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WIND TUNNEL EXPERIMENTS ON A 1/48 SCALE MODEL TO INVESTIGATE FU--ETC(U)
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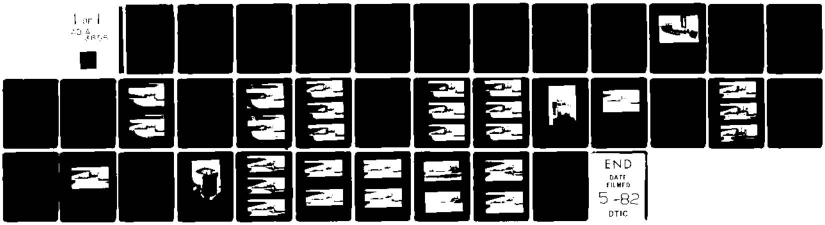

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DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION
AERONAUTICAL RESEARCH LABORATORIES
MELBOURNE, VICTORIA

AERODYNAMICS NOTE 404

WIND TUNNEL EXPERIMENTS ON A 1/48 SCALE MODEL TO INVESTIGATE FUNNEL EFFECTIVENESS OF THE RAN AMPHIBIOUS HEAVY LIFT SHIP

by

K. A. O'DWYER

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SUMMARY

The exhaust flow from the funnel of the RAN Amphibious Heavy Lift Ship has been investigated visually in a low-speed wind tunnel, using a 1/48 scale model. The effectiveness of the funnel as designed was found to be unsatisfactory and a funnel configuration, increased in height by 4.57 metres (15 feet), was then developed which eliminated contamination of a helicopter parked on the aft landing/servicing deck for the selected test conditions.

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ABSTRACT

The exhaust flow from the funnel of the RAN Amphibious Heavy Lift Ship has been investigated visually in a low-speed wind tunnel, using a 1/48 scale model. The effectiveness of the funnel as designed was found to be unsatisfactory. The tests showed that with a modified funnel configuration, increased in height by 4·57 metres (15 feet), contamination in the vicinity of a helicopter parked on the aft landing/servicing deck was eliminated for the selected test conditions.

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1. INTRODUCTION

The Department of Defence (Navy) requested that the path of efflux from the funnel on the Amphibious Heavy Lift Ship (AHLS) be examined, with a view to minimizing contamination from funnel effluent of the helicopter servicing area on the aft deck. Tests were carried out using a 1/48 scale waterline model in the 2·7 m by 2·1 m wind tunnel in the period April to June 1979.

2. OPERATIONAL DETAILS

Information on ship's speed, exhaust gas velocity and temperature provided by Navy Office is presented in Table 1,[1] and Figure 1 shows the arrangement of the uptakes in the funnel. Two test cases were to be considered:

(*a*) *cruise*—ship speed 16 kt in a wind of 15 kt on and 10° off the bow, with two main engines, any three of the four diesel generators, boiler L and the incinerator operating;

(*b*) *at anchor*—ship anchored or moored to a buoy in a wind of 15 kt on and 10° off the bow with two forward or two aft diesel generators, both boilers and the incinerator operating.

3. MODEL AND TEST EQUIPMENT

A timber waterline model (Fig. 2) was manufactured to a scale of 1:48 from the drawings supplied (Appendix 1). At this scale the model was as large as could be comfortably accommodated in the tunnel working section, while the diameter of the smallest funnel uptakes (diesel generators) were near the minimum from which satisfactory smoke could be produced.

The model was mounted on a turntable set in a groundboard which could be rotated for out-of-wind investigations. Smoke was made by vapourising oil on a hot plate in a container through which was passed inert nitrogen or helium gas to carry it at metered flow rates to the appropriate outlets. The smoke plume was illuminated by overhead lights and backlit by a spotlight. The funnel plumes were photographed on FP4 film using a Hasselblad reflex camera equipped with a 50 mm lens set to ½ second between f 8–f 11. In the reproductions some sharpness of detail has been lost around the edges of the plume for which reason, in some cases, the boundaries have been emphasised by dashed lines.

4. SCALING PARAMETERS

The governing parameter for modelling the smoke plume is the momentum ratio

$$K_V = \rho_g v_g^2 / \rho_a V_R^2,$$

where ρ_g = effluent density,

ρ_a = free stream air density,

v_g = effluent velocity,

V_R = relative wind speed over the ship.

Where buoyancy effects are considered, the parameter used for scaling is

$$K_B = \Delta\rho D g / \rho_a V_R^2,$$

1. Department of Defence (Navy). Letter to ARL dated 23 October 1978. Ref. N2320/2/18.

where $\Delta\rho = (\rho_a - \rho_g)$,

D = diameter of funnel uptake,

g = acceleration due to gravity.

Values of K_V and K_B were calculated for both the cruise and anchored test cases (Table 2) over a range of relative wind speeds (Figs 3, 4, 5 and 6).

The model exhaust plume was cold and of such density that K_B was effectively zero, so that the plume was neutrally buoyant. For convenience the tunnel wind speed was maintained at 3 m/s and required values of K_V were obtained by varying the smoke flow rate. In a few selected cases the effects of buoyancy were investigated for comparison with the non-buoyant plume, using helium instead of nitrogen in the model exhaust and setting the appropriate tunnel wind speed.

5. RESULTS

Dimensions are full scale unless specifically stated to be otherwise; funnel height is measured with respect to the funnel deck.

With the ship into wind and the funnel exhausts inoperative the turbulent region over the aft superstructure extended approximately 10·5 m (34′ 6″) above the funnel deck (Figs. 7 and 8). As the model was yawed out of wind the height of the lower boundary of the funnel plume dropped but the loss in height tended to be offset by the progressively shorter length of travel to the side of the ship. The worst case occurred at about 10° of yaw where the boundary of the plume passed close to the helicopter rotor hub and reached the ship's side near to the corner of the aft deck.

The funnel as designed (funnel 1, height 5·71 m (18′ 9″), Fig. 9) discharged its exhaust gases within and far below the top of the turbulent region. As a result effluent contaminated the aft decks for all test cases, as shown in Figures 10 and 11 for a cruise and anchored case respectively. Initially, the funnel was raised 4·27 m (14′, funnel 2, Fig. 9) and a top plate (top plate 1) added, but these modifications did not provide sufficient improvement for the effluent to clear the parked helicopter and aft deck (Fig. 12*a*, *b* and *c*). A further modification to the funnel top (similar to that developed for HMAS *Moresby*,[2] Fig. 13) was then made to facilitate separation of the exhaust gases from the top plate (Fig. 13, designated funnel top MOD. 1). This purpose was achieved by lowering and tilting the rain plate to direct free stream air (taken in via an inlet slot at the funnel crown) through an exit slot to the lower surface of the top plate. Funnel 2 fitted with the repositioned rain plate, which slightly lowered the overall funnel height, was re-designated funnel 3 (Fig. 13). When, in addition, the large top plate (no. 2) was fitted and set horizontal, the lower boundary of the plume was raised to an acceptable level (compare Fig. 14*a* and 14*b* cruise, and Fig. 15*a* and 15*b* anchored). In an attempt to effect further improvement the top plate was set at an angle of 10°, rear edge up, but the lower boundary of the plume was not then raised to the level achieved with the plate horizontal (compare Fig. 14*b* and 14*c* cruise, and Fig. 15*b* and 15*c* anchored).

At this stage further information was received from Navy Office indicating that the derrick boom was to be carried effectively upright (tilted slightly to starboard) instead of in the lowered position. This placed the boom and a derrick post nearly in line with the mast in front of the funnel when the relative wind was 10° off the starboard bow (Fig. 16), and it was found that this now presented the worst case. In this configuration and with a funnel height of 10·29 m (33′ 9″) the turbulent region extended to about 10·21 m (33′ 6″, Fig. 17). The lower boundary of the effluent from funnel 5(a) (height 10·29 m (33′ 9″) with top plate 2 and incorporating funnel top MOD. 1, Fig. 18) cleared the helicopter and aft deck (Fig. 19), but further slotting around the funnel rim resulted in the effluent impinging on the aft deck (Fig. 20). Substitution of a more slender funnel top section (funnel 7 also with a large top plate, Fig. 22) failed to show further improvement (for example compare Fig. 19 with Fig. 21).

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2. Malone, P. T. Development of a funnel to reduce exhaust contamination in a survey ship. Unpublished ARL (Aero.) work.

Rearranging the uptakes in the funnel crown (uptake MOD. 1, Fig. 23) to reduce the blockage of the incoming airflow through the funnel top (funnel top MOD. 1), did provide some further improvement (compare Fig. 21 with Fig. 24).

After due consideration of these results agreement was reached with Navy Office to test the following probable final configuration (designated funnel 8, Figs. 25 and 26), with:

(1) funnel height 10·29 m (33′ 9″), an extension of 4·57 m (15′) over the design funnel height;

(2) the upper and lower plan shapes of the design funnel (Fig. 1) retained;

(3) funnel top MOD. 1 incorporated;

(4) a large horizontal top plate at the top rim of the funnel (top plate 2);

(5) the modified uptake configuration (uptake configuration MOD. 1, Fig. 23) incorporated.

Navy Office also then agreed to an extension of the uptakes above the funnel rim to a maximum of 0·38 m (15″). Subsequent tests with the uptakes extended 0·23 m (9″), 0·30 m (12″) and 0·38 m (15″) respectively, established the optimum at approximately 0·30 m (12″, Fig. 27*a*, *b* and *c*). The 0·30 m (12″) uptake extension was then used in all subsequent work. Louvres which were fitted to the intake slot of the funnel top at the request of the Navy Office, were shown not to effect the funnel performance (Fig. 27*b* and Fig. 28*a*) and were also incorporated in all subsequent work. The height of the lower boundary of the plume from funnel 8 in this final configuration, was shown to clear the helicopter and aft deck adequately for the cruise and anchored cases, with the wind on and 10° off the bow (cruise—Fig. 28*a* and *b*, and at anchor—Fig. 29*a* and *b*).

Where the wind was on the stern significant cases occurred only with the ship at anchor. Scaling parameters applicable are then those listed in Table 2 but with the wind directed onto the stern. Effluent swept the foredeck when the wind was directly on the stern (Fig. 30), and extended amidships when the wind was 10° off the stern (Fig. 31).

Buoyancy effects were briefly investigated using helium as the carrier gas for the plume and adjusting the tunnel wind speed to achieve the correct buoyancy and momentum scaling. In all cases examined the lower boundaries of the buoyant plumes were slightly higher than those of the equivalent non-buoyant plumes (Fig. 32*a* and *b*).

6. CONCLUSIONS

From this investigation it is concluded that:

(1) In the configuration proposed by the Department of Defence (Navy) the effectiveness of the funnel is unsatisfactory.

(2) It is recommended that a funnel similar to funnel 8 be used, which incorporates—

(*a*) an envelope height of 10·29 m (33′ 9″) above the funnel deck;

(*b*) funnel top detail MOD. 1;

(*c*) top plate 2;

(*d*) uptake MOD. 1.

(3) Louvres fitted to the intake slot at the crown of funnel 8 will not effect the funnel performance.

(4) In conditions with the relative wind from the stern, the effluent from funnel 8 is unlikely to descend to the bridge, but will not clear the foredeck area.

APPENDIX 1

Drawings Used to Prepare Model

	Lines drawing (hull)	A 000016
LSH-01	General arrangement, profile	A 000075, sheet 1, issue 2
LSH-01	General arrangement, decks	A 000075, sheet 2, issue 2
LSH-01	General arrangement, 3 deck, 4 deck and tank top	A 000075, sheet 3, issue 2

TABLE 1

Ship Uptake Data

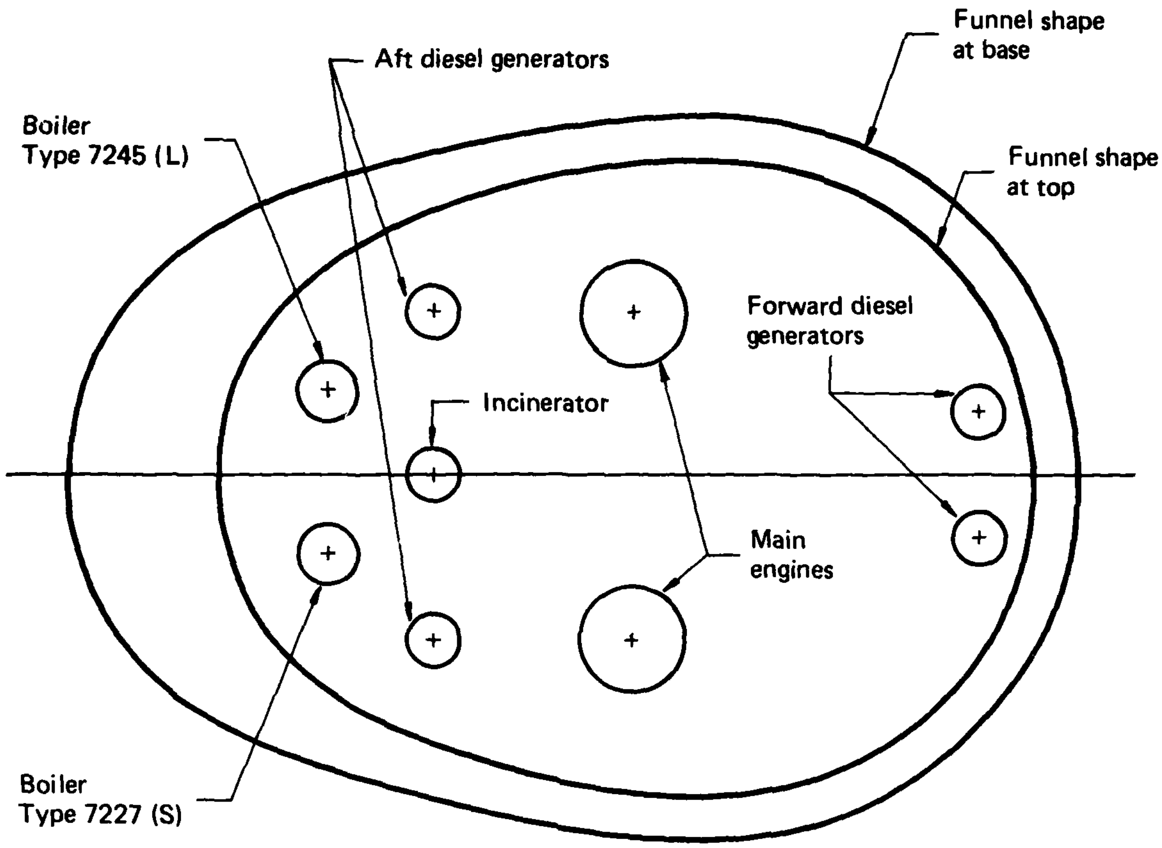
Item	Uptake diameter (mm)	Gas velocity (m/s)	Temperature (°C)
Marine engine exhausts (2 off)	700	38·2	427
Diesel generator exhausts (4 off)	350	27·2	435
Boiler type 7245 (L)	450	12·0	338
Boiler type 7227 (S)	350	12·0	304
Incinerator	400	6·0 (average)	250 (assumed)

TABLE 2

Wind on Bow

Momentum and buoyancy ratios for cruise and anchored test cases

Item	Cruise		At anchor	
	$V_R = 31$ kt (ship speed 16 kt, wind 15 kt)		$V_R = 15$ kt (ship stationary, wind 15 kt)	
	K_V	K_B	K_V	K_B
Main engines	2·28	0·0162	Not running	
Boiler type 7245 (L)	0·26	0·0094	1·11	0·0404
Boiler type 7227 (S)	0·27	0·0070	1·17	0·0299
Diesel generators	1·14	0·0082	4·91	0·0350
Incinerator	0·08	0·0072	0·32	0·0307



