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Calculations of Motions and Hydrodynamic Pressures for a Ship in Waves

Seakeeping pressures theory

by J. Fukuda and H. Fujii

This note summarizes briefly the results of theoretical calculations on the motions and hydrodynamic pressures induced on a ship in regular waves, which have been carried out as a part of the research works of the research committee "SR 131" by the cooperation with Kyushu University and Mitsubishi Nagasaki Technical Institute.

The calculation method is based upon the strip theory described in Refs. [1] and [2]. In the first place, the ship motions in regular waves from different directions are solved by assuming the coupled equations of heaving and pitching motions and those of swaying, yawing and rolling motions. The non-linear roll damping is introduced into the latter coupled equations of motion. Secondly the hydrodynamic pressures induced on the hull surface are evaluated by using the solutions of heave, pitch, sway, yaw and roll.

A series of calculations has been made for the ore carrier "KASAGISAN-MARU" in full loaded condition. Particulars of the ship are given in Tables 1 - 3, and the main results of calculations are shown in Figs. 2 - 20. Large pressures are found on the hull surface at the weather side in beam waves and in bow waves. Next to those cases, considerable pressures are found in head waves. Pressures obtained in following waves and in quartering waves are not large.

Comparisons between the calculations and model experiments have been performed by Nakamura at Osaka University for the case in head waves, where the practically good agreements are found for both motions and pressures. Model experiments in oblique waves have been continued at the seakeeping model basins of Tokyo University and of Ship Research Institute, but comparisons between the calculations and experiments are not yet accomplished.

References

[1] J. Fukuda: "Theoretical Evaluations of Transverse Wave Loads" Discussion to the Report of Committee 2, Proceeding of 4th ISSC, Tokyo, 1970.

[2] J. Fukuda, R. Nagamoto, M. Konuma and M. Takahashi: "Theoretical Calculations on the Motions, Hull Surface Pressures and Transverse Strength of a Ship in Waves" Journal of the Society of Naval Architects of Japan, Vol. 129, June 1971.

Nomenclature

h_o: wave amplitude
$H_w (=2h_o)$: wave height
λ : wave length
k $(=2\pi/\lambda)$: wave number
χ : heading angle
L : ship length
Fn.: Froude number
ζ_o: heaving amplitude
ϕ_o: pitching amplitude
θ_o: rolling amplitude
Z_{ro}: amplitude of ralative motion to the undisturbed wave surfase
P_o: amplitude of hydrodynamic pressure
ρg : specific weight of sea water
t : time
T_e: wave encountered period

Table 1 Main Particulars

Length between Perpendiculars (L)	247.000 m
Breadth Moulded (B_o)	40.600 m
Depth Moulded (D)	23.000 m
Draught Moulded (d_o)	16.000 m
Displacement (W)	135,666 t
Block Coefficient (C_b)	0.8249
Midship Coefficient (C_m)	0.9975
Water Plane Area Coefficient (C_w)	0.8817
Centre of Gravity from Midship (x_G)	7.301 m
Center of Gravity below Water Line (z_G)	3.720 m
Metacentric Radius (G_oM)	4.130 m
Longitudinal Gyradius (K_l)	0.2362L
Transverse Gyradius (K_t)	$0.2200B_o$
Rolling Period (T_R)	11.04 sec

Table 2 Estimation of Rolling Period

Density of Ore	1.77	2.20*	2.70
Occupied Ratio of Hold	100 %	80.5%	65.6%
KG	14.28 m	12.23 m	10.99 m
GM	2.18 m	4.18 m	5.42 m
GG_o (Free Surface Effect)	0.05 m	0.05 m	0.05 m
G_oM	2.13 m	4.13 m	5.42 m
K_t/B_o	0.2369	0.2200	0.2102
K_t'/B_o	0.1659	0.1659	0.1659
T_R	16.16 s	11.04 s	9.41 s

* In this report the density of ore is assumed to be 2.2

Table 3 Breadth, Draught and Sectional Area

S.S.	B/B_o	d/d_o	S/S_o
A.P.	0.1732	0.2324	0.0210
1/2	0.4823	1.0000	0.2190
1	0.7077	1.0000	0.4699
1-1/2	0.8671	1.0000	0.6774
2	0.9627	1.0000	0.8319
2-1/2	0.9991	1.0000	0.9322
3	1.0000	1.0000	0.9833
3-1/2	1.0000	1.0000	0.9985
4	1.0000	1.0000	1.0000
4-1/2	1.0000	1.0000	1.0000
5	1.0000	1.0000	1.0000
5-1/2	1.0000	1.0000	1.0000
6	1.0000	1.0000	1.0000
6-1/2	1.0000	1.0000	1.0000
7	1.0000	1.0000	1.0000
7-1/2	1.0000	1.0000	1.0000
8	1.0000	1.0000	0.9971
8-1/2	0.9721	1.0000	0.9511
9	0.8487	1.0000	0.8097
9-1/2	0.5818	1.0000	0.5422
F.P.	0.0796 (0.1317)	1.0000	0.1320

