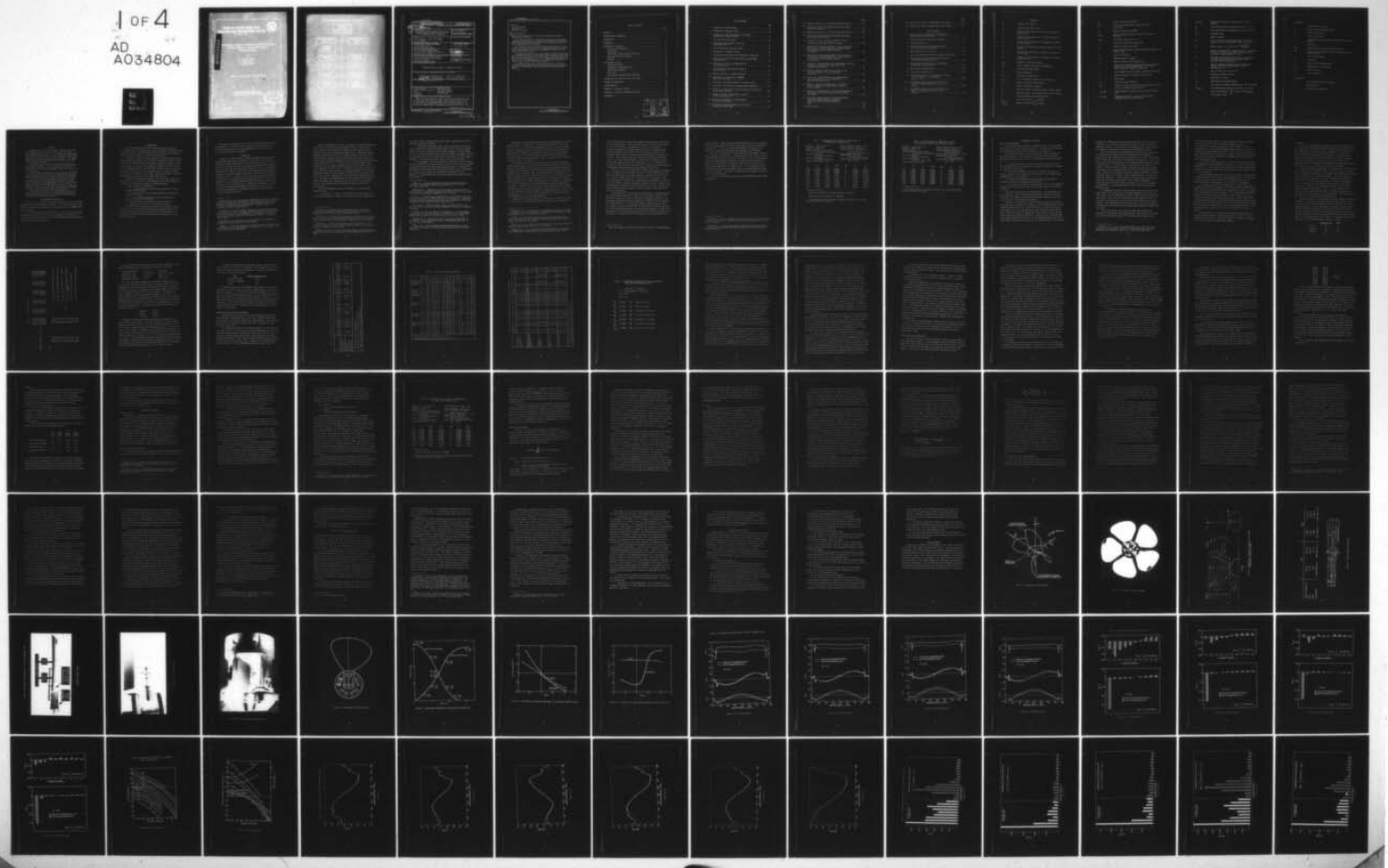
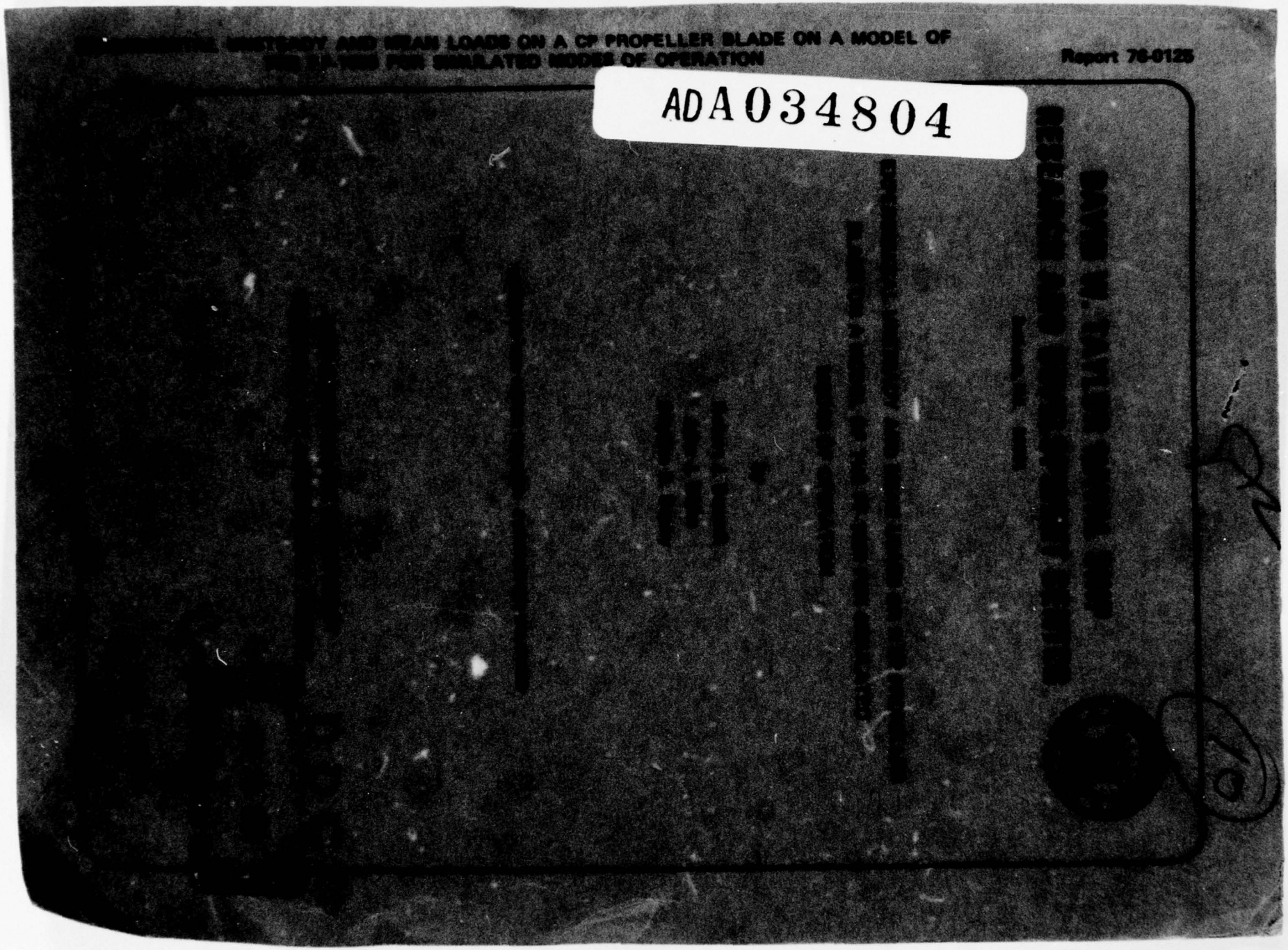
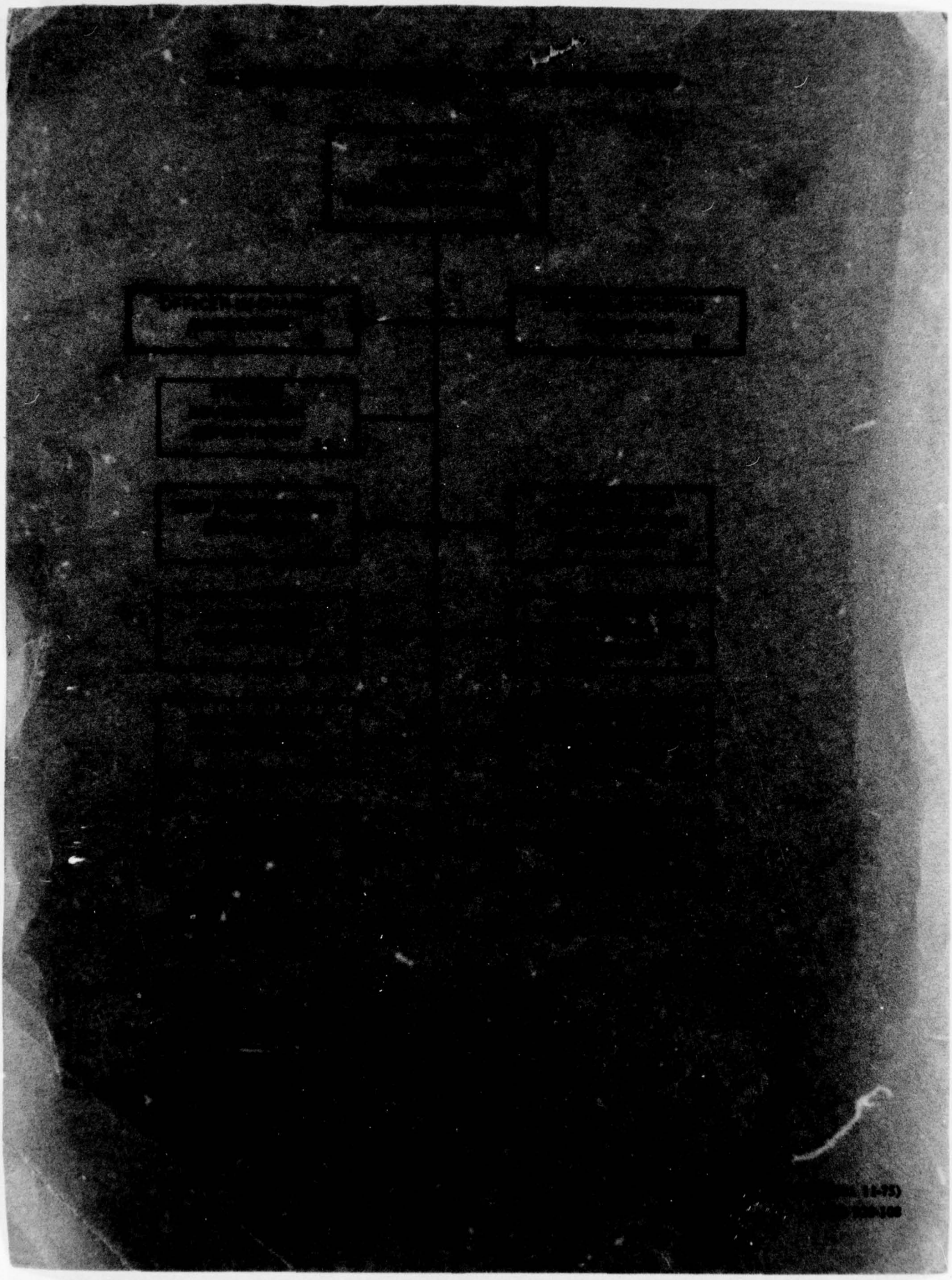
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Experiments are described in which the mean and unsteady loads were measured on a single blade of a model of the controllable-pitch propeller on the FF-1088. The experiments were conducted behind a model of the FF-1088 hull under steady ahead operation, hull pitching motions, simulated crash ahead maneuvers, and simulated crash astern maneuvers. The

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experimental techniques are outlined and the dynamometer and data analysis system described.

The results show that the circumferential variation of all measured components of blade loading is primarily a once-per-revolution variation, with maximum and minimum values occurring near the angular positions in which the spindle axis is horizontal.

For sinusoidal pitching of the model hull with amplitude of 2 deg and frequency of 0.8 Hz, the peak-to-peak circumferential variation of measured forces and moments increased by a minimum of 50 percent over the values without hull pitching.

For simulated operation during a crash ahead or crash astern maneuver, the circumferential variation of measured forces and moments varied approximately as the product of ship speed and propeller rotational speed, and was a function of propeller pitch. At no time during the simulated crash ahead or crash astern maneuvers were the circumferential variations of loads as large as during steady ahead operation.

For steady ahead operation, circumferential variation of loading determined from the model experiments agreed fairly well with full-scale data, but was substantially larger than the theoretically calculated values.

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## NOTATION

| | |
|---|---|
| $A_E$ | Expanded area, $Z\int_{r_h}^{R} c\,dr$ |
| $A_0$ | Propeller disc area, $\pi D^2/4$ |
| $A_r$ | Fourier cosine coefficients of radial component of wake velocity |
| $A_t$ | Fourier cosine coefficient of tangential component of wake velocity |
| $A_x$ | Fourier cosine coefficient of longitudinal component of wake velocity |
| $B_r$ | Fourier sine coefficient of radial component of wake velocity |
| $B_t$ | Fourier sine coefficients of tangential component of wake velocity |
| $B_x$ | Fourier sine coefficients of longitudinal component of wake velocity |
| $C_{i,j}$ | Elements of calibration matrix |
| $C_{Th}$ | Thrust loading coefficient, $T/[(\rho/2)V_A^2 A_0]$ |
| c | Blade section chord length |
| D | Propeller diameter |
| $(F)_n$ | nth harmonic amplitude of F |
| $F_{x,y,z}$ | Force components on blade in x,y,z directions |
| $f_M$ | Camber of propeller blade section |
| J | Advance coefficient, $J=V_A/nD$ |
| $J_T$ | Effective advance coefficient based on thrust identity |
| $J_Q$ | Effective advance coefficient based on torque identity |
| $J_V$ | Ship speed advance coefficient, $J=V/nD$ |
| $K_{F_{x,y,z}}$ | Force coefficient, $F_{x,y,z}/(\rho n^2 D^4)$ |
| $K_{M_{x,y,z}}$ | Moment coefficient, $M_{x,y,z}/(\rho n^2 D^5)$ |

| | |
|---|---|
| $K_Q$ | Torque coefficient, $Q/(\rho n^2 D^5)$ |
| $K_{SC}$ | Centrifugal blade spindle torque coefficient, $M_{Z_C}/(\rho_p n^2 D^5)$ |
| $K_T$ | Thrust coefficient, $T/(\rho n^2 D^4)$ |
| $M_{x,y,z}$ | Moment components about x,y,z axes from loading on one blade |
| $(M)_n$ | nth harmonic amplitude of M |
| n | Propeller revolutions per unit time |
| P | Propeller blade section pitch |
| Q | Time average propeller torque arising from loading on all blades, $-Z\bar{M}_x$ |
| R | Radius of propeller |
| $R_n$ | Reynolds number, $c_{0.7} V_R^*/\nu$ |
| r | Radial coordinate from propeller axis |
| S | Skew back of propeller blade section measured from the spindle axis to the midchord point of the blade section, positive towards trailing edge |
| T | Time average thrust of propeller, positive forward, $Z\bar{F}_x$ |
| t | Maximum thickness of propeller blade section |
| V | Model speed |
| $V_A$ | Propeller speed of advance |
| $V_R^*$ | Vector sum of speed of advance and rotational velocity at the 0.7 radius, $[V_A^2+(0.7\pi nD)^2]^{1/2}$ |
| $V_r(r,\theta_W)$ | Radial component of wake velocity, positive towards hub |
| $V_t(r,\theta_W)$ | Tangential component of wake velocity, positive counterclockwise looking upstream |

| | |
|---|---|
| $V_x(r,\theta_W)$ | Longitudinal component of wake velocity, positive forward |
| $w_Q$ | Taylor wake fraction determined from torque identity |
| $w_T$ | Taylor wake fraction determined from thrust identity |
| x,y,z | Coordinate axes |
| Z | Number of blades |
| $Z_R$ | Rake of propeller blade section measured from the propeller plane to the generator line. Positive aft |
| $\beta^*$ | Advance angle at 0.7 radius, $\tan^{-1} \frac{[V_x\ (r=0.7)]}{0.7\pi nD}$ |
| $\theta$ | Angular coordinate used to define location of blade and variation of loads, from vertical upward positive clockwise looking upstream, $\theta = -\theta_W$ |
| $\theta_S$ | Skew angle measured from spindle axis to projection of blade section midchord into propeller plane, positive toward trailing edge |
| $\theta_W$ | Angular coordinate of wake velocity, from upward vertical positive counterclockwise looking upstream, $\theta_W = -\theta$ |
| $\lambda$ | Ship to model linear scale ratio |
| $\nu$ | Kinematic viscosity of water |
| $\rho$ | Mass density of water |
| $\rho_P$ | Mass density of propeller blade |
| $\Phi$ | Pitch angle of propeller blade section, $\tan^{-1}$ [P/(πxD)] |
| $(\phi_{F,M})_n$ | nth harmonic phase angles of F,M based on a cosine series, $(F,M)=(\bar{F},M) + \sum_{n=1}^{N} (F,M)_n \cos (n\theta-(\phi_{F,M})_n)$ |
| $\psi$ | Pitch angle of hull |

Subscripts

| | |
|---|---|
| A | Applied values of loads |
| C | Arising from centrifugal loading |
| CW | Value in calm water |
| h | Value at hub radius |
| I | Indicated values of loads before calibration matrix is applied |
| M | Model value |
| MAX | Maximum value at any blade angular position |
| MES | Value at model conditions derived from measurements on full-scale ship |
| n | Value of nth harmonic |
| S | Ship value |
| SP | Value at self-propulsion point |
| x,y,z | Component in x,y,z direction |
| 0.4 | Value at r=0.4R |
| 0.7 | Value at r=0.7R |

Superscripts

| | |
|---|---|
| $\bar{}$ | Time average value per revolution |
| $\sim$ | Unsteady value |
| $\cdot$ | Rate of change with time |

## ABSTRACT

Experiments are described in which the mean and unsteady loads were measured on a single blade of a model of the controllable-pitch propeller on the FF-1088. The experiments were conducted behind a model of the FF-1088 hull under steady ahead operation, hull pitching motions, simulated crash ahead maneuvers, and simulated crash astern maneuvers. The experimental techniques are outlined and the dynamometer and data analysis system described.

The results show that the circumferential variation of all measured components of blade loading is primarily a once-per-revolution variation, with maximum and minimum values occurring near the angular positions in which the spindle axis is horizontal.

For sinusoidal pitching of the model hull with amplitude of 2 deg and frequency of 0.8 Hz, the peak-to-peak circumferential variation of measured forces and moments increased by a minimum of 50 percent over the values without hull pitching.

For simulated operation during a crash ahead or crash astern maneuver, the circumferential variation of measured forces and moments varied approximately as the product of ship speed and propeller rotational speed, and was a function of propeller pitch. At no time during the simulated crash ahead or crash astern maneuvers were the circumferential variations of loads as large as during steady ahead operation.

For steady ahead operation, circumferential variation of loading determined from the model experiments agreed fairly well with full-scale data, but was substantially larger than the theoretically calculated values.



## ADMINISTRATIVE INFORMATION

The work reported herein was funded by the Naval Sea Systems Command (NAVSEA 033) Task Area SSL24001, Task 19977. The work was performed under David W. Taylor Naval Ship Research and Development Center (DTNSRDC), Work Unit 1-1544-296.


The International System (SI) of units is used in the present report. The equivalent English units are shown in parentheses following the SI units in cases in which this will facilitate understanding and allow direct comparison with previous reports.

## INTRODUCTION

Major naval ships powered with marine gas turbines and using controllable-pitch (CP) propellers for thrust reversal are currently being added to the Fleet. Additional ships with gas turbine and CP propeller installations are planned for future Fleet application.

Accordingly, the Navy has been conducting a research and development (R&D) program to establish the technology for producing reliable CP propellers with delivered power in the range of 26,000 to 30,000 kW (35,000 to 40,000 hp). As part of this program, CP propellers were installed on the USS PATTERSON (FF-1061) and USS BARBEY (FF-1088) with delivered power of 26,100 kW (35,000 hp). These installations were intended to demonstrate that CP propellers in this range of power had adequate reliability for application to ships with gas turbine prime movers.

Because of the structural failure of the crank rings to which the blades of the CP propeller on the FF-1088 were bolted, R&D efforts were intensified. The program undertaken at DTNSRDC included:

1. Blade Loading of CP Propellers

    a. Model measurement and theoretical prediction of blade loading on CP propellers.

    b. Model and full-scale wake measurements and theoretical predictions of wake.

    c. Full-scale measurements of forces, pressures, and strains in CP propeller components.

2. Structural Design of CP Propeller Blade Attachments.

3. Development of Materials for CP Propeller Systems.

The current report presents the results of work conducted under Section 1a of the CP Propeller Research and Development Program, i.e., model measurement and theoretical prediction of blade loading of CP propellers. Work under the other sections of this program will be reported separately.

Most of the information contained in the current report has already been published.[1] The current report contains all that information as well as additional details on the experimental data and the pertinent full-scale conditions of the FF-1088.

## BACKGROUND

Extreme care must be taken to design the blades and pitch-changing mechanisms of high power CP propellers so that they possess adequate strength including consideration of yield and fatigue stresses. This requires an accurate estimate of the maximum time-average and alternating loads under all operating conditions. High time-average and alternating loads occur at steady full-power ahead conditions and during high-speed maneuvers including full-power crash astern, full-power crash ahead, and full-power turns. In addition, the influence of the seaway may substantially increase the time-average and alternating loads. At present there appears to be no confirmed technique whereby the pertinent loads can be predicted to the desired accuracy. Schwanecke and Wereldsma[2] reviewed the factors affecting blade loading for propellers in general, and Rusetskiy[3] and Hawdon et al.[4] discussed some of the factors peculiar to blade loading CP propellers.

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[1] Boswell, R.J. et al., "Experimental Determination of Mean and Unsteady Loads on a Model CP Propeller Blade for Various Simulated Loads of Ship Operation," Transactions of the Eleventh ONR Symposium on Naval Hydrodynamics, Government Printing Office (1976). A complete listing of references is given on pages 330--332.

[2] Schwanecke, H. and R. Wereldsma, "Strength of Propellers Considering Steady and Unsteady Shaft and Blade Forces, Stationary and Nonstationary Environmental Conditions," Proceedings of the Thirteenth International Towing Tank Conference, Report of the Propeller Committee, Appendix 2B, Vol. 2 (1972).

[3] Rusetskiy, A.A., "Hydrodynamics of Controllable Pitch Propellers," Shipbuilding Publishing House, Leningrad (1968).

[4] Hawdon, L. et al., "The Analysis of Controllable-Pitch Propeller Characteristics at Off-Design Conditions," Transactions of the Institute of Marine Engineers, Vol. 88 (1976).

Near the self-propulsion point in calm water, the time-average loads can probably be calculated with reasonable accuracy. However, even at these conditions, the variation of loads with blade angular position apparently cannot be calculated with high accuracy. Various techniques, including quasi-steady procedures, stripwise unsteady procedures, and methods based on unsteady lifting surface theory, have been proposed for calculating the unsteady loading arising from the circumferential variation in the inflow velocity.[5--8] However, all of these procedures require knowledge of the flow patterns (wake profile) in the propeller disk. In current practice, the wake profile is measured in the plane of the propeller behind the model hull with the propeller removed. For high-speed displacement ships of the type under consideration in this report, these results are usually extrapolated to full scale without making allowance for (1) the change in Reynolds number and the corresponding reduction in relative boundary layer thickness and (2) the effect of the propeller suction on the boundary layer and thereby the wake pattern in the propeller disk.

Existing measurements which give information on unsteady blade loading include:

1. Measurements of strain on the blades of the model propellers or full-scale propellers. However, some calculations and assumptions are

---

[5]Van Gent, W., "Unsteady Lifting Surface Theory for Ship Screws: Derivation and Numerical Treatment of Integral Equation," Journal of Ship Research, Vol. 19, No. 4, pp. 243--253 (Dec 1975).

[6]Schwanecke, H., "Comparative Calculations on Unsteady Propeller Blade Forces," Proceedings of the Fourteenth International Towing Tank Conference, Report of the Propeller Committee, Appendix 2c, vol. 2 (1972).

[7]Breslin, J.P., "Propeller Excitation Theory," Proceedings of the Fourteenth International Towing Tank Conference, Report of the Propeller Committee, Appendix 2c, Vol. 2 (1972).

[8]Boswell, R.J. and M.L. Miller, "Unsteady Propeller Loading-Measurement, Correlation with Theory, and Parametric Study," NSRDC Report 2625 (Oct 1968).

required to convert measured strains into loads. Published data of this have been summarized by Meyne.[9]

2. Measurement of bearing (shaft) forces and moments on model propellers operating in wakes generated by model hulls or wire grid screens. However, this gives information on only some components of blade loading and on only those harmonics of shaft rotational speed corresponding to nZ-1, nZ, and nZ+1, where n is an integer and Z is the number of blades. Measurements of this nature have been conducted by many investigators.[7,10]

3. Measurements of forces and moments on individual blades of model propellers operating in wakes generated by model hulls or wire grid screens. Measurements behind model hulls have been made by Huse[11] and Blaurock,[12] measurements behind screens have been made by Hawdon et al.,[4] measurements in inclined flow have been made by Albrecht and Suhrbier[13] and by Bednarzik,[14] and measurements on partially submerged propellers have been made by Dobay.[15]

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[9]Meyne, K., "Propeller Manufacture-Propeller Materials-Propeller Strength," International Shipbuilding Progress, Vol. 2, No. 247, pp. 77--102 (Mar 1975).

[10]Wereldsma, R., "Comparative Tests on Vibratory Propeller Forces," Proceedings of the Thirteenth International Towing Tank Conference, Report of the Propeller Committee, Appendix 2a, Vol. 2 (1972).

[11]Huse, E., "An Experimental Investigation of the Dynamic Forces and Moments on One Blade of a Ship Propeller," Proceedings of the Symposium on Testing Techniques in Ship Cavitation Research, The Norwegian Ship Model Experimental Tank, Trondheim, Norway (May--Jun 1967).

[12]Blaurock, J., "Propeller Blade Loading in Nonuniform Flow," The Society of Naval Architects and Marine Engineers, Propellers 75 Symposium, (Jul 1975).

[13]Albrecht, K. and K.R. Suhbrier, "Investigation of the Fluctuating Blade Forces of a Cavitating Propeller in Oblique Flow," International Shipbuilding Progress, Vol. 22, No. 248, pp. 132--147 (Apr 1975).

[14]Bednarzik, R., "Untersuchung uber die Belastungs-schwankungen am Einzelflugel schrag angestromter Proper," Schiffbauforschung, Vol. 8, No. 1/2, pp. 57--80 (1968).

[15]Dobay, G.F., "Time-Dependent Blade-Load Measurements on a Screw-Propeller," presented to the Sixteenth American Towing Tank Conference, (Aug 1971).

Experiments in wakes generated by screens are advantageous for evaluating the ability of a procedure to calculate the loading for a given wake since for this case, the propeller apparently does not influence the wake pattern. Although some good correlation has apparently been obtained between analytical predictions and unsteady bearing forces measured behind wire grid screens,[7,8] correlation has been rather inconsistent between analytically predicted unsteady blade loads, or resulting strains, and measured blade loads, or strains.[10,16]

The mechanism by which the seaway influences the mean and unsteady blade loads is complex. Factors include the increased mean propeller loading due to increased hull resistance and the increased unsteady loading resulting from the influence of the free surface and modification of the flow patterns into the propeller disk. This flow pattern is influenced (1) by direct trochoidal velocities from the ocean waves, (2) by relative velocities of the propeller due to ship motions, and (3) by modification of the hull wake pattern due to the seaway and ship motions. Procedures for calculating the loads in a seaway are much less refined than for steady operation in calm water. Tasaki[17] gives a good review of the mechanisms and procedures for predicting the effect of the seaway on bearing forces which, in principle, also applies to unsteady loading on an individual blade. Keil et al.[18] and Watanabe et al.[19] present strain measurements on the blades of full-scale propellers in both calm and rough seas.

Apparently no rational analytical procedures are available for accurately calculating the time-average loads per revolution or the unsteady

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[16] Wereldsma, R., "Last Remarks on the Comparative Model Tests on Vibratory Propeller Forces," Proceedings of the Fourteenth International Towing Tank Conference, Vol. 3, pp. 421--426 (1975).

[17] Tasaki, R., "Propulsion Factors and Fluctuating Propeller Loads in Waves," Proceedings of the Fourteenth International Towing Tank Conference, Vol. 4, pp. 224--236 (1975).

[18] Keil, H.G. et al., "Stresses in the Blades of a Cargo Ship Propeller," Journal of Hydronautics, Vol. 6, No. 1 (Jan 1972).

[19] Watanabe, K. et al., "Propeller Stress Measurements on the Container Ship HAKONE MARU," Shipbuilding Research Association of Japan (1973).

loads including variation with blade angular position during crash ahead or crash astern maneuvers. These loads may depend on many factors including the time rate of change of propeller pitch $\dot{P}$ (for CP propellers), time rate of change of rotational speed $\dot{n}$, time rate of change of ship speed $\dot{V}$, propeller blade section stall, cavitation, ventilation, flow separation from the hull, and large interactions between the propeller and the hull. Some of these factors are discussed and considered by Hawdon et al.[4] For crash astern maneuvers, a CP propeller has negative pitch P and develops negative thrust for forward speed, i.e., it decelerates the flow into the propeller, and this may tend to increase the time-average and time-dependent interaction between the propeller and the hull.

For turns, the factors affecting the time-average loads per revolution and the unsteady loads are somewhat the same as those affecting the loads under crash ahead and crash astern conditions except that for turns, there is a relatively large drift angle of the flow into the propeller. This drift angle tends to increase the circumferential nonuniformity of the flow into the propeller, thereby increasing the unsteady loading. However, this circumferential nonuniformity of the inflow tends to be offset by the lower values of ship speed and propeller rotational speed in turns compared to steady ahead operation.

The authors know of no experimental measurements of time-average loads and circumferential variation of loads with blade angular position on CP propellers behind a hull under a wide range of operating conditions. An experimental program was therefore undertaken to measure the six components of loading (Figure 1)* on a model CP propeller operating behind a model hull, namely, a model of the FF-1088. The experimental conditions included (1) steady ahead operation near the self-propulsion point, (2) steady ahead operation near the self-propulsion point with forced dynamic pitching of the model hull, (3) simulated crash ahead operation, and (4) simulated crash

*Main text figures are presented following the section on acknowledgments.

astern operation. Results for the steady ahead operation were correlated with predictions based on unsteady lifting surface theory as developed by Tsakonas et al.,[20] with the quasi-steady method of McCarthy,[21] and with strains measured on the full-scale propeller of the FF-1088.

The model propeller used in these experiments was DTNSRDC Propeller 4402; see Figure 2 and Table 1. Its geometry was nearly identical to that of the FF-1088 propeller; see Figure 3 and Table 2. The only differences between the two propeller designs are (1) the radial distributions of camber and pitch between the 70-percent radius and the tip and (2) the blade leading edge radii; see Tables 1 and 2. It was judged that these two propellers would have approximately the same loading under the same operating conditions. Therefore, no corrections were made for the difference in their geometries.

The hull of the FF-1088 was represented by DTNSRDC Model Hull 4989; see Figure 4.

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[20]Tsakonas, S. et al., "An Exact Linear Lifting Surface Theory for Marine Propeller in a Nonuniform Flow Field," Journal of Ship Research, Vol. 17, No. 4 (Dec 1974).

[21]McCarthy, J.H. "On the Calculation of Thrust and Torque Fluctuations of Propellers in Nonuniform Wake Flow," David Taylor Model Basin Report 1533 (Oct 1961).

TABLE 1 - CHARACTERISTICS OF PROPELLER CORRESPONDING TO DTNSRDC MODEL PROPELLER 4402

Diameter: 4.572 m (15.0 ft)
Rotation: Right Hand
Number of Blades: 5
Maximum Rotational Speed (Rated): 25.13 rad/sec (240 rev/min)
Full Power (Rated): 26,100 kW (35,000 hp)
Speed at Full Power: 14.5 m/sec (28.1 knots)
Expanded Area Ratio: 0.83
Blade Thickness Fraction: 0.059
Section Meanline: NACA 65
Section Thickness Distribution: NACA 16 (Modified)[1]
Design Advance Coefficient J: 0.767
Design Advance Angle $\beta^*$: 0.3356 rad (19.23 deg)
Design Thrust Loading Coefficient $C_{Th}$: 0.706

| x | c/D | P/D | $S/D^3$ | $Z_R/D$ | t/D | $f_M/c$ |
|---|---|---|---|---|---|---|
| 0.30 | 0.1853 | 1.008 | 0.0185 | 0 | 0.0437 | 0.0243 |
| 0.40 | 0.2482 | 1.044 | 0.0248 | 0 | 0.0328 | 0.0302 |
| 0.50 | 0.3111 | 1.067 | 0.0311 | 0 | 0.0250 | 0.0280 |
| 0.60 | 0.3740 | 1.072 | 0.0374 | 0 | 0.0187 | 0.0240 |
| 0.70 | 0.4369 | 1.061[2] | 0.0437 | 0 | 0.0131 | 0.0191[2] |
| 0.80 | 0.4760 | 1.025[2] | 0.0476 | 0 | 0.0089 | 0.0140[2] |
| 0.90 | 0.4600 | 0.964[2] | 0.0460 | 0 | 0.0061 | 0.0082[2] |
| 0.95 | 0.4587 | 0.922[2] | 0.0459 | 0 | 0.0051 | 0.0042[2] |
| 1.00 | 0.3400 | 0.878[2] | 0.0340 | 0 | 0.0040 | 0.0000 |

[1] Smaller leading edge radii than propeller on FF-1088.

[2] Different than for propeller on FF-1088.

[3] The spindle axis is the propeller reference line and passes through 40-percent chord for all radii.

TABLE 2 - CHARACTERISTICS OF PROPELLER ON FF-1088
(Corresponds to DTNSRDC Model Propeller 4402A)

Diameter: 4.572 m (15.0 ft)
Rotation: Right Hand
Number of Blades: 5
Maximum Rotational Speed (Rated):
25.13 rad/sec (240 rev/min)
Full Power (Rated):
26,100 kW (35,000 hp)
Speed at Full Power:
14.46 m/sec (28.1 knots)
Expanded Area Ratio: 0.83
Blade Thickness Fraction: 0.059
Section Meanline: NACA 65
Section Thickness Distribution:
NACA 16 (Modified)
Design Advance Coefficient J: 0.767
Design Advance Angle $\beta^*$:
0.3356 rad (19.23 deg)
Design Thrust Loading Coefficient
$C_{Th}$: 0.706

| x | c/D | P/D | S/D[1] | $Z_R/D$ | t/D | $f_M/c$ |
|---|---|---|---|---|---|---|
| 0.30 | 0.1853 | 1.008 | 0.0185 | 0 | 0.0437 | 0.0243 |
| 0.40 | 0.2482 | 1.044 | 0.0248 | 0 | 0.0328 | 0.0302 |
| 0.50 | 0.3111 | 1.067 | 0.0311 | 0 | 0.0250 | 0.0280 |
| 0.60 | 0.3740 | 1.072 | 0.0374 | 0 | 0.0187 | 0.0240 |
| 0.70 | 0.4369 | 1.056 | 0.0437 | 0 | 0.0131 | 0.0197 |
| 0.80 | 0.4760 | 1.018 | 0.0476 | 0 | 0.0089 | 0.0152 |
| 0.90 | 0.4600 | 0.956 | 0.0460 | 0 | 0.0061 | 0.0097 |
| 0.95 | 0.4587 | 0.911 | 0.0459 | 0 | 0.0051 | 0.0056 |
| 1.00 | 0.3400 | 0.861 | 0.0340 | 0 | 0.0040 | 0.0000 |

[1]The spindle axis is the propeller reference line and passes through 40-percent chord for all radii.

## EXPERIMENTAL TECHNIQUE

### FACILITY AND DYNAMOMETRY

All experiments were conducted on DTNSRDC Carriage I. The propeller was located in its proper position relative to the model hull but was isolated from the hull and driven from downstream (see Figure 5).

This downstream drive system was necessary in order to obtain the required characteristics of the system for measuring unsteady loading. The general criteria for the design of an unsteady force measuring system are:

1. The support structure of the force measuring system should be soft mounted and possess a large mass to eliminate transmission of extraneous vibration to the system.

2. The natural frequency of the system should be well above the highest frequency of the quantities to be measured (to avoid phase shift and amplification of the signal).

3. The system response in the force magnitude range should be sufficiently large to be measurable (sensitivity).

4. The system should be free of interaction, that is, each measuring element should respond only to that force or moment which it is intended to measure.

These four major aims are not complementary. The high natural frequency requires a stiff, rigid system whereas high sensitivity requires an elastic, soft system. The necessary compromise results in some interaction between the force-measuring elements.

Criterion 1 dictated that a massive flywheel be used, and Criterion 2 dictated that this flywheel be connected to the sensing elements (located inside the propeller hub) by a short thick shaft. Therefore, because of the geometry of the hull and shafting of the configuration under evaluation, it was not feasible to achieve both these criteria with an upstream drive system from inside the model hull. Criteria 1 and 2 controlled the the minimum allowable beam and draft of the downstream body and the maximum allowable clearance from the bow of the downstream body to the propeller.

Although the downstream body may exert some influence on the flow into the propeller, that location was considered necessary in order to meet these measuring criteria. The influence of the downstream body on the flow into the propeller is discussed in the section on experimental results.

The drive and mounting system was basically the same as that used in the DTNSRDC BASS dynamometer which has been described by Brandau.[22] Utilized from this dynamometer were the propeller (tail) shaft, drive shaft with flywheel, belt-type (quiet) transmission, and sliprings. Power to rotate the propeller was supplied by a d-c permanent-magnet servomotor capable of delivering up to 45 N-m of torque. This motor was selected for its ability to control and hold the shaft revolution rate over the wide range of propeller torque loadings required for some of the experimental conditions. Mounted on the propeller shaft was a digital encoder that generated electrical pulses as a function of shaft angular position. Two types of pulses were generated: a single pulse per revolution and a multipulse per revolution (90 equally spaced pulses for the current experiment). The single pulse was syncronized with the reference line of the instrumented propeller blade. The pulses generated by this encoder are accurate to within 0.01 deg.

The downstream body which housed the drive system was basically that used by Dobay[15] but modified to allow deeper submergence and an inclined shaft angle. Both the body housing the drive system (the drive system was soft mounted to this body) and the model hull were rigidly attached to a pitch-heave oscillator which, in turn, was rigidly mounted on the towing carriage. This arrangement enabled the model hull and the drive system to be dynamically pitched together while maintaining independent support from one another.

The sensing elements were flexures to which were bonded high-sensitivity, semiconductor strain-gage bridges. The design of these flexures has been described by Dobay.[15] There were three flexures, each

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[22] Brandau, J.H., "Static and Dynamic Calibration of Propeller Model Fluctuating Force Balances," David Taylor Model Basin Report 2350 (Mar 1967); see also Technologia Naval, Vol. 1, pp. 48--74 (Jan 1968).

of which measured two components of blade loading. Flexure 1 measured components $F_x$ and $M_y$, Flexure 2 measured components $F_y$ and $M_x$, and Flexure 3 measured components $F_z$ and $M_z$ (Figures 1 and 6). An arrangement of three separate flexures rather than one to measure all components of blade loading was adopted because it appeared to result in higher natural frequencies (Criterion 1), higher sensitivities (Criterion 3) and lower interactions (Criterion 4) than would have resulted had a single flexure been used.

The flexures were mounted inside a propeller hub which was specifically designed for these experiments (Figure 7). Only one flexure could be mounted at a time, because of space limitations, and this necessitated duplicate runs, as discussed later in the section on experimental conditions and procedures.

The strain-gage bridges were excited by a common d-c voltage source, transmitted through the sliprings on the propeller shaft. The constant-current excitation used by Dobay[15] was not employed in the present experiment because it appeared to be too sensitive to temperature.

The voltage output from the flexures (due to blade loading) was transmitted through the sliprings to individual amplifiers (NEFF 119-121). These amplifiers utilized field effect transistors to produce an extremely high input-impedance (100 MΩ, minimum). This high impedance essentially eliminated slipring noise to the amplifier. The voltage signals were transferred across the sliprings in the presence of only a small amount of noise-producing current. The amplifiers used here had zero-phase shift qualities in the d-c-20 kHz range. They were chopper-stabilized to enable both the steady and unsteady signals to be recorded simultaneously. This signal-conditioning system was essentially the same as that used by Dobay.[15]

The signals were then digitized and analyzed by using a Model 70 Interdata Digital Computer, and were then stored in digital form on a nine-track magnetic tape. The on-line analysis of the data is discussed in the section on data acquisition and analysis.

CALIBRATION

Prior to the experiment, each flexure was statically calibrated in air to establish flexure sensitivities, interactions, and linearity over the loading range of interest. These calibrations were conducted with the flexures mounted in the propeller hub which was connected to the flywheel and drive assembly as in the experiment. Each flexure was subjected to independently controlled forces in the axial, transverse, and radial directions (i.e., $F_x$, $F_y$, and $F_z$, respectively) and to independently controlled moments about the axial, transverse, and radial directions (i.e., $M_x$, $M_y$, and $M_z$, respectively); see Figure 1.

The static calibration showed that all flexures had a linear response over the load range of interest. Table 3 shows the interaction matrix. These calibrations indicated that all flexures had good sensitivity except $F_z$ whose sensitivity was lower than desirable. The interactions were small except for the effect of $M_z$ on $F_z$. The rather poor characteristics of the $F_z$ flexure is not considered a serious shortcoming since $F_z$ arises primarily from centrifugal loading and can be analytically calculated. In addition, no significant variation of $F_z$ with blade angular position is anticipated. Flexure 3, which measured $F_z$ and $M_z$, was further evaluated by correlation of air-spin experiments with analytically calculated results, as discussed later. The interactions were taken into consideration during data analysis.

The flexures used in this experiment had been dynamically calibrated by Dobay[15] to determine the frequency range over which unsteady forces and moments could be reliably measured. In this procedure, an electromagnetic shaker in air was used to apply a relatively constant, maximum amplitude, variable-frequency force or moment-excitation in all six-component directions to all six flexure elements. The force or moment amplitude imposed by the shaker was monitored through an extremely lightweight, strain-gaged single flexure element. The measured lowest natural frequencies of the three flexures in air were as follows:

| | Frequency (Hz) | Mode |
|---|---|---|
| Flexure 1 | 550 | $M_x$ |
| Flexure 2 | 450 | $M_y$ |
| Flexure 3 | 282 | $M_z$ |

TABLE 3 - CALIBRATION MATRIX

$$\text{Calibration Matrix} = [C_{i,j}] = \begin{bmatrix} 0.0652 & 0.0017 & -0.0003 & 0.0292 & -0.0531 & -0.0212 \\ -0.0025 & 0.0680 & -0.0001 & 0.0398 & 0.0434 & 0.0363 \\ 0.0002 & 0.0018 & 0.0203 & 0.0319 & -0.0027 & -0.3363 \\ 0.0005 & 0.0009 & 0.0004 & 1.6853 & -0.0080 & 0.0920 \\ -0.0018 & -0.0026 & 0.0013 & -0.0460 & 1.6605 & 0.0478 \\ -0.0002 & 0.0002 & 0.0000 & 0.0035 & 0.0035 & 1.1666 \end{bmatrix}$$

where

$$\begin{bmatrix} F_{x_I} \\ F_{y_I} \\ F_{z_I} \\ M_{x_I} \\ M_{y_I} \\ M_{z_I} \end{bmatrix} = \begin{bmatrix} F_{x_A} \\ F_{y_A} \\ F_{z_A} \\ M_{x_A} \\ M_{y_A} \\ M_{z_A} \end{bmatrix} \cdot [C_{i,j}]$$

$F_{x_I}$, $F_{y_I}$, $F_{z_I}$ are indicated forces in volts.

$M_{x_I}$, $M_{y_I}$, $M_{z_I}$ are indicated moments in volts.

$F_{x_A}$, $F_{y_A}$, $F_{z_A}$ are applied forces in Newtons.

$M_{x_A}$, $M_{y_A}$, $M_{z_A}$ are applied moments in Newton-meters.

$C_{i,j}$ for j=1,2,3 are in volts/Newton.

$C_{i,j}$ for j=4,5,6 are in volts/Newton-meters.

The measured amplification factor (ratio of output amplitude to input amplitude) and phase shift for all three flexures was as follows:

| Frequency Range (Hz) | 0 to 60 | 60 to 120 |
|---|---|---|
| Phase Shift (rad) | 0 to $8.7 \times 10^{-4}$ | $8.7 \times 10^{-4}$ to $2.6 \times 10^{-3}$ |
| Phase Shift (deg) | 0 to 0.05 | 0.05 to 0.15 |
| Amplification Factor | 1.00 | 1.00 to 1.05 |

After the experimental apparatus was completely assembled with propeller blades and attached in place under the towing carriage, the effect of submergence in water on flexure lowest natural frequency was checked. This check consisted of striking the blade a sharp, light blow and recording the response of Flexure 1 (the $F_x$, $M_y$ flexure). The measured response indicated that the lowest natural frequency of the flexure was approximately 250 Hz or approximately 0.45 times its value in air. Similar measurements were not made for the other two flexures but it was assumed that their natural frequencies in water were also approximately 0.45 times the measured values in air. Based on this assumption, the natural frequencies in water are:

| | |
|---|---|
| Flexure 1 | 250 Hz |
| Flexure 2 | 202 Hz |
| Flexure 3 | 127 Hz |

The highest propeller rotational speed during the experiment was 110.9 rad/sec (17.65 rev/sec). Thus, the flexures had a "true" dynamic response (determined in air) up to at least the third harmonic of shaft rotation and no greater than 5 percent amplification up to the sixth harmonic of shaft rotation. Assuming that the lowest natural frequency of each flexure in water was 0.45 times its measured value in air, the lowest natural frequencies of Flexures 1, 2, and 3 were respectively greater than 14, 11, and 7 times the highest propeller rotational speed used during the experiments. As discussed in the section on experimental results, extraneous signals appeared in the unfiltered experimental data at frequencies close to the deduced natural frequency of each flexure in water.

The propeller shaft drive and soft-mount support system were dynamically loaded in the vertical, longitudinal, and transverse directions to obtain the systems lowest natural frequencies. The natural frequencies of the system in air were found to be:

| Mode | Natural Frequency (Hz) |
|---|---|
| Vertical bending | 12.25 |
| Horizontal bending | 6.0 |
| Axial | 4.6 |

The support system had a low resonant range; however, the soft-mount system was specifically designed to prevent towing-carriage oscillation (with the resonance at 100 to 200 Hz) from being transmitted to the blade flexures. Based on the measured resonance, it is concluded that the soft-mount system should successfully meet this objective. Although some resonances were close to the propeller rotational speed for some experimental conditions, it was considered more desirable to isolate the system from towing-carriage vibration. Therefore, the soft mount system was considered to be satisfactory.

## EXPERIMENTAL CONDITIONS AND PROCEDURES

Experiments were conducted at several conditions including steady ahead operation, simulated pitching of the hull, simulated crash ahead (acceleration), and simulated crash astern (deceleration). All conditions were run with the model hull rigidly attached to its support, with no freedom to sink or trim.

The steady ahead condition is defined in Tables 4-7. The simulated full-scale speed for this condition was slightly higher than the speed at full power measured during standardization trials (see Table 4), but the propeller rotational speed was the same as that measured at full power during standardization trials. Model self-propulsion data (not corrected for wind drag at zero true wind) tend to agree with the standardization data; see Table 4. If the standardization data are correct, then the

TABLE 4 - PREDICTED FULL-SCALE STEADY AHEAD POWERING CONDITIONS FROM VARIOUS SOURCES

| | V | | n | | $\overline{T}$ | | $\overline{Q}$ | | $P_D$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| | m/sec | (knots) | rad/sec | (rev/min) | N x $10^{-6}$ | (lb x $10^{-5}$) | N-m x $10^{-6}$ | (ft-lb x $10^{-5}$) | kw x $10^{-4}$ | (hp x $10^{-4}$) |
| Model Experiments in Present Study[1] | 14.7 | (28.6) | 25.1 | 240 | 1.14 | (2.57) | 0.97 | (7.13) | 2.44 | (3.27) |
| Standardization Trials | 14.4 | (28.1) | 25.1 | (240) | 1.13 | (2.55) | 1.04 | (7.66) | 2.61 | (3.50) |
| Model Data[2] | 14.5 | (28.2) | 25.1 | (240) | 1.19 | (2.67) | 1.04 | (7.66) | 2.61 | (3.50) |
| Full-Scale Blade Stress Trials[3] | 13.3 | (25.8) | 23.8 | (227) | 1.10 | (2.48) | 1.33 | (9.80) | 3.15 | (4.23) |

[1]Corrected for influence of dynamomenter boat.

[2]No correction for full-scale wind drag at zero true wind.

[3]Conducted by C.J. Noonan and G.P. Antonides, DTNSRDC Code 1962.

TABLE 5 - MODEL EXPERIMENTAL CONDITIONS

| | Condition No. | V m/sec | V (knots) | n rad/sec | n (rev/sec) | $J_V$ | P/D | $(\psi-\psi_{CW})$ deg | $\dot{V}$ m/sec$^2$ | $\dot{V}$ (knots/sec) | $t-t_0$ sec |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Self-Propulsion | 1 | 3.33 | (6.50) | 110.9 | (17.65) | 0.80 | 1.06 | 0 | 0 | (0) | N/A |
| Quasi-Steady Hull Pitch | 2 | 3.33 | (6.50) | 110.9 | (17.65) | 0.80 | 1.06 | -2 | 0 | (0) | N/A |
| | 3 | 3.33 | (6.50) | 110.9 | (17.65) | 0.80 | 1.06 | -1 | 0 | (0) | N/A |
| | 4 | 3.33 | (6.50) | 110.9 | (17.65) | 0.80 | 1.06 | +1 | 0 | (0) | N/A |
| | 5 | 3.33 | (6.50) | 110.9 | (17.65) | 0.80 | 1.06 | +2 | 0 | (0) | N/A |
| Unsteady Hull Pitch | 6 | 3.33 | (6.50) | 110.9 | (17.65) | 0.80 | 1.06 | variable[2] | 0 | (0) | N/A |
| Quasi-Steady Crash Forward | 7 | 0.33 | (0.64) | 39.3 | ( 6.26) | 0.22 | 1.39 | 0 | 0 | (0) | N/A |
| | 8 | 0.81 | (1.59) | 58.7 | ( 9.35) | 0.37 | 1.39 | 0 | 0 | (0) | N/A |
| | 9 | 1.46 | (2.85) | 70.3 | (11.19) | 0.56 | 1.39 | 0 | 0 | (0) | N/A |
| | 10 | 2.26 | (4.41) | 75.8 | (12.07) | 0.80 | 1.39 | 0 | 0 | (0) | N/A |
| | 11 | 3.10 | (6.05) | 84.2 | (13.40) | 0.99 | 1.39 | 0 | 0 | (0) | N/A |
| Unsteady Crash Forward | 12 | 0.33[1] | (0.64)[1] | 39.3 | ( 6.26) | 0.22 | 1.39 | 0 | +0.19[1] | ( 0.10)[1] | 4.53 |
| | 13 | 0.81[1] | (1.59)[1] | 58.7 | ( 9.35) | 0.37 | 1.39 | 0 | +0.23[1] | ( 0.12)[1] | 9.05 |
| | 14 | 1.46[1] | (2.85)[1] | 70.3 | (11.19) | 0.56 | 1.39 | 0 | +0.33[1] | ( 0.17)[1] | 13.58 |
| | 15 | 2.26[1] | (4.41)[1] | 75.8 | (12.07) | 0.80 | 1.39 | 0 | +0.33[1] | ( 0.17)[1] | 18.11 |
| | 16 | 3.10[1] | (6.05)[1] | 84.2 | (13.40) | 0.99 | 1.39 | 0 | +0.01 | ( 0.01)[1] | 31.69 |
| Quasi-Steady Crash Astern | 17 | 3.33 | (6.50) | 110.9 | (17.65) | 0.80 | 1.06 | 0 | 0 | (0) | N/A |
| | 18 | 2.57 | (5.03) | 109.5 | (17.43) | 0.63 | 0.61 | 0 | 0 | (0) | N/A |
| | 19 | 1.67 | (3.26) | 104.2 | (16.59) | 0.43 | 0.14 | 0 | 0 | (0) | N/A |
| | 20 | 0.74 | (1.44) | 42.5 | ( 6.77) | 0.46 | -0.67 | 0 | 0 | (0) | N/A |
| | 21 | 0.17 | (0.34) | 48.0 | ( 7.64) | 0.10 | -0.67 | 0 | 0 | (0) | N/A |
| Unsteady Crash Astern | 22 | 3.33[1] | (6.50)[1] | 110.9 | (17.65) | 0.80 | 1.06 | 0 | 0.00[1] | ( 0.00)[1] | 0 |
| | 23 | 2.57[1] | (5.03)[1] | 109.5 | (17.43) | 0.63 | 0.61 | 0 | -0.32[1] | (-0.16)[1] | 9.05 |
| | 24 | 1.67[1] | (3.26)[1] | 104.2 | (16.59) | 0.43 | 0.14 | 0 | -0.43[1] | (-0.22)[1] | 13.58 |
| | 25 | 0.74[1] | (1.44)[1] | 42.5 | ( 6.77) | 0.46 | -0.67 | 0 | -0.32[1] | (-0.16)[1] | 18.11 |
| | 26 | 0.17[1] | (0.34)[1] | 48.0 | ( 7.64) | 0.10 | -0.67 | 0 | -0.18[1] | (-0.09)[1] | 22.64 |

[1]Varies with time (Figure 8); value shown is at time of interest.

[2]Sinusoidal with amplitude equal to 2.0 deg, frequency equal to 0.8 Hz.

