NAVY DEPARTMENT

DAVID TAYLOR MODEL BASIN

HYDROMECHANICS

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APPLIED MATHEMATICS

PRELIMINARY REPORT OF STRAINS AND MOTIONS OF USS RANGER (CVA 61) DURING A VOYAGE AROUND CAPE HORN

[redacted]

by

Norman H. Jasper

and John N. Andrews

STRUCTURAL MECHANICS LABORATORY

RESEARCH AND DEVELOPMENT REPORT

January 1959 Report 1289

PRNC-TMB-648 (11-56)

DEPARTMENT OF THE NAVY
DAVID TAYLOR MODEL BASIN
WASHINGTON 7, D.C.

IN REPLY REFER TO
S29/12
A9/1
(751:NHJ:ns)
Ser 7-14
22 Jan 1959

From: Commanding Officer and Director
To: Chief, Bureau of Ships (312)

Subj: Response of hull structure of USS RANGER (CVA 61) to rough seas; forwarding of preliminary report on

Ref: (a) BUSHIPS ltr CVA 61(442), Ser 442-3 of 23 Jan 1958 to DTMB
(b) TMB ltr S29/12, Ser 7-122 of 3 June 1958 to CO, USS RANGER and others

Encl: (1) DTMB Report 1289 entitled "Preliminary Report of Strains and Motions of USS RANGER (CVA 61) during a Voyage around Cape Horn" 20 copies

1. Reference (a) authorized the David Taylor Model Basin to make measurements of the hull response to rough seas during the westward voyage of USS RANGER around Cape Horn in July 1958. The objectives and general test procedures were outlined in enclosure (1) of reference (b).

2. The sea tests were conducted on schedule. Unfortunately the severe storms expected in the Cape Horn area did not materialize, although heavy swells from distant storm areas were experienced. Results of a preliminary analysis of the data obtained during the most severe operating conditions encountered are given in enclosure (1).

W J Sette

W.J. SETTE
By direction

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PRELIMINARY REPORT OF STRAINS AND MOTIONS OF USS RANGER (CVA 61) DURING A VOYAGE AROUND CAPE HORN

by

Norman H. Jasper
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January 1959

Report 1289

NS731-037

ABSTRACT

Preliminary results obtained from measurements of motions and stresses on USS RANGER (CVA 61) during a westward passage around Cape Horn are presented. Storms were not encountered during the voyage, but data were obtained during operation in heavy swells with wave heights of the order of 40 ft. Measurements reported include hull-bending stresses forward and amidships, local stresses around a large side opening, shear stresses in the shell plating forward, linear and angular ship motions obtained under conditions free of slamming as well as during a mild slam.

It is concluded that the flight deck sponson makes a partial contribution to hull-girder strength, that slamming stresses contribute appreciably to the stress level, and that, for the most severe conditions of ship motions observed, the area of minimum ship motion is near Frame 150.

INTRODUCTION

USS RANGER (CVA 61) was instrumented with transducers to measure strains, pressures, and ship motions during a westward passage of the ship around Cape Horn in July 1958 at the request of the Bureau of Ships.* Very stormy seas were

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*Bureau of Ships letter CVA 61(442) Serial 442-3 of 23 Jan 1958.

expected during this passage (southern latitude winter), but unfortunately not a single storm was encountered. However, very heavy swells arising from distant storms were experienced during the voyage, and a variety of data was obtained.

The main objectives of the test were:

A. Determinations of hull-girder stresses (bending moments) and ship motions for a wide variety of operating conditions.

B. Determination of the stresses around the large deck edge elevator openings in the shell.

C. Determination of the intensity and characteristics of hull stresses and motions accompanying slamming in rough seas.

D. Determination of the dynamic water pressures acting on the bow and port flight-deck sponsons.

E. Determination of the magnitude and character of vibrations at the fantail and at the radar platform.

Although the analysis of the data has not been completed, this preliminary report has been prepared to furnish the more significant information obtained. This report gives the results of an analysis made for a moderate slam and for the condition which resulted in the largest hull stresses and ship motions. The sea conditions were not sufficiently severe to yield pressure data for evaluation of Objective D.

INSTRUMENTATION

Strain gages were installed at Frame 141 to determine the stress distribution near the midship section and the contribution of the sponsons to the section modulus, around the coaming of the port side opening at Frame 81 to determine stress concentration factor, and on the shell plating at Frame 37 near the neutral axis to determine the shear stresses in the plating.

Accelerometers were installed near the bow (Frame 19½), at the center of gravity (Frame 127), and at the touchdown point on the flight deck (Frame 205).

In addition a wave height meter was installed amidships, a wave elevation gage at the bow. Stable elements were used to measure roll and pitch angle. Vibration pickups were installed at the fantail and at the base of the forward radar.

Exact locations of the measuring instruments are given in Table 1.

TEST RESULTS

The maximum stresses and motions observed during the tests and the pertinent environmental data are listed in Table 2. Case 1 is representative of a record showing maximum values of ordinary wave-induced hull-bending stresses and pitch and heave motions observed during the tests. Case 4 refers to observations made during a moderate slam. Figures 1 through 4 show the distributions of stresses and accelerations for Cases 1 and 4. The oscillograms from which the data for Cases 1 and 4 are taken have been reproduced in Figures 5 and 6.

Figure 7 shows the variation of linear vertical acceleration along the length of the ship.