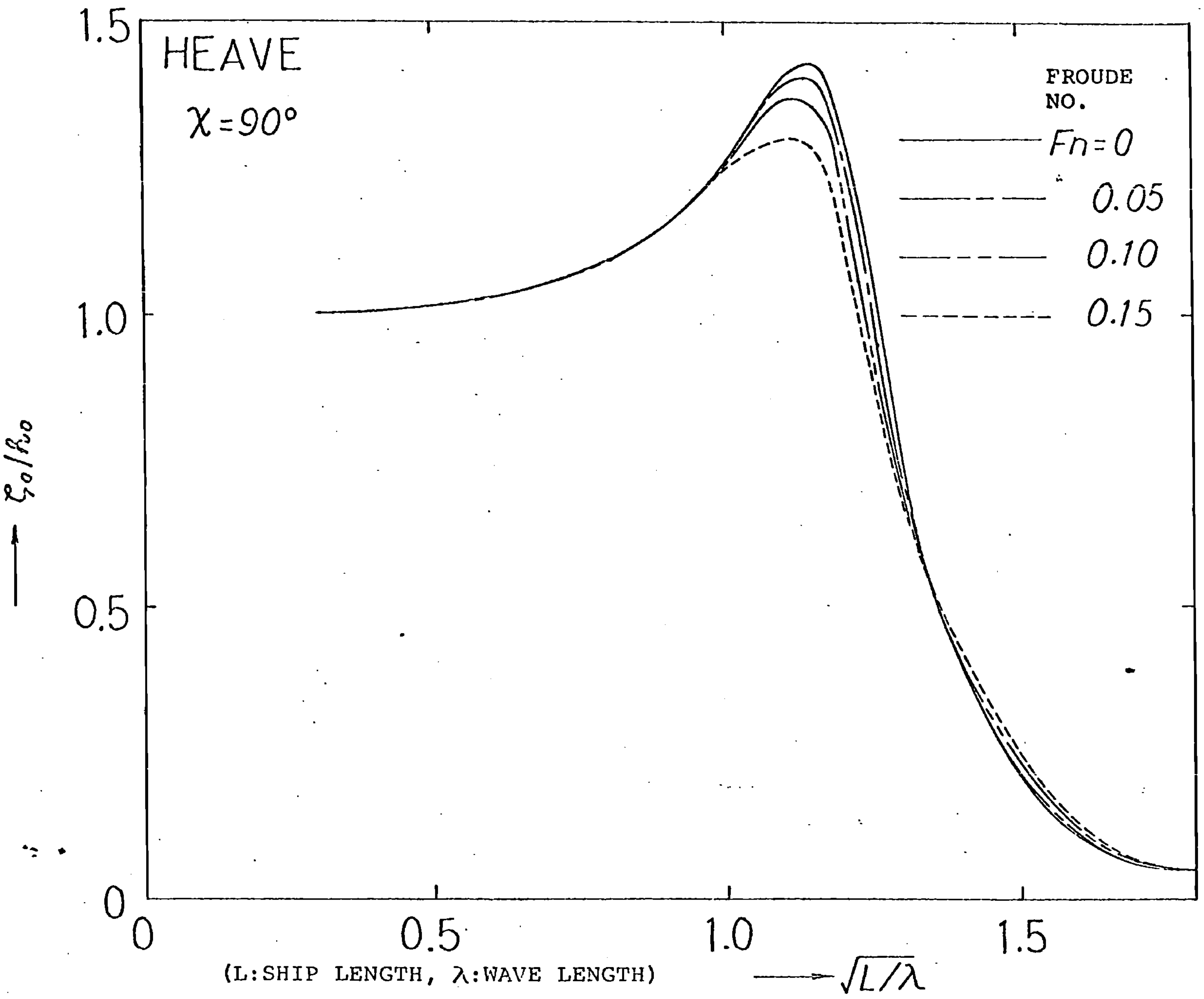


Fig. 2 Heaving Amplitudes in Regular Beam Waves

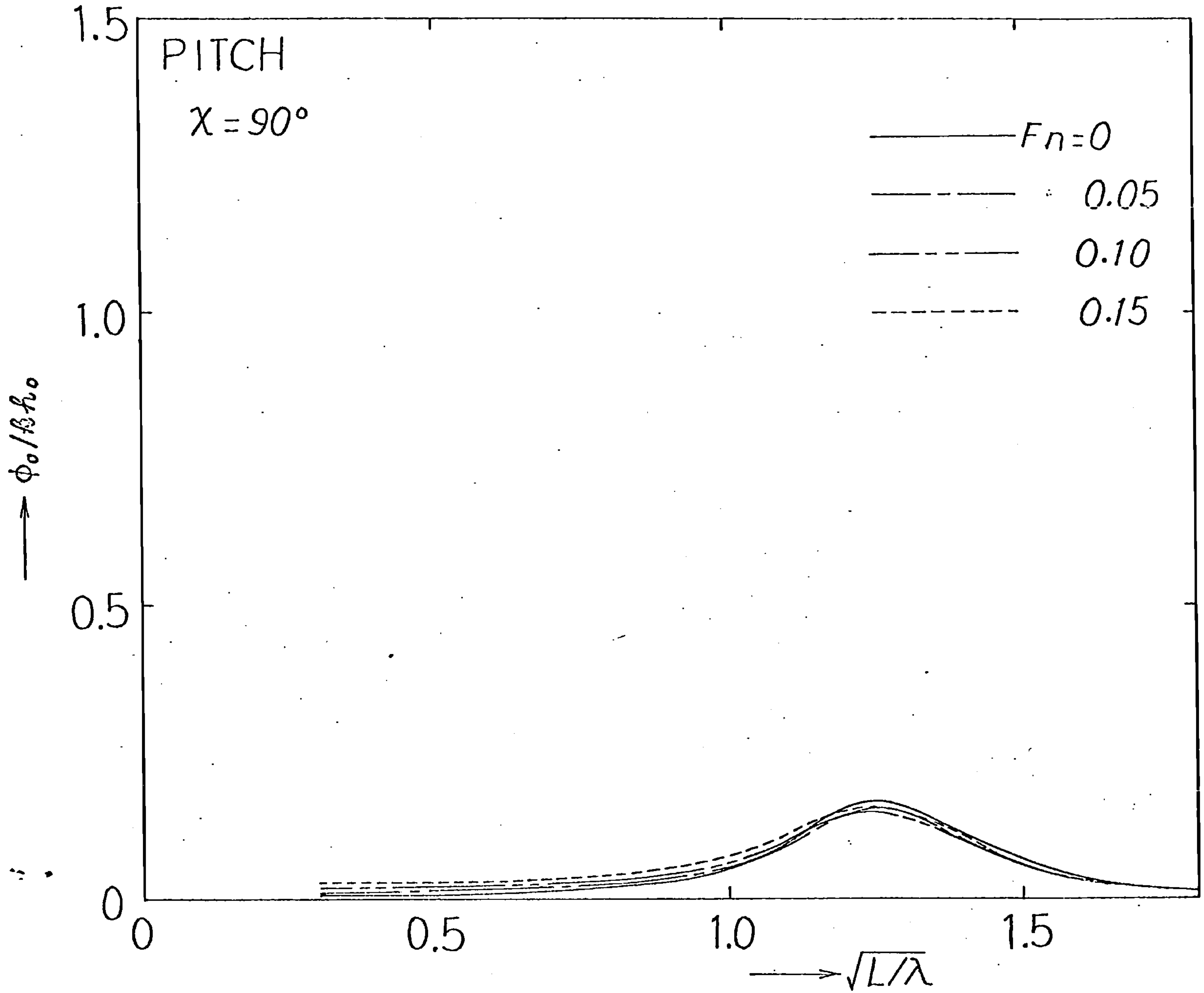


Fig. 3 Pitching Amplitudes in Regular Beam Waves

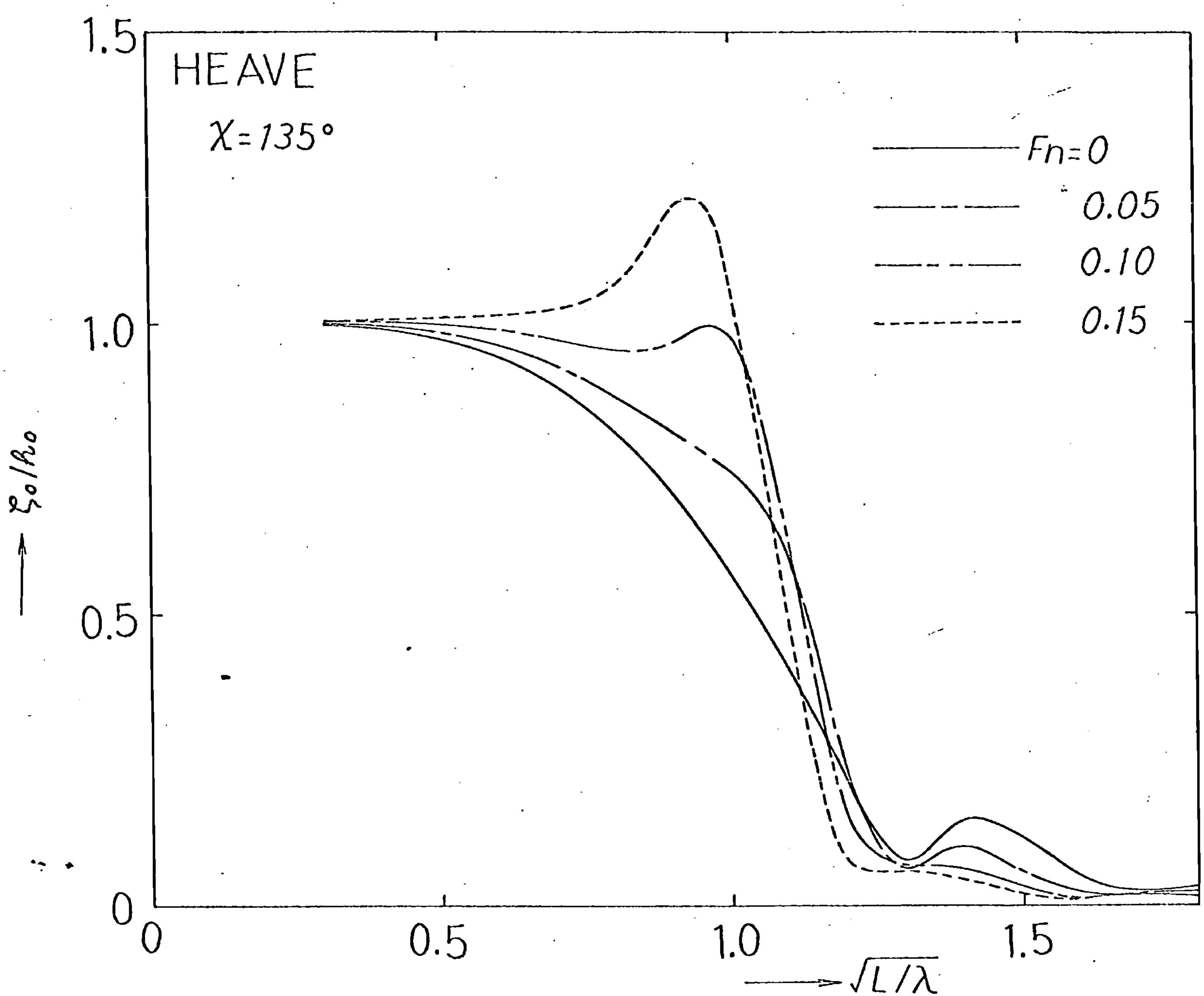


Fig. 4 Heaving Amplitudes in Regular Bow Waves

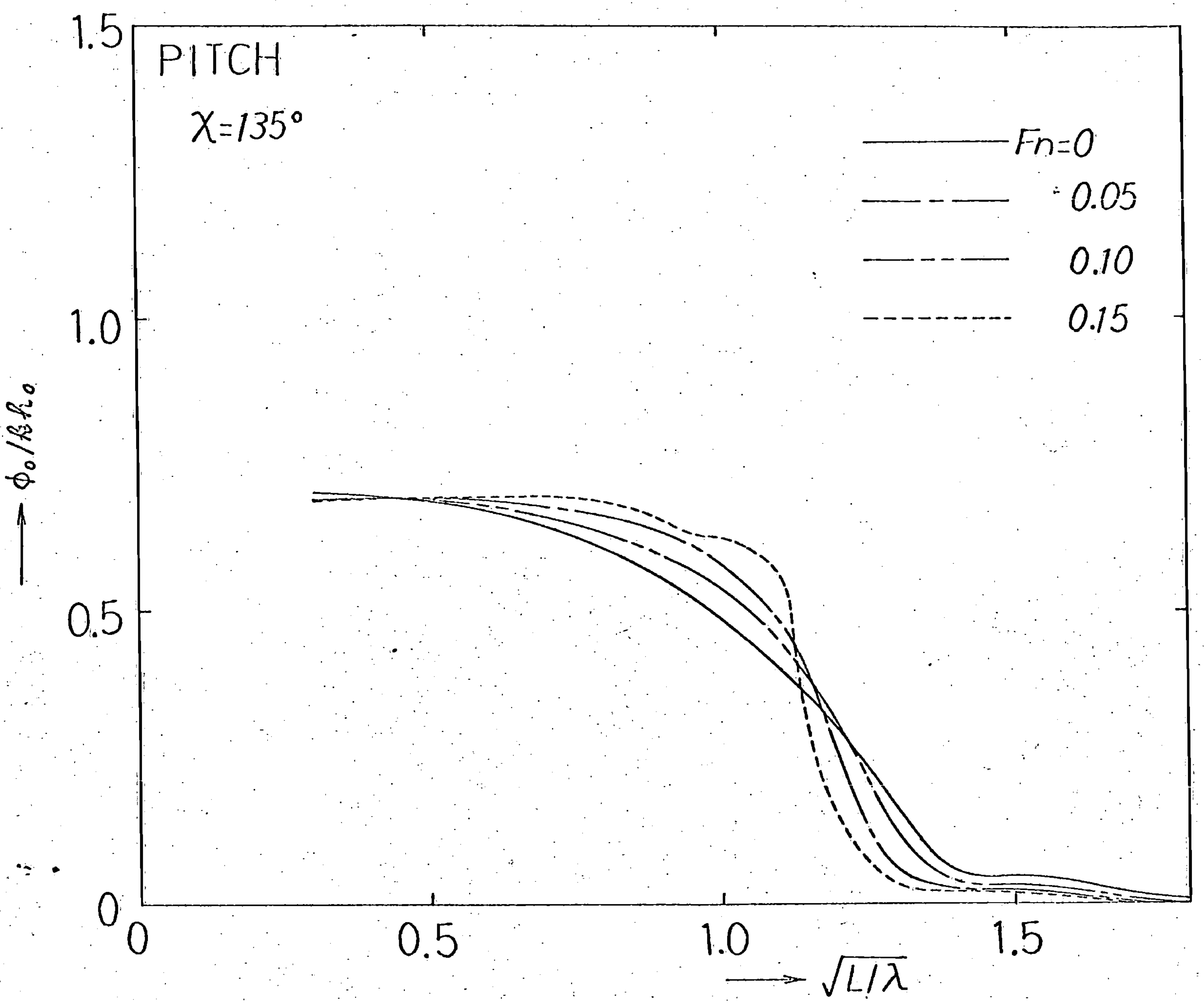


Fig. 5 Pitching Amplitudes in Regular Bow Waves

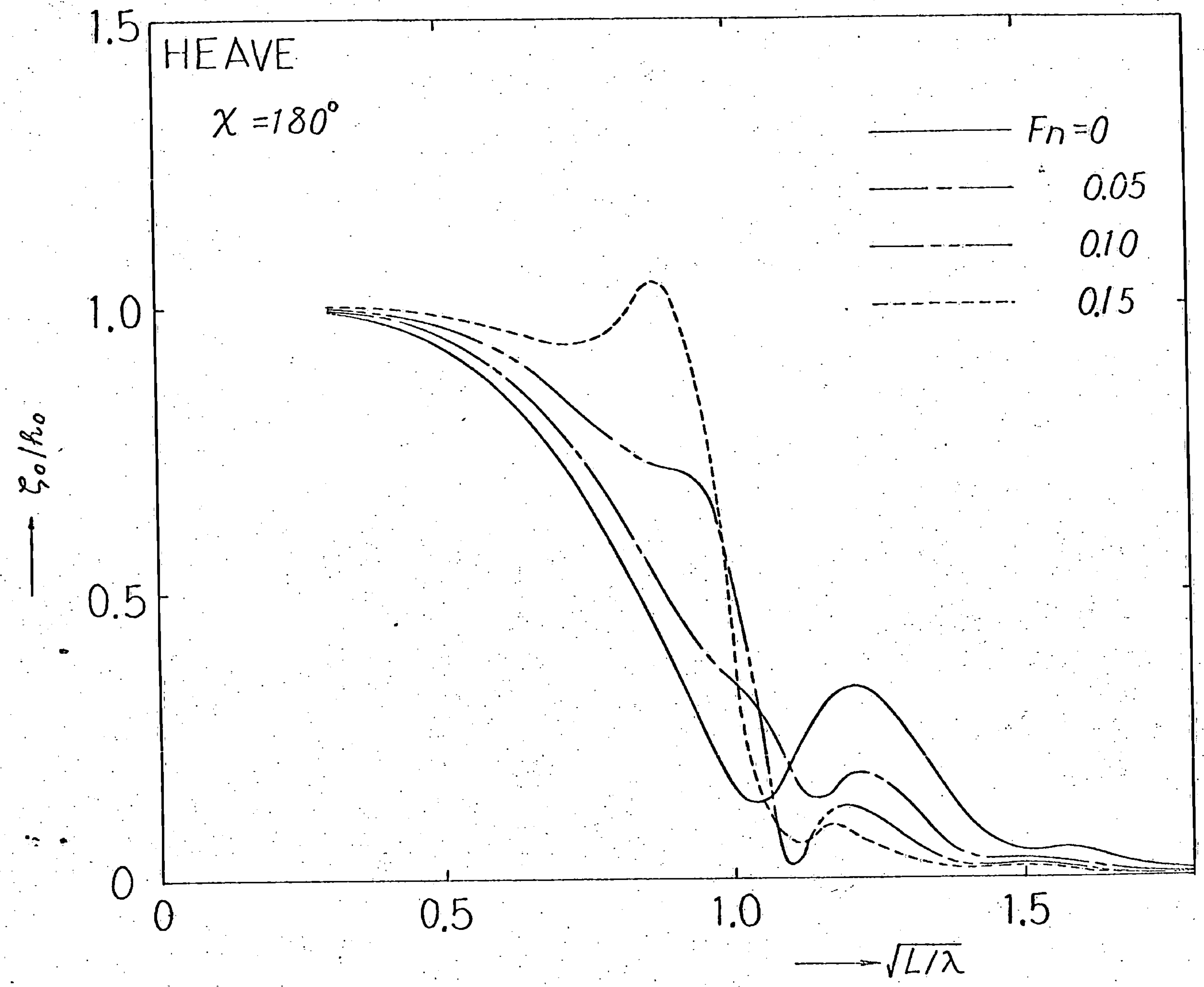