TABLE 6 - FULL-SCALE CONDITIONS SIMULATED BY MODEL EXPERIMENTS

| | Condition No. | V m/sec | V (knots) | n rad/sec | n (rev/sec) | $J_V$ | P/D | $(\psi-\psi_{CW})$ deg | $\dot{V}$ m/sec$^2$ | $\dot{V}$ (knots/sec) | $t-t_o$ sec |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Self-Propulsion | 1 | 14.7 | 28.6 | 25.10 | 4.00 | 0.80 | 1.06 | 0 | 0 | 0 | N/A |
| Quasi-Steady Hull Pitch | 2 | 14.7 | 28.6 | 25.10 | 4.00 | 0.80 | 1.06 | -2 | | | |
| | 3 | 14.7 | 28.6 | 25.10 | 4.00 | 0.80 | 1.06 | -1 | | | |
| | 4 | 14.7 | 28.6 | 25.10 | 4.00 | 0.80 | 1.06 | +1 | | | |
| | 5 | 14.7 | 28.6 | 25.10 | 4.00 | 0.80 | 1.06 | +2 | | | |
| Unsteady Hull Pitch | 6 | 14.7 | 28.6 | 25.10 | 4.00 | 0.80 | 1.06 | variable[2] | | | |
| Quasi-Steady Crash Forward | 7 | 1.6 | 2.8 | 8.90 | 1.42 | 0.22 | 1.39 | 0 | | | |
| | 8 | 3.6 | 7.0 | 13.29 | 2.12 | 0.37 | 1.39 | 0 | | | |
| | 9 | 6.4 | 12.6 | 15.91 | 2.53 | 0.56 | 1.39 | 0 | | | |
| | 10 | 10.0 | 19.5 | 17.16 | 2.73 | 0.80 | 1.39 | 0 | | | |
| | 11 | 13.7 | 26.7 | 19.06 | 3.03 | 0.99 | 1.39 | 0 | 0 | 0 | N/A |
| Unsteady Crash Forward | 12 | 1.6[1] | 2.8[1] | 8.90 | 1.42 | 0.22 | 1.39 | 0 | +0.19[1] | (0.10)[1] | 20 |
| | 13 | 3.6[1] | 7.0[1] | 13.29 | 2.12 | 0.37 | 1.39 | 0 | +0.23[1] | (0.12)[1] | 40 |
| | 14 | 6.4[1] | 12.6[1] | 15.91 | 2.53 | 0.56 | 1.39 | 0 | +0.33[1] | (0.17)[1] | 60 |
| | 15 | 10.0[1] | 19.5[1] | 17.16 | 2.73 | 0.80 | 1.39 | 0 | +0.33[1] | (0.17)[1] | 80 |
| | 16 | 13.7[1] | 26.7[1] | 19.06 | 3.03 | 0.99 | 1.39 | 0 | +0.01[1] | (0.01)[1] | 140 |
| Quasi-Steady Crash Astern | 17 | 14.7 | 28.6 | 25.10 | 4.00 | 0.80 | 1.06 | 0 | 0 | 0 | N/A |
| | 18 | 11.4 | 22.2 | 24.78 | 3.94 | 0.63 | 0.61 | 0 | | | |
| | 19 | 7.4 | 14.4 | 23.59 | 3.76 | 0.43 | 0.14 | 0 | | | |
| | 20 | 3.3 | 6.4 | 9.62 | 1.53 | 0.46 | -0.67 | 0 | | | |
| | 21 | 0.8 | 1.5 | 10.86 | 1.73 | 0.10 | -0.67 | 0 | 0 | 0 | N/A |
| Unsteady Crash Astern | 22 | 14.7[1] | 28.6[1] | 25.10 | 4.00 | 0.80 | 1.06 | 0 | 0.00[1] | 0.00[1] | 0 |
| | 23 | 11.4[1] | 22.2[1] | 24.78 | 3.94 | 0.63 | 0.61 | 0 | -0.32[1] | -0.16[1] | 40 |
| | 24 | 7.4[1] | 14.4[1] | 23.59 | 3.76 | 0.43 | 0.14 | 0 | -0.43[1] | -0.22[1] | 60 |
| | 25 | 3.3[1] | 6.4[1] | 9.62 | 1.53 | 0.46 | -0.67 | 0 | -0.32[1] | -0.16[1] | 80 |
| | 26 | 0.8[1] | 1.5[1] | 10.86 | 1.73 | 0.10 | -0.67 | 0 | -0.18[1] | -0.09[1] | 100 |

[1] Varies with time (Figure 8); value shown is at time of interest.

[2] Sinusoidal with amplitude equal to 2.0 deg, frequency equal to 0.8 Hz.

TABLE 7 - TIME-AVERAGE LOADS FOR STEADY AHEAD OPERATION NEAR THE SELF-PROPULSION POINT

$V$ = 3.33 m/sec = 10.92 ft/sec

$n$ = 110.9 rad/sec = 17.65 rev/sec

$J_V$ = 0.80

P/D = 1.06

| | | | |
|---|---|---|---|
| $\overline{K}_{F_x}$ | = 0.0321 | $\overline{F}_x$ | = 30.0 N = 6.74 lb |
| $\overline{K}_{F_y}$ | = 0.0213 | $\overline{F}_y$ | = 19.9 N = 4.48 lb |
| $\overline{K}_{M_x}$ | =-0.0059 | $\overline{M}_x$ | =-1.29 N-m =-11.42 in-lb |
| $\overline{K}_{M_y}$ | = 0.0118 | $\overline{M}_y$ | = 2.59 N-m = 22.94 in-lb |
| $\overline{K}_{M_z}$ | =-0.0006 | $\overline{M}_z$ | =-0.13 N-m = -1.15 in-lb |
| $\overline{K}_{M_h}$ | = 0.0069 | $\overline{M}_h$ | = 1.51 N-m = 13.37 in-lb |
| $\overline{K}_{M_{0.4}}$ | = 0.0050 | $\overline{M}_{0.4}$ | = 1.10 N-m = 9.74 in-lb |

steady ahead condition run during the present study represents a slightly "overpropelled" condition. However, the thrust and propeller rotational speed determined from the present experiment were in good agreement with the standardization data; although the scaled torque and power were lower on the model experiment. This is not a serious shortcoming since the net bending moment on the blade at steady ahead operation is controlled predominantly by the bending moment arising from thrust.

The trim and draft at this speed was determined by setting the specified still water trim (even keel) and draft (4.65 m (15.27 ft) full-scale equivalent), attaching the model to the carriage so that it was free to trim and sink, running at the specified speed, and locking the model at this equilibrium trim and draft.

Runs simulating hull pitching were conducted at the same conditions as the steady ahead run, except that the hull pitch was varied. Two types of runs were conducted: (1) quasi-steady simulation in which the hull pitch angle $\psi$ was set at various fixed position and (2) unsteady simulation in which $\psi$ was varied sinusoidally with time. For the quasi-steady simulation, runs were conducted at five different values of $\psi$, from 2-deg bow up from the calm water equilibrium $\psi$ ($\psi=\psi_{CW}$) to 2-deg bow down from $\psi_{CW}$ (Tables 5 and 6). For the unsteady pitch simulation, the value of $\psi$ was varied sinusoidally about $\psi_{CW}$ with an amplitude of 2 deg and a frequency of 0.8 Hz. The selected scaled amplitude and frequency were within the predicted response characteristics of the FF-1088. All runs were conducted in calm water; therefore, the response of the hull to the seaway was simulated but the seaway was not simulated.

Crash ahead runs were conducted by using the still-in-the-water point as the initial condition. Trim and displacement were fixed at the values corresponding to the self-propulsion condition (Condition 1 of Table 5). Two types of runs were conducted: (1) quasi-steady runs in which all quantities including model speed V, rotational speed n, and propeller pitch P were held constant ($\dot{V}=\dot{n}=\dot{P}=0$) and (2) unsteady runs in which V was varied with time but n and P were held constant ($\dot{V}>0$, $\dot{n}=\dot{P}=0$). For the quasi-steady simulation,

runs were conducted at five different combinations of V, n, and P. The conditions for each run represent the conditions at one instant of time during a "true" crash ahead in which V, n, and P vary with time. Thus, one "true" crash ahead run is represented by five steady runs which do not simulate the time rate of change of V, n, and P. For the unsteady simulation, runs were conducted at the same five combinations of fixed n and P as used for the quaso-steady simulation, and V was varied with time (the same variation was used for each run) representing an acceleration of the model hull (Figure 8). For each of these runs, data are of interest only near that value of V which occurred concurrently with the fixed values of n and P during the "true" crash ahead ($\dot{V}\neq 0$, $\dot{n}\neq 0$, $\dot{P}\neq 0$). Thus, one "true" crash ahead run is represented by five runs which simulate the proper time rate of change of V but not the proper time rate of change of n and P. The quasi-steady and unsteady crash ahead simulations were for the same conditions, the only difference being that $\dot{V}=0$ for the quasi-steady simulation whereas $\dot{V}>0$ for the unsteady simulation. In general, P varied with time during a "true" crash ahead run; however, for the crash ahead run under simulation here, P was constant throughout the portion of the run simulated.

Crash astern runs were conducted by using the self-propulsion condition (Condition 1 in Table 5) as the initial condition. Both quasi-steady ($\dot{V}=\dot{n}=\dot{P}=0$) and unsteady ($\dot{V}<0$, $\dot{n}=P=0$) runs were conducted (Table 5 and Figure 8) to simulate one "true" crash astern ($\dot{V}\neq 0$, $\dot{n}\neq 0$, $\dot{P}\neq 0$) condition by procedures similar to those described for the crash ahead condition. Unlike the crash ahead simulation, the value of propeller pitch P varied through the portion of "true" crash astern under simulation.

For the unsteady crash ahead and crash astern runs, the carriage speed was manually varied with time in a carefully controlled manner. This was achieved with the aid of an inked pen on a two-dimensional Cartesian plotter. In one direction, the pen was controlled so that it moved linearly with time, and in the orthogonal direction, it was controlled so that it varied with the instantaneous carriage speed. When a crash ahead or crash astern maneuver was to be executed, the switch moving the pen with time was turned on and the carriage operator manually varied the carriage speed so that the inked pen followed a prescribed velocity versus time curve.

As discussed earlier, each of the three load-sensing flexures measured only two components of blade loading. Therefore, each of the experimental conditions described in Table 5 was run with each of the three blade loading flexures.

The blade pitch was set by using a template. In order to change either the blade pitch or the flexure, the propeller had to be removed from the drive system.

Supplemental experiments were conducted to assess the influence of the downstream dynamometer boat on the flow in the propeller plane. These supplemental experiments consisted of (1) wake surveys in the propeller plane at the self-propulsion point (Condition 1 in Table 5) with and without the downstream body, (2) measurement of time-average thrust and torque using a transmission dynamometer in the model hull near the self-propulsion point with and without the downstream body, and (3) measurement of the six components of blade loading at P/D=1.06 over a range of advance coefficient J with the downstream body at zero shaft angle but without the upstream ship model. The supplemental experiment on wake surveys yielded a direct measure of the change in volume mean velocity through the propeller disk attributable to the downstream body. The change in effective velocity through the propeller disk was deduced from Supplemental Experiments (2) and (3) by thrust and torque identity between similar conditions with and without the downstream body.

Some air spin experiments were conducted with the $F_z$, $M_z$ flexure over a range of pitch settings in order (1) to isolate the centrifugal loading in the $F_z$ and $M_z$ directions and (2) to evaluate the reliability of the results with this flexure by correlation with analytically calculated centrifugal loading.

## DATA ACQUISITION AND ANALYSIS

Data were collected, stored, and analyzed on-line by using a Model 70 Interdata Digital Computer. A special-purpose computer program was written with options for analyzing each of the three basic types of runs: (1) steady ahead, (2) dynamic hull pitching, and (3) unsteady crash-ahead or crash-astern. These types of runs have already been discussed in detail.

The program allowed the propeller blade force and moment data to be sampled and stored on magnetic tape as a function of shaft position. Sampling was triggered by external pulses generated by a digital encoder mounted on the propeller shaft, as discussed earlier. Pulses were generated as a function of shaft angular position; hence, the sampling of blade force and moment data was related to shaft position. There were two outputs from the shaft encoder; a single pulse per revolution and multipulse (90 pulses per revolution for the current experiments).

When the experimental condition was achieved, the computer operator initiated the data collection cycle. The program "waited" for the occurrence of the first following pulse of the 90 pulses; data were then sampled for all channels through an analog-to-digital converter and stored in computer memory. This process was repeated for 180 pulses, or two shaft revolutions. At the same time, the program "read" two frequency counters into core memory which measured model velocity V and propeller rotational speed n. V and n were measured by counting the pulses from geared wheels attached to the towing carriage drive system and to the propeller shaft, respectively. The V and n were averaged over two shaft revolutions. Thus, there was an average V and n corresponding to each pair of two consecutive revolutions.

After two revolutions of data were sampled and stored in core memory, the data were transmitted from core to a nine-track digital tape recorder. The transfer time was small and no pulses were missed during the transfer. The data collect cycle proceeded continuously until the operator disengaged the computer. The sampling procedure was the same for all types of experimental conditions, and at the completion of an experimental run, all data were stored on magnetic tape and were available for analysis immediately or at any later time. For that analysis, the computer operator selected the appropriate option of the program depending on the type of run, i.e., (1) steady ahead, (2) dynamic hull pitching, or (3) unsteady crash ahead or crash astern.

The appropriate calibration factors were stored in the computer and considered in the analysis. However, since only two of the six components of blade loading were measured during a given run, the interactions between

the various loading components could not be considered during the on-line analysis. The interactions were taken into account later after measurements were completed with all three flexures for a given condition.

For the steady ahead condition, blade force and moment data at each 4-deg increment of blade angular position were averaged over the number of cycles recorded (usually over more than 200 cycles). Spurious data not related to shaft position are averaged out by this method. A harmonic analysis was then performed on the average wave forms of the blade loading components. This gave the amplitude and phase of the first 16 harmonics.

For the dynamic pitch runs, the hull pitch angle $\psi$ varied sinusoidally with a frequency of 0.8 Hz. A position potentiometer translated bow vertical displacement into hull pitch angle, and thus was read into the computer in the same manner as blade loading components. During dynamic pitching, the shaft rotated independent of the pitch oscillator. During a single propeller revolution, 90 pitch positions were measured. Thus, to correlate pitch angle position and revolution, an average pitch must be taken over each revolution.

The 16 dynamic pitch angle positions selected for analysis were characterized by pitch angle $\psi$ and the sign of the time rate of change of pitch angle $\dot{\psi}$. The computer calculated an average $\psi$ and sign of $\dot{\psi}$ corresponding to each propeller revolution. Based on these calculated average values of $\psi$ and sign of $\dot{\psi}$, each propeller revolution was either placed in a suitable hull pitch angle category or discarded if its average $\psi$ fell outside the tolerance band of all the 16 specified values of $\psi$. Several passes down the towing tank were required in order to obtain a sufficient number of samples. After all the data had been sorted based on ($\psi$, sign of $\dot{\psi}$), and tolerance, the cycles for each combination of ($\psi$, sign of $\dot{\psi}$) were analyzed in exactly the same manner as the data for the steady ahead condition at fixed $\psi$.

For unsteady crash ahead and crash astern runs, the model speed V varied with time t. During a crash ahead or crash astern run, data, including a measure of V, were sampled and stored in the same manner as for the steady ahead runs.

Five values of V were specified for analysis. For each crash ahead or crash astern run and for each specified V, the computer selected the propeller revolution which had the average value of measured V nearest to the specified V. However, because only one revolution at each specified velocity was obtained for a single crash ahead or crash astern run, each such run was repeated from three to five times. This yielded three to five revolutions at each specified velocity. All the cycles for each specified V were then analyzed in exactly the same manner as the data for the steady ahead conditions.

Thus the on-line analysis system yielded average wave forms and harmonic analysis of the average wave forms for steady ahead conditions, for specified conditions of ($\psi$, sign of $\dot{\psi}$) during the dynamic pitch cycle, and for specified velocities V during the crash ahead or crash astern operation. However, these on-line results are preliminary because:

1. They do not consider the interactions between the various load components. These interactions were determined during the static calibration of the flexures.

2. They include the complete measured signals with no filtering. As discussed in the section on experimental results, some extraneous signals near the natural frequency of the flexure being used appeared to be superimposed on the signals generated by blade loading.

Final analyses were conducted after completion of the experiment to consider interactions and to filter out extraneous high frequency noise. These analyses were conducted by using a CDC 6700 Computer. For each condition, the average wave form for each of the six loading components was multiplied by the inverse of the calibration matrix given in Table 2.

$$\begin{bmatrix} F_{xA} \\ F_{yA} \\ F_{zA} \\ \\ M_{xA} \\ M_{yA} \\ M_{zA} \end{bmatrix} = \begin{bmatrix} F_{xI} \\ F_{yI} \\ F_{zI} \\ \\ M_{xI} \\ M_{yI} \\ M_{zI} \end{bmatrix} \qquad \begin{bmatrix} C_{i,j} \end{bmatrix}^{-1}$$

This matrix multiplication was performed at 0.07-rad (4-deg) increments of blade angular position. A harmonic analysis was then performed on the signals corrected for the interactions. Based on a harmonic analysis of the wake in the propeller plane, it was judged that there should be no significant loading of hydrodynamic origin at frequencies above ten times shaft frequency. Therefore, the wave form was then reconstructed by using the first ten harmonics of shaft frequency, except for the spindle torque $M_z$ which used the first five harmonics of shaft frequency. This reconstruction using only the first ten (or five) harmonics had the same effect as filtering out all frequencies above ten (or five) times shaft frequency.

From the known values of $F_x$, $F_y$, $M_x$ and $M_y$, the values of the bending moment normal to the nose-tail line at the blade root (the 0.289 radius) and at the 0.4 radius were calculated. For the calculation about the 0.4 radius, it was assumed that the loading between the blade root and the 0.4 radius accounted for 3 percent of the moments about the shaft centerline. These bending moments were calculated at every 4 deg of blade angular position, harmonically analyzed, and the wave form reconstructed by using the first 10 harmonics of blade angular position in exactly the same manner as was used for the other components of blade loading.

Plots of the data were generated by the CDC computer system using a Calcomp Plotter.

ACCURACY

During experiments for steady ahead operation $\dot{V}=0$, the model speed V and rotational speed n could be controlled to within accuracies of $\pm 0.005$ M/sec and $+0.01$ rev/sec, respectively. For the unsteady crash ahead and crash astern maneuvers ($\dot{V}\neq 0$), the average of the three to five values of V and n during the unsteady runs for which data are presented was generally within $\pm 0.01$ M/sec and $\pm 0.05$ rev/sec, respectively, of the target values.

For runs with fixed hull pitch angle $\psi$, ($\dot{\psi}=0$), the value of $\psi$ could be controlled to within 0.005 deg. For dynamic pitch runs $\dot{\psi}\neq 0$, the selection of a propeller revolution at a specified $\psi$ necessitated a tolerance of 0.1 deg to $\psi$; however, the average value of $\psi$ during the unsteady runs for which data are presented was generally within 0.02 deg of the target $\psi$.

The forces $F_x$ and $F_y$ and moments $M_x$, $M_y$, and $M_z$ were accurate to within (plus or minus) the following variations:

| | $F$ [N] | $F_{MAX}$ [N] | $\overline{M}$ [N-m] | $M_{MAX}$ [N-m] |
|---|---|---|---|---|
| Steady ahead $\dot{V}=0, \dot{\psi}=0$ | 1.0 | 1.5 | 0.04 | 0.06 |
| Dynamic pitch $\dot{V}=0, \dot{\psi}\neq 0$ | 1.5 | 2.0 | 0.06 | 0.08 |
| Crash ahead $\dot{V}>0, \dot{\psi}=0$ | 2.0 | 2.5 | 0.08 | 0.10 |
| Crash astern $\dot{V}<0, \dot{\psi}=0$ | 2.0 | 2.5 | 0.08 | 0.10 |

The values are somewhat more accurate for the steady ahead runs than for the time-dependent runs, because the experimental conditions could be controlled more precisely for the steady runs and the measured forces and moments were averaged over many more revolutions of the propeller. The time-average values per revolution (based on 90 samples

per revolution) are slightly more accurate than the maximum values (based on one sample per revolution) which took into account the variation with blade angular position. Further, the peak values may have been slightly influenced by the dynamic response of the flexures, as discussed in the section on calibration.

The measured values of $F_z$ were substantially less accurate than the other components of blade loading and these results are not presented as explained in the following section.

## EXPERIMENTAL RESULTS

### CENTRIFUGAL LOADS

The results of the air-spin experiments with the $F_z$, $M_z$ flexure were compared with calculated values of $F_z$ and $M_z$ by using the method of Boswell.[23] Previous measurements of spindle torque by Boswell et al.[24] and by Hawdon et al.[4] have correlated well with values calculated by this procedure. Figures 9 and 10 show the correlation for $M_z$ and $F_z$, respectively. $M_z$ correlated fairly well except at P/D=-0.67, but the correlation for $F_z$ was rather poor. This poor correlation for $F_z$, combined with the large interaction effect of $M_z$ on $F_z$ and the low natural frequency of this flexure, casts doubt on the reliability of the measured values of $F_z$. In addition, the experimental values of $F_z$ in water were rather inconsistent. Since $F_z$ arises primarily from centrifugal loading, no experimental results are presented for $F_z$ in water.

### INFLUENCE OF DYNAMOMETER BOAT

The results of the wake surveys with and without the downstream body (dynamometer boat) are presented in Figures 11 and 12, and in Appendix A.

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[23] Boswell, R.J., "A Method of Calculating the Spindle Torque of a Controllable-Pitch Propeller at Design Conditions," David Taylor Model Basin Report 1529 (Aug 1961).

[24] Boswell, R.J. et al., "Experimental Spindle Torque and Open-Water Performance of Two Skewed Controllable-Pitch Propellers," DTNSRDC Report 4753 (Dec 1975).

These data indicate that the downstream body had only a small effect on the circumferential and radial variation in the flow and only a small effect on the harmonic content of the flow. However, they also indicate that the downstream body reduced the volume mean velocity through the propeller disk by approximately 12 percent. This reduction in mean flow due to the downstream body was confirmed by values deducted from thrust and torque identity between model experimental values with and without the downstream body in place. The values of reduction in effective velocity deduced in this manner are as follows:

1. A reduction of 10 to 14 percent from measurement of mean thrust and torque using a transmission dynamometer inside the model hull at the self-propulsion point (Condition 1 in Table 5) with and without the downstream body in place.

2. A reduction of 10 to 14 percent from mean thrust and torque deduced from the blade loading experiments at the self-propulsion point (condition 1 in Table 5) and thrust and torque measured during a previous self-propulsion model experiment.

3. A reduction of 9 to 12 percent from mean thrust and torque coefficients deduced from blade loading experiments at P/D=1.06 over a range of advance coefficient J with the downstream body at zero shaft angle with no upstream hull, and thrust and torque coefficient determined by previous open-water experiments (Figure 13).

Based on these results it was concluded that the downstream body reduced the mean velocity into the propeller by 12 percent at the self-propulsion condition. It was assumed that this 12-percent reduction occurred at all conditions at which experiments were conducted. Therefore, the time-average value per revolution of each loading component was corrected for the effect of the downstream body as follows: From the measured blade thrust ($\bar{F}_x$) and blade torque ($\bar{M}_x$), an effective advance coefficient J based on thrust identity ($J_T$) and torque identity ($J_Q$) was deduced from the open-water data (Figure 13). These

values were multiplied by (1/0.88) to obtain corrected values of $J_T$ and $J_Q$, i.e., without the downstream body. The corrected values of $\overline{F}_x$ and $\overline{M}_x$ were obtained from the open-water data at the corrected advance coefficients $J_T$ and $J_Q$, respectively. It is assumed that the downstream body did not affect the radial center of thrust $\overline{F}_x$ and tangential force $\overline{F}_y$. Therefore,

$$\overline{M}_y \text{ corrected} = (\overline{F}_x \text{ corrected}/\overline{F}_x \text{ measured})\ \overline{M}_y \text{ measured}$$

$$\overline{F}_y \text{ corrected} = (\overline{M}_x \text{ corrected}/\overline{M}_x \text{ measured})\ \overline{F}_y \text{ measured}$$

The spindle torque ($\overline{M}_z$) was corrected by the same procedure as used for $\overline{F}_x$ and $\overline{M}_x$, except that the centrifugal and hydrodynamic components of spindle torque were separated so that the correction was applied only to the hydrodynamic component. Centrifugal spindle torque was determined by air spin experiments, as discussed previously. The open-water hydrodynamic spindle torque data used for these corrections were those reported by Denny and Stevens[25] on DTNSRDC Model Propeller 4496. These data were presented over a range of pitch ratio P/D and advance coefficient J. The geometry of Propeller 4496 is nearly identical to that of the propeller on the FF-1088. The only differences between the two propeller designs are the chordwise distributions of camber and thickness, the radial distributions of camber and pitch, and the chord length and skewback between the 90-percent radius and the tip; see Tables 2 and 8. It was judged that these two propellers would have approximately the same spindle torque at the same advance coefficients and pitch ratios.

In addition to the correction to hydrodynamic spindle torque for mean advance coefficient, the centrifugal spindle torque was corrected for the difference in density between the aluminum model propeller and a nickel-aluminum-bronze full-scale propeller. Since centrifugal spindle

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[25] Denny, S.B. and H.G. Stephens, "Blade Spindle Moment on Controllable-Pitch Propellers," NSRDC Departmental Report SPD-011-14 (Jul 1974).

TABLE 8 - CHARACTERISTICS OF PROPELLER CORRESPONDING TO DTNSRDC MODEL PROPELLER 4496

Diameter: 4.572 m (15.0 ft)
Rotation: Right hand
Number of Blades: 5
Maximum Rotational Speed (Rated): 25.13 rad/sec (240 rev/min)
Full Power (Rated): 26,100 kW (35,000 hp)
Speed at Full Power: 14.5 m/sec (28.1 knots)
Expanded Area Ratio: 0.83
Blade Thickness Fraction: 0.059
Section Meanline: NACA a=0.8[1]
Section Thickness Distribution: NACA 66 (Modified)[1]
Design Advance Coefficient J: 0.767
Design Advance Angle $\beta^*$: 0.3356 rad (19.23 deg)
Design Thrust Loading Coefficient, $C_{Th}$: 0.706

| x | c/D | (P/D)[1] | S/D[2] | $Z_R/D$ | t/D | $(f_M/c)$[1] |
|---|---|---|---|---|---|---|
| 0.30 | 0.1853 | 0.998 | 0.0185 | 0 | 0.0437 | 0.0189 |
| 0.40 | 0.2482 | 1.070 | 0.0248 | 0 | 0.0328 | 0.0197 |
| 0.50 | 0.3111 | 1.104 | 0.0311 | 0 | 0.0250 | 0.0190 |
| 0.60 | 0.3740 | 1.102 | 0.0374 | 0 | 0.0187 | 0.0168 |
| 0.70 | 0.4369 | 1.078 | 0.0437 | 0 | 0.0131 | 0.0128 |
| 0.80 | 0.4760 | 1.035 | 0.0476 | 0 | 0.0089 | 0.0105 |
| 0.90 | 0.4600 | 0.979 | 0.0460 | 0 | 0.0061 | 0.0098 |
| 0.95 | 0.4228[1] | 0.944 | 0.0423[1] | 0 | 0.0051 | 0.0099 |
| 1.00 | 0.1500[1] | 0.906 | 0.0150[1] | 0 | 0.0040 | 0.0100 |

[1]Different than for propeller on FF-1088.

[2]The spindle axis is the propeller reference line and passes through the 40-percent chord for all radii.

torque is directly proportional to the density of the material, this correction factor is simply $(\rho_{NI\text{-}AL\text{-}BR})/(\rho_{AL})$. The time-average spindle torque per revolution presented in this report is the sum of the hydrodynamic spindle torque corrected for the downstream body and the centrifugal spindle torque which corresponds to nickel-aluminum-bronze propeller blades.

No correction for the effect of the downstream dynamometer boat was made to the measured circumferential variation of the loading components. Calculations made by the methods of Tsakonas et al.[20] and McCarthy[21] indicated that the influence of the downstream body may reduce the peak-to-peak circumferential variation of the loads by approximately 10 percent of the uncorrected unsteady loading. However, these methods did not agree well with the experimental results, as discussed in the section on correlation with full-scale data and theory.

## STEADY AHEAD OPERATION

For operation near the self-propulsion point (Condition 1 in Table 5), Figure 14 presents the variation of the various components of blade loading with blade angular position and Figure 15 presents the amplitude of the first 25 harmonics of the various components of blade loading. For the harmonic amplitude and phases, the variation of $F_x$ with blade angular position is represented as:

$$F_x(\theta)=\overline{F}_x + \sum_{n=1}^{N} (F_x)_n \cos\,(n\theta - (\phi_{Fx})_n)$$

where $\overline{F}_x$ = circumferential average value of $F_x$

$(F_x)_n$ = amplitude of the nth harmonic of $F_x$

$\theta$ = angular position in disk, positive clockwise from the vertical upward looking upstream

The reference line on the blade is the radial line through midchord at the hub radius. $(\phi_{Fx})_n$ = phase angle of nth harmonic of $F_x$. A similar representation is used for all components of blade loading.

Based on the dynamic calibration, as discussed in the section on calibration, it was judged that for all loading components the data are valid for the first 10 harmonics, except $M_z$ which was judged to be valid for the first 5 harmonics. Therefore, all data and analysis except Figures 14 and 15 are based on reconstructed signals using 5 harmonics for $M_z$ and 10 harmonics for other loading components. The circles shown on Figure 14 indicate unfiltered values determined from the experiment; each represents the average value at the indicated blade angular position for over 200 propeller revolutions. The lines are the signals reconstructed from the first 10 harmonics. Figure 14 indicates that the variation of the signal with blade angular position is adequately represented by the number of harmonics retained. Figures 14 and 15 show that there was a resonance in the $F_x$ signal near the fourteenth harmonic. This corresponded to (14) x (17.65 Hz) = 247 Hz which is near the natural frequency of this flexure in water, as discussed in the section on calibration.

The variation of all measured loading components with blade angular position for Condition 1 in Table 5 is shown in Figure 16 and in Appendix B. Figure 17 and Appendix B present the amplitude and phases of the harmonics of these loading components. The values for each loading component are presented as decimal fractions of the time-average value of the corresponding loading component. These average values are presented in Table 7. These data indicate that the extreme values for all loading components occurred near $\theta$=90 and 270 deg and that the variation was predominantly a once-per-revolution variation. This suggests that the tangential component of the wake is the primary driving force.

For $F_x$ and $M_y$, the largest measured force and moment components, the maximum values were approximately 1.38 times the time-average values; the range of values with blade angular position, i.e., the maximum value minus the minimum value (double amplitude) was approximately 0.80 times the time-average value. For $F_y$ and $M_x$, the maximum values and range of values with blade angular position were somewhat smaller fractions of

the respective time-average values. For $M_z$, the maximum value and range of values with blade angular position were much greater fractions of its time average. This large fractional variation in $M_z$ occurs because $M_z$ was very small at the self-propulsion point (the blade is designed with its area balanced forward and aft the spindle axis at the self-propulsion point).

HULL PITCH

Figure 18 presents the variation of the peak values and time-average values per revolution of the various components of blade loading with hull pitch angle $\Psi$ for both quasi-steady simulation (time rate of change of hull pitch angle $\dot{\Psi}=0$) and unsteady simulation ($\dot{\Psi}\neq 0$). These data show that except for spindle torque $M_z$, the time-average value per revolution of each loading component remains within 4 percent of its value corresponding to self-propulsion in calm water. This holds true for both quasi-steady simulation ($\dot{\Psi}=0$) and unsteady simulation ($\dot{\Psi}\neq 0$). The time-average spindle torque per revolution $\overline{M}_z$ varied as much as 20 percent from its calm-water value ($\Psi=\Psi_{CW}$). This large percentage variation occurred because $\overline{M}_z$ was very small at $\Psi=\Psi_{CW}$ as discussed earlier.

Data at each specified value of hull pitch angle $\Psi$ for the quasi-steady runs were recorded and averaged for a minimum of 200 propeller revolutions whereas data for the dynamic pitching runs at each specified $\Psi$ represented an average of from 10 to 35 propeller revolutions. As discussed earlier, the selection of a propeller revolution at a specified $\Psi$ during the dynamic pitch runs necessitated a tolerance of 0.1 deg to $\Psi$; however, the average value of $\Psi$ during unsteady runs for which data are presented was generally within 0.02 deg of the target $\Psi$. Therefore, the differences between the results for the quasi-steady and unsteady simulations, including the time-average values per revolution, was significantly larger than any errors which may have arisen from inaccuracies in setting the experimental conditions.

For quasi-steady simulation, the absolute value of the time-average value per revolution of all loading components, except spindle torque $M_z$, decreased slightly for stern down and increased slightly for stern up. This suggests that the effective speed of advance of the propeller increases slightly for the stern-down condition and decreases slightly for the stern-up condition. This appears reasonable since for stern-up the propeller tends to be further into the boundary layer of the hull.

For dynamic simulation, the absolute value of the time-average value per revolution of all loading components, except spindle torque $M_z$, increased slightly for stern-down and decreased slightly for stern-up. Comparison of the time or location during the cycle of hull pitch angle $\psi$ at which the largest time average loads occurred for quasi-steady and unsteady simulations shows a lag of approximately 0.65 sec, or 0.5 cycles, between the motion of the hull and the flow into the propeller resulting from this motion. This time lag is the period required for a particle of fluid to move approximately one-third the length of the hull.

There was a significant difference between the peak values for the quasi-steady simulation and the unsteady simulation. For the quasi-steady simulation, the variation of the peak values with hull pitch angle $\psi$ followed the same trend as the variation of time-average values per revolution. These quasi-steady results indicated that for $\psi-\psi_{CW}$ up to 2 deg, the maximum increase in the peak value of any loading component above the corresponding value for $\psi=\psi_{CW}$ was 4 percent. For the dynamic simulation, however, the maximum value of the peak loads increased as much as 20 percent above the corresponding value for steady ahead at a fixed hull pitch $\psi=\psi_{CW}$.

The dynamic simulation exhibited a dramatically different trend of peak load with $\psi$ than indicated by the quasi-steady simulation. For the dynamic simulation, the largest value of the peak loading occurred near $\psi=\psi_{CW}$ as the hull passed from the stern-up to the

stern-down position of the cycle, and the smallest value of peak loading occurred near $\psi=\psi_{CW}$ as the hull passed from the stern-down to the stern-up position of the cycle.

This difference in the unsteady loading between the quasi-steady and unsteady simulations is apparently due to an additional relative velocity component arising from the motion of the hull during dynamic pitching. As the hull passes through $\psi=\psi_{CW}$, the vertical velocity of the hull (and propeller) is a maximum. As the hull goes from stern-up to stern-down through $\psi=\psi_{CW}$, the upward velocity component relative to the propeller in the plane of the propeller tends to increase above the values at fixed hull pitch at $\psi=\psi_{CW}$. This tends to increase the amplitude of the first harmonic of the tangential velocity, and thereby increase the unsteady loading (and increase the peak loading). The maximum vertical velocity of the propeller for sinusoidal pitching with $(\psi_{MAX}-\psi_{CW})=$ 2.0 deg and frequency = 0.8 Hz is approximately 0.086 m/sec. This is equivalent to an additional tangential velocity ratio $(V_t/V)$ of 0.025. For $\psi$ fixed at $\psi=\psi_{CW}$, $((V_t)_1/V) = 0.155$ (see Figure 12 and Appendix A). Therefore

$$\frac{((V_t)_1/V)_{MAX,\dot{\psi}\neq 0}}{((V_t)_1/V)_{\dot{\psi}=0,\psi=\psi_{CW}}} = \frac{0.155 + 0.025}{0.155} = 1.16$$

This maximum occurs at the same position during the dynamic pitch cycle as the maximum measured loads. The measured increase in unsteady loads arising from dynamic pitching was somewhat larger than this calculated increase in tangential velocity, for example:

$$\frac{(F_{x_{MAX}} - \bar{F}_x)_{\dot{\psi}\neq 0,\ \psi=\psi_{CW}}}{(F_{x_{MAX}} - \bar{F}_x)_{\dot{\psi}=0,\ \psi=\psi_{CW}}} = \frac{0.57}{0.38} = 1.50$$

However, on the basis of two-dimensional quasi-steady theory, the increase unsteady loading should be approximately proportional to the increase in tangential velocity.

The unsteady loading is important from consideration of fatigue of the propeller blades and hub mechanism. Since a ship may operate for an extended period in a seaway, the effect of the ship motions, such as dynamic hull pitching, on unsteady blade loads is significant. The difference between the peak load and the time-average load per revolution is a measure of the unsteady loading. With this difference as a measure of the unsteady loading, the quasi-steady simulation indicates that for hull pitch angles $\psi$ up to 2 deg, each unsteady loading component increases by not more than 5 percent above its corresponding value for $\psi=\psi_{CW}$. By contrast, the dynamic simulation showed that unsteady loading components are increased by at least 50 percent above their corresponding values for $\psi=\psi_{CW}$. This indicates that the quasi-steady simulation is completely inadequate for estimating the effect of the seaway on unsteady loading. This also shows that the effect of the ship motions can dramatically increase the unsteady loading on the blades. Therefore, the effect of the ship motions due to operation in a seaway should be considered in any analysis of blade loading and in any fatigue analysis of the propeller blades or hub mechanism.

## CRASH AHEAD AND CRASH ASTERN MANEUVERS

Figures 19 and 20 and Appendix B present the variation of components of blade loading with blade angular position along with the corresponding harmonic amplitudes and phases for the quasi-steady simulated crash-ahead

condition $\dot{V}=\dot{P}=\dot{n}=0$. Figures 21 and 22 and Appendix B present similar results for the quasi-steady simulated crash-astern conditions $\dot{V}=\dot{n}=\dot{P}=0$. The values for each loading component are presented as decimal fractions of the time-average values of the corresponding loading component at the self-propulsion condition (Condition 1 of Table 5). These time-average values are presented in Table 7.

Figure 23 presents the Taylor wake fraction based on thrust $1-w_T$ and the Taylor wake fraction based on torque $1-w_Q$ as derived from the measured values of $\overline{F}_x$ and $\overline{M}_x$ and the open-water characteristics of the propeller (Figure 13). These data indicate a substantial variation in $1-w_T$ and $1-w_Q$ during the simulated crash ahead and crash astern maneuvers. During the crash-ahead maneuver, $1-w_T$ and $1-w_Q$ were respectively larger and smaller than their values near the self-propulsion point. For the crash astern maneuver, both $1-w_T$ and $1-w_Q$ initially decreased with decreasing speed and then increased dramatically as speed was further reduced. At the lowest experimental speed during simulated crash astern (V=0.17 m/sec), both $1-w_T$ and $1-w_Q$ were greater than 2.5.

These indicated values of $1-w_T$ and $1-w_Q$ are subject to significant inaccuracies in the initial portion of the simulated crash forward and in the final portion of the crash astern (dashed lines in Figure 23). These inaccuracies arise because the thrust and torque, which are measured on only one blade, are small in these regions, ($\overline{F}_x \leq 15N, \overline{M}_x \leq 0.5N\text{-m}$).

Figure 19 shows that for almost all measured loading components, the maximum time-average values per revolution and the peak values, including variation with blade angular position, occurred at the third experimental condition (V=1.46 m/sec, n=11.19 rev/sec, P/D=1.39) during the crash-ahead maneuver. For $M_y$, which is the largest moment component, the peak value and the maximum time-average value per revolution were respectively 1.51 and 1.35 times the time-average value at the self-propulsion point. For the other loading components, except spindle torque $M_z$, the peak

value and the maximum time-average value per revolution were respectively in the range 1.35--1.60 and 1.20--1.45 times the corresponding time-average value at the self-propulsion point. For spindle torque $M_z$, the peak value and the maximum time-average value per revolution were respectively 5.6 and 4.8 times the time-average value at the self-propulsion point. These represent large increases for $M_z$ because $\overline{M}_z$ was quite small at the self-propulsion point, as already discussed.

Results for the crash astern maneuver show that, except for spindle torque, the maximum time-average load per revolution and the peak load, including variation with blade angular position, occurred at the initial (steady ahead) condition.

Higher loads than those shown in Figures 19 and 21 could, of course, be developed during crash ahead or crash astern maneuvers, depending on values of $\dot{V}$, $\dot{n}$, and $\dot{P}$.

For all loading components, the variation with blade angular position tended to be dominated by the first harmonic for all conditions throughout the simulated crash ahead and crash astern maneuvers. For all conditions at which there was significant variation in loading with blade angular position, the maximum and minimum values occurred near $\theta$=90 or 270 deg. This suggests that the variation in loading with blade angular position is produced primarily by the circumferential variation of the tangential velocity in the propeller plane (see Figures 11 and 12). For the crash ahead simulation, in which pitch P was constant throughout, the angular variation of each loading component retained basically the same shape independent of speed and advance coefficient. By contrast, for the crash astern simulation, in which P/D changed from +1.06 to -0.67 for the different simulated conditions, the circumferential variation of each loading component changed shape substantially for different simulated combinations of speed, advance coefficient, and pitch ratio.

For both crash ahead and crash astern simulations, there was a dramatic reduction in the circumferential variation of all measured

loading components with decreasing speed V and decreasing rotational speed n. Previous data have shown that for a given propeller in a given flow field, the circumferential variation in the loading varies approximately as the product of ship speed V and rotational speed n; see Wereldsma.[26] Figure 24 presents some "typical" results in a form which allows evaluation of how closely the measured unsteady loading varies with nV. The ordinate is $(F_x)_1 \sin \phi$ which is the portion of the first harmonic in phase with the tangential velocity. This measure of the unsteady loading was selected because it may be positive or negative depending on $\phi$. The abscissa is nV sin $\Phi_{0.7}$. The term sin $\Phi_{0.7}$ is intended to correct for the difference in pitch for the various runs, since the tangential component of the first harmonic of the wake $(V_t)_1$ is the primary forcing function, and the component of $(V_t)_1$ normal to the blade is $(V_t)_1 \sin \Phi_{0.7}$; see Wereldsma.[26]

The data shown in Figure 24 indicate that the unsteady loading $(F_x)_1 \sin \phi$ was approximately proportional to nV sin $\Phi_{0.7}$. The results for the crash ahead simulation, with P/D=1.39, were consistently somewhat higher than those for the crash astern simulation, and they followed a linear variation with nV sin $\Phi_{0.7}$ somewhat more closely than did the results for the crash astern simulation.

The reason for the systematic difference between the crash ahead data and crash astern data in Figure 24 is not clear; however, it may have resulted from one or more of the following:

1. The difference in the time-average loading between the crash ahead and crash astern conditions. Thrust loading coefficient $\bar{C}_{Th}$ is a measure of this time-average loading. For crash ahead simulation, the algebraic value of $\bar{C}_{Th}$ is much larger than it is for crash astern. This tends to increase the axial induced velocities and increase the spacing of the downstream vortex sheets for a given value of nV sin $\Phi_{0.7}$. This would tend to reduce the influence of the shed vorticity and thereby increase the net unsteady loading.

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[26] Wereldsma, T., "Tendencies of Marine Propeller Shaft Excitations," International Shipbuilding Progress, Vol. 19, No. 218 (Oct 1972).

2. The effect of the action of the propeller on the wake pattern in the propeller disk. During a portion of the crash astern maneuver, the propeller generates negative thrust so that the time-average induced velocity is upstream. This may interact with the flow over the hull and thereby influence the circumferential mean and circumferential variation of the flow pattern. As discussed previously, the time-average loading indicated that $1-w_T$ and $1-w_Q$ varied substantially over the simulated crash ahead and crash astern maneuvers (see Figure 23). However, if $V(1-w_T)$ rather than V is used as the reference velocity, the trends shown in Figure 24 would not change substantially.

3. Failure of the factor $\sin \Phi_{0.7}$ to properly account for the difference in propeller pitch over the range of $(P/D)_{0.7}$ from +1.39 to -0.67. As nominal pitch is changed over this range, the radial distribution of pitch changes dramatically.

4. Experimental accuracy. For $nV \sin \Phi_{0.7} < 2.0$ m/sec$^2$, the measured unsteady loading is quite small; therefore, these results are not nearly as accurate as the results for higher values of $nV \sin \Phi_{0.7}$.

The trends shown in Figure 24 for $(F_x)_1$ are typical of the trends of all measured loading components when plotted versus nV times the appropriate function of pitch as presented by Wereldsma.[26] Even though there is some scatter, the data follow the nV law quite well considering the wide range of advance coefficient J and pitch ratio P/D covered.

Figure 25 presents the variation of the time-average values per revolution and peak values of the various components of blade loading for both quasi-steady simulated crash ahead ($\dot{V}=\dot{n}=\dot{P}=0$) and unsteady simulated crash ahead ($\dot{V}>0$, $\dot{n}=\dot{P}=0$). Figure 26 gives similar data for quasi-steady and unsteady simulated crash astern runs.

There was only a small variation in the measured loading components between the quasi-steady simulated crash ahead and the unsteady simulated crash ahead. Except for spindle torque, the largest variation between the results from two types of simulation expressed on a decimal fraction

of the corresponding time-average value at the self-propulsion point was 0.05 for the peak values and 0.03 for the time-average value per revolution. For most cases, the variation was much smaller. In fact, the variation in the results between the two types of simulation appeared to be almost random. This suggests that these deviations are some measure of the experimental accuracy and do not represent any systematic trends arising from the difference in $\dot{V}$ between the two types of simulation.

For the crash astern runs, the variation in loads between the quasi-steady simulation and the unsteady simulation was not great, but it was somewhat larger than the variation for the crash ahead simulations. Except for spindle torque, the largest variation between the results for the two types of simulation was approximately 0.20 times the time-average steady-ahead value for the peak load and 0.15 times the time-average steady-ahead value for the mean load. For most cases, the variation was much smaller. The magnitude of most loading components was larger for the unsteady simulation for time $t \geq 13.6$ sec ($V \leq 1.67$ m/sec) and larger for the quasi-steady simulation for t=9.05 sec (V=2.57 m/sec).

Data for the quasi-steady simulation were recorded and averaged for a minimum of 200 propeller revolutions whereas data presented for the unsteady runs represent an average of only three revolutions for crash ahead simulation and five revolutions for crash astern simulation. Further, the steady experimental conditions which were set during the quasi-steady simulation allow the values of V and n to be controlled more precisely than during the unsteady runs; however, the average of the three to five values of V and n during the unsteady runs for which data are presented was generally within 1 percent of the target values.

Therefore, for crash astern the differences between the results for the quasi-steady simulation and the unsteady simulation was significantly greater than the errors arising from inaccuracies in setting the experimental results. It is concluded that there was a small

influence of $\dot{V}$ on the measured loads at a given combination of V, n, and P. However, this difference did not affect the peak loads that occurred during a crash astern maneuver.

## CORRELATION WITH FULL-SCALE DATA AND THEORY

For operation near the self-propulsion point (Condition 1 in Table 5), correlation was made between the model experimental results obtained in the present investigation, bending moments deduced from strains measured on the corresponding full-scale propeller, and analytical calculations.

From the experimental values of $F_x$, $F_y$, $M_x$, and $M_y$, the bending moment can be calculated about any radial station $r_o \leq r_h$ and about any axis normal to the radial direction. However, in calculating bending moments about $r_o > r_h$, an adjustment must be made to allow for the contribution of the loading in the region $r_o > r > r_h$. In calculating the bending moment about the 0.4 radius $M_{0.4}$ from experimental values of $F_x$, $F_y$, $M_x$, and $M_y$, it was estimated that for all harmonics including the time-average values, 3 percent of $M_x$ and $M_y$ was contributed by the loading in the region $0.4R > r > r_h$.

The full-scale strains used for correlation were measured* at the midchord position of the 40-percent radius on the face of the propeller under steady ahead operation. The full-scale operating condition corresponds approximately, but not precisely, to the Froude scaled steady ahead condition on the model; see Table 4.

The correlation is based on the bending moment vector parallel to the nose-tail line at the 40-percent radius at conditions corresponding to Condition 1 in Table 5. Radial stresses for the trial data were deducted from strains by using the appropriate values of Young's modulus and Poisson's ratio. The bending moment vector parallel to the nose-tail line was deduced from the stress by assuming that the blade behaves structurally as a cantilever beam.

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*The full-scale measurements were conducted by C.J. Noonan and G.P. Antonides of DTNSRDC Code 1962. The details of this full scale trial will be reported in a future DTNSRDC report.

The time-average bending moment deduced from the full-scale data was corrected for the difference between the scaled thrust and torque measured during the full-scale trial and the thrust and torque measured on the model. With this correction, the time-average bending moment determined from the full-scale data is 1.02 times the value determined from the model experiment.

The unsteady bending moment determined from the full-scale data was adjusted to the model conditions by using

$$M_{MES} = (M_S/\lambda^4)\,[V_M n_M \rho_M/(V_S n_S \rho_S)]$$

Here subscripts M refer to model values, subscript S refers to ship values, $M_{MES}$ is the equivalent bending moment at the model conditions as deduced from the ship data, and $\lambda$ is the linear scale ratio $L_S/L_M$. This adjustment assumes that the unsteady loading varies linearly with nV; see Wereldsma.[26] Since the ship conditions are near the Froude scaled model conditions, this adjustment is small except for the factor $\lambda^4$.

The time-average bending moment from the full-scale data was determined* from analysis of records of many propeller revolutions. The variation of the full-scale bending moment with blade angular position was determined from analysis of 37 consecutive propeller revolutions. Six of these revolutions were selected for detailed analysis: the two with the largest peak-to-peak variation, the two with the smallest peak-to-peak variation, and the two with the mean peak-to-peak variation. These six revolutions were harmonically analyzed and reconstructed by using the first ten harmonics; see Figures 27 and 28. The results from these six revolutions were averaged to obtain an effective variation of full-scale blade bending moment with blade angular position for comparison with model data.

Figures 29 and 30 present the variation with blade angular position and the first ten harmonics, respectively, of $M_{0.4}$ from the model data and from the full-scale ship data. All data are nondimensionalized

*By C.J. Noonan, DTNSRDC Code 1962.

on the same quantity, i.e., the time-average bending moment determined from the model experiments. This comparison indicated reasonable agreement of model and full-scale results for peak-to-peak values and for the first harmonic.

Theoretical calculations were made by using the method of Tsakonas, Jacobs, and Ali[20] (which is based on unsteady lifting surface theory) and the method of McCarthy,[21] a quasi-steady technique which utilizes the open-water characteristics of the propeller. These calculations were made for Condition 1 in Table 5 using the symmetric part* of the wake measured in the plane of the propeller both with and without the downstream dynamometer boat in place (Figures 11 and 12 and Appendix A). The difference in the calculated results with and without the dynamometer boat is a measure of the effect of the dynamometer boat on the circumferential variation of the unsteady loads.

For the method of Tsakonas et al.,[20] calculations were conducted for the first ten harmonics of the wake. These calculations were made by using the computer program developed by Davidson Laboratory including refinements made in December 1975. The "normal" components of wake harmonics, as required by this method, were defined as the wake harmonics normal to the chord line of the blade section at the local radius rather than normal to the advance angle at the local radius as recommended by Tsakonas, Breslin, and Miller.[27]. With the wake harmonics resolved normal to the blade chord, this method apparently considers both the unsteady flow parallel to the resultant inflow and the unsteady flow normal to the resultant inflow.

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*Although the model hull and dynamometer boat were intended to be symmetric about a vertical plane containing the propeller axis, the measured wakes were not perfectly symmetrical; see Appendix A. The measured asymmetrical part of the wake apparently arises from inaccuracies in construction of the model hull, alignment of the model in the towing basin, and in the wake measurements. Calculations (unreported) were in slightly worse agreement with experimental results when the complete wake was used rather than only the symmetric part of the wake.

[27]Tsakonas, S. et al., "Correlation and Application of an Unsteady Flow Theory for Propeller Forces," Transactions of the Society of Naval Architects and Marine Engineers, Vol. 75, pp. 158-193 (1967).

The quasi-steady calculations are based on the circumferential variation of the wakes measured at the 0.71 radial station except that the narrow velocity defects behind the struts at approximately $\theta_w$=25 and 335 deg are not considered. Since these defects are narrow relative to the blade width, it is judged that they should have only a slight influence on the circumferential variation of blade loading. It is assumed that the radial centers of the unsteady thrust and tangential force are the same as the radial centers of the respective mean values.

Figures 30-32 present the variation with blade angular position and the first ten harmonics of $M_{0.4}$ from the model experiment and analytical calculations. All data are nondimensionalized on the same quantity, i.e., the time-average bending moment determined from the model experiments. This comparison indicated that the experimental results were considerably higher than the calculated results. For other components of blade loading $F_x$, $F_y$, $M_x$, and $M_y$, the circumferential variation in the model experimental results was larger than the values calculated by the two indicated procedures by approximately the same ratio as shown for $M_{0.4}$. These comparisons are not shown.

In previous investigations, experimentally determined unsteady forces and moments on a single blade of various propellers in inclined flow have been compared with forces and moments calculated by a quasi-steady procedure similar to that described by McCarthy.[21] These experimental loads were obtained by direct measurement of unsteady forces and moments on a single blade (References 13 and 14) or were deduced from measured steady transverse forces and moments along axes fixed relative to the flow, i.e., not rotating with the propeller (Reference 28). References 13, 14, and 28 all show that for noncavitating conditions, the experimental unsteady blade loading was from 1.7 to 2.0 times as large as the values calculated by the quasi-steady method. This agrees with the results of the present investigation; see Figure 31.

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[28]Gutsche, F., "Untersuchung von Schiffsschrauben in schrager Anstromung," Schiffbauforschung, Vol. 3, No. 3/4 (1964).

