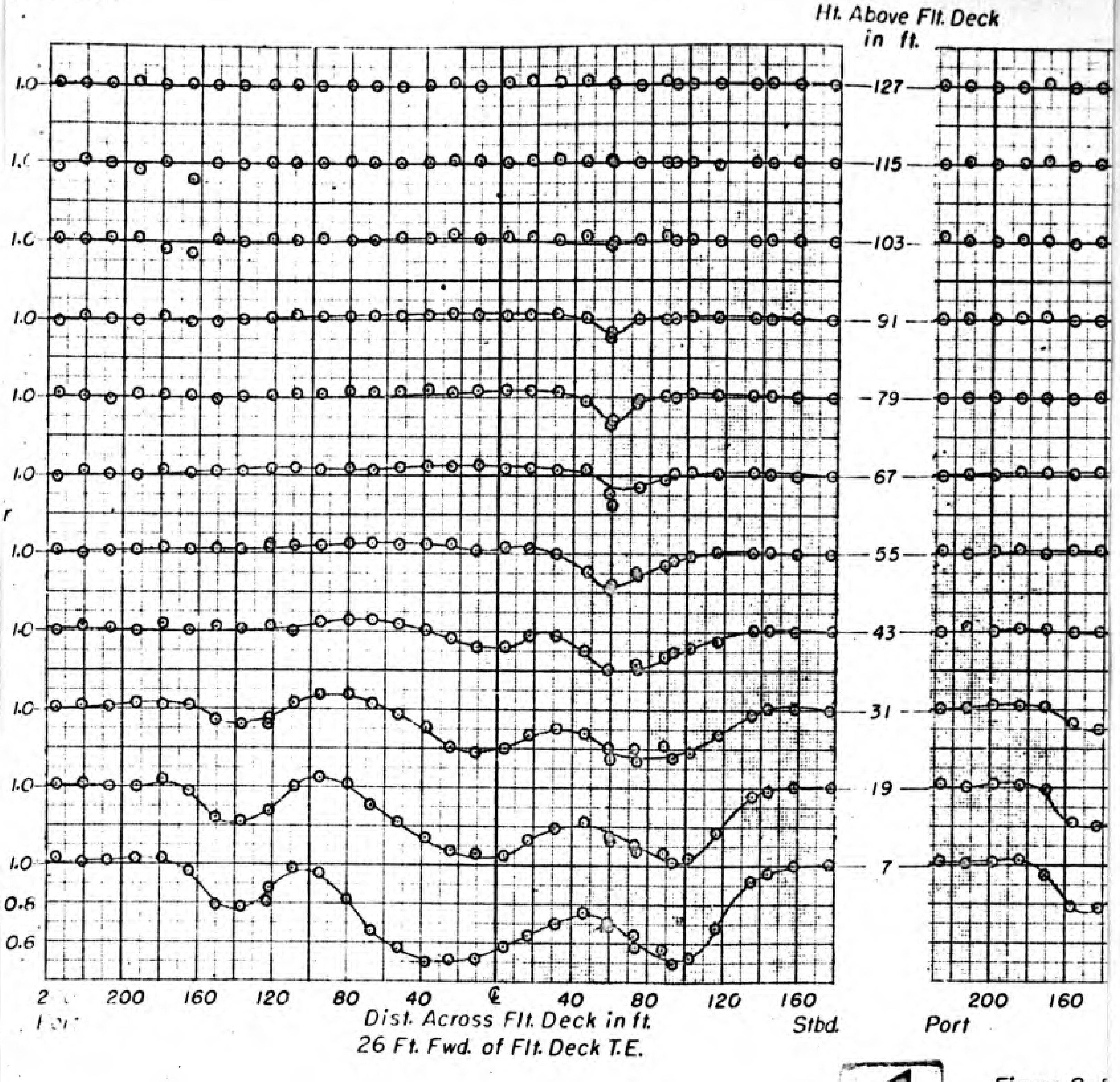

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Figure 8-

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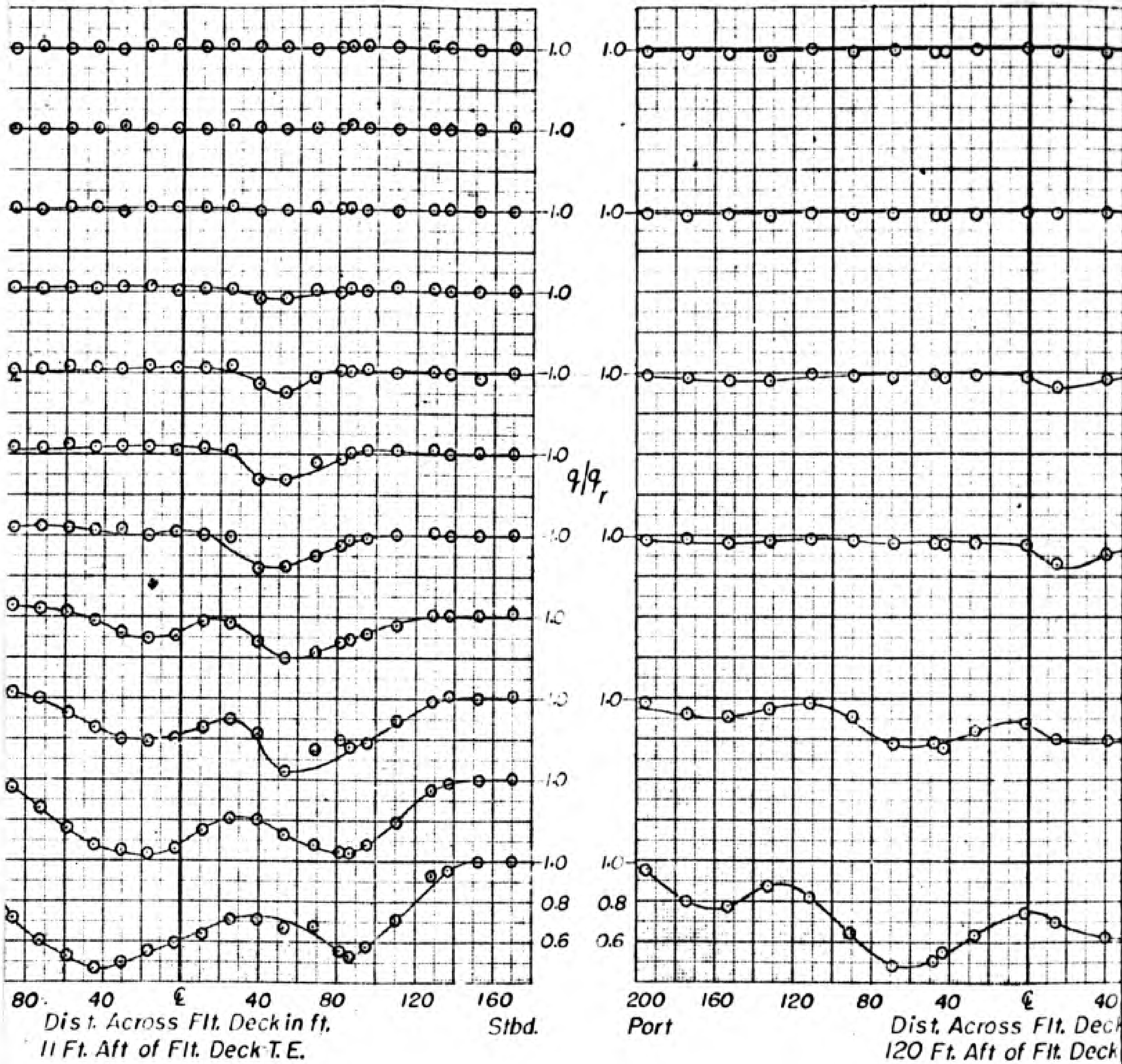

of the Ratio of Local to Free-Stream Dynamic Pressure in the Wake of a CVA65 Mod

(a) $\psi = 0°$

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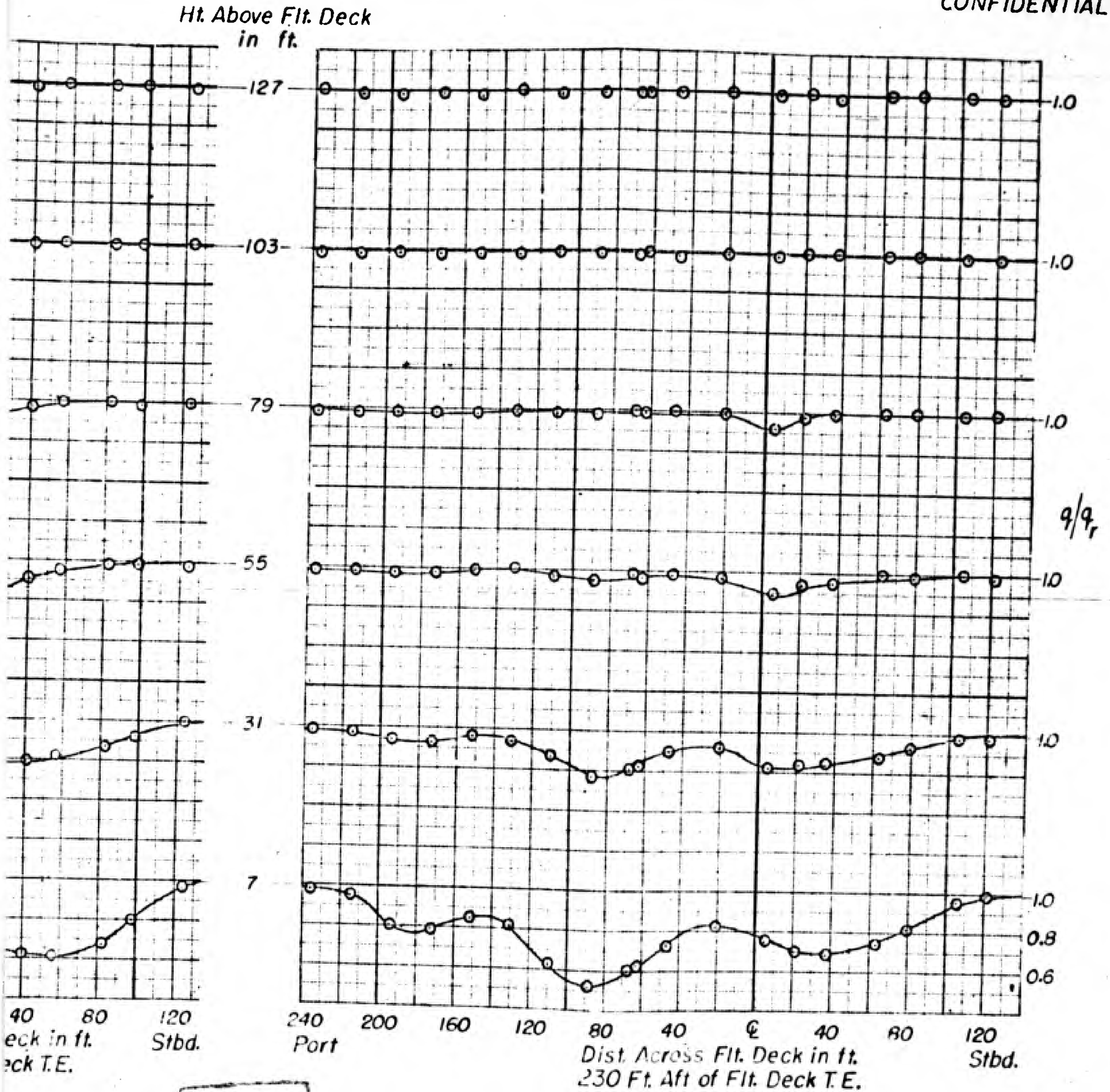
2


