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ACOUSTICS AND VIBRATION

USS TRIPOLI (LPH 10) UNDERWAY VIBRATION TRIALS

by

Donald C. Robinson
and
Gary P. Antonides

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ACOUSTICS AND VIBRATION LABORATORY

RESEARCH AND DEVELOPMENT REPORT

October 1966

Report 2306

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ABSTRACT

An underway vibration trial of USS TRIPOLI (LPH 10) was conducted on 24 September through 25 September 1966. Measurements were concentrated on the mast and island structure, the hospital area, the hull, and the main propulsion system. Data were analyzed to determine the nature and cause of excessive vibrations in the mast and island structure and in the hospital area at high ship speeds during free route (straight course) and maneuvering operation. Similar conditions were reported on both the LPH 9 and on LPH 2 class vessels.

The results of the underway trial were evaluated with data obtained during an earlier vibration generator survey of the mast-island structure and hospital area of TRIPOLI and compared with measurements obtained during an underway trial on USS OKINAWA (LPH 3) conducted in March 1963.

Structural modifications to the island prior to the underway trial are shown to have changed the fundamental athwartship frequency of the island. An increase in the levels of athwartship vibration measured on the mast during high speed turns relative to those measured on OKINAWA is attributed to increased loading caused by added electronic equipment.

The results of the various tests are used as a basis for suggested recommendations in order to mitigate the excessive vibrations of TRIPOLI and for further effort required for correction of the LPH class vibration problems.

ADMINISTRATIVE INFORMATION

This assignment was authorized by Naval Ship Systems Command letter LPH 10/9400, Serial 522.34 of 12 July 1966. Funds were provided under Project SCN 70195.

INTRODUCTION

USS TRIPOLI (LPH 10) is the second ship of the LPH 9 class, a modification of the LPH 2 class amphibious assault carrier having reduced ballistic plating and whose main propulsion gears and turbine were built by a different manufacturer. The island structure of TRIPOLI was constructed with the same dimensions as that of other LPH class vessels but with the omission of about two-thirds of its corner stiffener brackets.

An exceptionally high level of vibration was reported in the mast and island structure of TRIPOLI during high speed turns, similar to that measured on USS OKINAWA (LPH 3) at 85 shaft RPM to full power.[1*] The Naval Ship Systems Command requested that the Model Basin conduct vibration measurements needed to determine the nature and probable cause of excessive vibration in the mast and island. In addition, Philadelphia Naval Shipyard requested that vibration tests be conducted to investigate excessive vibration levels reported in the hospital area.

Vibration generator tests were conducted on the mast and island structure and in the medical spaces of TRIPOLI from 29 August to 14 September 1966 during her fitting-out period while dockside at Philadelphia Naval Shipyard. It was found during these tests that (1) the island structure had an athwartship resonance at 6.6 cycles per second characterized by apparent racking (sidesway) of the island, (2) the mast had athwartship and longitudinal resonances at about 5.0 cycles per second with large amplification measured in both directions on the mast and island from the 03 to the 04 level, and (3) the 01 Deck in the hospital area exhibited diaphram-like motion at a vertical resonant frequency of 13.7 cycles per second with large flexibility of the deep 14-inch transverse

*References are listed on page 16

beams as well as of the deck between the transverse beams. Based on the analysis of the vibration generator test results, initial recommendations were made to the shipyard to mitigate the excessive vibrations.

Underway vibration trials were conducted during 24 through 25 September 1966 in order to evaluate the longitudinal shafting vibration and its effect on vibration of the hull, mast-island, and hospital spaces and to obtain additional information required for arriving at recommendations for corrective action. Prior to these tests, missing structural members were incorporated in the island, with approximately 100 corner brackets being installed. In addition, two 6-inch longitudinal beams were welded to the existing longitudinal beams in way of the operating tables between the deep transverse members at Frames [illegible] and 123.

Ship and Propeller Characteristics

The hull characteristics and the main dimensions are as follows:

Ship Characteristics

Length (overall)	602 ft. 3 1/2 in.
Length (waterline)	548 ft. 3 1/2 in.
Length (BP)	556 ft. 0 in.
Beam (extreme)	84 ft. 2 1/8 in.
Depth (to main deck, molded)	47 ft. 2 in.
Draft (mean)	26 ft. 1 in.
Displacement (design)	17,983 long tons

Propeller Characteristics

Diameter	21 ft. 0 in.
Pitch at 0.7 x R	22 ft. 6 1/8 in.
Pitch ratio at 0.7 x R	1.07
Area ratio (expanded)	0.522
Mean width ratio (MWR)	0.256
Blade thickness fraction (BTF)	0.045
Number of propellers	1
Number of blades	4
Direction of rotation	R.H.
Weight	21,500 lb.
Propeller tip clearance	5 ft. 6 in.
Maximum shaft rpm	121
Appendages	rudder and bilge keels

Figure 1 shows the propeller and adjacent stern area of the ship.

INSTRUMENTATION

In order to collect as much data as possible, the instrumentation was divided into three separate sections, one for the mast-island, one for the machinery system, and one for the hospital area.

Velocity pickups (CEC type 4-102A), linear/integrating amplifiers (DTMB signal conditioning amplifiers Type 484-1A in the intergration mode), one 36-channel string oscillograph (CEC type 5-119), and a 14-channel tape recorder (Ampex FR 1300) were used to obtain vibratory displacements for the measurements on the mast, island, and **hull girder**. A block diagram of this system is shown in Figure 2a.

Velocity transducers, strain gages (Kulite 1000 ohm semi-conductor), a linear displacement transducer (Collins model SS203), 3-channel Telemetry system (DTMB 499-1A), 3 linear integrating amplifiers (CEC 112-C integrate model), one 36-channel string oscillograph, and one 14-channel tape recorder (CEC model 2300) were used in the machinery spaces. Velocity pickup signals were integrated to give an output signal proportional to the vibratory displacements. The signals from the gages were recorded on both the oscillograph and tape recorders. A block diagram is shown in Figure 2b.

The DTMB Portable Vibration Measurement Kit was used to measure vibrations in the hospital spaces. The major components of this unit were: a DTMB 6-channel Signal Conditioning Amplifier System Type 484, a CEC 18-channel Direct-Rite Oscillograph, CEC model 5-124, and 6 CEC type 4-102-0001 Velocity Transducers. The block diagram for this system is the same as that for the mast-island except that no tape recorder was used.

Prior to the trial the propeller and its rope guard were inspected. No damage was noted of the surfaces and edges of the propeller or of its rope guard.

TRIAL CONDITIONS

The trials were conducted in the Atlantic Ocean enroute from Philadelphia Naval Shipyard and return at a State 4 sea in water depths of 16 fathoms (96 feet) or more. In Table 1 are presented the displacements, drafts and trim for TRIPOLI and those for USS OKINAWA (LPH 3) during their respective sea trials, [illegible] 13 for comparison.

TEST PROCEDURE

The measurements on the mast, island, and hull were made in two recording groups, Phase 1 and Phase 2, at the locations shown in Figures 3 and 4 and summarized in Tables 2 and 3. During Phase 1, athwartship gages were measured on the mast and island at Frame 67, on the hull at Frames 67 and 135 at the locations shown in Figure 3 and summarized in Table 2. Additional athwartship positions were used at the stern tube bearing and thrust bearing, and vertical vibration was measured on the main deck at Frame 135 for a reference position for Phase 1 and Phase 2. During Phase 2, measurements were made on the main deck, island, mast, AN/SPS-10 Radar Platform, signal yardarm, and on the AN/SPN-6 Radar. The location and direction of these gages are shown in Figure 4 and are summarized in Table 3.

To evaluate the vibrations of the 01 Deck and of various medical equipment in the hospital area, the following measurements were made, as summarized in Table 4:

1. Vertical displacement at the base of the operating table at Frame 120.

2. Vertical, athwartship, and longitudinal displacement at the top of the operating table at Frame 120.

3. Vertical displacement on the deck supporting the X-Ray unit at Frame 128.

4. Vertical displacement on the table of the X-Ray Unit, and athwartship displacement on the bulkhead supporting the exposure plate for chest X-Rays.

5. Vertical displacement on the deck under the seat of the dental chair at Frame 116.

6. Vertical and athwartship displacement under the seat of the dental chair at Frame 116.

To evaluate longitudinal shaft vibration, the following measurements were made in the machinery spaces and shaft alley, as shown in Figure 5.

1. Alternating thrust near the reduction gear and near the stern tube bearing (with strain gages and telemetering equipment).

2. Longitudinal displacement of the shaft near the reduction gear (with CEC velocity pick-up and telemetering equipment).

3. Longitudinal displacement of the thrust bearing housing, gear case, gear case foundation, LP turbine casing, HP turbine casing, and condenser (with CEC velocity pick-ups and integrating amplifiers).

4. Relative displacement between the LP turbine rotor and casing (with probe attached to a Collins linear-motion transducer).

Measurements at all positions were taken from 50 to 120 rpm at 5 rpm increments and during full power 40° rudder turns to port and starboard. Measurements were also taken on the mast, island, hull, and hospital spaces at 72, 78, 88, 92, and 102 rpm.

TEST RESULTS

Free Route (Straight Course) Tests

The vertical, athwartship, and longitudinal maximum amplitudes measured at the fantail (Main Deck Centerline, Frame 135) versus rpm are shown in Figure 6. The torsional maximum amplitudes measured on the main deck at Frames 135 and 67 at blade frequency are shown in Figure 7. The athwartship maximum amplitudes at Frame 67 measured at blade frequency on the hull main deck and on the mast at the 07 level, (110 ft. level), first platform (140 ft. level), and at the antenna yardarm (168 ft. level) are given in Figure 8. In Figure 9 are presented the maximum athwartship amplitudes measured on the stern-tube bearing and thrust bearing foundation at blade frequency. These results are summarized in Tables 5 and 6. The latter table also includes measurements on the AN/SPS-10 and AN/SPN-6 Radar.

In Figure 10 is shown the alternating thrust versus rpm in the shaft near the propeller and bull gear. The maximum longitudinal displacements versus rpm of the shaft and thrust bearing housing; of the reduction gear and foundation; of the L.P. turbine, condenser and relative motion between the L.P. turbine rotor and casing; and of the H.P. turbine are shown in Figures 11, 12, 13, and 14, respectively.

The vertical response of the operating table at Frame 120 and of the medical area between Frames 115 and 123 to blade and double blade frequency excitation are shown in Figures 15 and 16, respectively. In Figure 17 is presented the athwartship response of the chest X-Ray exposure mount.

Maneuvering Tests

The vibration measurements during the maneuvers are given in Tables 7, 8 and 9.

During the hard turns to port and starboard, "spoking" of the AN/SPS-10 radar screen light trace was observed during which all targets on the screen became blanked out. After the turns were completed, the signals on the radar screen reappeared. This phenomenon did not occur during the steady speed (straight course) runs.

The vibration of such items as bulletin boards and metal fastenings on the bunks in the ward areas became excessive during the high speed tests. Metal joiner bulkheads in the latter area vibrated as much as 1000 mils at high speeds.

The comparison of maximum vibration blade rate amplitudes of the hull and mast of TRIPOLI and OKINAWA during straight course and maneuvering operations are summarized in Table 10.

DISCUSSIONS AND CONCLUSIONS

Comparison of the vibrations measured on the fantail, presented in Figures 6 and 7 and in Table 5, with hull vibration calculations for OKINAWA[2] indicate that (1) the fundamental vertical hull resonance of TRIPOLI was excited by shaft frequency forces at full power (2.0 cps), (2) an athwartship hull resonance which also involves torsional vibration was excited by blade frequency forces at about 90 rpm (6.0 cps), and (3) a vertical hull mode was excited by blade frequency forces at 115 rpm (7.7 cps). Comparison of the vibrations measured during underway trials on USS TRIPOLI (LPH 10) and USS OKINAWA (LPH 3)[1] in similar sea conditions but with different loading indicates that the hull, mast and island structure, and main propulsion system for these two ships have approximately the same vibration characteristics during free route (straight course) operation; see Tables 1 and 10. Thus the distinction between the LPH 2 and LPH 9 class due to differences in ballastic plating, main propulsion gears, and turbine appear to have no major influence on the ship's vibration response.

Comparison of the athwartship vibrations measured on the mast and island with measurements from vibration generator tests show that (1) an athwartship resonance of the mast was excited by blade frequency forces at 75 rpm (5.0 cps), and (2) an athwartship resonance of the island was excited by blade frequency forces at 110 rpm (7.3 cps).

The maximum athwartship amplitude measured at the top of the radar mast was amplified by a factor of 3.4 during both the port and starboard maneuvers relative to the maximum amplitude measured during the straight course operation. The corresponding amplifications measured at the top of the mast for OKINAWA during the port and starboard maneuvers were 2.4 and 3.2, respectively. The maximum athwartship amplitudes at the topmast during the port and starboard turns of TRIPOLI were 89% and 40% larger, respectively, than those measured during the sea trials of OKINAWA. These differences in the mast vibration response between the LPH 10 and LPH 3 during maneuvers can be partly attributed to the addition of approximately 1000 pounds of electronic equipment and supporting structure to the topmast of TRIPOLI.