The reason for the large discrepancy between the experimental and calculated results is not clear. Some possibilities are as follows:

1. Inaccuracies in theoretical results. The unsteady lifting surface procedure of Tsakonas et al.[20] is based on linearized theory which considers the harmonic content of the longitudinal and tangential components of the wake. It is possible that nonlinear effects or the significant radial component of the wake may influence the circumferential variation of the loading. In addition, there may be inaccuracies in the numerical evaluation of the theory. The quasi-steady procedure of McCarthy[21] is exceedingly simple and should give reasonable results, especially for the first harmonic which has a low reduced frequency. However, this method does not consider any possible effects of the circumferential variation of the radial component of inflow velocity.

2. Interaction between the propeller and the hull may increase the circumferential nonuniformity of the flow into the propeller from the values measured without the propeller in place. (Both sets of calculations are based on the wake measured in the plane of the propeller with propeller removed.) The experimental data show that the maximum and minimum loading occurs near $\theta$=90 and 270 deg. This implies that the dominant influence of the wake is the tangential velocity. Therefore, if the effect of the propeller on the wake pattern is the reason for the large discrepancy between theory and experiment, the propeller must increase the upsweep angle between the flow and the propeller shaft from approximately 10 deg without the propeller to approximately 20 deg with it.

3. Other interactions between the propeller and the nearby surfaces which are not considered in the calculations based on the measured wake distribution.

4. Inaccuracies in the measured wake. This is unlikely since the tangential component of the wake indicates that the flow is approximately parallel to the stern.

5. Error in the experimental results. This appears unlikely in view of the reasonably good agreement between model experiments and full-scale experiments conducted entirely independently. In addition, previous experimental results in which the dominant component of wake was the tangential yielded results which were substantially larger than calculated by quasi-steady procedures.[13,14,28]

## SUMMARY AND CONCLUSIONS

Experiments were described in which the mean and unsteady loads were measured on a single blade of a model of the CP propeller on the FF-1088. The experiments were conducted behind a model of the FF-1088 hull under steady ahead operation, hull pitching motions, simulated crash ahead maneuvers, and simulated crash astern maneuvers. The discussion of experimental techniques included a description of the dynamometer and data analysis system. The results are summarized as follows:

1. The circumferential variation of all measured components of blade loading is primarily a first harmonic, with maximum and minimum values occurring near the blade angular position at which the blade spindle axis is horizontal.

2. For steady ahead operation:

   a. The maximum values and the peak-to-peak circumferential variations for measured forces and bending moments were up to approximately 1.38 and 0.80, respectively, the time average values.

   b. The model results for circumferential variation of bending moments about the nose-tail line of the 0.4 radius agreed fairly well with loads deduced from strain measurements on the full-scale propeller, but they were larger than theoretically calculated values.

3. For simulated hull pitch (maximum pitch angle of 2 deg):

   a. The maximum value of measured forces and bending moments increased over the corresponding values without hull pitch by 4 percent for quasi-steady simulation and by 20 percent for unsteady simulation with pitching frequency equal to 0.8 Hz.

b. The peak-to-peak circumferential variation of the measured forces and bending moments increased over the corresponding values without hull pitch by approximately 5 percent for quasi-steady simulation and by 50 percent or more for unsteady simulation with pitching frequency equal to 0.8 Hz. Therefore, any quasi-steady simulation of ship motions is completely inadequate for estimating the effect of ship motions on unsteady propeller blade loading.

4. For the simulated crash ahead maneuver:

a. The dominant first harmonic of the measured forces and bending moments varied in a nearly linear manner with the product of ship speed and propeller rotational speed.

b. The acceleration of the hull did not have a significant effect on the measured loads. Therefore, propeller blade loading during a crash ahead maneuver can be adequately estimated by quasi-steady experiments.

c. The maximum time-average values of measured forces and bending moments per revolution were in the range of 1.20 to 1.45 of the time-average values at the self-propulsion point.

d. The peak values of measured forces and bending moments were in the range of 1.35 to 1.60 of the time-average values at the self-propulsion point.

e. The Taylor wake fractions deduced from the time-average thrust and torque per revolution varied substantially from the values at the self-propulsion point.

5. For the simulated crash astern maneuver:

a. The first harmonic of the measured forces and bending moments varied approximately linearly with the product of ship speed and propeller rotational speed and was a function of propeller pitch.

b. The decleration of the hull altered the peak value of a given component of loading at a given condition by up to 20 percent of the

time-average value at the self-propulsion point; however, this did not alter the peak load occurring at any time during the maneuver. Therefore, propeller blade loading during a crash astern maneuver can be adequately estimated from quasi-steady experiments.

c. The largest time-average loads per revolution and the peak loads including circumferential variation occurred at the initiation of the maneuver; i.e., loads during the crash astern maneuver did not exceed the loads at the self-propulsion point.

d. The Taylor wake fractions deduced from the time-average thrust and torque per revolution varied substantially from the values at the self-propulsion point.

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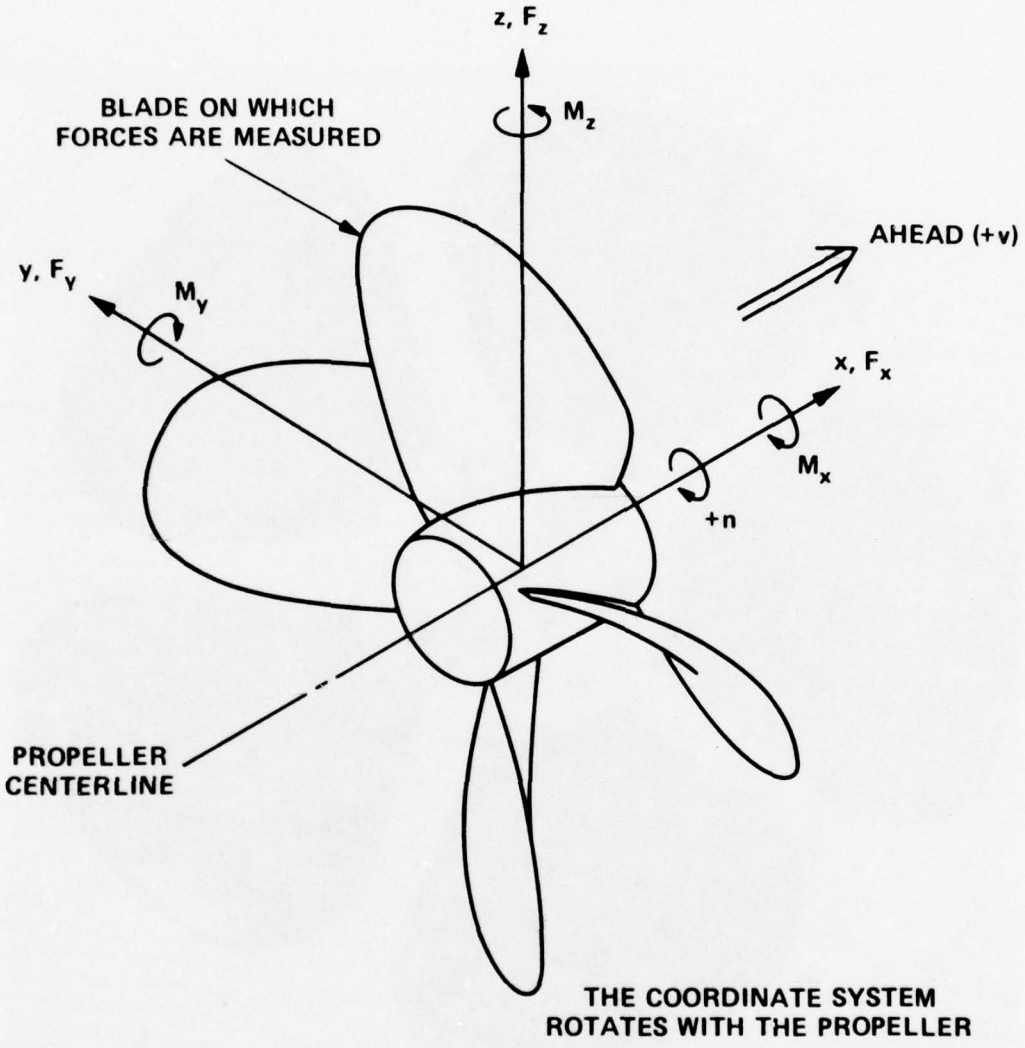



Figure 1- Components of Blade Loading

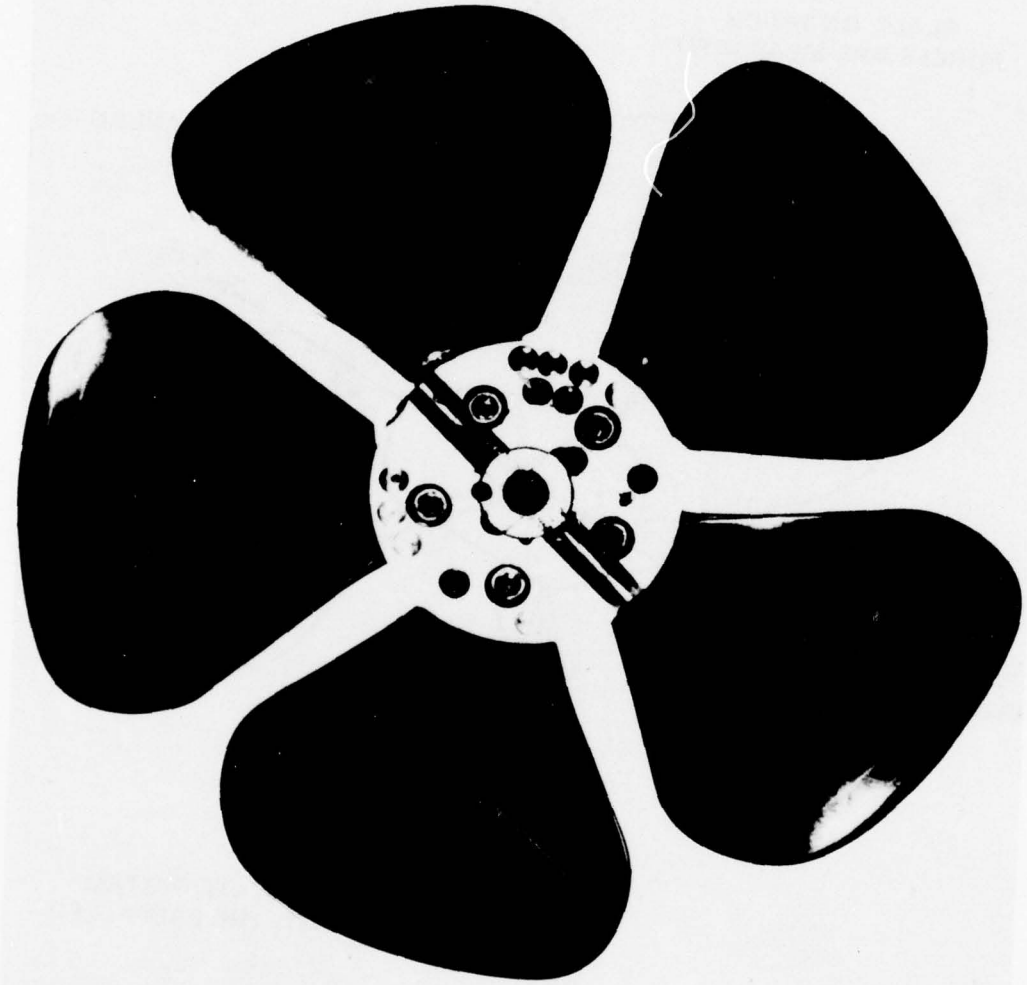


Figure 2- DTNSRDC Model Propeller 4402A

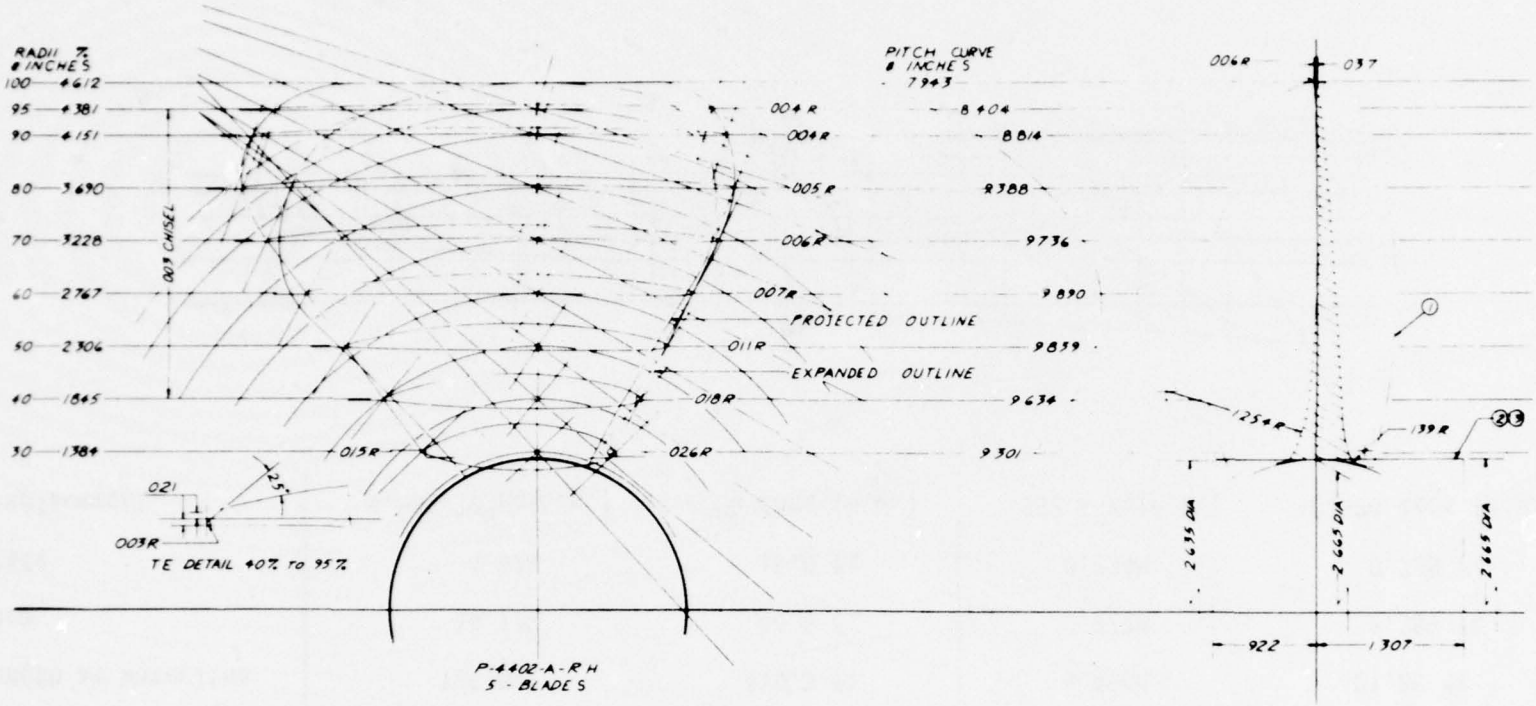



Figure 3- Geometries of Model of Propeller on FF-1088;
DTNSRDC Model Propeller 4402A

| | Ship | | Model | |
|---|---|---|---|---|
| Length at Waterline | 126.6M | 415.3 ft | 6.486M | 21.28 ft |
| Beam | 14.17M | 46.5 ft | 0.727M | 2.385 ft |
| Draft | 4.57M | 15.0 ft | 0.234M | 0.769 ft |
| Displacement | $4.064 \times 10^6$ Kg(S.W.) | 4000 tons (S.W.) | 532.4 Kg(F.W.) | 0.524 tons (F.W.) |