Scale 1 : 48 (actual model size)

FIG. 1 ARRANGEMENT OF UPTAKES IN FUNNEL

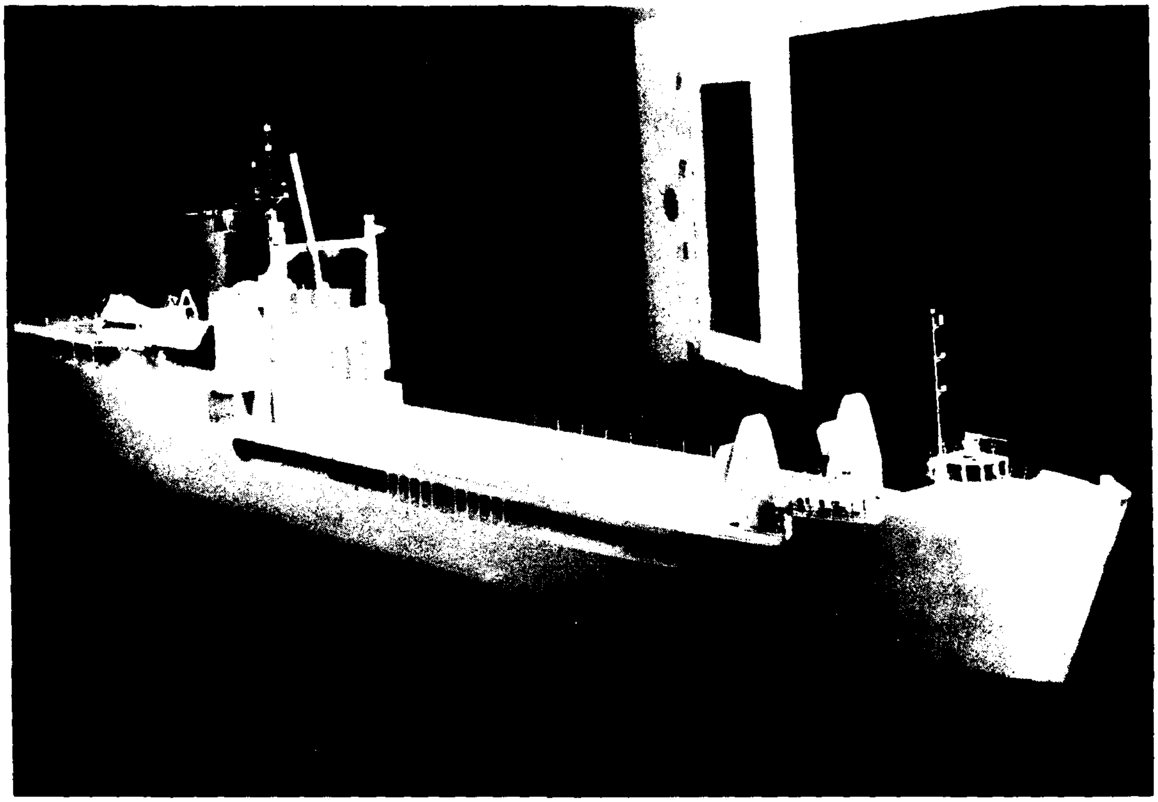


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FIG. 2 – 1/48 SCALE MODEL IN WORKING SECTION