The installation of approximately 100 corner stiffener brackets in the island from the 04 to the 07 levels resulted in an increase in the island athwartship fundamental resonance from 6.6 cps (100 rpm), measured during vibration generator tests prior to the addition of the brackets, to 7.3 cps (110 rpm), measured during the sea trials. Hurty and Rubinstein have shown that the effect of joint rotation on natural modes of multi-story framed structures,which would tend to be resisted by corner brackets,is most prevalent in the fundamental mode[3]. Rogers has found that for framed structures having height to width ratios of five or less, which is the case for the island of the LPH class, the frequency of the fundamental mode can be reduced by approximately 20% by joint rotations[4].

The double blade frequency component of longitudinal vibration measured on the shaft and thrust bearing housing peaks at 65 rpm, indicating a longitudinal resonance of the main propulsion system at 8.7 cycles per second. This is the first mode frequency and would correspond with blade frequency at 130 rpm, or 111% of full power rpm. At full power, the amplitudes of the various parts of the machinery in the longitudinal direction are about ±10 mils. The alternating thrust near the thrust bearing is about ±38,000 pounds, which is about ±13% of full power thrust. During the starboard turn, the amplitudes are about ±20 mils, and the alternating thrust is ±64,000 pounds, or 22.5 percent of full power mean thrust. All the machinery components move in phase and at about the same amplitudes throughout the speed range. No local resonances in the machinery or associated piping were detected. The vibrations measured on the main propulsion system indicate that the longitudinal shafting vibration amplitudes on the LPH 10 and LPH 3 are higher than would be expected on this type of ship, but are not high enough to require immediate corrective action. Also, no additional stiffening is required on the machinery foundation.

Problems of radar spoking during the high speed turns have not been known to occur on previous ships of the LPH class. The spoking was observed on all of the repeaters (PPI position indicator scopes) of the AN/SPS-10 Radar and has also been observed for the AN/SPS-40 and AN/SPN-6 Radar during previous trials of TRIPOLI. In view of this problem and the tendency to install more electronic equipment on the mast, a tripod or a quadropod structure may become more desirable than a pole mast for future LPH class vessels unless the existing mast can be sufficiently strengthened to resist the increasing inertia loads created by additional electronics.

RECOMMENDATIONS

The following recommendations are made on the basis of vibration generator tests and the underway vibration trials:

1. Investigate the strength analyses of the mast and island to determine the effects of additional electronic equipment since the LPH 3 which has been installed on the mast and island. The design of the mast, which was based on the assumption of zero mast deflection at the 07 level of the island[5], should be recomputed assuming zero deflection at its base and applying appropriate dynamic load factors. This recalculation should be used as a basis for stiffening of the mast. If additional support of the mast below the flight deck is required, cableways and ducts should be rearranged where necessary to prevent weakening of the load-carrying structural members due to cut-outs. For future LPH class ships, emphasis should be placed on increasing the athwartship flexural rigidity of the island and on taking steps to assure that the connectors between the mast and island act in friction and do not slip.

2. The AN/SPS-10 Radar Antenna gearing system should be investigated to determine if backlash (play) in the gears is a source of spoking of the radar sweep during high speed turns. If backlash is a probable source of spoking, consideration should be given to anti-backlash gears in order that motion between the gears does not cause a dead zone when tracking during ship maneuvers at high speeds.

3. The 6-inch longitudinal I beams at the 01 Deck port side between Frames 115 and 123 that intersect athwartship channels should be removed since they contribute little to the stiffness of the deck due to their flanges being cut where they intersect the shallow athwartship channels and piping. The longitudinal beams should be replaced with continuous beams (i.e., beams which are not weakened due to flange cut-outs) and the piping rearranged where necessary to avoid cut-outs.

4. Permanent stanchions should be installed under the 14-inch transverse beams at the 01 Deck port and starboard sides from Frame 115 aft to the ward areas between the center line and shell. These stanchions should be installed midway between the centerline and shell (i.e., midspan of unsupported beam) or as close to the midspan of the unsupported 14-inch beams as possible. The 01 Deck should be reinforced under the operating tables and the X-Ray unit to mitigate local deck vibration measured near this equipment.

5. Longitudinal channel members should be connected to the metal joiner (MJ) bulkheads in the hospital spaces to provide support between existing vertical bulkhead stiffeners in areas where X-Ray equipment, bookshelves, etc., must be mounted to the MJ bulkheads. For future ships of the LPH class, consideration should be given to the use of fiberglass or dented steel metal in place of the uniform thin steel panels presently used for the MJ bulkheads.

6. Rubber or similar isolation material should be installed between the mating surfaces of bulletin boards and between the mating surfaces of poles and collars on the bunks in the ward area to reduce the excessive noise experienced in the living quarters during high ship speeds.

7. Underway vibration measurements should be made by the shipyard after structural modifications are completed to determine the degree of improvement achieved by the modifications. This information should be used, together with existing data, as a basis for structural changes on future LPH class ships to mitigate excessive vibrations.

8. Although no immediate corrective action is recommended on the LPH 10 main propulsion system, consideration should be given to improvements on the remaining ships of this class. Increasing the number of propeller blades should be investigated even though it would bring the longitudinal critical within the operating range of blade frequency.

A rough approximation can be made of what can be expected with 5, 6, and 7-bladed propellers. Table 11 presents the results of such an approximation. The alternating thrust at what would be the new critical speeds was taken from data on this trial . Experience has shown that increasing the number of blades decreases the alternating thrust at the propeller to about the percentages given. From this, the expected alternating thrust at critical rpm is found for each number of blades. Experience has also shown that there is a magnification factor of about 7 at the thrust bearing due to the resonance. With these assumptions the approximate resonant alternating thrust at the thrust bearing is found. (Last row of table.) It appears that five blades would be definitely undesirable, six would be acceptable, and seven may be a definite improvement.

Since an increased number of blades may improve this class, DTMB plans to make calculations of alternating thrust and torque on the basis of a model wake survey of this hull. The results of these calculations will be used to recommend a specific number of blades for this class of ship.

ACKNOWLEDGMENTS

The cooperation of the officers and the crew of TRIPOLI and the assistance during the trials of Messrs. P. Dear, E. Hines, and J. Cianciarulo of the Philadelphia Naval Shipyard design office contributed greately to the successful conduct of the trial.

The authors acknowledge also the assistance of the following members of the DTMB Vibration Division for their participation in the trials: Drs. E. Buchmann and H.F. Alma, and Messrs. J. Peoples and F.W. Smith for the data analysis of measurements taken on the mast-island structure ; Messrs. A. Zaloumis and M. Lipari for the data analysis of the propulsion system vibrations; Messrs. S. Lee, N. Huzil, and H. Ali for the data analysis of the hospital area vibrations; and Mr. J. Viner and Mr. R. Tuckerman in the interpretation of structural and radar vibration measurements, respectively.

The assistance of Messrs. C. Onesty of the Naval Ships Engineering Center and A. Mallon of the Naval Ship Systems Command in the data analysis of the propulsion system vibrations and in the interpretation of the structural vibration measurements, respectively, are also gratefully acknowledged.

REFERENCES

1. Robinson, D., "Underway Vibration Survey on the USS OKINAWA (LPH 3)," DTMB Acoustics and Vibration Laboratory Report 2161, April 1966.
2. Robinson, D., "Calculated Natural Frequencies and Normal Modes of Vibration of the USS OKINAWA (LPH 3)," DTMB Structural Mechanics Laboratory Report 1766, Aug 1963.
3. Hurty, W.C. and Rubinstein, M.F., "Dynamics of Structures," Prentice-Hall, Inc. (1964).
4. Rogers, G.L., "Dynamics of Framed Structures," Wiley and Sons, Inc. (1959).
5. "Stress Analysis, Foremast and Topmast," Bureau of Ships Drawing No. LPH-9-125-2107528.