ANALYSIS AND DISCUSSION OF TEST RESULTS

The maximum ordinary wave-induced stresses were observed at times of maximum pitch and heave; see Table 2, Case 1. It is significant that the stress variation at the port side opening was 10,400 psi when the corresponding value at the flight deck amidships was 4200 psi (average of stresses from port and starboard gages). Thus, the stress concentration factor at the opening based on girder stress in the flight deck is about 2.5.

The stress distributions shown in Figures 1 and 3 suggest that the port sponson <u>does</u> contribute to the hull-girder section modulus but that the connection between the hull and the sponson is relatively "soft" so that stresses in the sponson are not as fully developed as in beam theory. The bottom plating of this sponson makes <u>no</u> contribution to the hull strength. The contribution to the section modulus of the sponson carrying the island structure is negligible. These stress distributions also suggest that the principal axes of inertia of the cross section have been shifted and rotated because of the presence of the port sponson. A rough estimate of this effect indicates a rotation of 7 3/4 deg to starboard for the principal axis and a shift of 5.8 ft to port and 2.8 ft upward of the neutral axis for the hull alone. This shift of principal axes results in an increase of stresses on the starboard side and a decrease of the stress on the port side of the upper flange of the hull girder.

Case 4 of Table 2 corresponds to a moderate slam. It is interesting to note that a high-frequency whipping stress variation of 5300 psi in shear at Frame 37 was superimposed on an ordinary wave-induced shear stress of 3900 psi. Similarly at the side opening a whipping stress variation of 6200 psi was superimposed on an 8500-psi stress variation at the frequency of wave encounter. If the seas had been severe enough to cause immersion of the bow flare, severe whipping stresses would probably have been observed.

Figure 7 shows how the rigid body acceleration of the ship varies along its length. Several occasions of relatively large acceleration have been plotted including four cases listed in Table 2. It is significant that the point of minimum motion (the apparent pitching axis) lies about 100 ft aft of Frame 127, i.e., about 200 ft forward of the normal touchdown point (Frame 206) for the observed operating conditions. The apparent pitching axis may shift for different operating conditions. If planes must be landed at times of severe ship motions, safer landings can probably be made if the touchdown point is chosen near the area of minimum motion which is somewhat forward of the normal touchdown point.

CONCLUSIONS

1. The port flight-deck sponson is only partially effective in contributing to the hull-girder strength. Because of the effect of the sponson the principal axes of inertia of the cross section have been rotated through an angle of approximately 7 3/4 deg and the neutral axis has been shifted approximately 5.8 ft to port and 2.8 ft upward from the axes computed for the hull alone.

2. The starboard sponson, which supports the island structure, does not contribute appreciably to the hull-girder strength.

3. The stress concentration factor applicable to the forward side openings is of the order of 2.5, i.e., the maximum stress in the coaming was about 2.5 times the hull-girder bending stress in the flight deck (strength deck).

4. Data obtained under conditions of moderate slamming indicate that, incident to the elastic response of the ship to the slamming force, high-frequency stress variations of magnitudes comparable with the ordinary wave-induced stresses were induced in the side shell in shear and around the side openings.

5. The flight-deck area of minimum motion is near Frame 150, for the most severe conditions of heave and pitch observed during these tests. If aircraft must be landed under similar operating conditions, safer landings could probably be made forward of the present touchdown area.

6. The level of hull vibration was low throughout the tests.

TABLE 1

Identification and Location of Gages

Data recorded on CEC oscillographs.