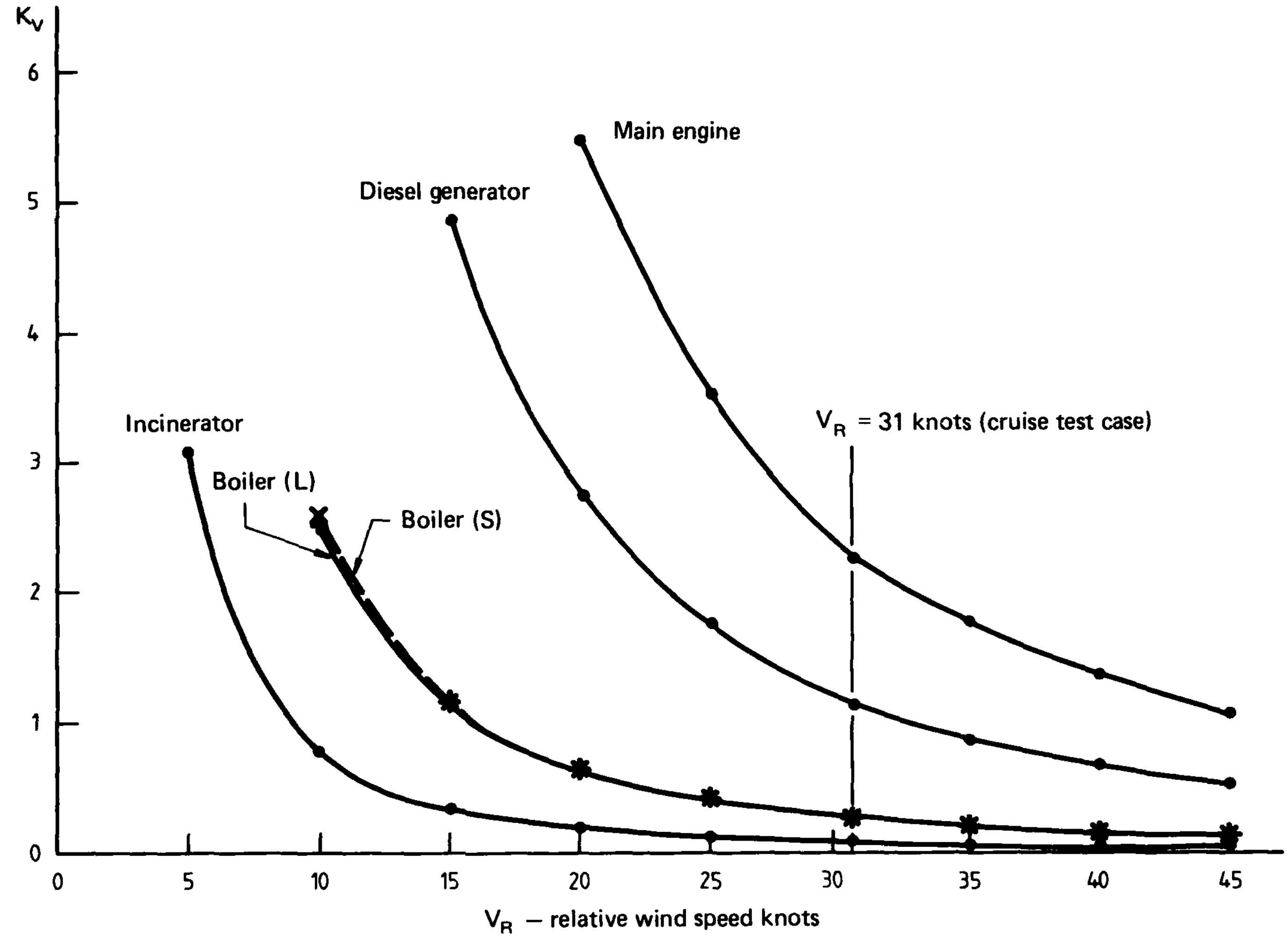

FIG. 3 K_v v RELATIVE WIND SPEED FOR CRUISE CONDITIONS

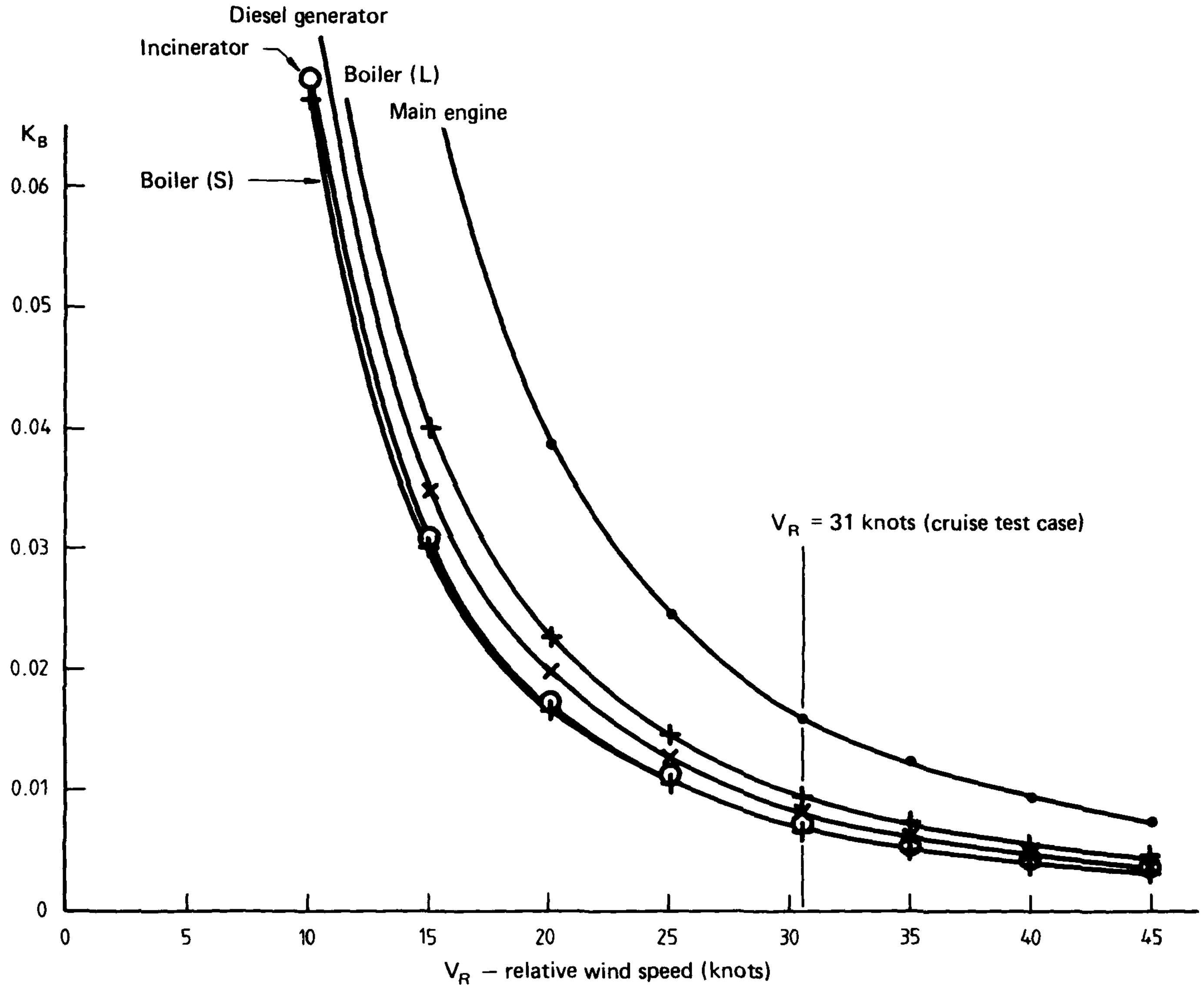

FIG. 4 K_B v RELATIVE WIND SPEED FOR CRUISE CONDITIONS

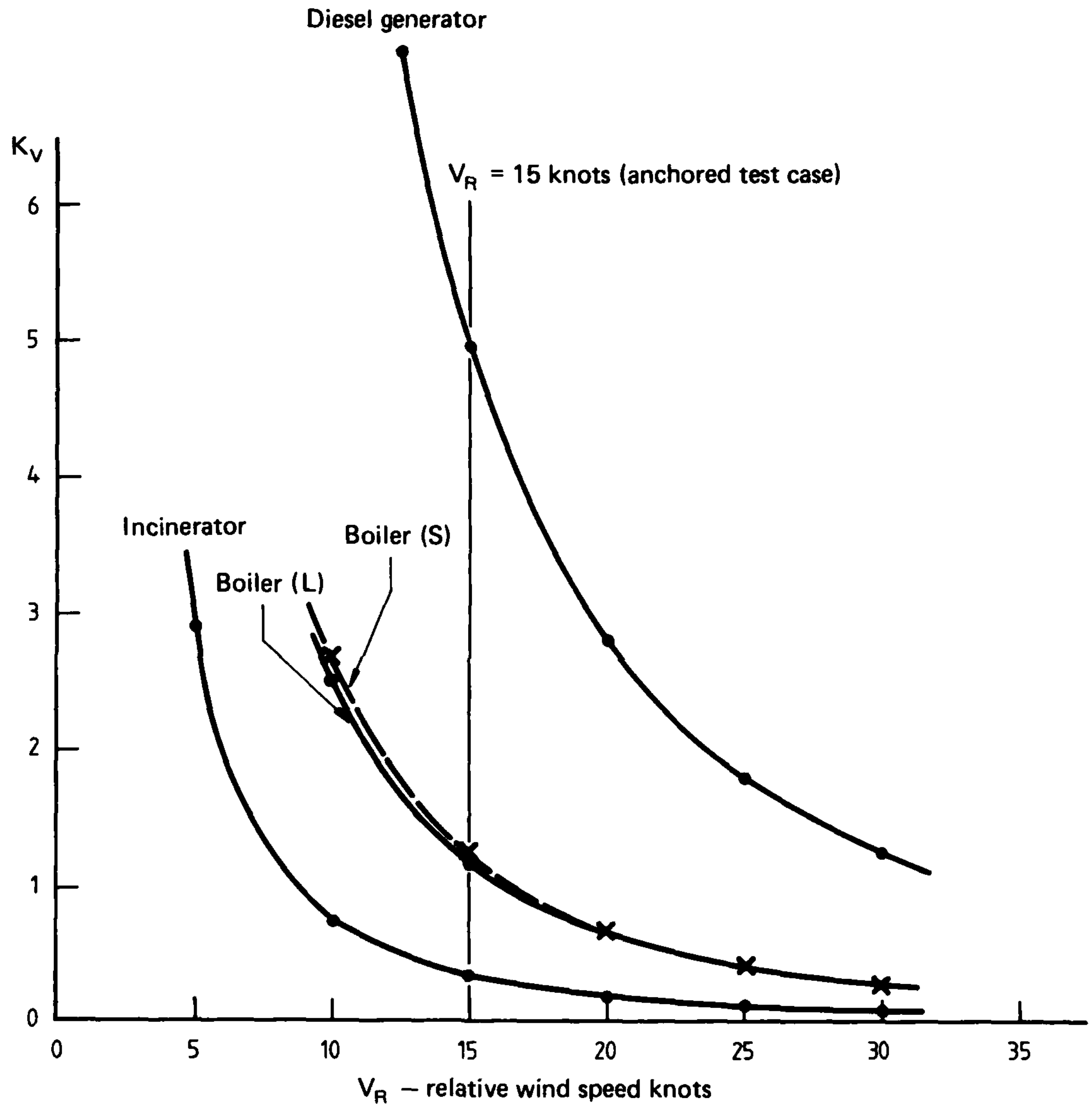

FIG. 5 K_V v RELATIVE WIND SPEED FOR ANCHORED CONDITIONS

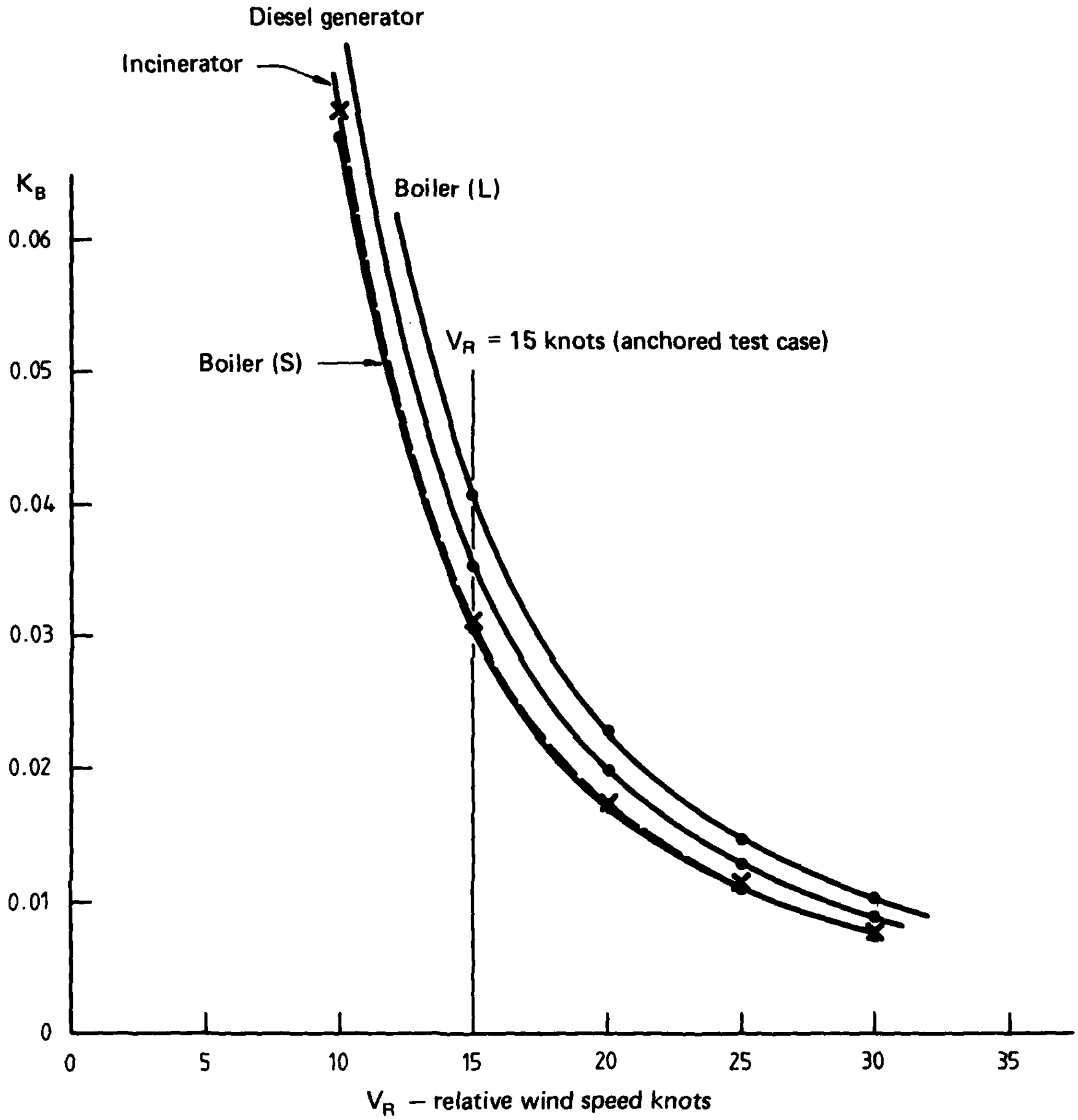

FIG. 6 K_B v RELATIVE WIND SPEED FOR ANCHORED CONDITIONS

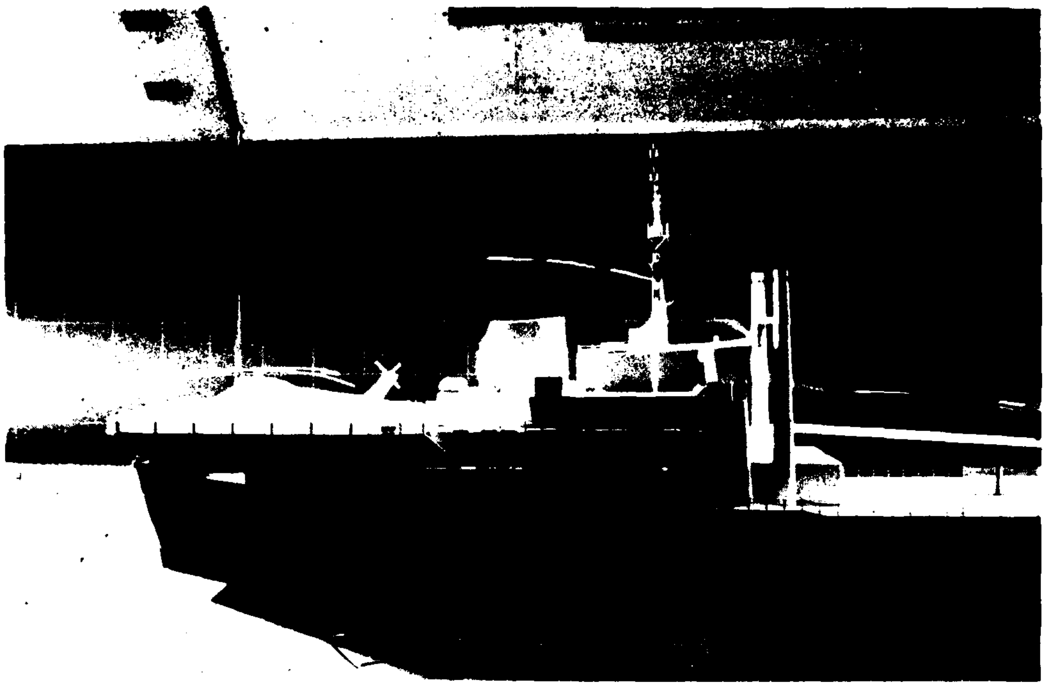

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FIG. 7 HEIGHT OF TURBULENT REGION AT FUNNEL
SHIP INTO WIND, FUNNEL EXHAUSTS INOPERATIVE

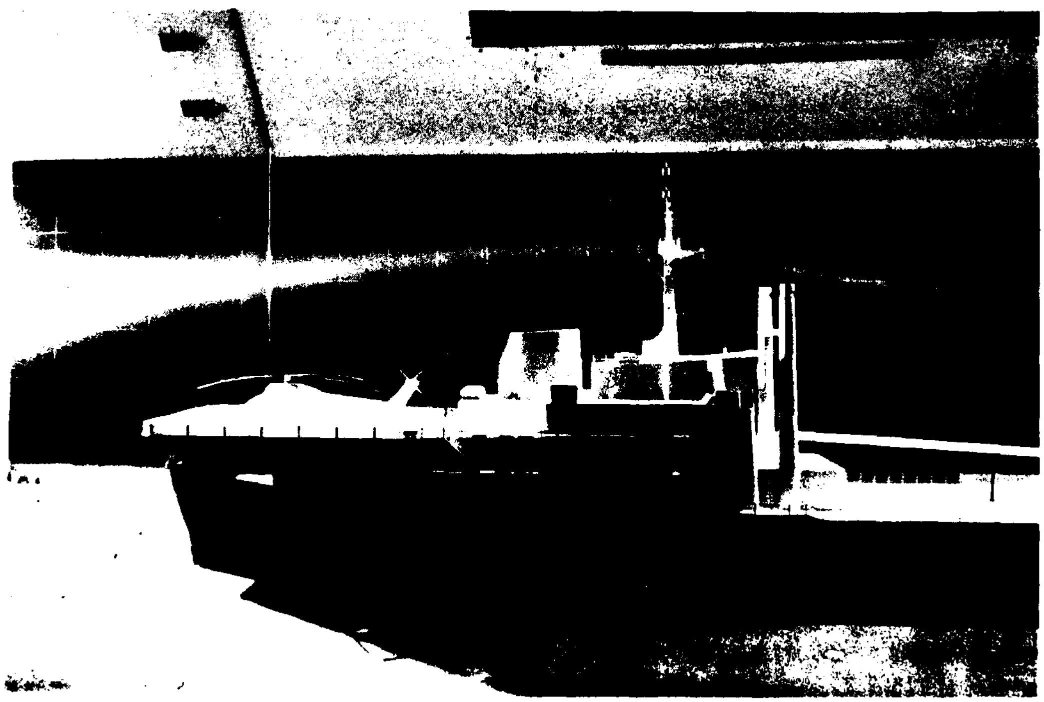

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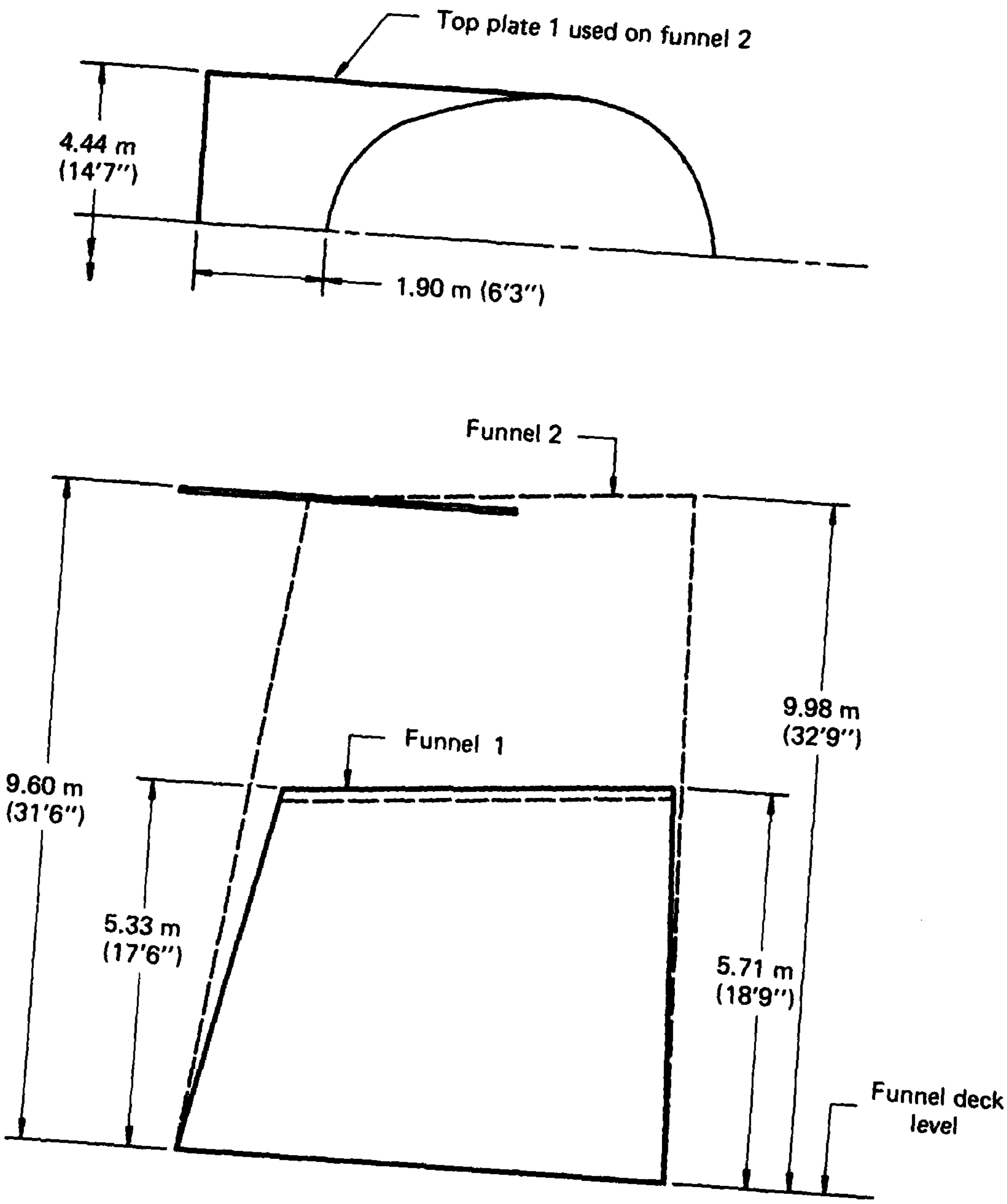
FIG. 8 FLOW ABOVE SUPER-STRUCTURE
SHIP INTO WIND, FUNNEL EXHAUSTS INOPERATIVE



Top and bottom plan shapes shown in Fig. 1
uptakes flush with top of funnel shell