Ht. Above Flt. Deck in ft.
127
103
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7
1.0
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q/q_r
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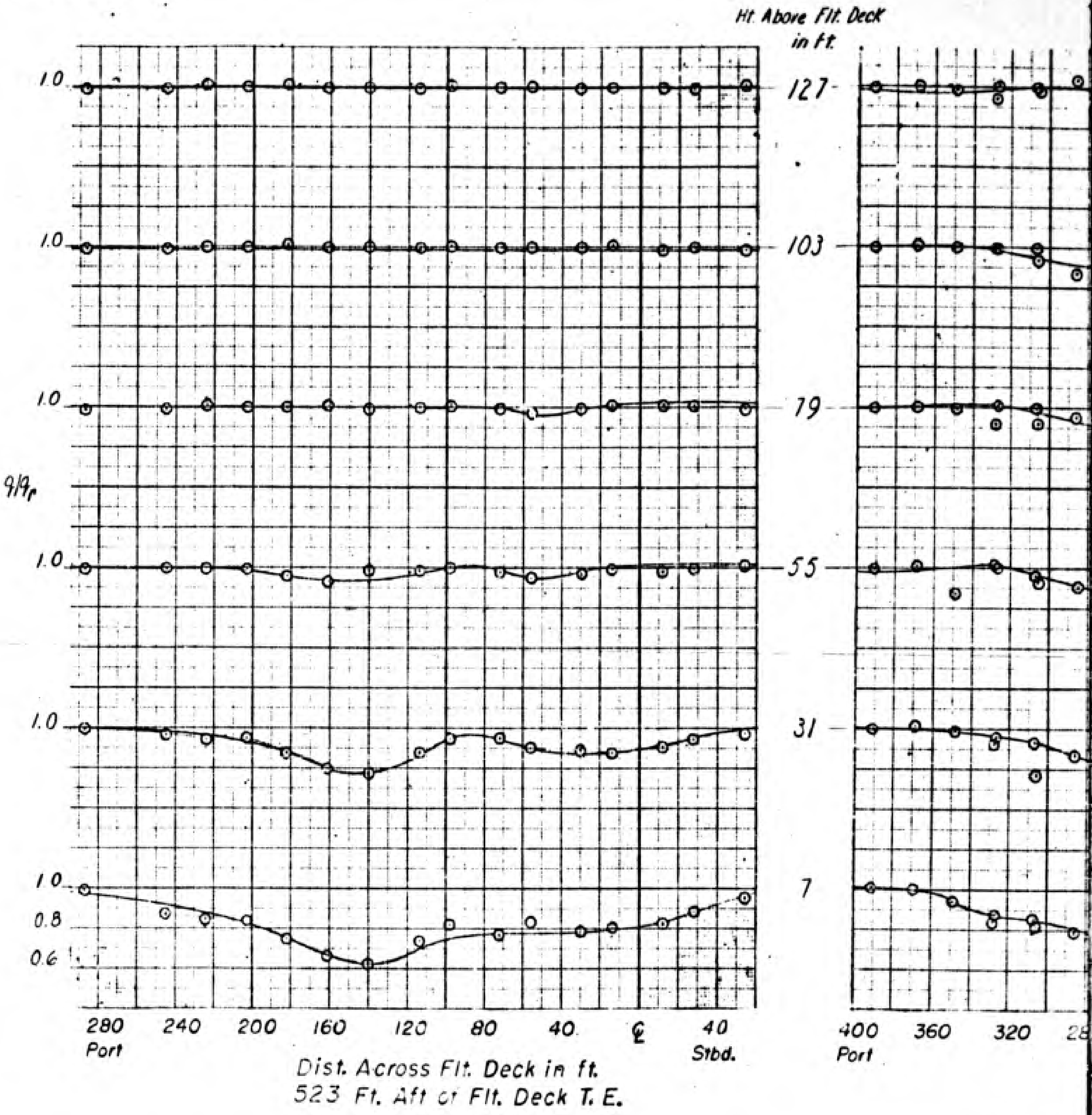
1.0
1.0
0.8
0.6
40
80
120
eck in ft.
Stbd.
eck T.E.
240
Port
200
160
120
80
40
℄
40
80
120
Stbd.
Dist. Across Flt. Deck in ft.
230 Ft. Aft of Flt. Deck T.E.

3

FIGURE 8 a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q/q_r
280 Port
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40 Stbd.
400 Port
360
320
Dist. Across Flt. Deck in ft.
523 Ft. Aft of Flt. Deck T. E.

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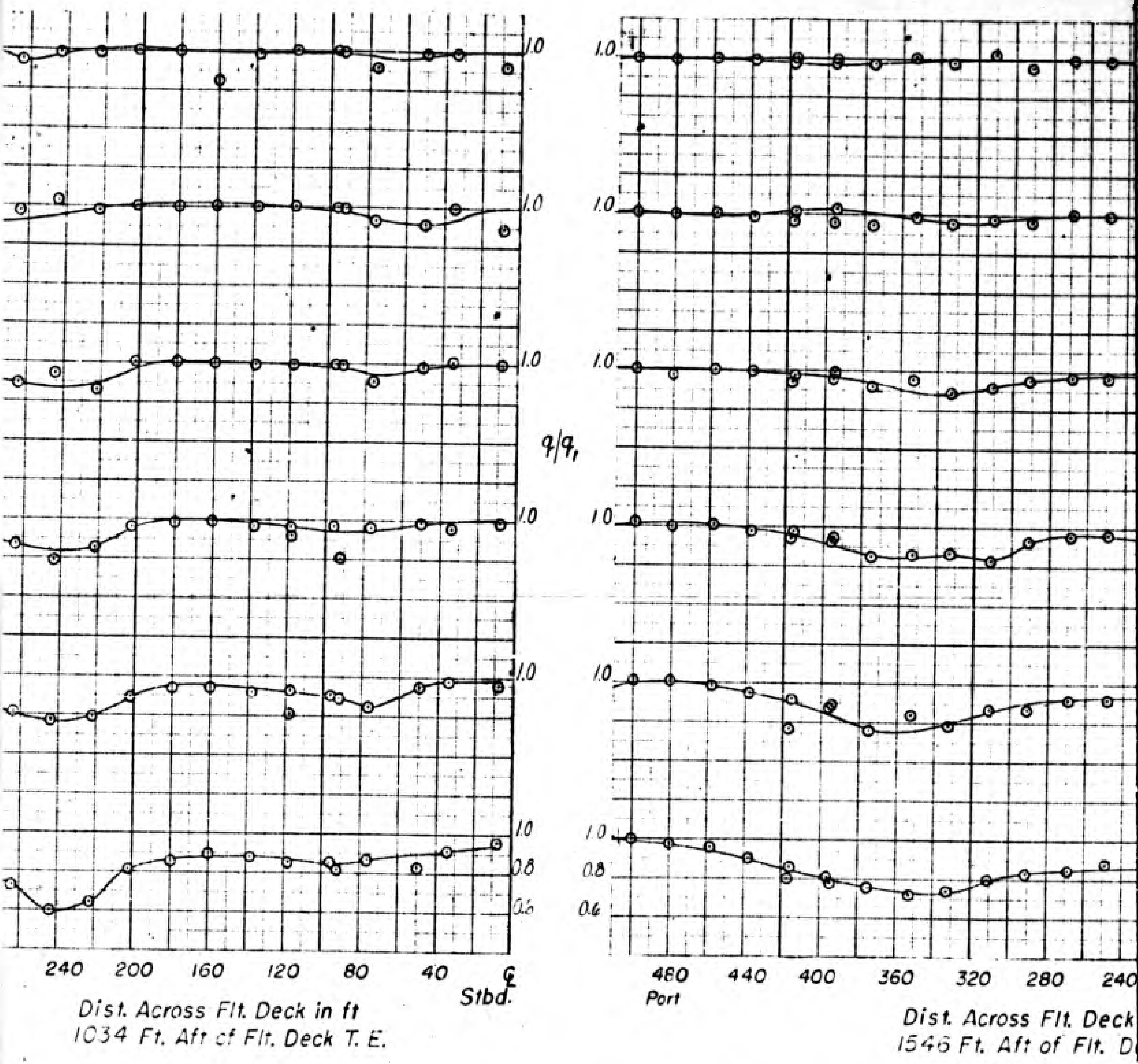

Figure 8 (Continued)
(a) (Concluded)