Fig. 6 Heaving Amplitudes in Regular Head Waves

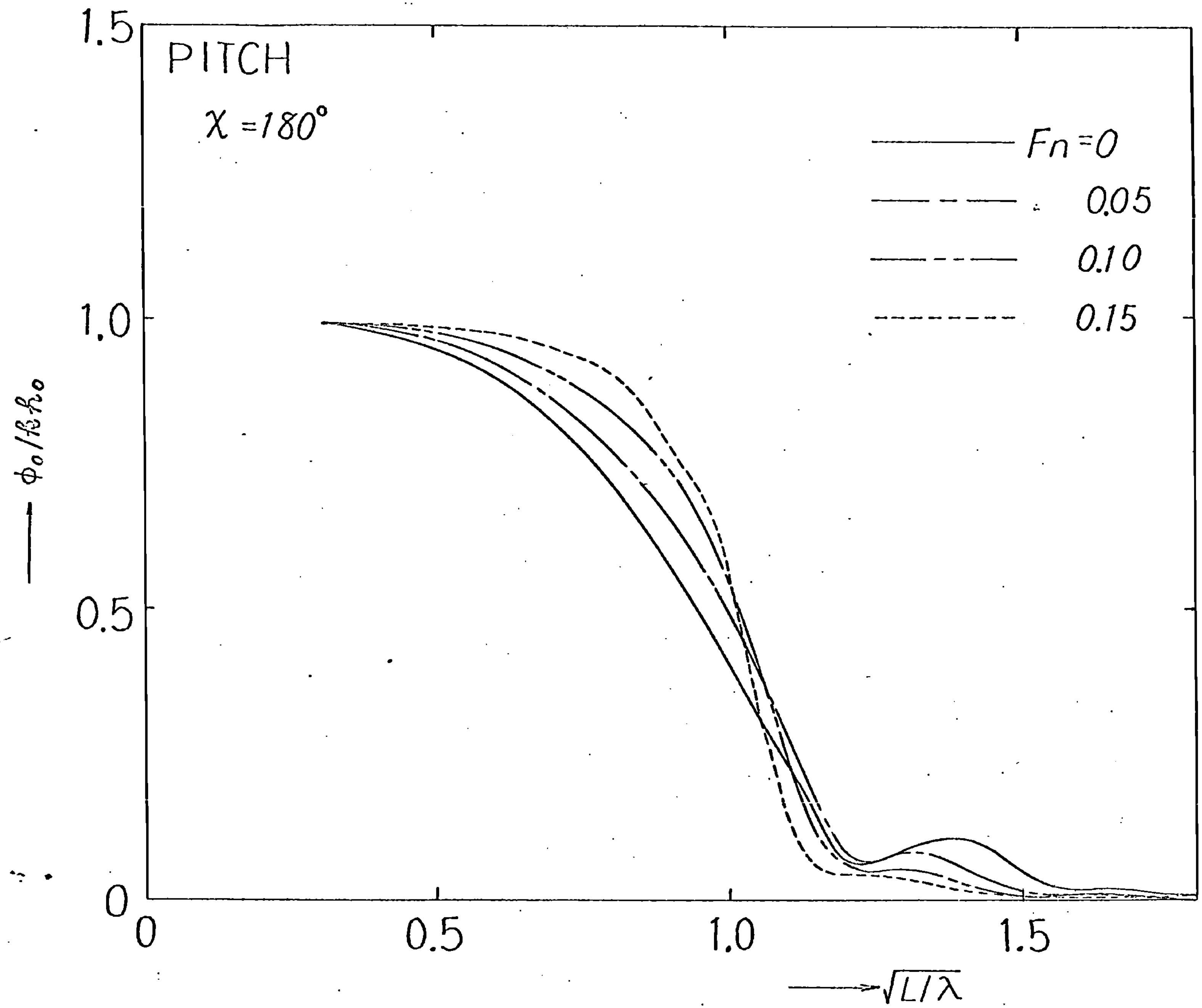


Fig. 7 Pitching Amplitudes in Regular Head Waves

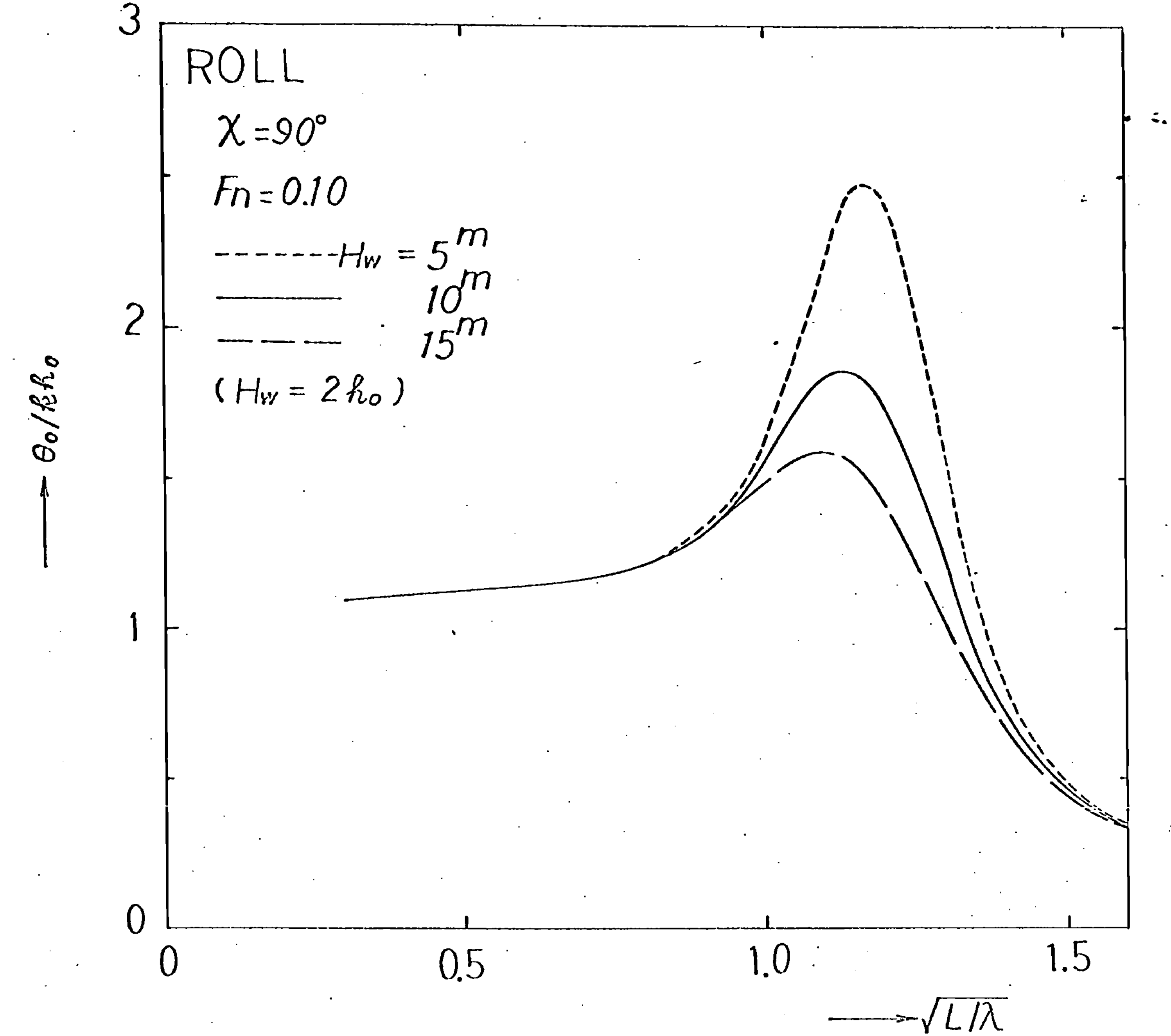


Fig. 8 Rolling Amplitudes in Regular Beam Waves

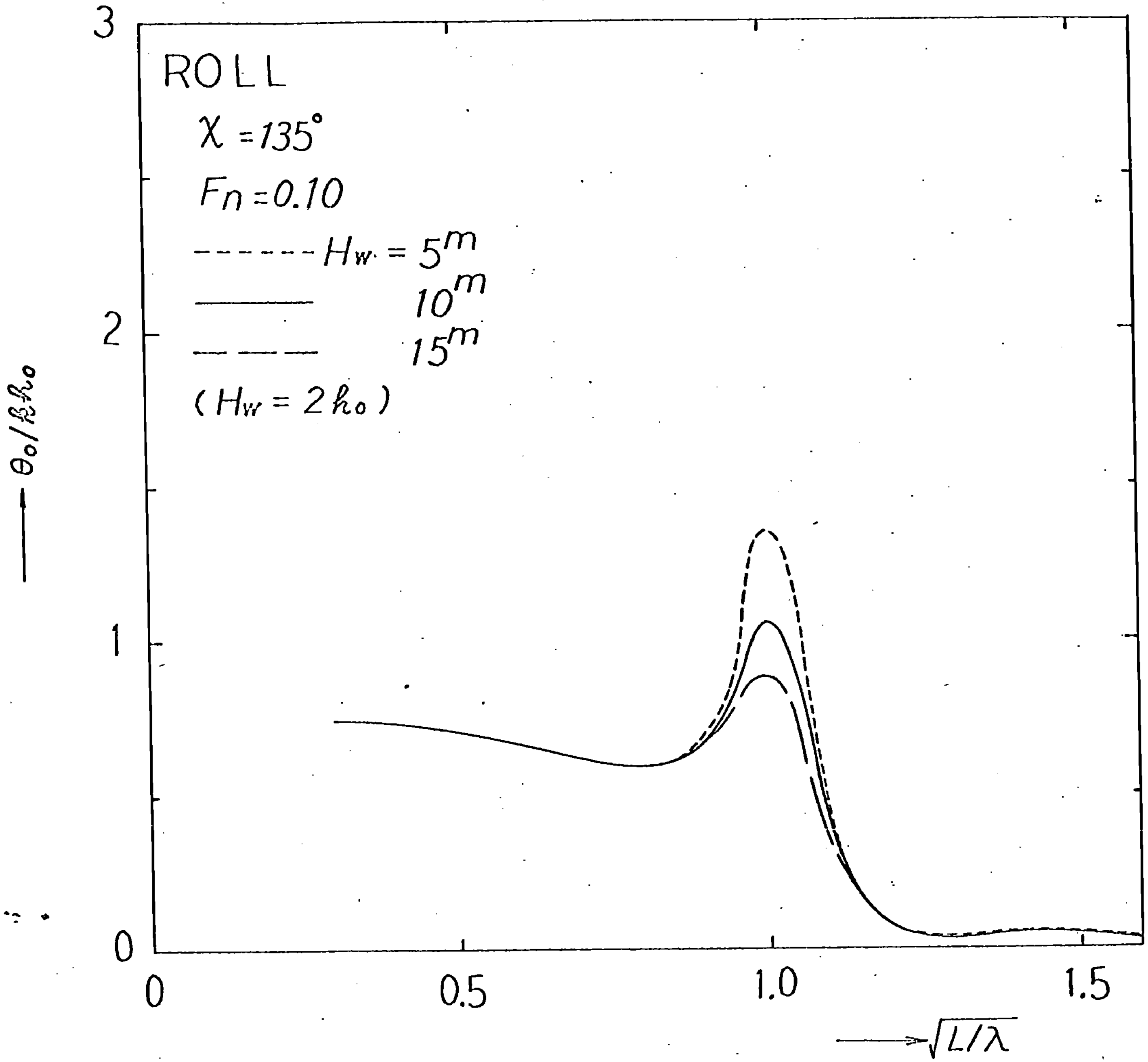


Fig. 9 Rolling Amplitudes in Regular Bow Waves

SECTION	WEATHER SIDE	LEEWARD SIDE