FIG. 9 DESIGN FUNNEL (FUNNEL 1), FUNNEL 2
AND TOP PLATE 1

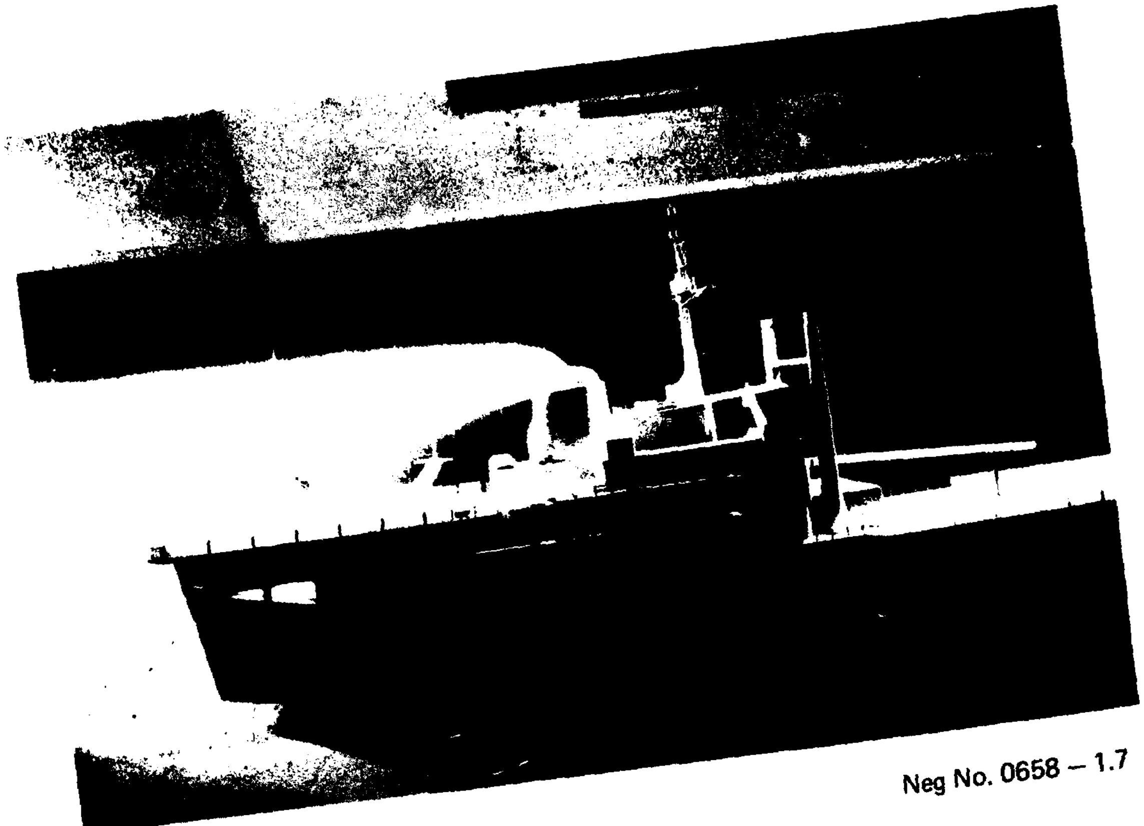


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FIG. 10 DESIGN FUNNEL – CRUISE CASE, WIND 10°
OFF STARBOARD BOW

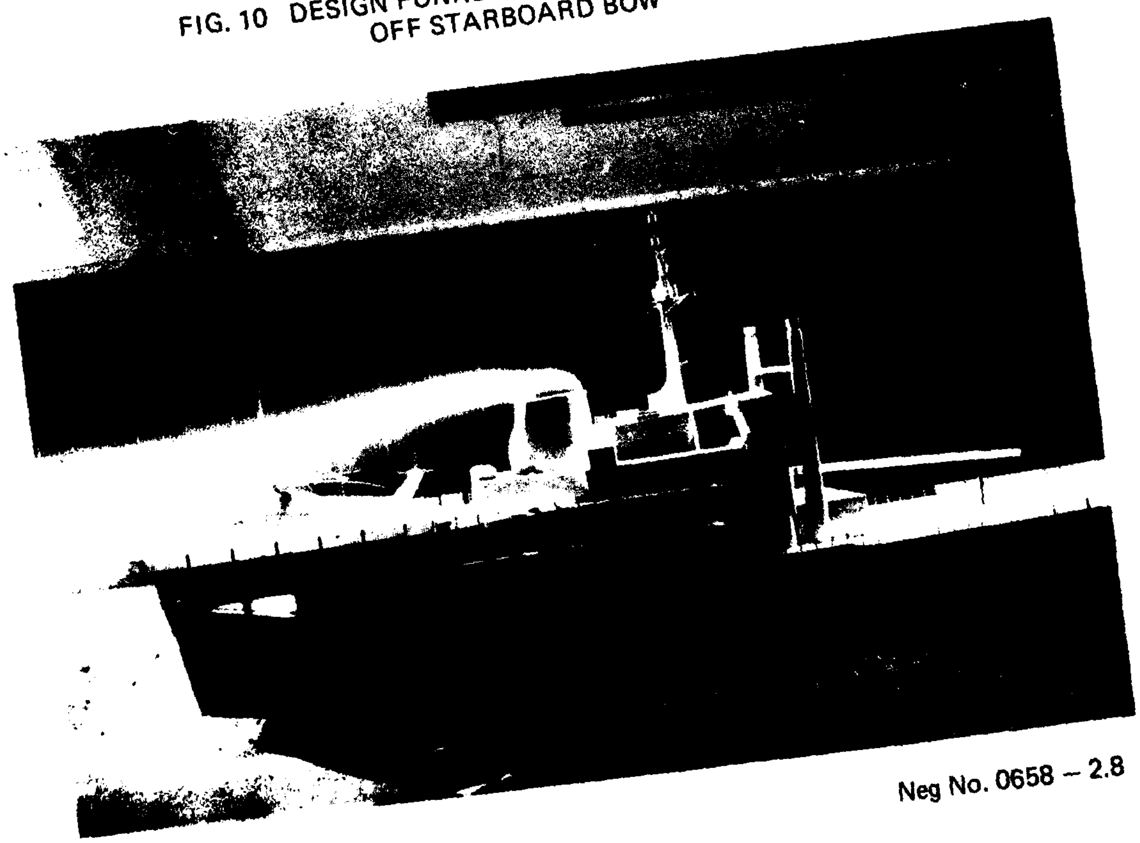

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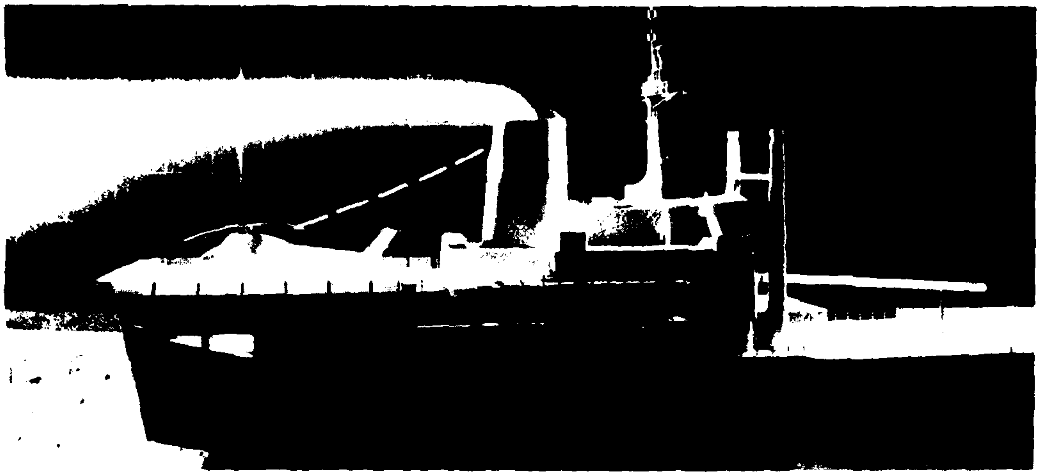
FIG. 11 DESIGN FUNNEL – ANCHORED CASE,
WIND 10° OFF STARBOARD BOW



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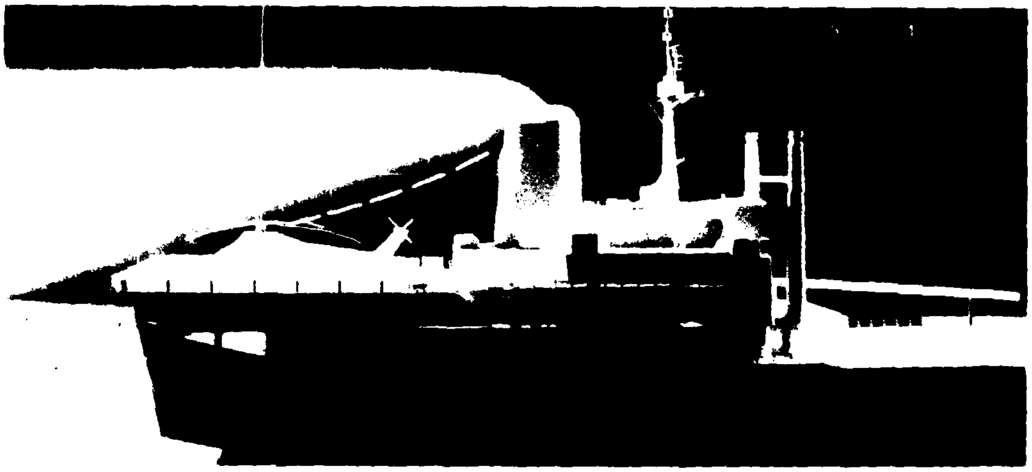
(a) Cruise case – wind 10° off starboard bow



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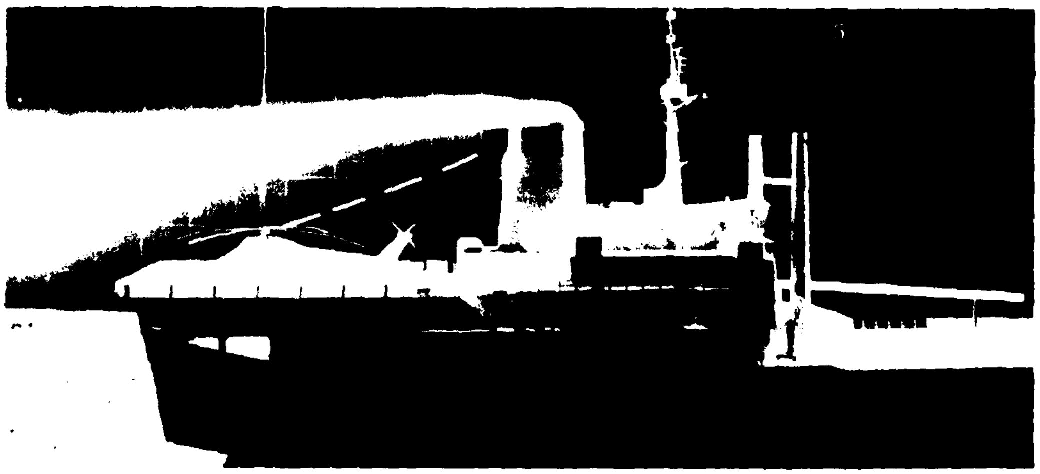
(b) Cruise case – wind 10° off starboard bow
Top plate 1



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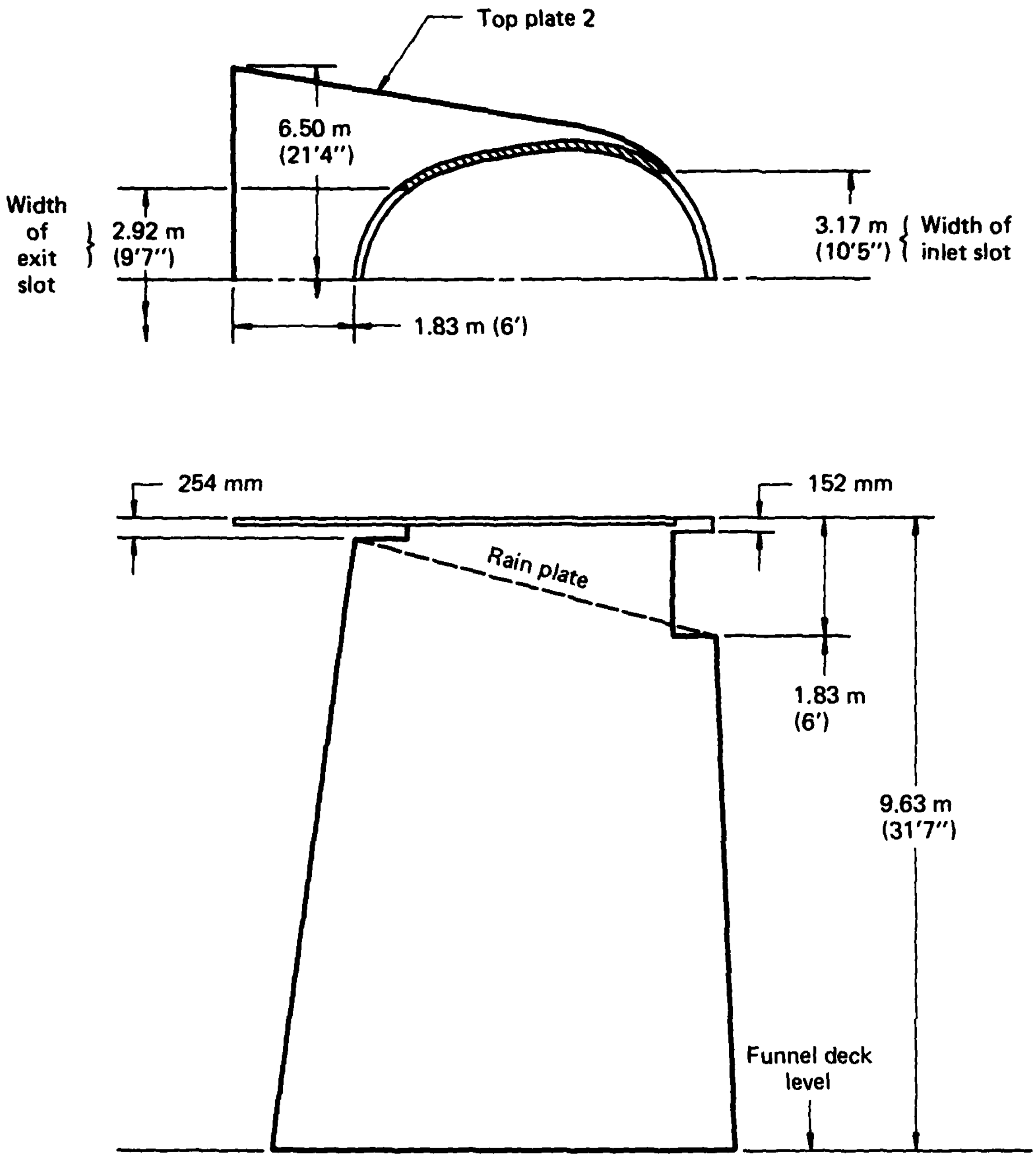
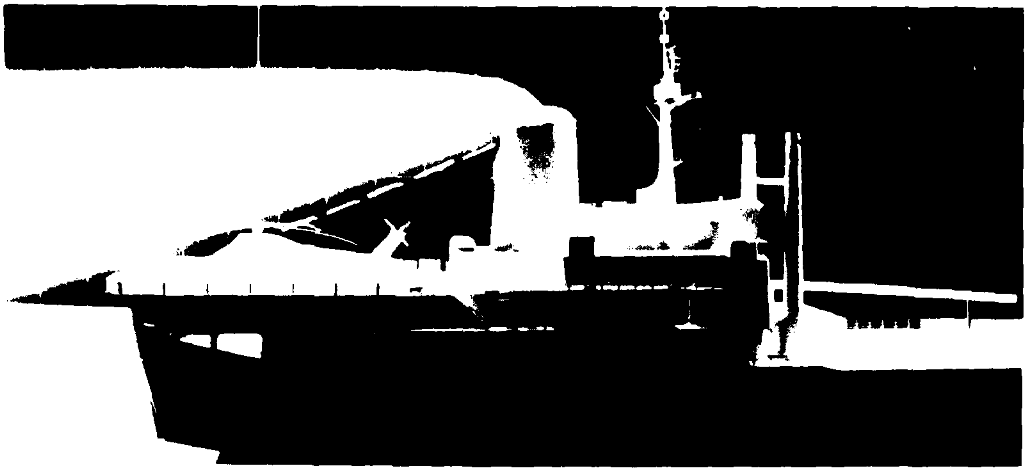
(c) Anchored case – wind 10° off starboard bow
Top plate 1

FIG. 12 FUNNEL 2 (BASIC FUNNEL EXTENDED 4.27m)



Top and bottom plan shapes as for funnel 1 (Fig. 1)

FIG. 13 FUNNEL 3



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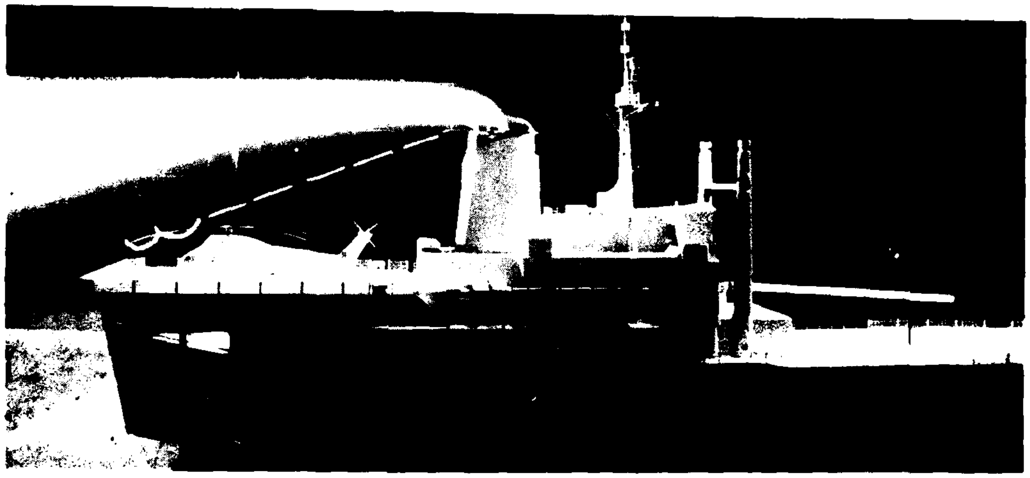
(a) Funnel 2 with top plate 1