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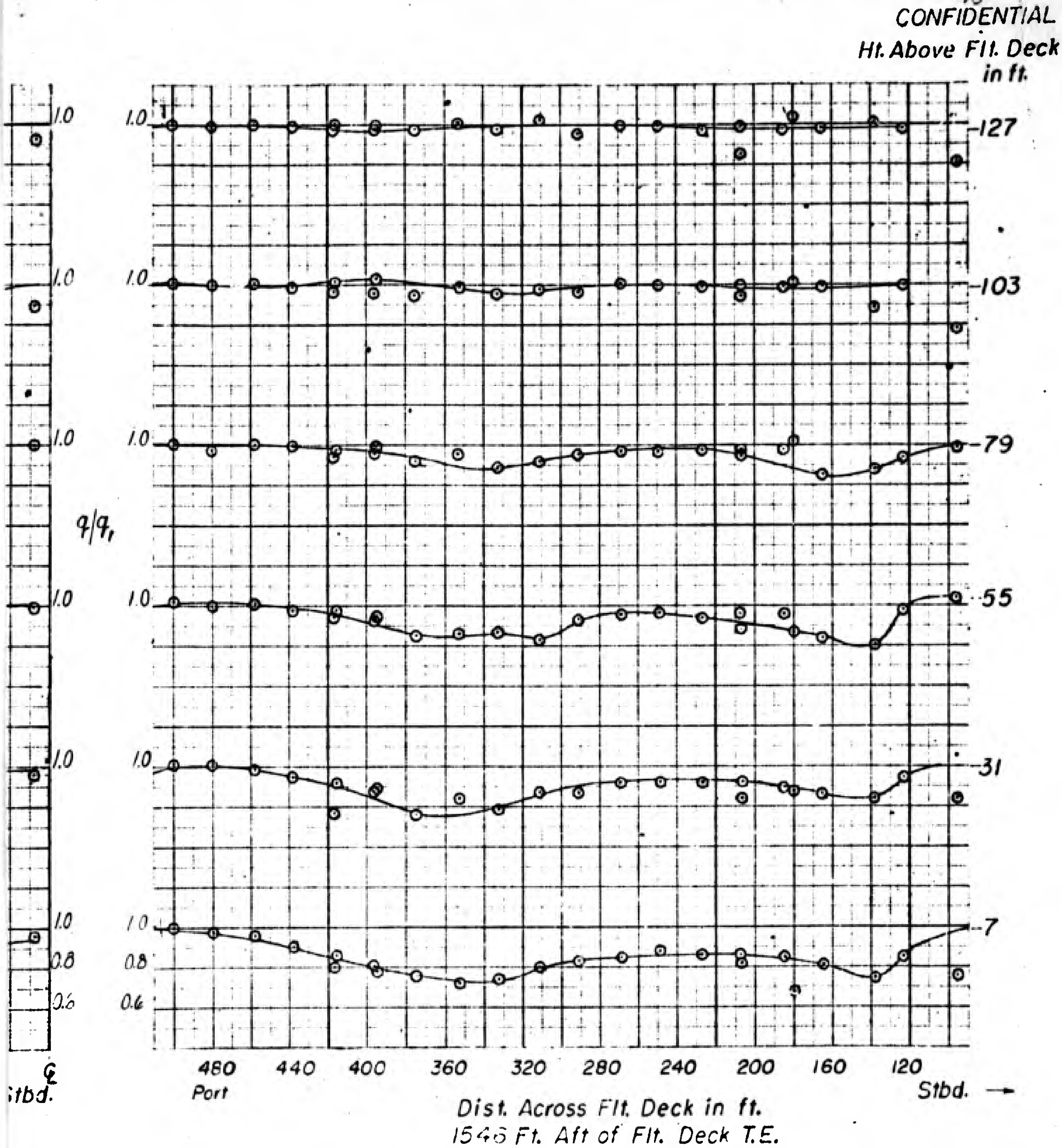

FIGURE 8 a (concl)

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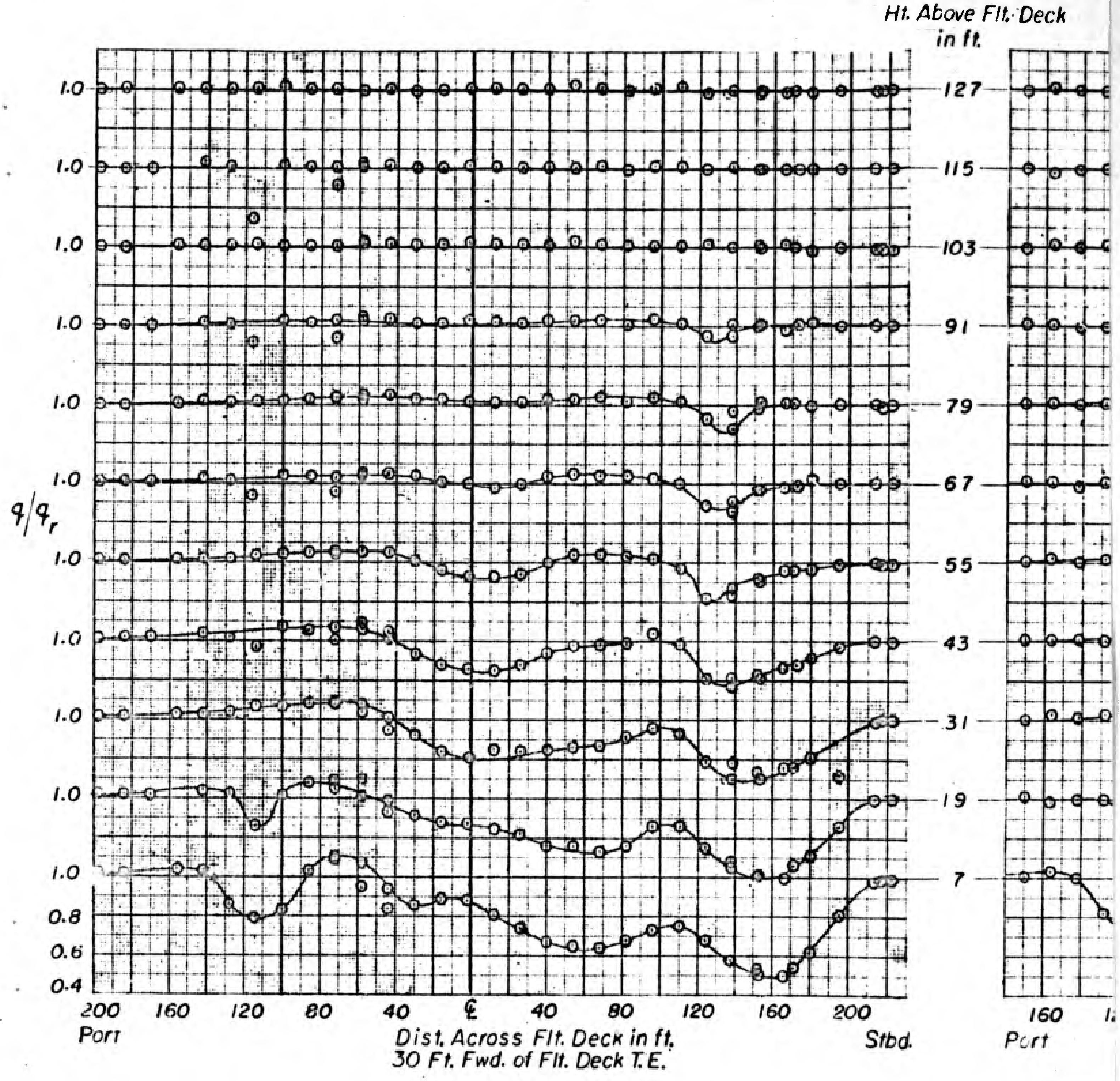

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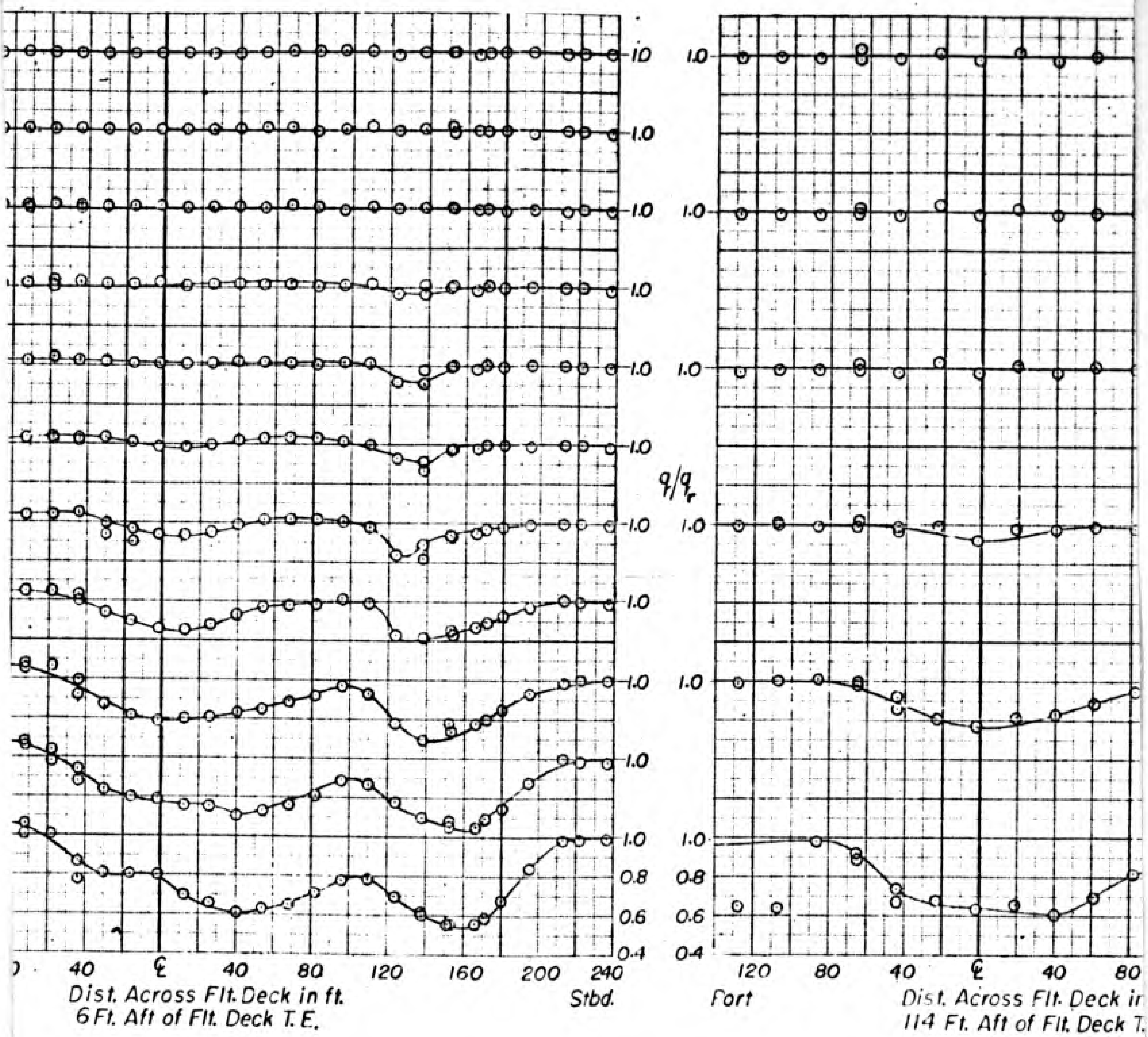