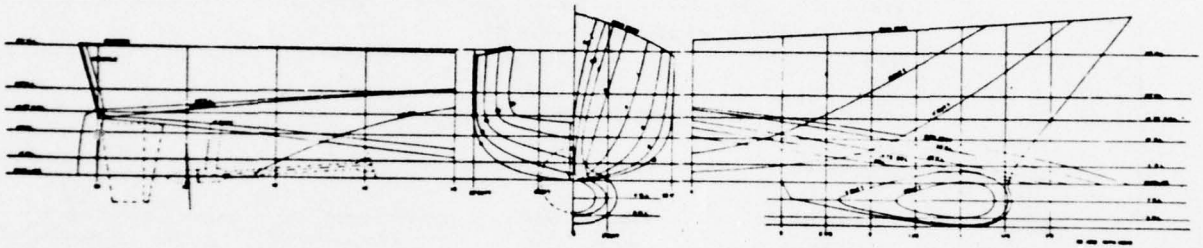


Figure 4 - Ship and Model Particulars

Figure 5- Experimental Arrangement of Hull and Dynamometer Boat

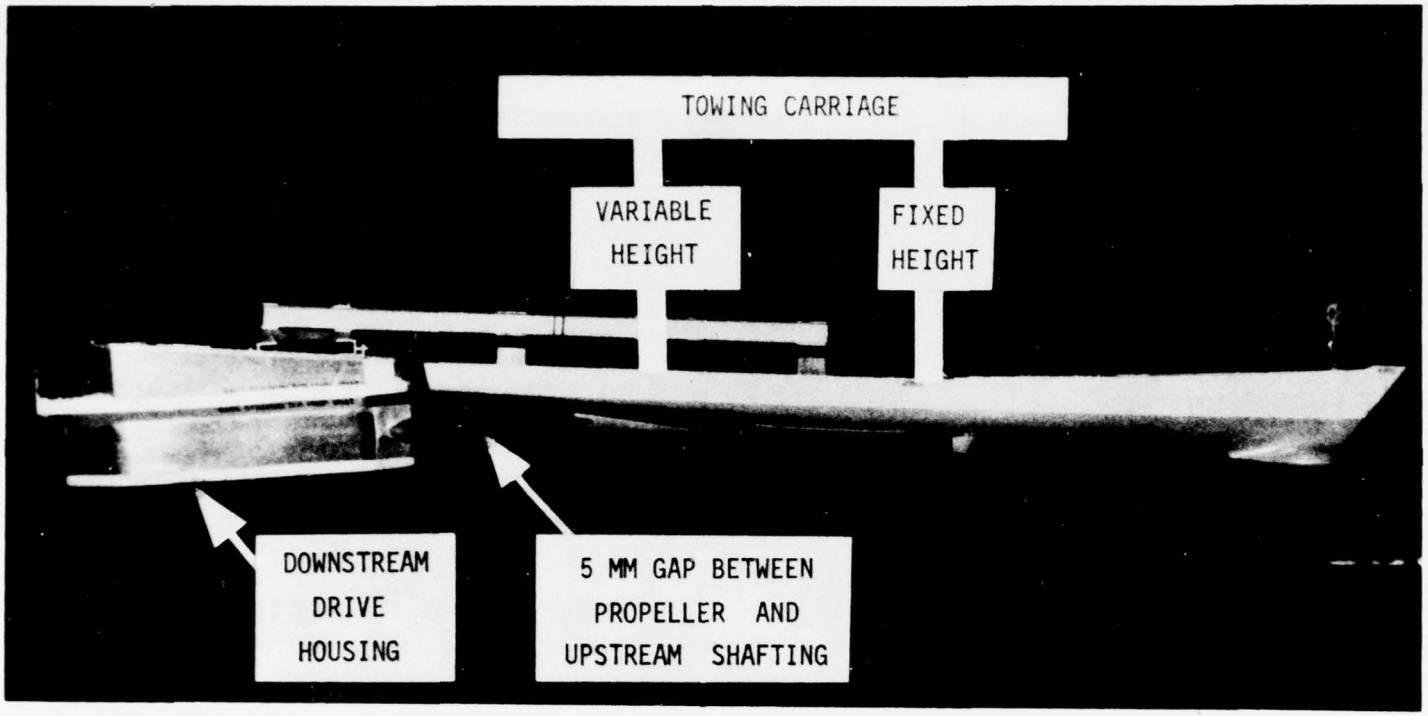



Figure 5a- Overall View

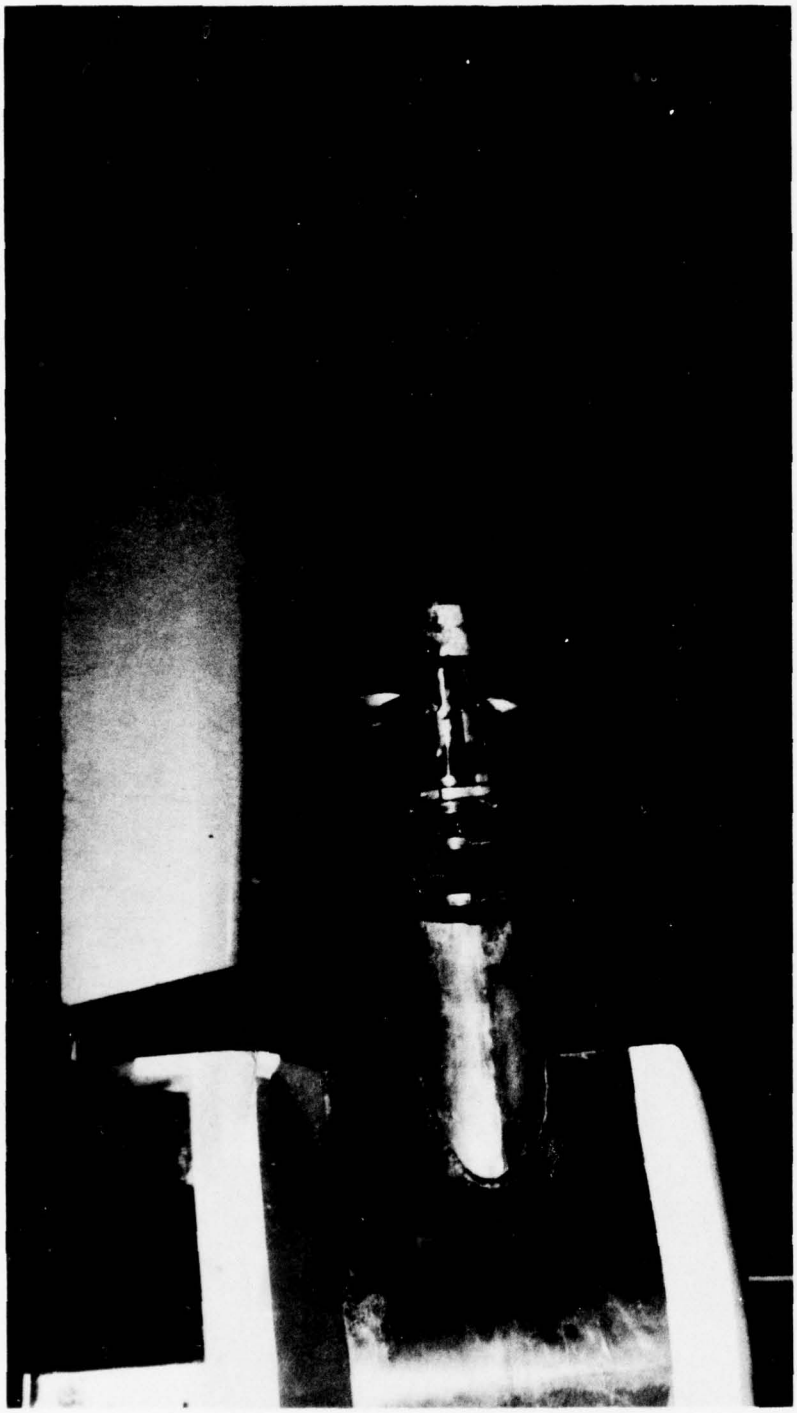


Figure 5b- Closeup of Propeller

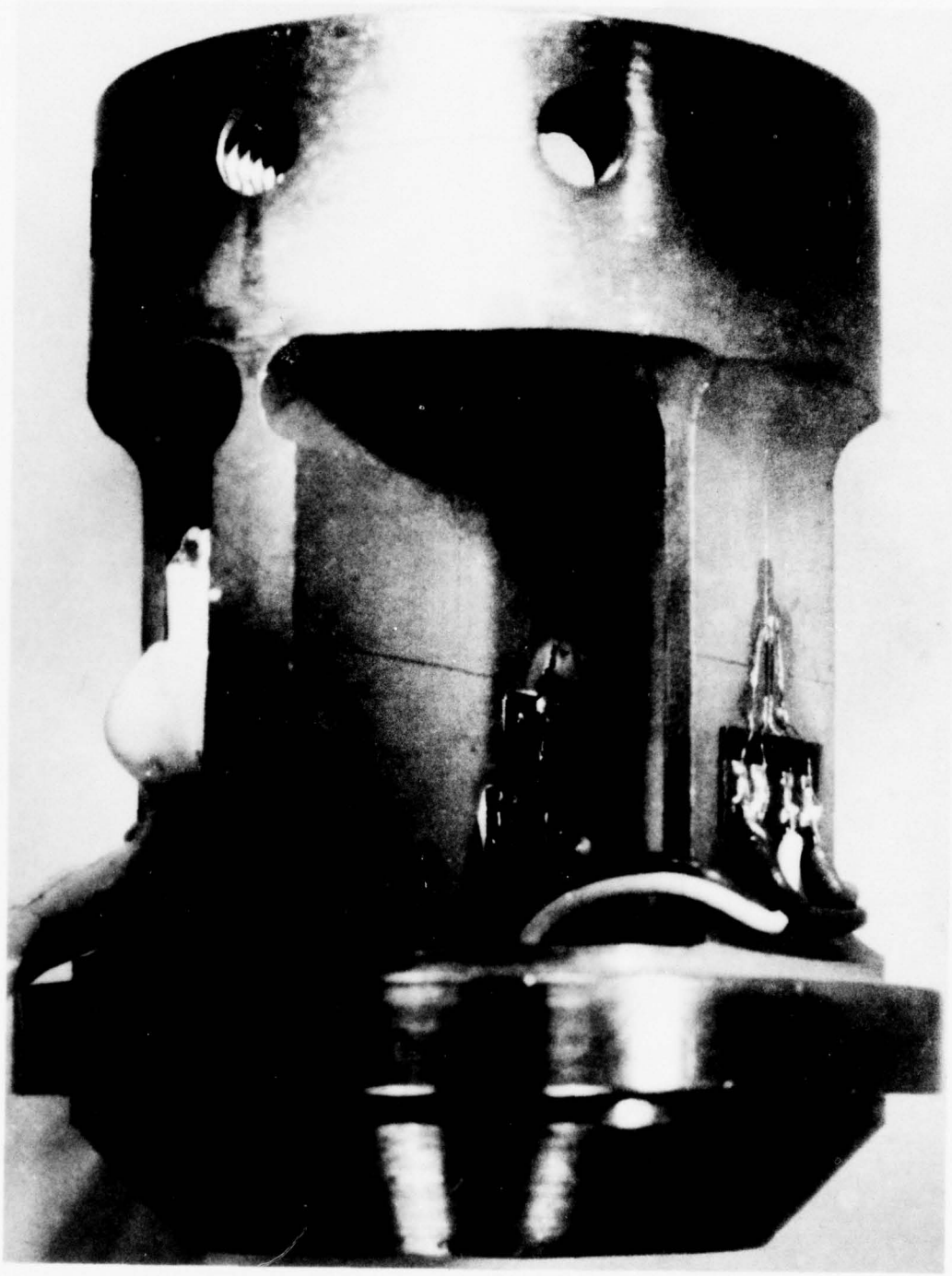


Figure 6- Strain-Gaged Blade Flexures in Hub

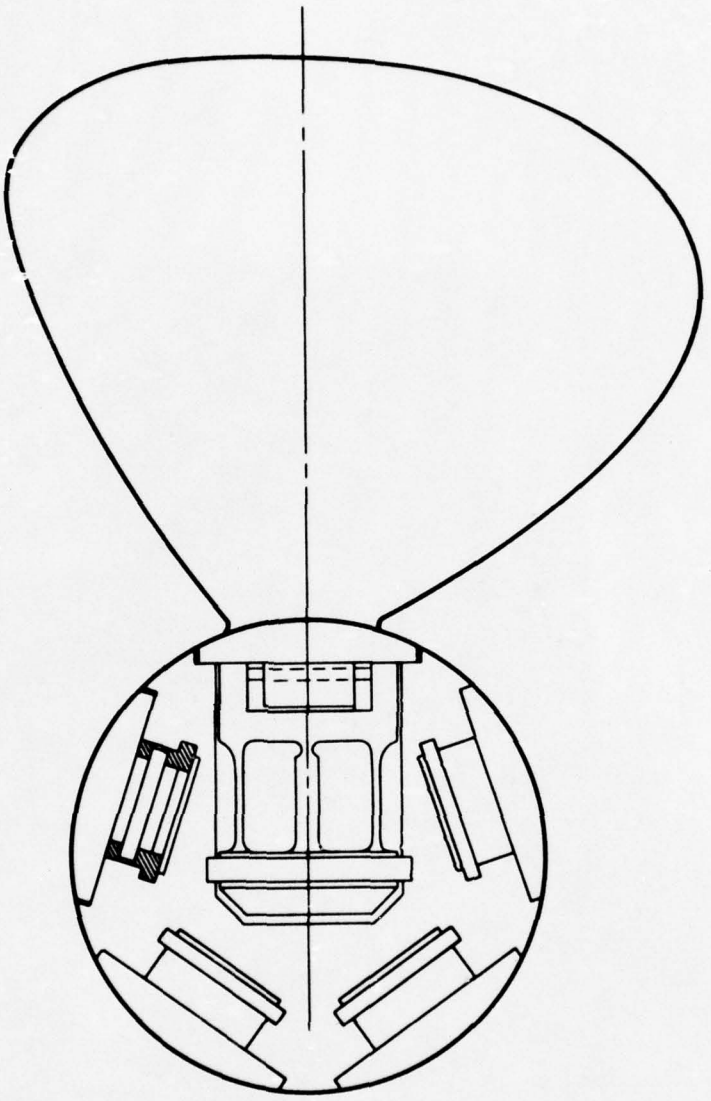


Figure 7- Arrangement of Flexures in Hub

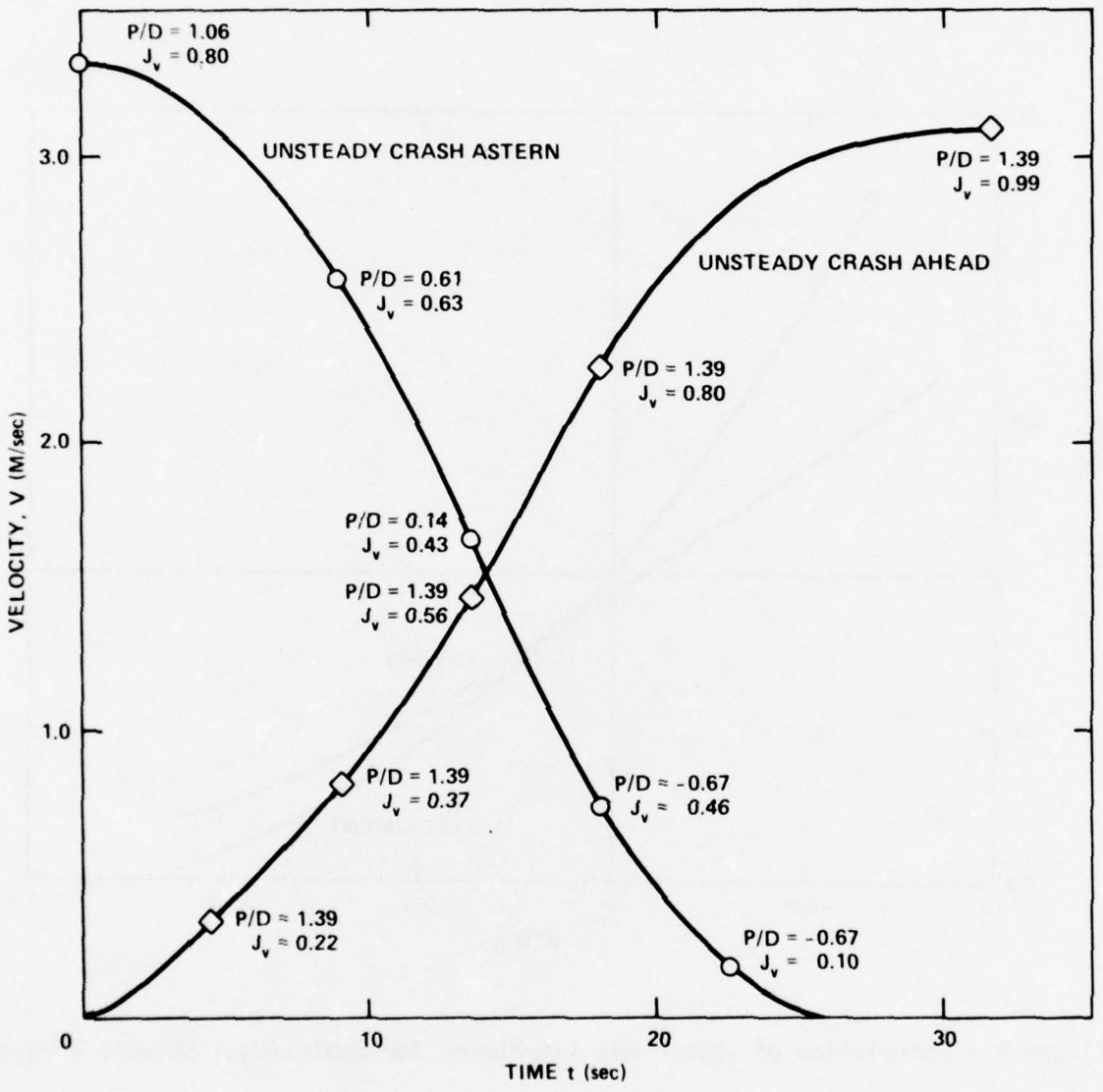



Figure 8 - Experimental Deceleration and Acceleration Conditions

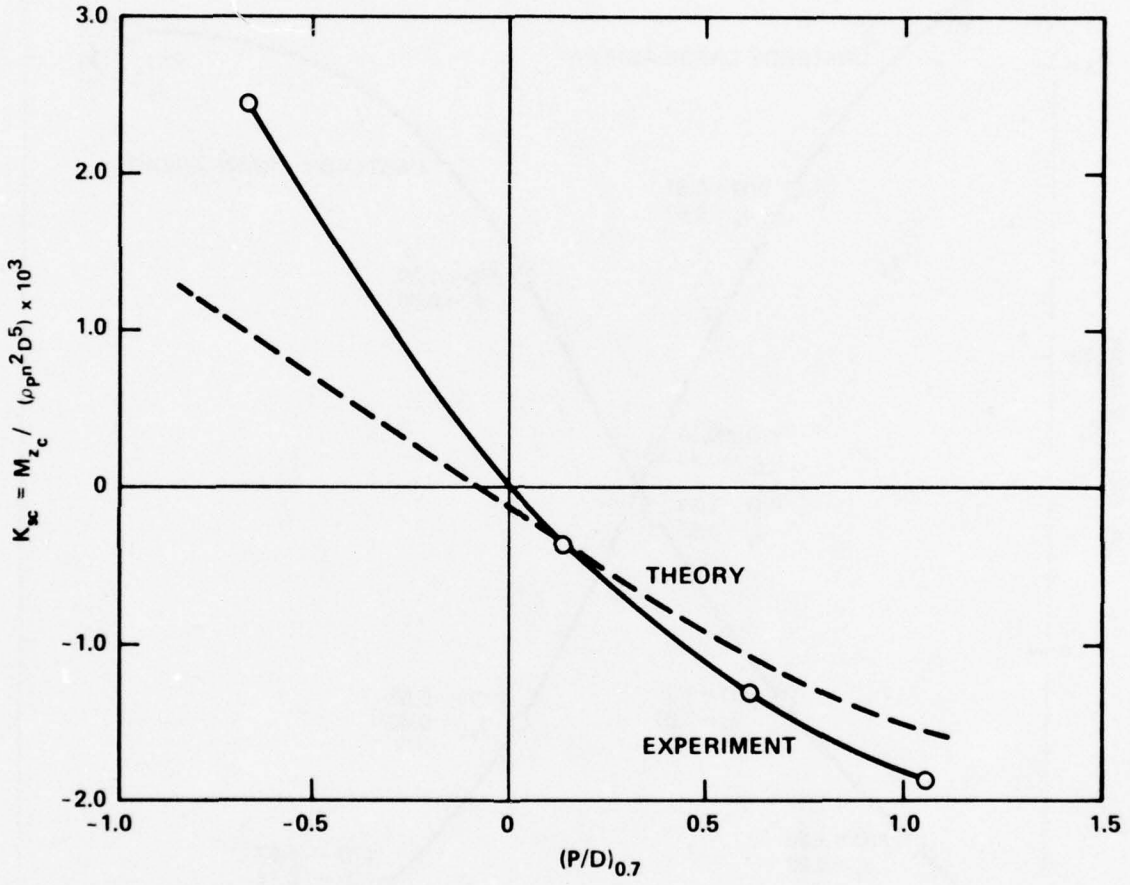



Figure 9 - Correlation of Theory and Experiment for Centrifugal Spindle Torque

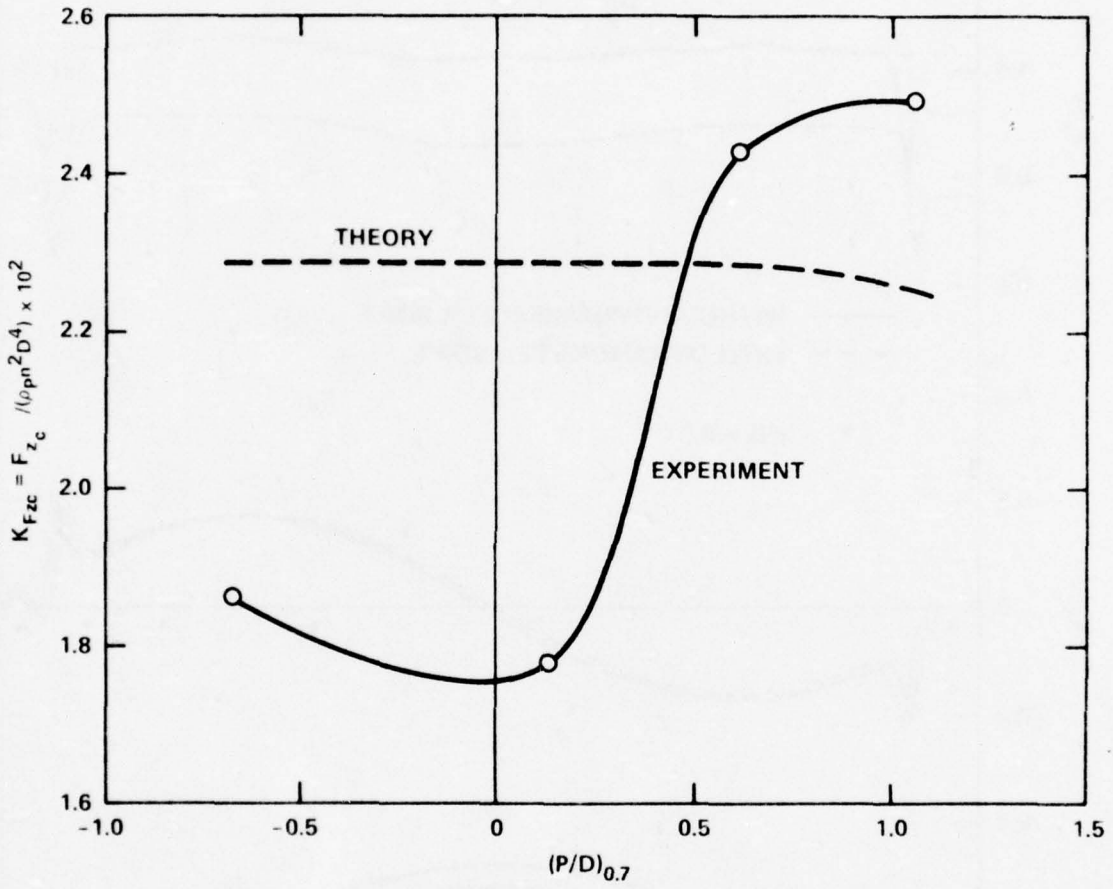



Figure 10 - Correlation of Theory and Experiment for Centrifugal Force

Figure 11- Circumferential Distribution of Wake in Propeller Disk

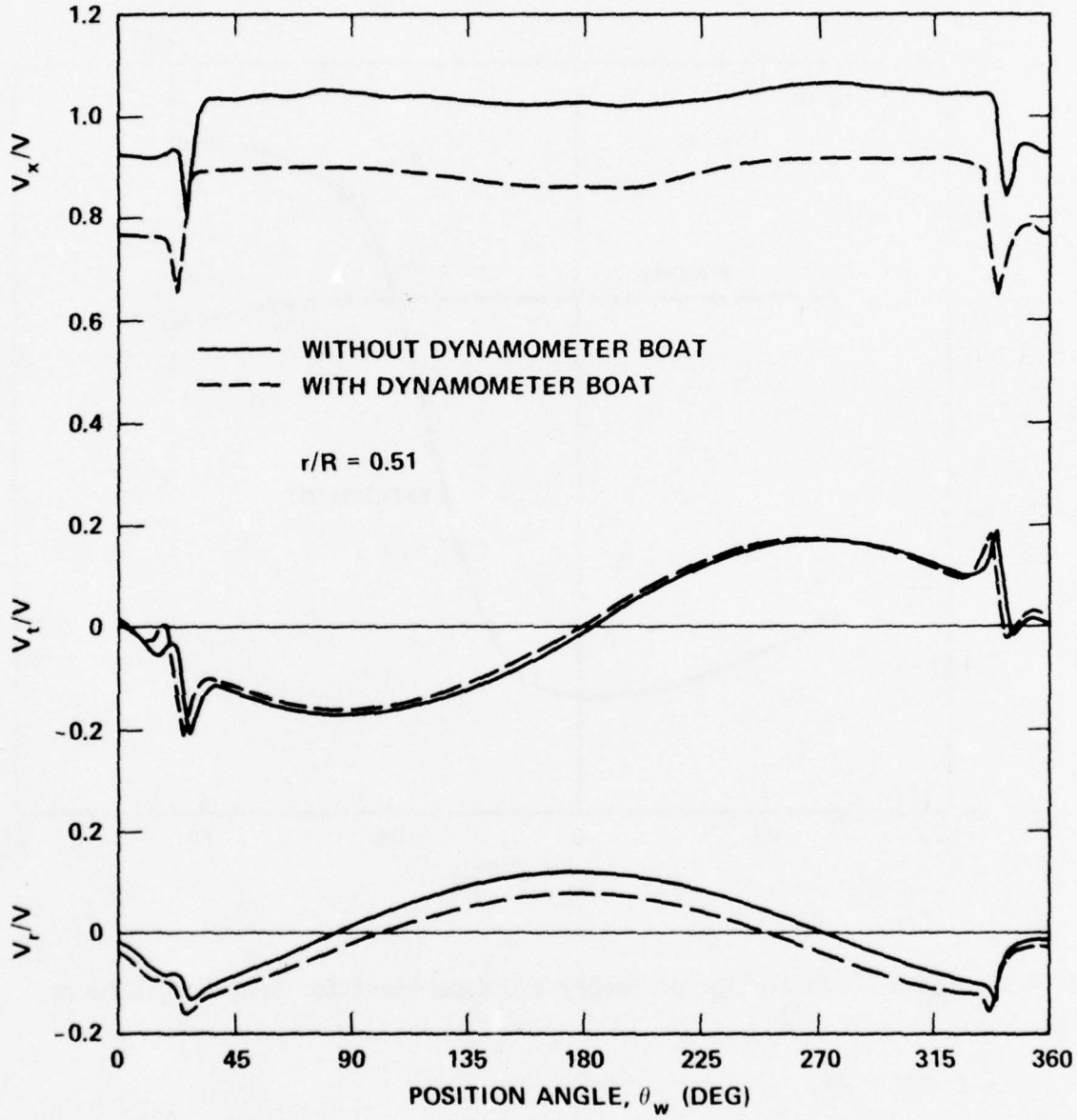



Figure 11a- 51 Percent Radius

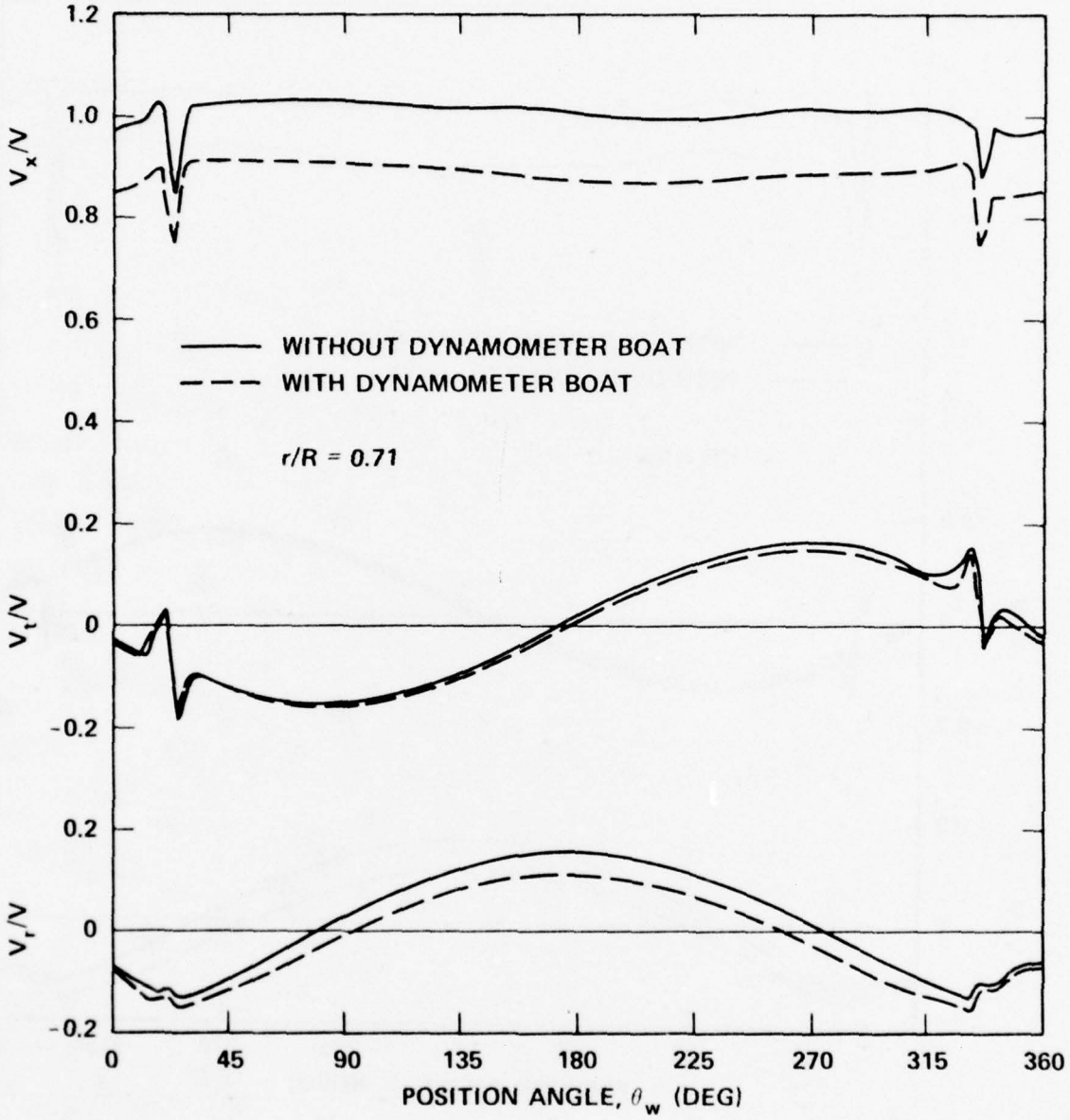



Figure 11b- 71 Percent Radius

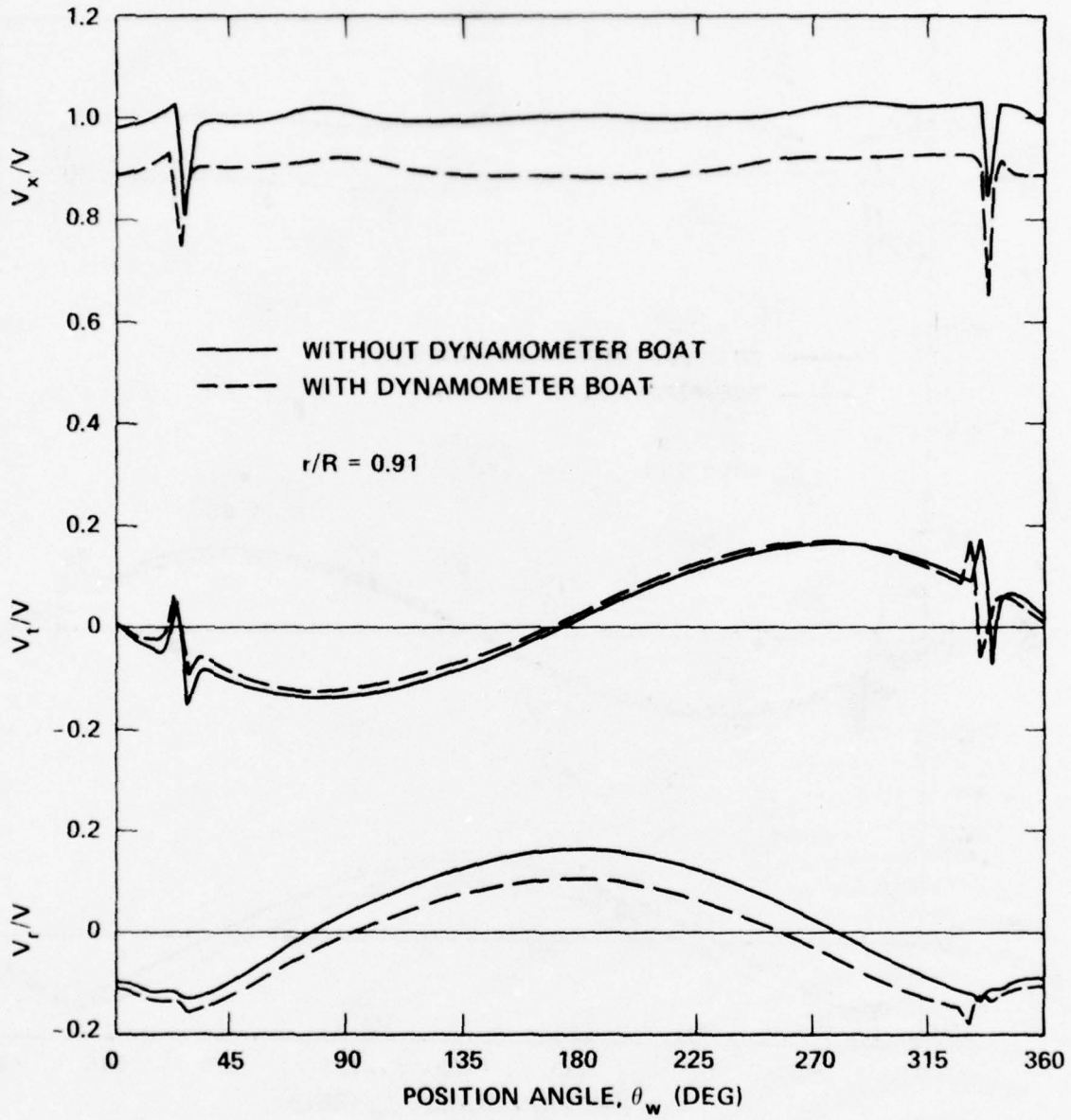



Figure 11c- 91 Percent Radius

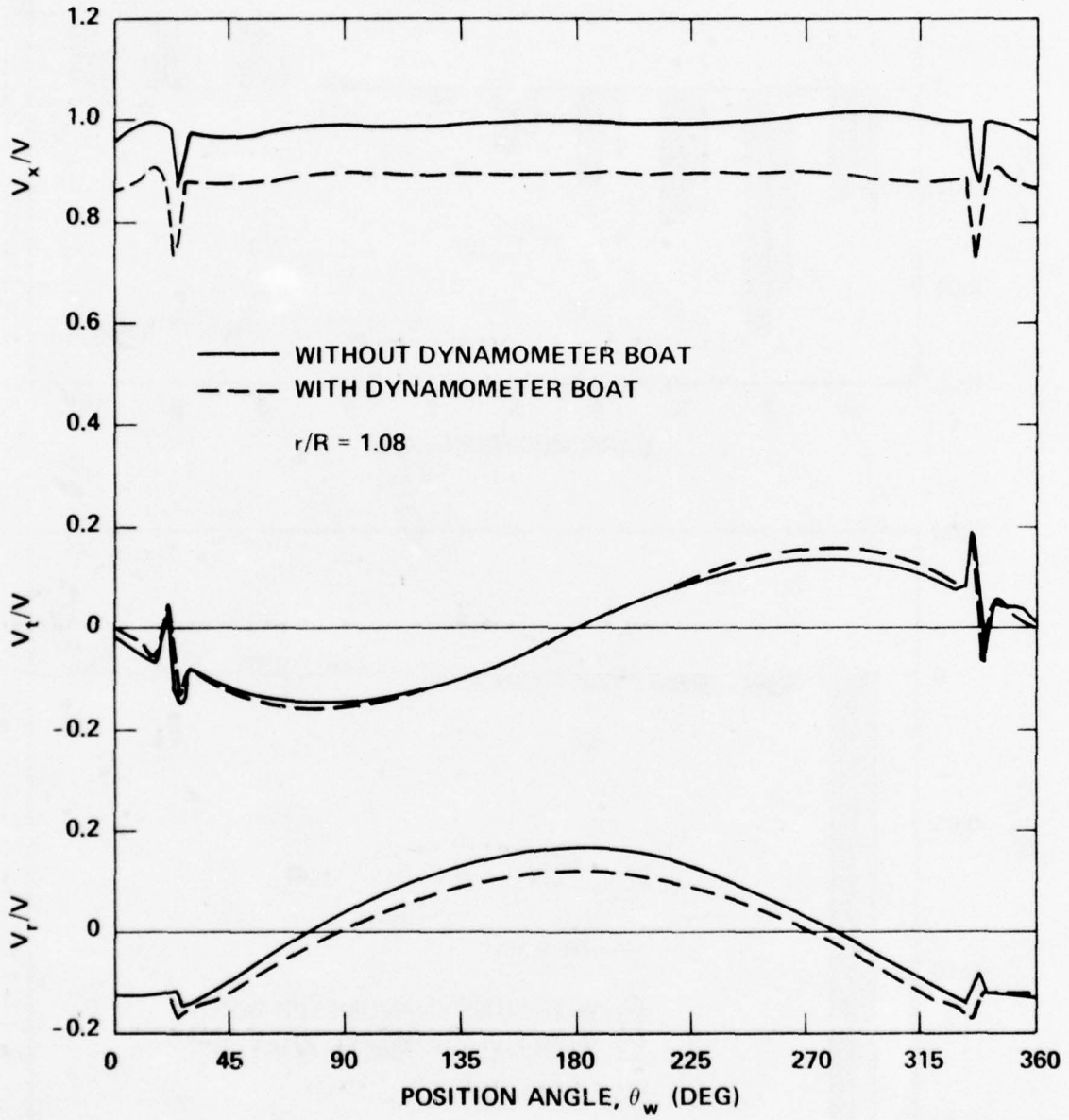



Figure 11d- 108 Percent Radius

Figure 12- Harmonic Amplitudes of Wake Velocities

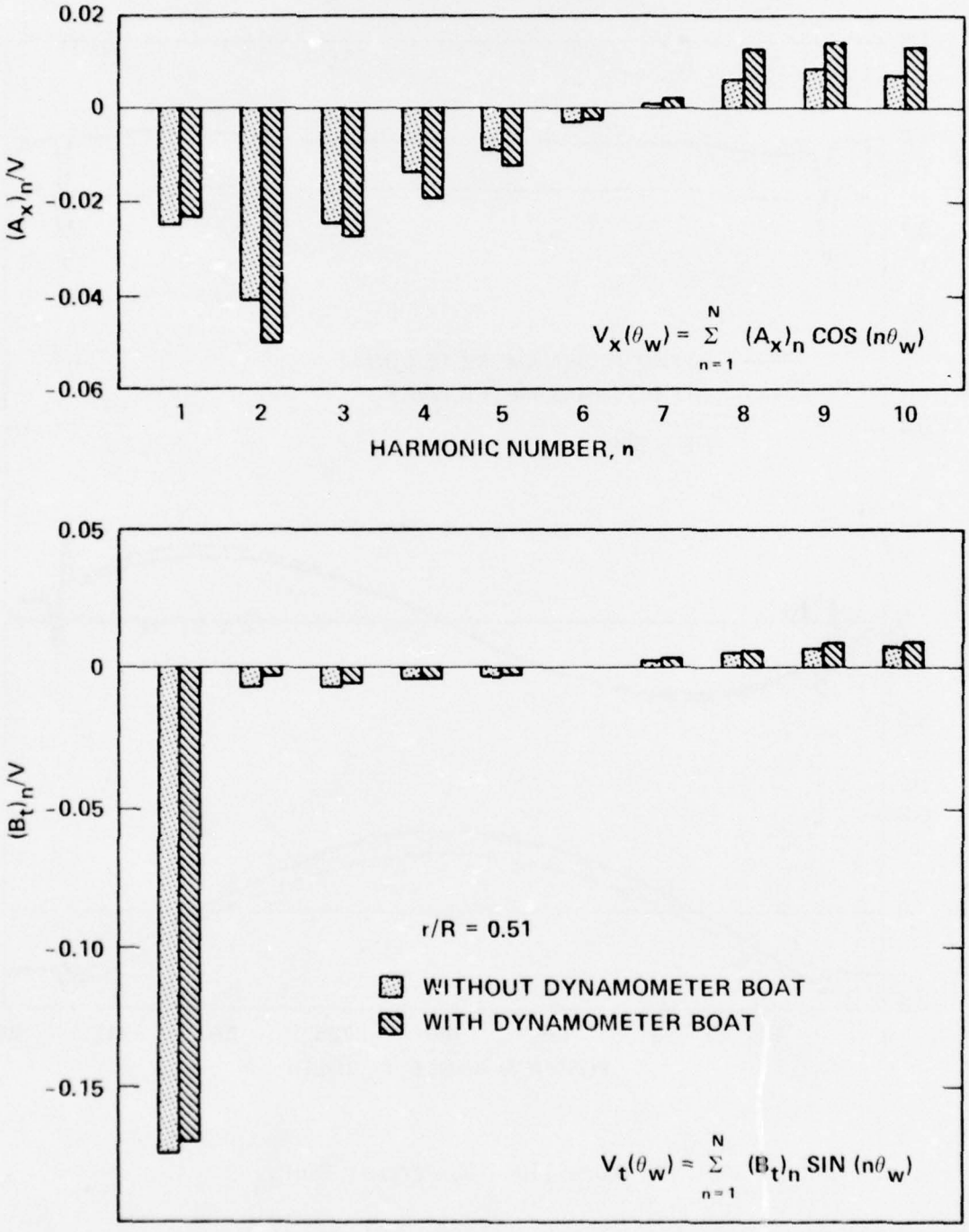



Figure 12a- 51 Percent Radius

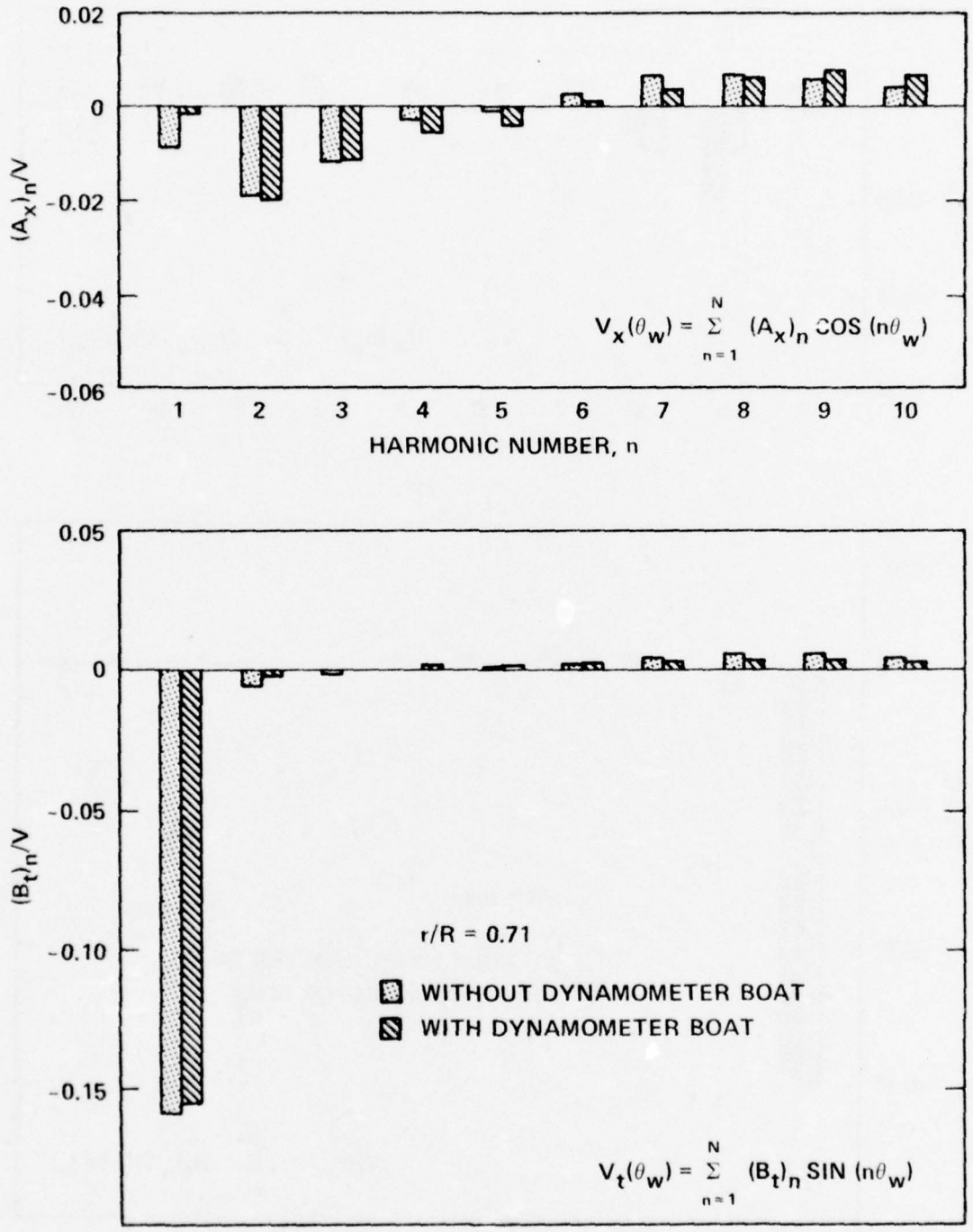
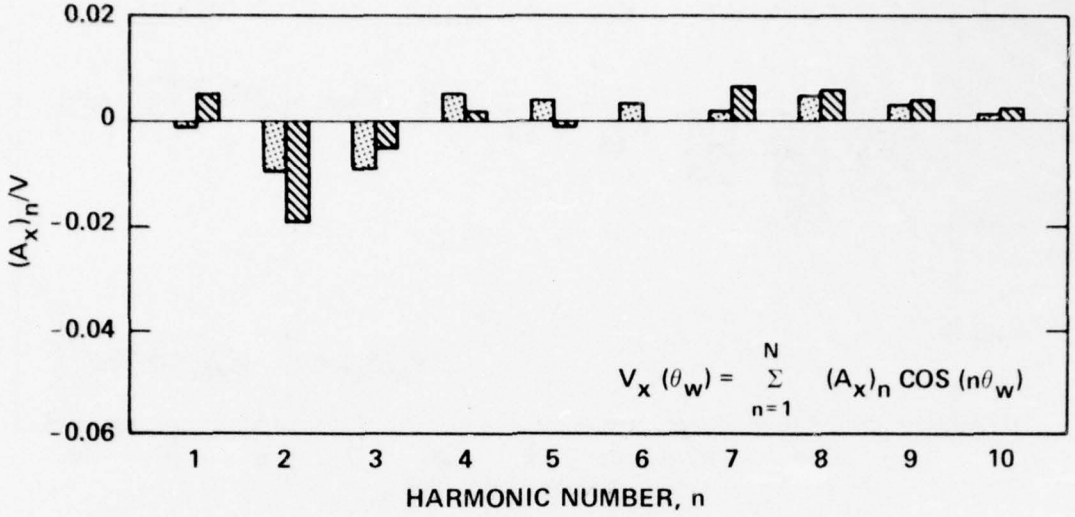