Gage	Quantity Measured	Longitudinal	Location Vertical from Baseline	Athwartship	Compartment	Remarks
1SA	Strain	5 1/2 in. Forward Frame 141	96 ft 11 in	57 ft 7/8 in. Starboard	03-137-12-L	On web starboard flight deck longitudinal
2SA	Strain	2 1/2 in. Forward Frame 141	96 ft 11 in.	0	03-137-0-L	On web flight deck longitudinal at centerline
2SB	Strain	2 1/2 in. Forward Frame 141	95 ft 9 in.	0	03-137-0-L	On flange flight deck longitudinal at centerline
$3SA_1$	Strain	2 1/2 in. Forward Frame 141	96 ft 11 in.	57 ft 7/8 in. Port	03-139-1-A	On web port flight deck longitudinal
3SB	Strain	2 in. Forward Frame 141	95 ft 9 in.	57 ft 7/8 in. Port	03-139-1-A	On flange port flight deck longitudinal
1-3SL	Strain	5 1/2 in. Forward Frame 141	96 ft 11 in.	57 ft 7/8 in. Port	Same as 1 and 3SA	Same as 1 and 3SA
1-3ST	Strain	7 1/2 in. Forward Frame 141	96 ft 11 in.	57 ft 7/8 in. Port	Same as 1 and 3SA	Same as 1 and 3SA
4SA	Strain	4 in. Aft Frame 141	96 ft 11 in.	88 ft 6 in. Port	03-141-14-Q	On web flight deck longitudinal port sponson near catapult 3
5SA	Strain	2 7/8 in. Forward Frame 141	96 ft 11 in.	118 ft Port	03-137-20-L	Port sponson shell plate above opening to catwalk
6SA	Strain	2 in. Forward Frame 141	73 ft 4 in.	93 ft 4 in. Port	03-141-4-A	Web sponson shell longitudinal between 01 and 02 level
7SA	Strain	2 5/8 in. Forward Frame 137	59 ft 6 in.	0	2-132-6-L	Web main deck centerline longitudinal
8SA	Strain	2 in. Forward Frame 140	7 ft 9 in.	45 ft 4 in. Port	7-132-0-E	Web port tank stiffener 44 in. above I beam
9SA	Strain	2 in Aft Frame 140	7 ft 9 in.	45 ft 4 in. Starboard	7-132-0-E	Web starboard tank stiffener 44 in. above I beam
10SA	Strain	2 in. Aft Frame 141	96 ft 11 in.	118 ft Starboard	03-141-13-L	Web main deck longitudinal starboard sponson
11SA	Strain	7 ft 11 1/4 in. Forward Frame 141	96 ft 11 in.	0	03-137-0-L	Web flight deck longitudinal at centerline
11SB	Strain	7 ft 11 1/4 in. Forward Frame 141	95 ft 9 in.	0	03-137-0-L	Flange flight deck longitudinat at centerline
12SA	Strain	2 1/2 in. Aft Frame 137	96 ft 11 in.	0	03-137-0-L	Same as 11SA
12SB	Strain	2 1/2 in. Aft Frame 137	95 ft 9 in.	0	03-137-0-L	Same as 11SB
14SA	Strain	8 ft 2 1/2 in. Forward Frame 141	96 ft 11 in.	57 ft 7/8 in. Port	03-137-12-L	Web port flight deck longitudinal
14SB	Strain	8 ft 2 1/2 in. Forward Frame 141	95 ft 9 in.	57 ft 7/8 in. Port	03-137-12-L	Flange port flight deck longitudinal
15SA	Strain	3 in. Forward Frame 94	97 ft	0	03-59-01-L	Web flight deck longitudinal on center-line
22SO	Strain	12.67 ft Aft Frame 81	85 ft 2 in.	51 ft Port	1-59-0-Q	Inboard coaming of outboard opening
23SO	Strain	7.95 ft Aft Frame 81	83 ft 8 in.	50 ft 10 in. Port	1-59-0-Q	Same as above
24SO	Strain	3.85 ft Aft Frame 81	81 ft 10 in.	50 ft 6 in. Port	1-59-0-Q	Same as above
25SO	Strain	1.1 ft Aft Frame 81	77 ft 10 in.	50 ft 6 in. Port	1-59-0-Q	Same as above
26SO	Strain	Frame 81	72 ft 10 in.	50 ft 6 in. Port	1-59-0-Q	Same as above
27SO	Strain	1.1 ft Aft Frame 81	67 ft 10 in.	50 ft 6 in. Port	1-59-0-Q	Same as above
28SO	Strain	3.85 ft Aft Frame 81	66 ft 9 1/2 in.	50 ft 6 in. Port	1-59-0-Q	Same as above

TABLE 1 (Continued)

Gage	Quantity Measured	Location Longitudinal	Location Vertical from Baseline	Location Athwartship	Compartment	Remarks
29SO	Strain	7.95 ft Aft Frame 81	62 ft 2 in.	50 ft 10 in. Port	1-59-0-Q	Inboard coaming of outboard opening
30SO	Strain	12.67 ft Aft Frame 81	85 ft 2 in.	62 ft 6 in. Port	1-59-0-Q	Outboard coaming of inboard opening
31SO	Strain	7.95 ft Aft Frame 81	83 ft 8 in.	62 ft 4 in. Port	1-59-0-Q	Same as above
32SO	Strain	3.85 ft Aft Frame 81	81 ft 10 in.	62 ft 4 in. Port	1-59-0-Q	Same as above
59AV	Accel. Heave	5 in. Aft Frame 127	40 ft 1 in.	2 1/2 in. Port	4-119-0-Q	On H beam at centerline
58DR	Roll Angle	6 in. Forward Frame 137	90 ft 8 in.	16 in. Starboard	03-137-1-L	Bulkhead near centerline
58DP	Pitch Angle	6 in. Forward Frame 137	90 ft 8 in.	16 in. Starboard	03-137-1-L	Bulkhead near centerline
57DW	Wave Height	2 ft Forward Frame 124	14 ft 7 in.	Port Starboard	8-119-16-V 8-119-15-V	Port shell strake Starboard shell strake
$40P_1$	Pressure	3 ft 3/4 in. Forward Frame 19	2 in.	48 in. Port	8-16-0-V	Bow bottom plate
$41P_2$	Pressure	11 3/4 in. Forward Frame 19	2 in.	48 in. Port	8-16-0-V	Bow bottom plate
$42P_3$	Pressure	Frame F	79 ft	11 ft Port	02-H-0-Q	Bow flare plate
$43P_4$	Pressure	Frame F	79 ft	14 ft Port	02-H-0-Q	Bow flare plate
$44P_5$	Pressure	Frame F 1/2	81 ft	14 ft Port	02-H-0-Q	Bow flare plate
$45P_6$	Pressure	10 ft Forward Frame 104	65 ft 10 in.	76 ft 4 in. Port	Port Sponson	Port sponson shell plate
$46P_7$	Pressure	10 ft Forward Frame 104	67 ft 5 in.	80 ft 4 in. Port	Shell plate	Port sponson shell plate
$47P_8$	Pressure	11 ft Forward Frame 104	72 ft 6 in.	91 ft 4 in. Port	Between main and 03 deck	Port sponson shell plate
$48P_9$	Pressure	11 ft 5 in. Forward Frame 104	81 ft	109 ft 4 in. Port	Between main and 03 deck	Port sponson shell plate
$50SS_1$	Strain	Frame 37	58 ft	31 ft 6 in. Port	2-32-2-L	Port shell strake 7 ft above 2nd deck
$50SS_2$	Strain	Frame 37	58 ft	31 ft 6 in. Port	2-32-2-L	Port shell strake 7 ft above 2nd deck
$50SS_3$	Strain	Frame 37	58 ft	31 ft 6 in. Port	2-32-2-L	Port shell strake 7 ft above 2nd deck
$51SS_1$	Strain	Frame 37	58 ft	31 ft 6 in. Starboard	2-29-3-L	Starboard shell strake 7 ft above 2nd deck
$51SS_2$	Strain	Frame 37	58 ft	31 ft 6 in. Starboard	2-29-3-L	Starboard shell strake 7 ft above 2nd deck
$51SS_3$	Strain	Frame 37	58 ft	31 ft 6 in. Starboard	2-29-3-L	Starboard shell strake 7 ft above 2nd deck
53SA	Strain	Frame 38	91 ft 8 in.	0	03-38-0-Q	Web flight deck longitudinal at centerline
$54SS_3$	Strain	Frame 19	65 ft	28 ft Port	1-12-0-Q	Port shell strake 4 ft 2 in. above main deck
55AV	Accel.	Frame 19 1/2	51 ft 2 1/2 in.	0	2-12-0-A	Centerline main deck
56AV	Accel.	14 in. Forward Frame 19	6 ft 11 1/2 in.	0	7-16-0-E	Centerline 3 ft above I beam
70AV	Accel. Touchdown	3 ft 10 in. Forward Frame 206	88 ft 9 in.	0	03-207-0-L	
71DW	Wave Height	45 in. Forward Frame I	88 ft 6 in.	0	03-J-0-C	5 ft above 03 level on outside skin
52SS	Strain	Frame 37	96 ft	0	03-24-6-L	Port shell strake 8 1/2 ft above 03 deck