Figure 8 (Continued)

(b) $\psi = 10°$

CONFIDENTIAL CVA 65

2

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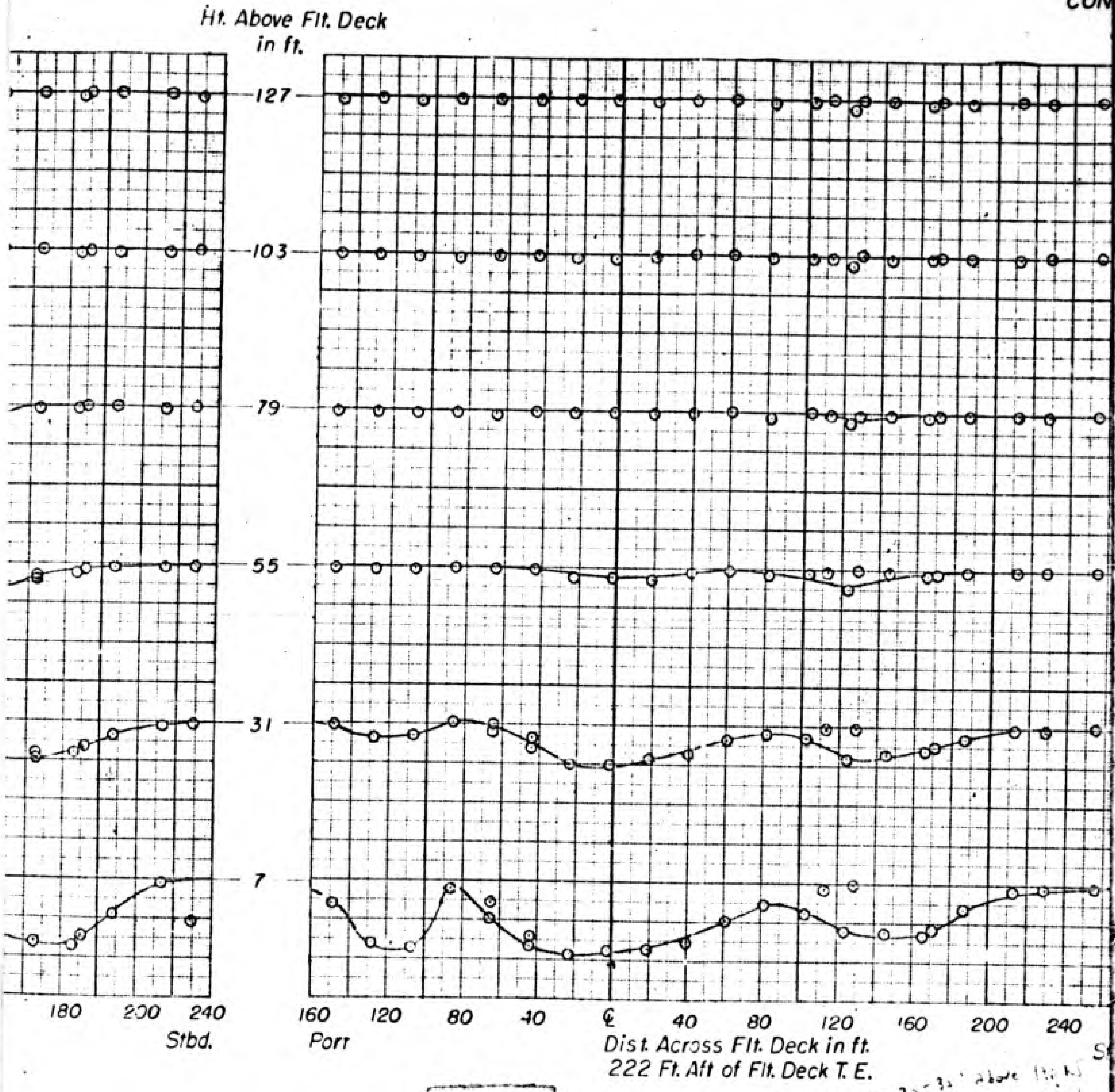

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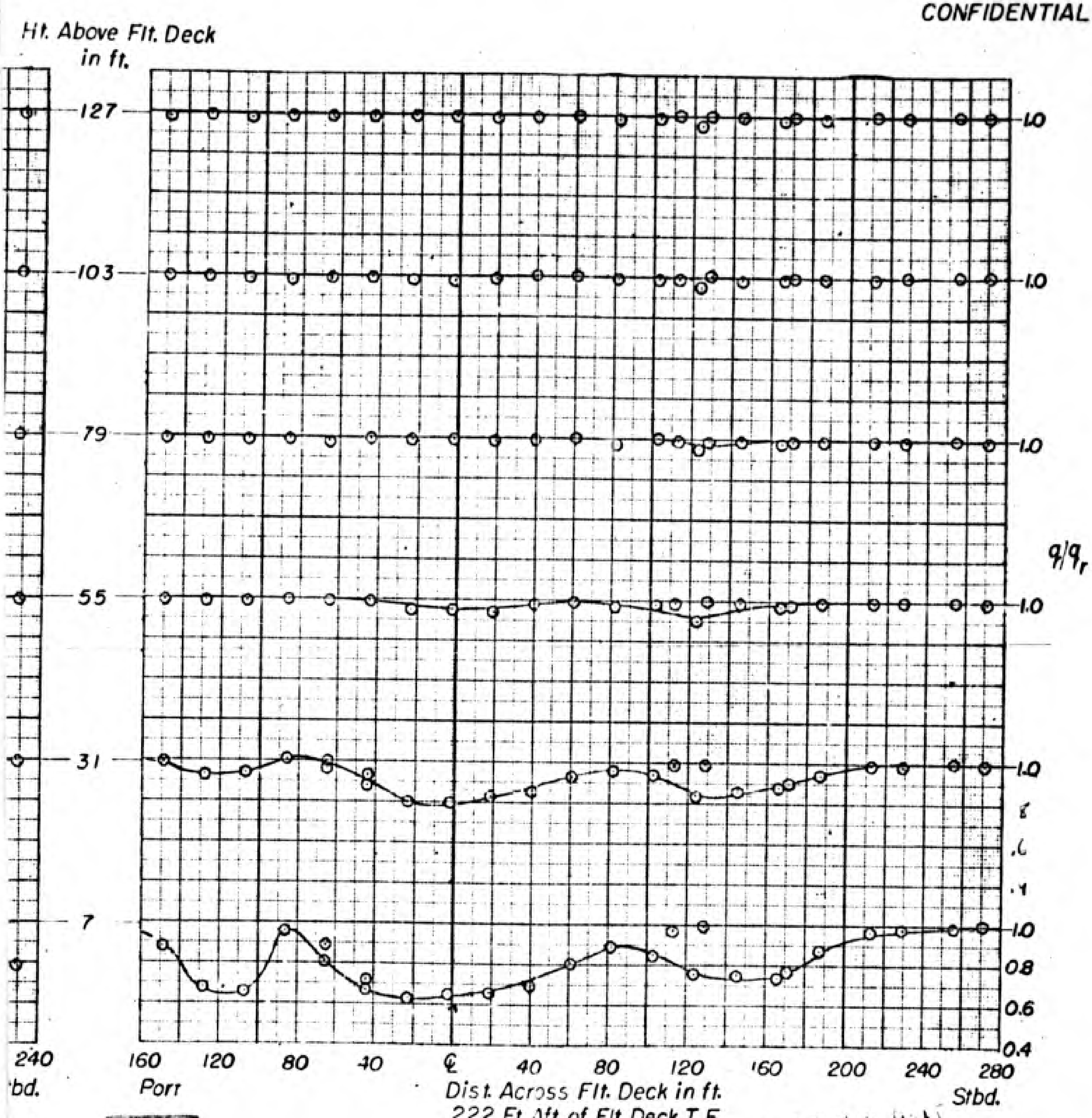
FIGURE 8