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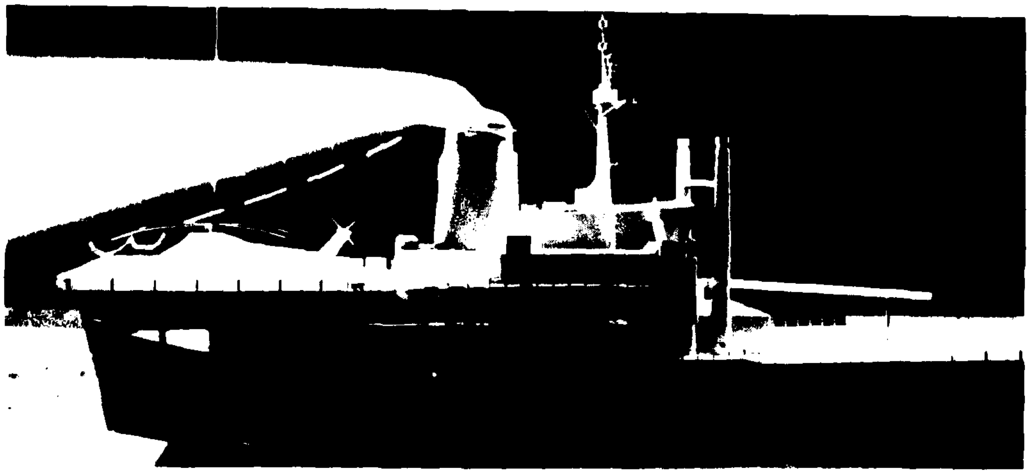
(b) Funnel 3 with top plate 2



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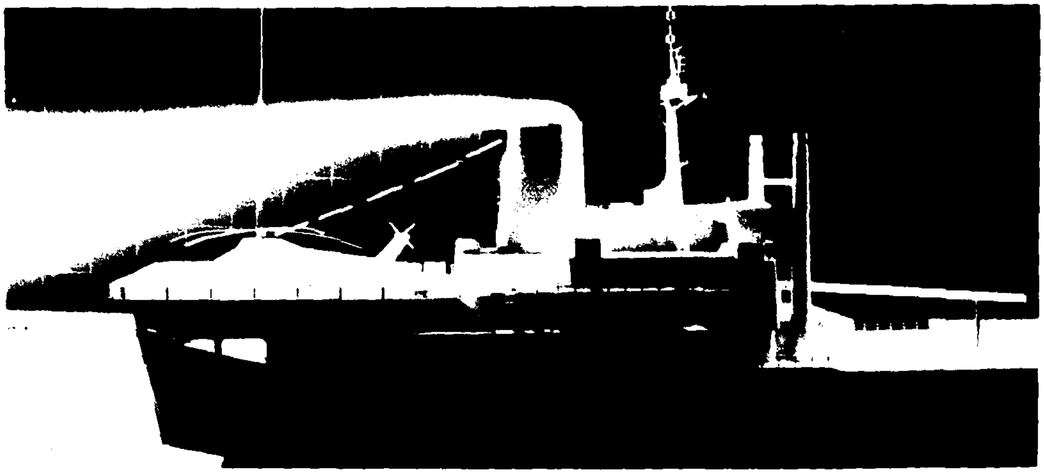
(c) Funnel 3 with top plate 2 angled 10°

FIG. 14 CRUISE CASE, WIND 10° OFF STARBOARD BOW



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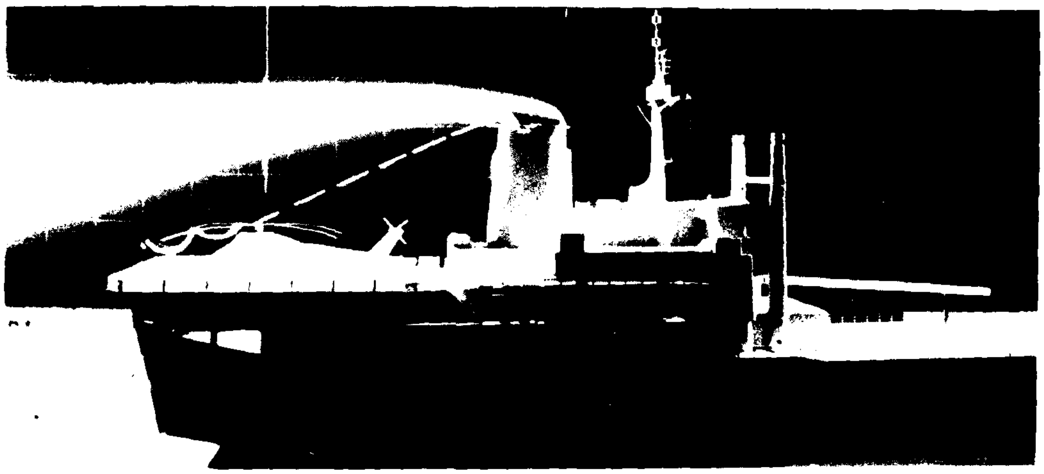
(a) Funnel 2 with top plate 1



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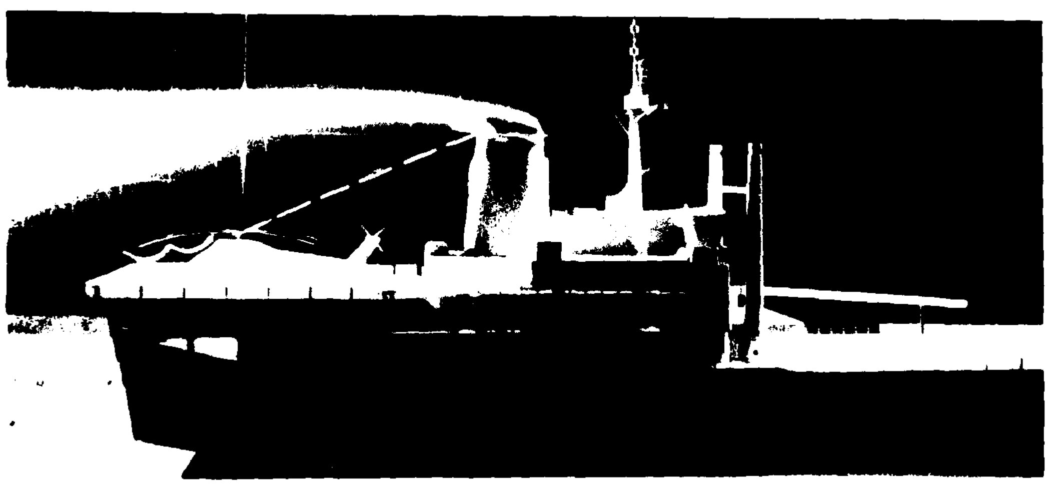
(b) Funnel 3 with top plate 2



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(c) Funnel 3 with top plate 2 angled 10°

FIG. 15 ANCHORED CASE, WIND 10° OFF STARBOARD BOW

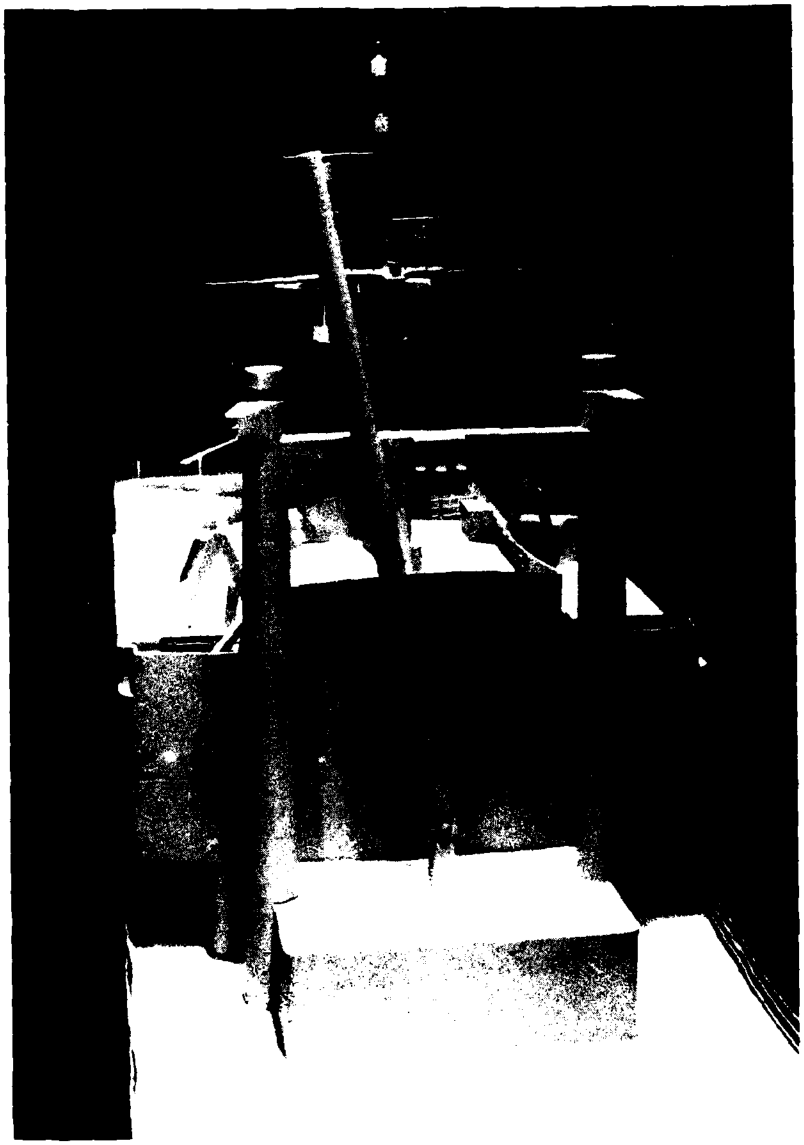

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FIG. 16 VIEW FROM APPROXIMATELY 10° OFF STARBOARD BOW

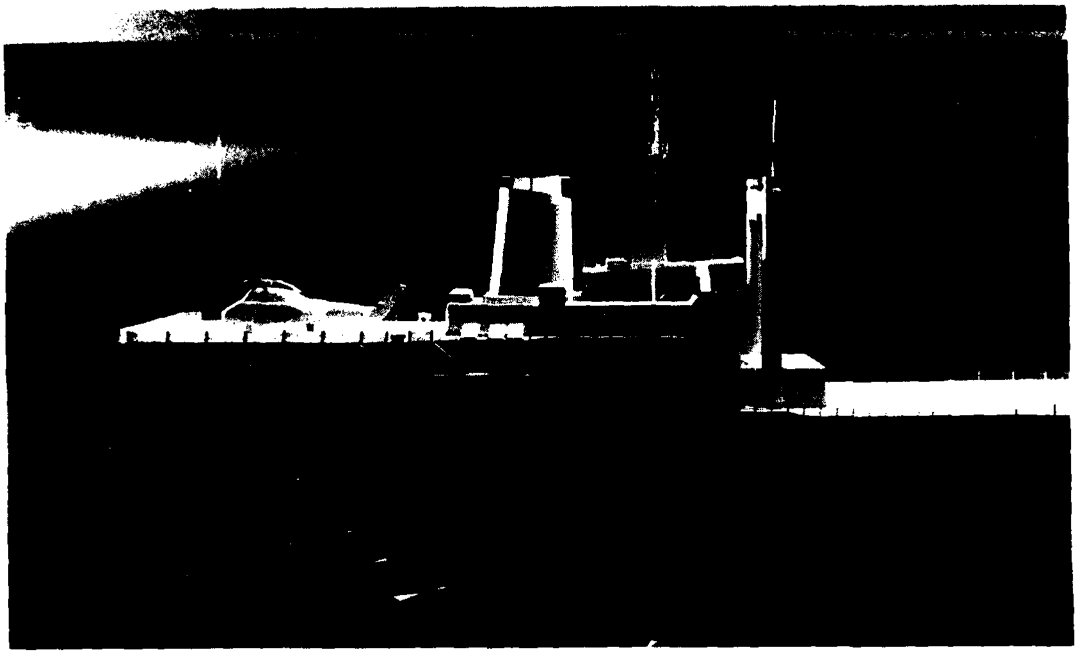

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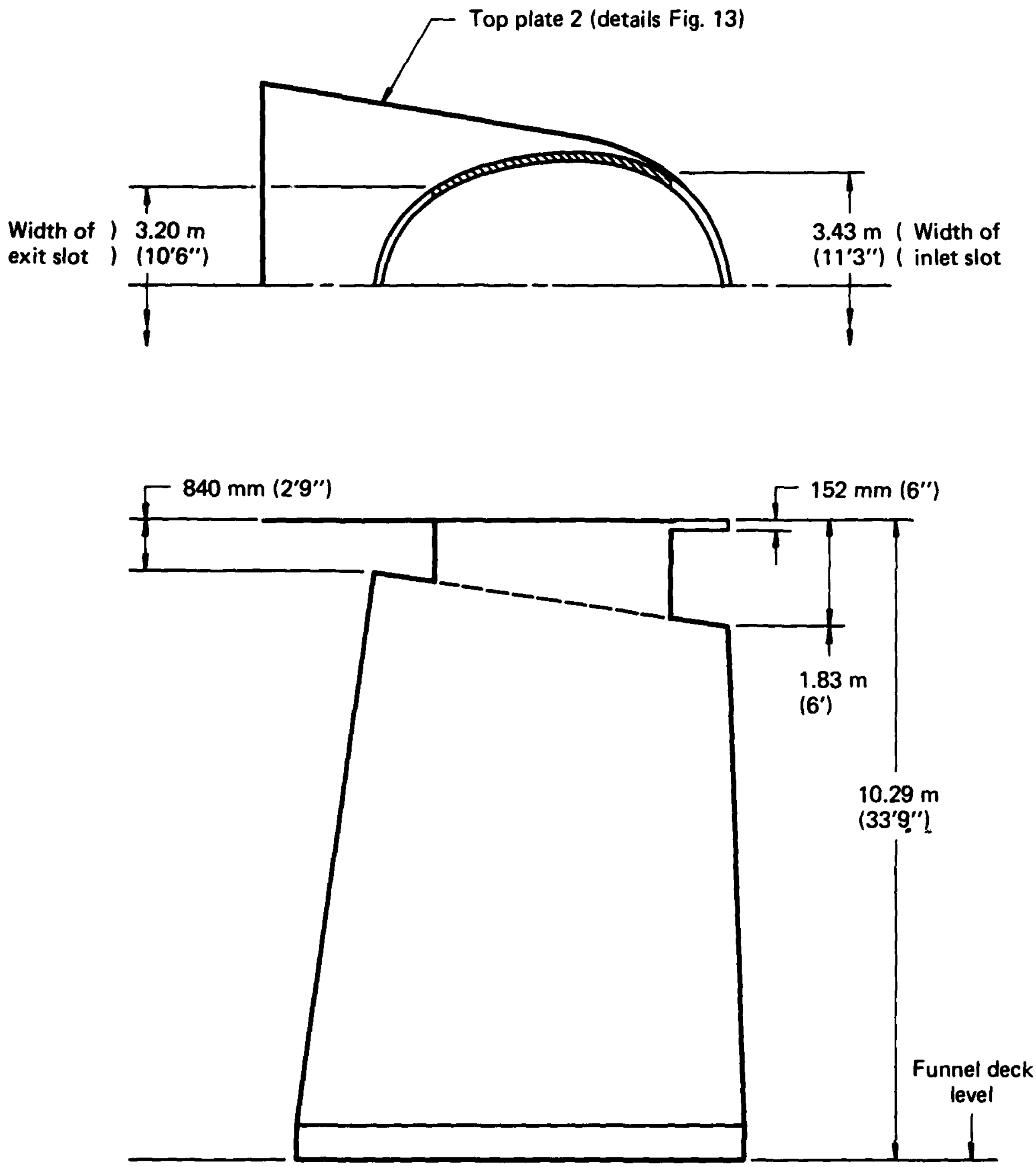
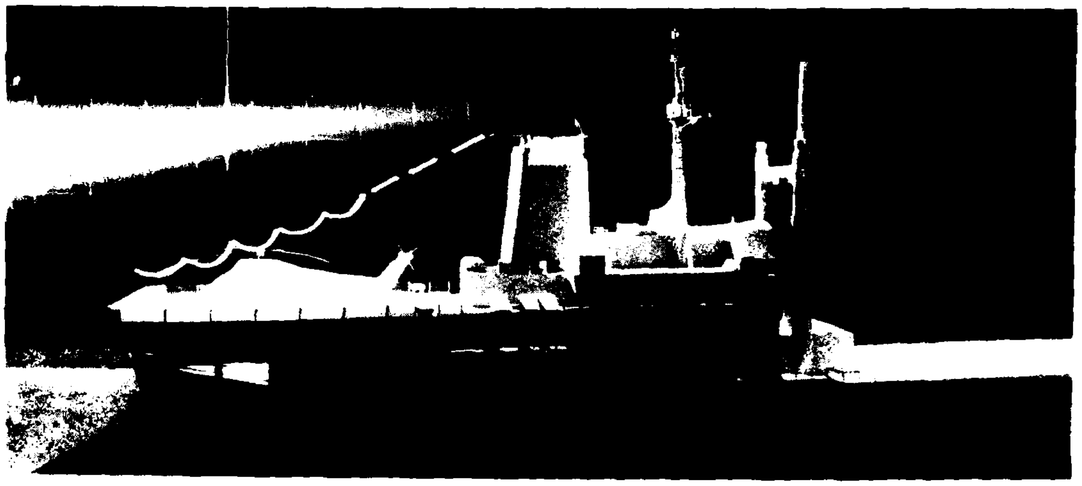
FIG. 17 HEIGHT OF TURBULENT REGION OVER FUNNEL
FUNNEL 5(a) HEIGHT 10.29 m (33'9") SHIP INTO WIND,
FUNNEL EXHAUSTS INOPERATIVE