S.S.$2\frac{1}{2}$	— — —	— - —
MIDSHIP	———	———
S.S.$8\frac{1}{2}$	- - - -	- - - -

HEADING	90°
WAVE HEIGHT	10m
FROUDE NO.	0.10

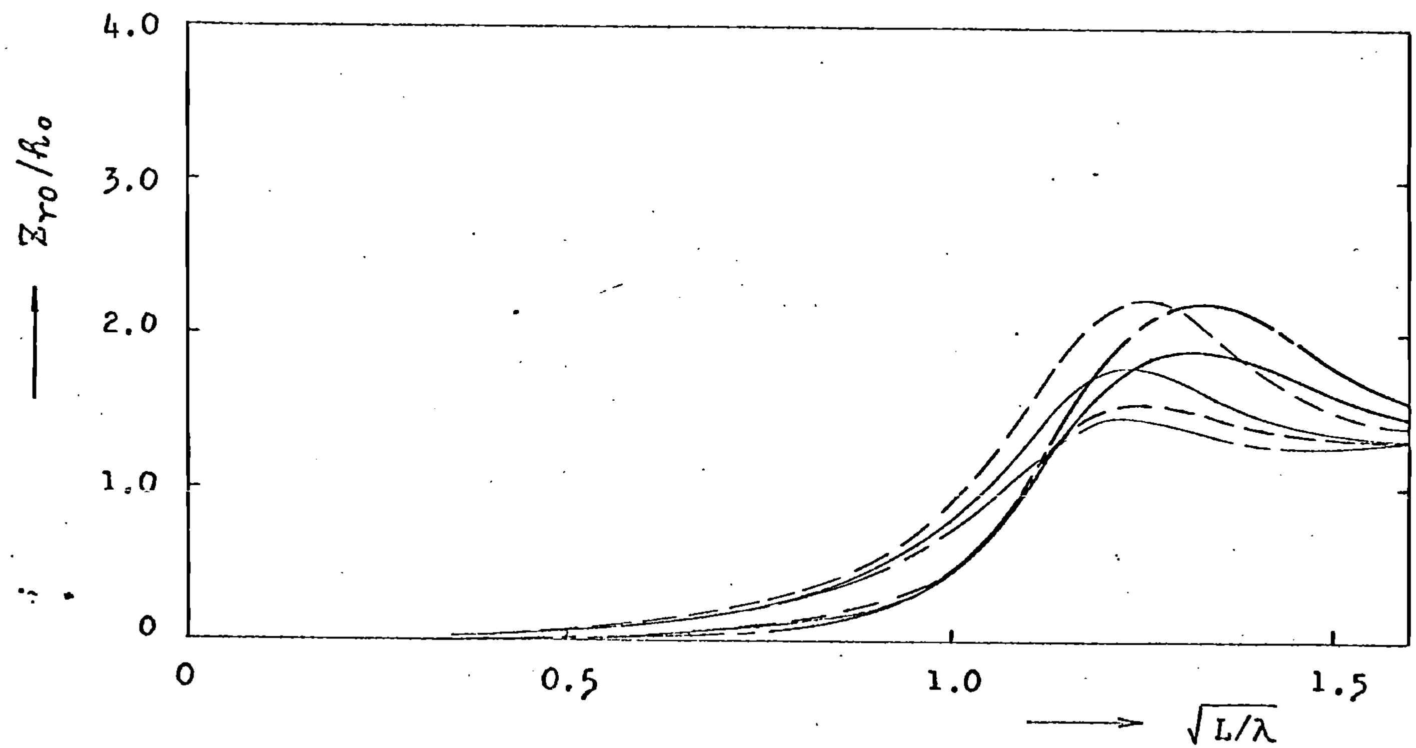


Fig. 10 Amplitudes of Relative Motion in Regular Beam Waves

S.S. $8\frac{1}{2}$ SECTION

POSITION		
KEEL CENTRE LINE		———
BILGE	WEATHER SIDE	—— — ——
	LEEWARD SIDE	——— - ———
WATER LINE	WEATHER SIDE	— — — —
	LEEWARD SIDE	- — — — —