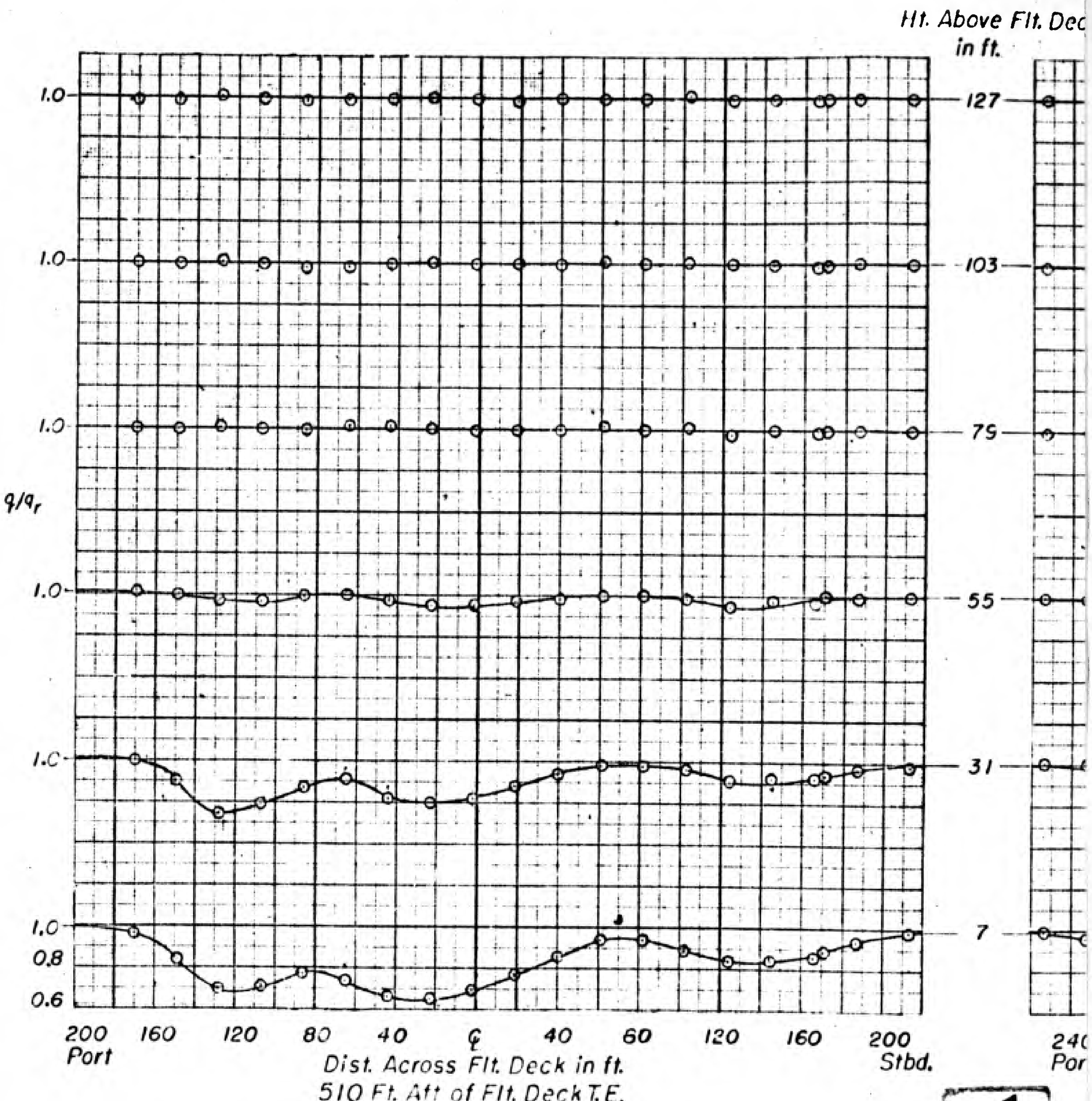


Just about 30-35' above flight deck here. This q/q_r = .8 is horrible. It means a loss of [illegible] of about [illegible]

FIGURE 8 b

4

AERO 955



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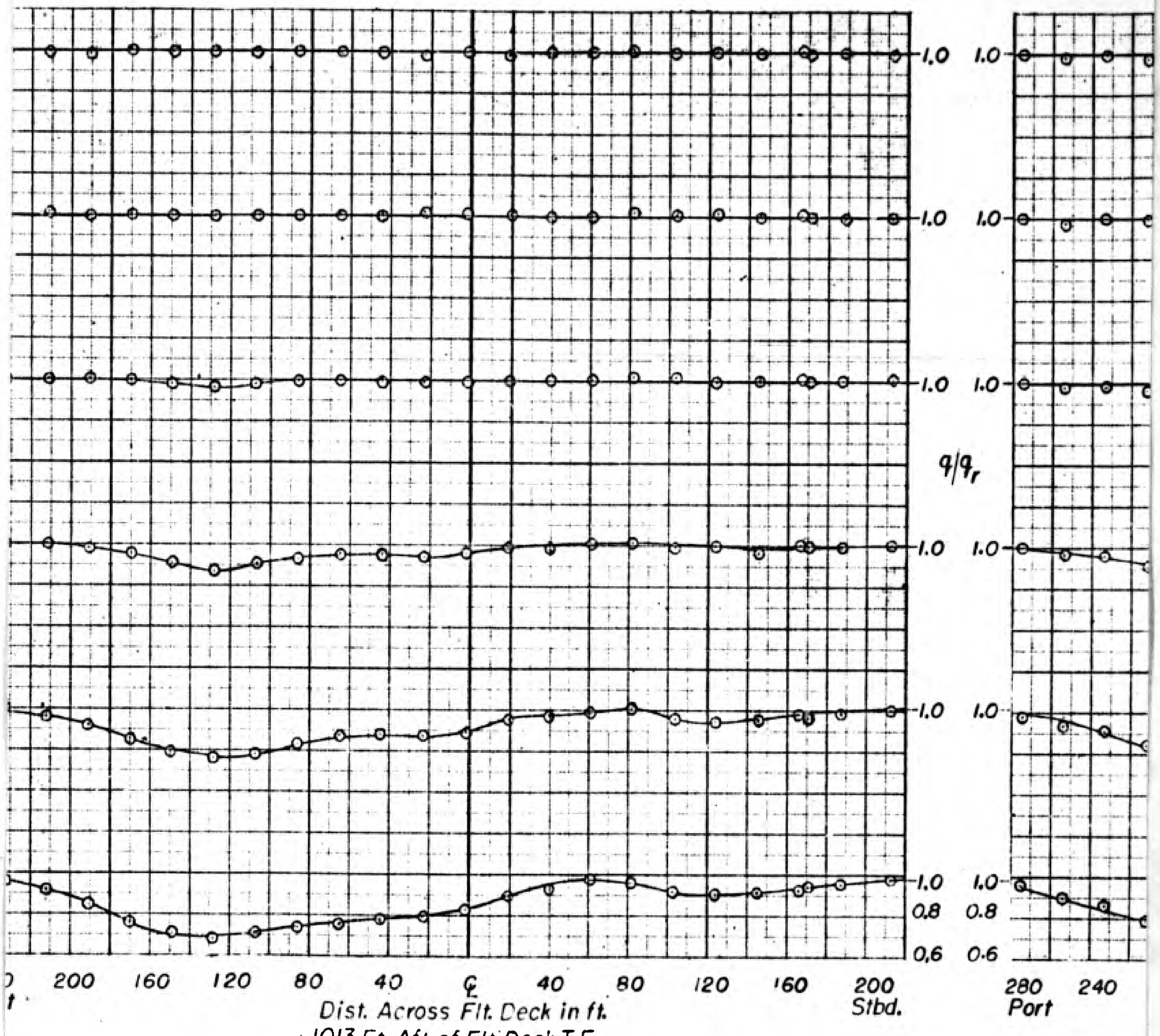

Figure 8 (Continued)
(b) Concluded

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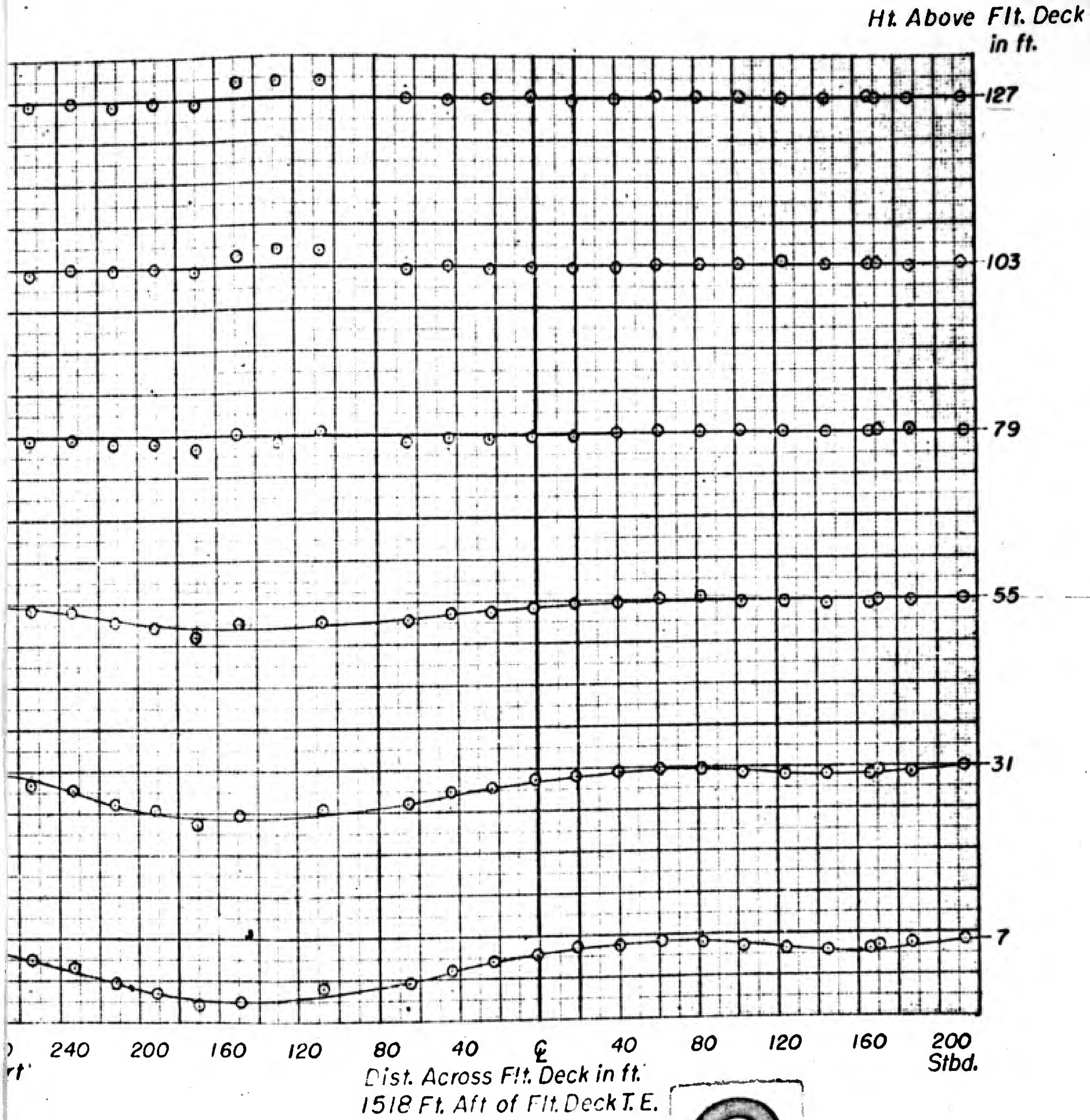

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FIGURE 8 b (concl)