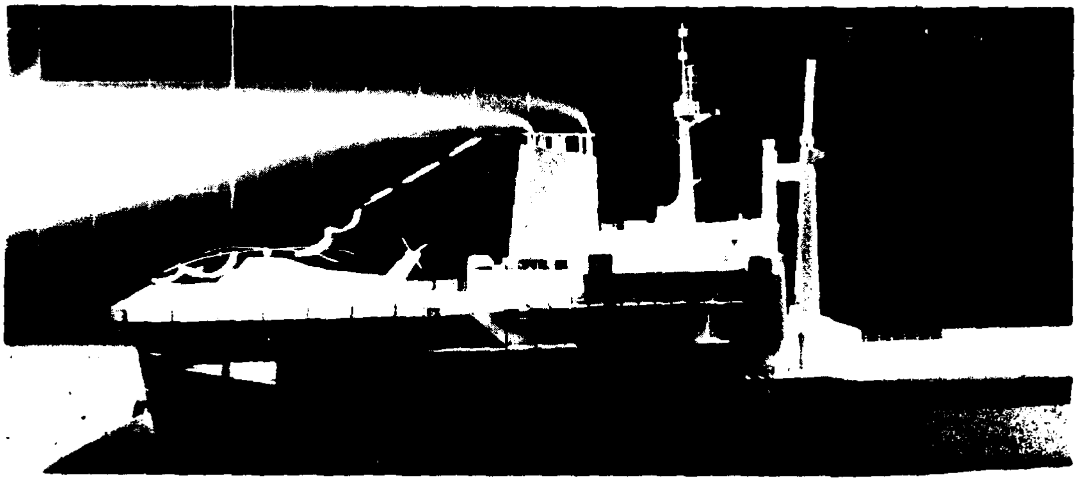
Top and bottom plan shapes as for funnel 1 (Fig. 1)

FIG. 18 FUNNEL 5 (a)



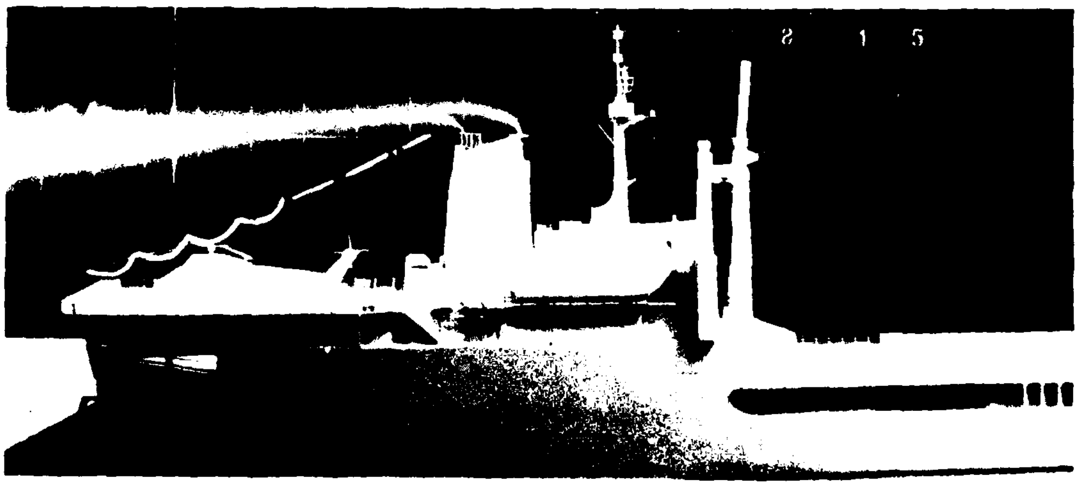
Neg No. 0693 – 7.16

FIG. 19 FUNNEL 5(*a*) WITH TOP PLATE 2



Neg No. 0693 – 7.14

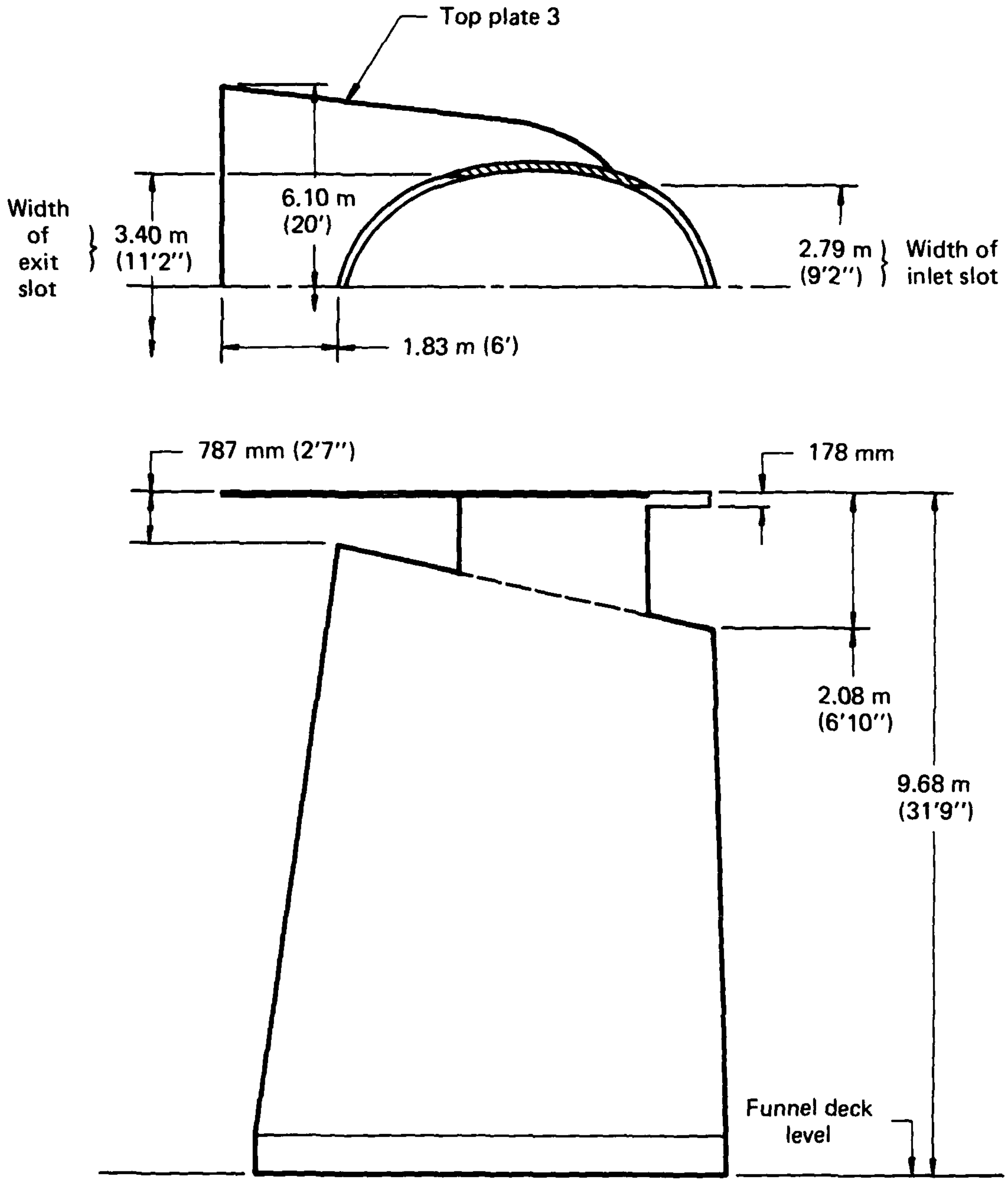
FIG. 20 FUNNEL 5(a) SLOTTED, WITH TOP PLATE 2



Neg No. 0695 – 8.15

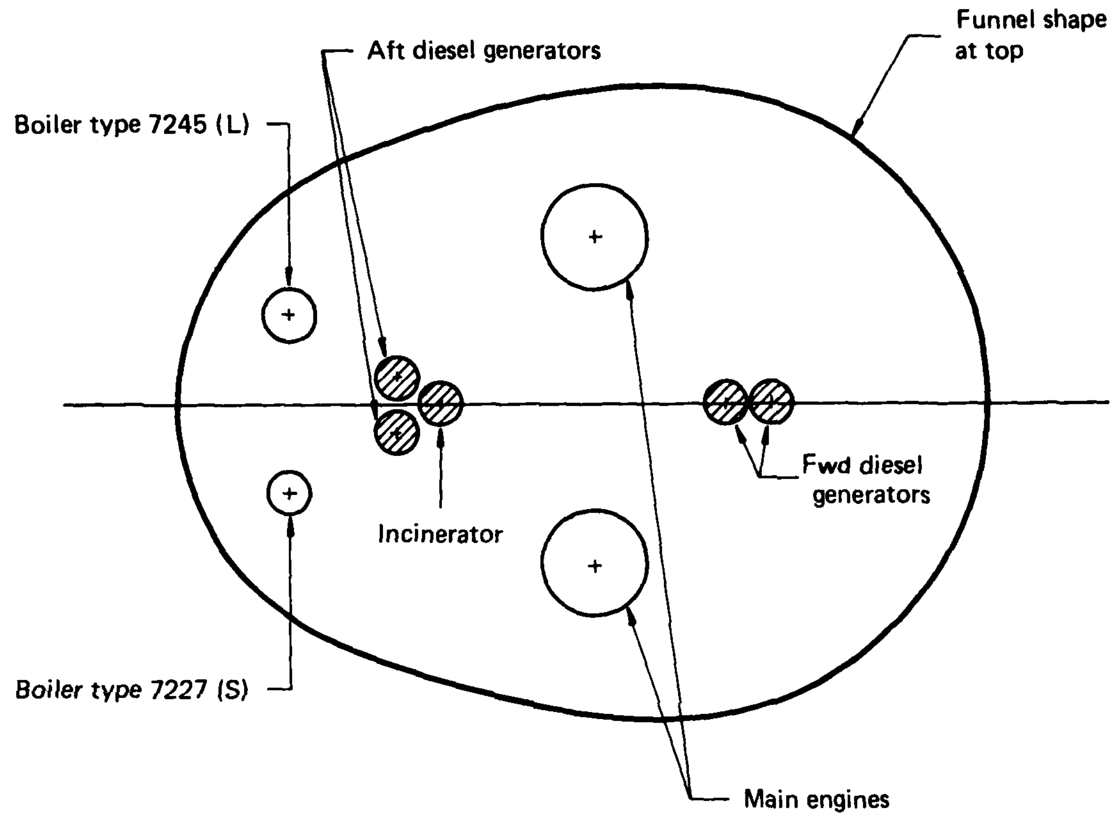
FIG. 21 FUNNEL 7 WITH TOP PLATE 3

ANCHORED CASE, WIND 10° OFF STARBOARD BOW
3.94 m (15') FUNNEL HEIGHT EXTENSION ABOVE DESIGN FUNNEL



Elliptic top plan shape
Bottom plan shape as for funnel 1 (Fig. 1)

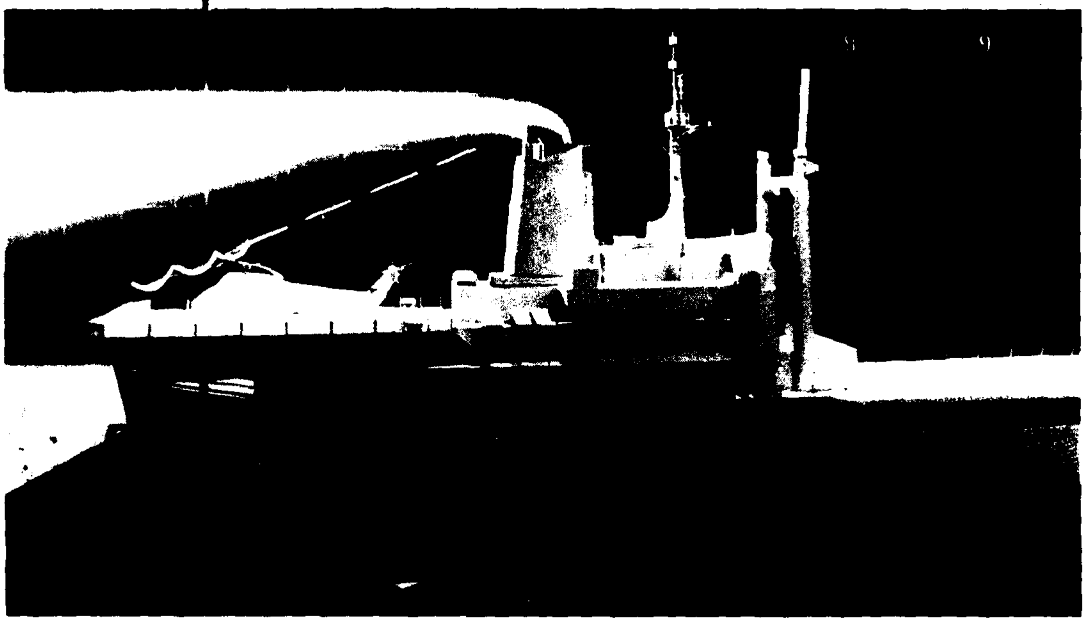
FIG. 22 FUNNEL 7



Scale 1 : 48 (actual model size)