TABLE 2

List of Maximum Values Measured

The values given are defined by the function $A_{max} \cos(\omega t + \phi)$. The phase angle ϕ for the pitch angle is taken equal to zero. Maximum values are shown boxed. All values refer to wave-induced values except as noted.

			1	2	3	4	5
Case			1	2	3	4	5
Run			25-2	25-1	25-2	23-5	23-5
Date-Time**			252157	251508	252203	231516	231517
Ship Position		Latitude Longitude	S35.2 W72.9	S36.1 W73.5	S35.2 W72.9	S45.3 W75.9	S45.3 W75.9
Ship Heading			220	030	220	004	004
Wave Heading			060	045	060	135	135
Speed, Knots			22	11	25	25	25
Wave Data		Maximum Height, ft	[42.8]	12.9	38.0	-	15.7
		Length λ, ft	1200	580	1100	-	600
		Period, sec	11.0	15.9	10.5	5.0	7.4
		Phase Angle ϕ_W, deg	170	200	200	250	200
Motion	Maximum Pitch Angle, deg		[4.5]	1.1	3.5	0.93	1.4
	Roll	Maximum Angle, deg	0.57	[5.8]	0.38	1.73	3.8
		Phase Angle ϕ_R, deg	0	85	180	0	180
	Heave at Center of Gravity	Maximum Acceleration, g	[0.18]	0.02	0.13	0.13 0.05*	0.06
		Phase Angle ϕ_H, deg	320	320	320	300	280
	Heave at Touchdown	Maximum Acceleration, g	0.19	-	0.20	0.090 0.037*	[0.23]
		Phase Angle ϕ_T, deg	170	-	170	260	200
Stress	Flight Deck	Maximum Value,† psi	[4200]	860	3800	2800 970*	1450
		Phase Angle ϕ_S, deg	140	160	150	200	210
	Opening††	Maximum Value, psi	10,400	2000	[10,700]	8500 6200*	3200
		Phase Angle ϕ_{SO}, deg	140	280	150	200	170
	Shear‡	Maximum Value, psi	[5200]	-	1800	3900 5300*	2200
		Phase Angle ϕ_τ, deg	340	-	340	340	60
	Maximum Whipping,†† psi		500*	0*	0*	[6200*]	500*
Pressure‡‡		Maximum Value, psi	18.5	-	[19.0]	9.5	5.5
		Phase Angle ϕ_P, deg	160	-	151	180	180

*These values refer to whipping motions and stresses, not wave-induced values.
**All dates in July 1958, times GCT
†Average of Gages 1SA and 3SA
††Gage 23SO
‡Gage $51SS_{1-3}$
‡‡Gage $41P_2$