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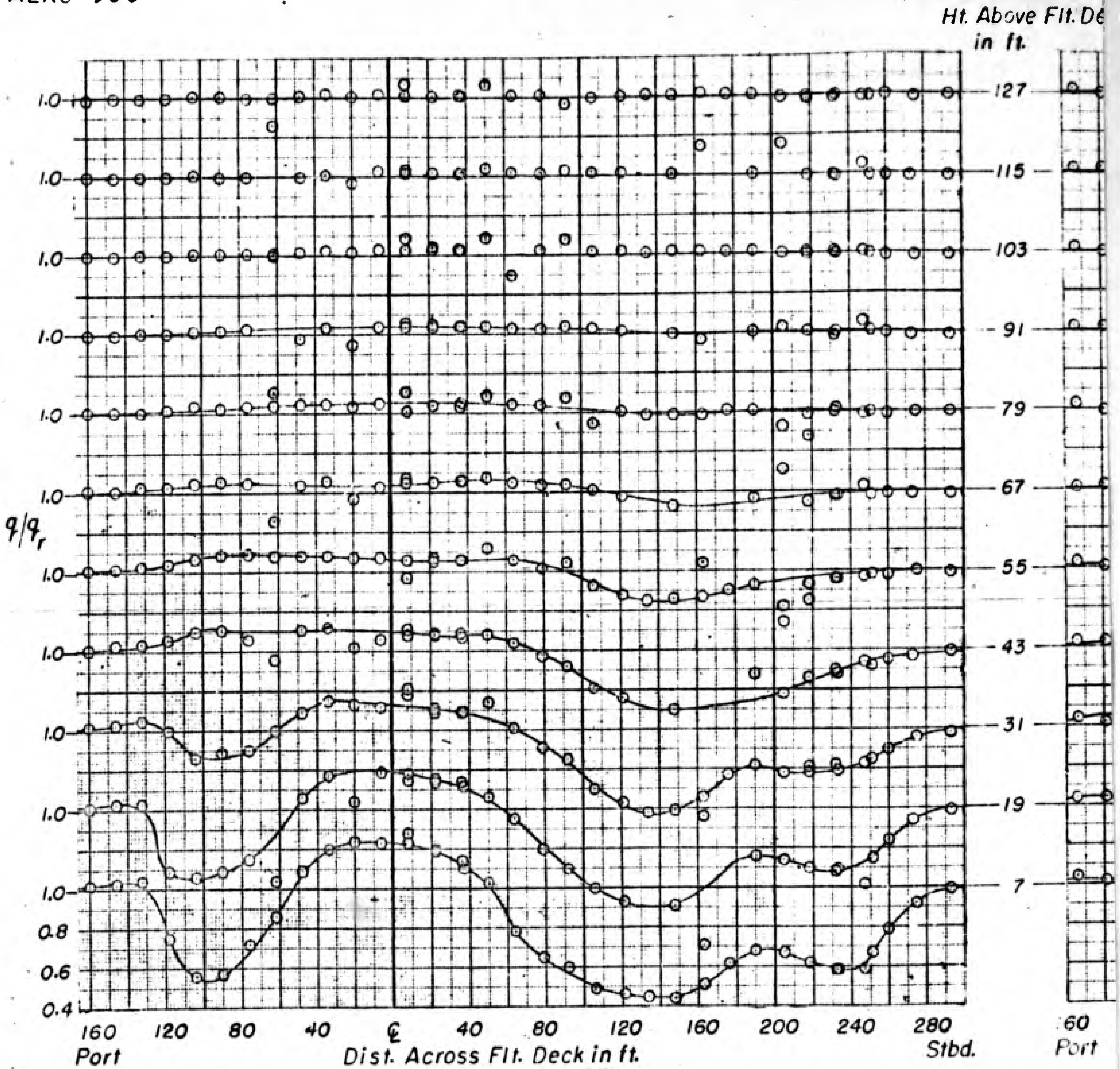

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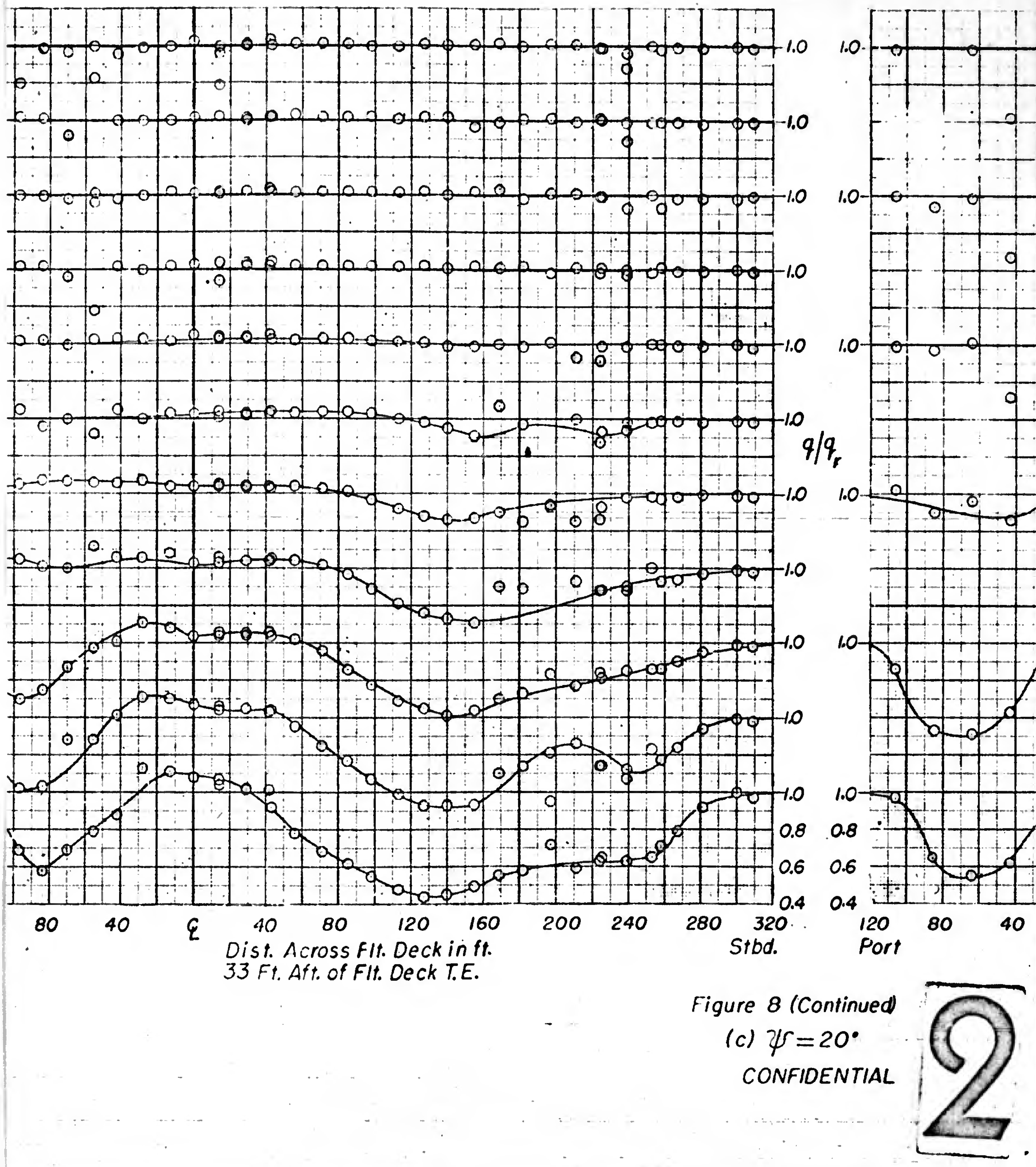
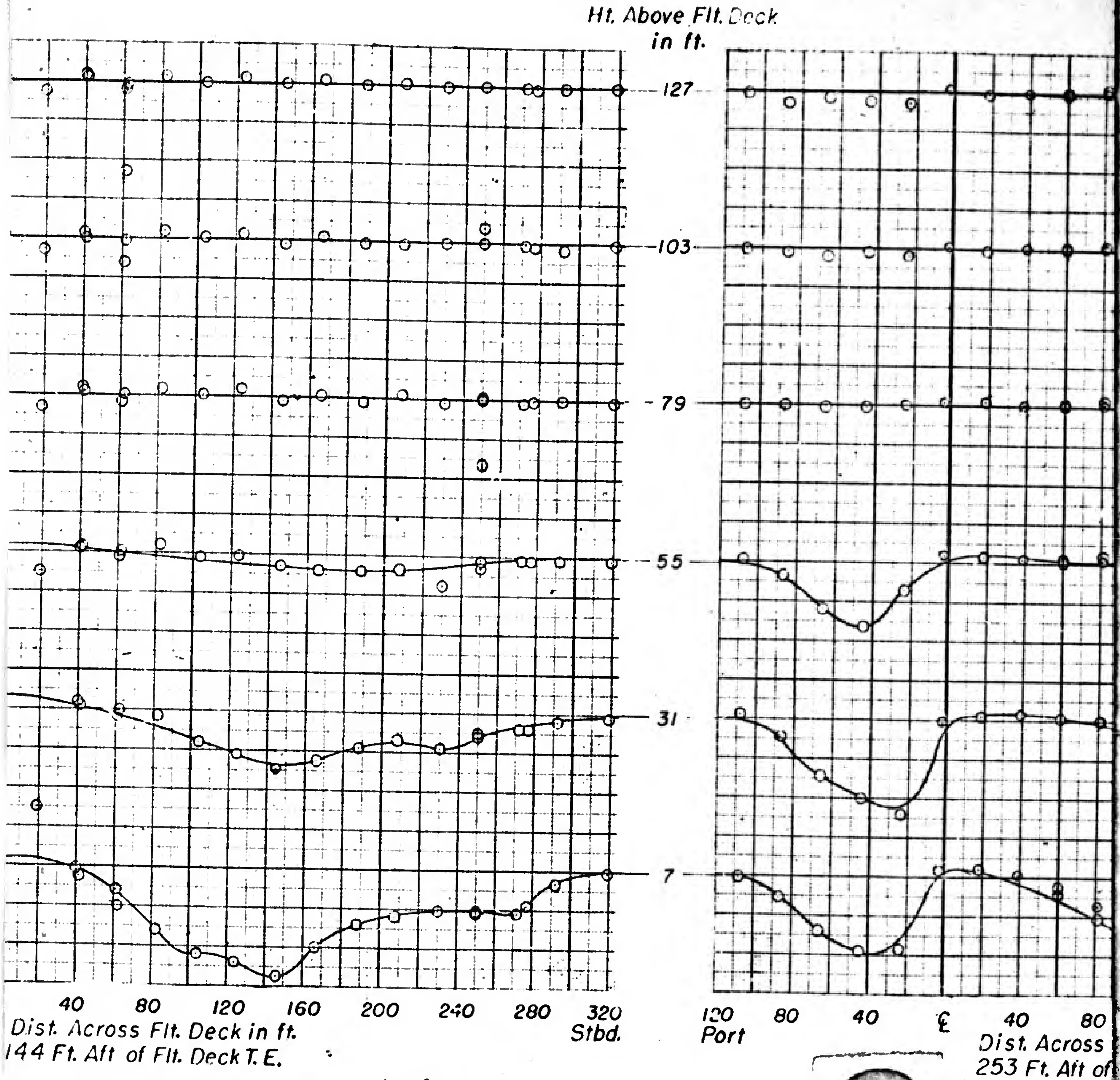