Figure 12b- 71 Percent Radius



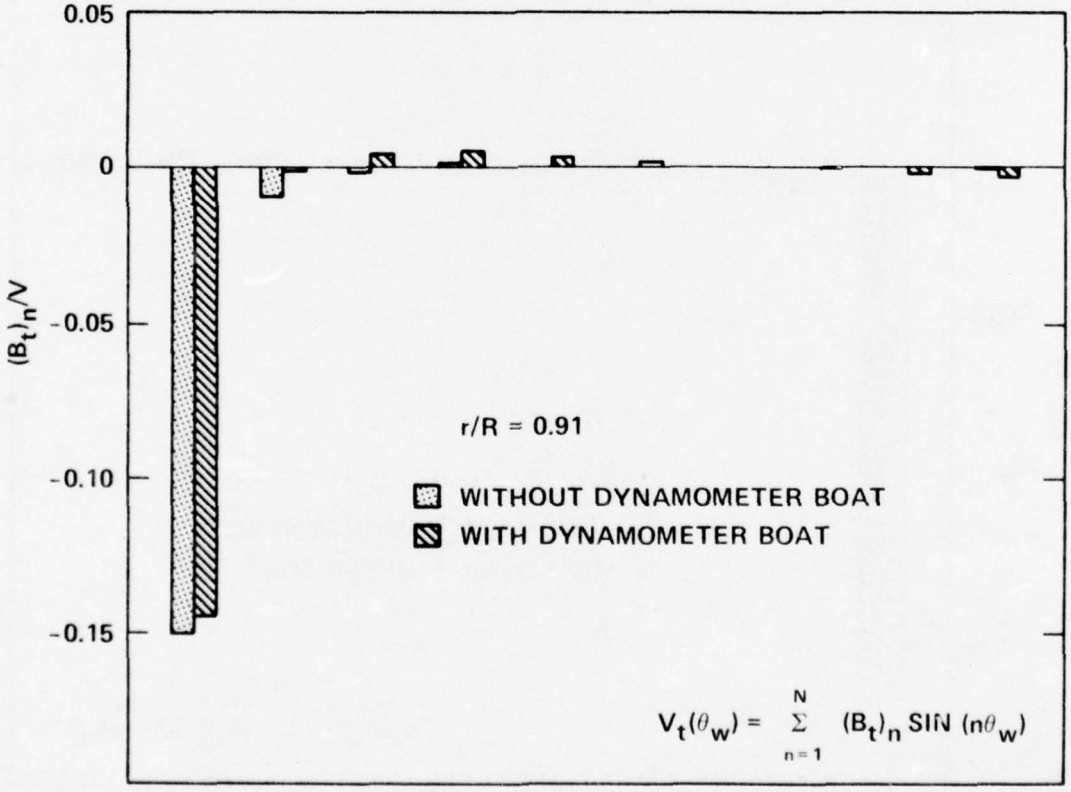




Figure 12c- 91 Percent Radius

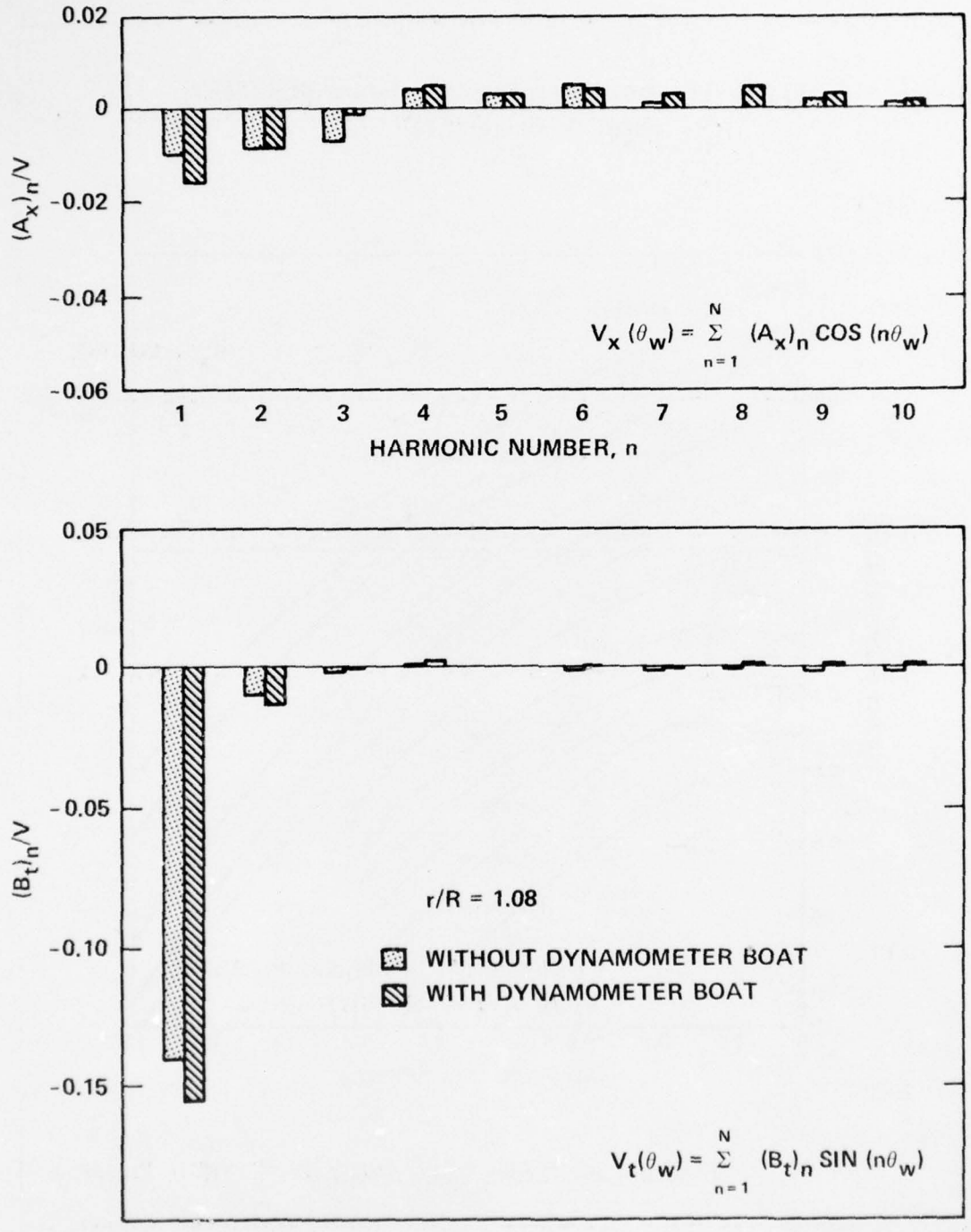



Figure 12d- 108 Percent Radius

Figure 13- Open Water Characteristics of DTNSRDC
Model Propeller 4402

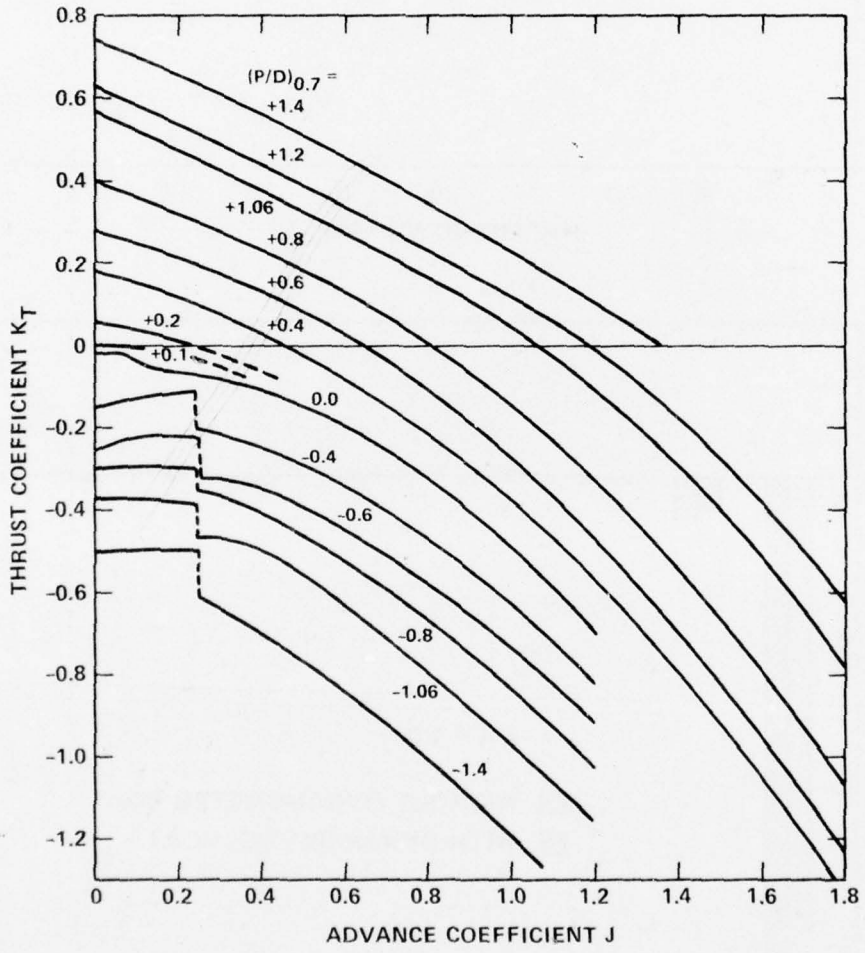



Figure 13a- Thrust Coefficient

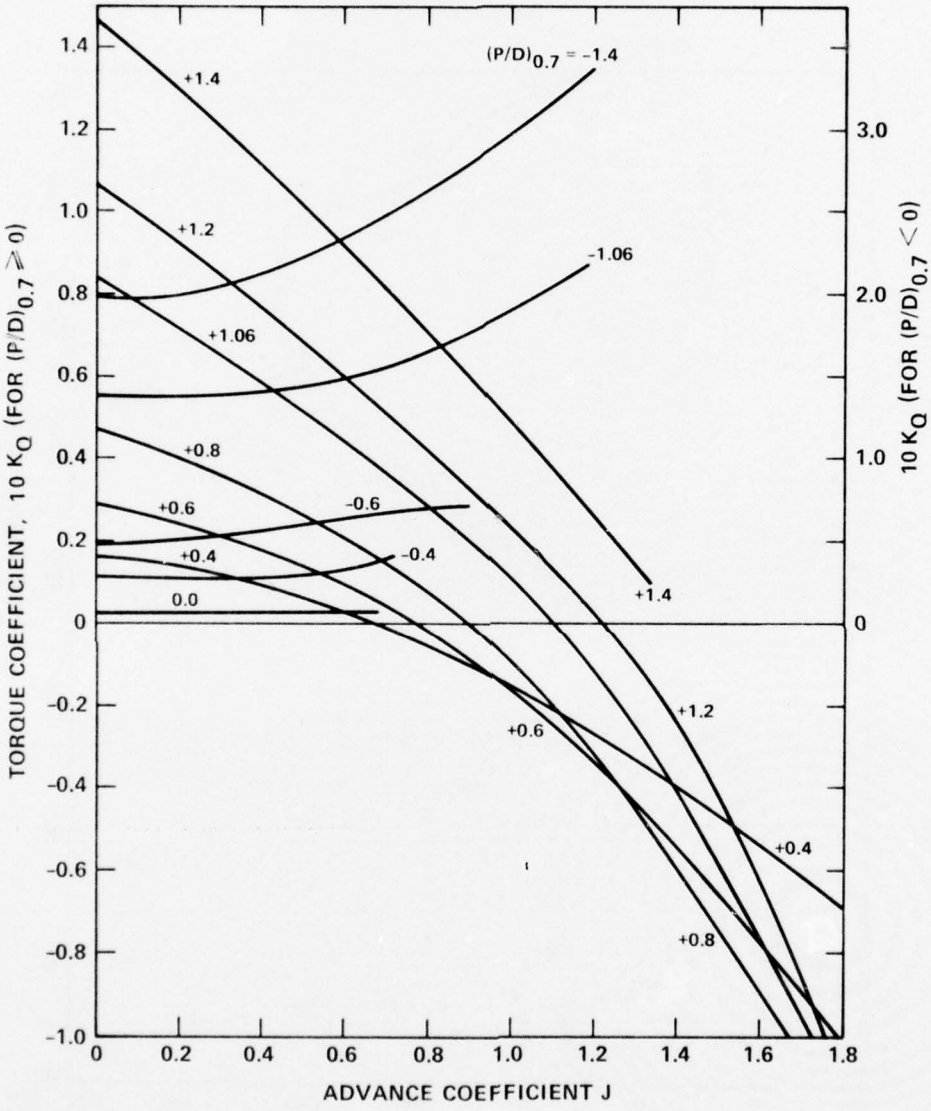



Figure 13b- Torque Coefficient

Figure 14- Influence of Extraneous Signals on Measured Loads

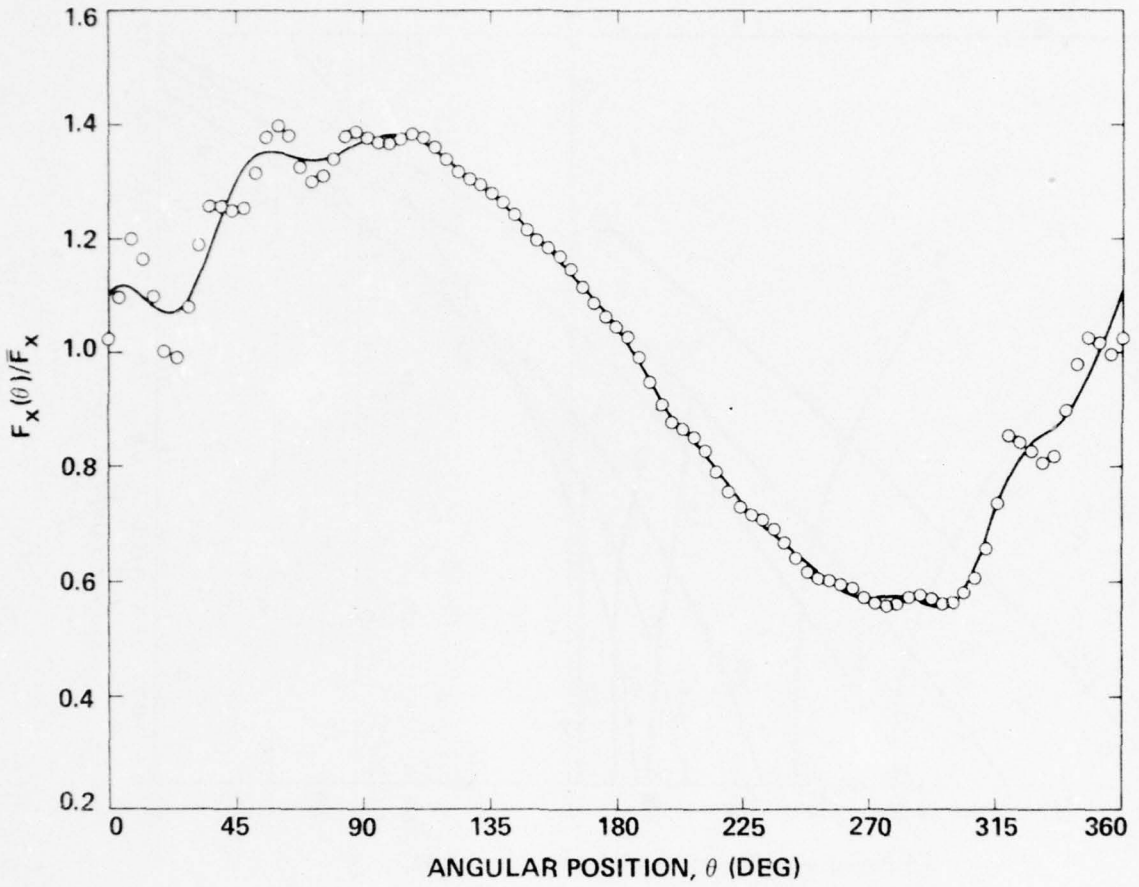



Figure 14a- $F_x$

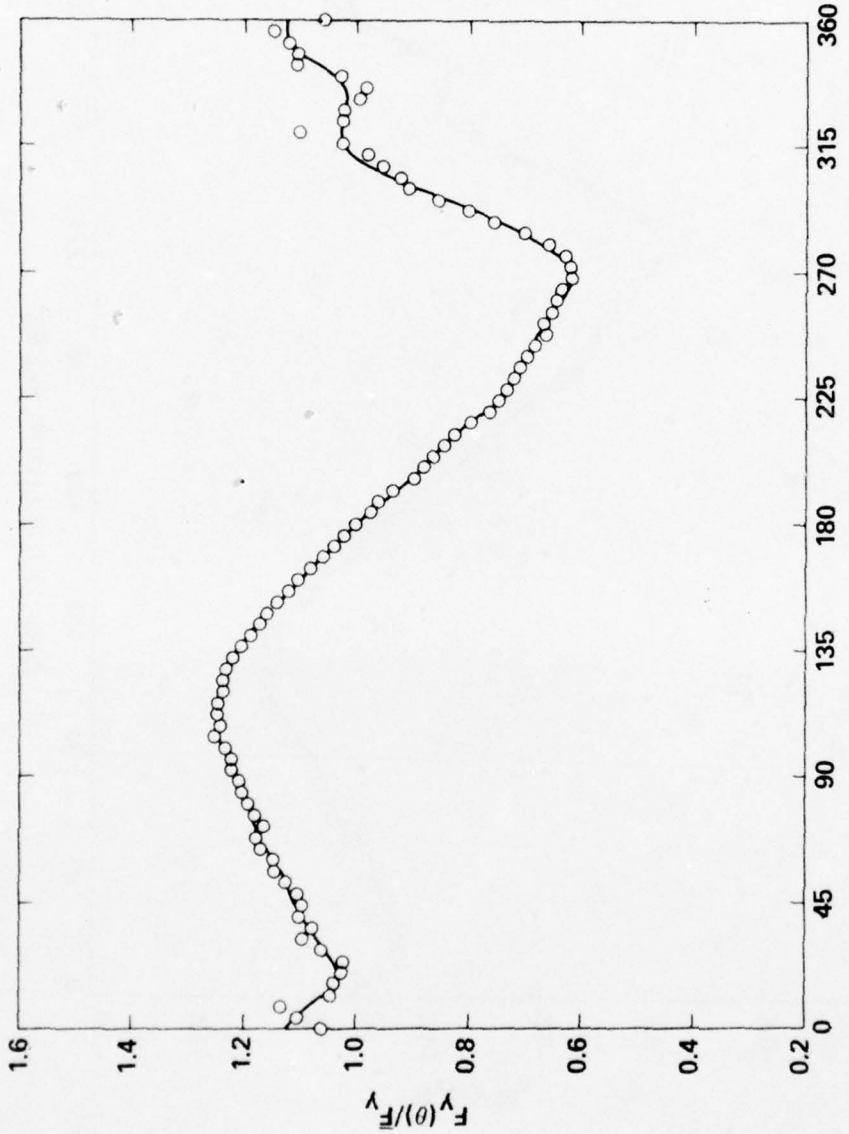



Figure 14b- $F_y$

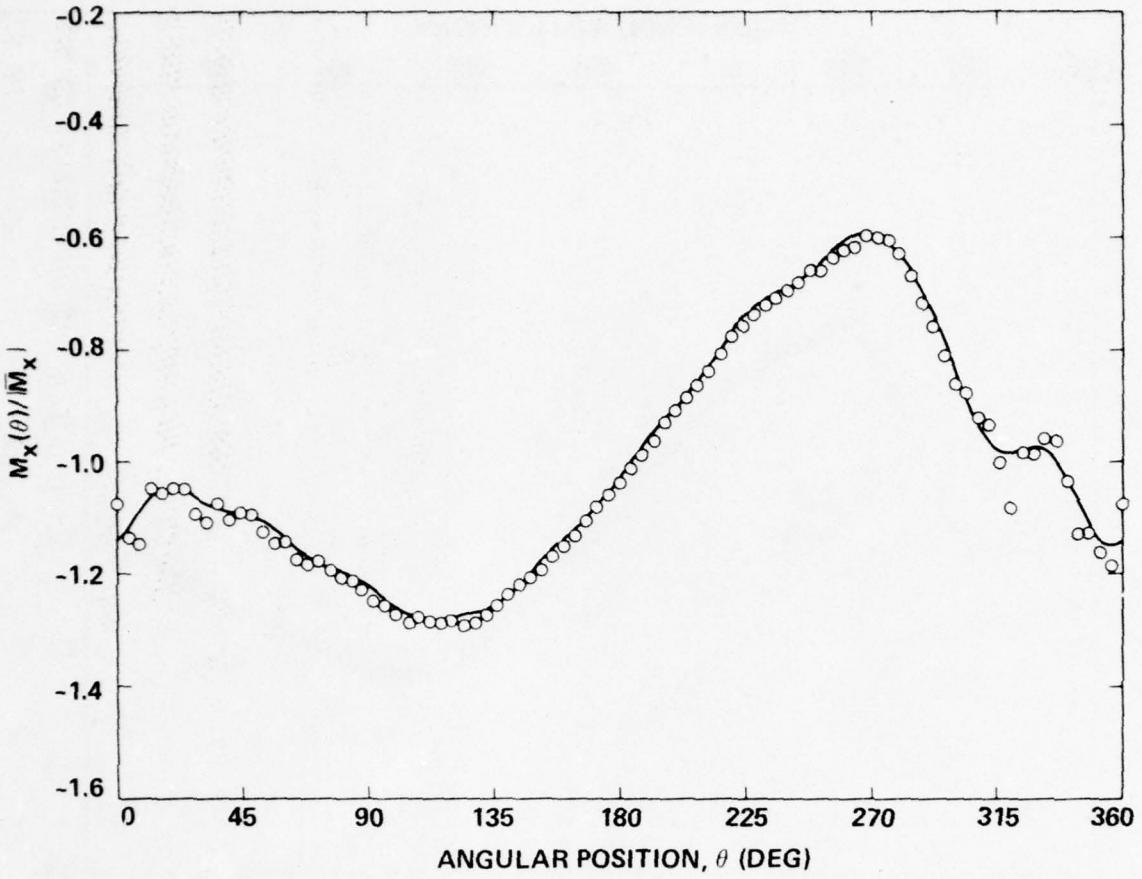



Figure 14c- $M_x$

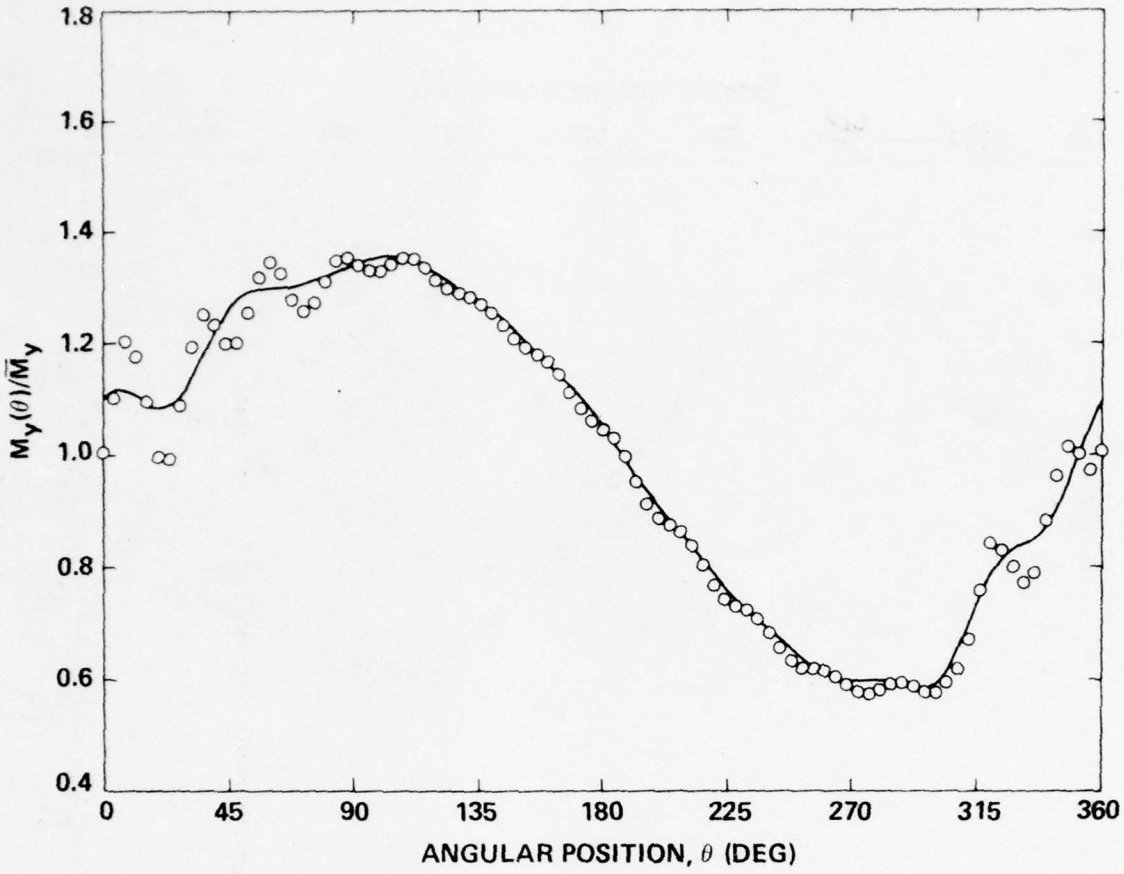



Figure 14d- $M_y$

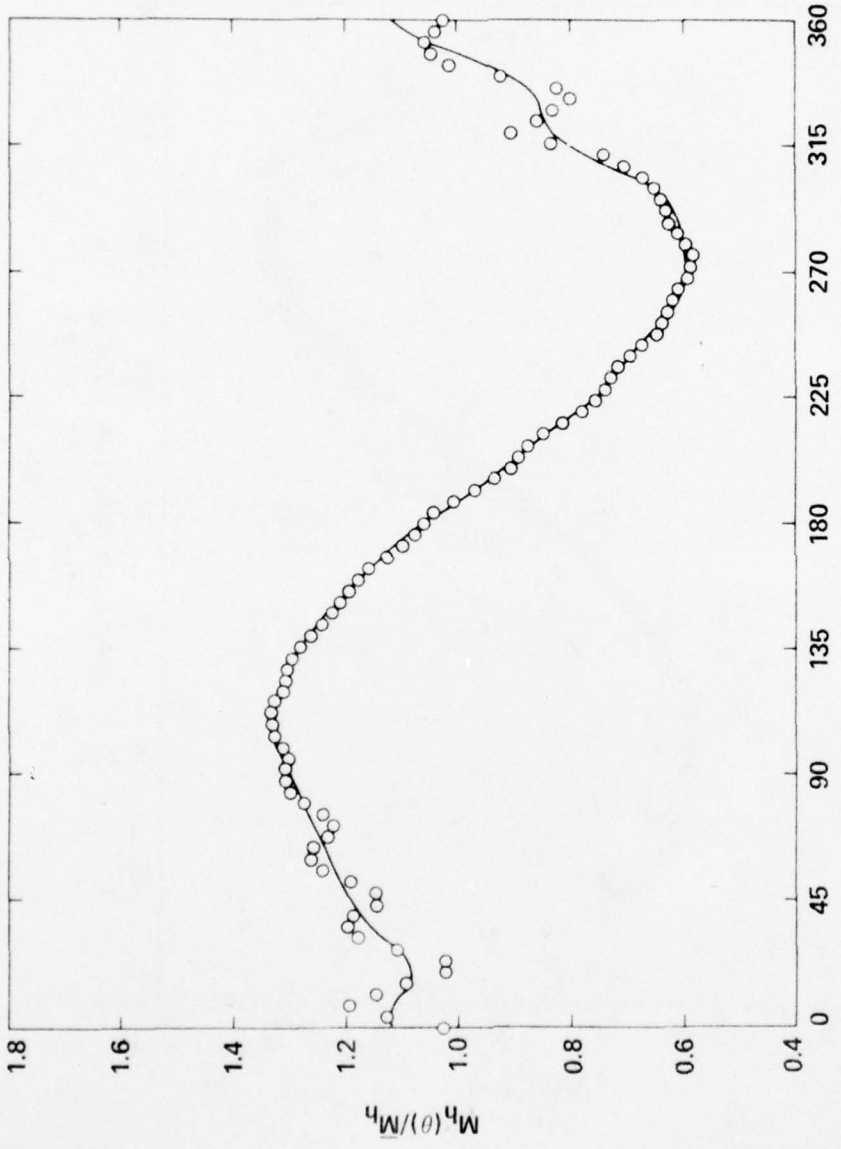



Figure 14e- $M_h$

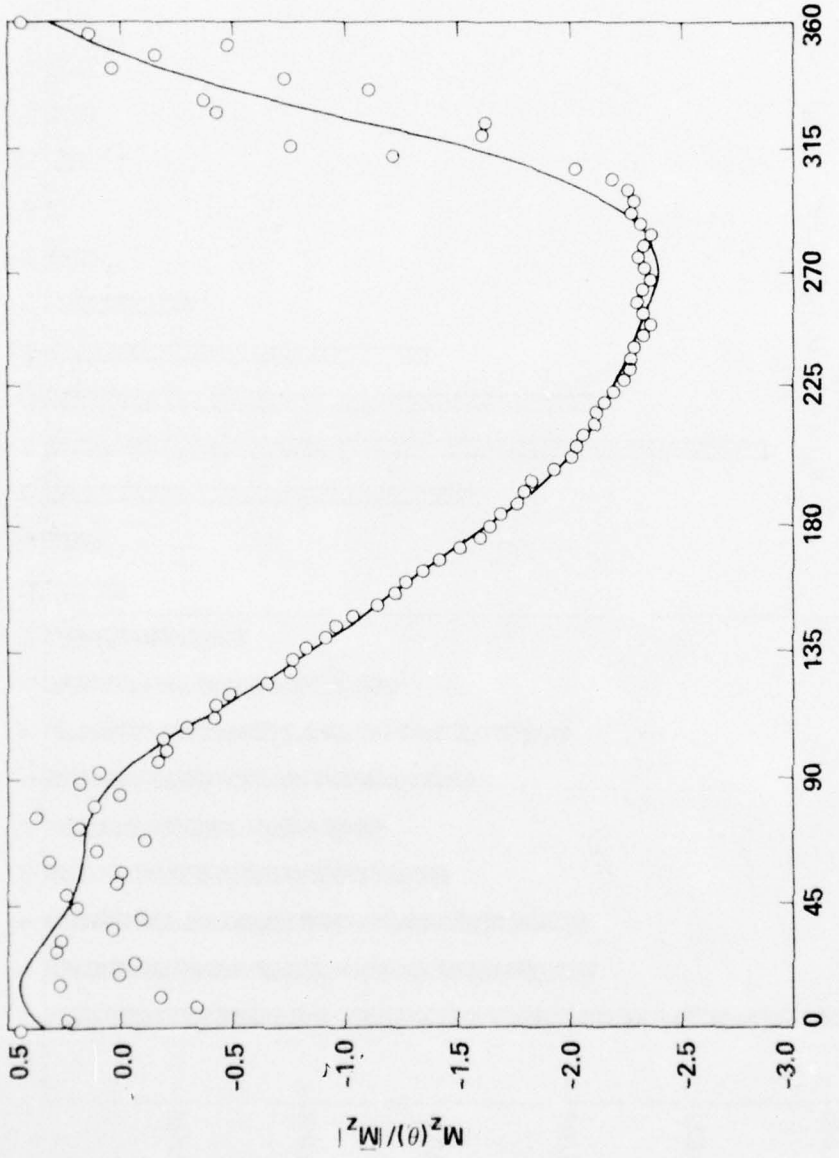



Figure 14f- $M_z$

Figure 15 - Experimental Data Showing Extraneous Higher Harmonics

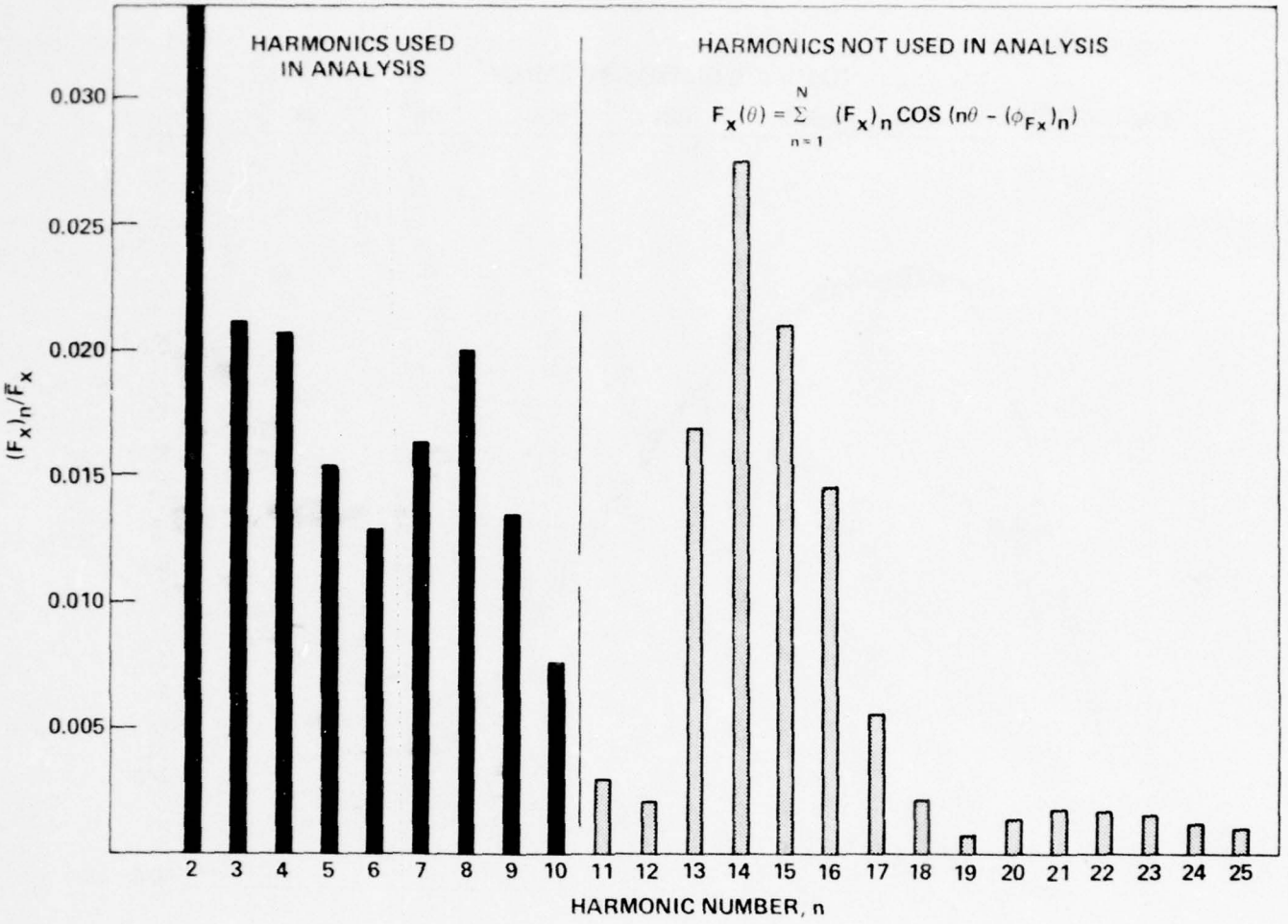



Figure 15a - $F_x$

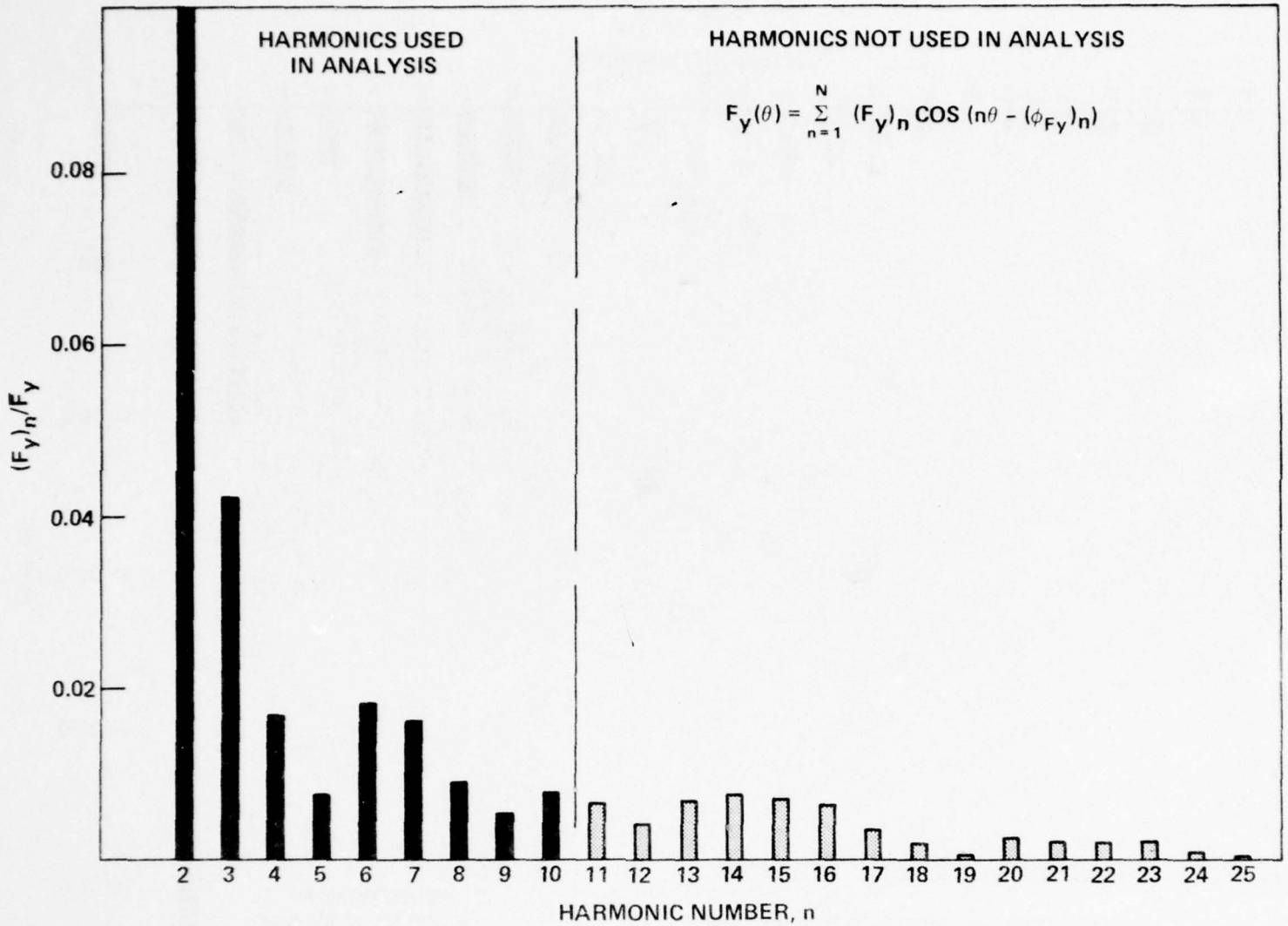



Figure 15b- $F_y$

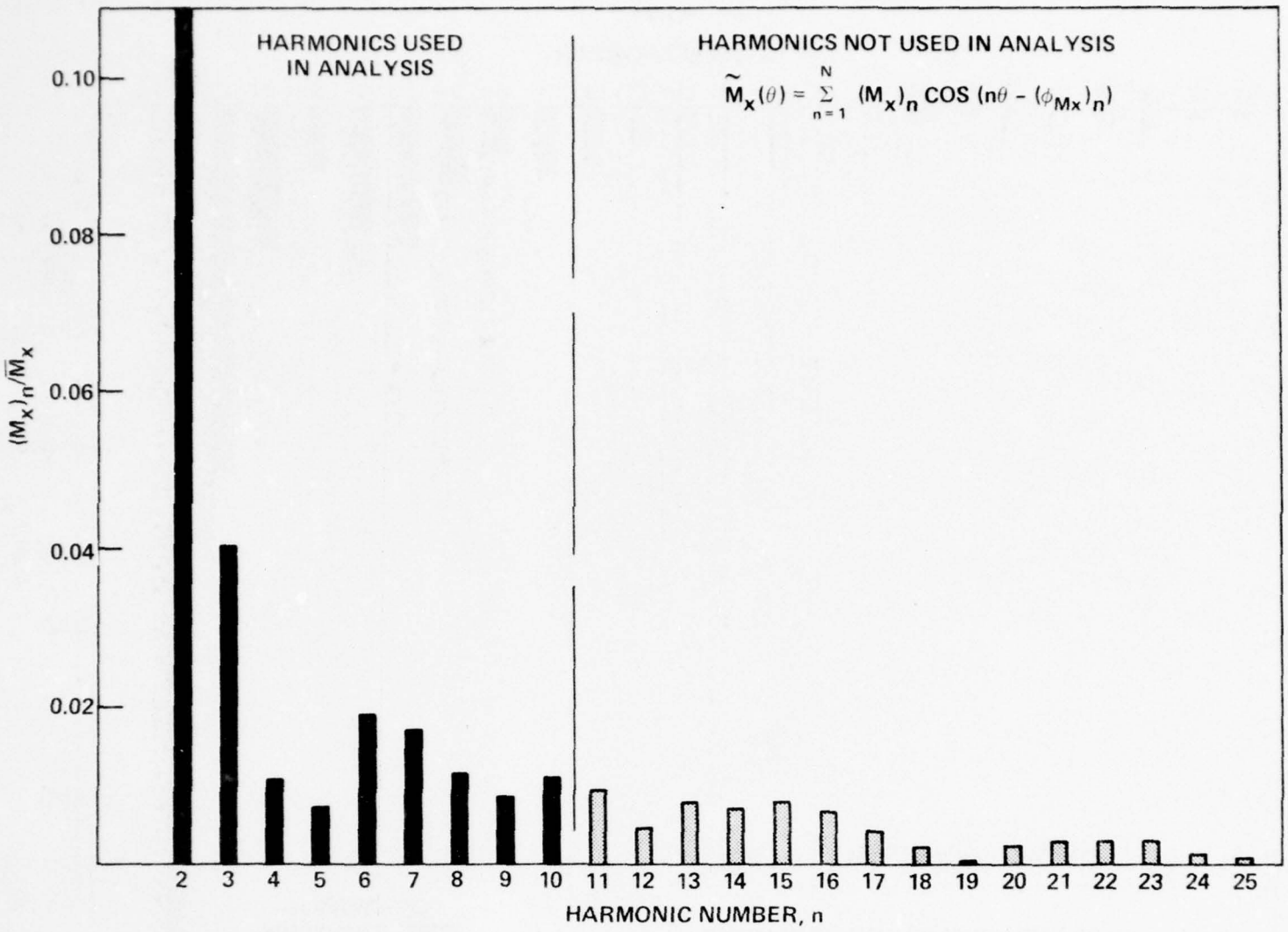



Figure 15c- $M_x$

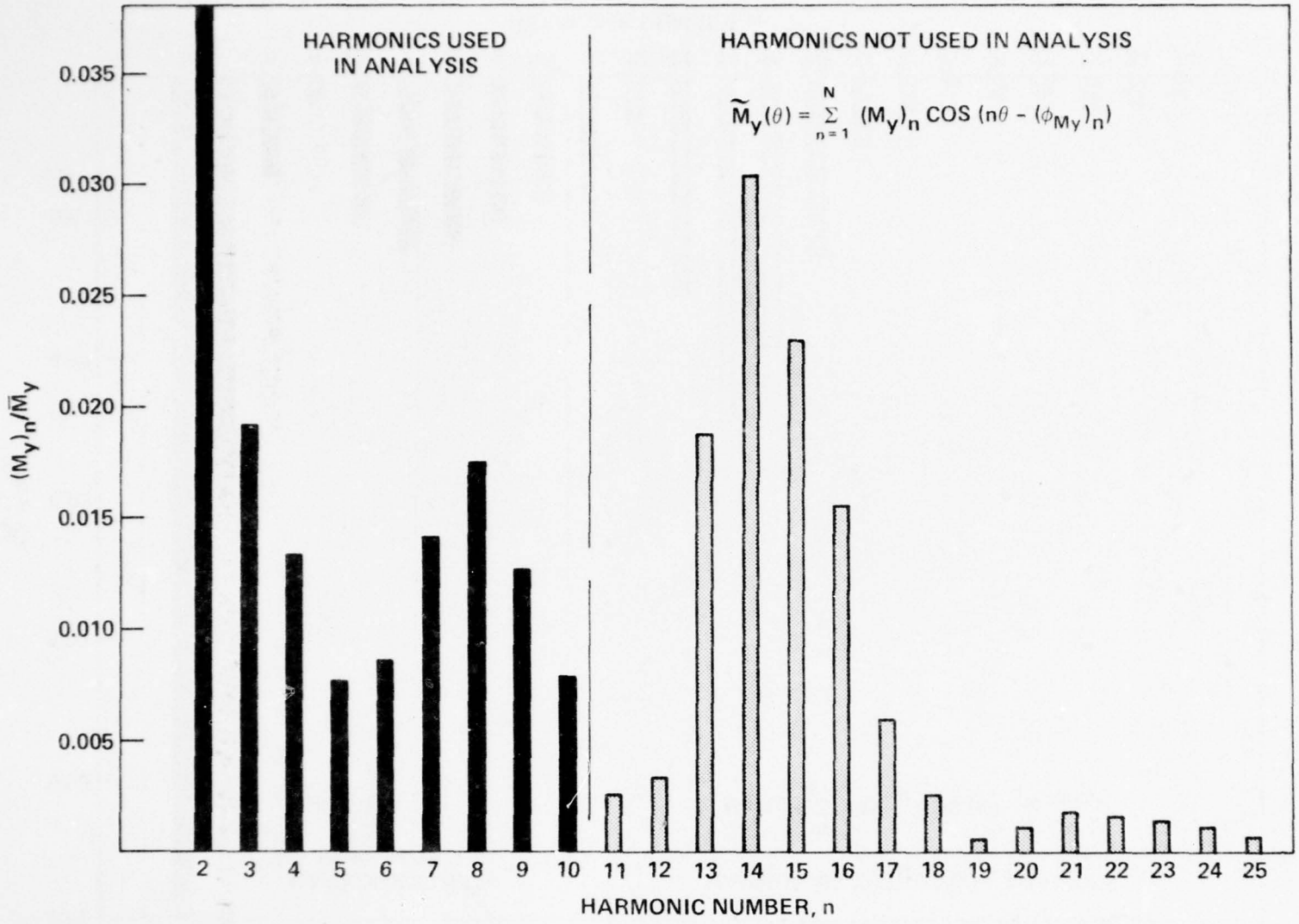



Figure 15d- $M_y$

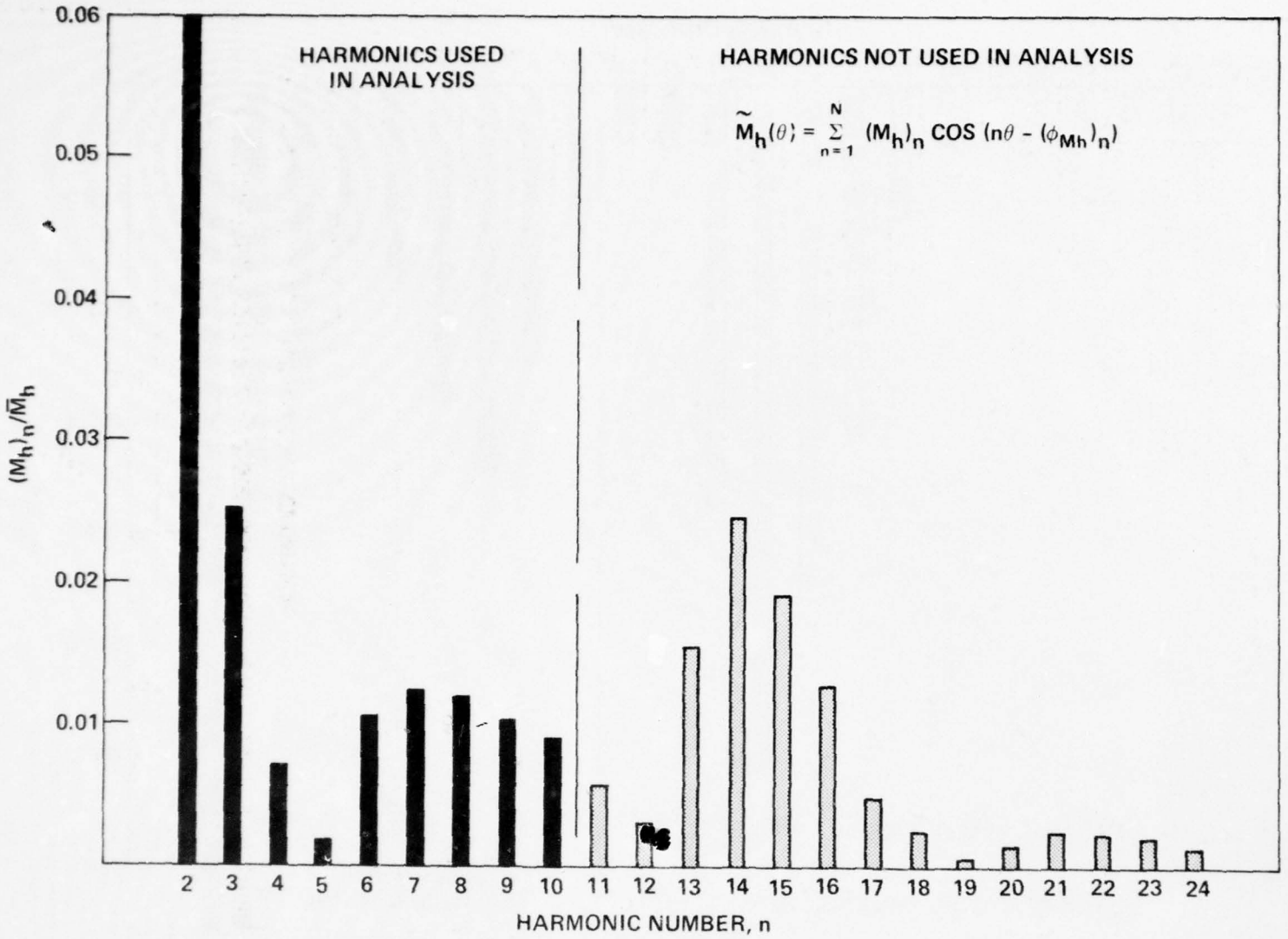
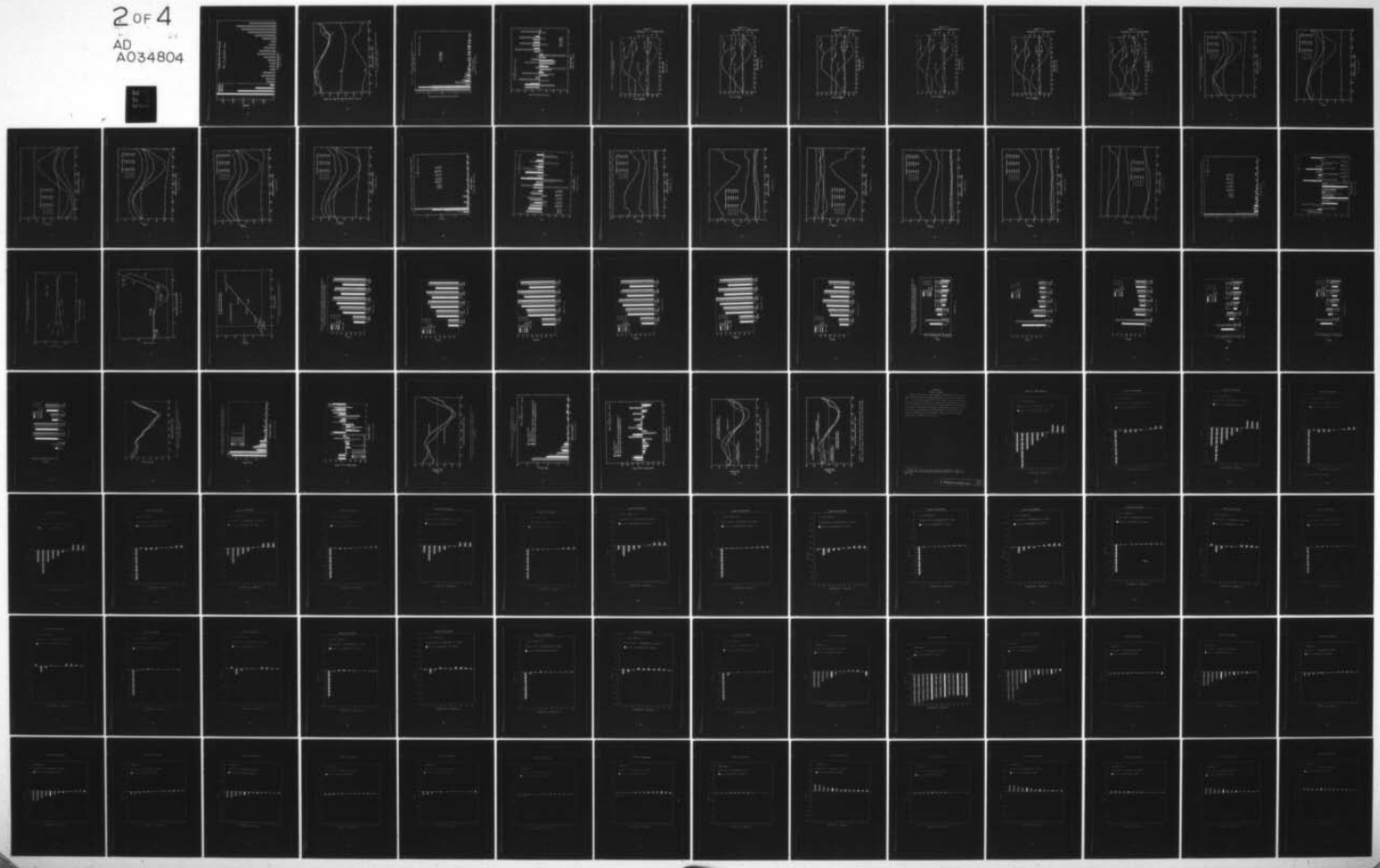



Figure 15e- $M_h$

AD-A034 804 DAVID W TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CE--ETC F/G 13/10
EXPERIMENTAL UNSTEADY AND MEAN LOADS ON A CP PROPELLER BLADE ON--ETC(U)
OCT 76 R J BOSWELL, J J NELKA , S B DENNY

UNCLASSIFIED DTNSRDC-76-0125 NL

2 OF 4
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A034804



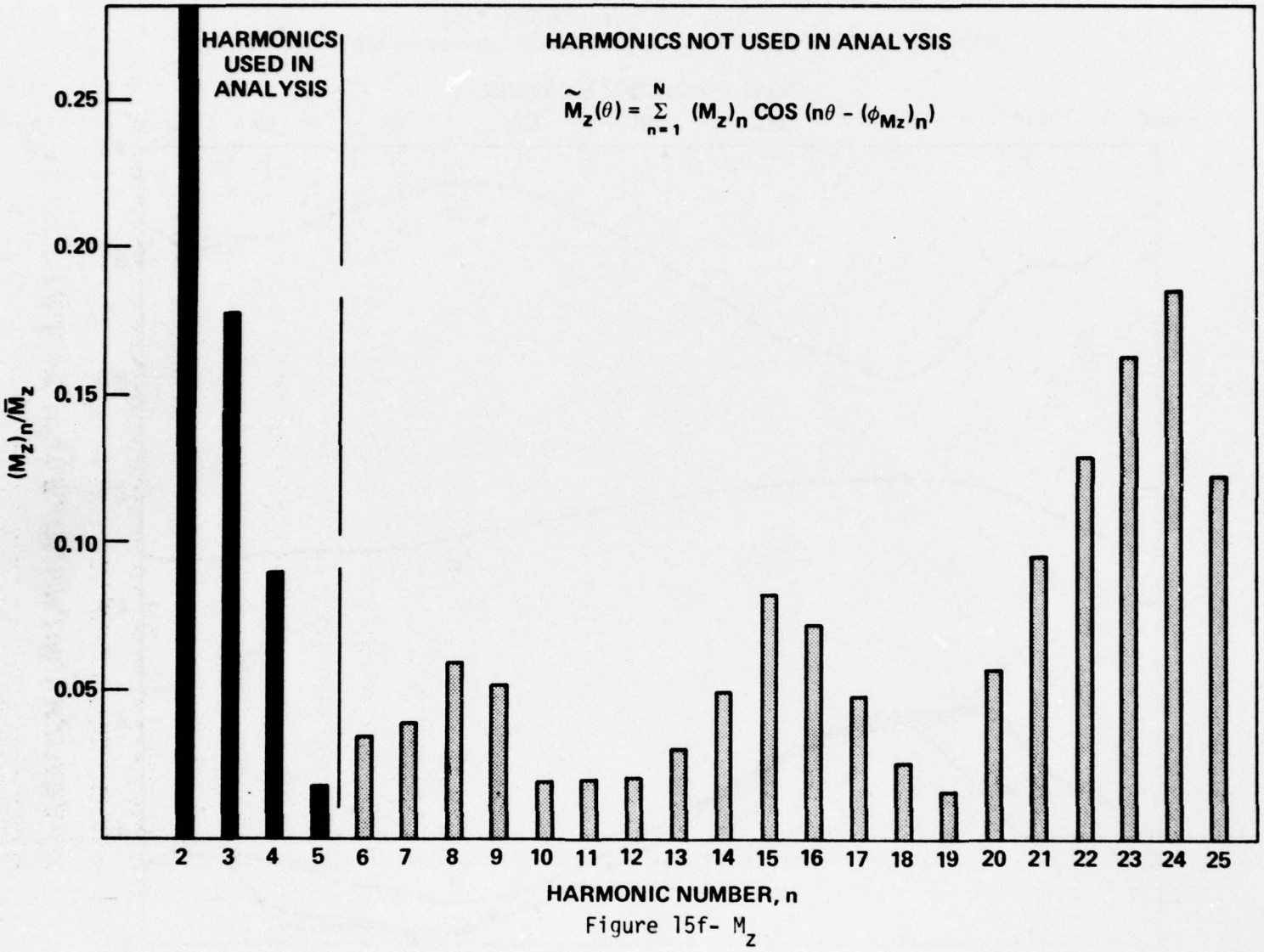



Figure 15f- $M_z$

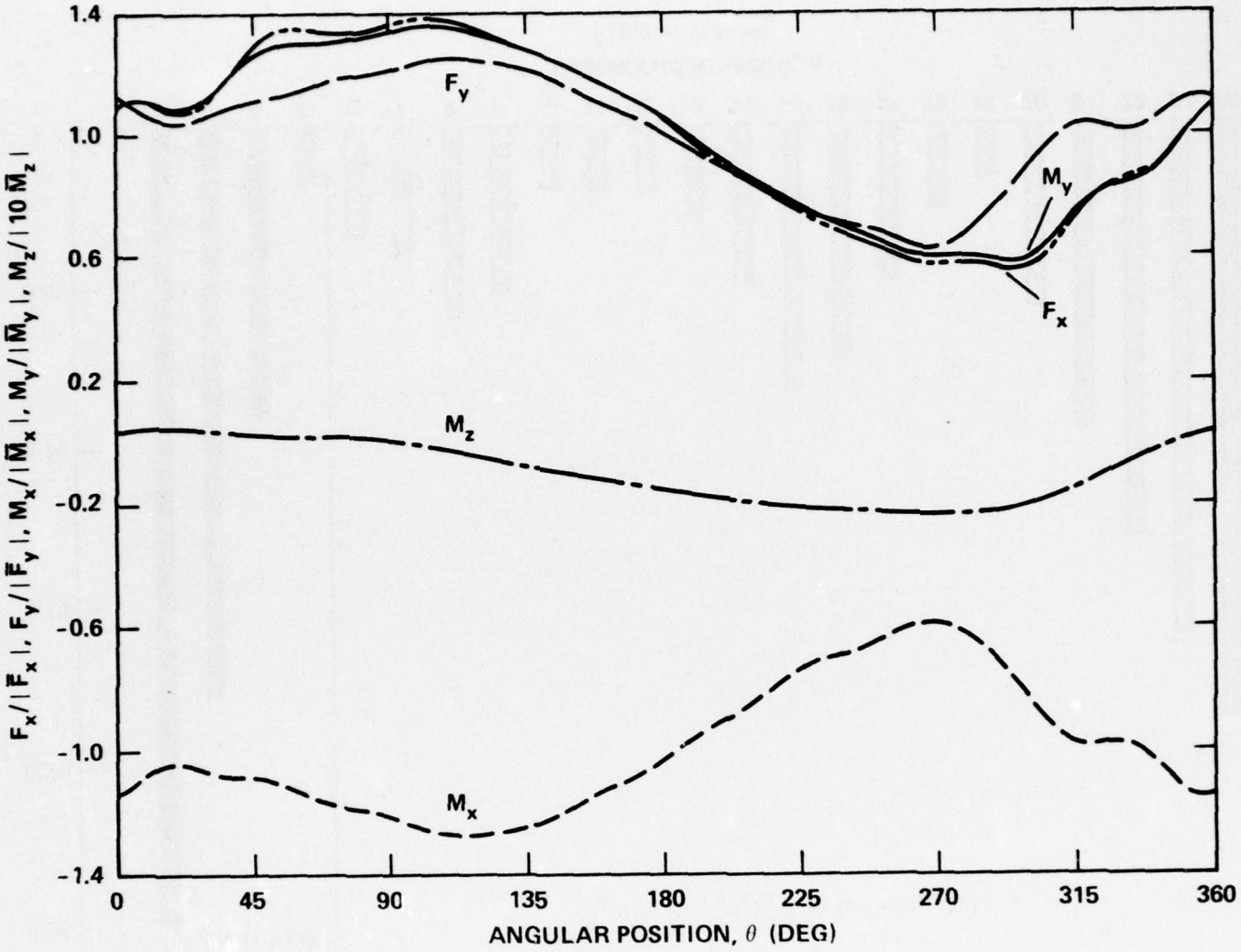



Figure 16 - Variation of Experimental Loads with Angular Position for Steady Ahead Operation

Figure 17 - Harmonic Content of Experimental Loads for Steady Ahead Operation

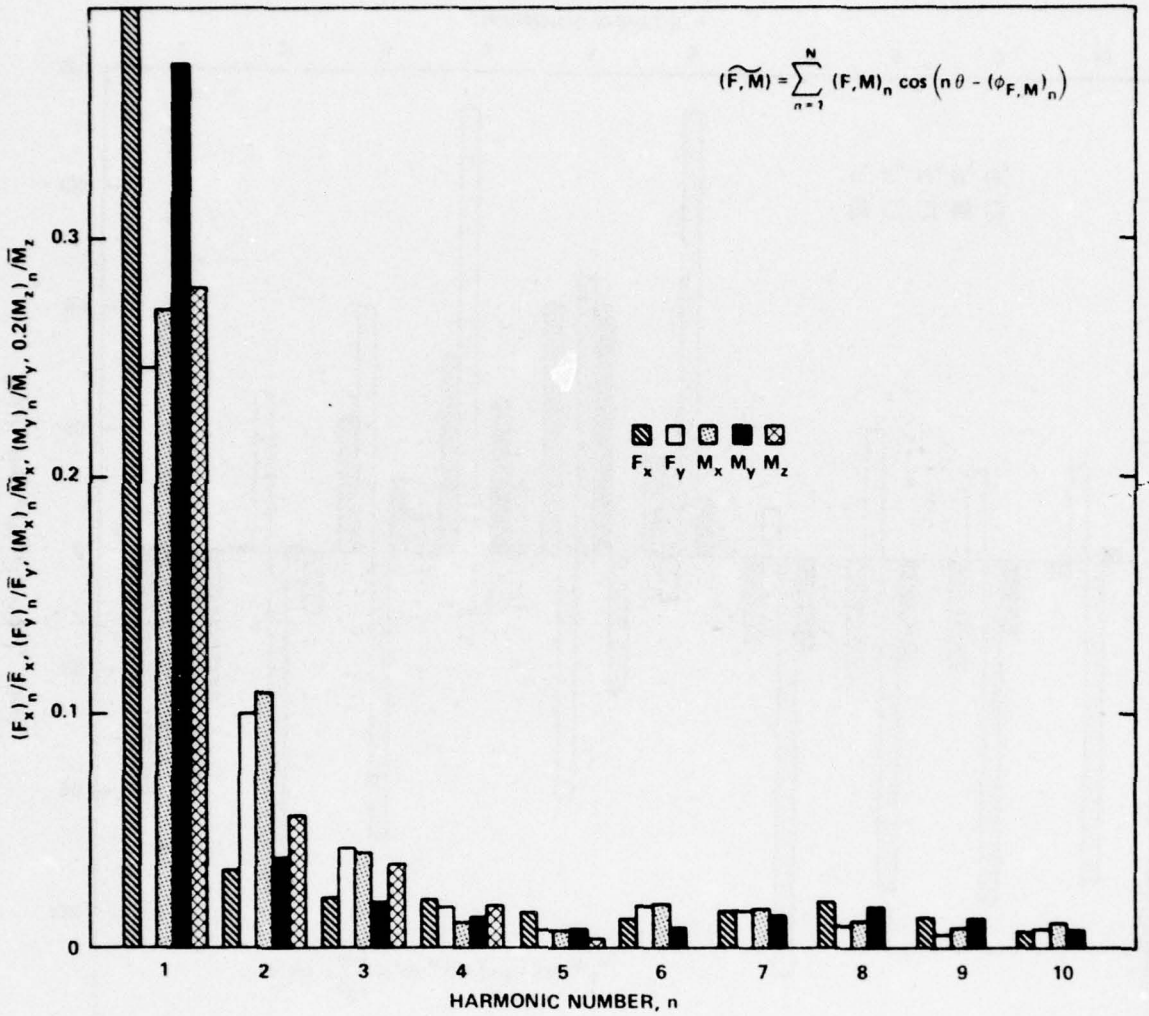



Figure 17a - Amplitudes

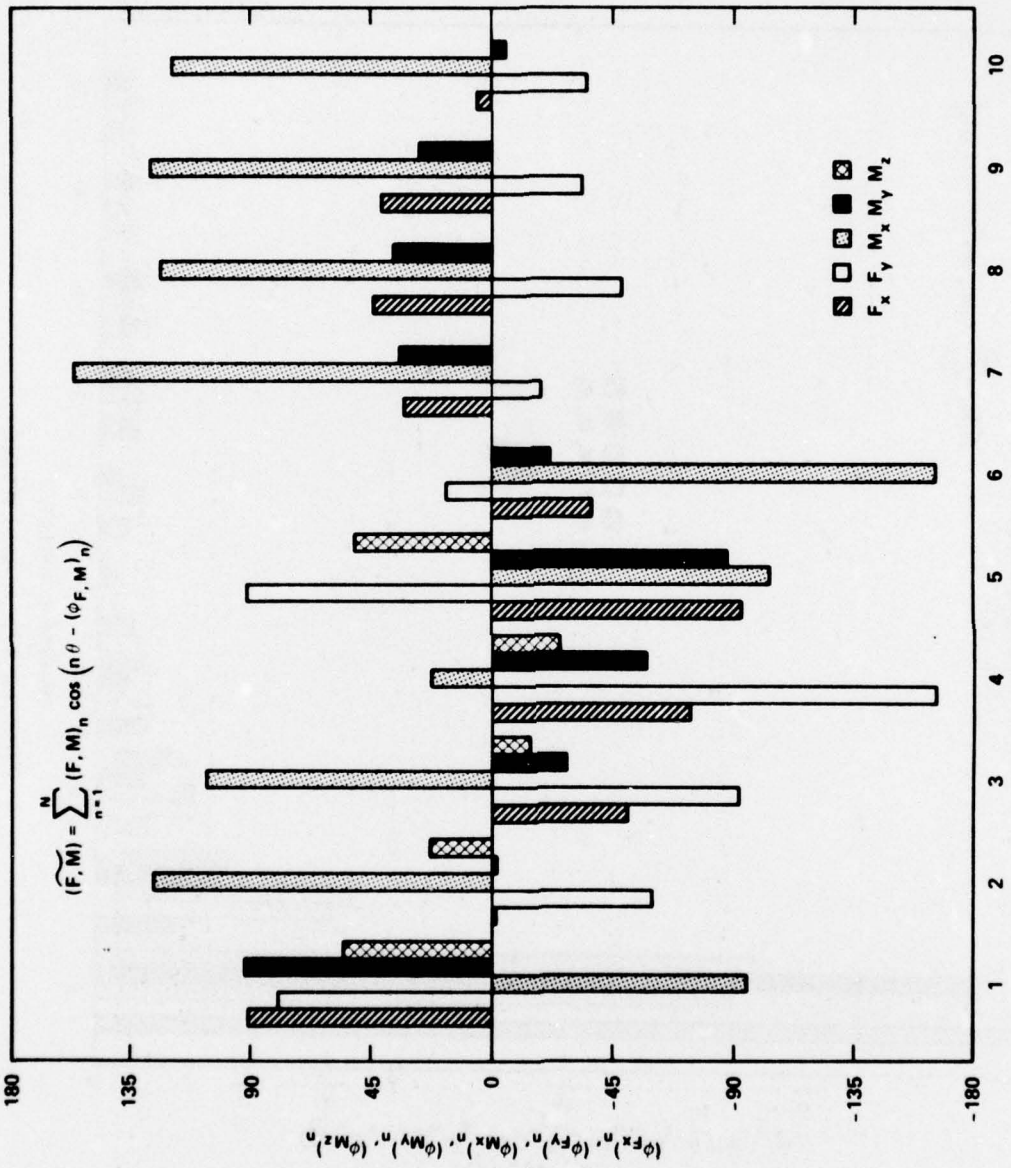



Figure 17b - Phases

Figure 18 - Variation of Components of Blade Loading with Hull Pitch Angle $\psi$

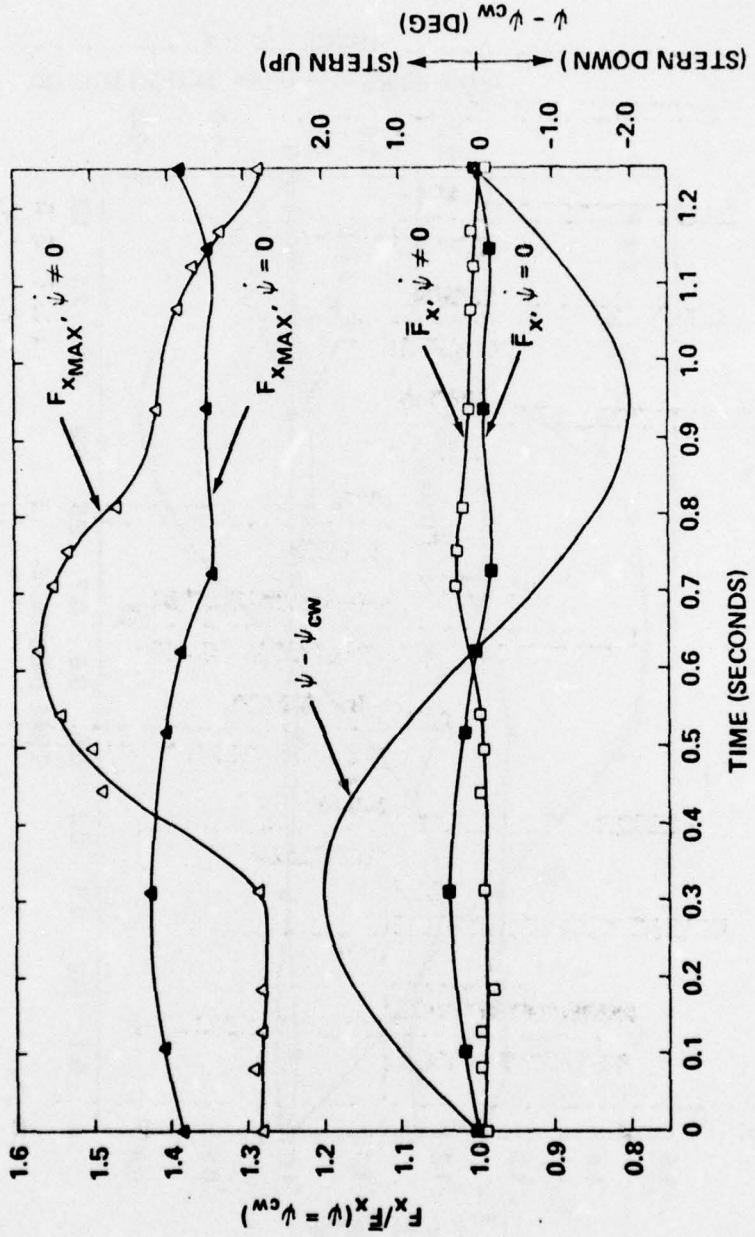



Figure 18a - $F_x$

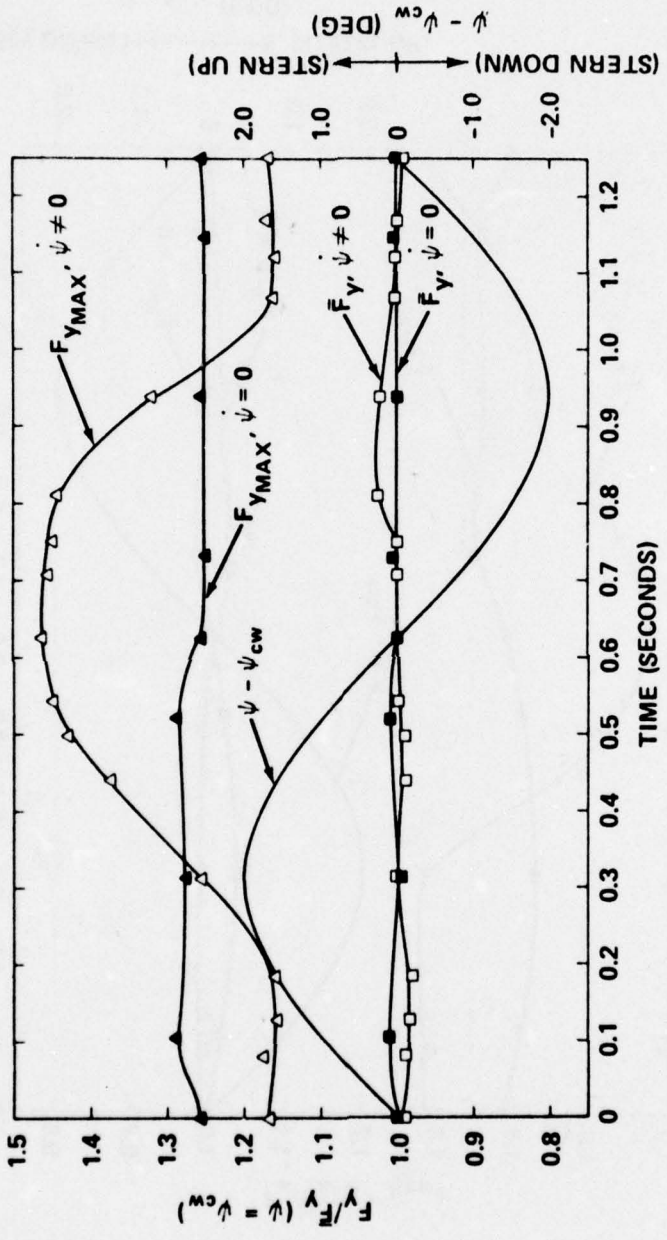



Figure 18b - $F_y$

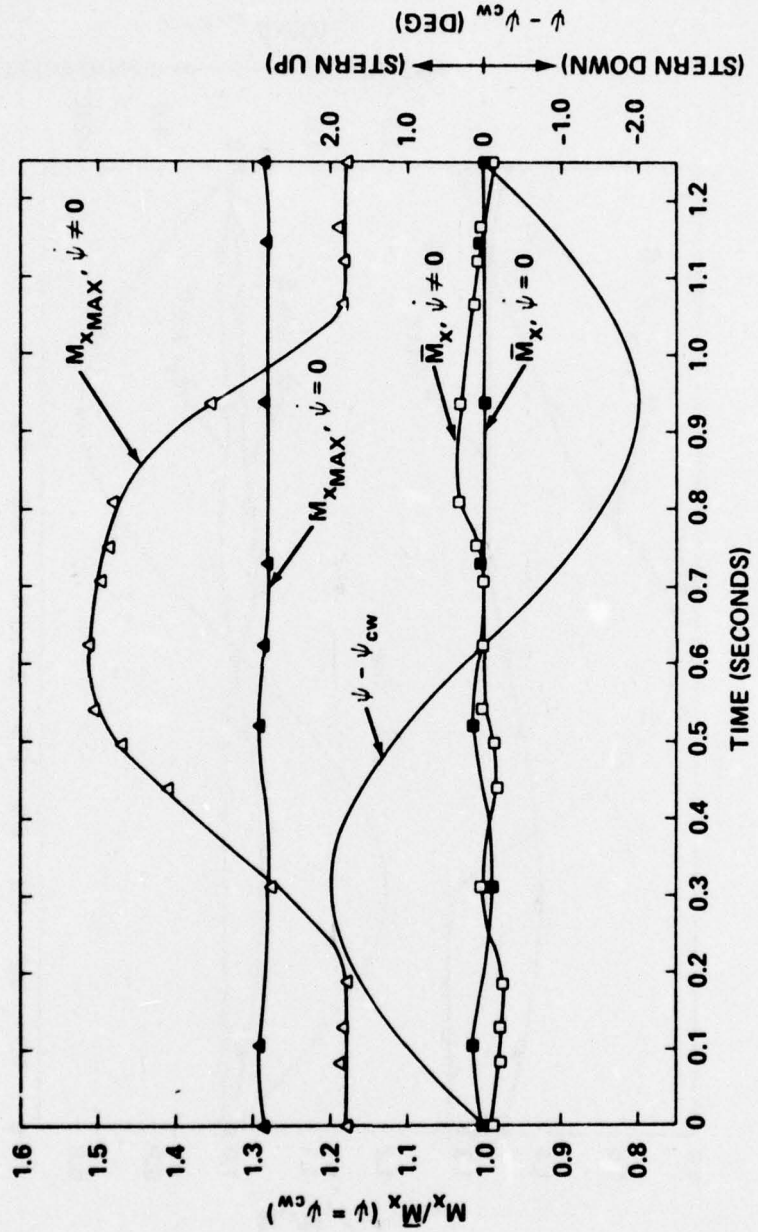



Figure 18c - $M_x$

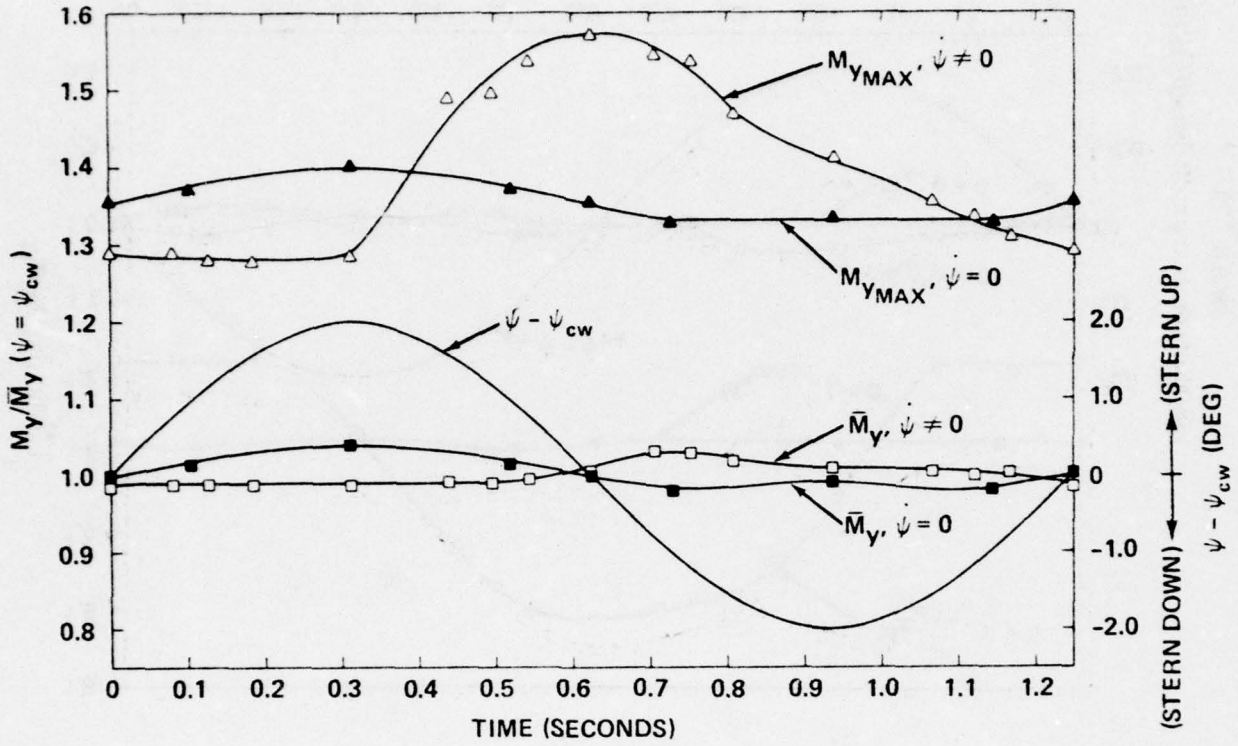



Figure 18d - $M_y$

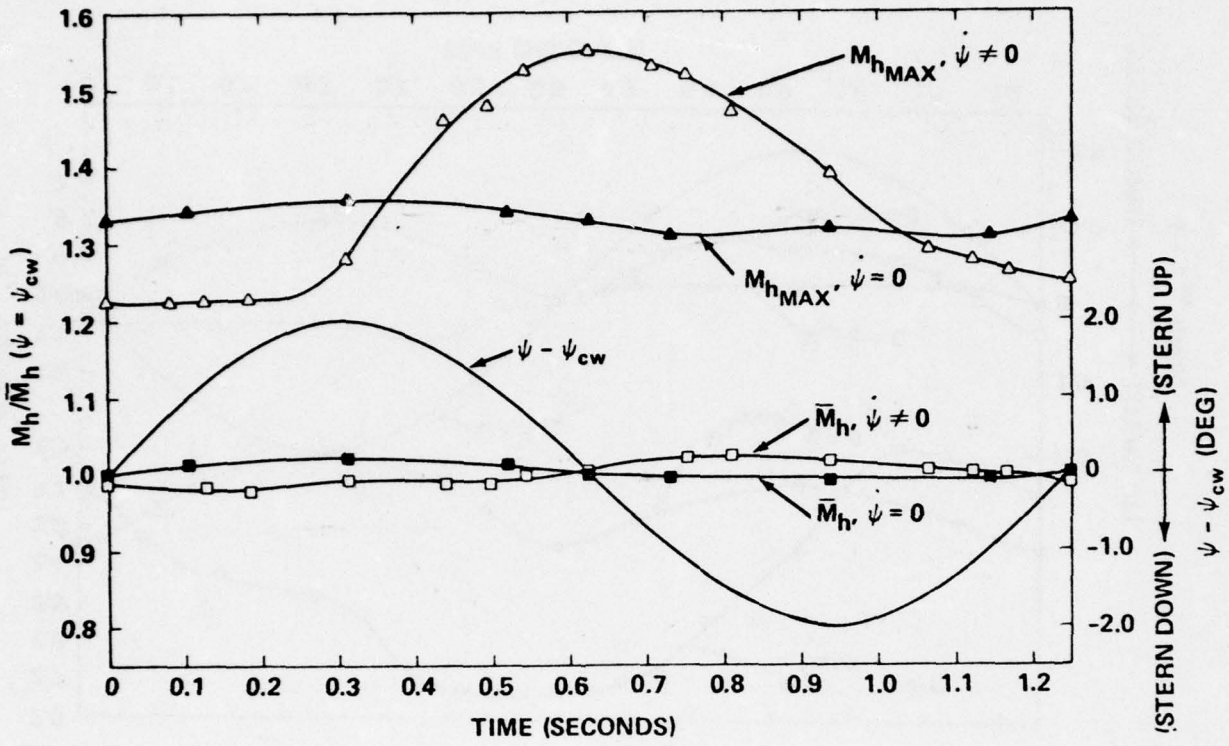



Figure 18e - $M_h$

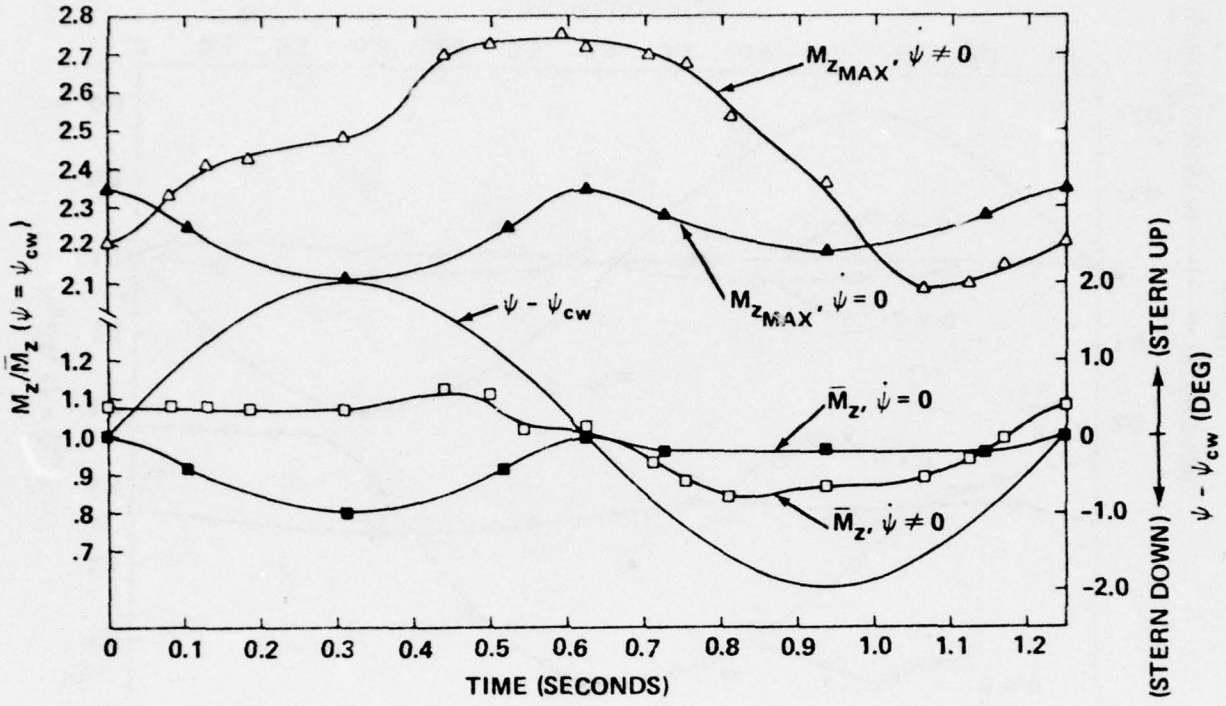



Figure 18f - $M_z$

Figure 19 - Variation of Loads with Angular Position for Quasi-Steady Crash Ahead