HEADING	90°
WAVE HEIGHT	10m
FROUDE NO.	0.10

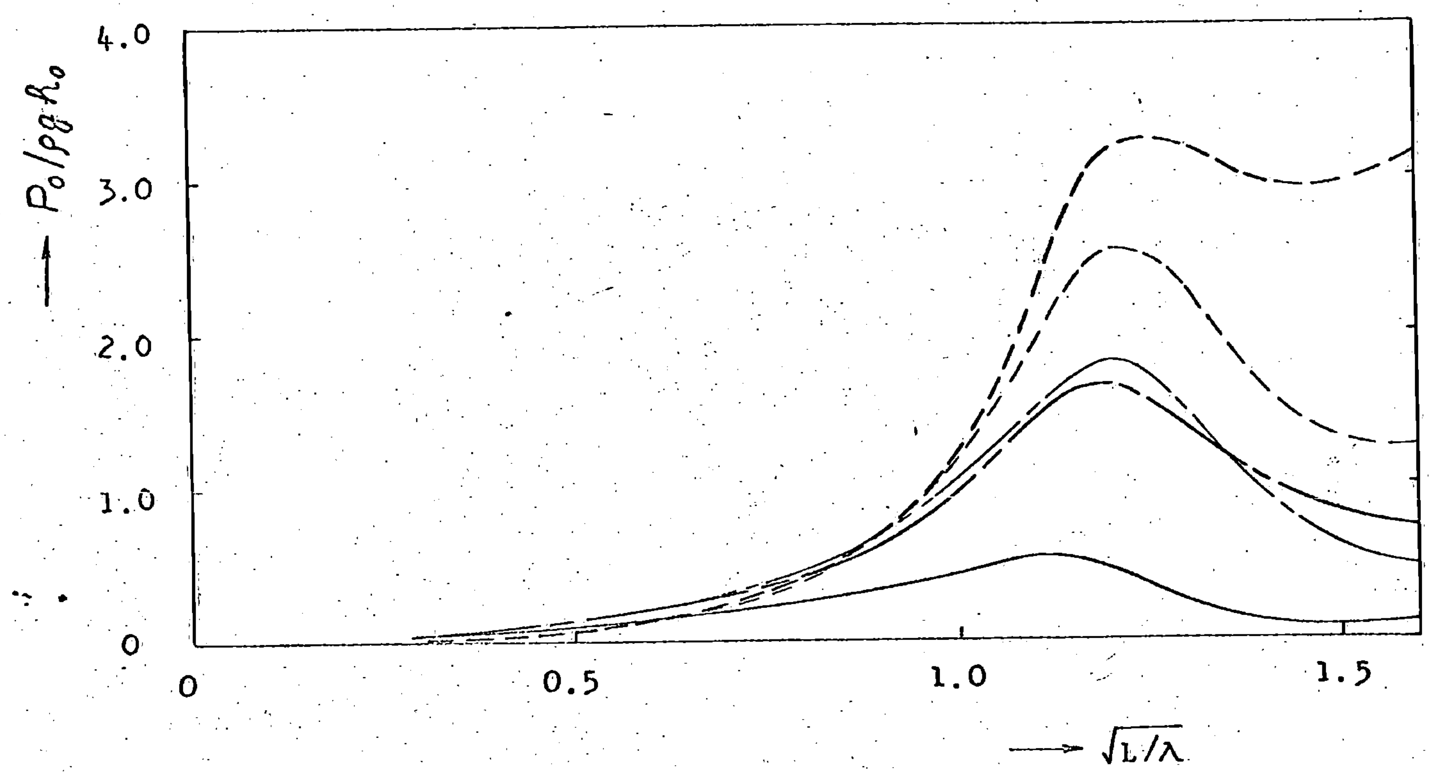


Fig. 11 Amplitudes of Hydrodynamic Pressure in Regular Beam Waves

SECTION	WEATHER SIDE	LEEWARD SIDE
S.S. $2\frac{1}{2}$	—— – ——	—— - ——
MIDSHIP	————	————
S.S. $8\frac{1}{2}$	— — — —	— — — —

HEADING	135°
WAVE HEIGHT	10m
FROUDE NO.	0.10

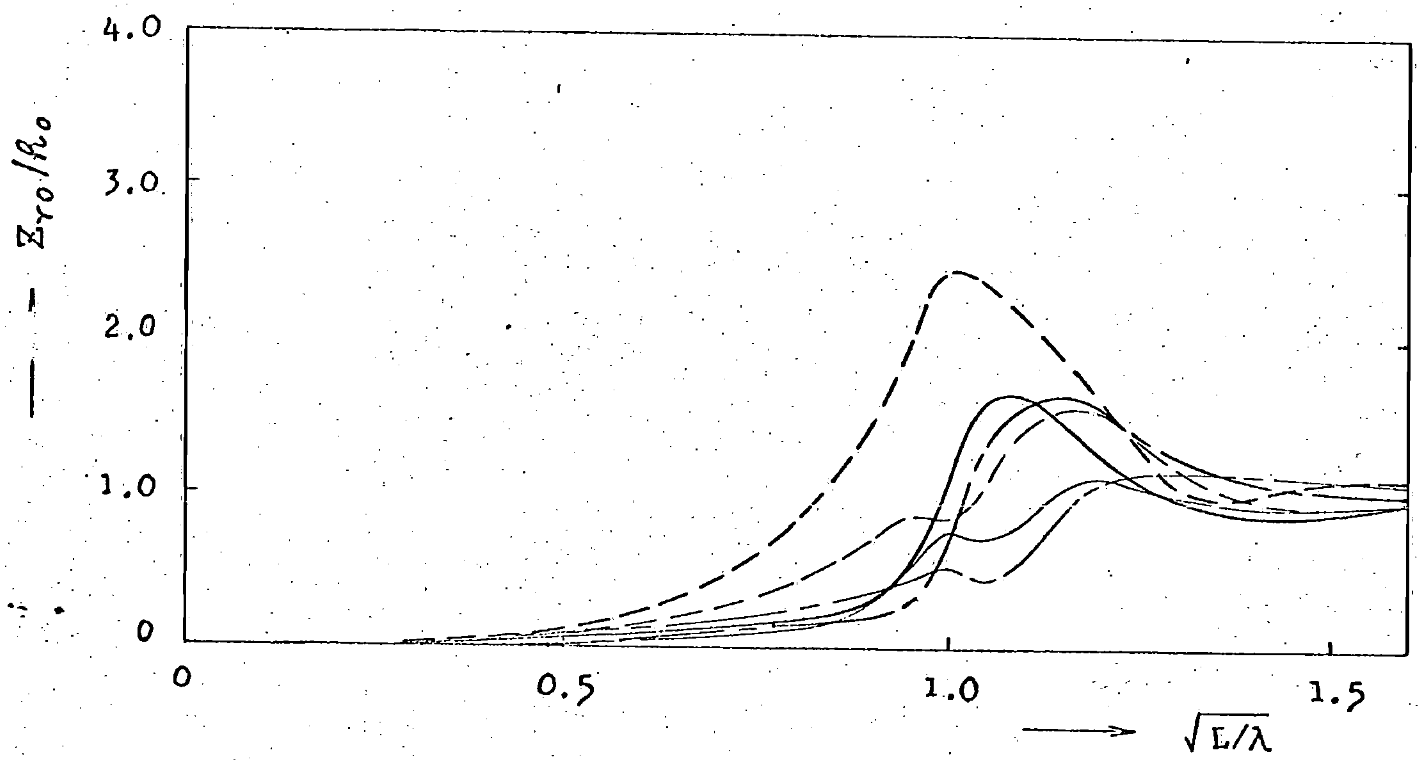


Fig. 12 Amplitudes of Relative Motion in Regular Bow Waves

S.S. $8\frac{1}{2}$ SECTION

POSITION		
KEEL CENTRE LINE		————
BILGE	WEATHER SIDE	—— — ——
	LEEWARD SIDE	—— — —
WATER LINE	WEATHER SIDE	— — — —
	LEEWARD SIDE	- - - - - -