Figure 8 (Continued)

(c) $\psi = 20°$

2



26' Above Flt Deck

Things are going "APE"

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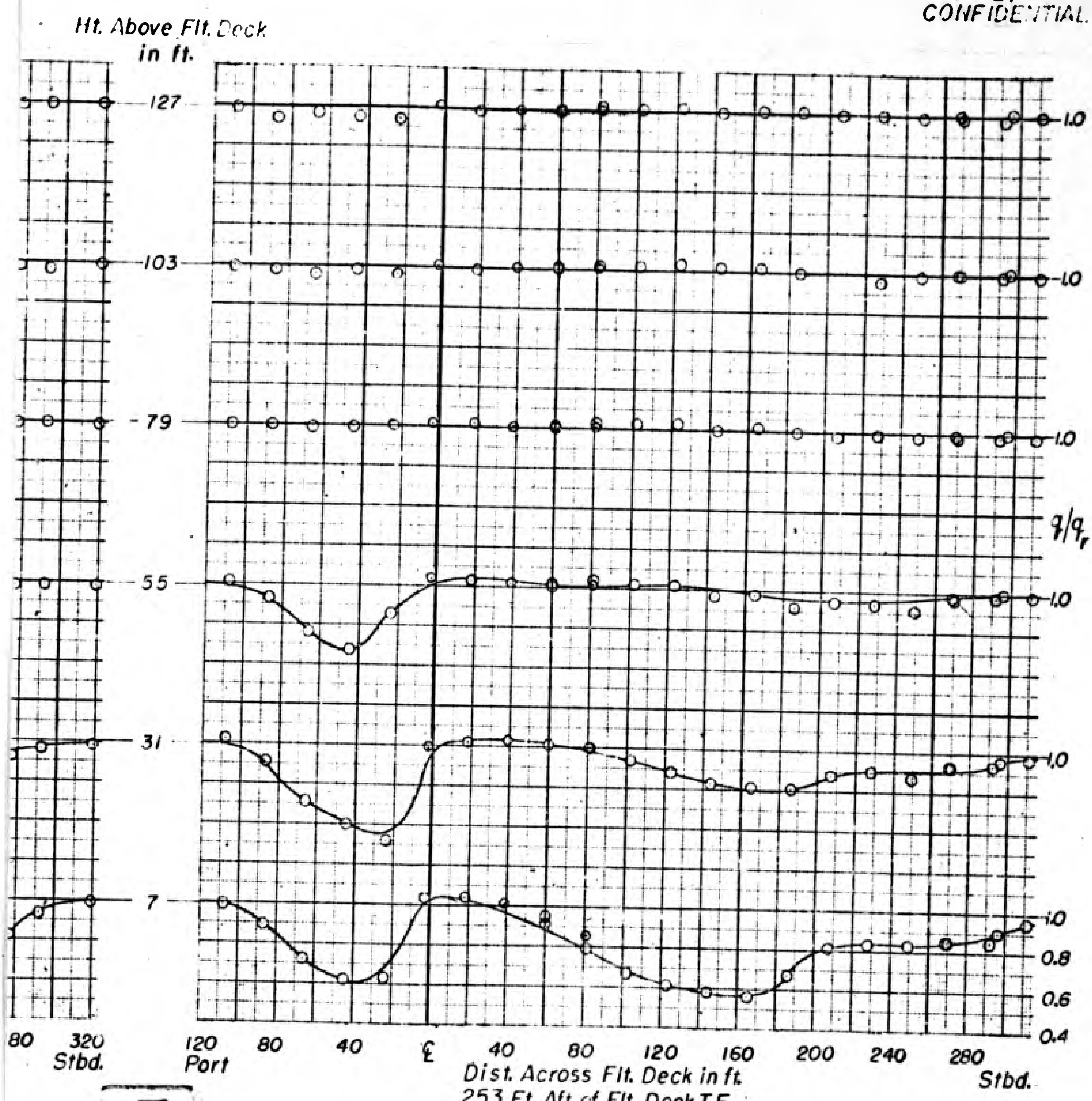
3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0.8
0.6
0.4
80
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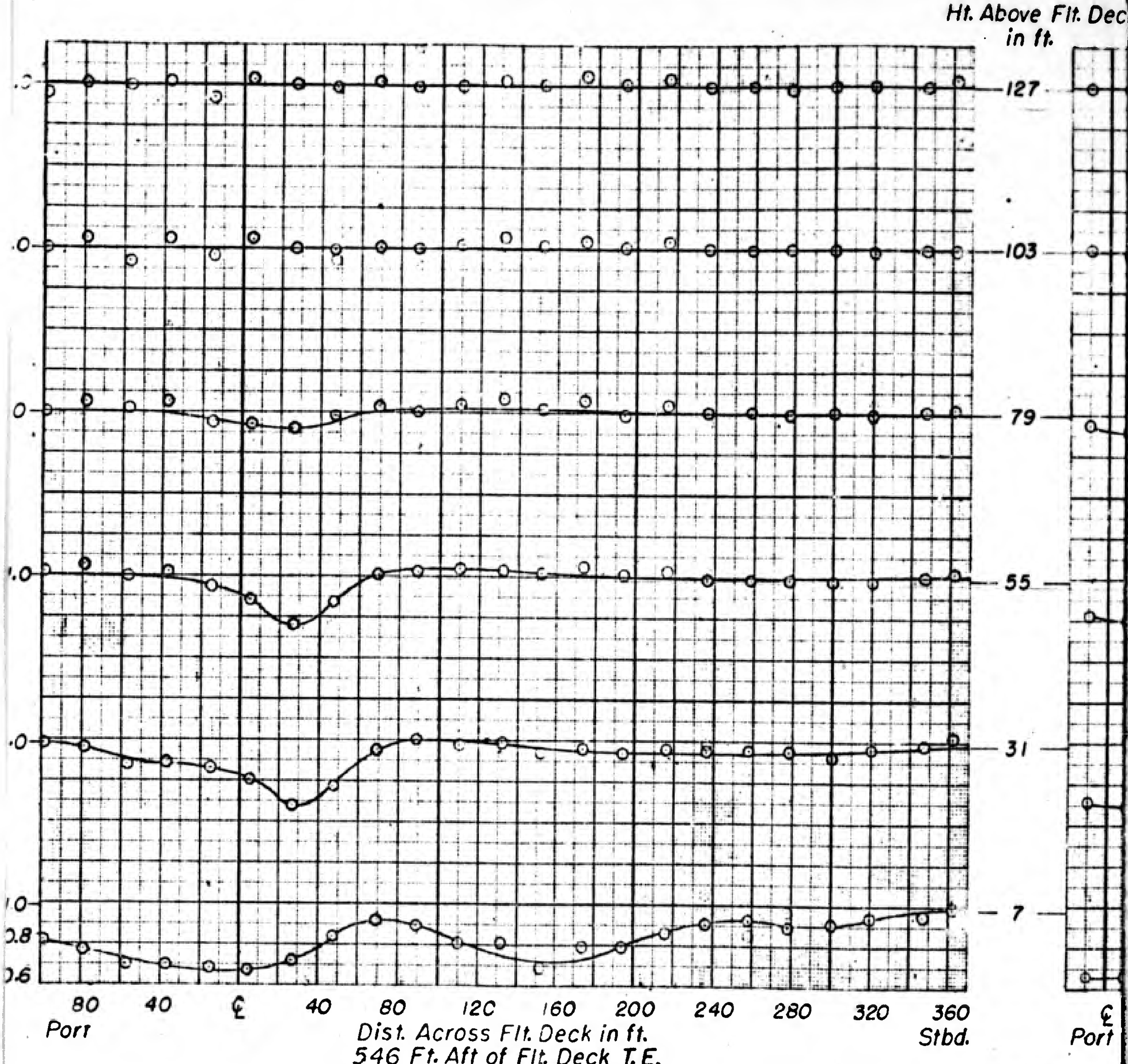
Stbd.
120
Port
80
40
℄
40
80
120
160
200
240
280
Stbd.
Dist. Across Flt. Deck in ft.
253 Ft. Aft of Flt. Deck T.E.