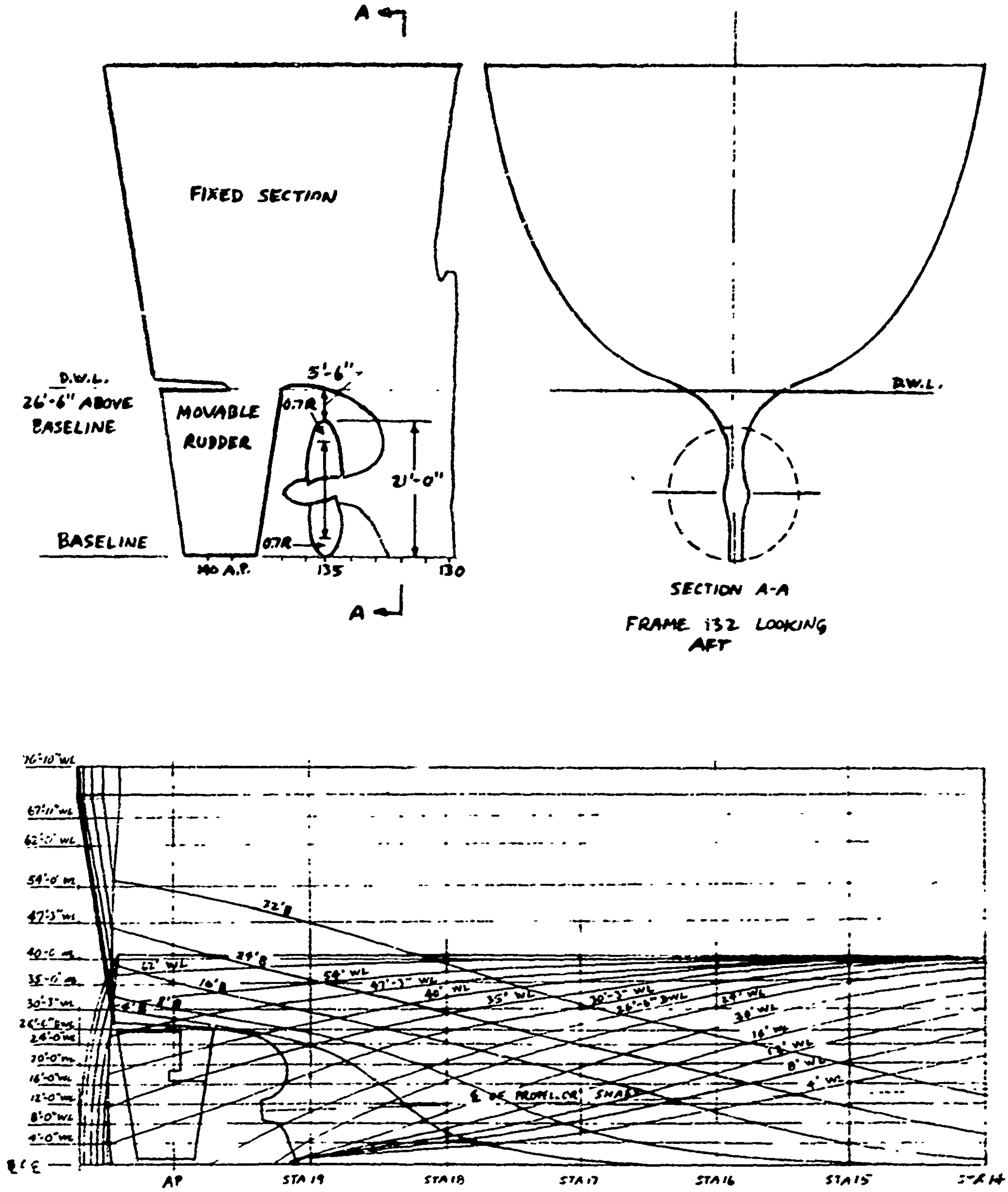


Figure 1 - Propeller and Adjacent Stern Area

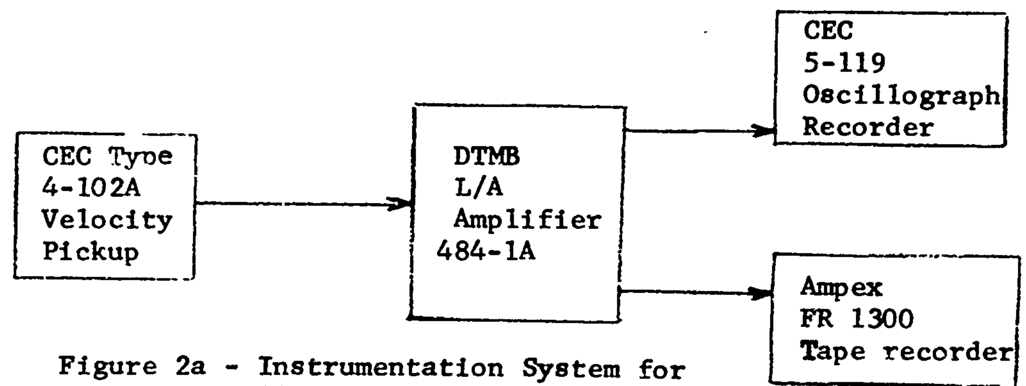


Figure 2a - Instrumentation System for Hull and Mast-Island Structure

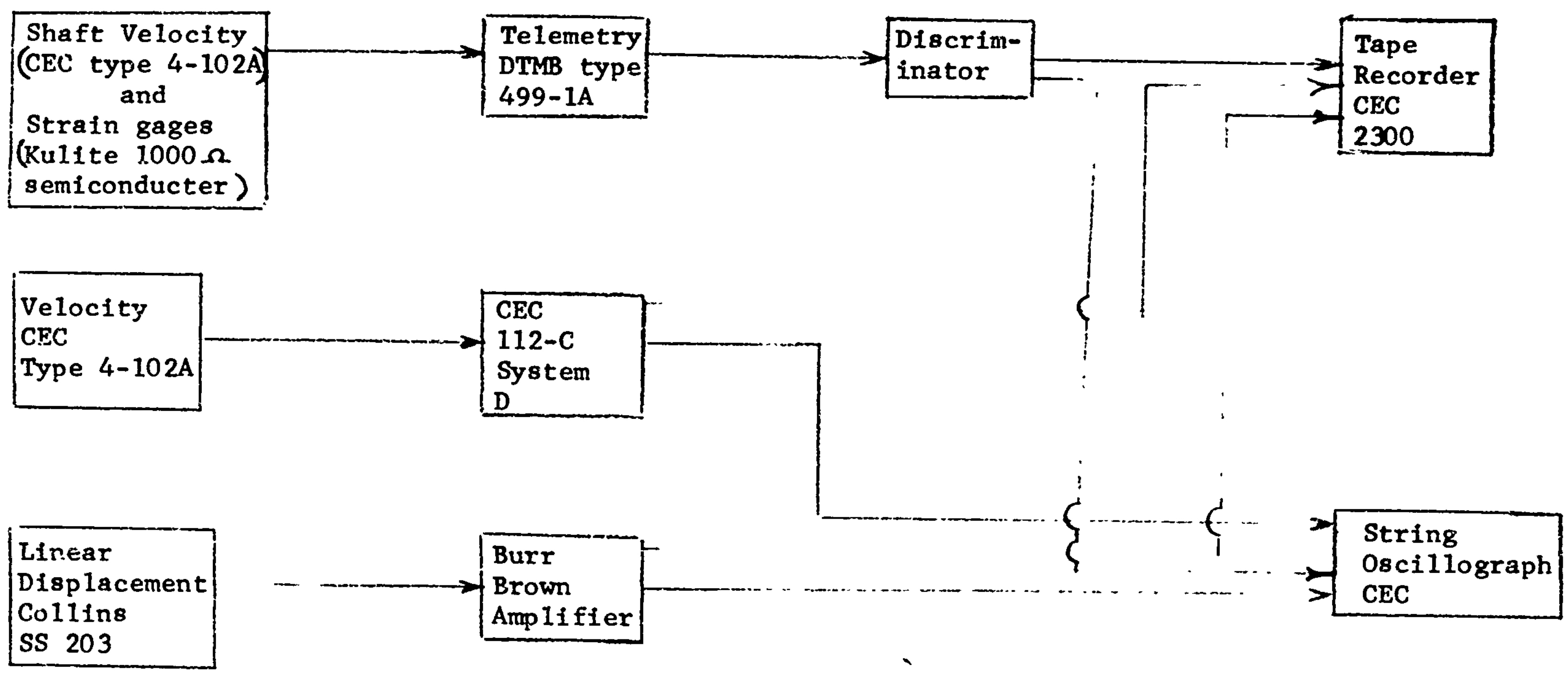


Figure 2b - Machinery Space Instrumentation

Figure 2 - Instrumentation System

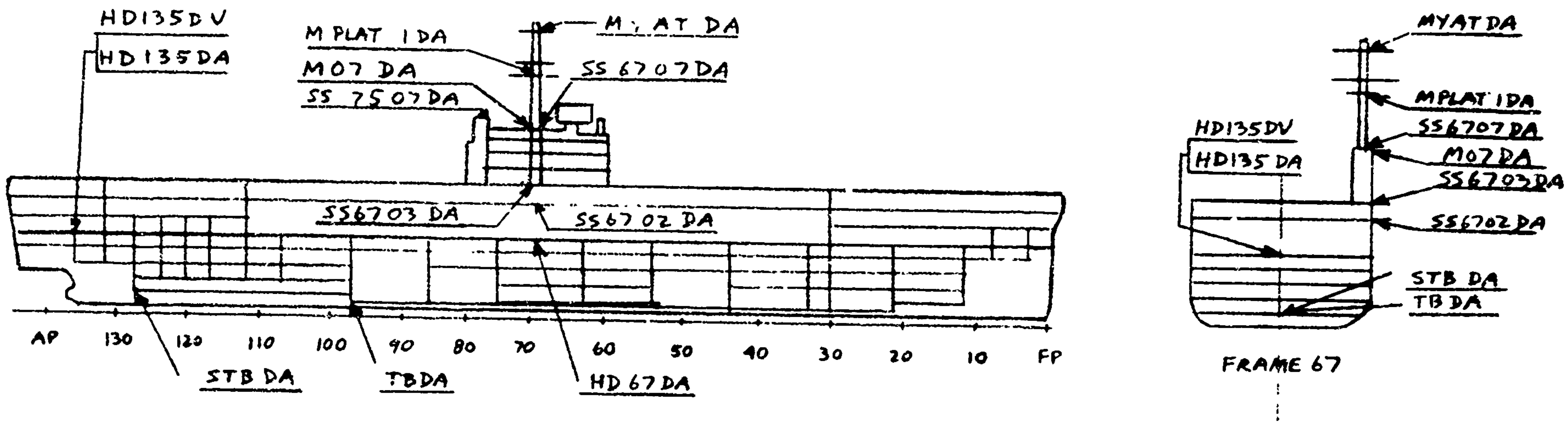


Figure 3 - Inboard Profile Showing Phase 1 Measurement Locations

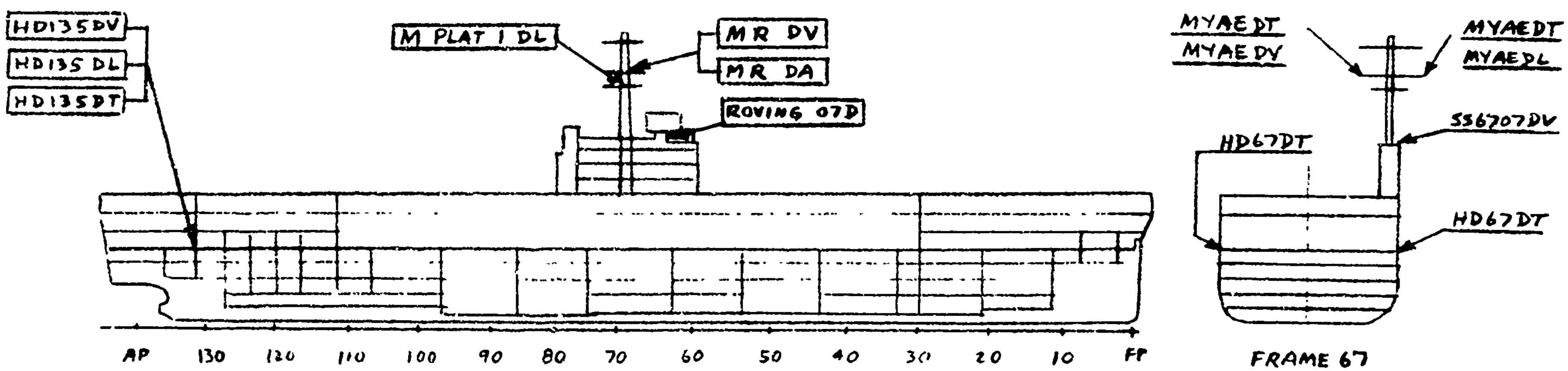
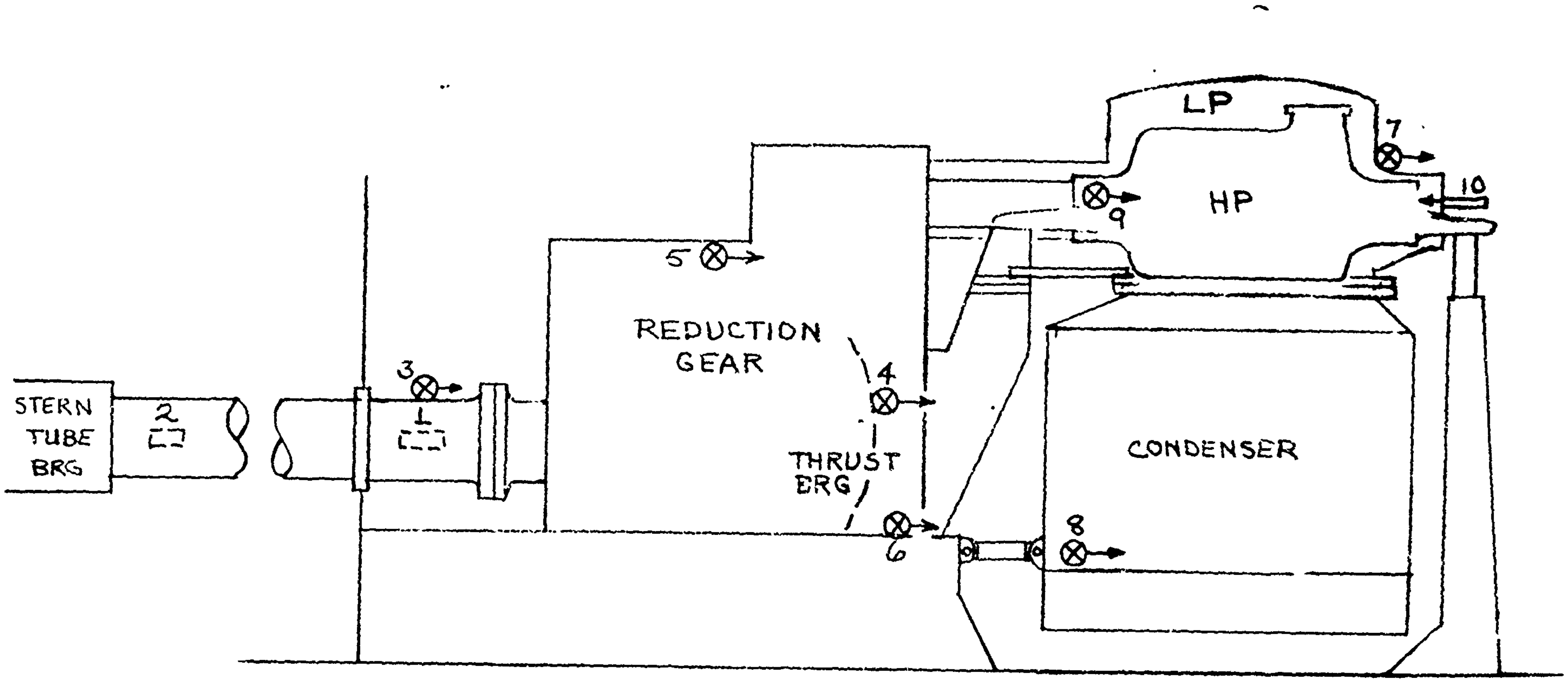


Figure 4 - Inboard Profile Showing Phase 2 Measurement Locations



1. Strain Gage Fwd
2. Strain Gage Aft
3. Shaft Displacement
4. Thrust Brg Hsg Displ.
5. Gear Case Displ.
6. Gear Case Foundation Displ.
7. LP Turbine Casing Displ.
8. Condenser Displ.
9. HP Turbine Casing Displ.
10. Displacement Between HP Turbine & Rotor

Figure 5 - Schematic of LPH 10 Propulsion System Showing Location and Orientation of Gages and Quantities Measured