HEADING	135°
WAVE HEIGHT	10m
FROUDE NO.	0.10

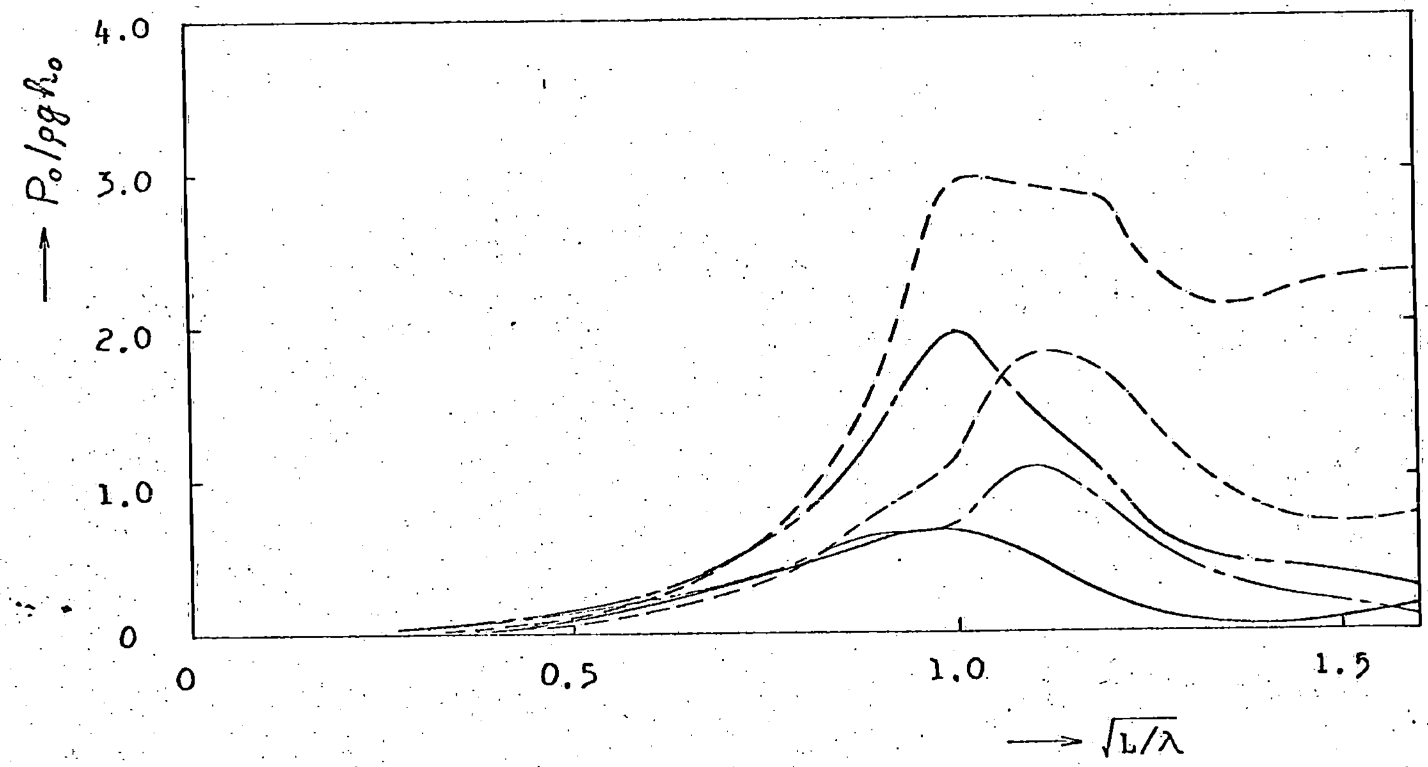


Fig. 13 Amplitudes of Hydrodynamic Pressure in Regular Bow Waves

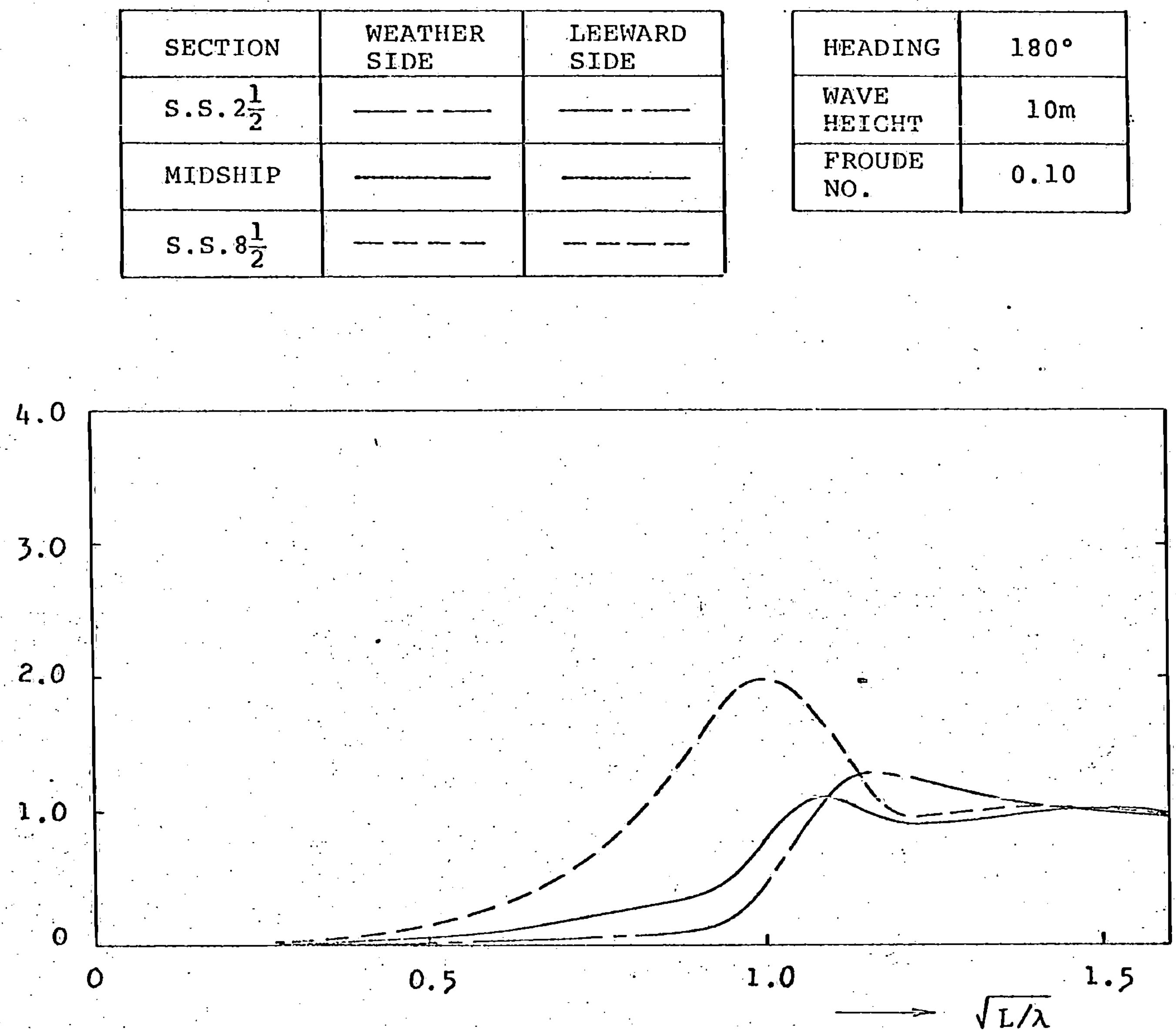


Fig. 14 Amplitudes of Relative Motion in Regular Head Waves

S.S. $8\frac{1}{2}$ SECTION

POSITION		
KEEL CENTRE LINE		———
BILGE	WEATHER SIDE	—·—·—
	LEEWARD SIDE	—— - ——
WATER LINE	WEATHER SIDE	— — — —
	LEEWARD SIDE	— — — —

HEADING	180°
WAVE HEIGHT	10m
FROUDE NO.	0.10

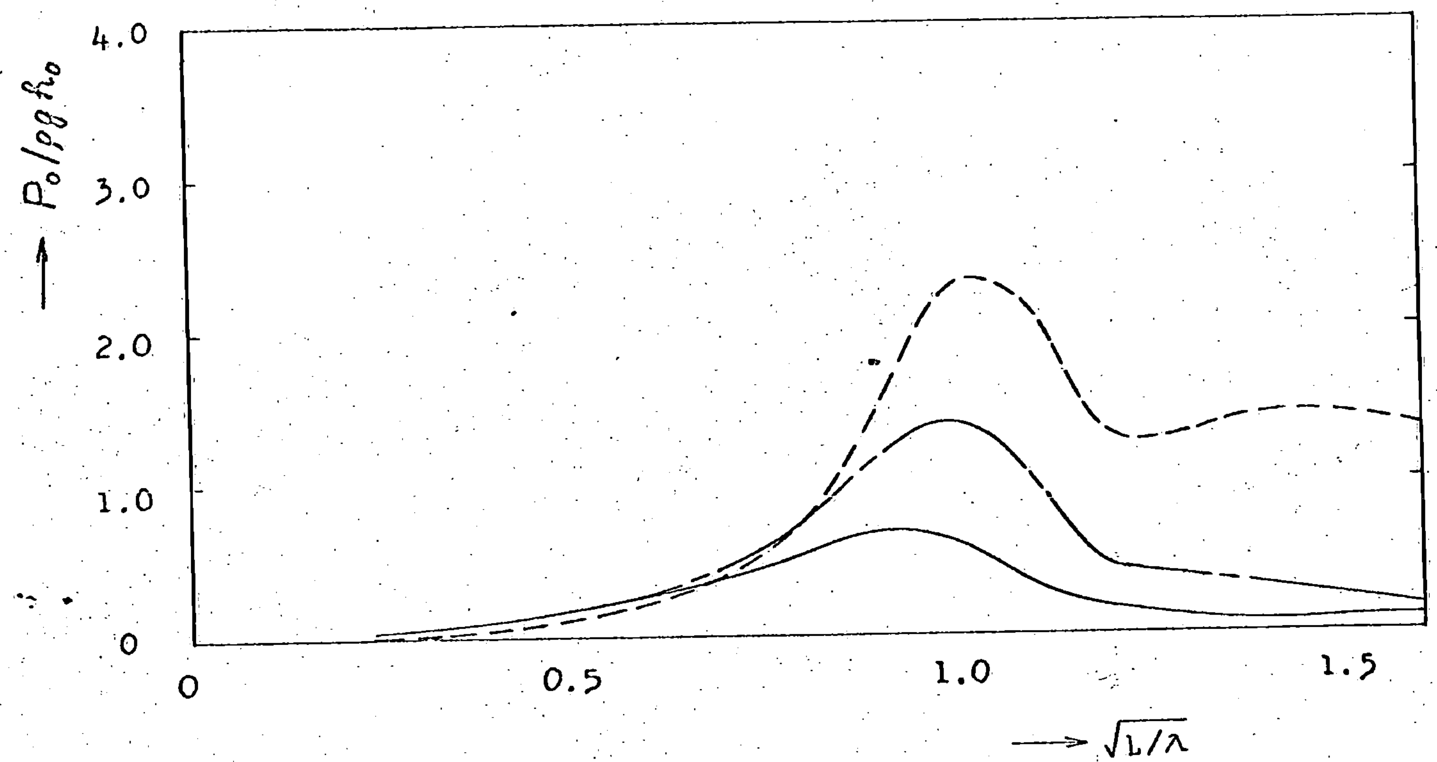
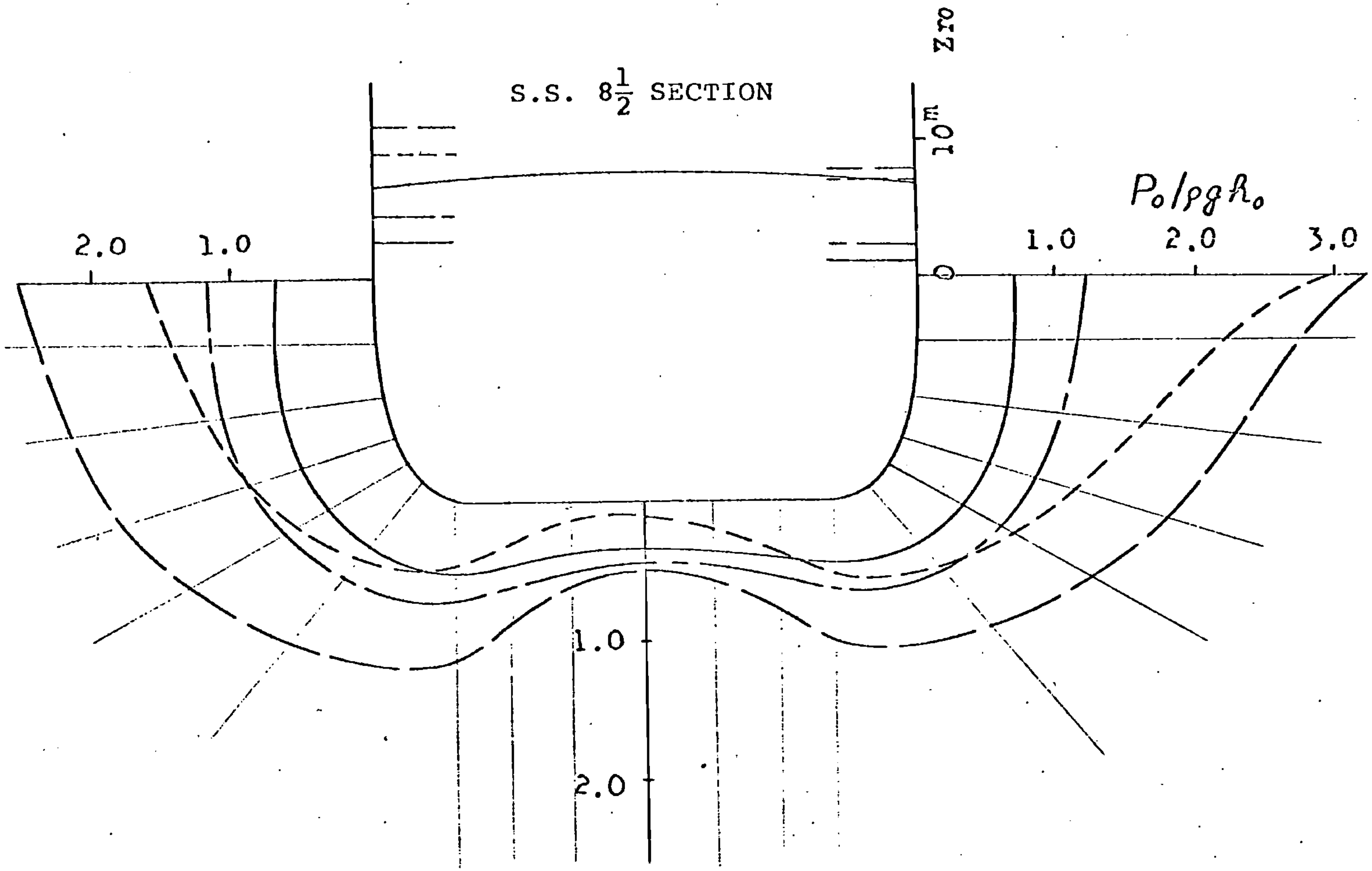
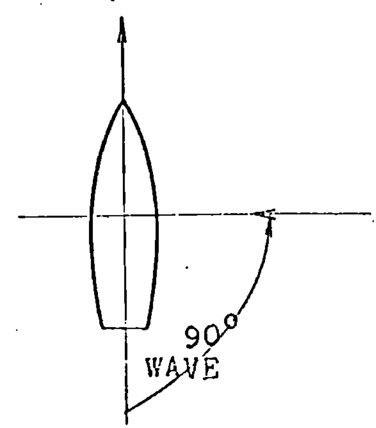