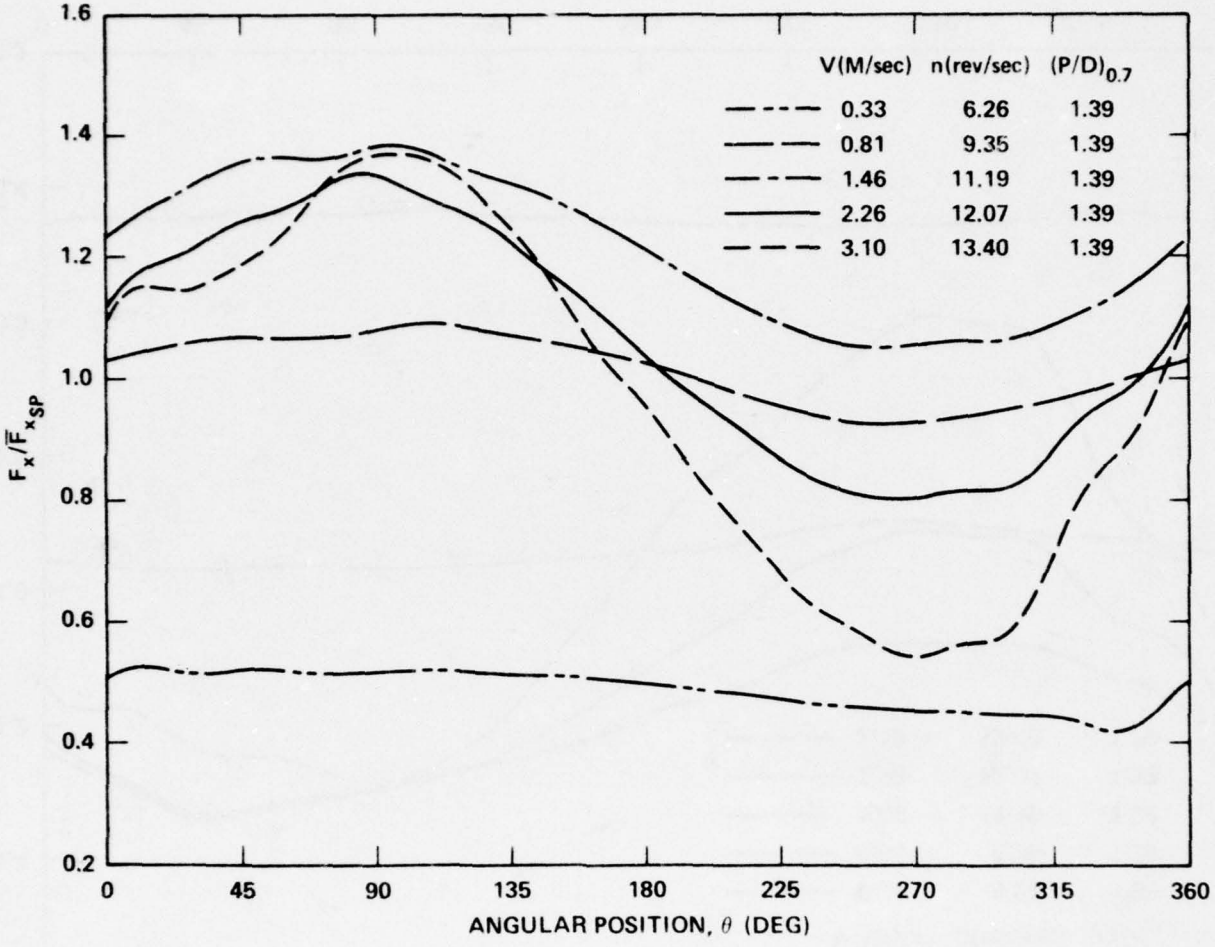



Figure 19a - $F_x$

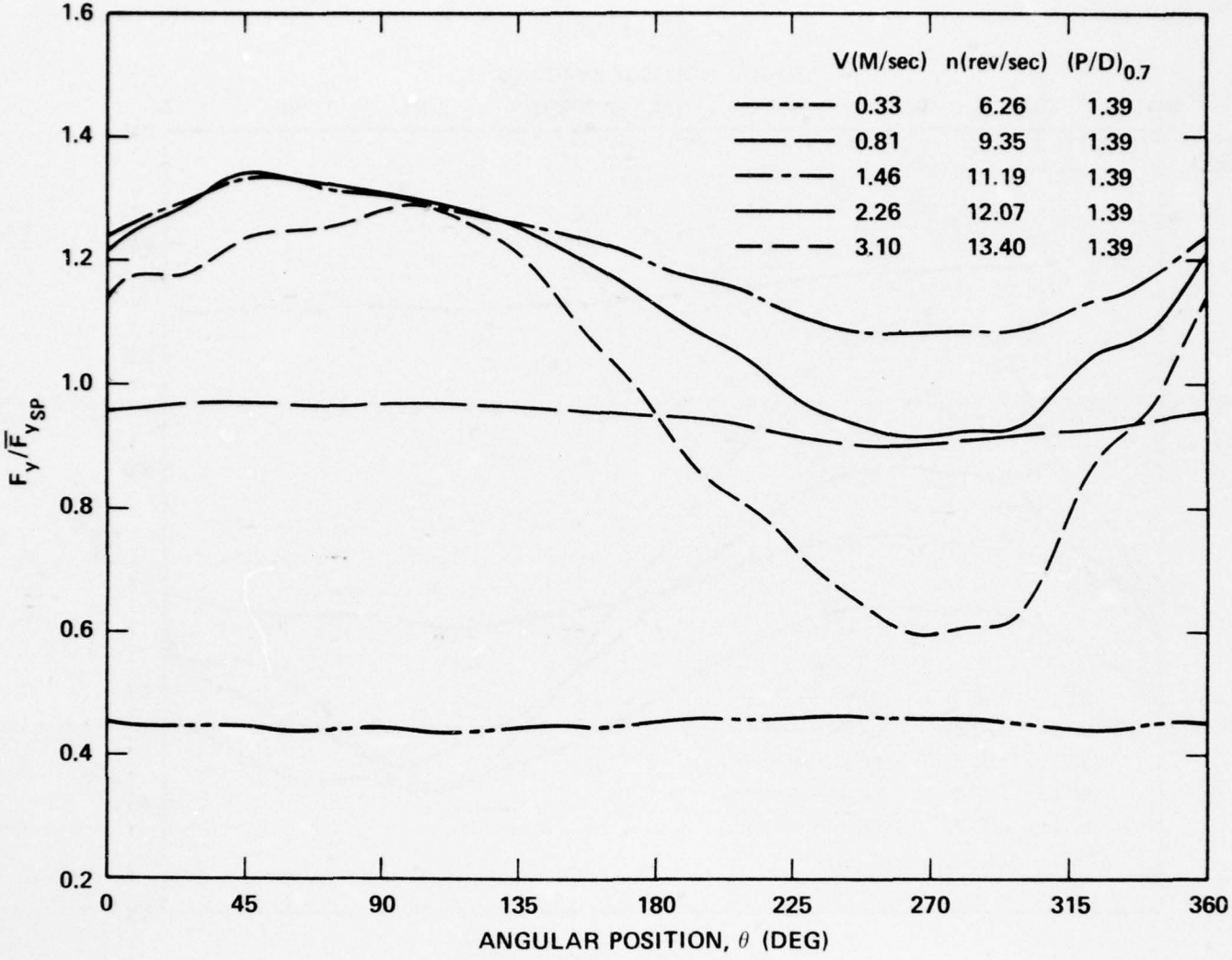



Figure 19b- $F_y$

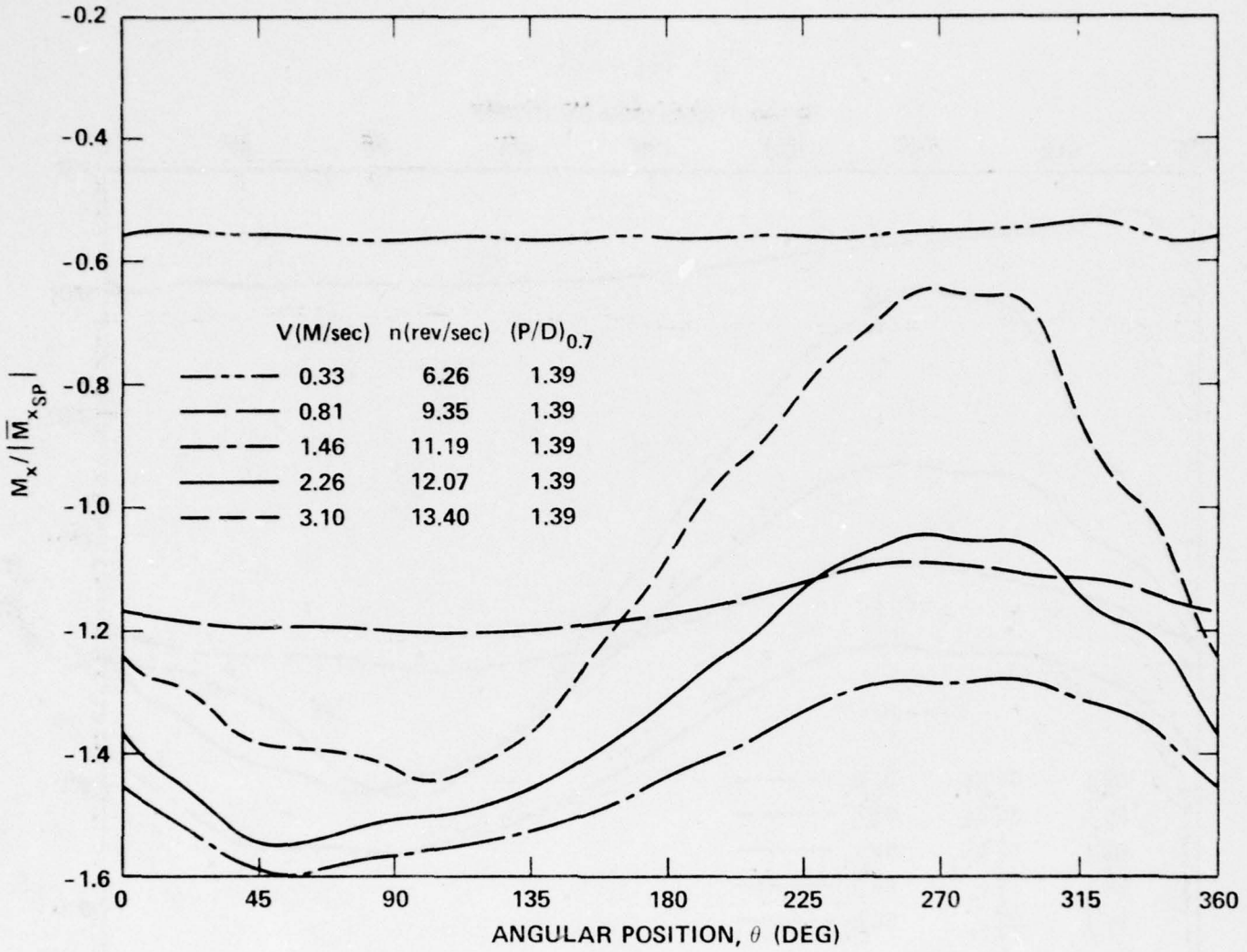



Figure 19c- $M_x$

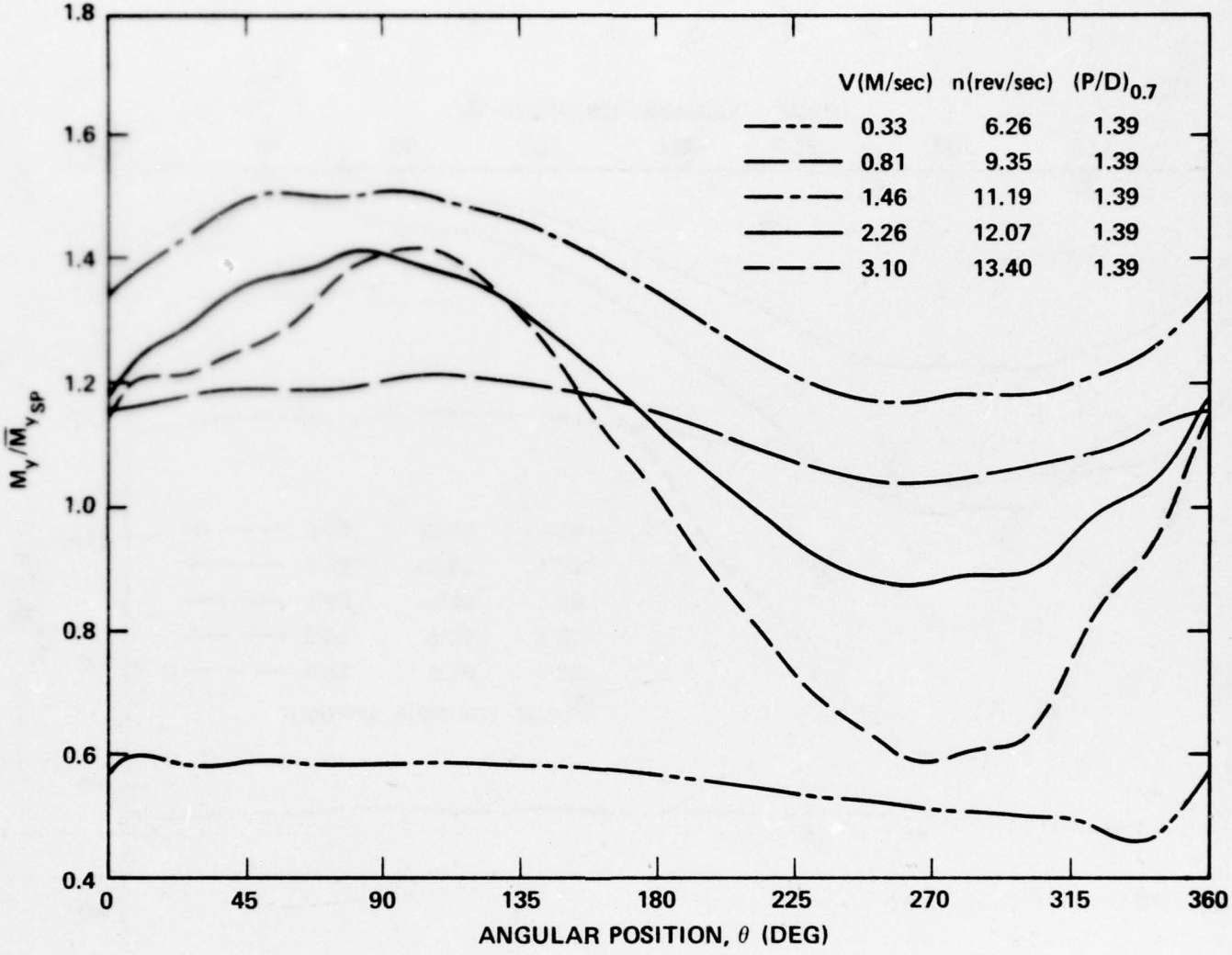



Figure 19d - $M_y$

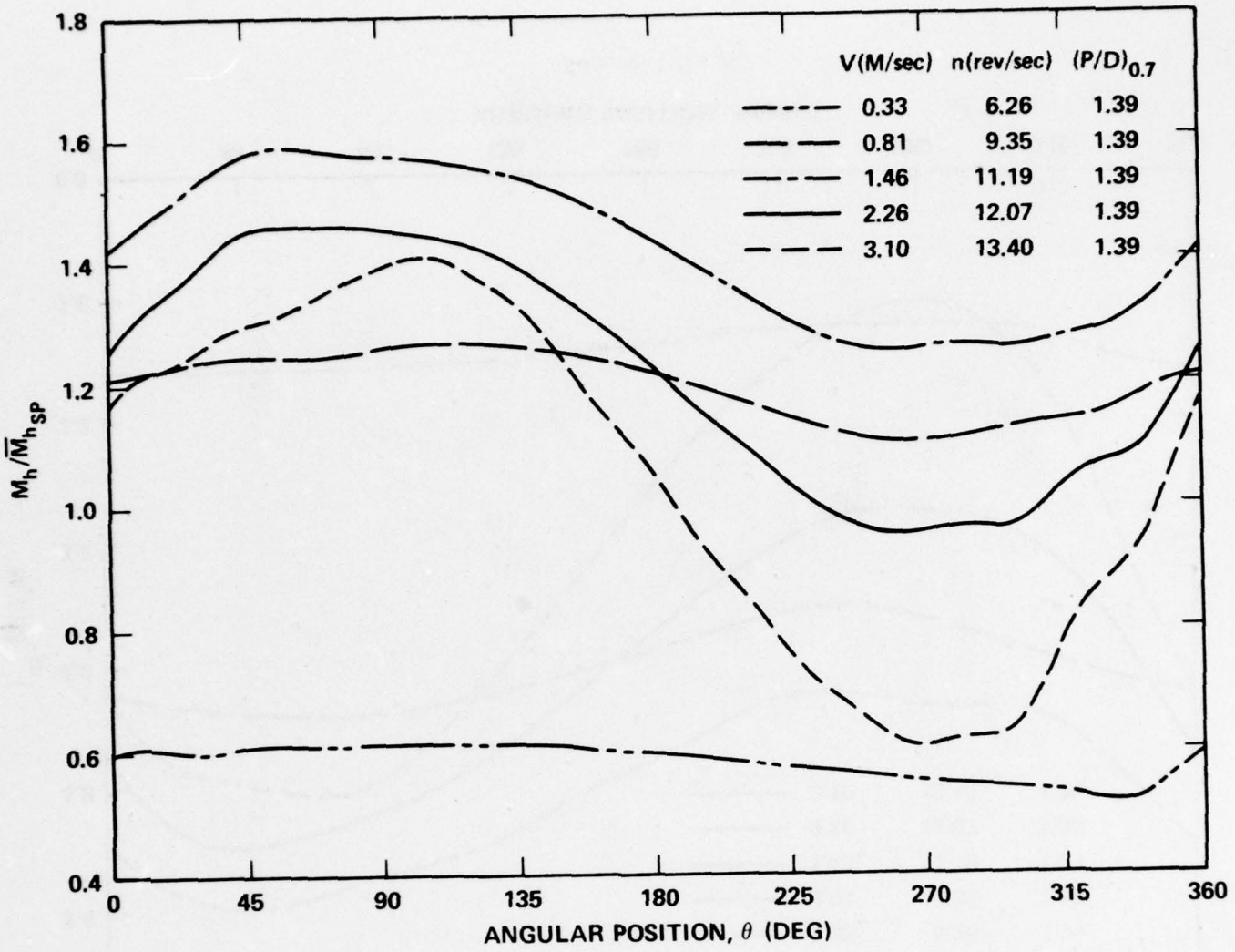



Figure 19e- $M_h$

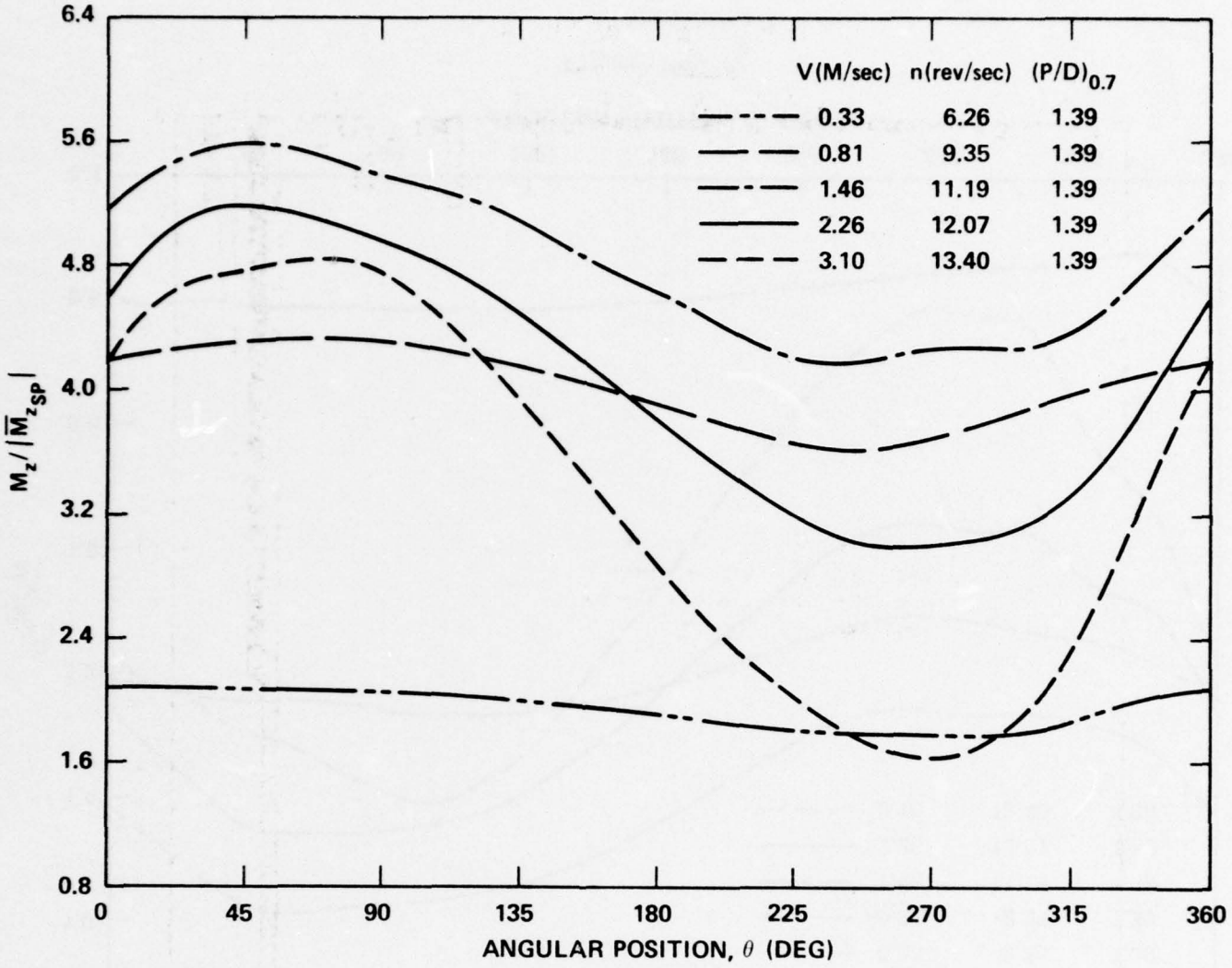



Figure 19f- $M_z$

Figure 20 - Harmonic Content of $F_x$ for Quasi-Steady Crash Ahead

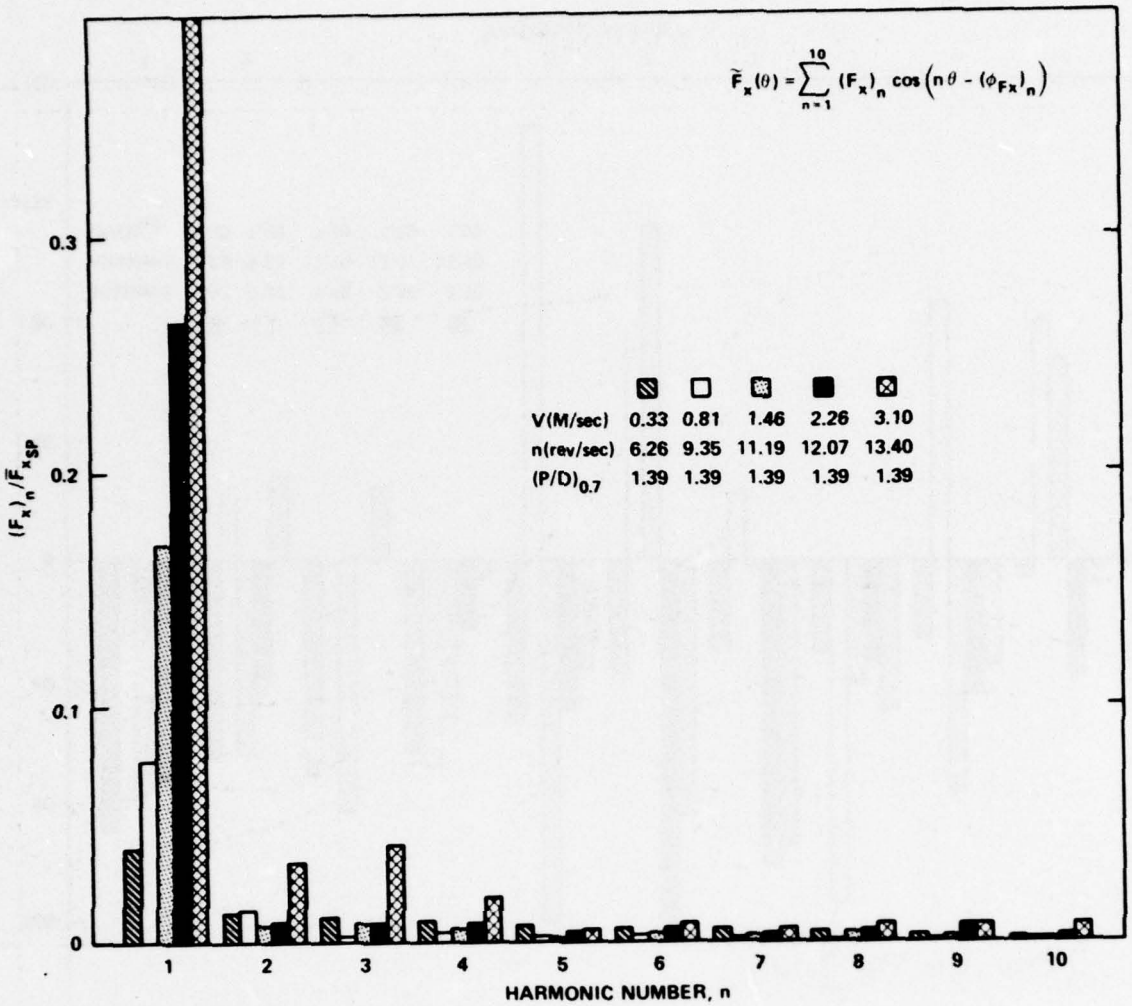



Figure 20a - Amplitudes

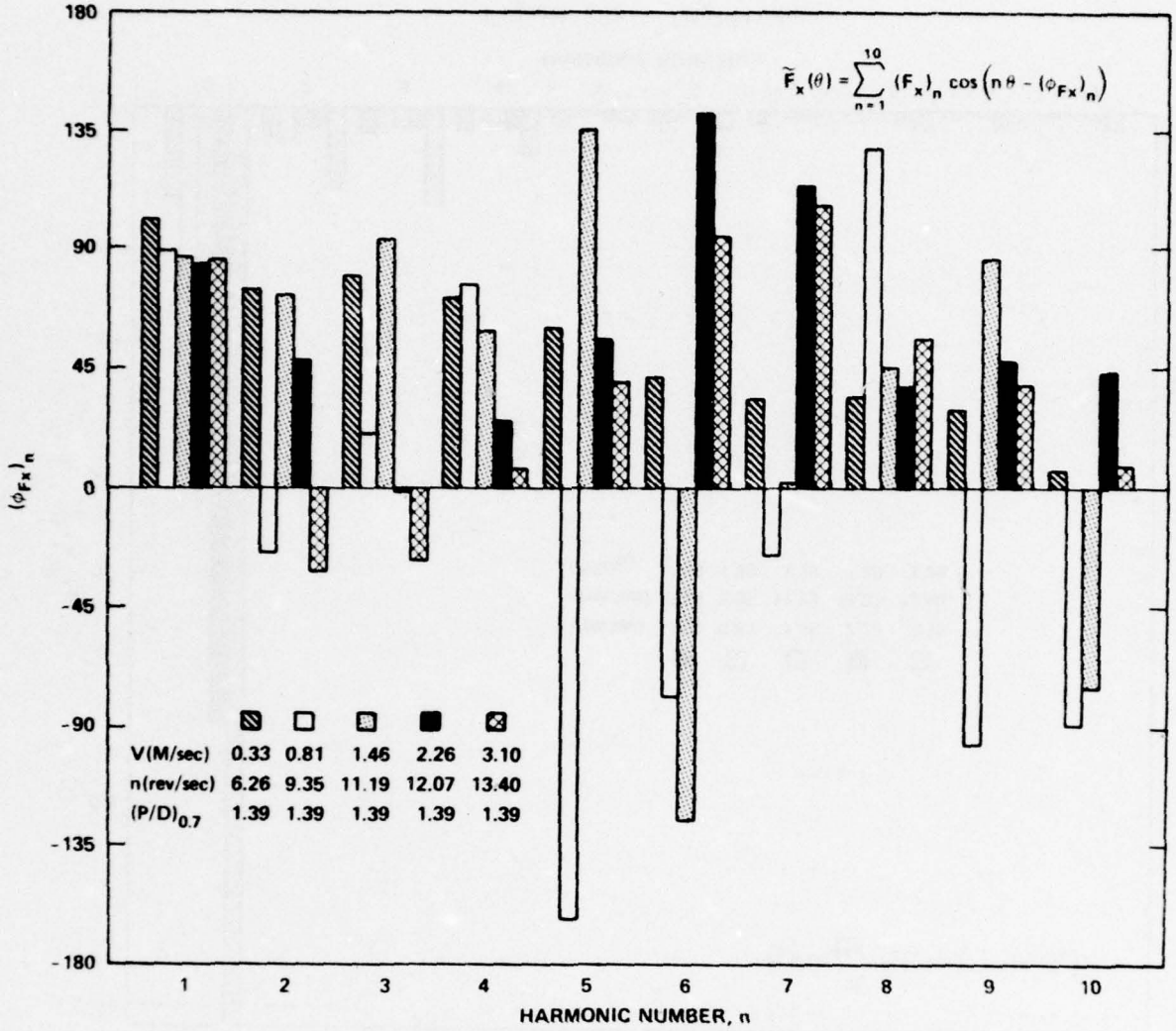



Figure 20b - Phases

Figure 21 - Variation of Loads with Angular Position for Quasi-Steady Crash Astern

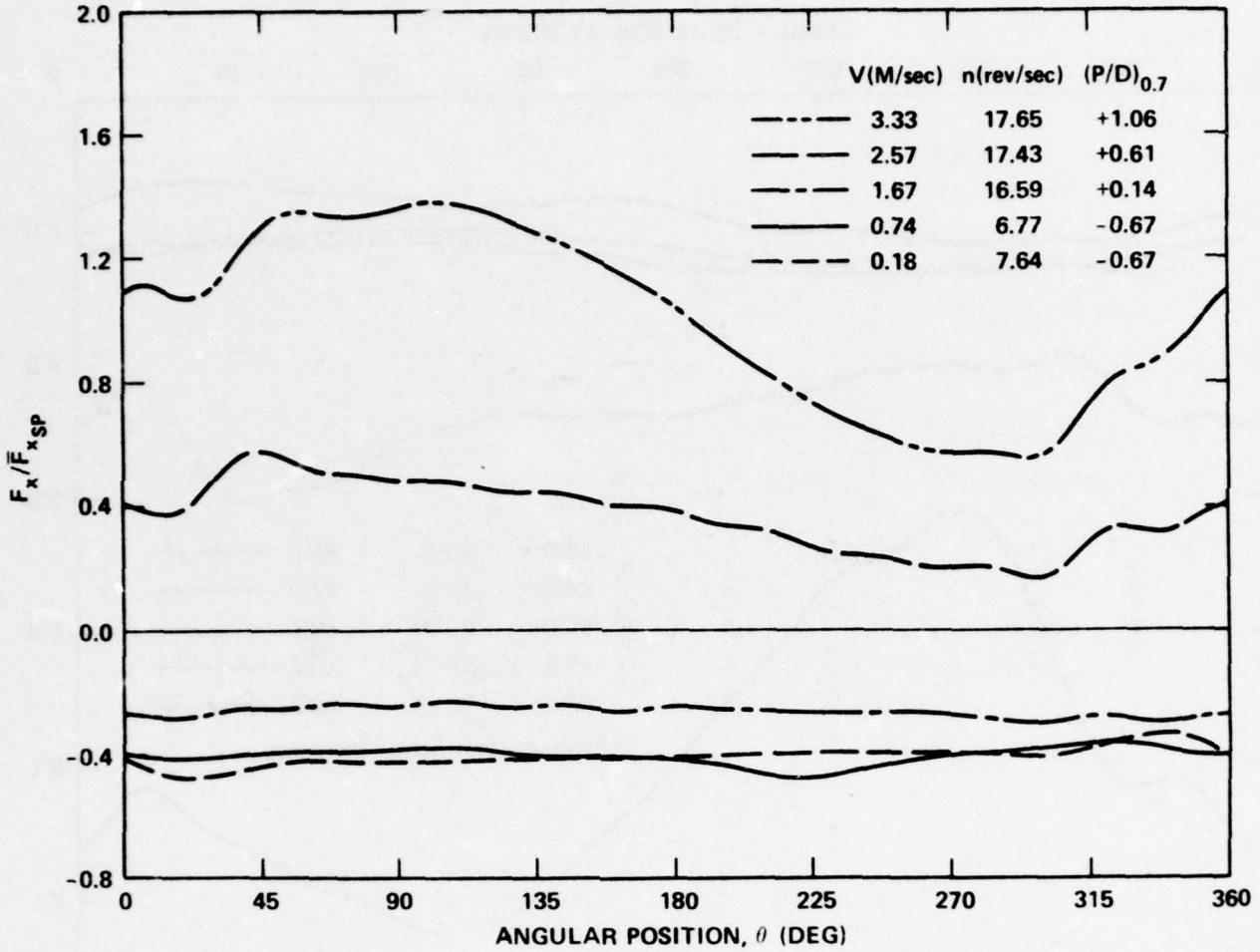



Figure 21a - $F_x$

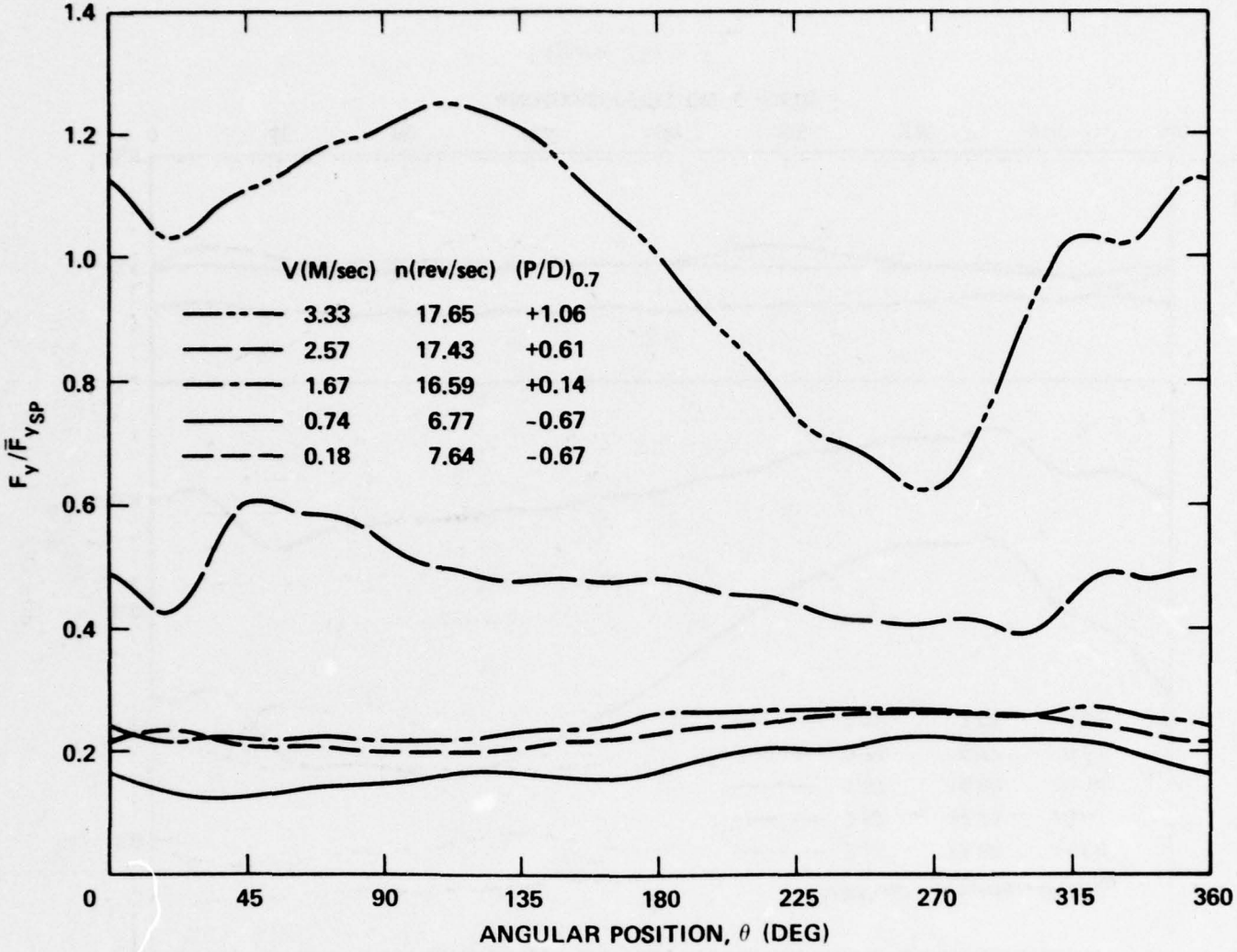



Figure 21b- $F_y$

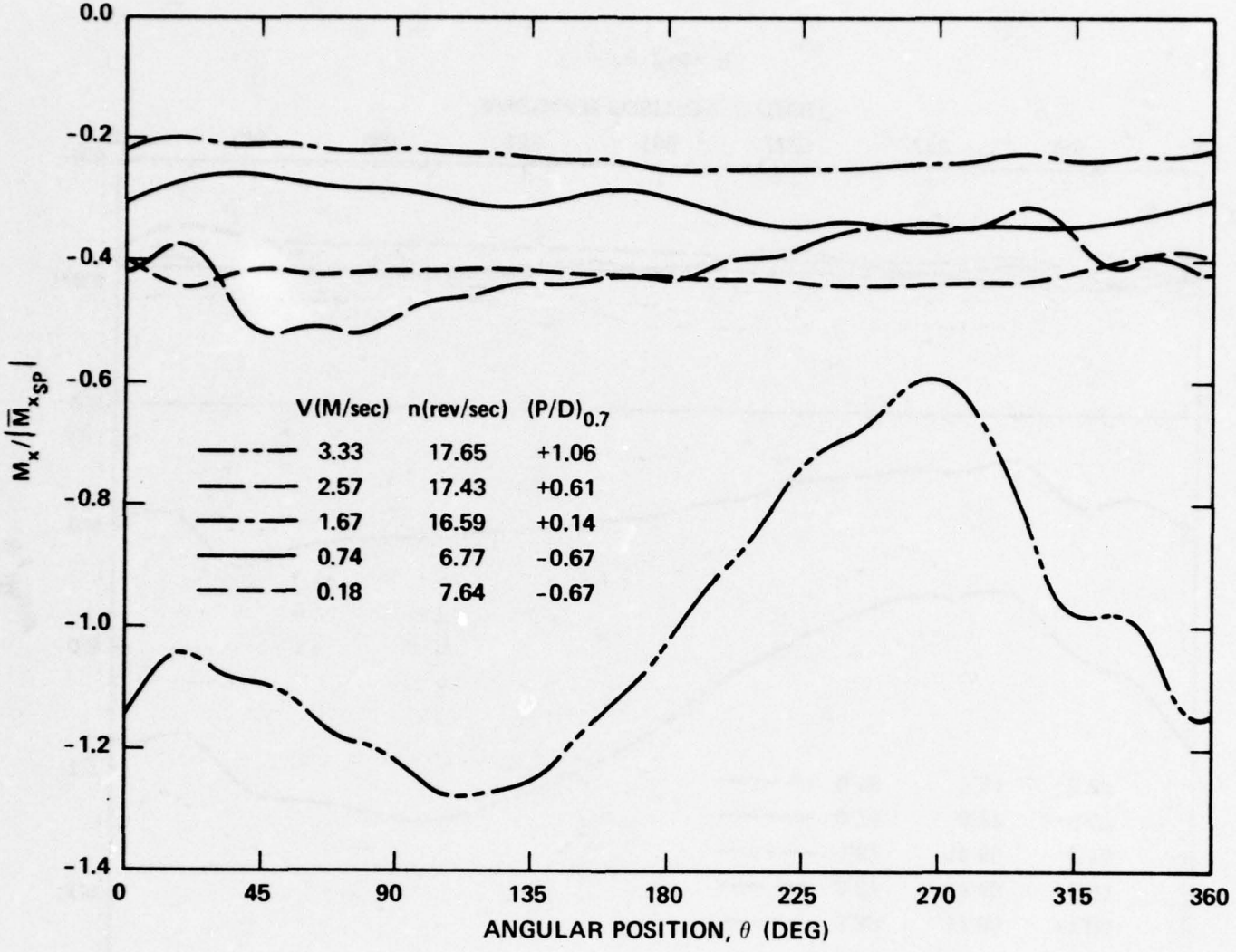



Figure 21c- $M_x$

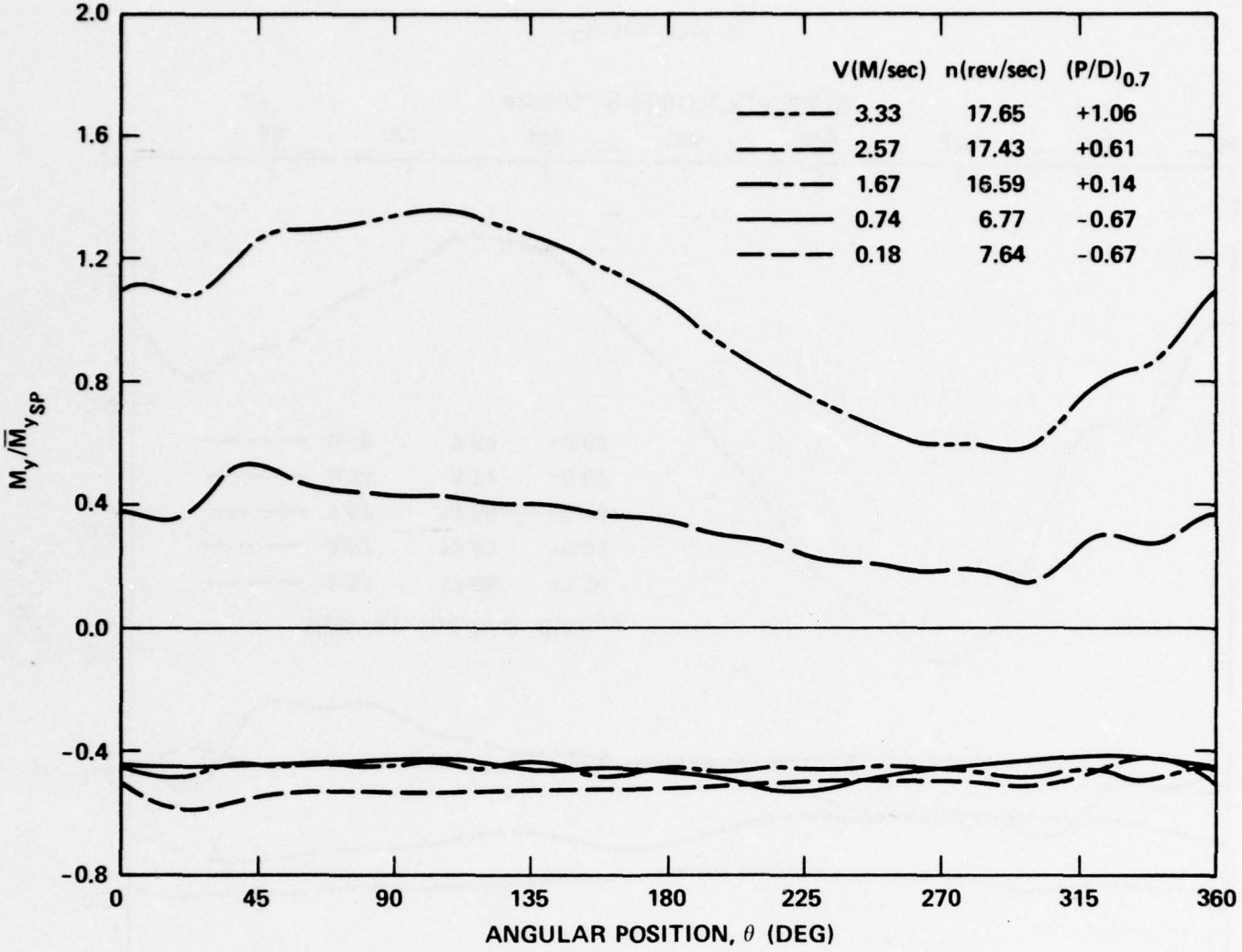



Figure 21d- $M_y$

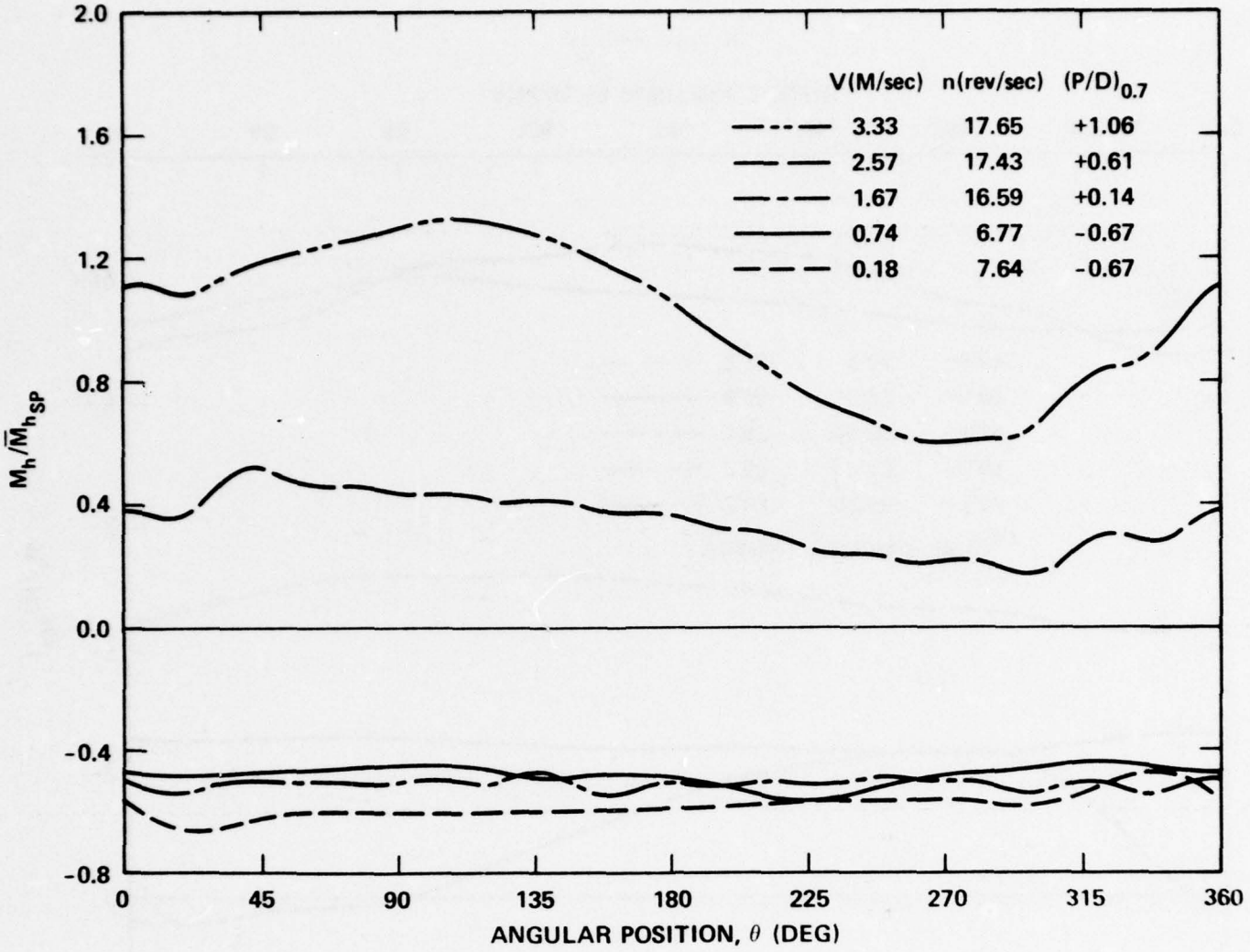



Figure 21e- $M_h$

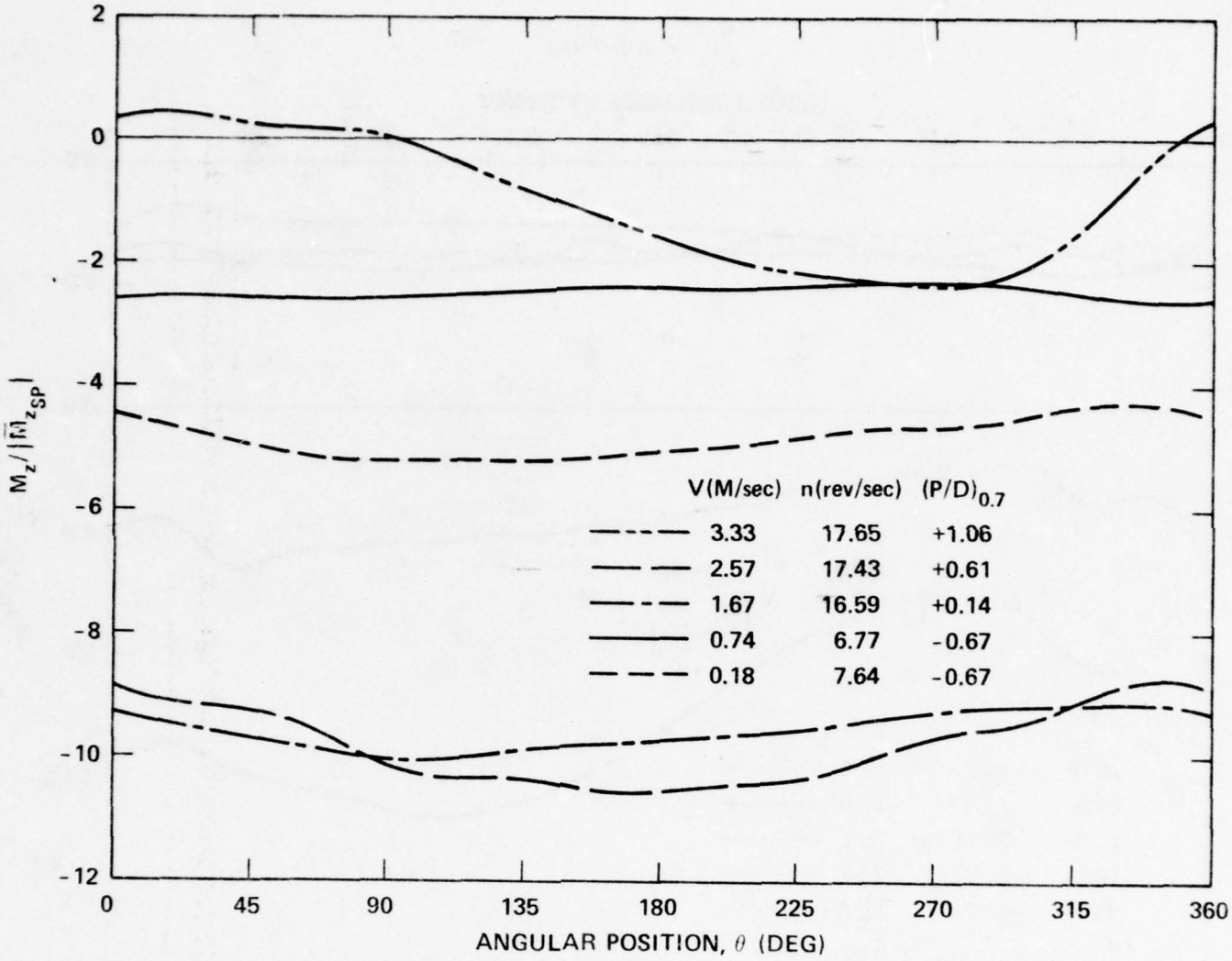



Figure 21f- $M_z$

Figure 22 - Harmonic Content of $F_X$ for Quasi-Steady Crash Astern

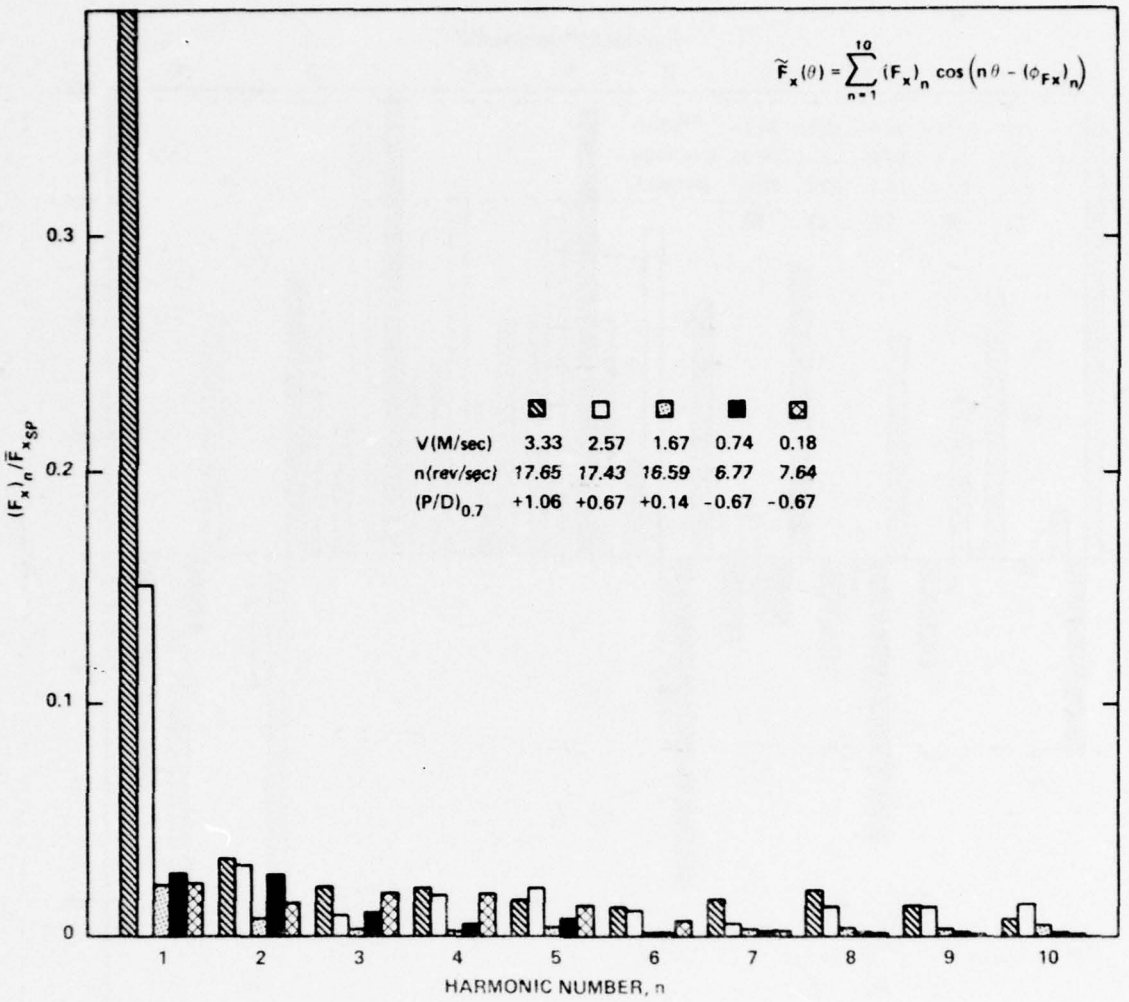



Figure 22a - Amplitudes

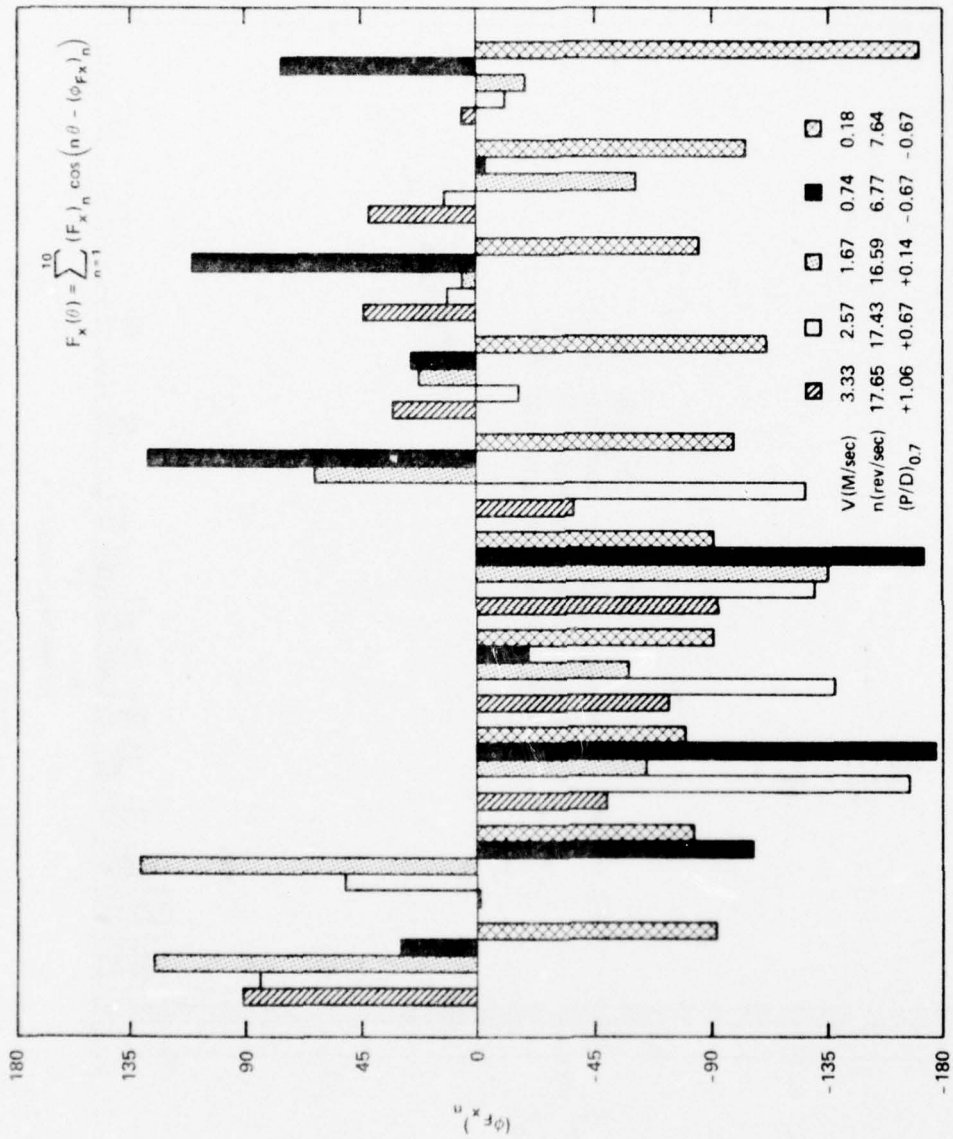



Figure 22b - Phases

Figure 23 - Taylor Wake Fractions during Simulated Crash Ahead and Crash Astern Maneuvers