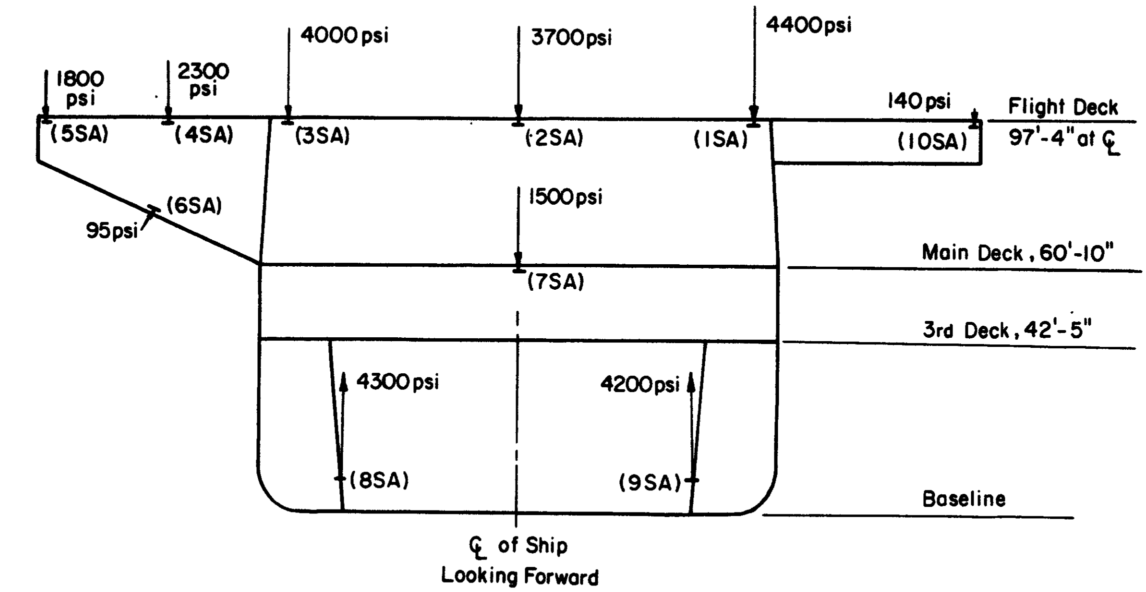

Figure 1 - Bending Stress Distribution at Frame 141 for Ordinary Wave Action (Case 1, Table 2)

Legends in parentheses are gage identifications.

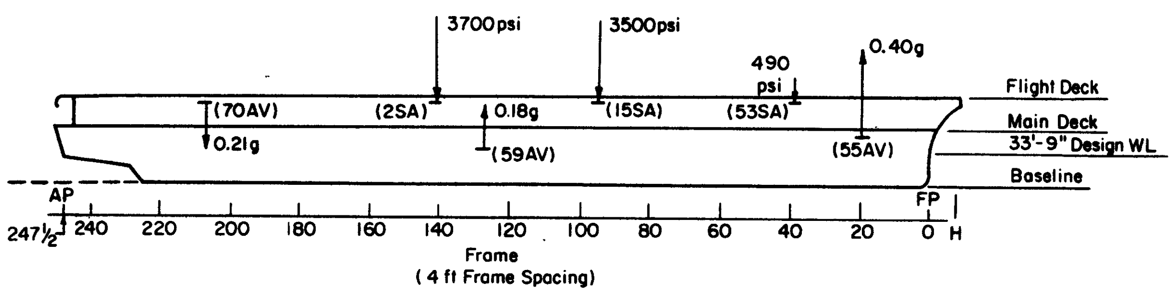

Figure 2 - Longitudinal Variation of Bending Stress and Vertical Acceleration for Ordinary Wave Action (Case 1, Table 2)

Legends in parentheses are gage identifications. Shear stress in shell at Frame 37 is 5200 psi starboard (Gages $51SS_{1-3}$) and 4900 psi port (Gages $50SS_{1-3}$).

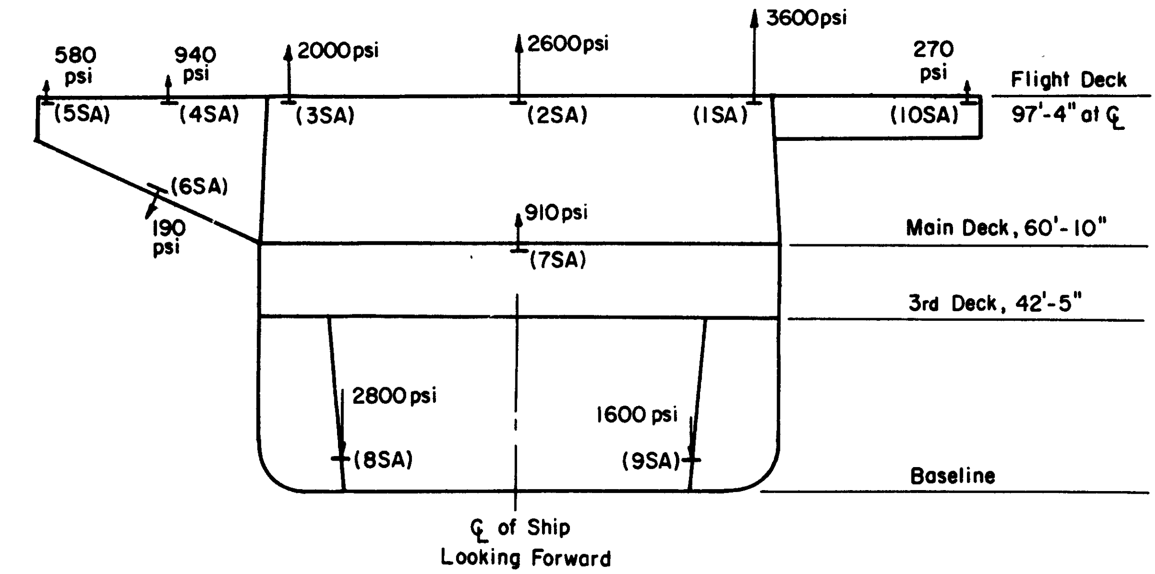

Figure 3 - Bending Stress Distribution at Frame 141 for a Moderate Slam (Case 4, Table 2)

Legends in parentheses are gage identifications.