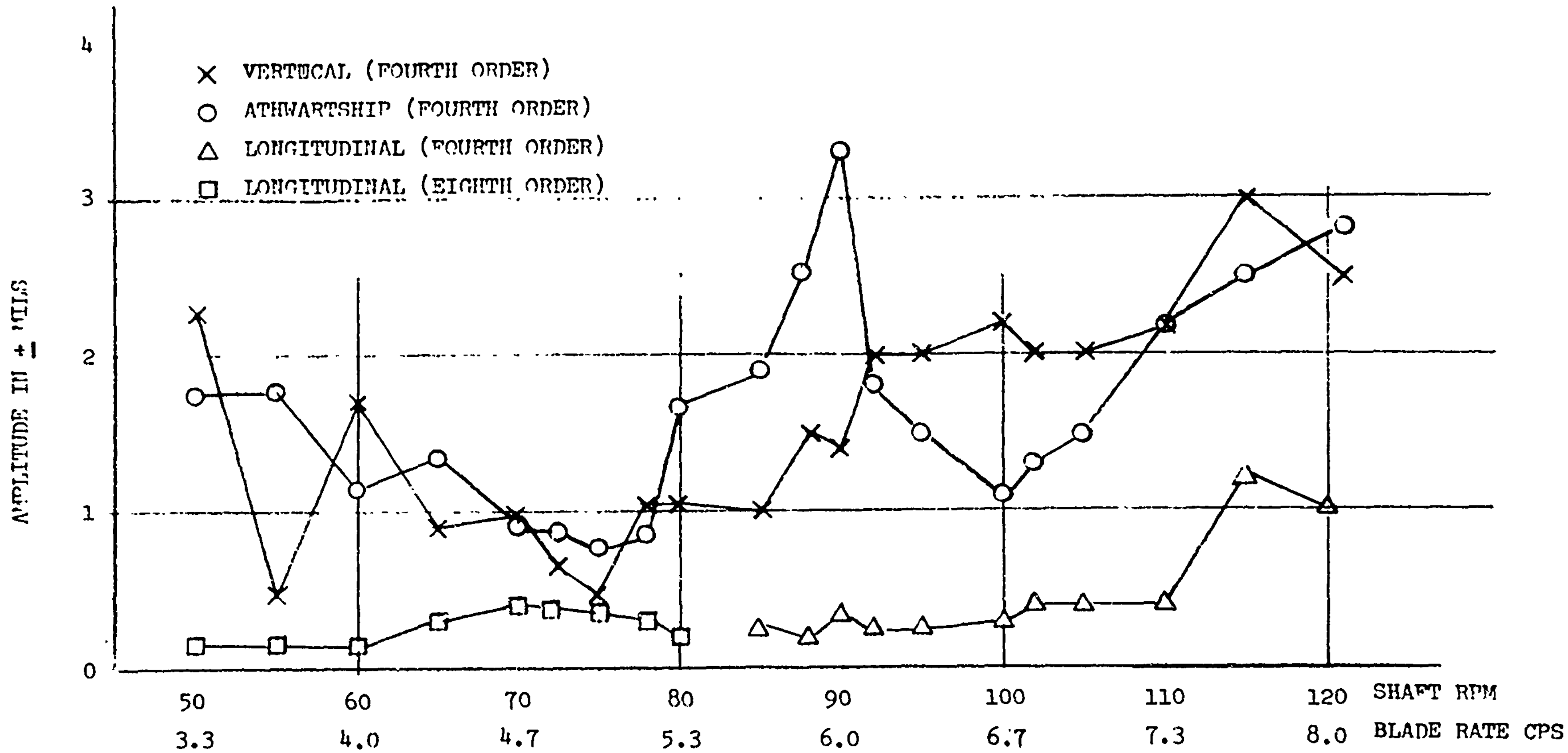


FIGURE 6 - Vertical, Athwartship and Longitudinal Vibration of Hull at Stern, Frame 135

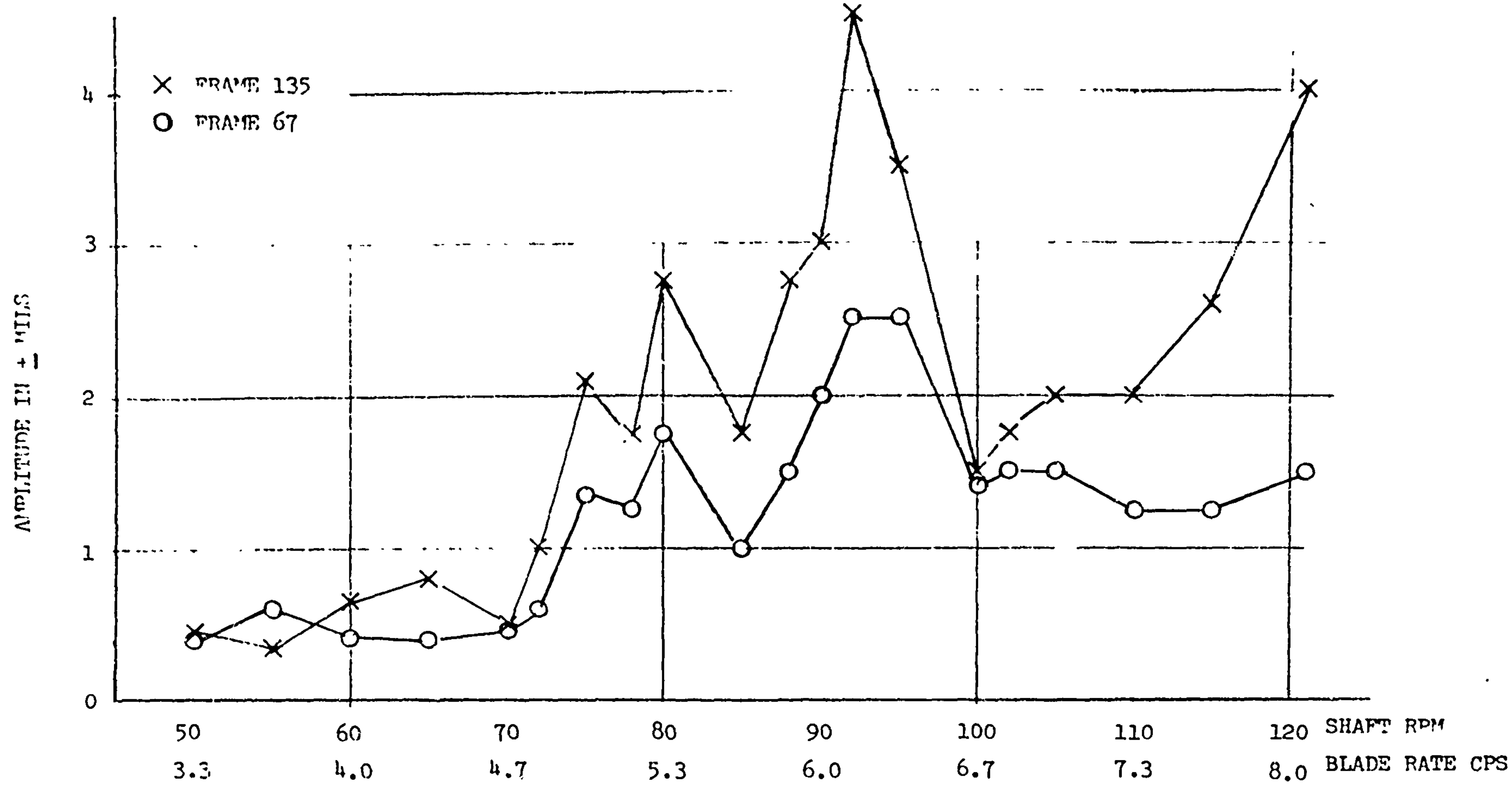


FIGURE 7 - Torsional Vibration of Hull at Frames 135 and 67

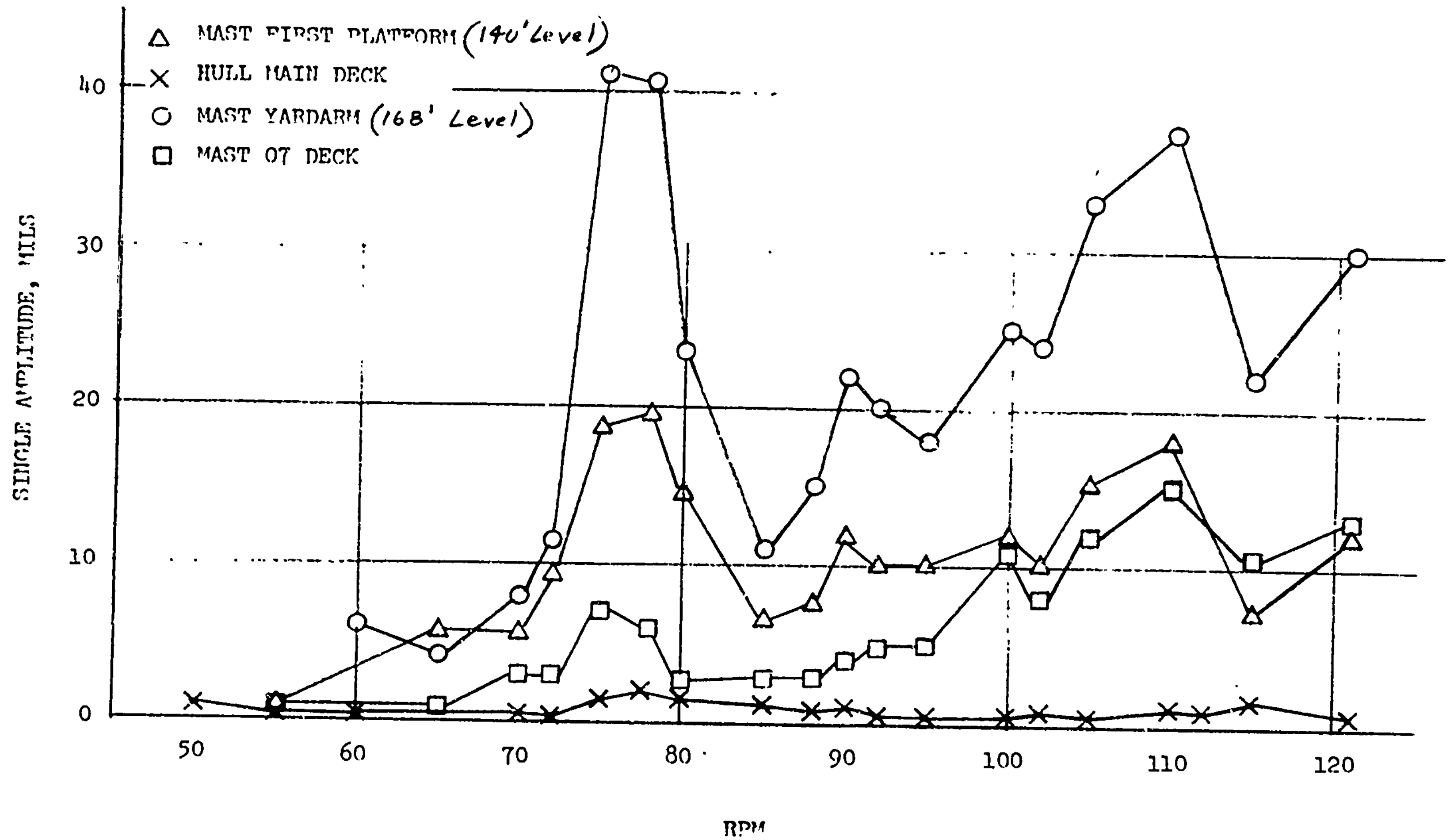


FIGURE 8 - Athwartship Vibration at Frame 67 (Blade Frequency)

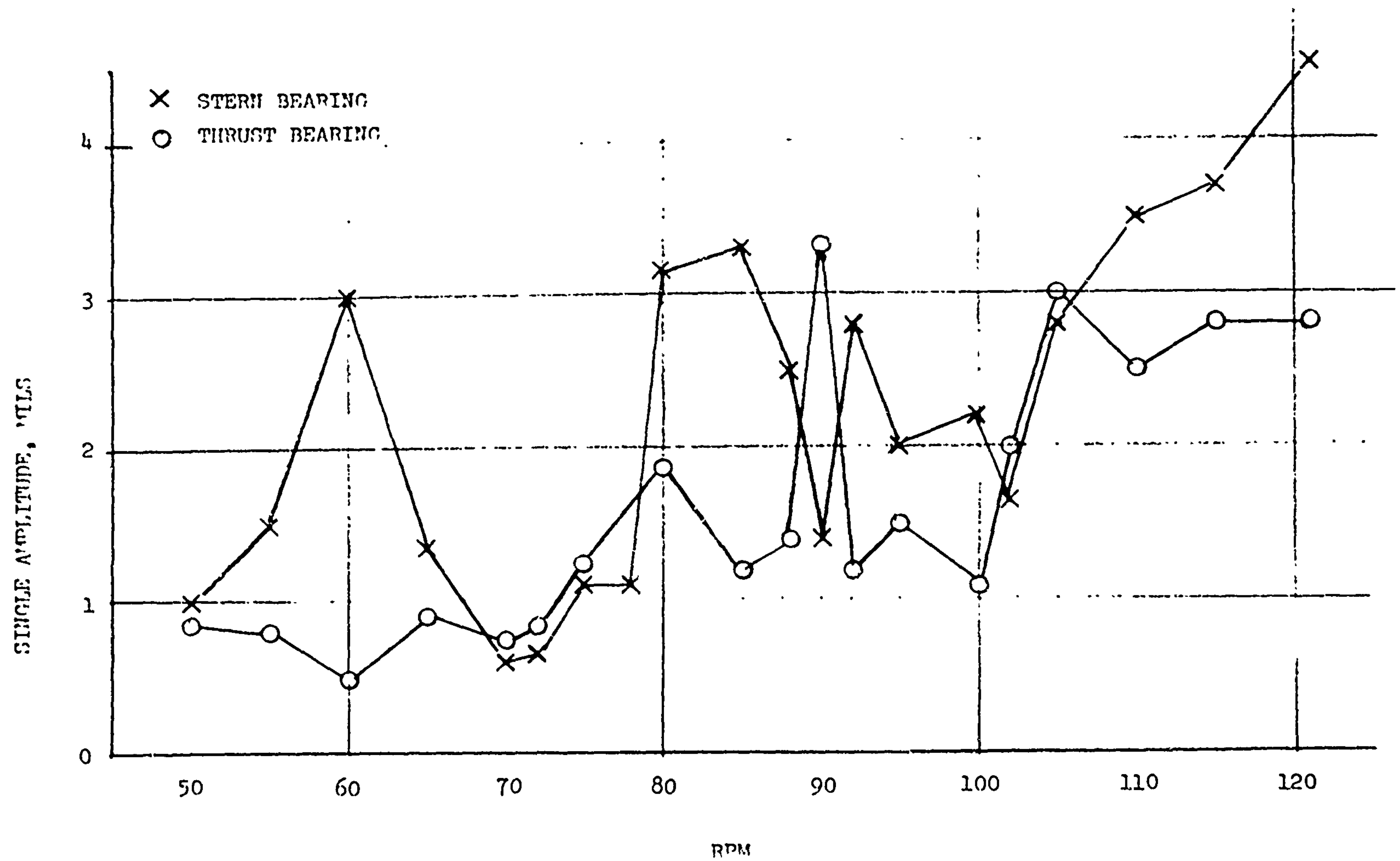


FIGURE 9 - Athwartship Vibration at Stern Tube Bearing and Thrust Bearing Foundation
(Blade Frequency)