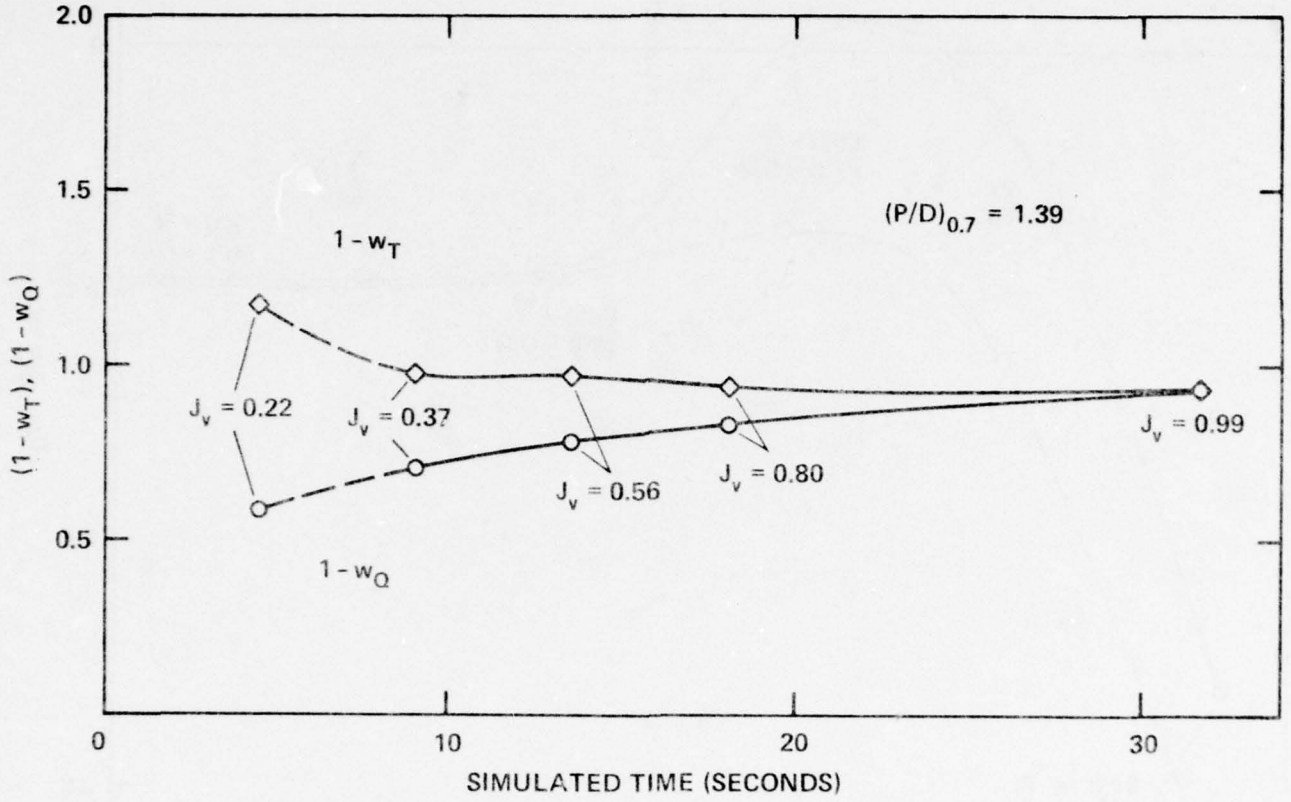



Figure 23a - Crash Ahead

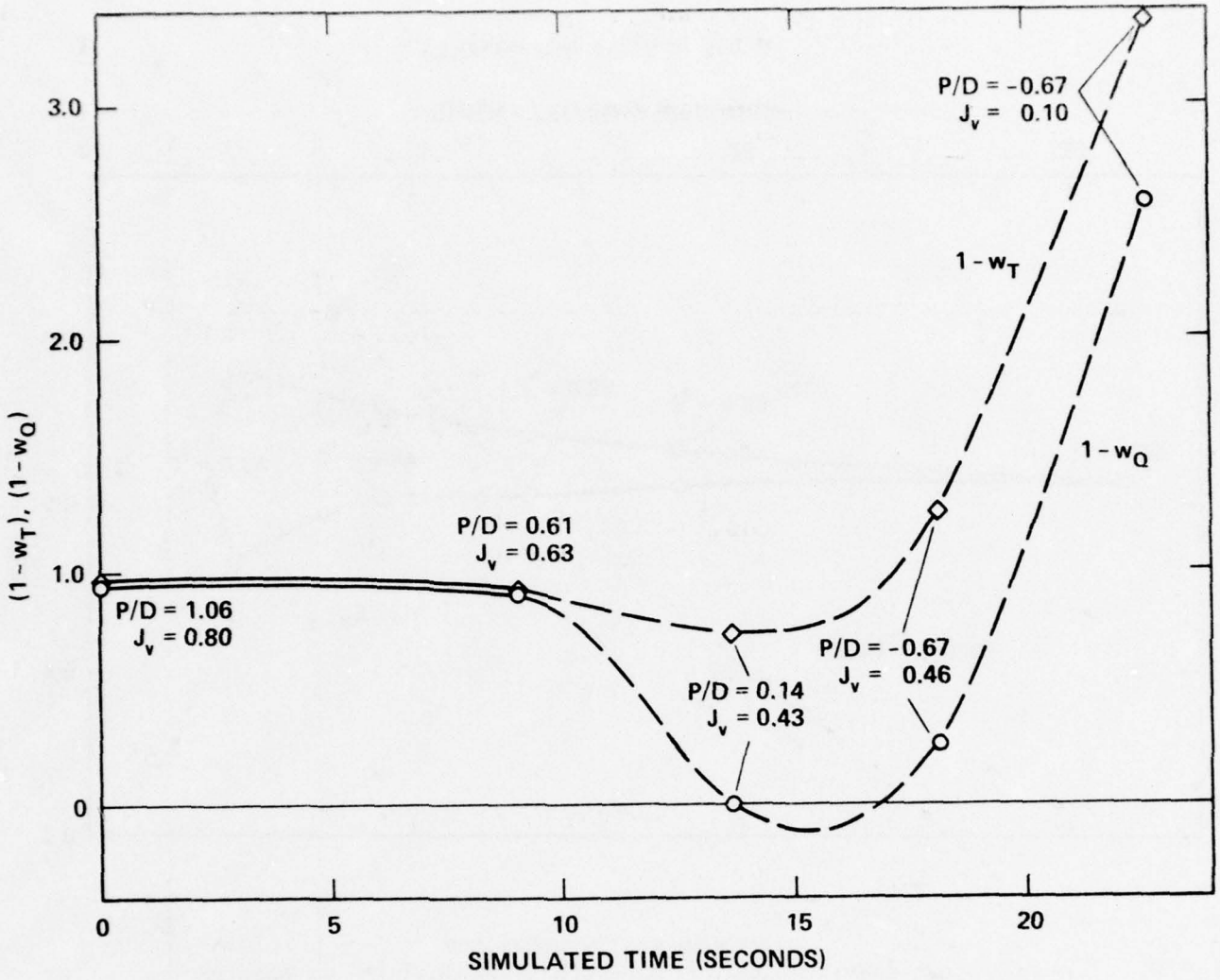



Figure 23b - Crash Astern

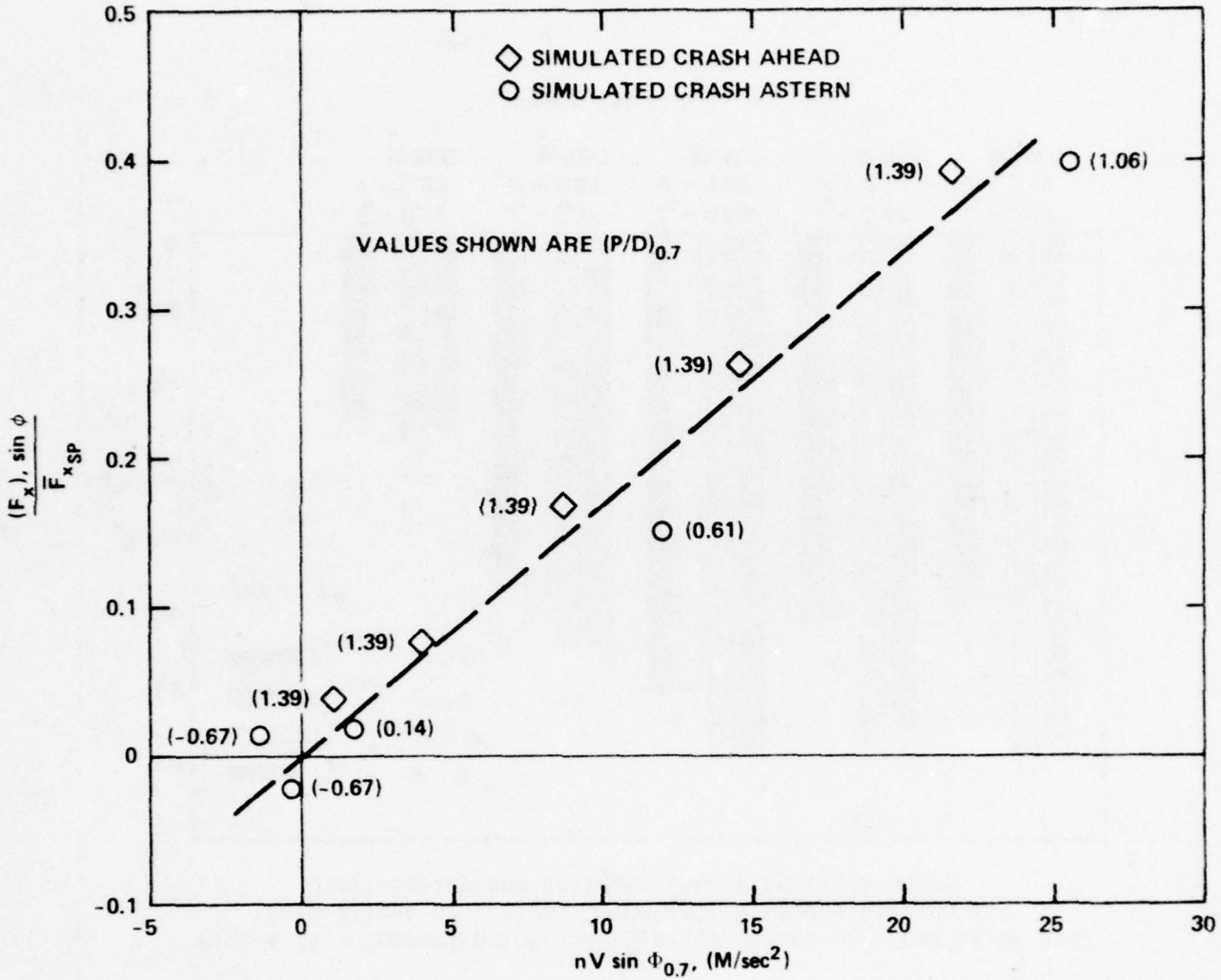



Figure 24- Variation of $(F_x)_1 \sin \phi / \overline{F}_{xSP}$ with nV sin $\phi$ for Quasi-Steady Crash Ahead and Crash Astern

Figure 25 - Comparison of Time-Average Values per Revolution and Peak Values of Various Components of Blade Loading for Quasi-Steady and Unsteady Simulated Crash Ahead

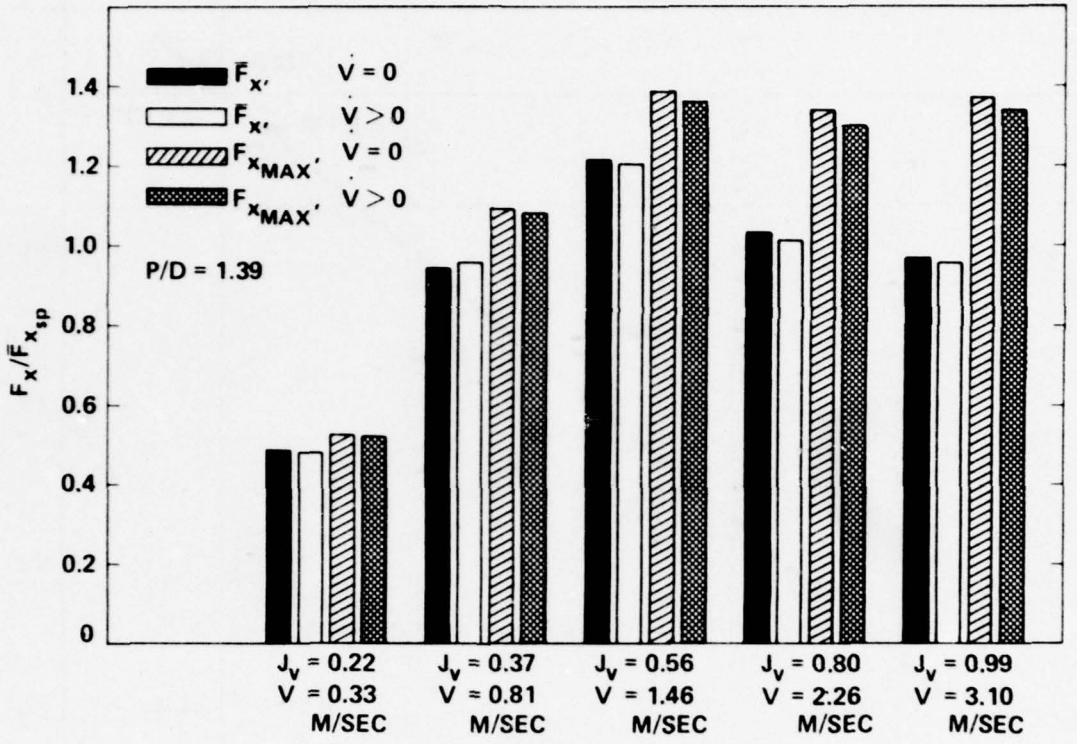



Figure 25a - $F_x$

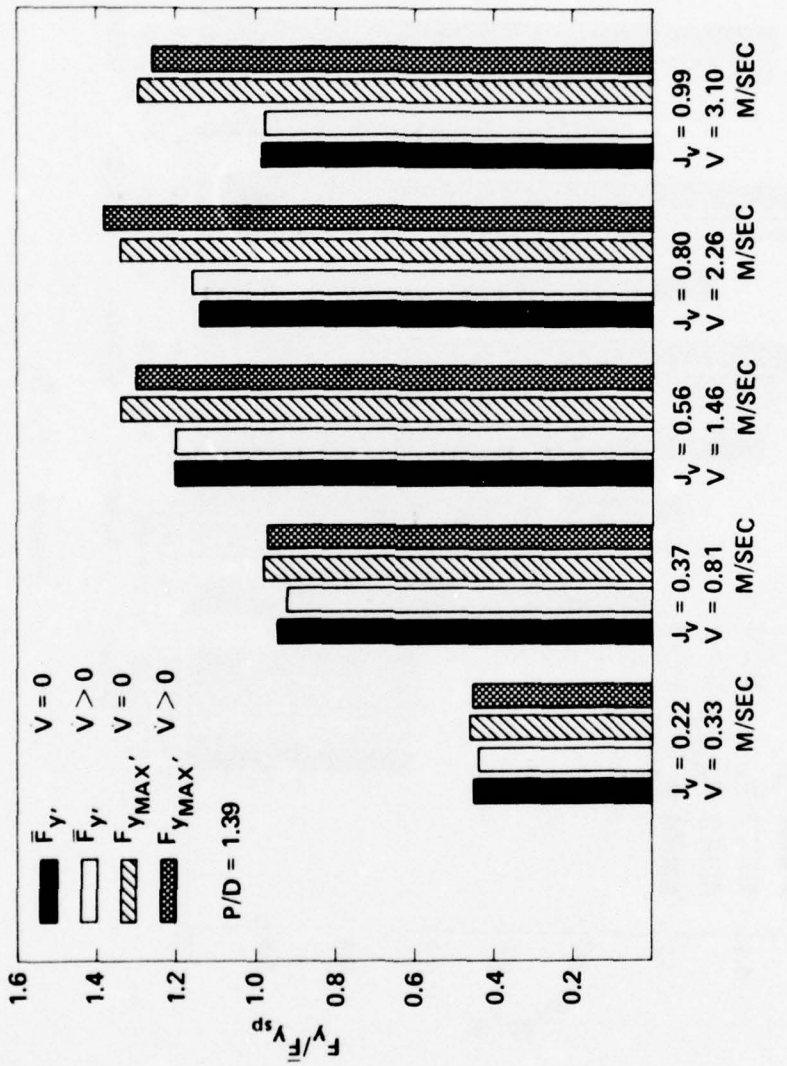



Figure 25b - $F_y$

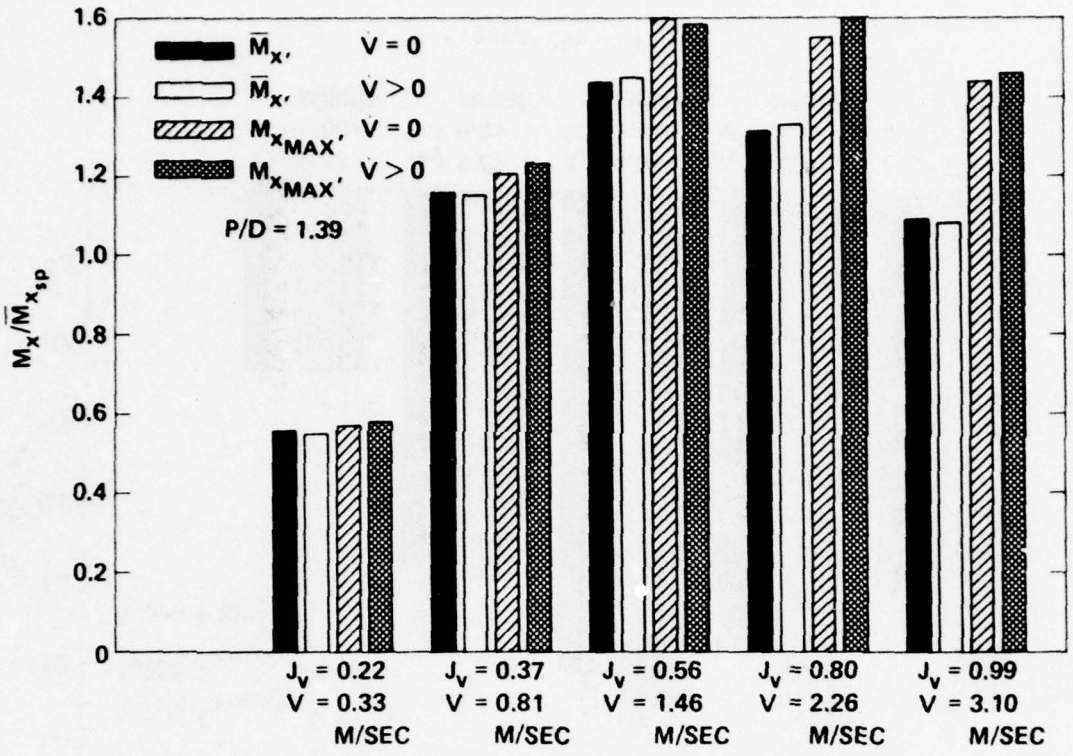



Figure 25c - $M_x$

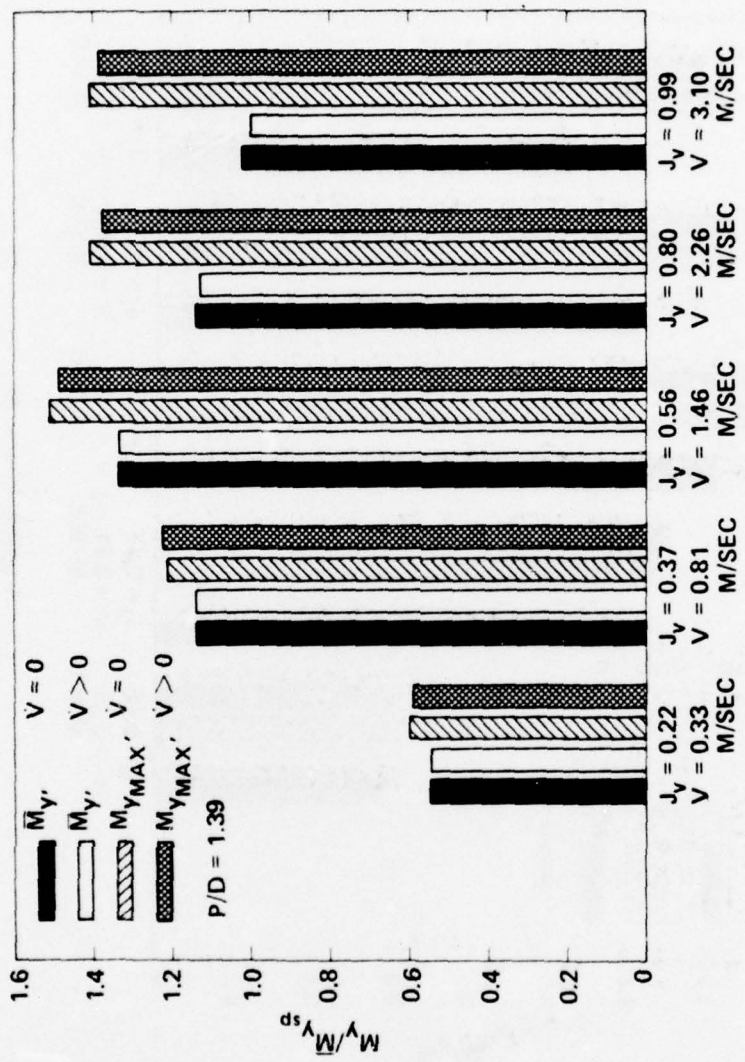



Figure 25d - $M_y$

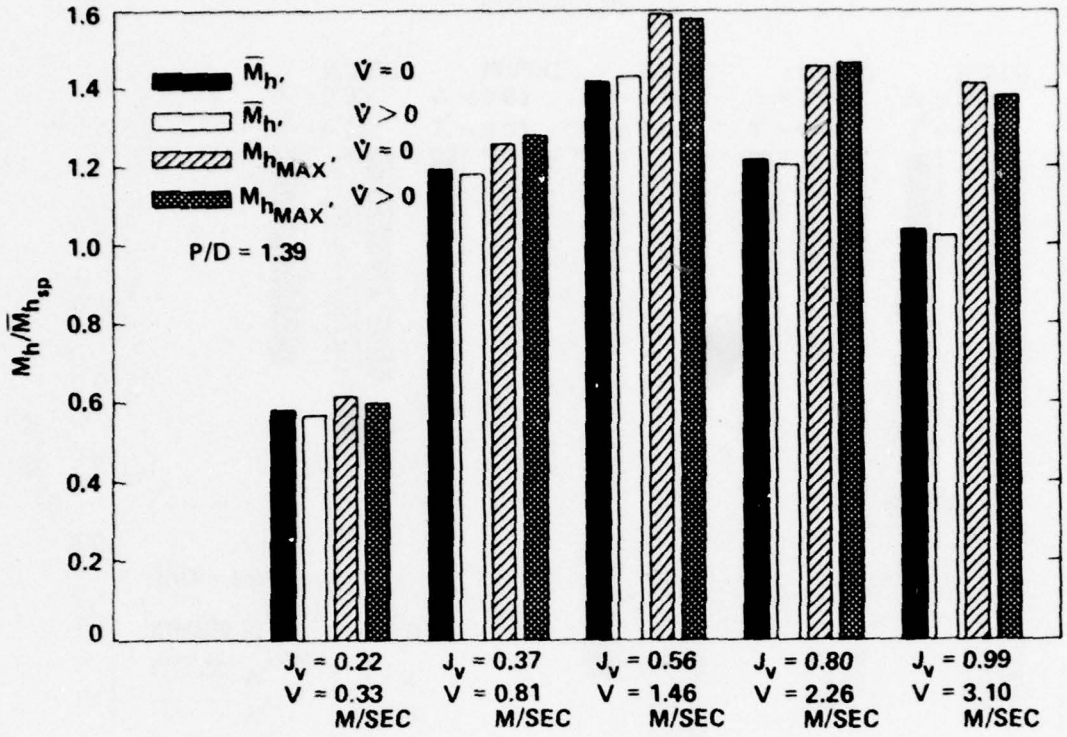



Figure 25e - $M_h$

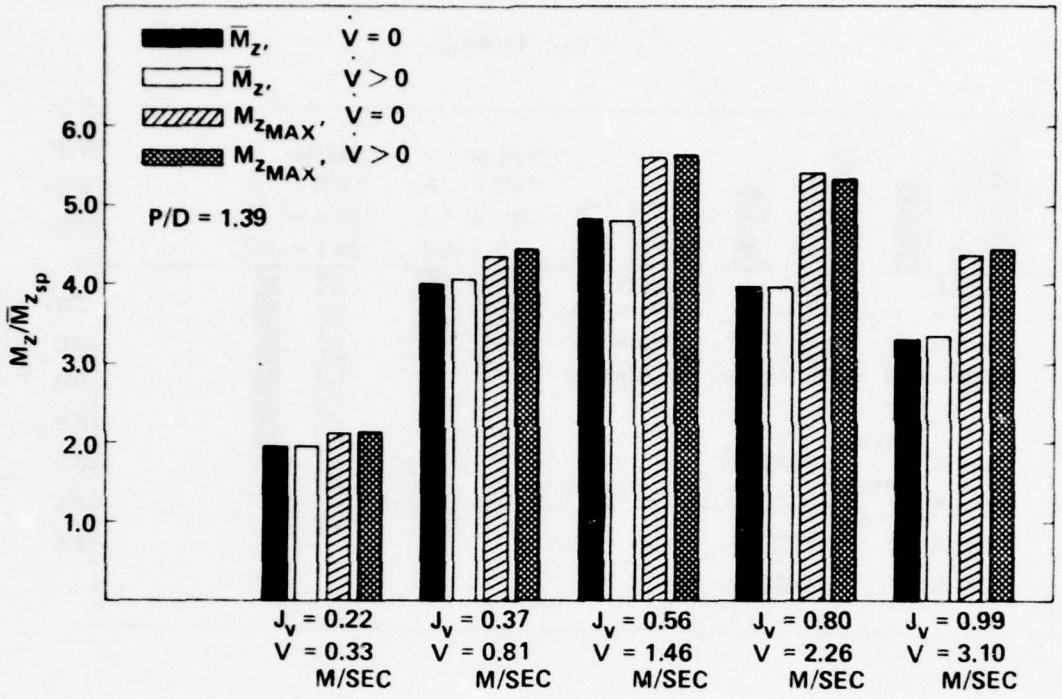



Figure 25f - $M_z$

Figure 26 - Comparison of Time-Average Values per Revolution and Peak Values of Various Components of Blade Loading for Quasi-Steady and Unsteady Simulated Crash Astern

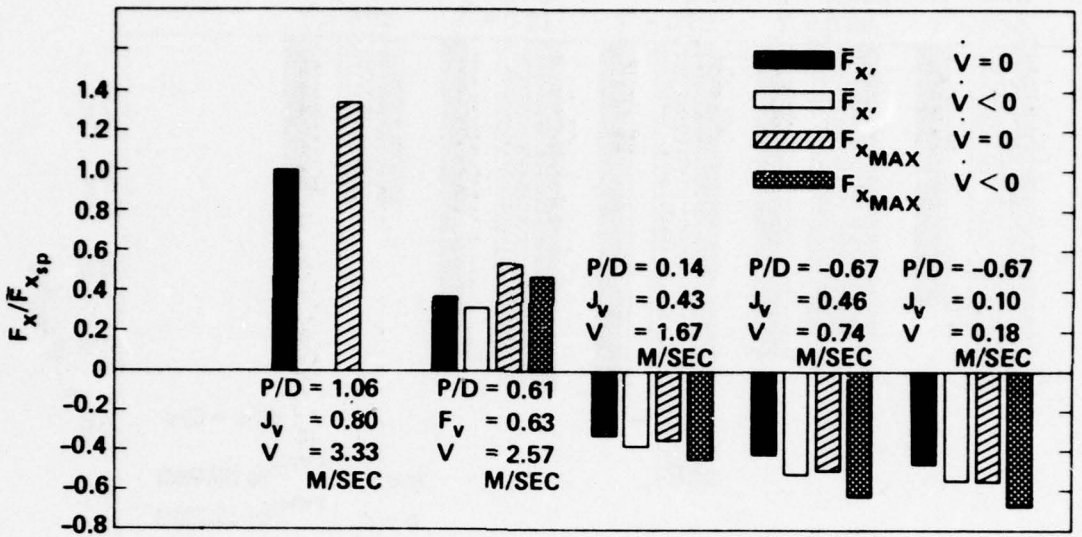



Figure 26a - $F_x$

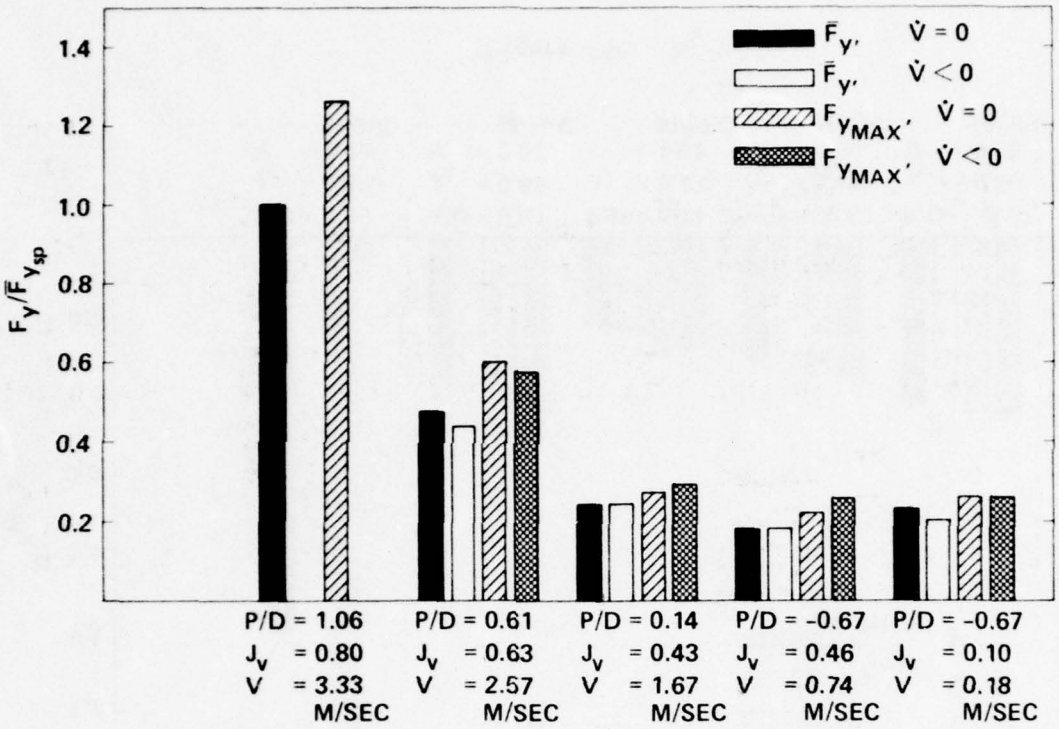



Figure 26b - $F_y$

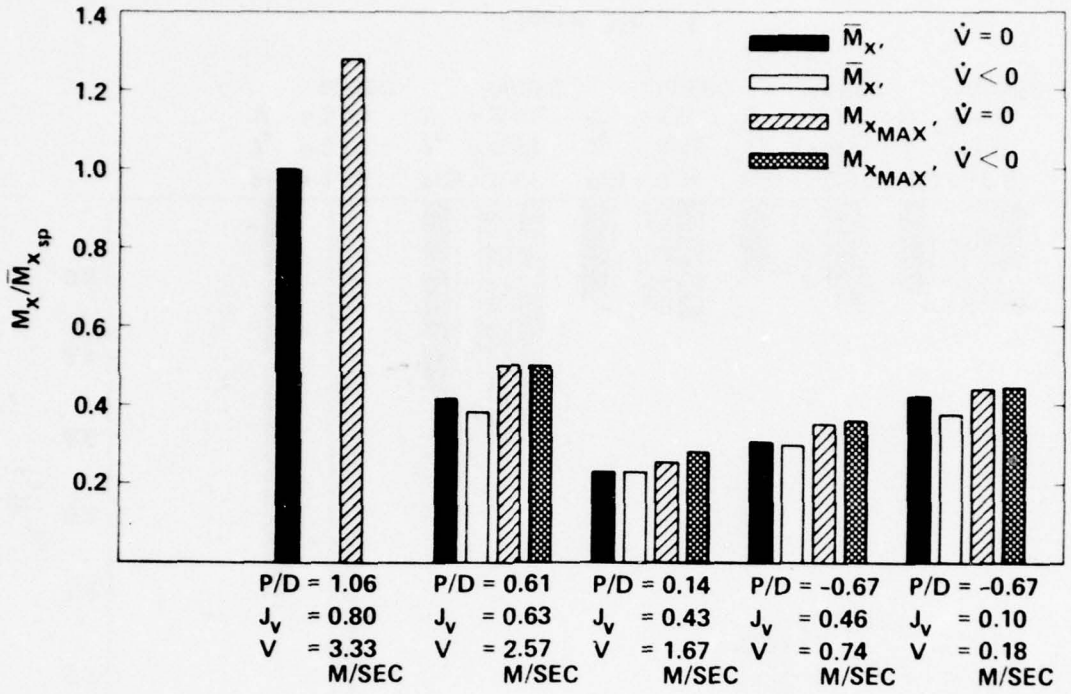



Figure 26c - $M_X$

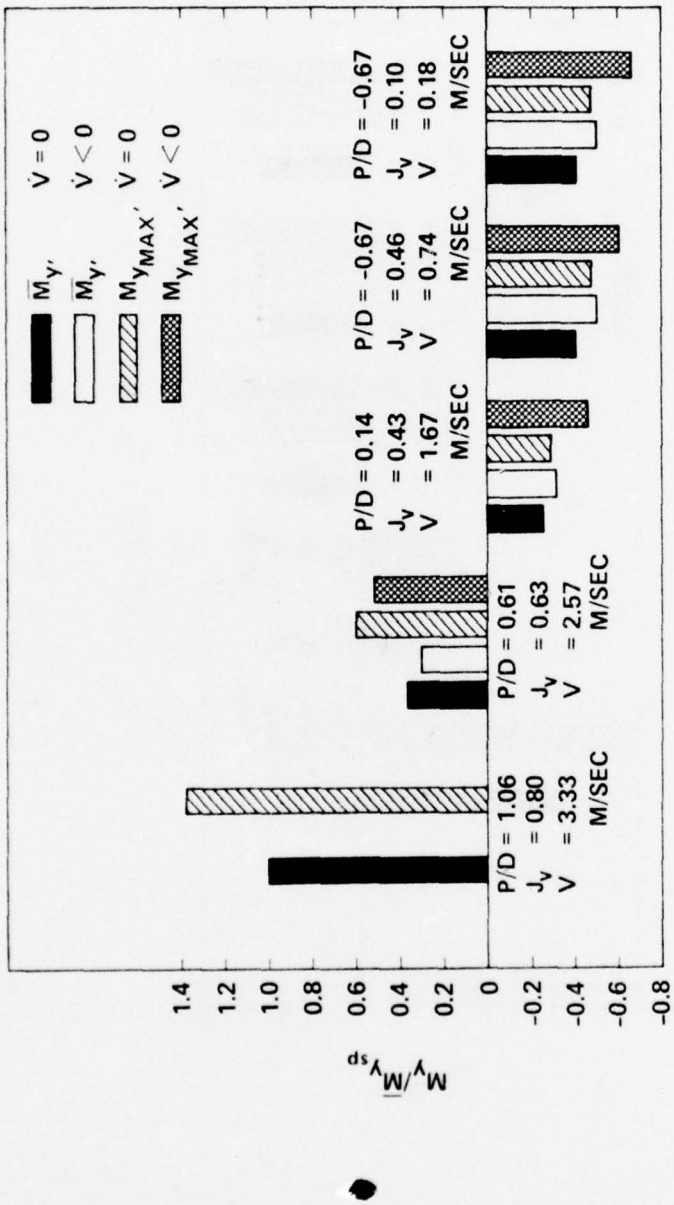



Figure 26d - $M_y$

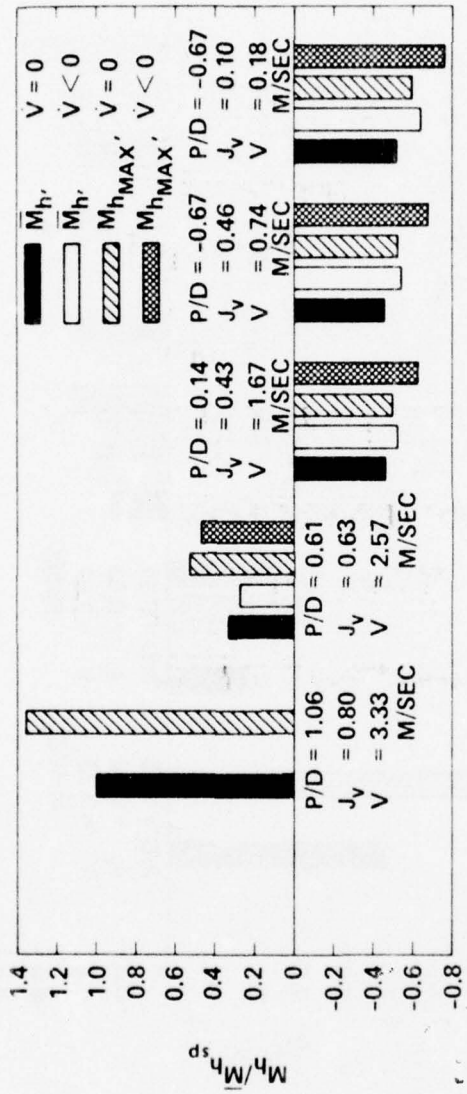



Figure 26e - $M_h$

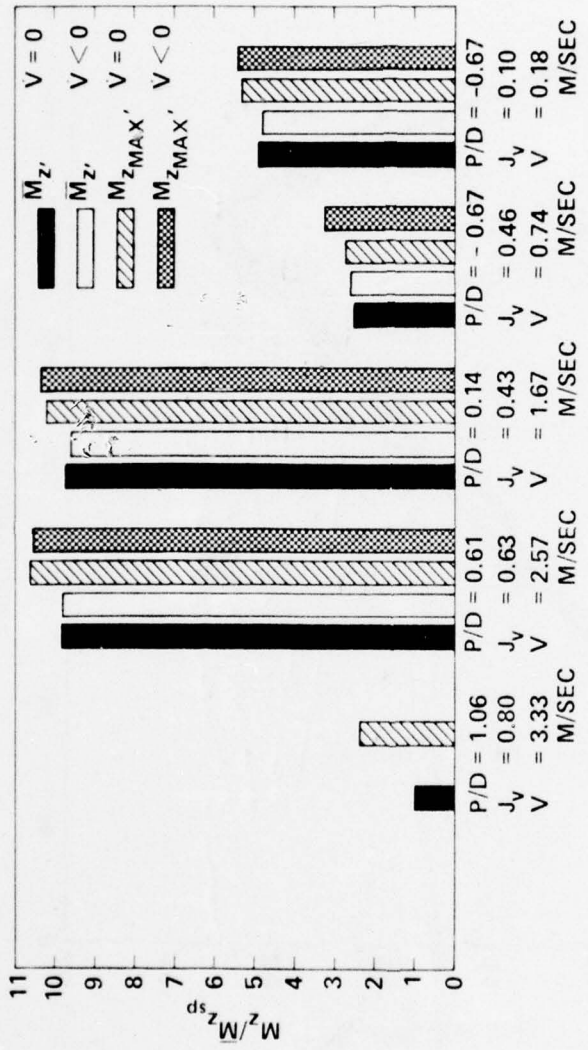



Figure 26f - $M_z$

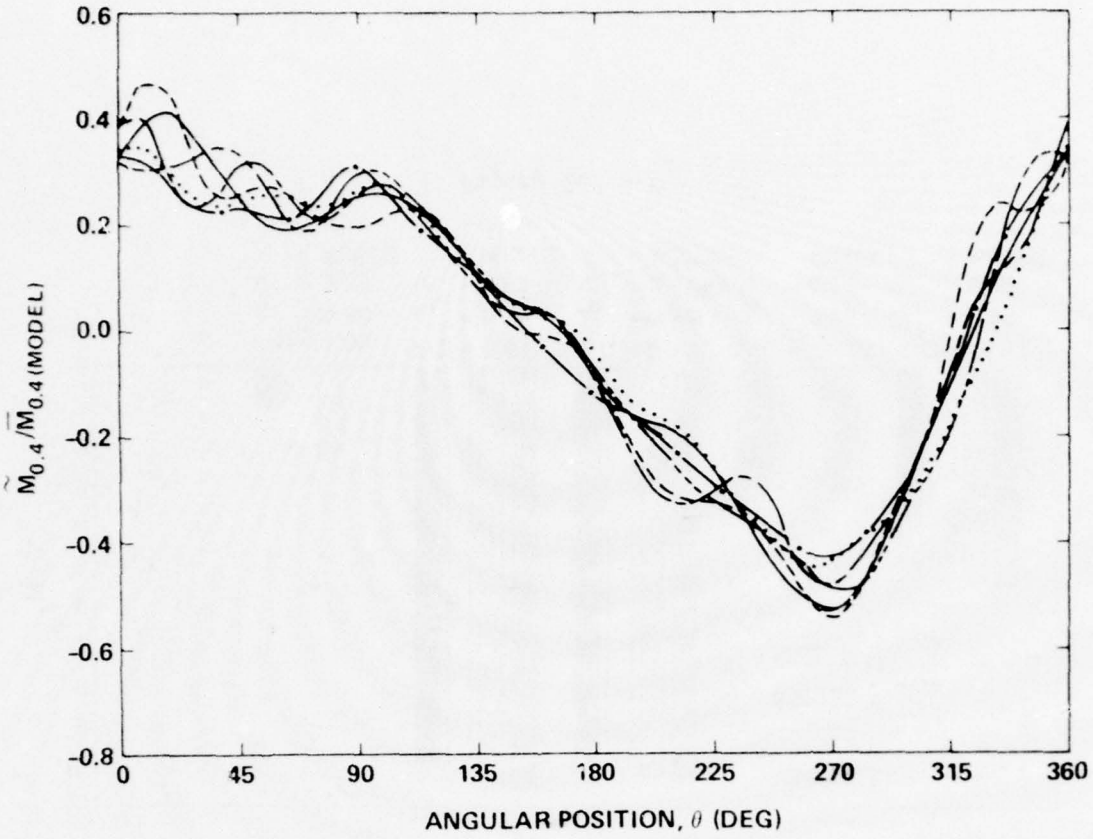



Figure 27 - Variation of Bending Moment with Blade Angular Position Measured on the Full-Scale Propeller for Six Individual Revolutions

Figure 28 - Harmonic Content of Blade Bending Moment on the Full-Scale Propeller for Six Individual Revolutions

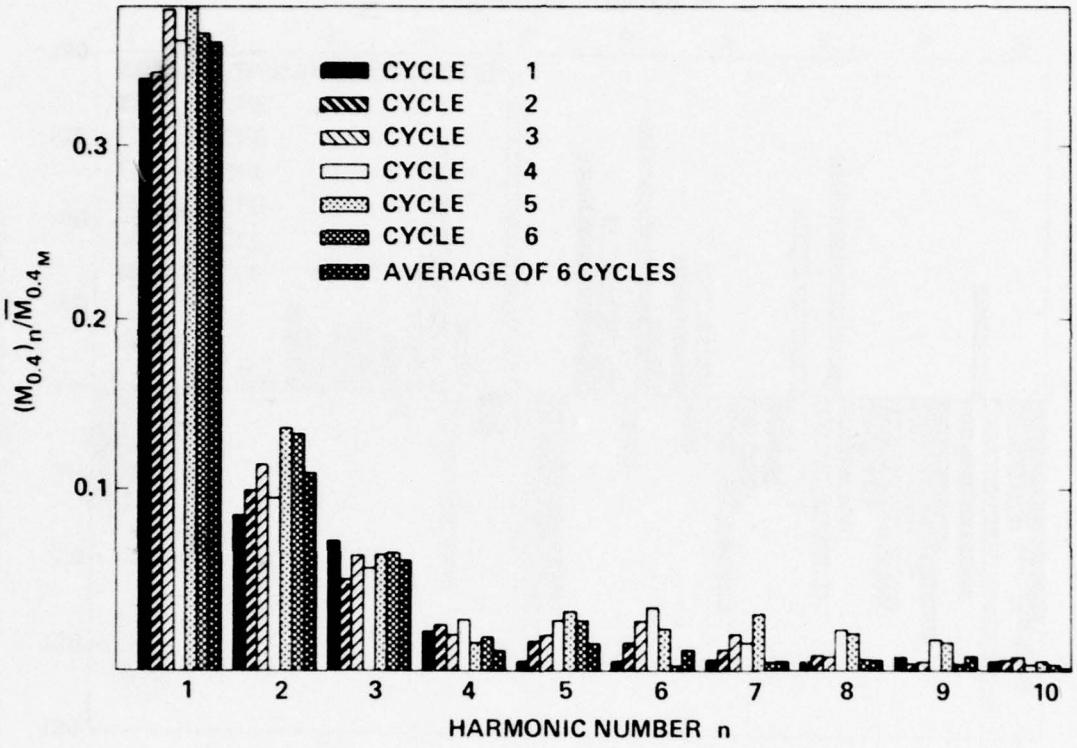



Figure 28a - Amplitudes

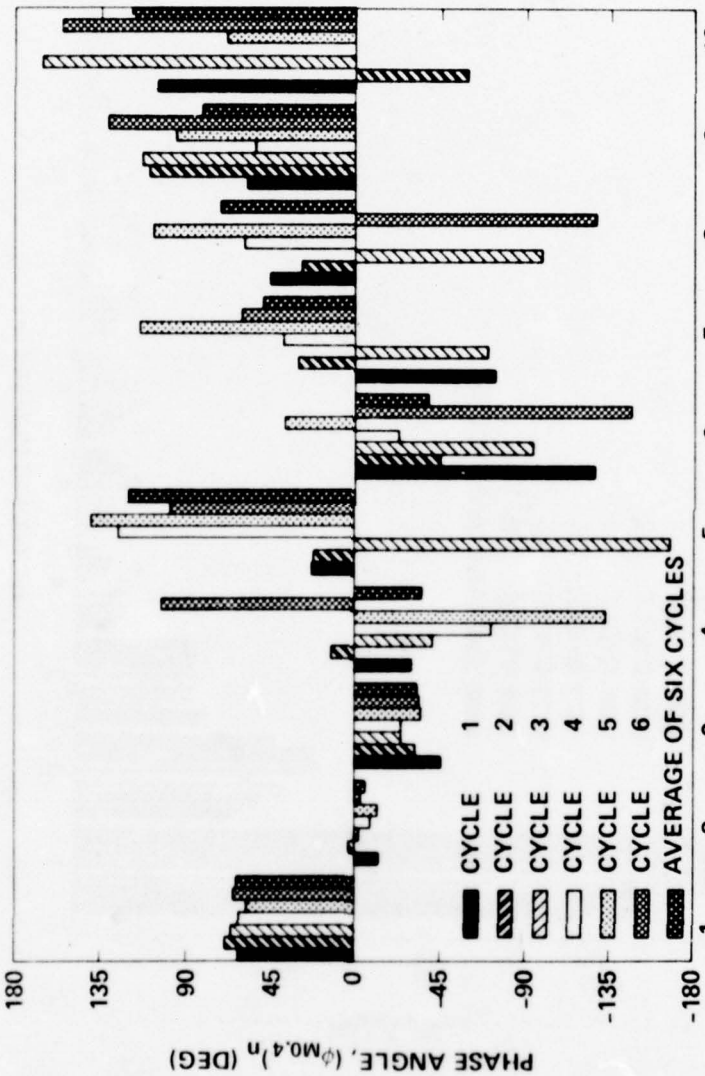



Figure 28b - Phases

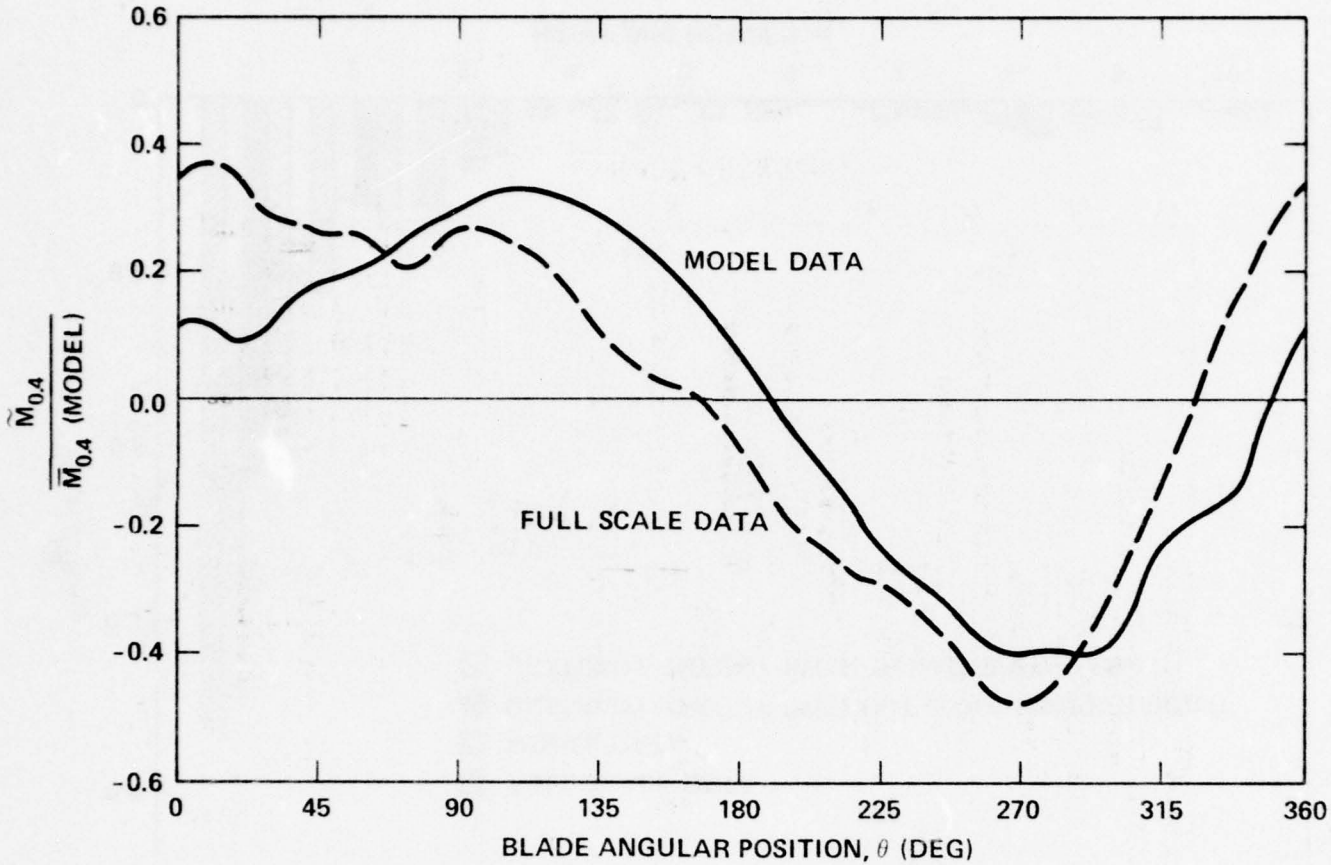



Figure 29- Variation of Bending Moment at 40 Percent Radius with Blade Angular Position, Comparison of Model Data and Scale Data

Figure 30- Harmonic Content of Bending Moment at 40 Percent Radius-Comparison of Model Data, Full Scale Data and Theory

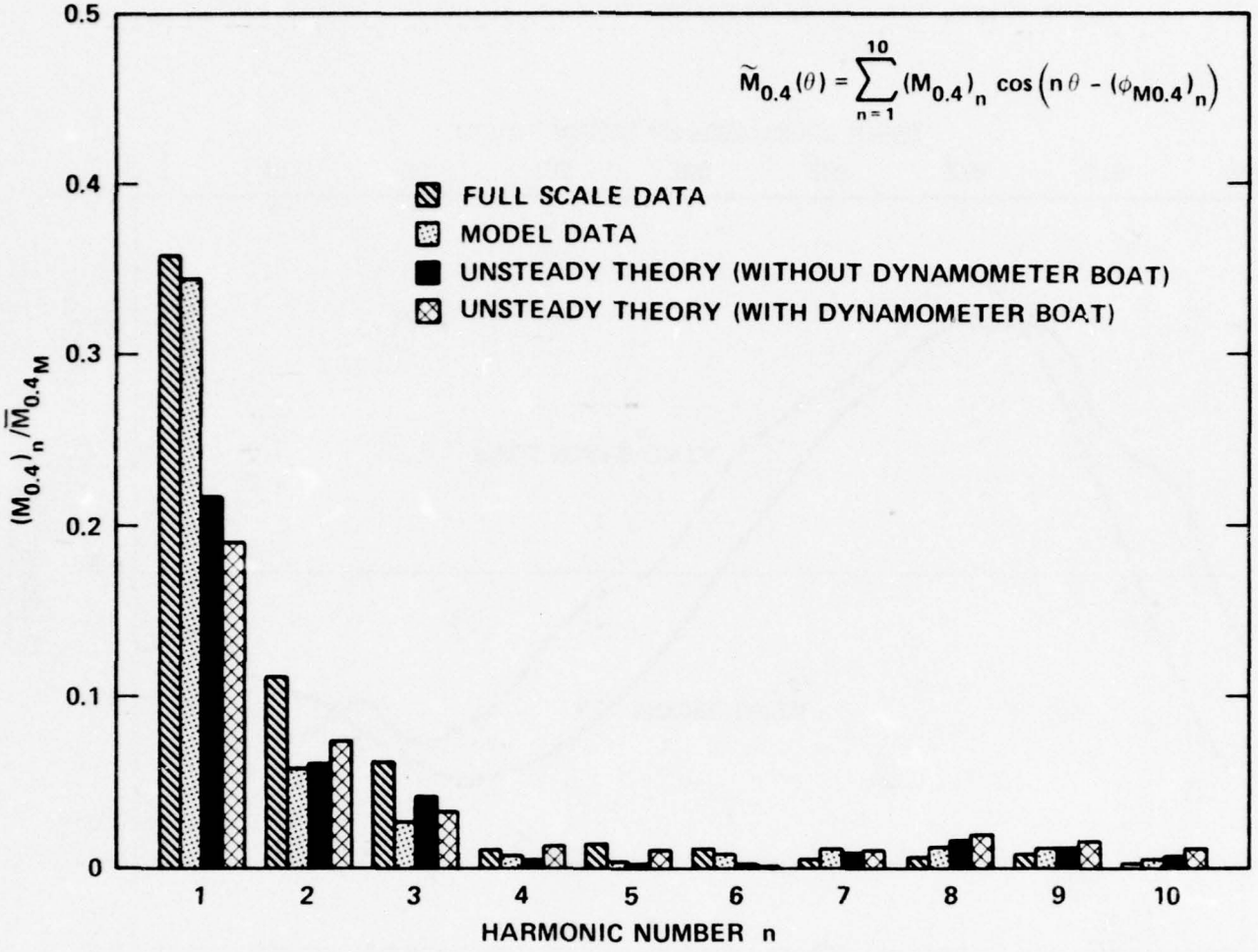



Figure 30a- Amplitudes

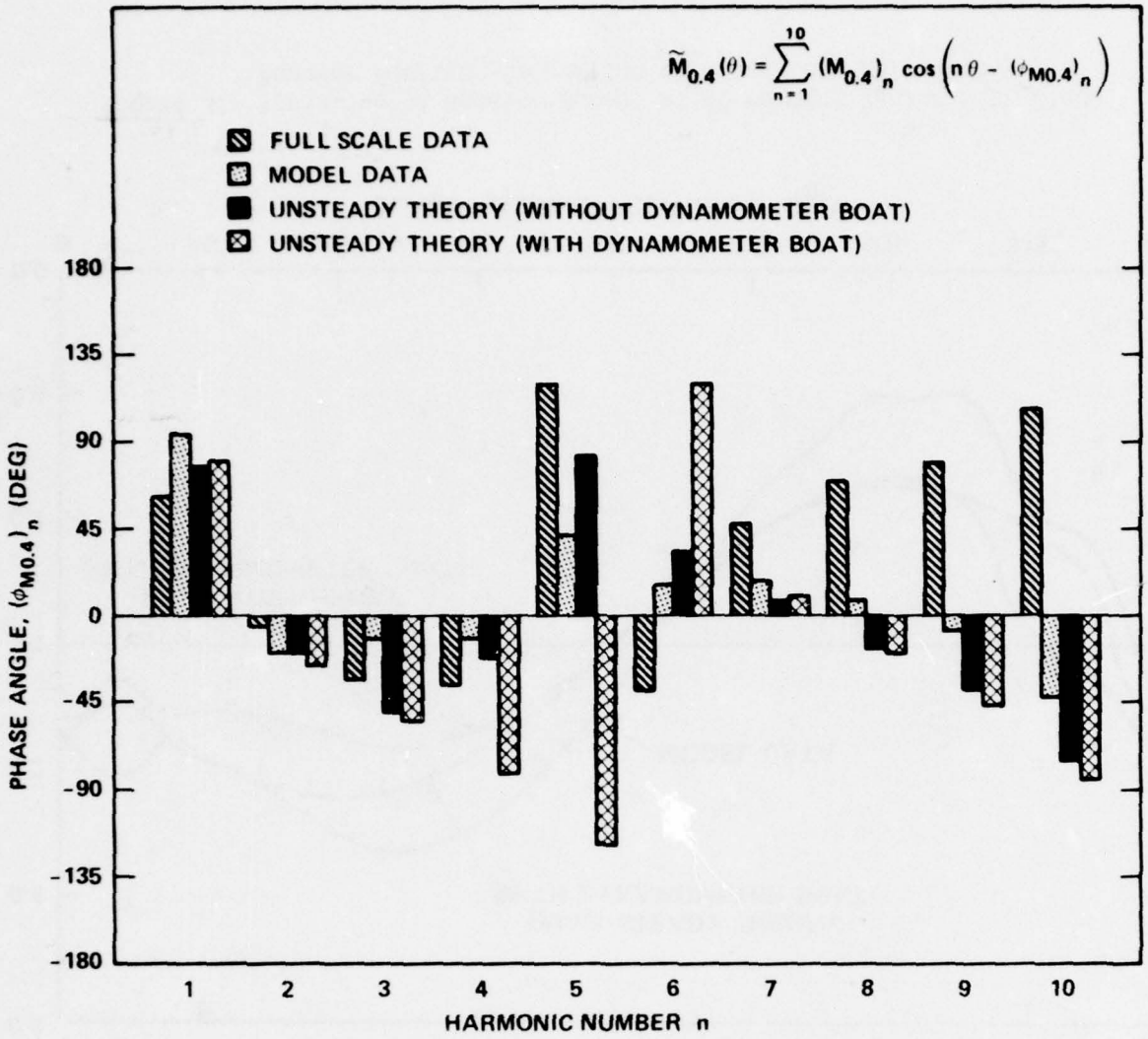



Figure 30b - Phases

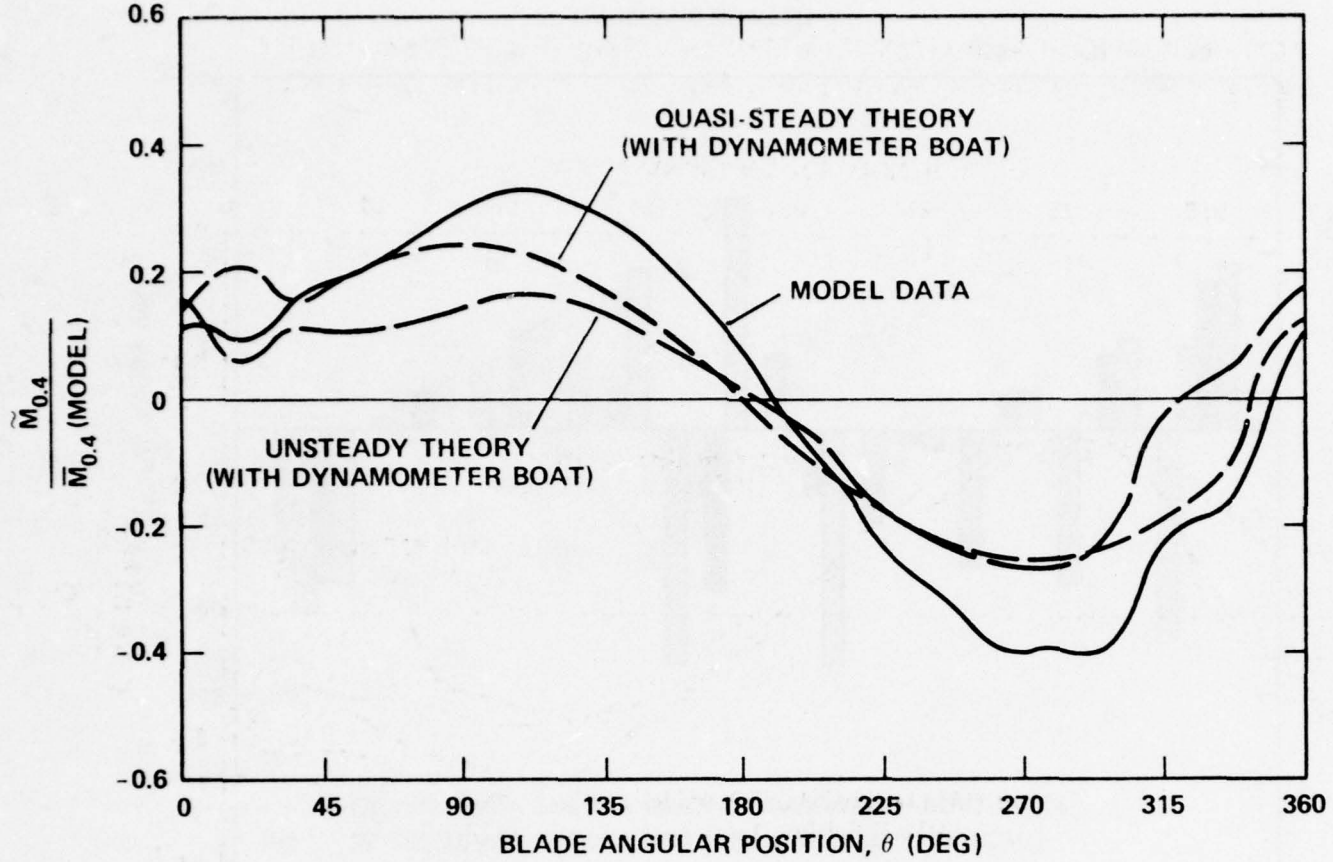



Figure 31- Variation of Bending Moment at 40 Percent Radius With Blade Angular Position-Comparison of Model Data with Theory