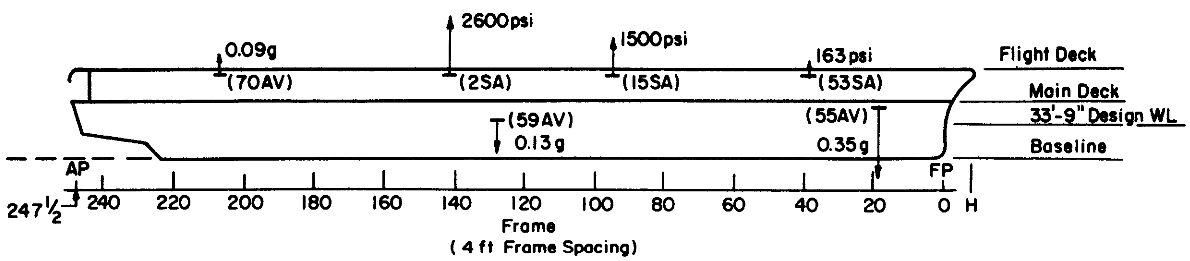

Figure 4 - Longitudinal Variation of Bending Stress and Vertical Acceleration for a Moderate Slam (Case 4, Table 2)

Legends in parentheses are gage identifications. Shear stress in shell at Frame 37 is 3900 psi starboard (Gages $51SS_{1-3}$) and 2600 psi port (Gages $50SS_{1-3}$).

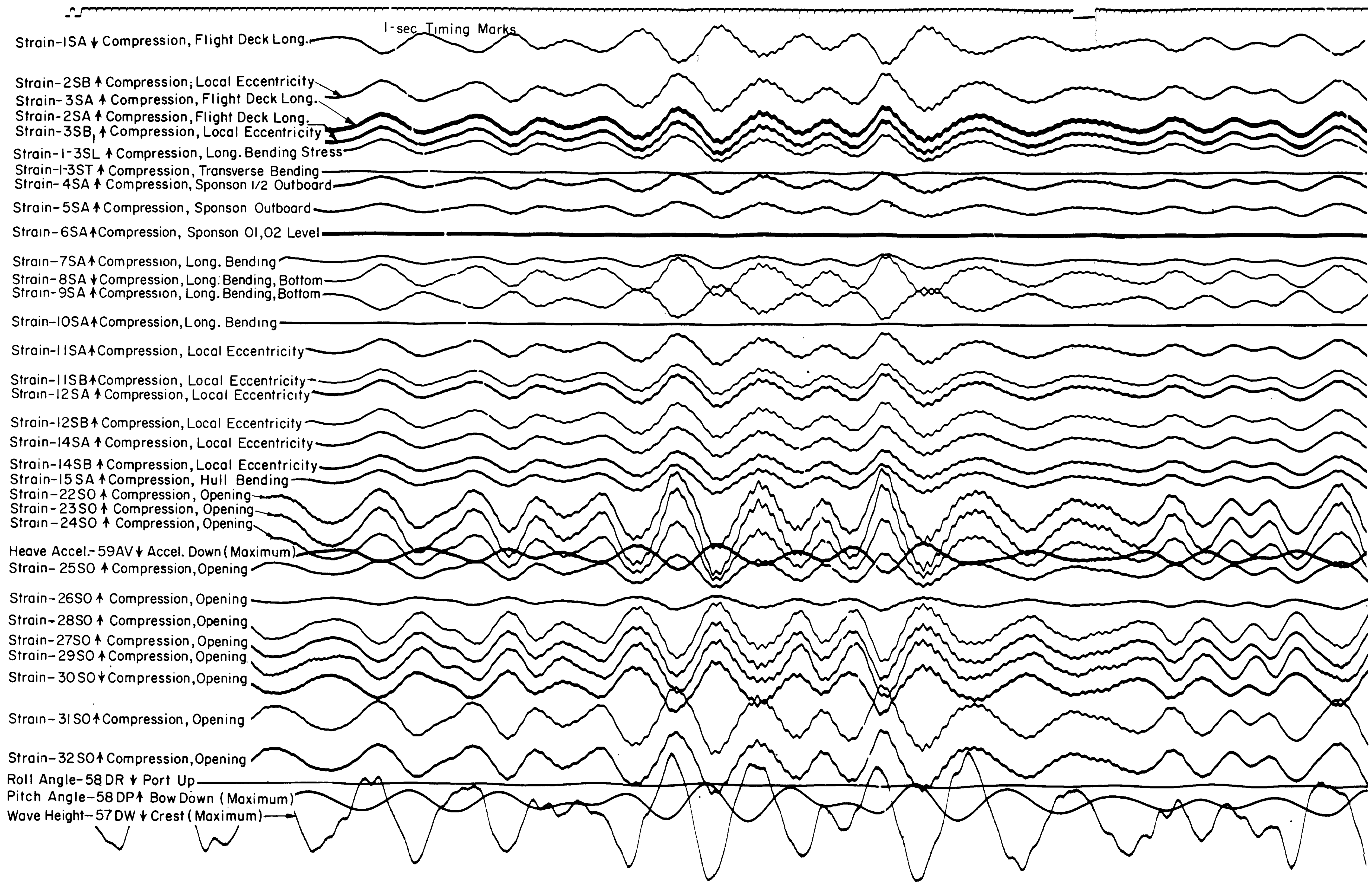

Figure 5 - Sample Oscillogram for Ordinary Wave Action
(Case 1, Table 2)