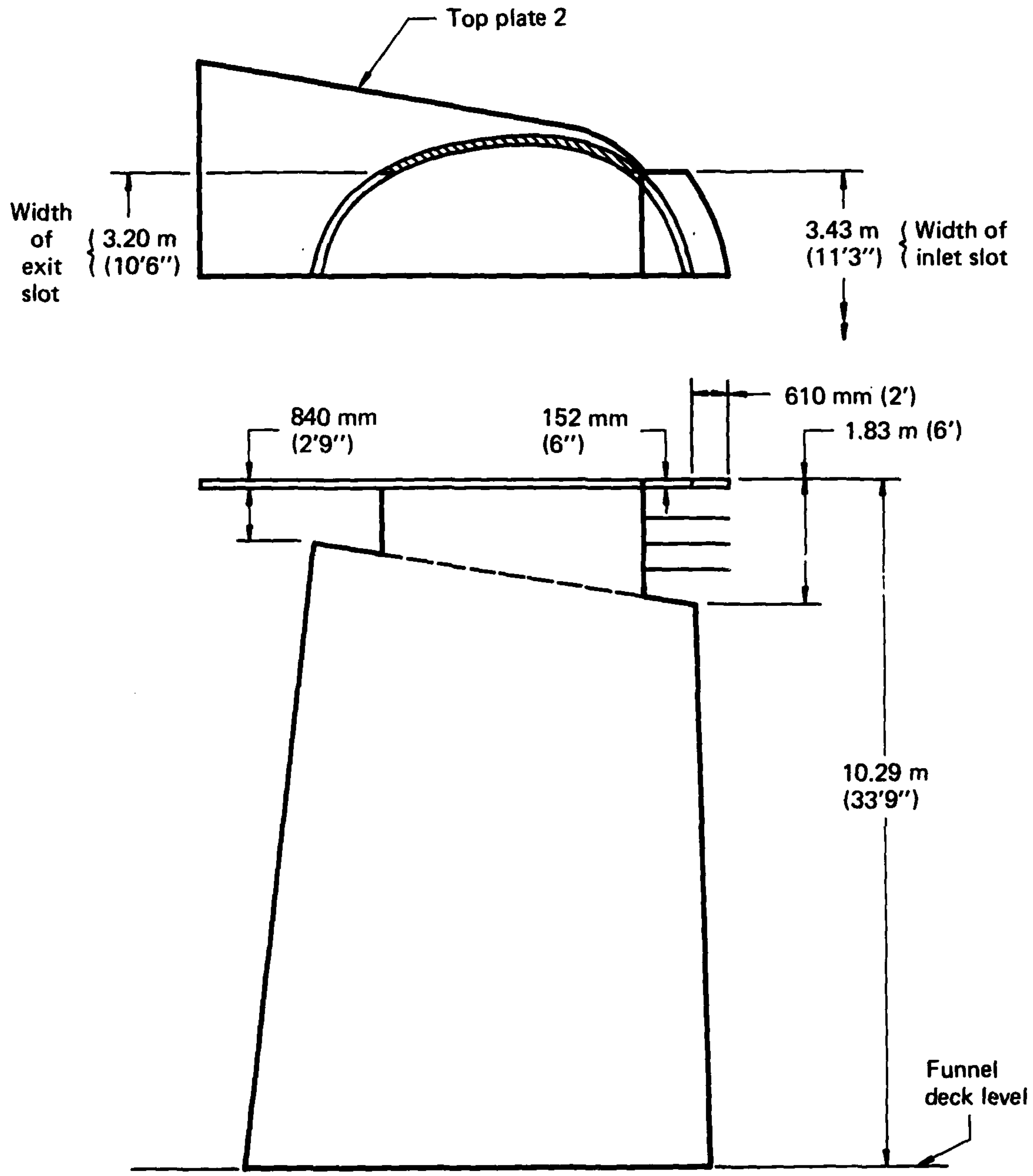
The incinerator, forward and aft diesel generators
(shown cross-hatched) have been relocated.
(Original uptake configuration shown in Fig. 1.)

FIG. 23 MODIFIED UPTAKE CONFIGURATION



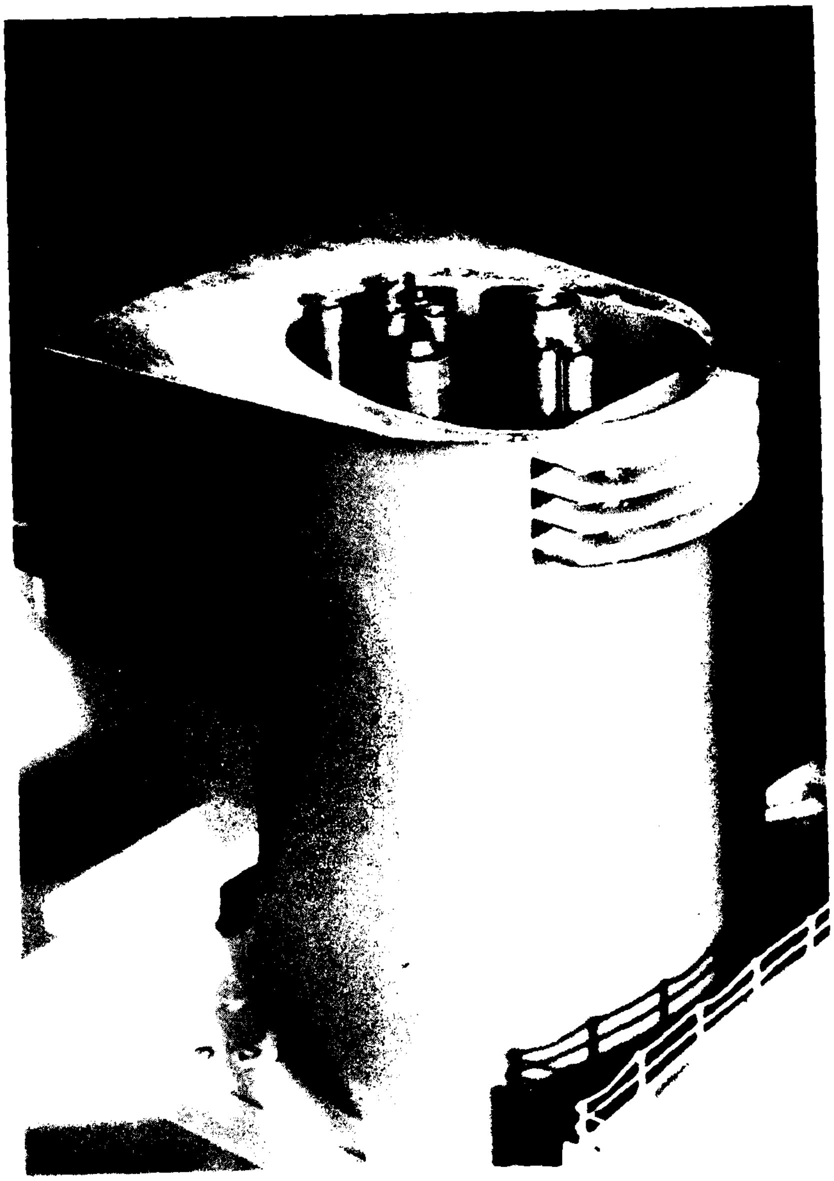
Neg No. 0699 – 9.9

FIG. 24 FUNNEL 7 WITH TOP PLATE 3 AND MODIFIED UPTAKE CONFIGURATION
ANCHORED CASE, WIND 10° OFF STARBOARD BOW
3.94 m (15') FUNNEL HEIGHT EXTENSION ABOVE DESIGN FUNNEL



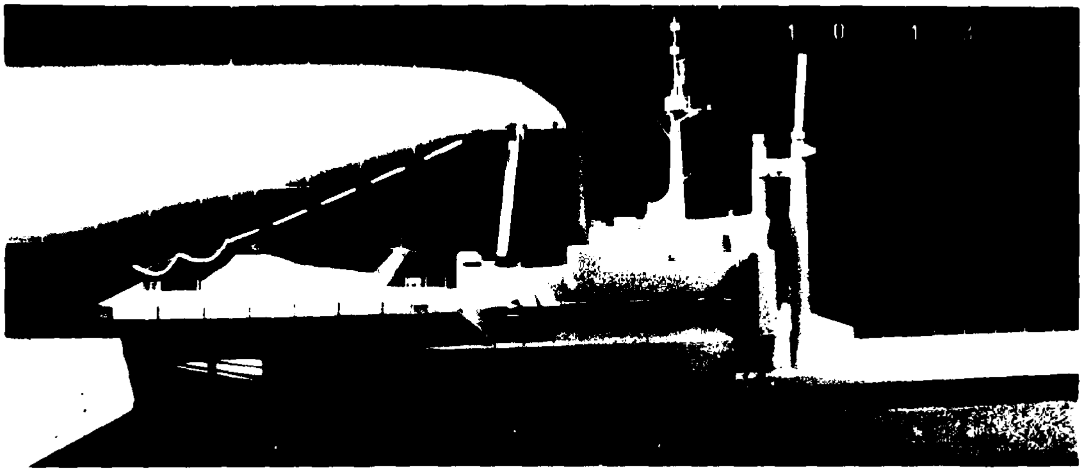
Top and bottom plan shapes as for funnel 1 (Fig. 1)

FIG. 25 FUNNEL 8



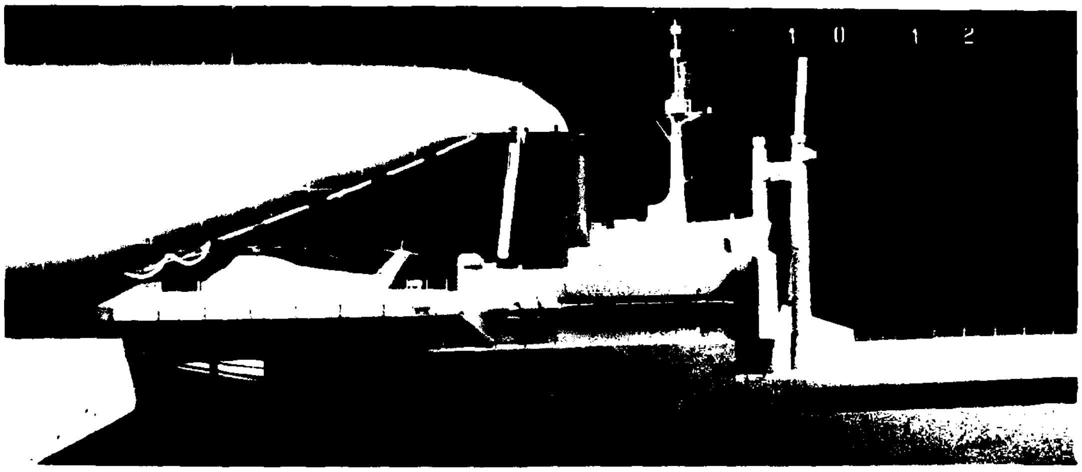
Neg No. 0718 – C

FIG. 26 FUNNEL 8 WITH UPTAKES EXTENDED 0.30 m (12")
ABOVE FUNNEL RIM



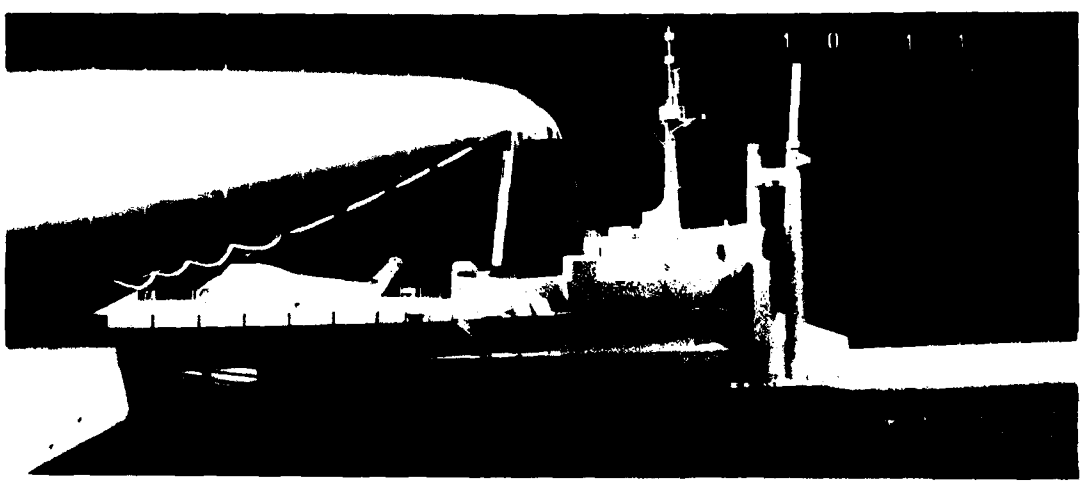
Neg No. 0706 – 10.13

(a) 0.23 m (9″) Uptake extension above funnel rim



Neg No. 0706 – 10.12

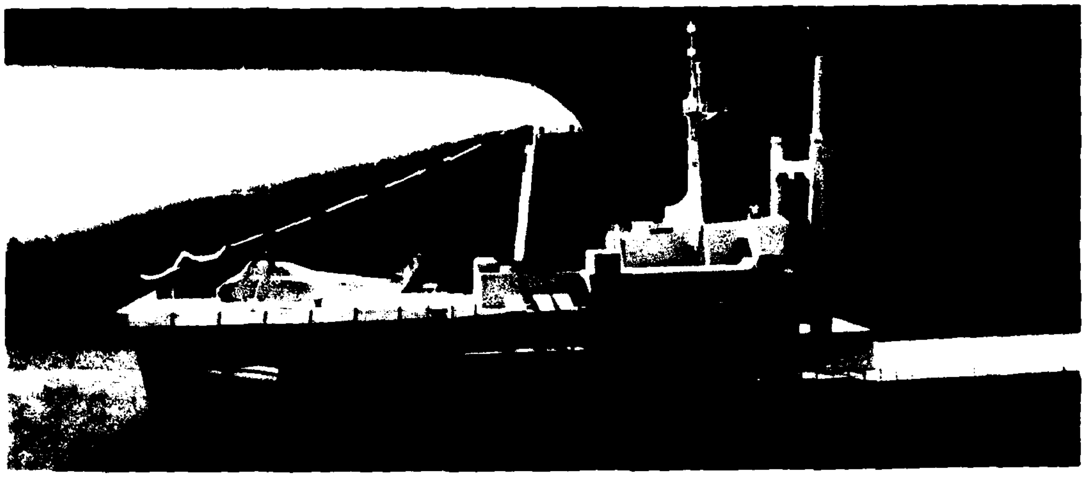
(b) 0.30 m (12″) Uptake extension above funnel rim



Neg No. 0706 – 10.11

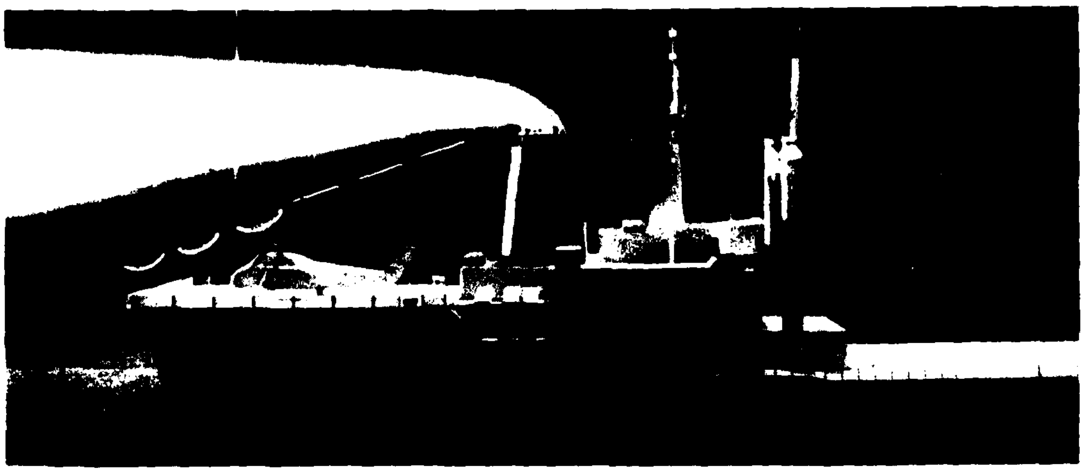
(c) 0.38 m (15″) Uptake extension above funnel rim