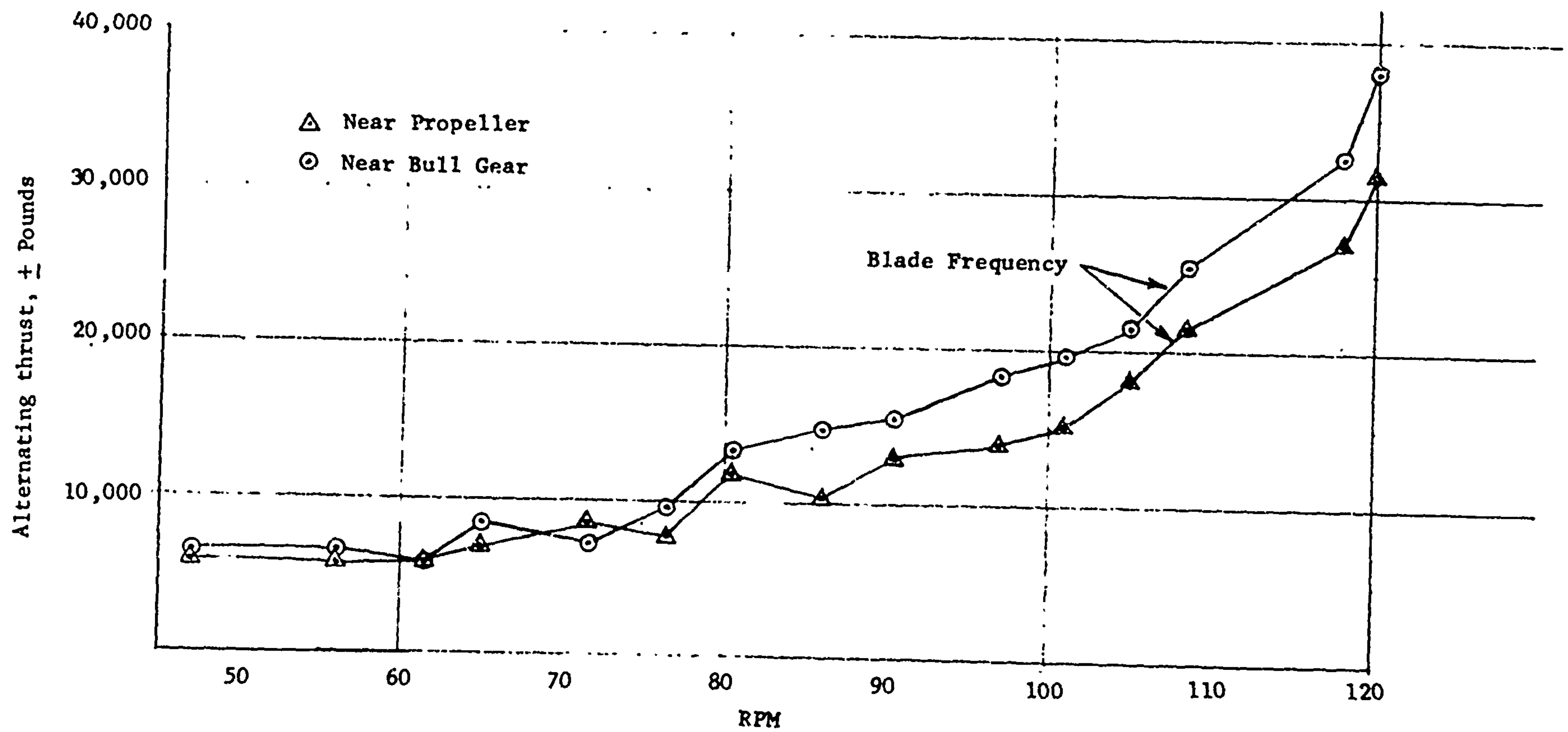


Figure 10- Alternating Thrust in Shaft Near Propeller and Bull Gear, LPH-10.

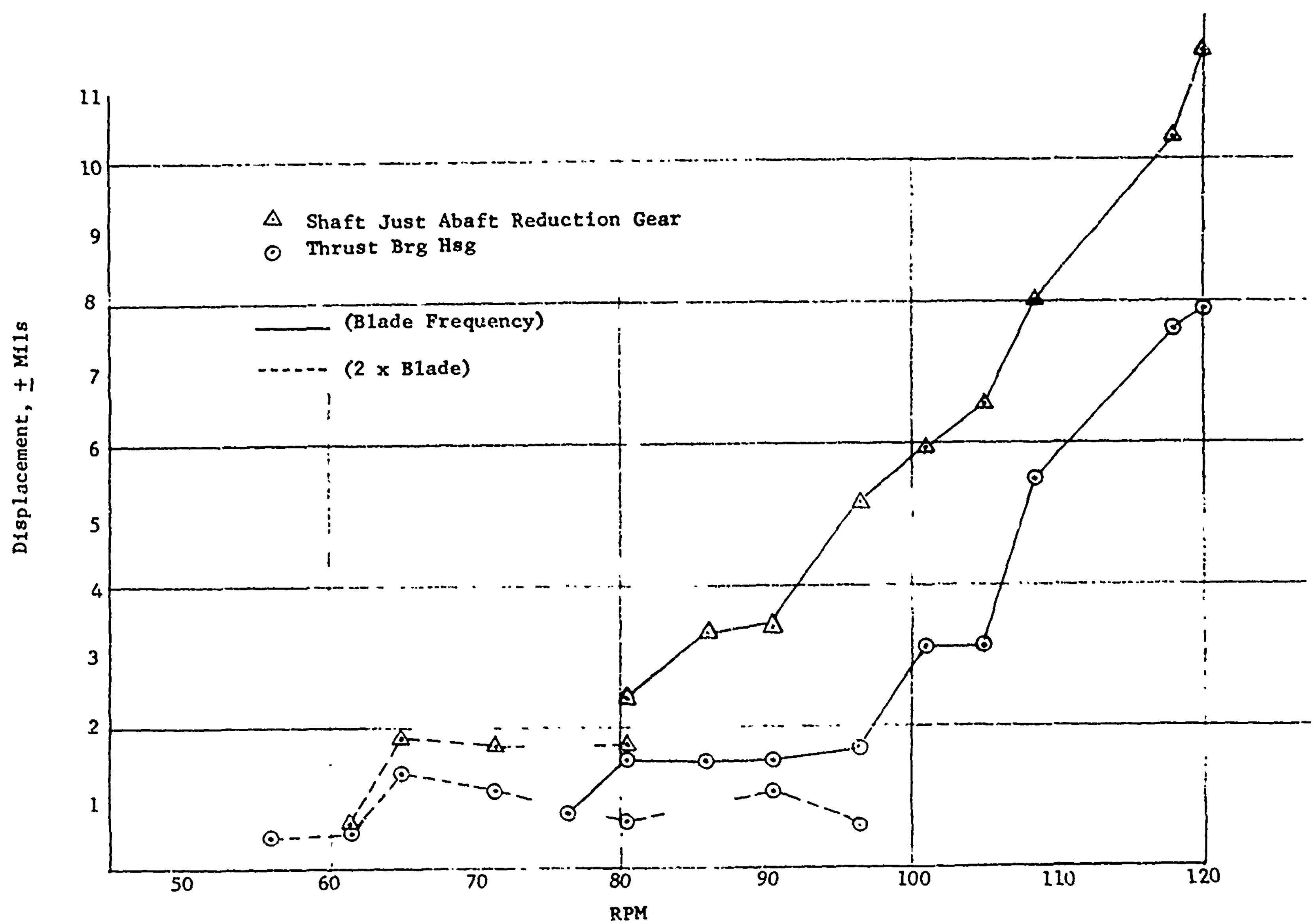


Figure 11- Longitudinal Displacements of Shaft and Thrust Bearing Housing, LPH-10.

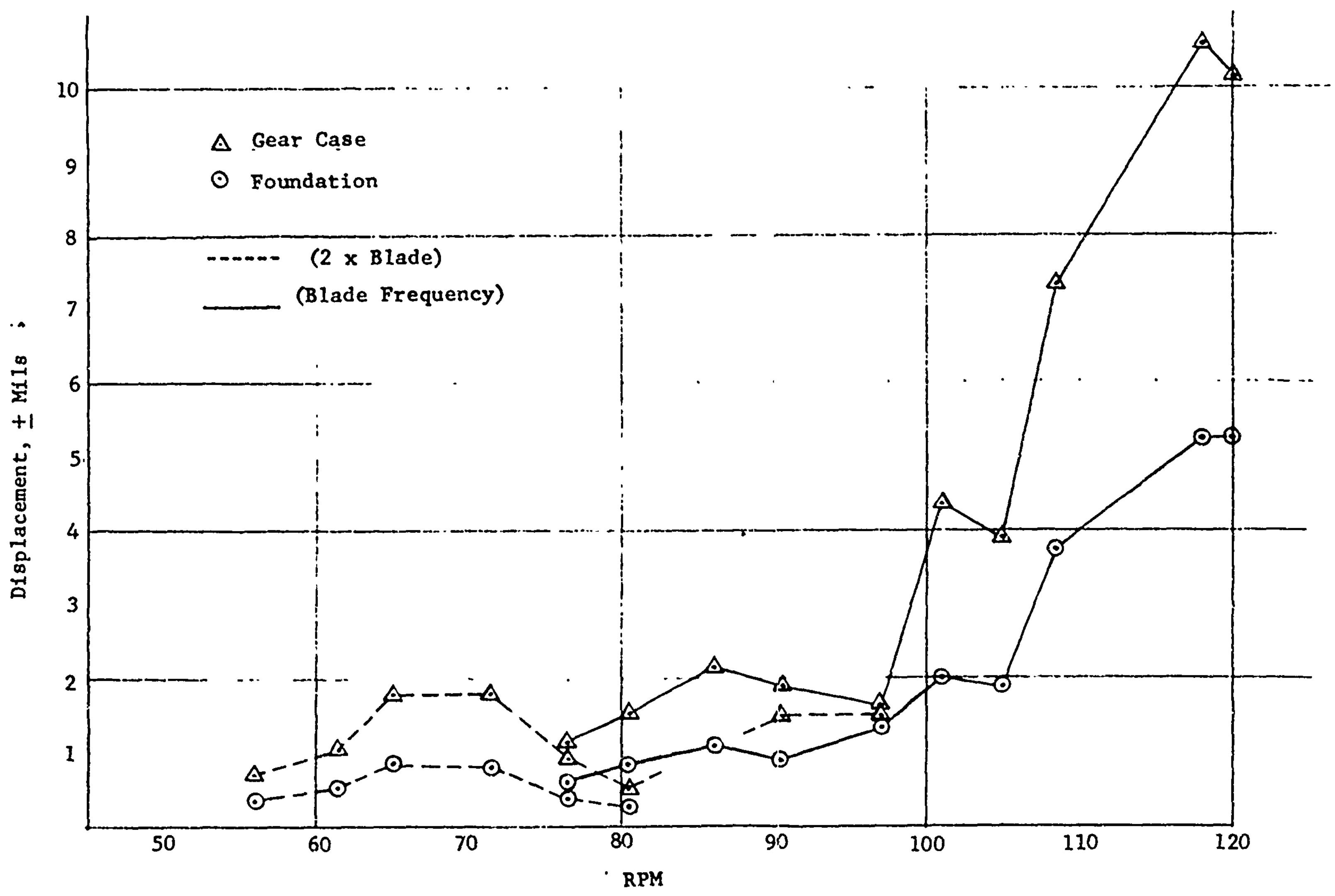


Figure 12 - Longitudinal Displacements of Reduction Gear and Foundation, LPH-10.