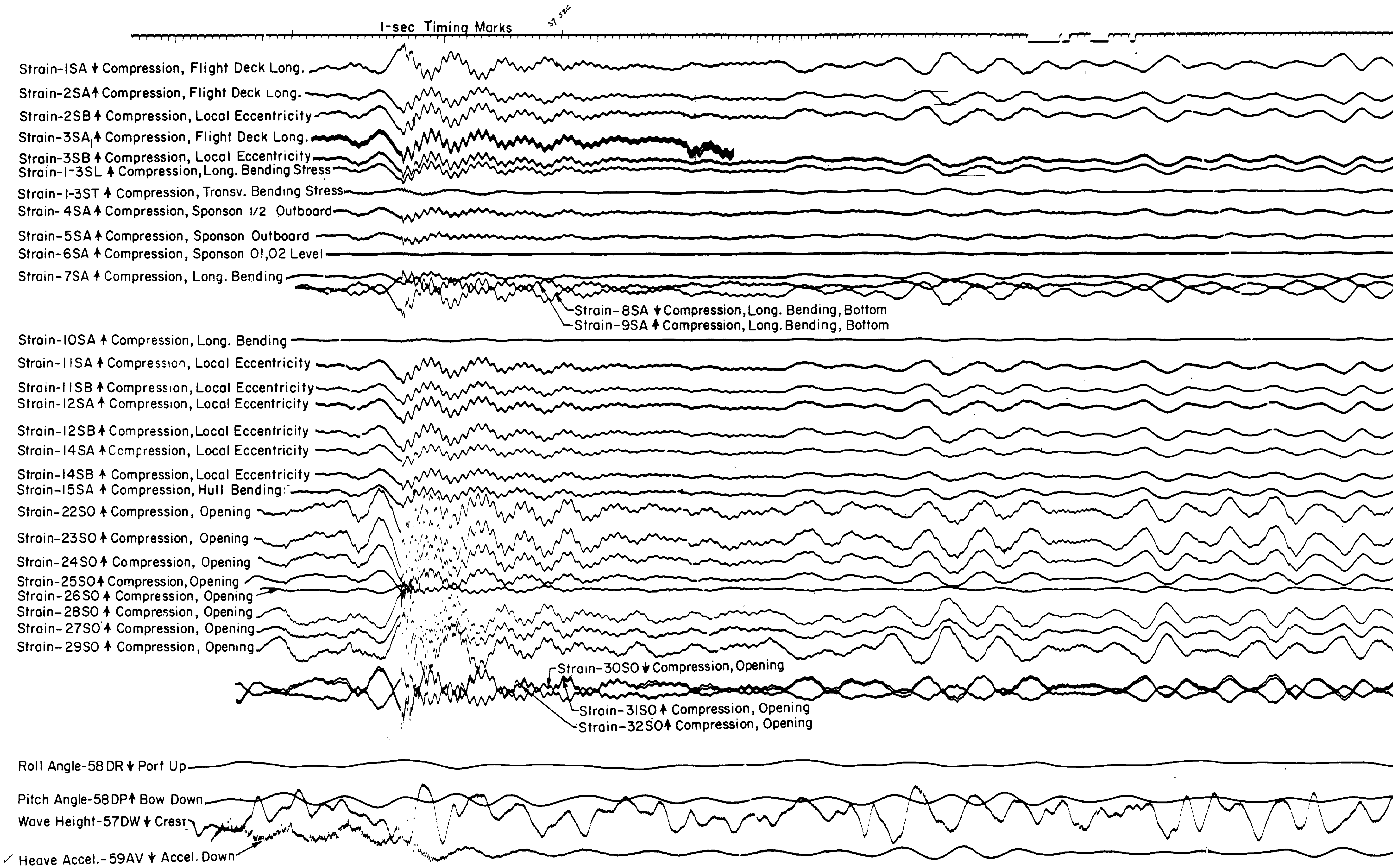

Figure 6 - Sample Oscillogram for a Moderate Slam
(Case 4, Table 2)