Fig. 15 Amplitudes of Hydrodynamic Pressure in Regular Head Waves

SHIP LENGTH	247m
WAVE HEIGHT	10m
FROUDE NO.	0.10





	$\sqrt{L/\lambda}$
———————	0.90
—— · ——	1.00
—— —— ——	1.20
- - - - -	1.40

Fig. 16 Amplitudes of Hydrodynamic Pressure on the Hull Section in Regular Beam Waves of Different Lengths

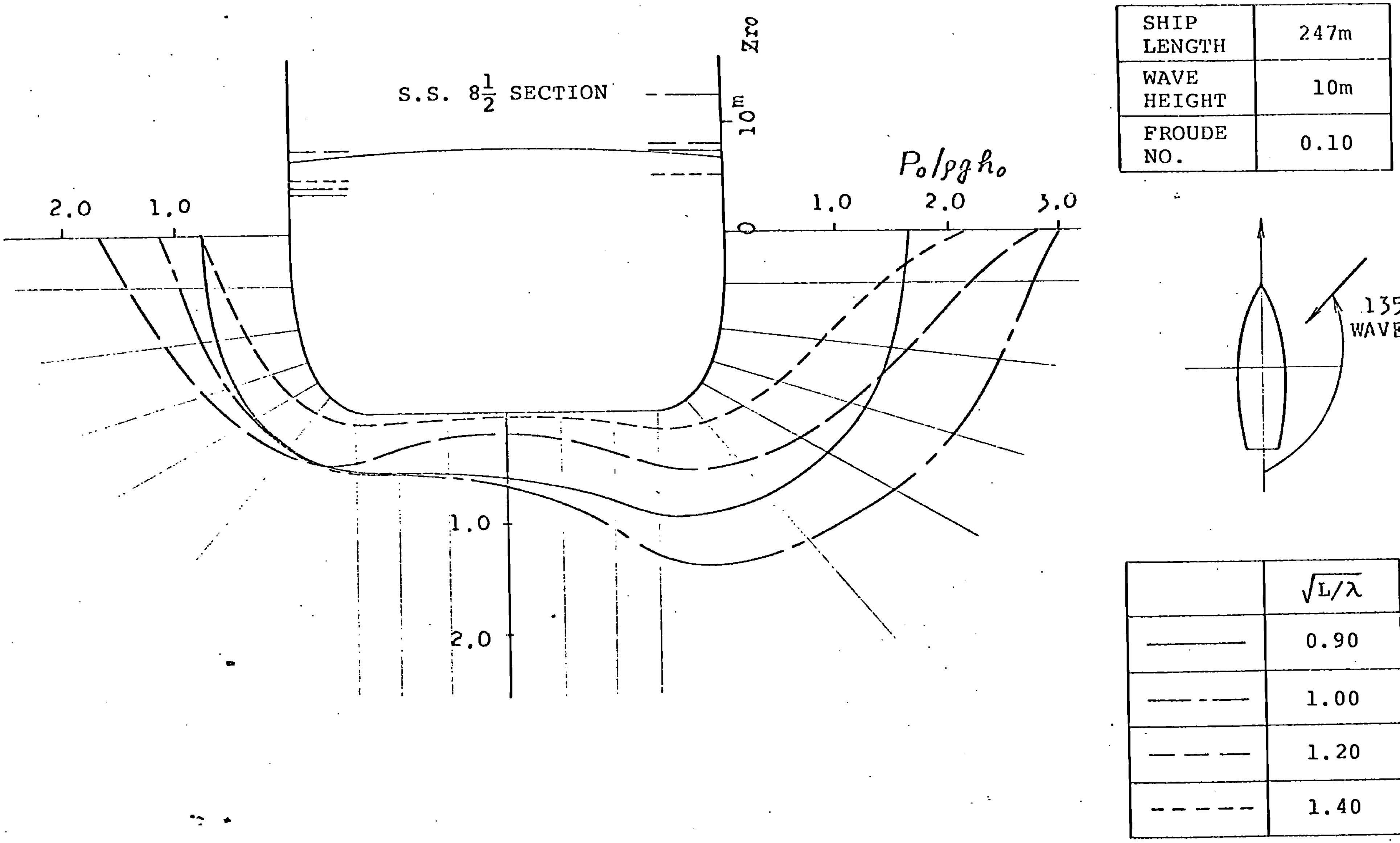
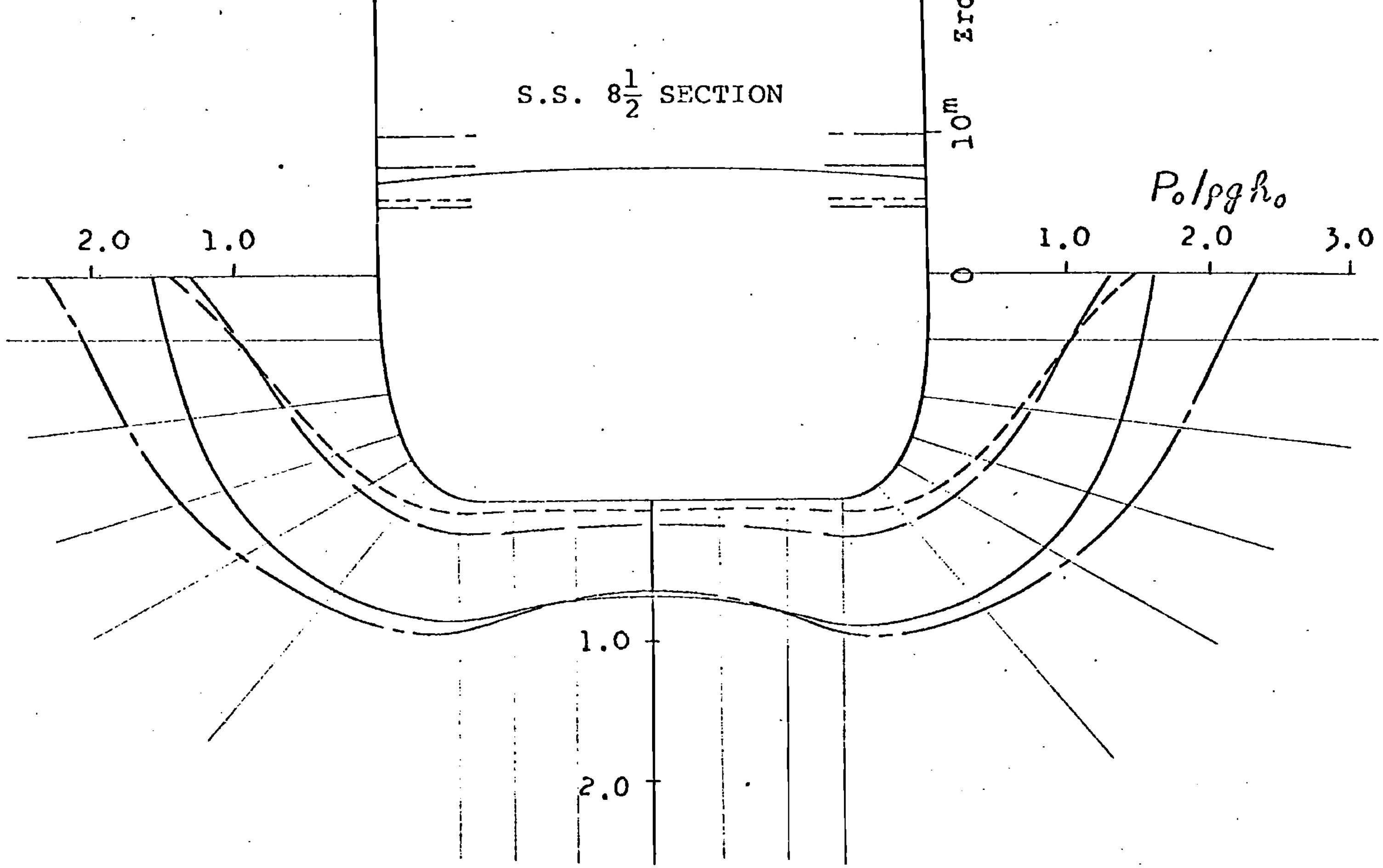
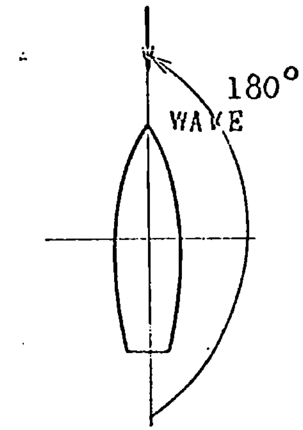