4

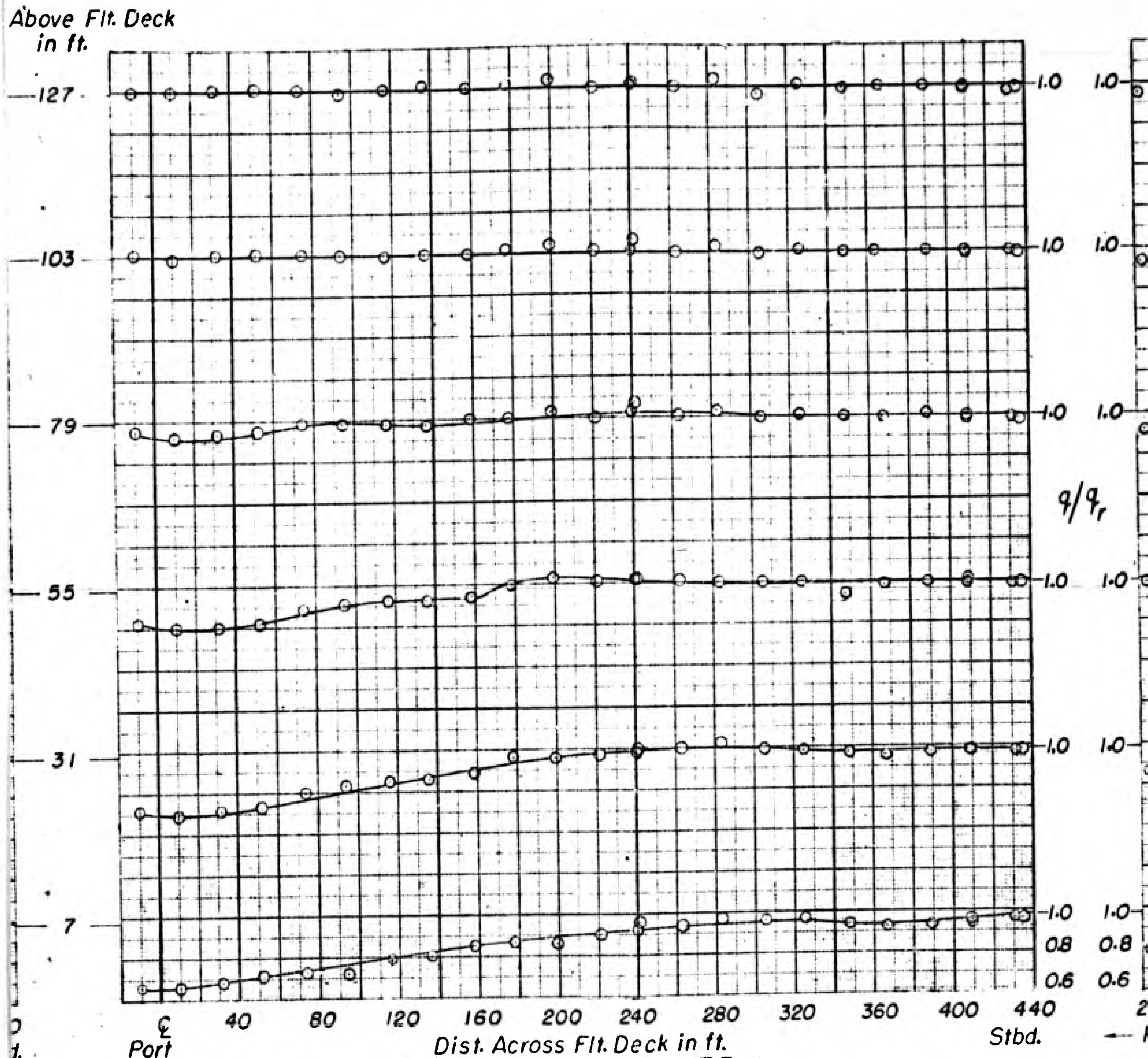
FIGURE 8 c

50 955



24 May.'58

1



Dist. Across Flt. Deck in ft.
1058 Ft. Aft of Flt. Deck T.E.

Figure 8 (Concluded)

(c) (Concluded)

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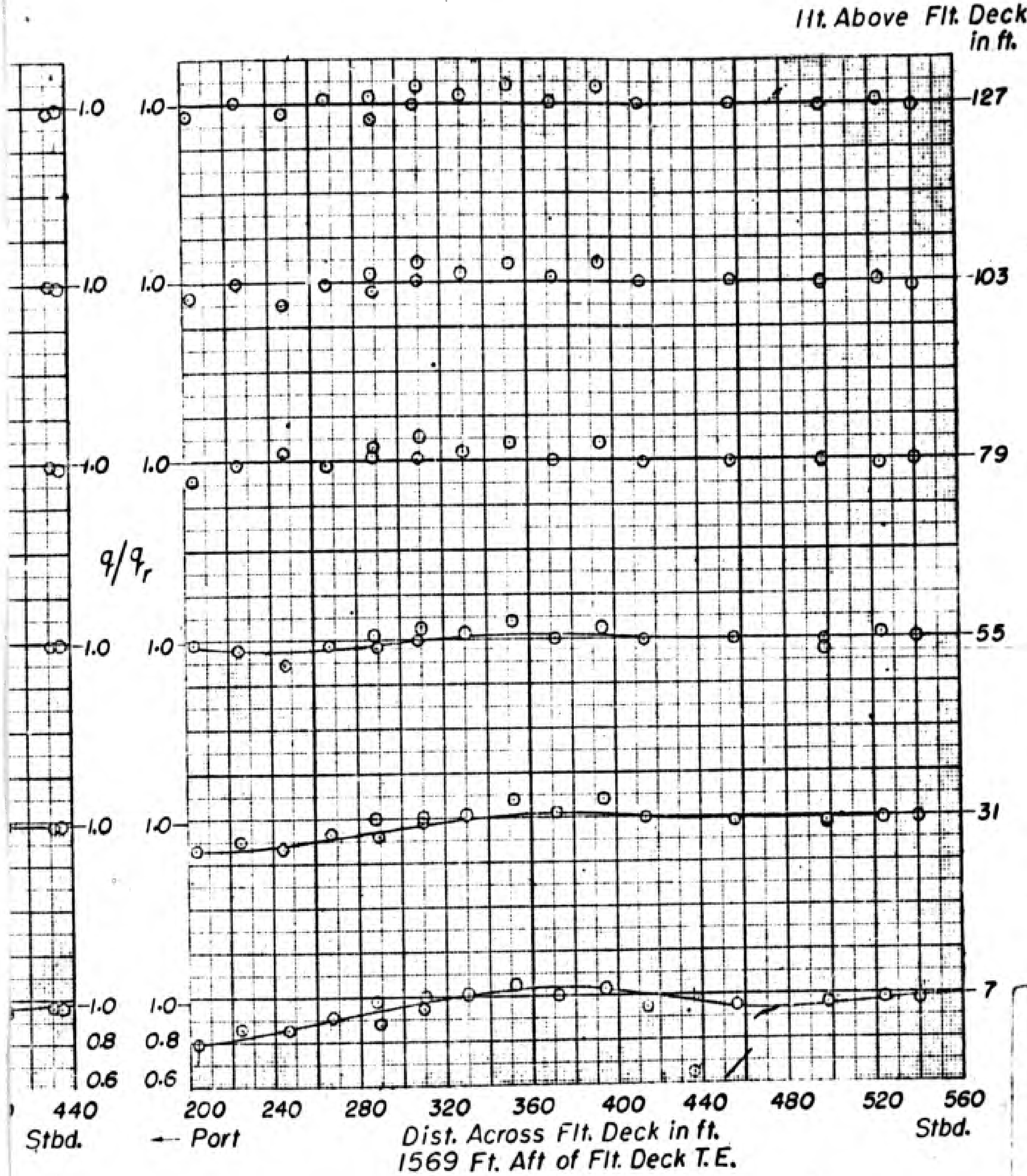

3

FIGURE 8 c (concl)

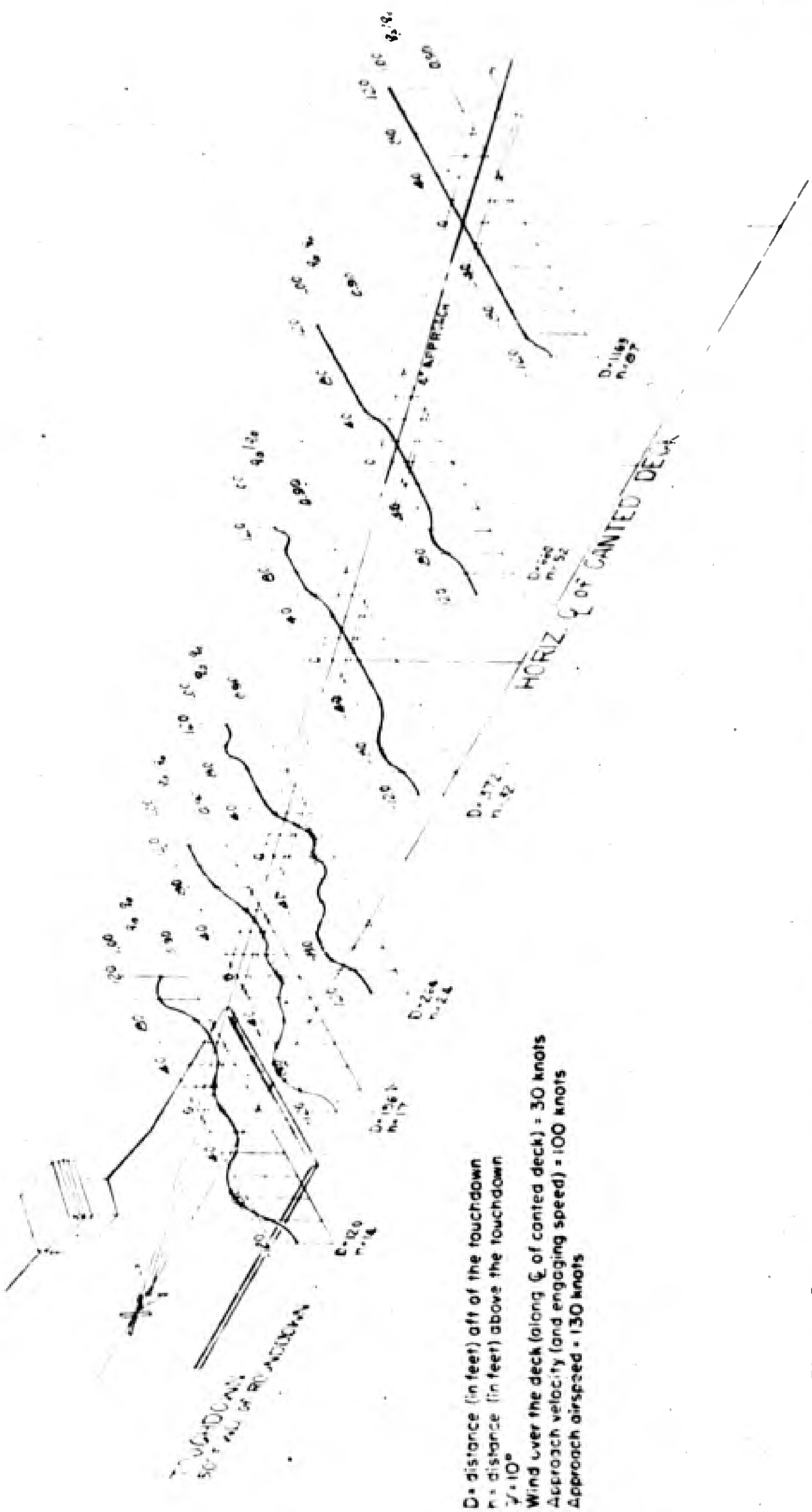

Figure 9 - Local Dynamic Pressure Ratios Encountered by an Airplane Approaching the CVA 65

DTMB Aero Rpt 955 Pt. 1

David Taylor Model Basin. Rpt C-1051
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