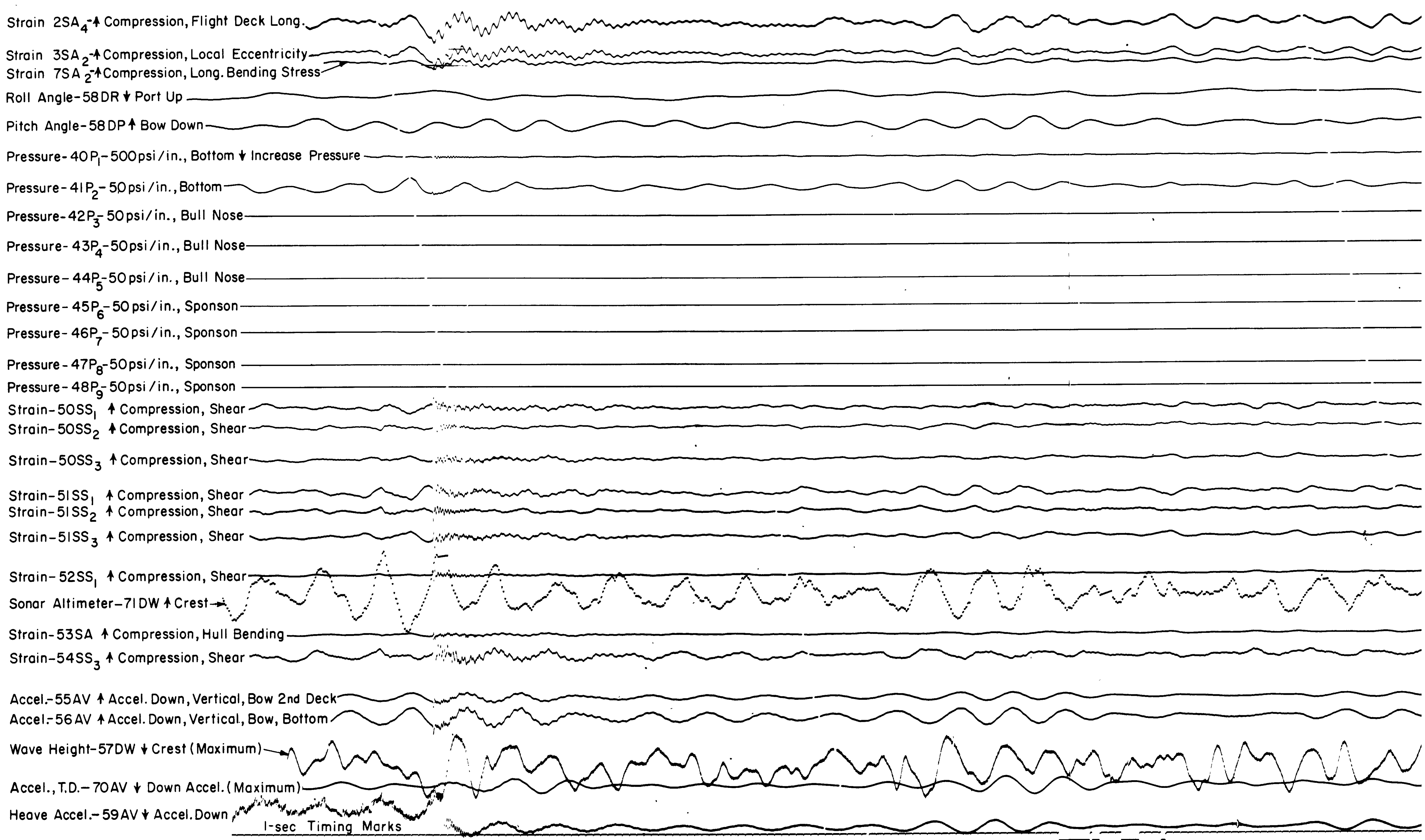

Figure 6 (Continued)

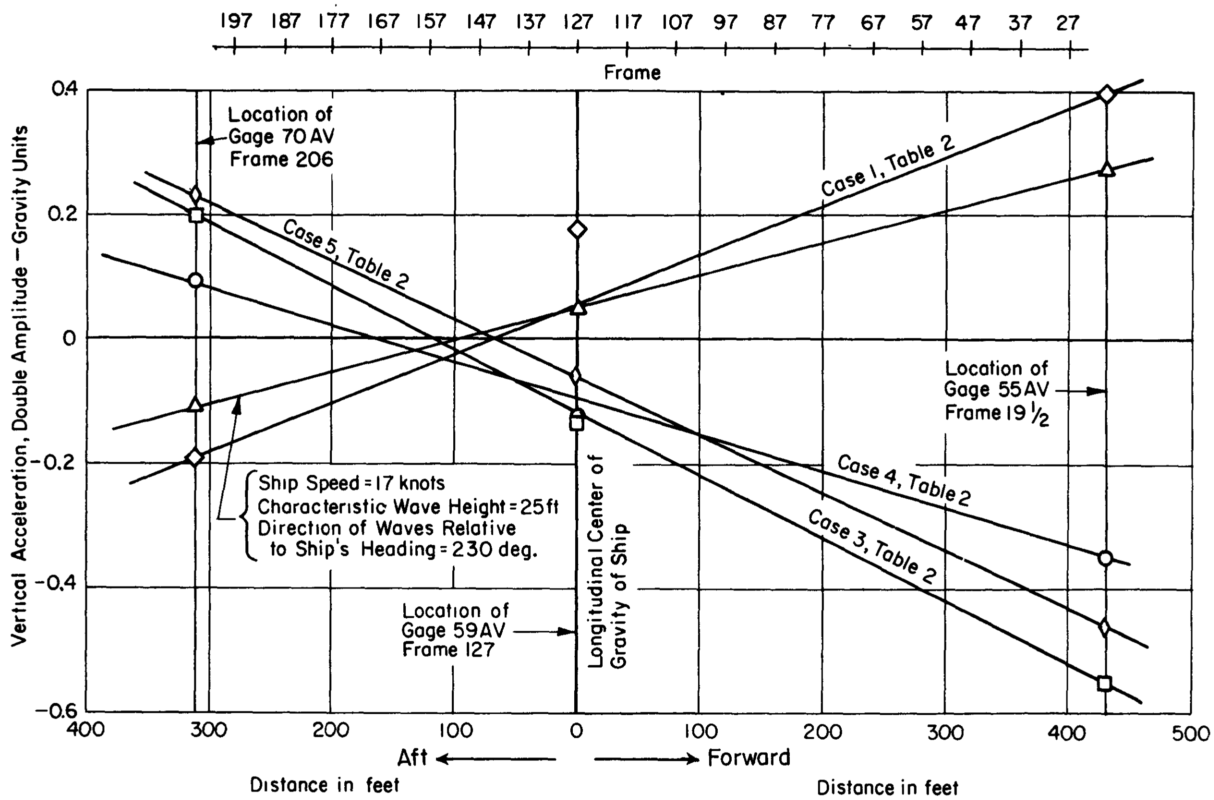

Figure 7 - Longitudinal Variation of Vertical Acceleration

The sign denotes the relative phase of the acceleration.

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