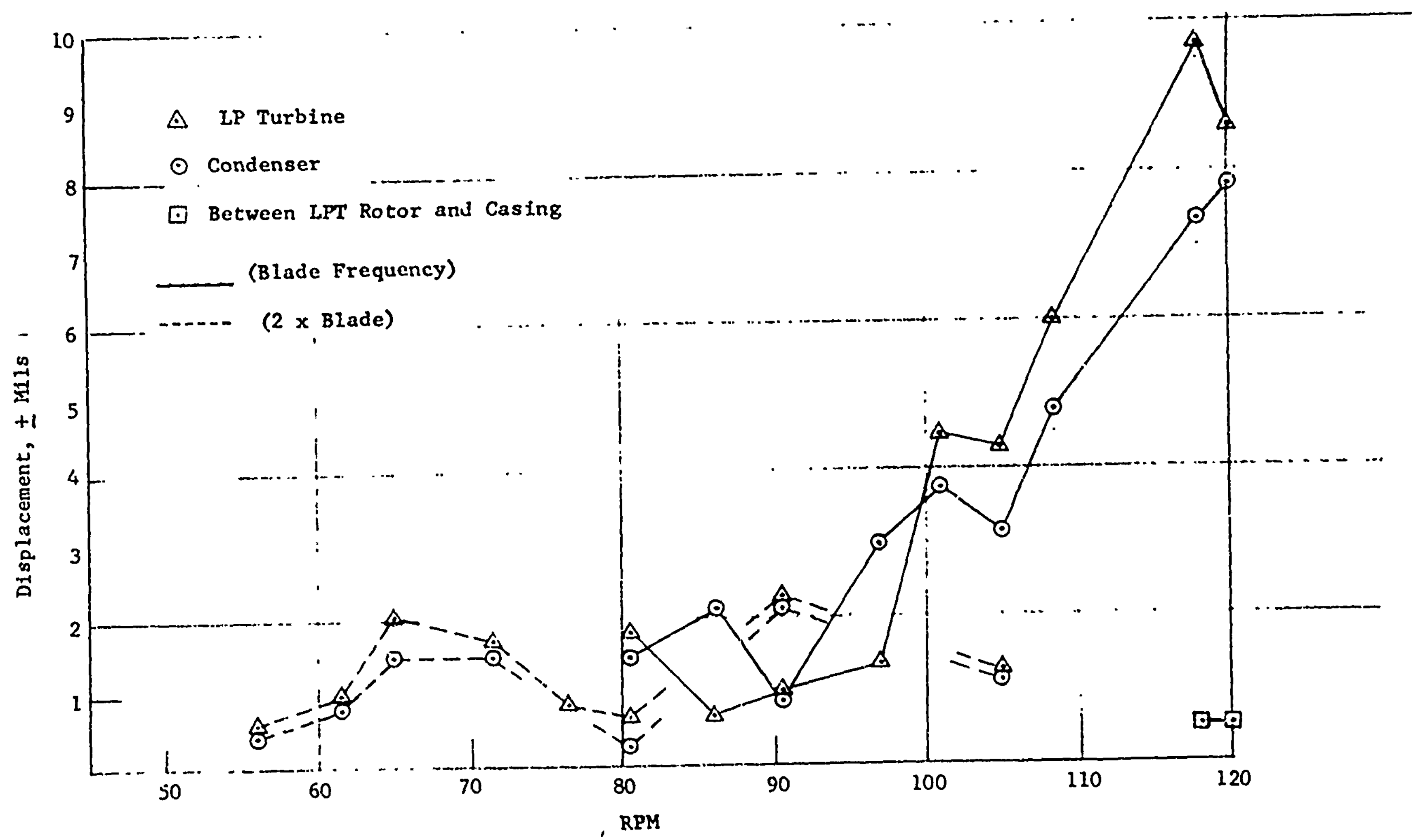


Figure 13 - Longitudinal Displacements of L.P. Turbine, Condenser and Relative Motion Between L.P. Turbine Rotor and Casing, LPH-10.

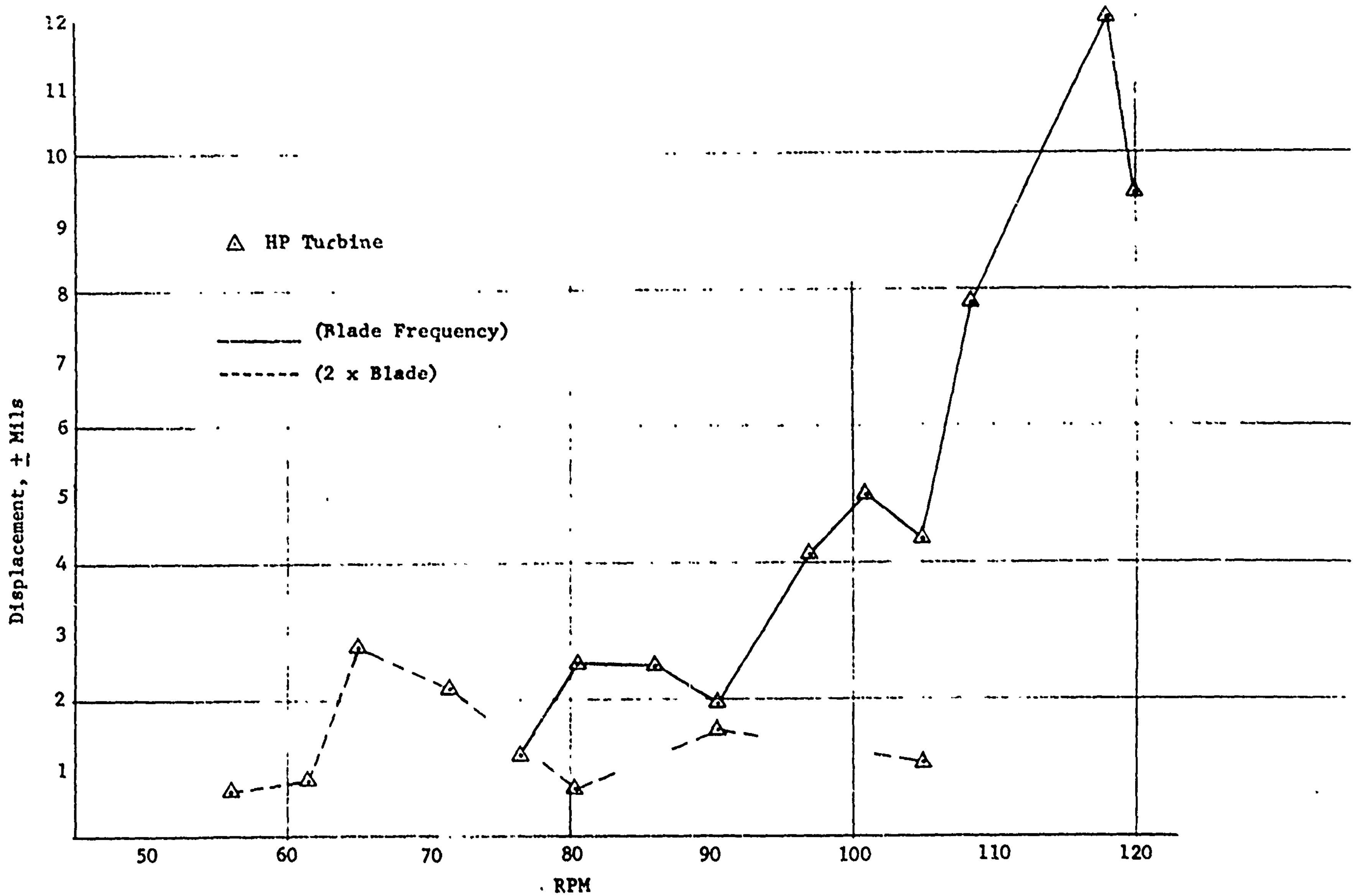


Figure 14 - Longitudinal Displacement of H.P. Turbine, LPH-10.

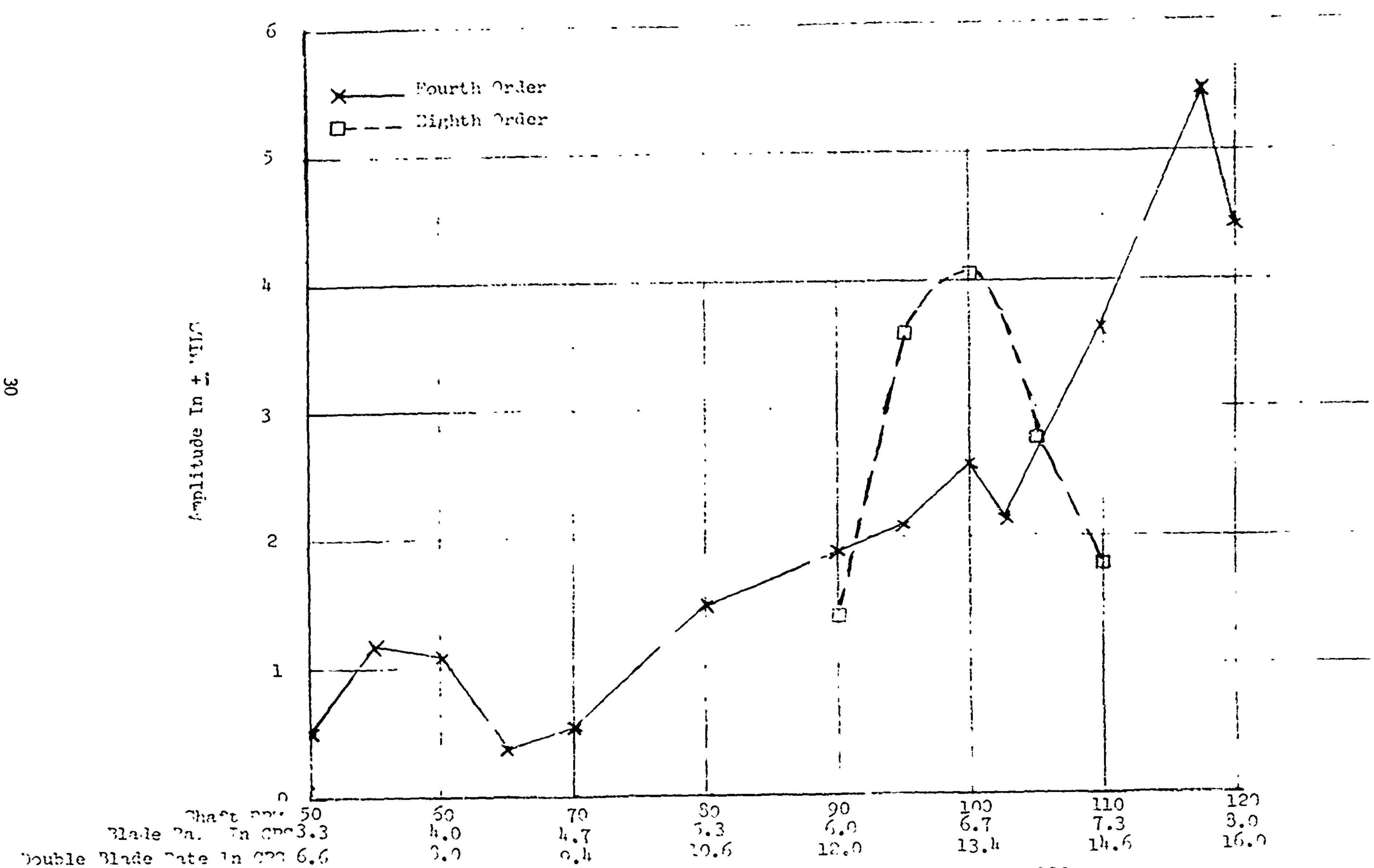
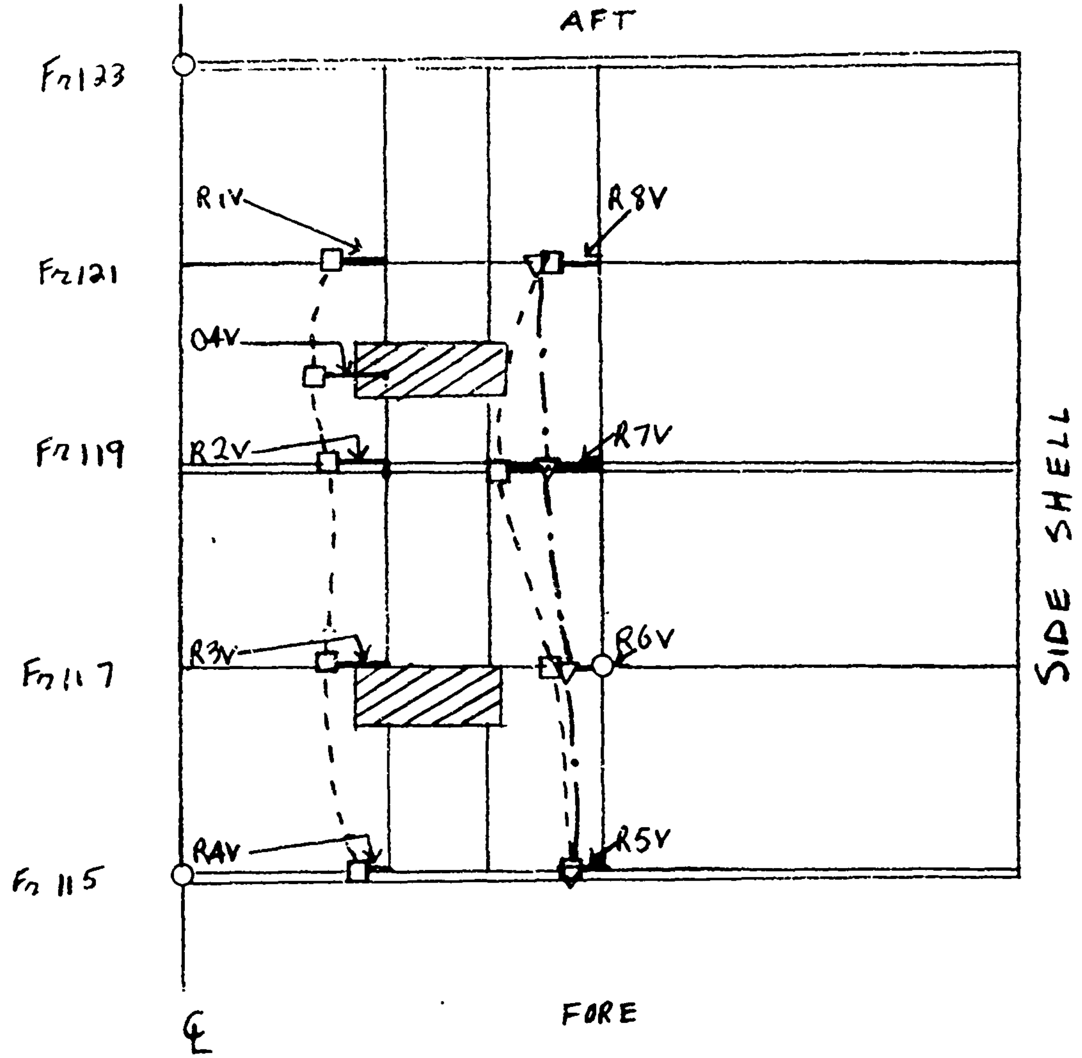