Fig. 17 Amplitudes of Hydrodynamic Pressure on the Hull Section in Regular Bow Waves of Different Lengths

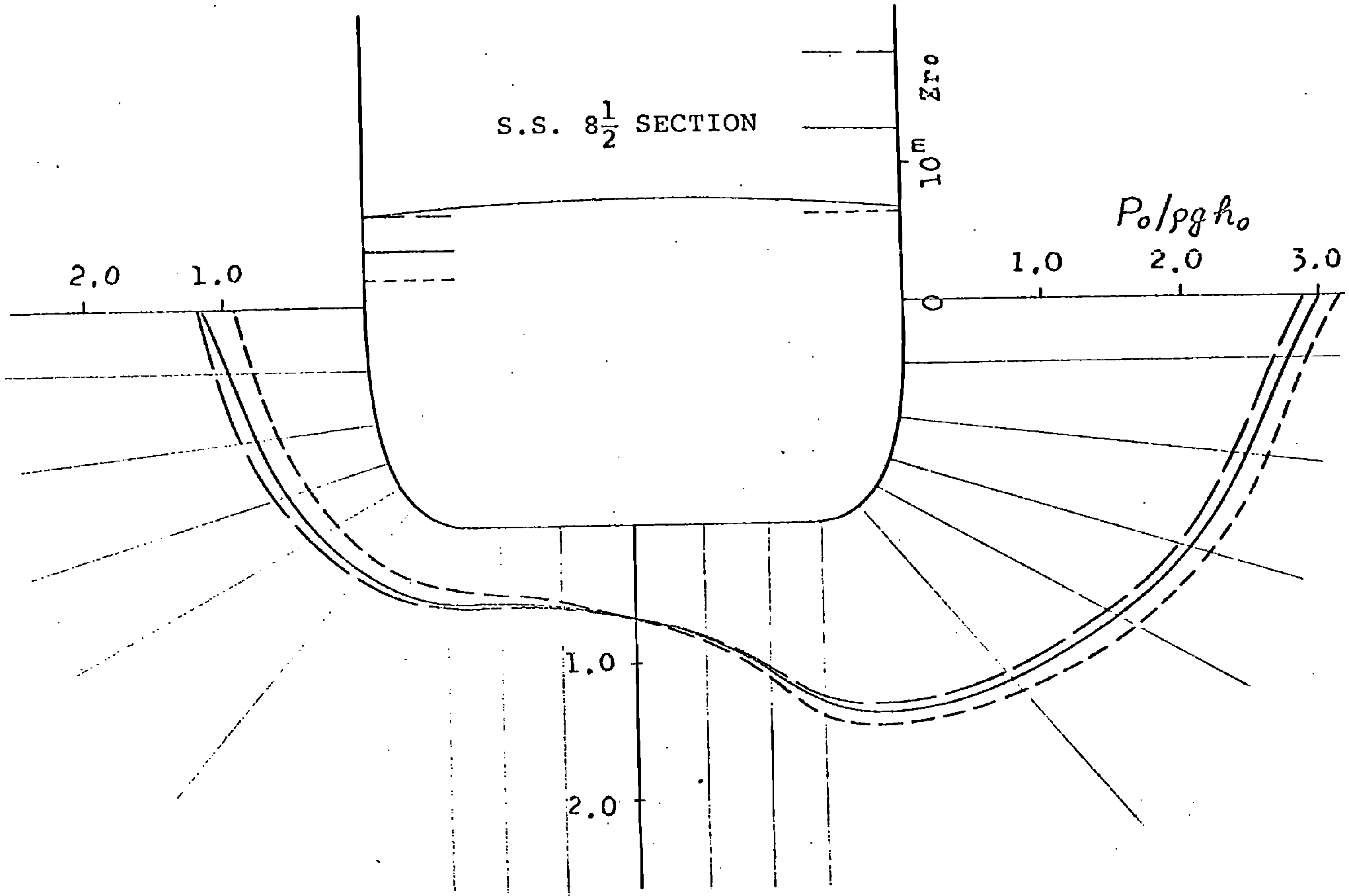


SHIP LENGTH	247m
WAVE HEIGHT	10m
FROUDE NO.	0.10

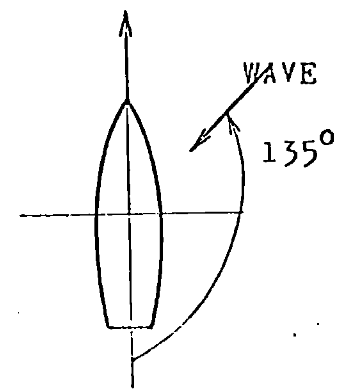


	$\sqrt{L/\lambda}$
———— (solid)	0.90
— - — (long-short dash)	1.00
— — — (long dash)	1.20
- - - - (short dash)	1.40

Fig. 18 Amplitudes of Hydrodynamic Pressure on the Hull Section in Regular Head Waves of Different Lengths



SHIP LENGTH	247m
$\sqrt{L/\lambda}$	1.00
FROUDE NO.	0.10



	WAVE HEIGHT
- - - - -	5m
————	10m
— — —	15m

Fig. 19 Amplitudes of Hydrodynamic Pressure on the Hull Section in Regular Bow Waves of Different Heights

SHIP SECTION	$8\frac{1}{2}$
$\sqrt{L/\lambda}$	1.0
χ	135°
Fn	0.10
Te	10.689 sec

MOTION	AMP.	PHASE
WAVE	5 m	
HEAVE	4.895 m	−33.89°
PITCH	4.168°	51.49°
ROLL	7.732°	175.23°

SCALE 0 10 20m

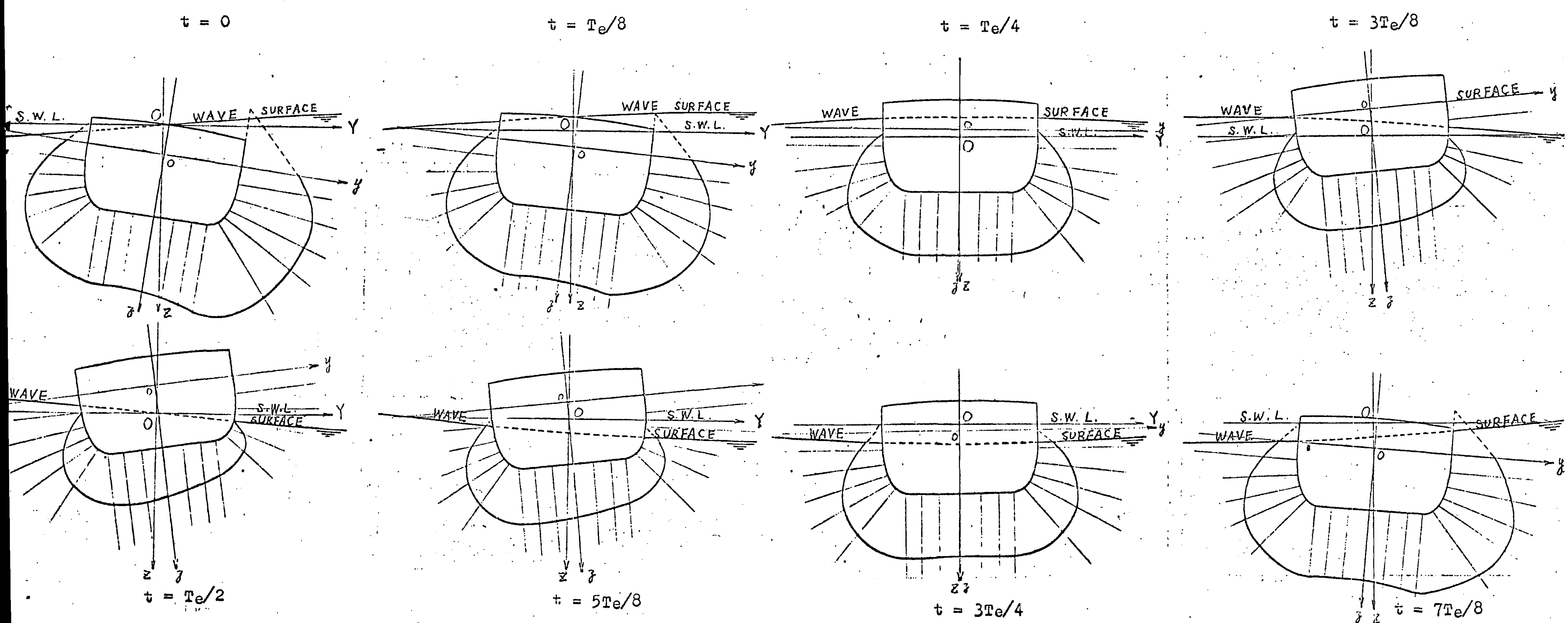


Fig. 20 Pressure Distributions on the Hull Section during an Encountered Period in Regular Bow Waves