FIG. 27 FUNNEL 8 CRUISE CASE, WIND 10° OFF STARBOARD BOW.
EFFECT OF UPTAKE EXTENSION ABOVE FUNNEL RIM



Neg No. 0710 – 11.5

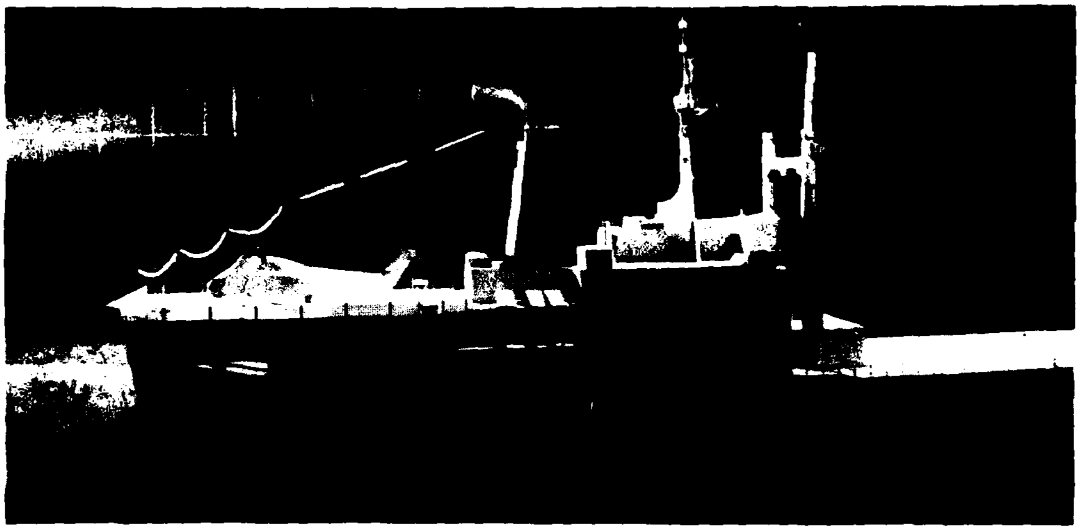
(a) Wind 10° off starboard bow



Neg No. 0710 – 11.4

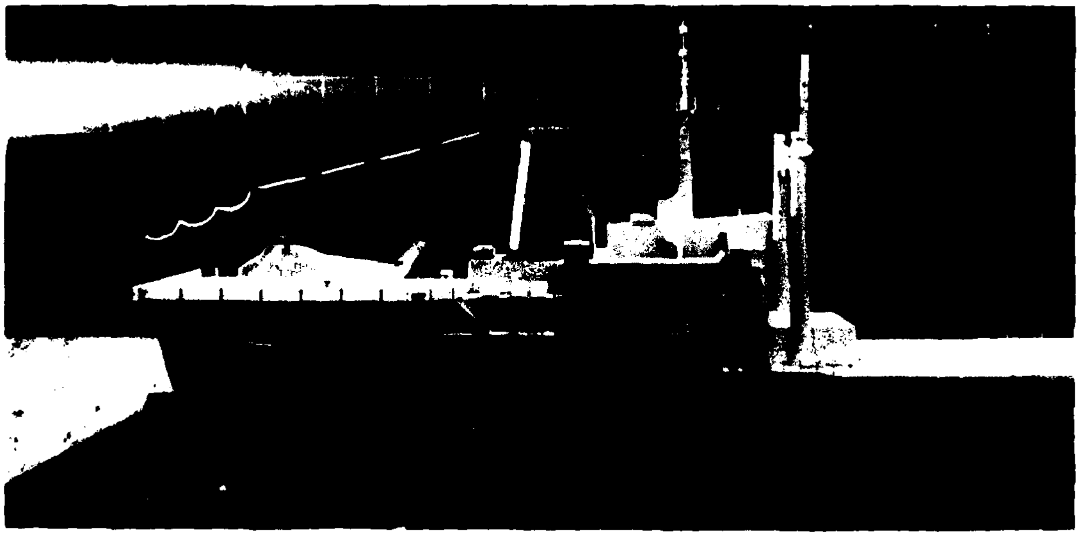
(b) Wind on bow

FIG. 28 CRUISE CASE
FUNNEL 8 – LOUVRES IN INTAKE SLOT
– UPTAKES EXTENDED 0.30 m (12") ABOVE FUNNEL RIM



Neg No. 0710 – 11.6

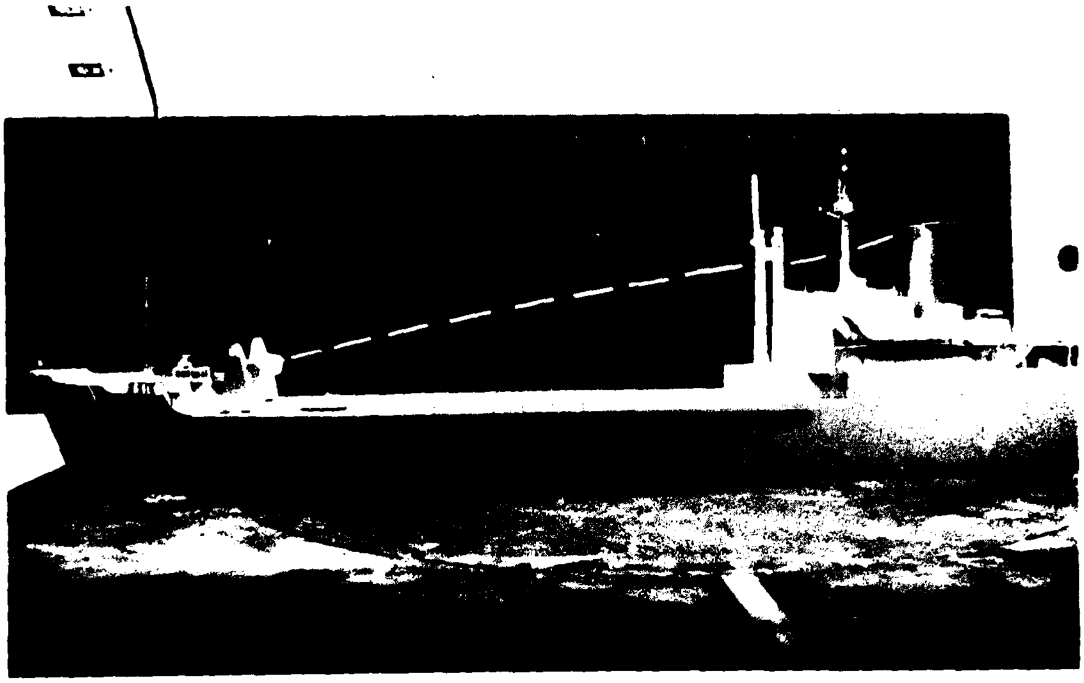
(a) Wind 10° off starboard bow



Neg No. 0710 – 11.11

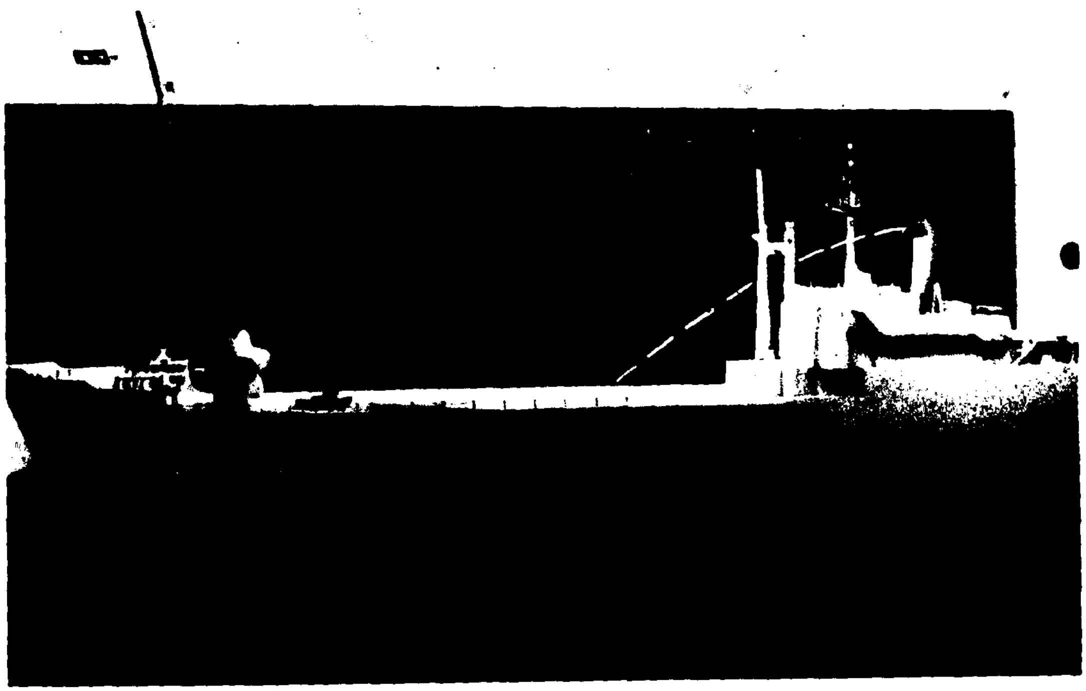
(b) Wind on bow

FIG. 29 ANCHORED CASE
FUNNEL 8 – LOUVRES IN INTAKE SLOT
– UPTAKES EXTENDED 0.30 m (12") ABOVE FUNNEL RIM



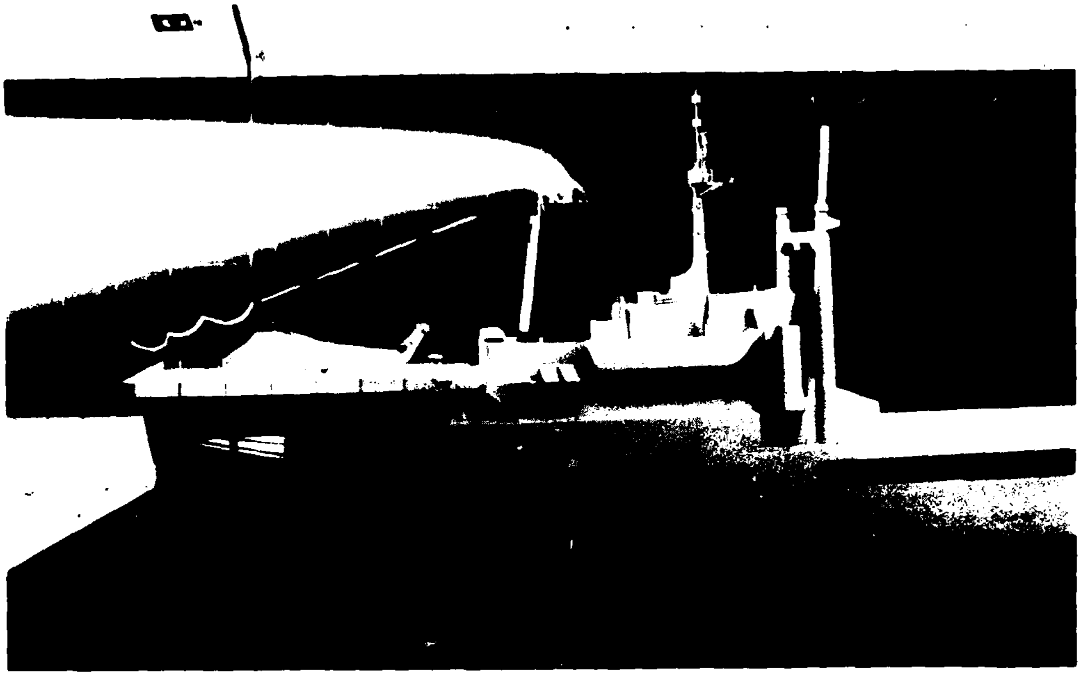
Neg No. 0710 – 12.11

FIG. 30 FUNNEL 8 WITH LOUVRES IN, UPTAKES EXTENDED
0.30 m (12") ABOVE FUNNEL RIM.
ANCHORED CASE WITH WIND ON STERN



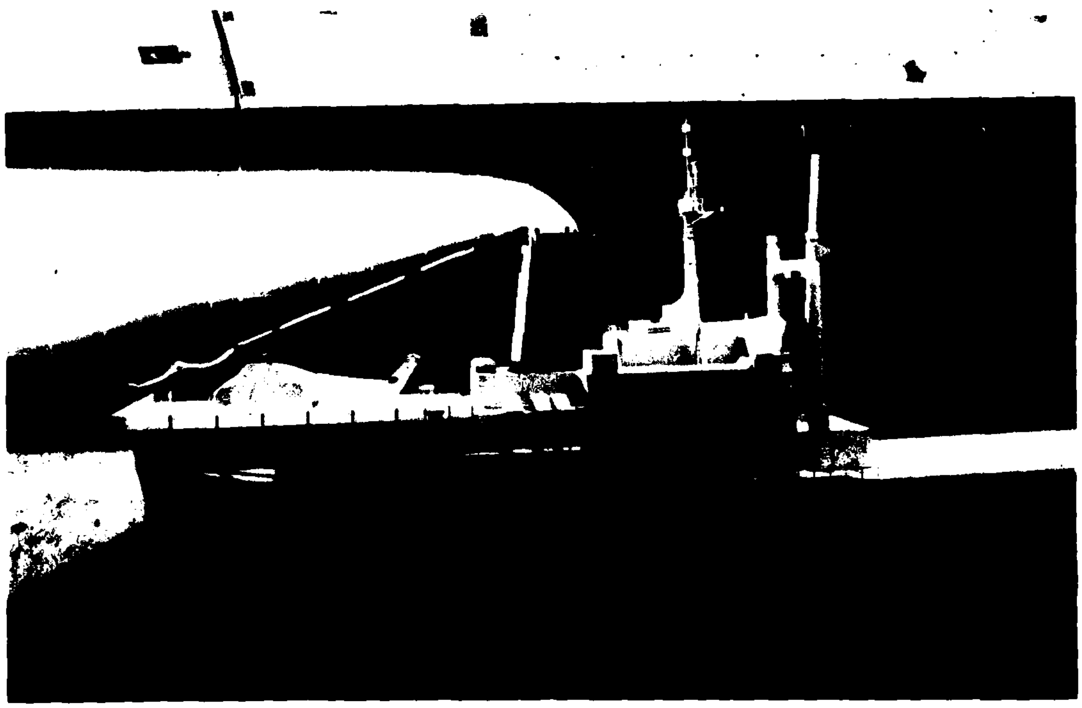
Neg No. 0710 – 12.14

FIG. 31 FUNNEL 8 WITH LOUVRES IN, UPTAKES EXTENDED
0.30 m (12") ABOVE FUNNEL RIM.
ANCHORED CASE WITH WIND 10° OFF PORT STERN



Neg No. 0710 – 12.8

(a) Buoyant plume



Neg No. 0710 – 11.5

(b) Non-buoyant plume

FIG. 32 FUNNEL 8 WITH LOUVRES, UPTAKES EXTENDED
0.30 m (12") ABOVE FUNNEL RIM.
CRUISE CASE WITH WIND 10° OFF STARBOARD BOW
EFFECT OF BUOYANCY

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