Figure 15 - Vertical Response of Operating Table at Frame 120

Gauge	Amplitude in ± Mils	
	01 level	02 level
R1V	2.7	
04V	3.6	
R2V	2.9	
R3V	3.0	
R4V	1.9	
R8V	2.3	3.0
R7V	5.0	2.4
R6V	2.3	1.3
R5V	1.4	1.7



═ Primary Transverse

▨ Operating tables

□ Roving Measurements on 01 Level

○ Stanchion

▽ Roving Measurements on 02 Level

Figure 16 - Vertical Response of Medical Area to Double Blade Frequency Excitation at 100 RPM (13.3 CPS)

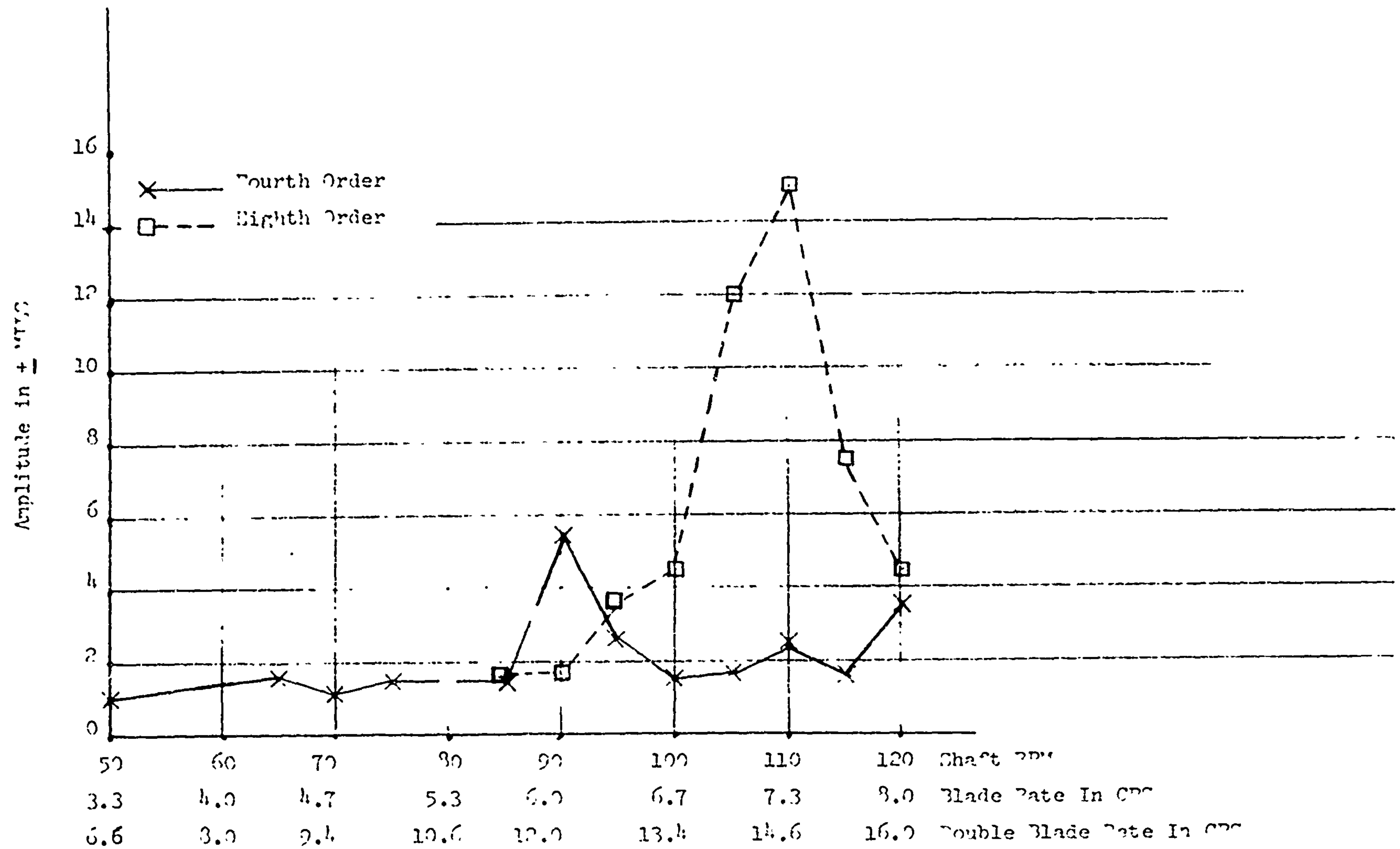


Figure 17 - Athwartship Response of Chest X-Ray Exposure Mount

TABLE 1

Displacements, Drafts and Trim During Vibration Trials

of USS TRIPOLI (LPH-10) and USS OKINAWA (LPH-3)

Ship (Trial Date)	Fwd.	Draft Mean	Aft	Trim by Stern	Displacement (tons)	Sea State
USS TRIPOLI (Sept 1966)	22'-2"	23'-11"	25'-3"	3'-6"	15,920	4
USS OKINAWA (March 1963)	24'-0"	25'-10½"	27'-9"	3'-9"	17,700	3-4

TABLE 2

Phase 1 Measurement Locations

Position Number	Frame	Deck	Description
HD135D(V)	135	1	Main deck Centerline
HD135D(A)	135	1	Main deck centerline
HD67D(A)	67	1	Main deck
SS670D(A)	67	02	Galley deck, starboard
SS6703D(A)	67	03	Island, starboard
SS6707D(A)	67	07	Island, starboard
SS7507D(A)	75	07	Island, starboard
MO7D(A)	67	07	Mast, starboard
MPLAT1D(A)	67		First Platform (140' above B.L.)
MYATD(A)	67		Antenna Yardarm (168' above B.L.)
STBD(A)			Stern tube bearing
TBD(A)			Thrust bearing

Note: The letters V and A in parentheses stand for vertical and athwartship directions, respectively.

TABLE 3

Phase 2 Measurement Locations

Position Number	Frame	Deck	Description
HD135D(V)	135	1	Main Deck Centerline
HD135D(L)	135	1	Main Deck Centerline
HD135D(T)	135	1	Main Deck
HD67D(T)	67	1	Main Deck
SS6707D(V)	67	07	Island 07 Level
M·PLAT·1·D(L)	67		Mast at First Platform
MR·D(V)	67		AN/SPS-10 Radar
MR·D(A)	67		AN/SPS-10 Radar
MYAED(L)	67		Signal Yardarm End
MYAED(V)	67		Signal Yardarm End
MYAED(T)	67		Signal Yardarm End
ROVING 07D(A)		07	AN/SPN-6 Base

Note: The letters V, A, L, and T in parentheses stand for vertical, athwartship, longitudinal, and torsional, respectively.

TABLE 4

Measurement Locations for Hospital Area (Fixed Gage Locations)

Channel	Phase	Designation	Direction	Location
1	A and B	RPM	---	on shaft
2	A and B	HIV	Vertical	stern centerline Frame 135
3	A	03V	Vertical	top operating table Frame 120
4	A	04A*	Athwartship	top operating table Frame 120
4	A	04V	Vertical	base operating table Frame 120
5	A	05L*	Longitudinal	top operating table Frame 120
5	A	05V	Vertical	on hydraulic lift of operating table
6	A	X6A	Athwartship	on BHD supporting X-ray exposure plate for chest X-rays
3	B	D7V	Vertical	under seat of dental chair at Frame 116
4	B	D8A*	Athwartship	under seat of dental chair at Frame 116
4	B	D8V	Vertical	on deck under seat
5	B	X9V	Vertical	on deck supporting X-ray table Frame 128
6	B	X10V	Vertical	on X-ray table

*these gages were recorded during deceleration runs only.

TABLE 5

Steady Speed (Straight Course) Runs

Maximum Amplitudes of Hull, Island, Mast, Stern tube and Thrust

Bearings in Vertical, Athwartship, and Longitudinal Directions

Gage Location	Shaft RPM	Freq. CPS	Order	Vert. Ampl MILS, SA	Athw. Ampl MILS, SA	F & A Ampl MILS, SA
Hull	120	2.0 H*	1	12.0	---	---
Main Deck	90	6.0 H*	4	---	3.3	---
Frame 135	115	7.7	4	3.0	---	1.2
	70	9.3	8	0.4	---	---
Hull, Main Deck Frame 67	78	5.2	4	---	2.0	---
Gal. Deck (Fr 67)	105	7.0	4	---	4.0	---
Island (03 Level)	110	7.3 I*	4	---	4.7	---
Island (07 Level)	92	6.1	4	3.0	---	---
	110	7.3 I*	4	---	17.0	---
Radar Mast (140' Level)	78	5.2	4	---	19.4	---
	115	7.7	4	---	---	6.0
Radar Mast (168' Level)	75	5.0 M*	4	---	41.5	---
Stern tube Bearing	121	8.1	4	---	4.5	---
Thrust Bearing	90	6.0	4	---	3.3	---

*H, I, M indicates modes of hull, island, and mast, respectively.

TABLE 6

Steady Speed (Straight Course) Runs

Maximum Amplitudes of AN/SPS-10 Radar,

Hull and Signal Yardarm, and AN/SPN-6 Radar

Gage Location	Shaft RPM	Freq. CPS	Order	Vert. Ampl. MILS, SA	Athw. Ampl. MILS, SA	Torsional Ampl. MILS, SA	F&A Ampl. MILS, SA
AN/SPS-10 Radar Platform	92 110 55	6.1 7.3 7.3	4 4 8	4.0 --- ---	--- 20.0 7.0	--- --- ---	
Hull, Main Dk. Frame 135	92	6.1 H*	4	---	---	4.5	
Hull, Main Dk. Frame 67	92	6.1 H*	4	---	---	2.5	
Signal Yardarm	75 121	5.3 8.1	** 4	--- 20.0	--- ---	70.0 ---	65.0 ---
AN/SPN-6	121	8.1	4	---	22.5	---	

*H indicates mode of hull
** Constant frequency

TABLE 7

Maneuvering Runs - Hard Turns, Maximum Amplitudes of Hull, Island, Mast, AN/SPS-10 and AN/SPN-6 Radar, and Sterntube and Thrust Bearings in Vertical, Athwartship, and Longitudinal (F & A) Directions

Gage Location	Maneuvers	Shaft RPM	Freq. CPS	Order	Vert. Ampl. MILS, SA	Athw. Ampl. MILS, SA	F&A Ampl. MILS, SA
Hull, Main Dk. Frame 135	Port	105	7.0	4	5.5	5.0	2.2
	Stbd	108	7.2	4	6.0	9.0	1.5
Hull, Main Dk. Frame 67	Port	105	7.0	4	-	2.5	-
	Stbd	108	7.2	4	-	4.0	-
Gal. Deck Frame 67	Port	105	7.0	4	-	15.0	-
	Stbd	108	7.2	4	-	16.0	-
Island (03 Level)	Port	105	7.0	4	-	20.0	-
	Stbd	108	7.2	4	-	23.0	-
Island (07 Level)	Port	105	7.0	4	14.0	65.0	-
	Stbd	108	7.2	4	14.0	80.0	-
Radar Mast (140' Level)	Port	105	7.0	4	-	65.0	22.5
	Stbd	108	7.2	4	-	65.0	22.5
Radar Mast (168' Level)	Port	105	7.0	4	-	140.0	-
	Stbd	108	7.2	4	-	140.0	-
AN/SPS-10 Plat.	Port	105	7.0	4	20.0	100.00	-
	Stbd	108	7.2	4	20.0	120.0	-
AN/SPN-6 Base	Port	105	7.0	4	-	80.0	-
	Stbd	108	7.2	4	-	130.0	-
Sterntube Bearing	Port	105	7.0	4	-	13.0	-
	Stbd	108	7.2	4	-	12.0	-
Thrust Bearing	Port	105	7.0	4	-	10.0	-
	Stbd	108	7.2	4	-	12.0	-

TABLE 8

Maneuvering Runs - Port and Starboard Turns

Maximum Amplitudes of Signal Yardarm and Hull Torsional Vibration

Gage Location	Maneuver	Shaft RPM	Freq. CPS	Order	Vert. Ampl. MILS, SA	F&A Ampl. MILS, SA	Torsional Ampl. MILS, SA
Signal Yardarm	Port	105	5.3	*	---	175.0	50.0
	Port	105	7.0	4	80.0	---	
	Stbd	108	5.3	*	---	100.0	75.0
	Stbd	108	7.2	4	90.0	---	
Hull, Main Dk. Frame 135	Port	105	7.0	4	---	---	10.0
	Stbd	108	7.2	4	---	---	15.0
Hull, Main Dk. Frame 67	Port	105	7.0	4	---	---	12.5
	Stbd	108	7.2	4	---	---	12.5

*Constant Frequency

TABLE 9

Longitudinal Vibration Amplitudes and Alternating Thrust Measured During
Full Power Turns Port & Stbd. (Blade Freq.)

Maneuver	Thrust + Lbs		Displacement - MILS, S.A.						
	Aft Line Shaft	Fwd Line Shaft	Line Shaft	Thrust Brg. Housing	Gear Found.	Gear Case	L.P. Turbine	H.P. Turbine	Condenser
Gradual Turn to Stbd. 20°-40° Rudder	55,000	64,300	16.8	12.4	8.2	18.0	19.5	23.4	15.0
Hard Turn to Stbd. 40° Rudder	47,000	59,000	19.2	15.4	10.0	20.0	20.0	26.2	13.8
Hard Turn to Port 40° Rudder	44,000	55,000	16.0	11.7	8.6	15.3	16.2	16.4	14.1
Hard Turn to Port 40° Rudder	29,100	34,600	10.6	9.9	6.6	13.5	12.4	15.0	9.0

TABLE 10

TABLE 10

Comparison of Maximum Vibration Blade Rate Amplitudes of Hull Island, Mast and Main Propulsion Machinery of USS TRIPOLI (LPH 10) and USS OKINAWA (LPH 3)

Gage Location	Ship	Maneuver	Shaft RPM	Freq CPS	Vert. Ampl. MILS, SA	Athw. Ampl. MILS, SA	F & A Ampl. MILS, SA
Hull, Mn. Dk.	LPH 10	Free Route	90	6.0	---	3.3	0.3
			115	7.7	3.0	---	1.2
Frame 135		Port Turn	105	7.0	5.5	5.0	2.2
		Stbd. Turn	108	7.2	6.0	9.0	1.5
	LPH 3	Free Route	115	7.7	---	3.1	---
			118	7.8	2.4	---	---
		Port Turn	105	7.0	6.5	9.5	---
		Stbd. Turn	108	7.2	5.6	13.2	---
Island	LPH 10	Free Route	110	7.3	---	4.7	---
Frame 67		Port Turn	105	7.0	---	20.0	---
03 Level		Stbd. Turn	108	7.2	---	23.0	---
	LPH 3	Free Route	118	7.9	---	4.0	---
		Port Turn	100	6.7	---	12.5	---
		Stbd. Turn	107	7.1	---	16.6	---
Island	LPH 10	Free Route	92	6.1	3.0	---	---
			110	7.3	---	17.0	---
Frame 67		Port Turn	105	7.0	14.0	65.0	---
(07 Level)		Stbd. Turn	108	7.2	14.0	80.0	---
	LPH 3	Free Route	118	7.9	---	17.4	---
		Port Turn	105	7.0	7.9	60.4	10.5
		Stbd. Turn	108	7.2	11.1	83.3	14.7
Radar Mast	LPH 10	Free Route	75	5.0	---	41	---
Frame 67		Port Turn	105	7.0	---	140	---
(168' Level)		Stbd. Turn	108	7.2	---	140	---
	LPH 3	Free Route	115	7.7	---	31.2	---
		Port Turn	105	7.0	---	73.5	112
		Stbd. Turn	108	7.2	---	100	164
Thrust-Bearing Foundation	LPH 10	Free Route	90	6.0	---	3.3	---
			120	8.0	---	---	7.9
		Port Turn	105	7.0	---	10.0	11.7
		Stbd. Turn	108	7.2	---	12.0	15.4
	LPH 3	Free Route	118	7.9	---	---	9.0
		Port Turn	107	7.1	---	---	12.2
		Stbd. Turn	109	7.3	---	---	17.8

TABLE 11

Estimated Effects of Number of Blades on Longitudinal Shaft Vibrations

Number of Blades	5	6	7
Critical Speed	104 rpm	87 rpm	75 rpm
Alternating Thrust at above speeds with 4 blades	±15,000 lbs	±12,000 lbs	±8,500 lbs
Expected Percentage of Above Thrust with New Props	75%	55%	40%
Alternating Thrust at above speeds with number of blades shown	±11,200 lbs	±6,600 lbs	±3,400 lbs
Magnification Factor	7	7	7
Expected Alternating Thrust at Thrust Bearing	±78,000 lbs	±46,000 lbs	±24,000 lbs

Table 12
Vibration Data Sheet

CLASS LPH 9 SHIP: USS TRIPOLI (LPH 10)

TEST: ACTIVITY DTMB LOCATION: Enroute from Philadelphia Naval Shipyard and return
DATE 24-25 Sept 1966

VESSEL CHARACTERISTICS

Light Displacement	15,691 tons	Length O. L.	602 ft. 3½ in.
Test Displacement	15,920 tons	Length Between Perp.	556 ft. 0 in.
Mean Draft (test)	23 ft. 11 in.	Beam	84 ft. 2 1/8 in.
Trim by Stern (test)	3 ft. 6 in.	Depth	47 ft. 2 in.

Type of Propulsion Machinery: cross-compound two-casing turbine, double reduction gear.

Propellers
Type Magnesium Bronze — Number of Blades 4
No. of Propellers 1
Propeller Blade Tip Clearance 5'6"

TEST CONDITIONS

Max. Speed in Knots
Max. rpm 121
Test Speed Range, rpm 50-121
Sea State: Sea4 Swell

Min. Water Depth during Test over 100 ft.

TEST EQUIPMENT

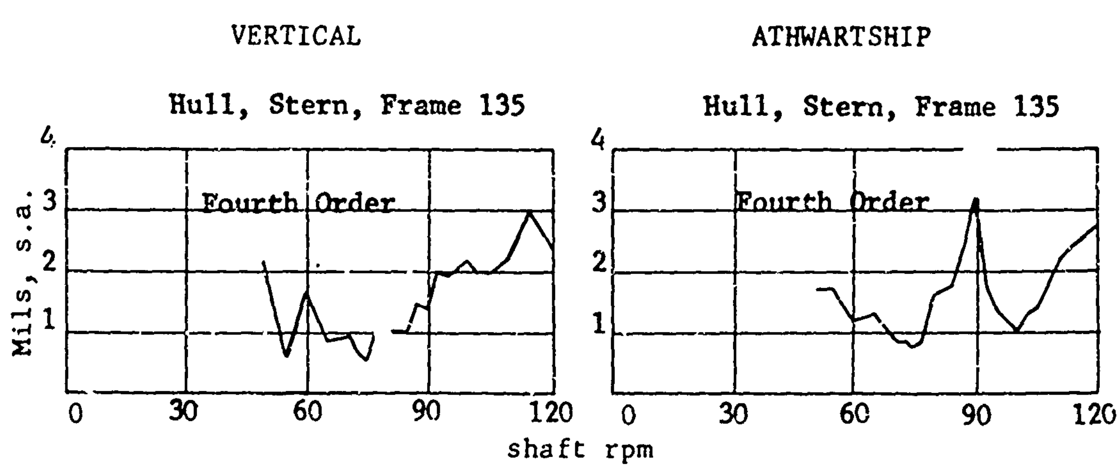


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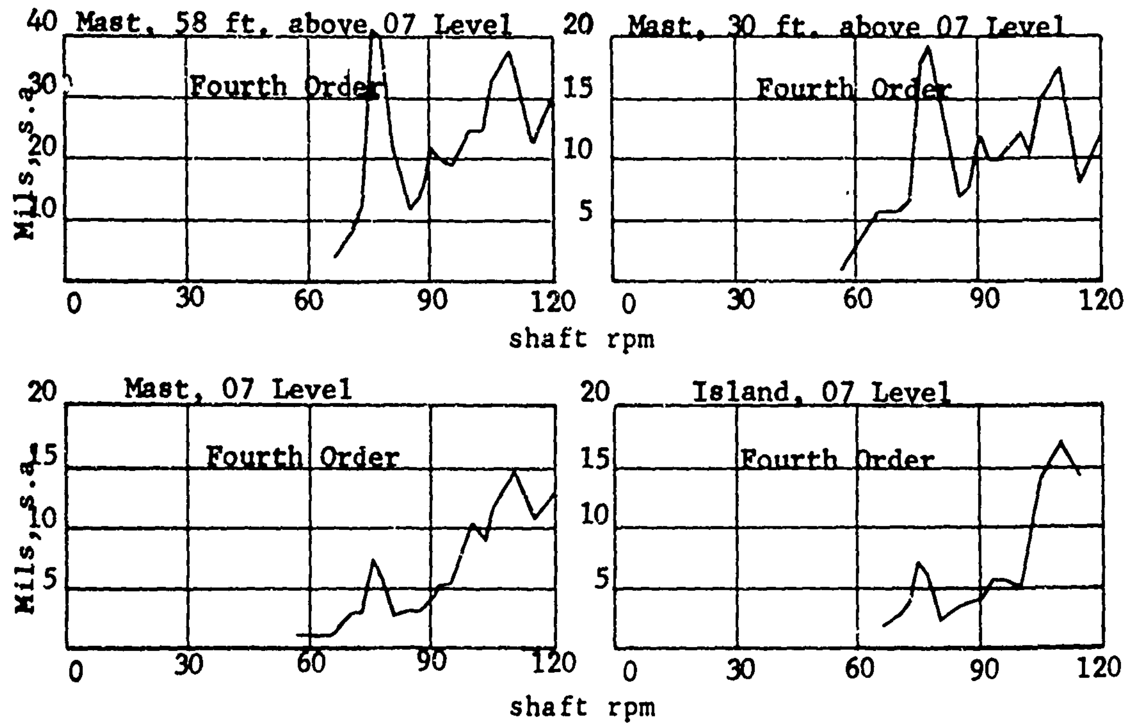
Table 12

-ation Data Sheet

ATHWARTSHIP ATHWARTSHIP



SUMMARY OF VIBRATION DATA

Location of Measurement	Direc-tion	Shaft rpm	Order	Freq. cps	Mils S.A.	Remarks
Hull, Main Deck, Fr 67 Starboard	Athw.	78	Fourth	5.2	1.7	Near second mast athw. mode
Hull, Stern, Frame 135	Vert.	121	First	2.0	12.0	Fundamental hull vertical mode
Hull, Stern, Frame 135	Vert.	115	Fourth	7.7	3.0	Near fifth hull vertical mode
Hull, Stern, Frame 135	Athw.	90	Fourth	6.0	3.3	Near third hull athw. mode
Hull, Stern, Frame 135	Long.	115	Fourth	7.7	1.2	Near fifth hull vertical mode
Gallery Deck, Frame 67	Athw.	105	Fourth	7.0	4.0	
Island 03 Level	Athw.	110	Fourth	7.3	4.7	Fundamental island athwartship mode
Island 07 Level	Vert.	92	Fourth	6.1	3.0	
Island 07 Level	Athw.	110	Fourth	7.3	17.0	Fundamental island athwartship mode
Mast, 30 ft. Above 07 Level	Athw.	78	Fourth	5.2	19.4	Near second mast athwartship
Mast, 30 ft. Above 07 Level	Long.	115	Fourth	7.7	6.0	Near fifth hull vertical mode
Mast, 58 ft. Above 07 Level	Athw.	75	Fourth	5.0	41.5	Second mast athw. mode
Thrust Bearing	Athw.	90	Fourth	6.0	3.3	
Thrust Bearing Foundation	Long.	120	Fourth	8.0	7.9	Below first long. shafting mode

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13 ABSTRACT

An underway vibration trial of USS TRIPOLI (LPH 10) was conducted with measurements concentrated on the mast and island structure, the hospital area, the hull, and the main propulsion system. Data were analyzed to determine the nature and cause of excessive vibrations in the mast and island structure and in the hospital area at high ship speeds during free route (straight course) and maneuvering operation.

The results of the underway trial are evaluated with data obtained during an earlier vibration generator survey of the mast-island structure and hospital area of TRIPOLI and compared with measurements obtained during an underway trial on USS OKINAWA (LPH 3) conducted in March 1963. The results of the various tests are used as a basis for recommendations in order to mitigate the excessive vibrations of TRIPOLI and for further effort required for correction of the LPH class vibration problems.

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14. KEY WORDS	LINK A		LINK B		LINK C	
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Mast Vibration						
Island Vibration						
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