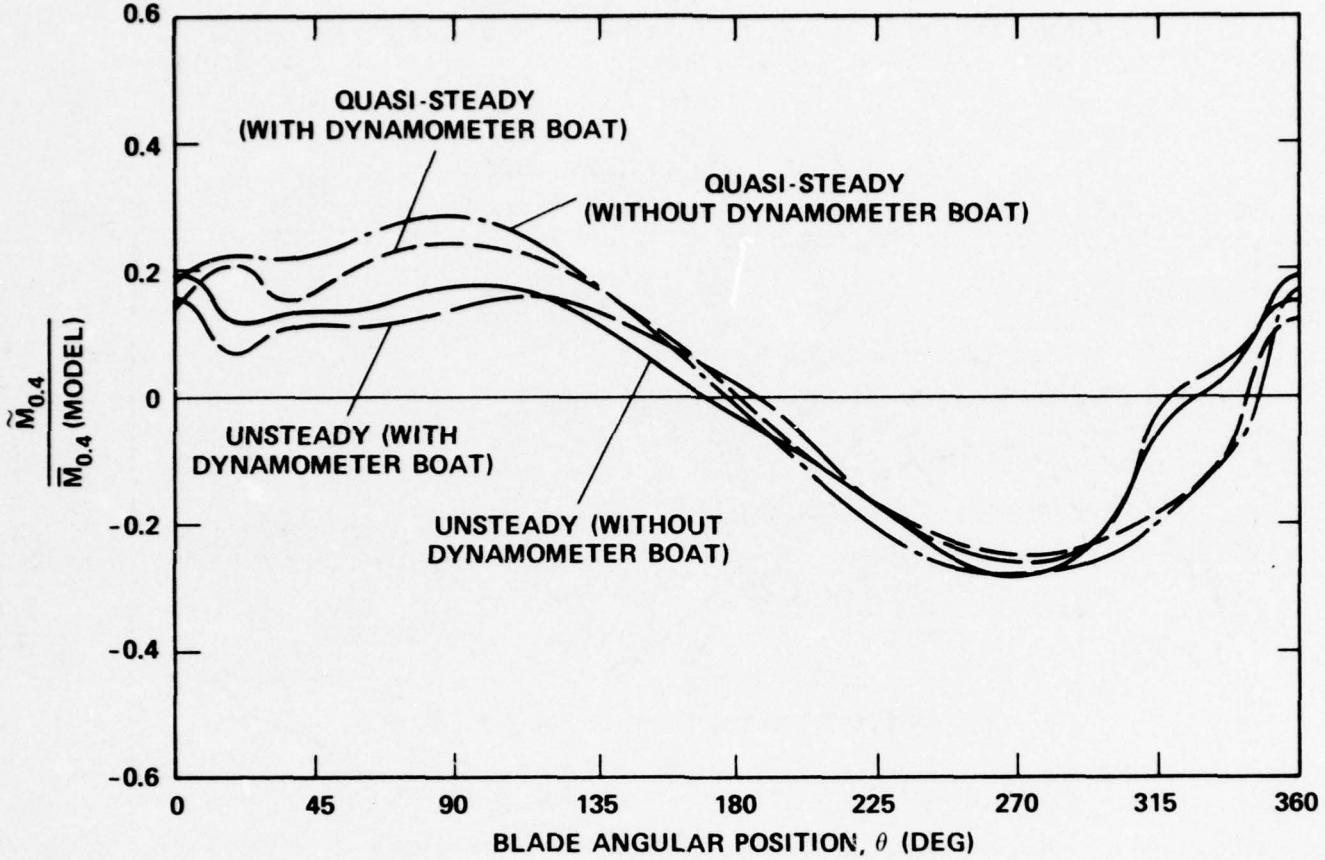



Figure 32 - Variation of Bending Moment at 40 Percent Radius With Blade Angular Position-Theoretical Prediction With and Without Downstream Body

## APPENDIX A

## DETAILS OF WAKES

Figure 33 and Tables 9 and 10 present the wake data measured in the plane of the propeller, both with and without the downstream dynamometer boat. The data presented in Figure 33 are similar to those in Figure 12 except that here wake harmonics are given at even radial stations whereas the data of Figure 12 are only for the radial stations at which the wake was measured. The data at even radial stations were obtained by extrapolation and interpolation of the measured data.[29] The wake data presented in Tables 9 and 10 are tabulated values of the data presented graphically in Figures 11, 12, and 33.

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[29] Cheng, H.M., "Analysis of Wake Survey of Ship Models - Computer Program AML Problem No. 840-219F," David Taylor Model Basin Report 1804 (Mar 1964).



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Figure 33 - Wake Harmonics

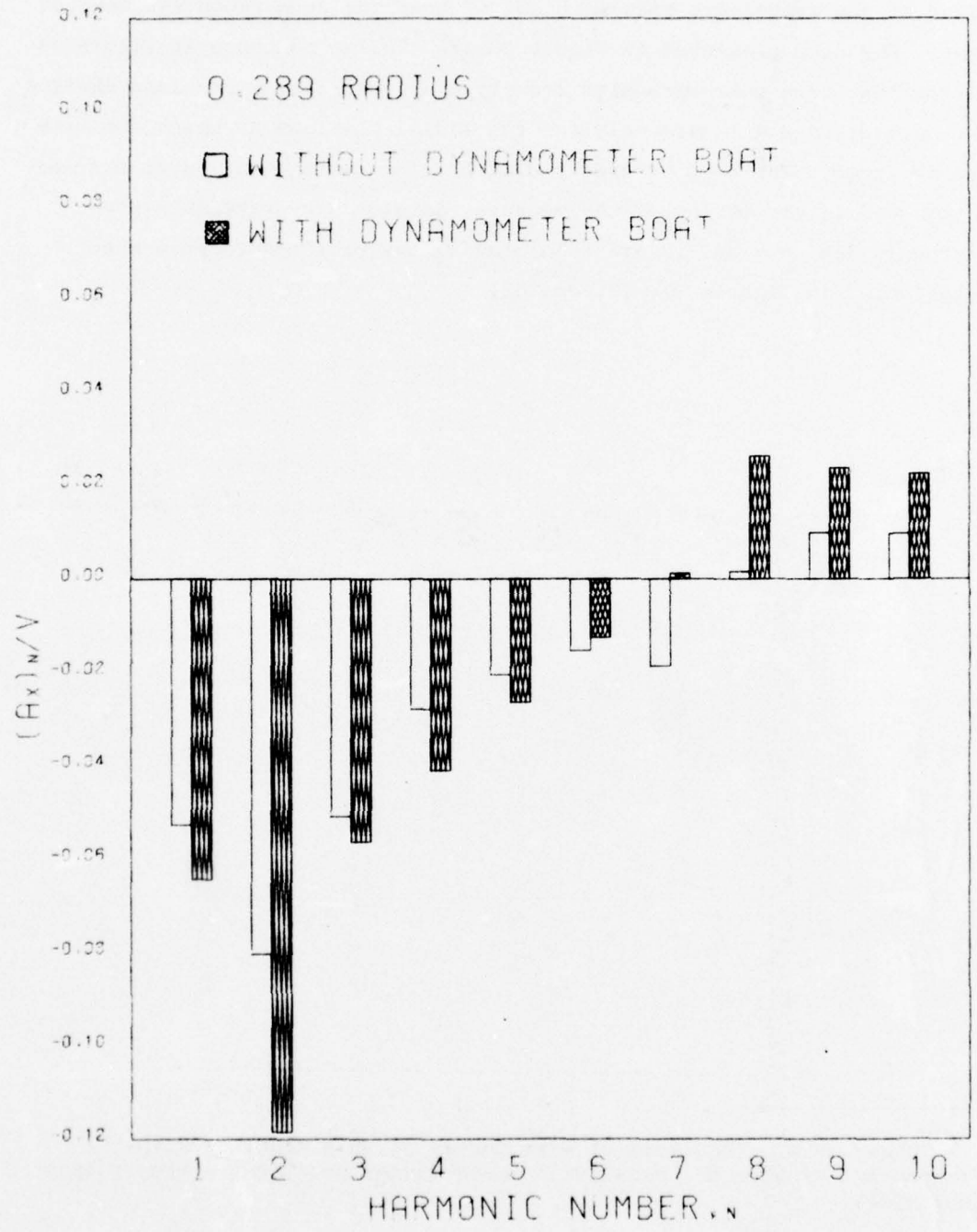


Figure 33 (Continued)

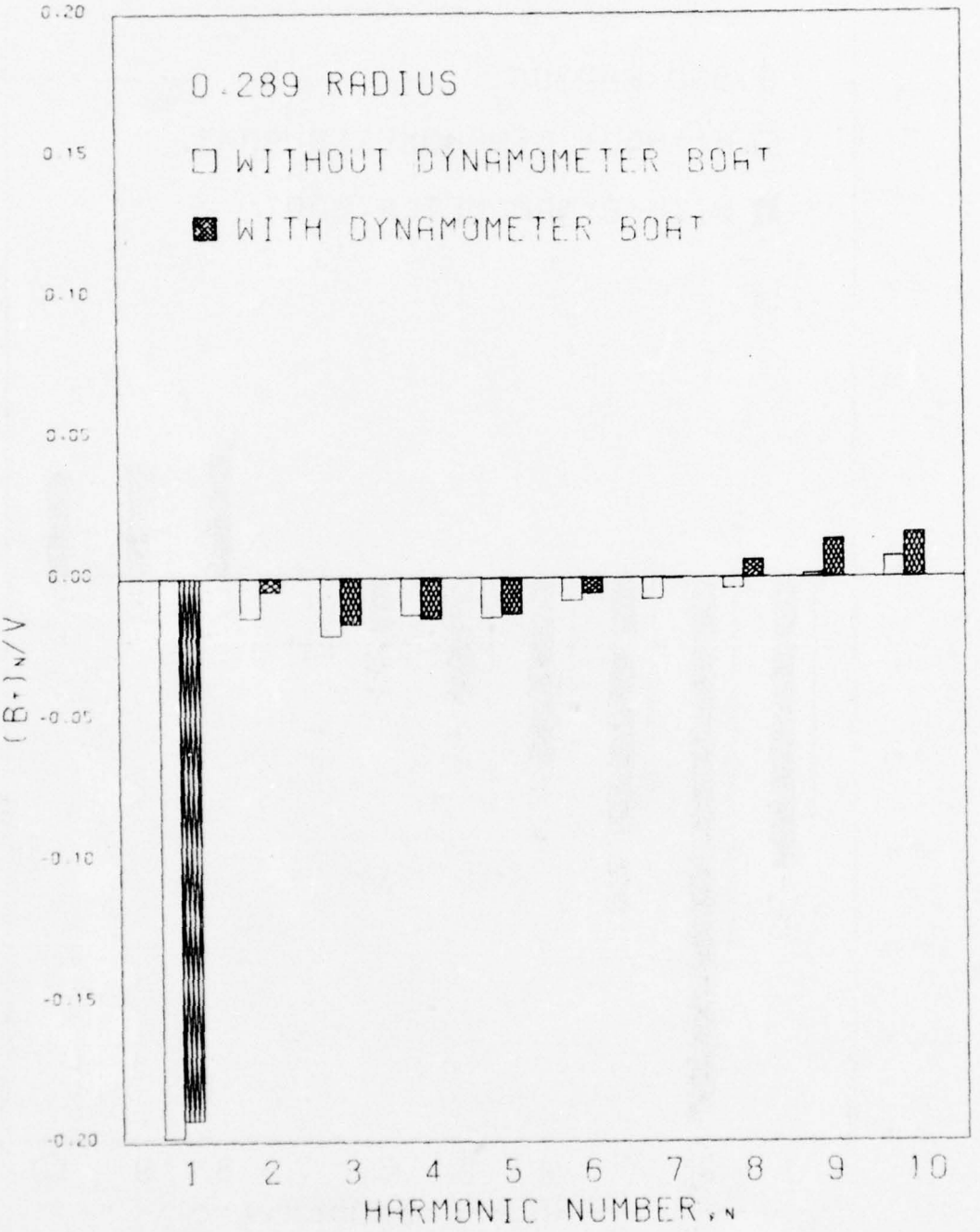


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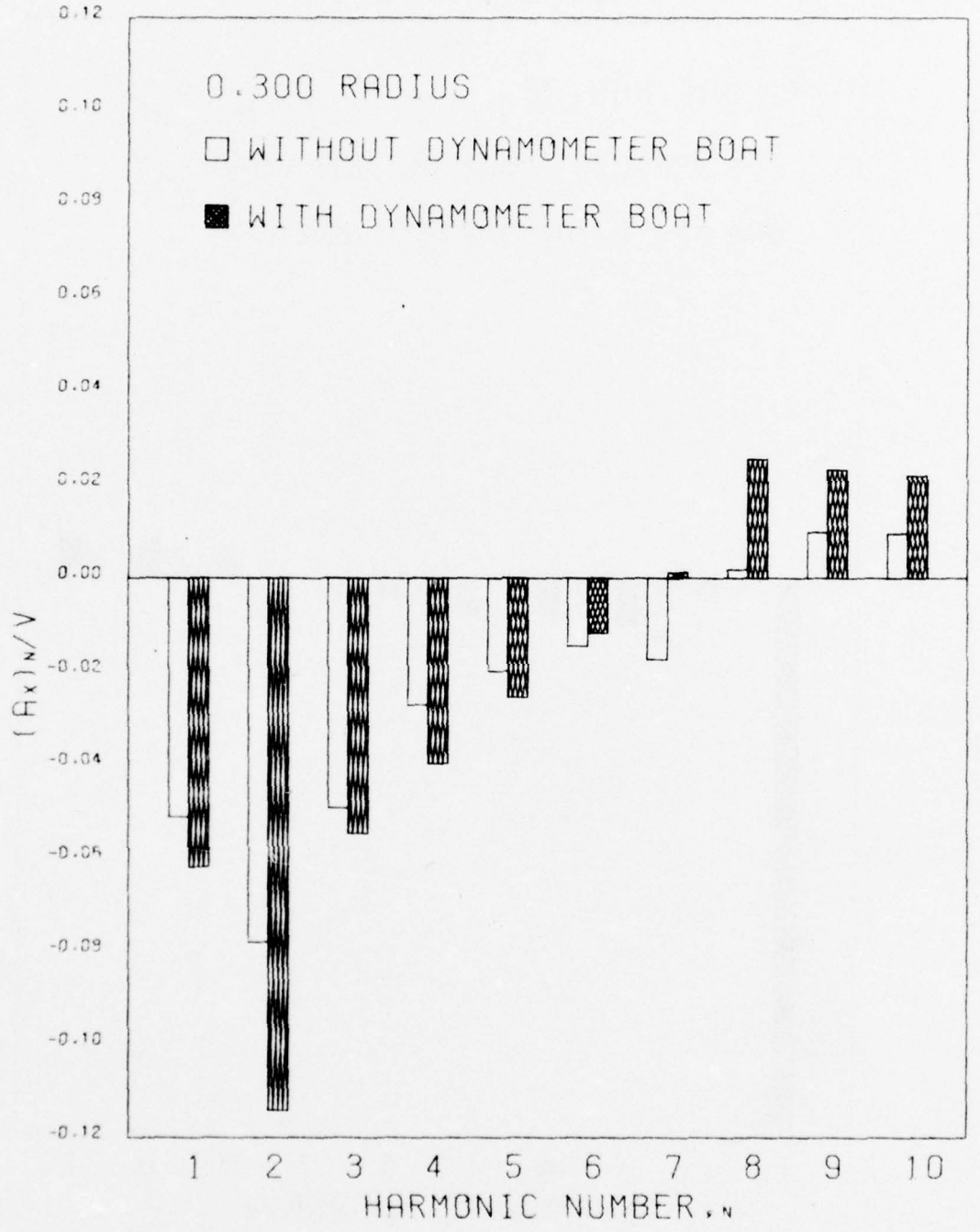


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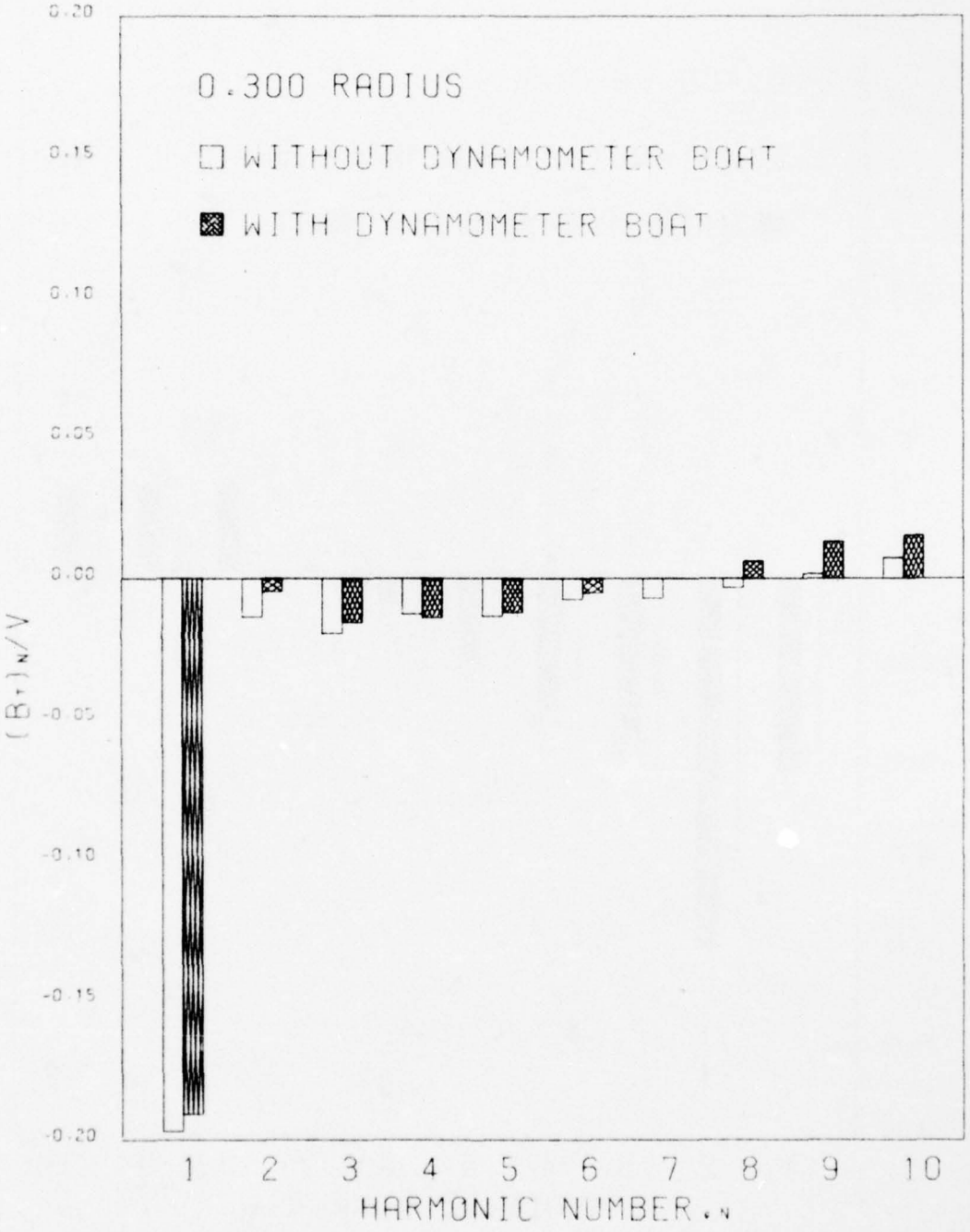



FIGURE 33 - WAKE HARMONICS(CONTINUED)

Figure 33 (Continued)

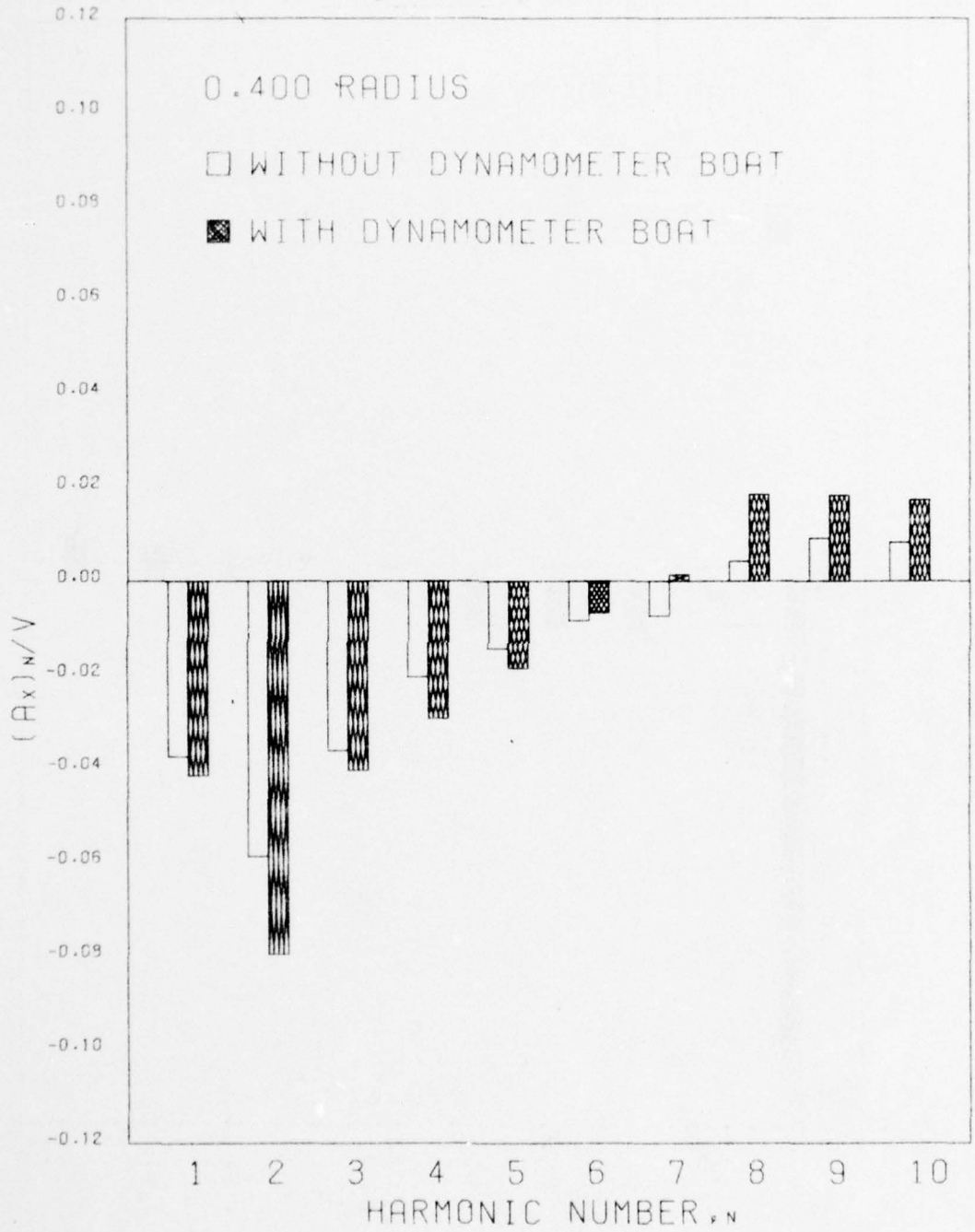


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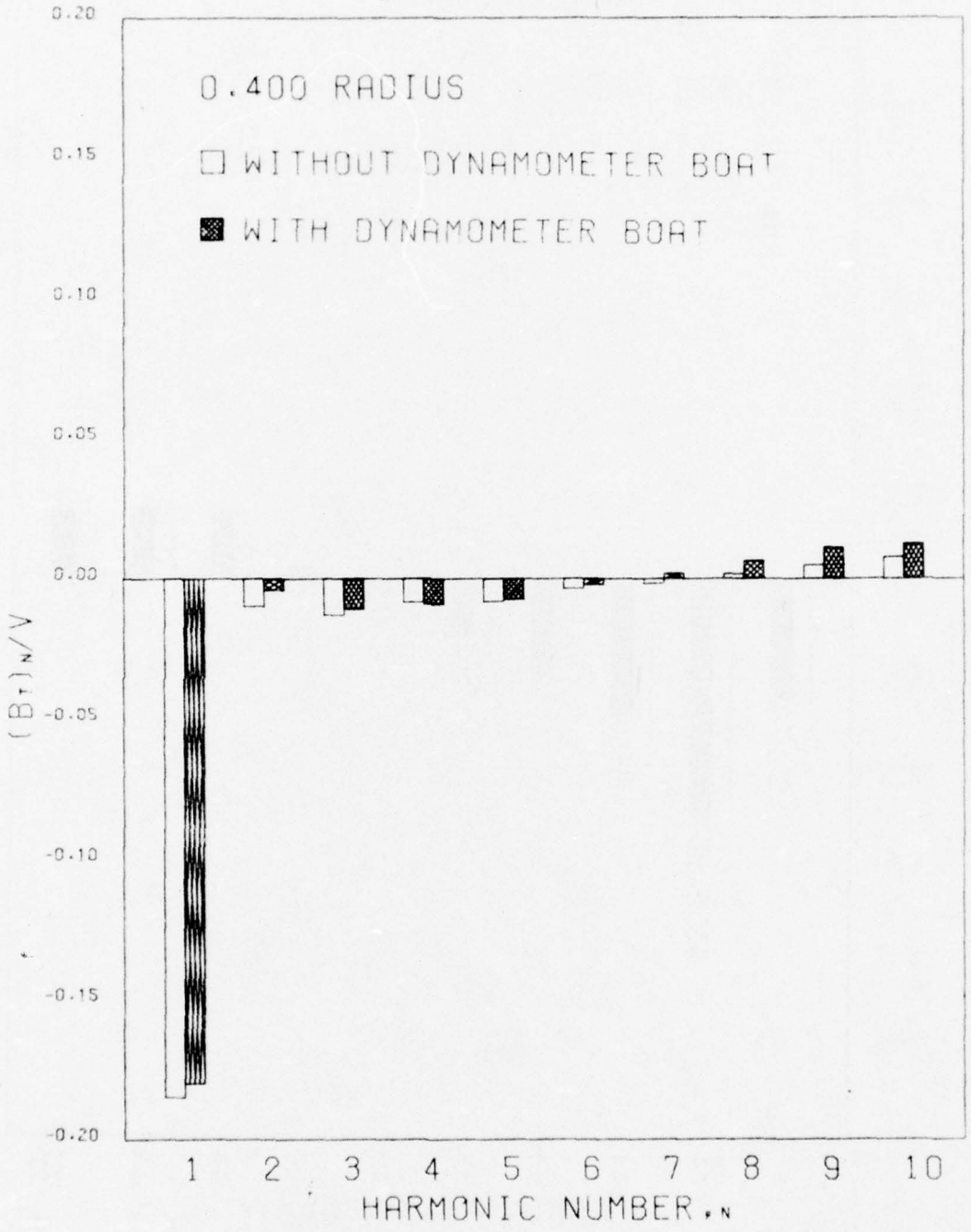


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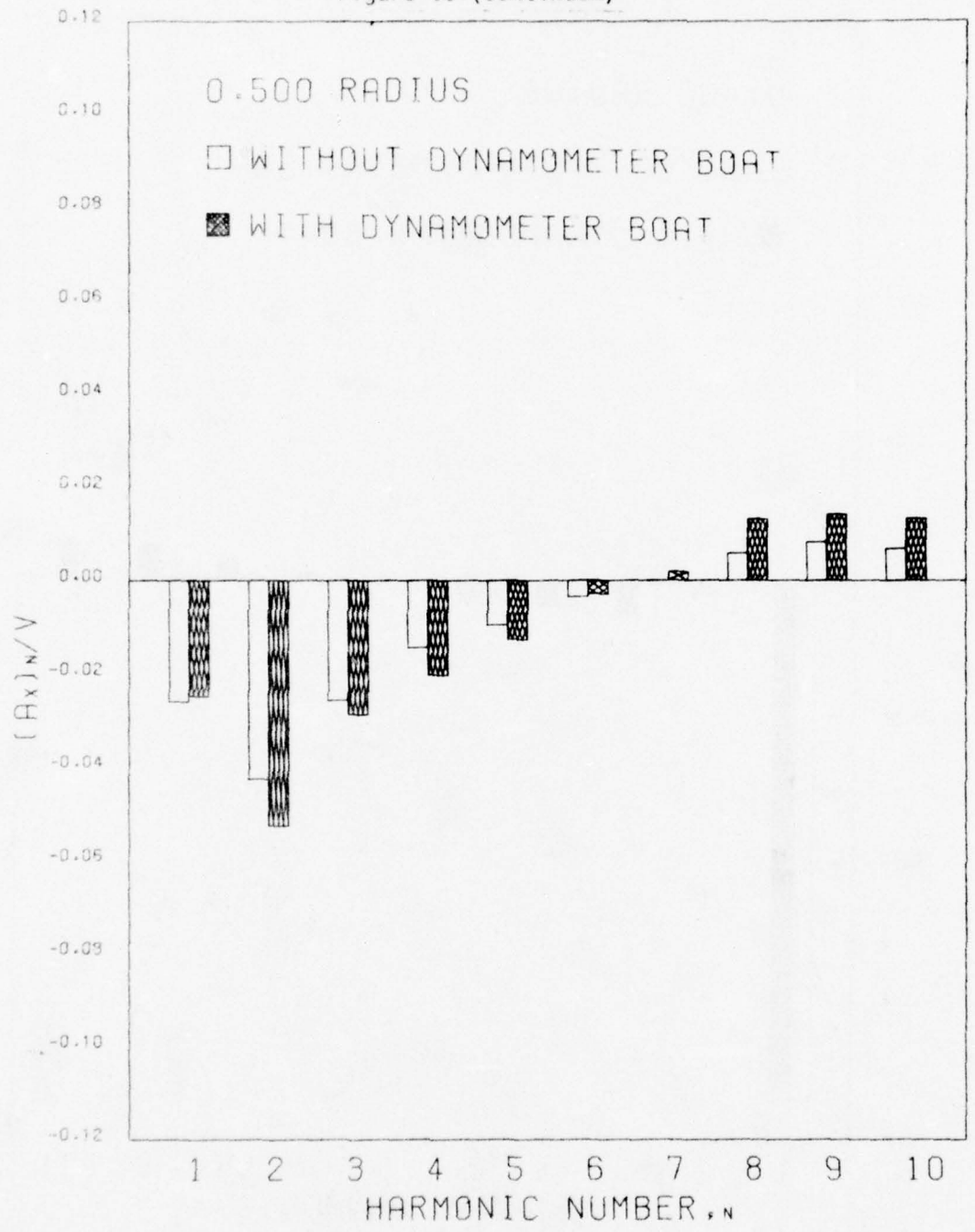


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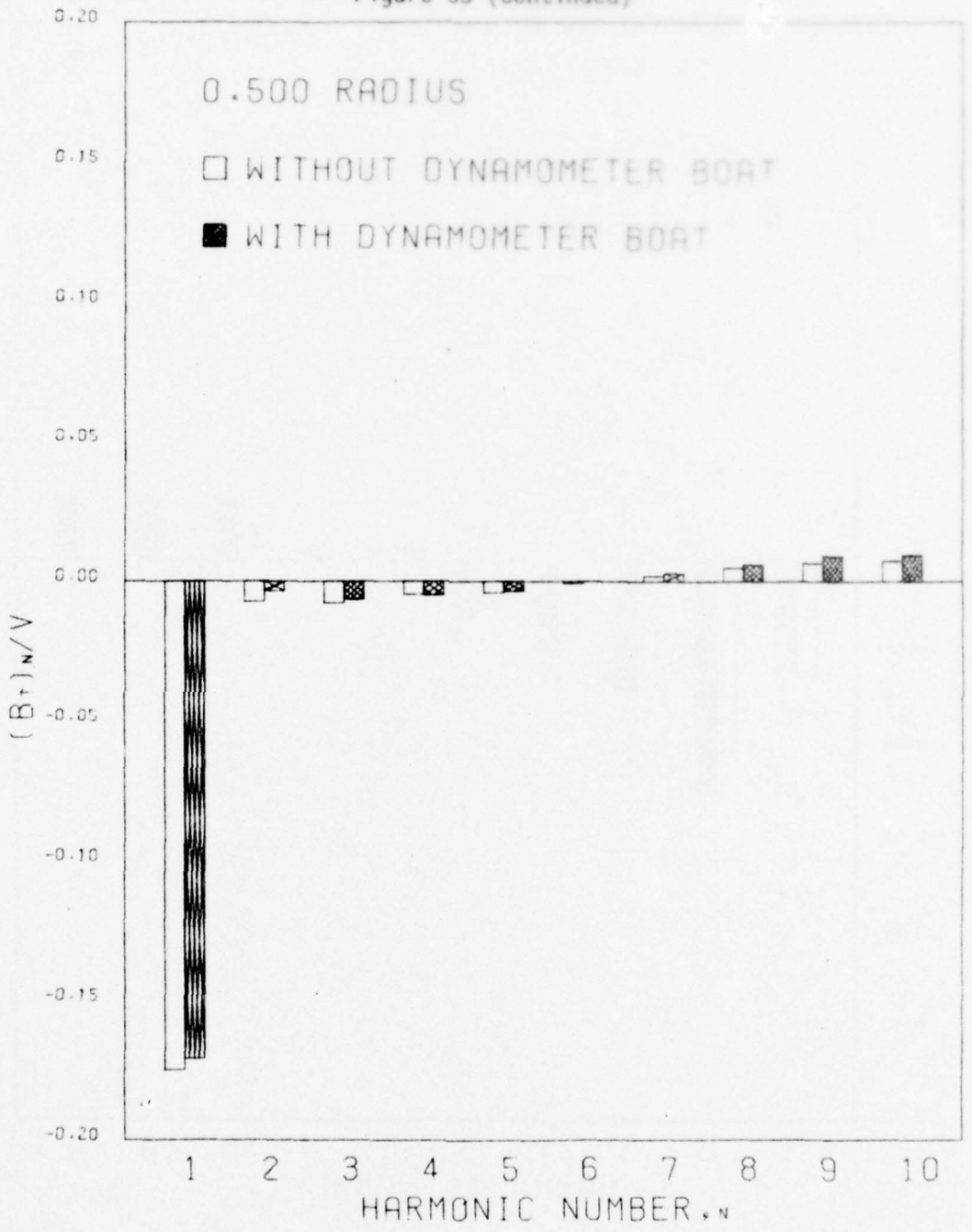


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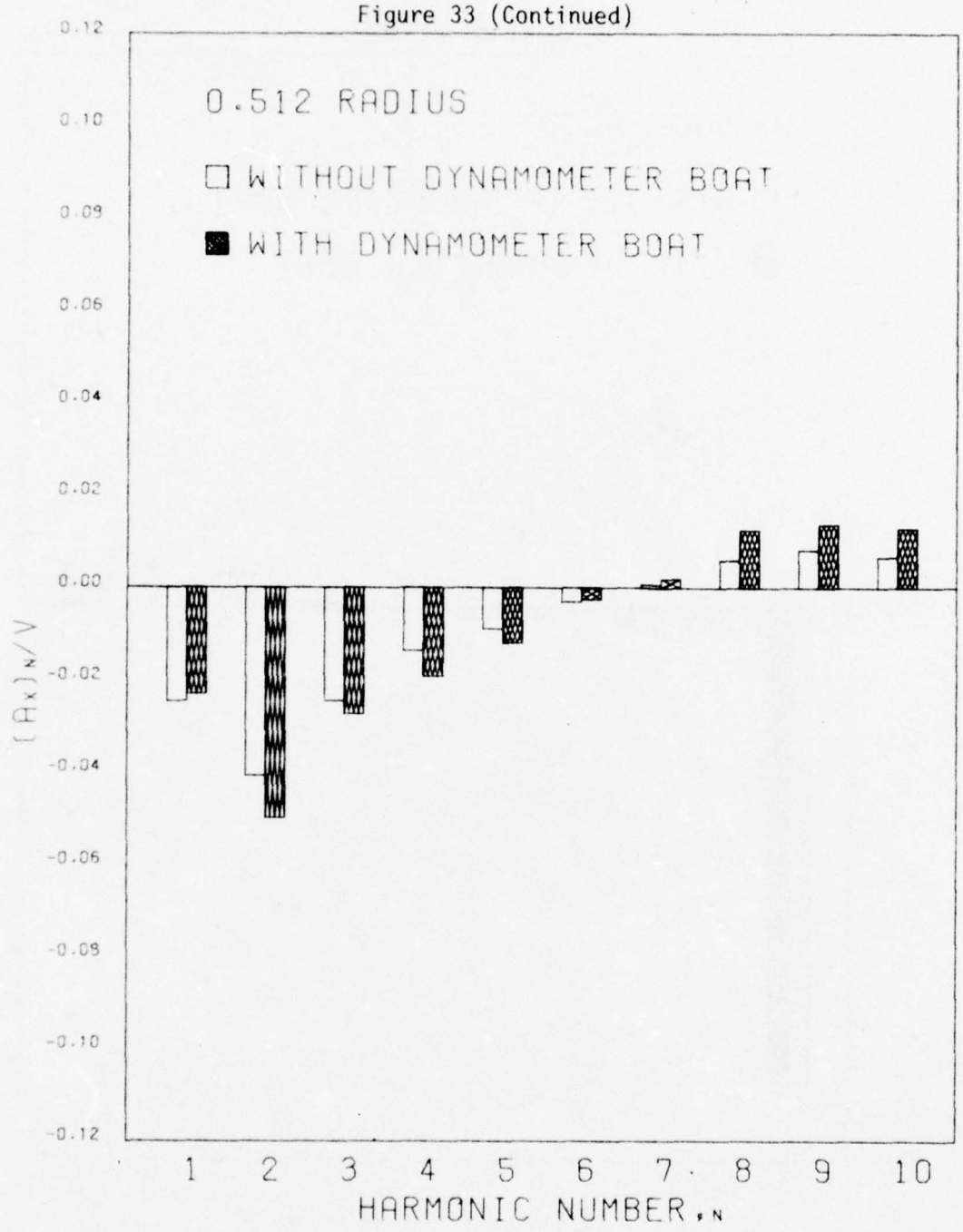


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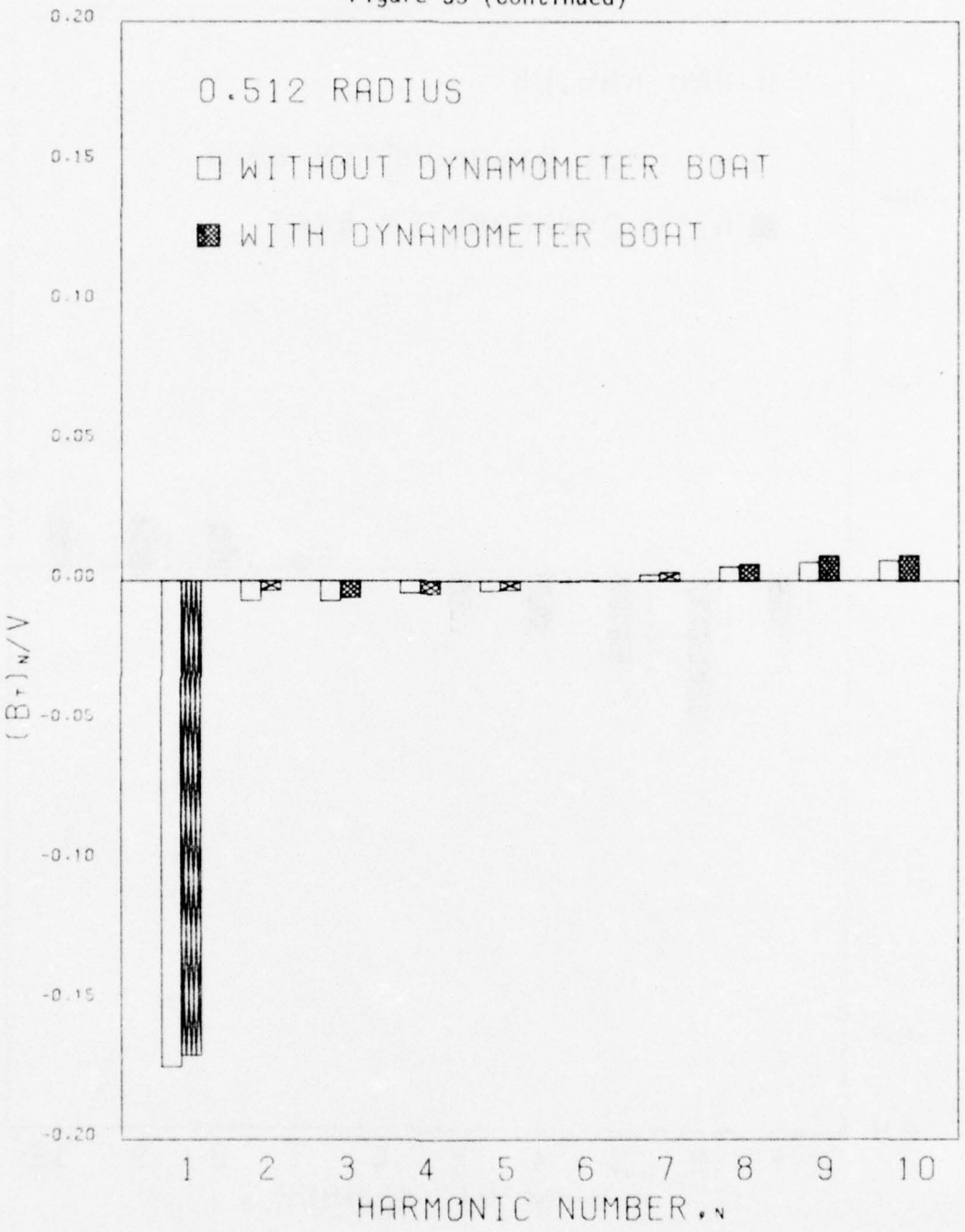


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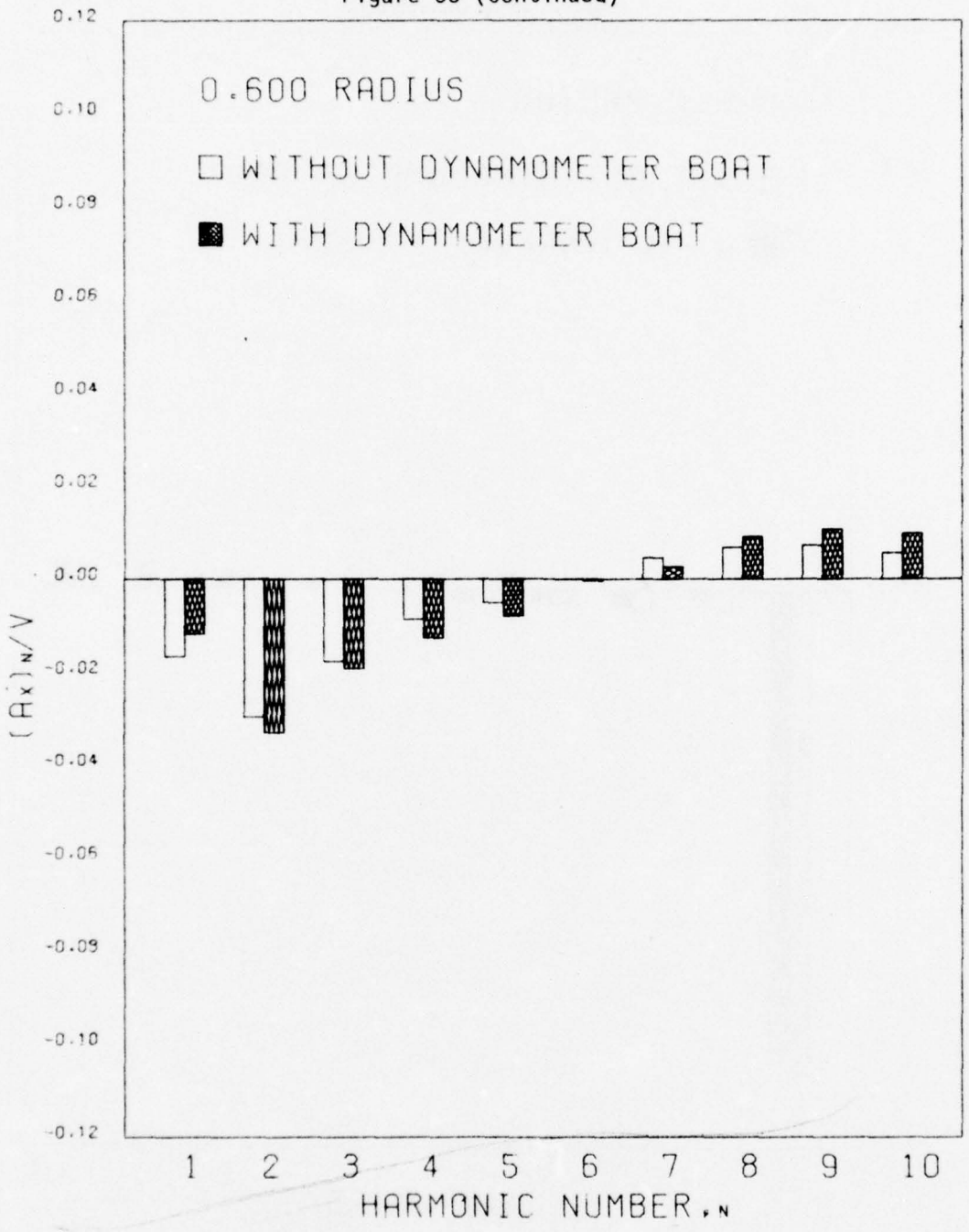


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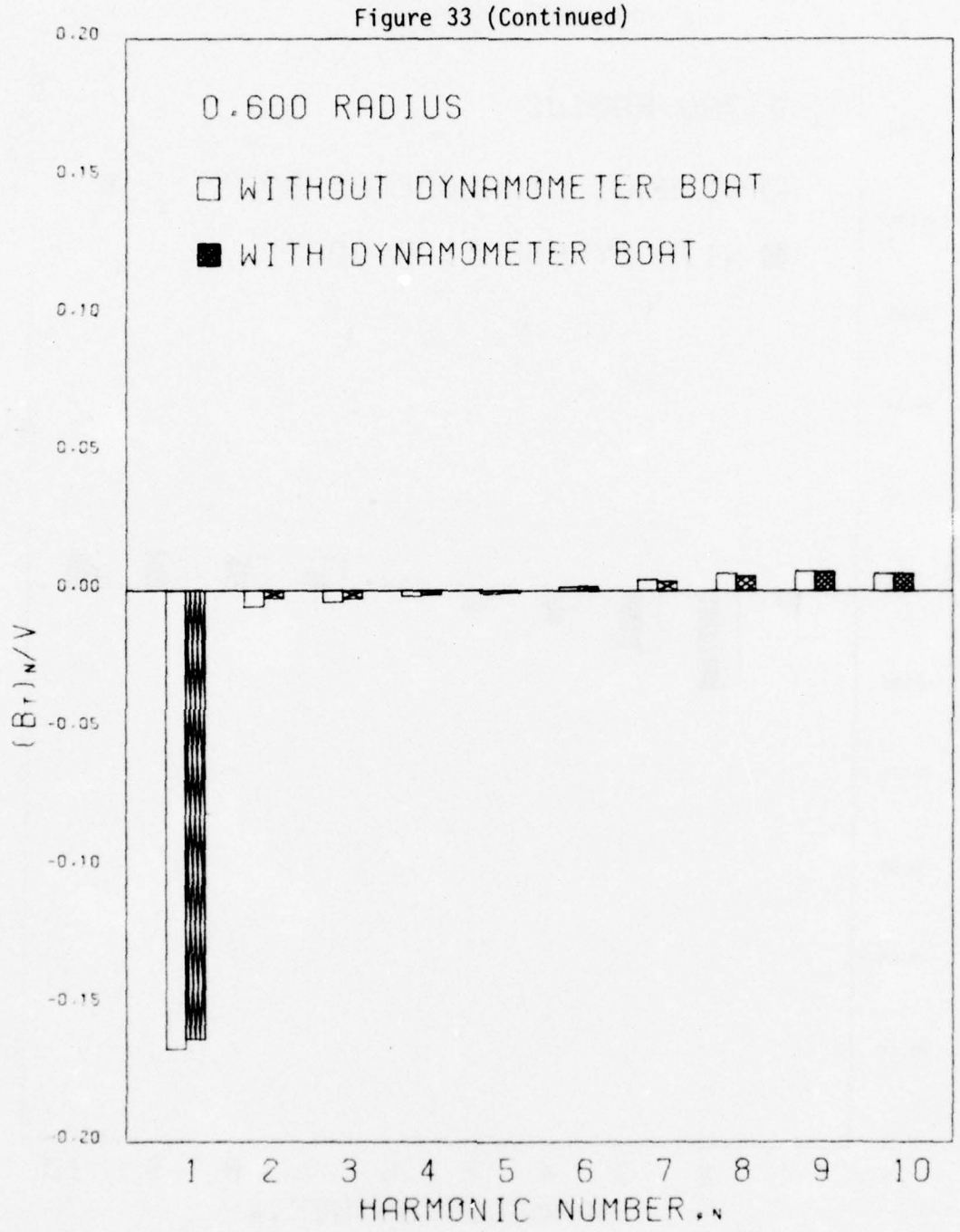


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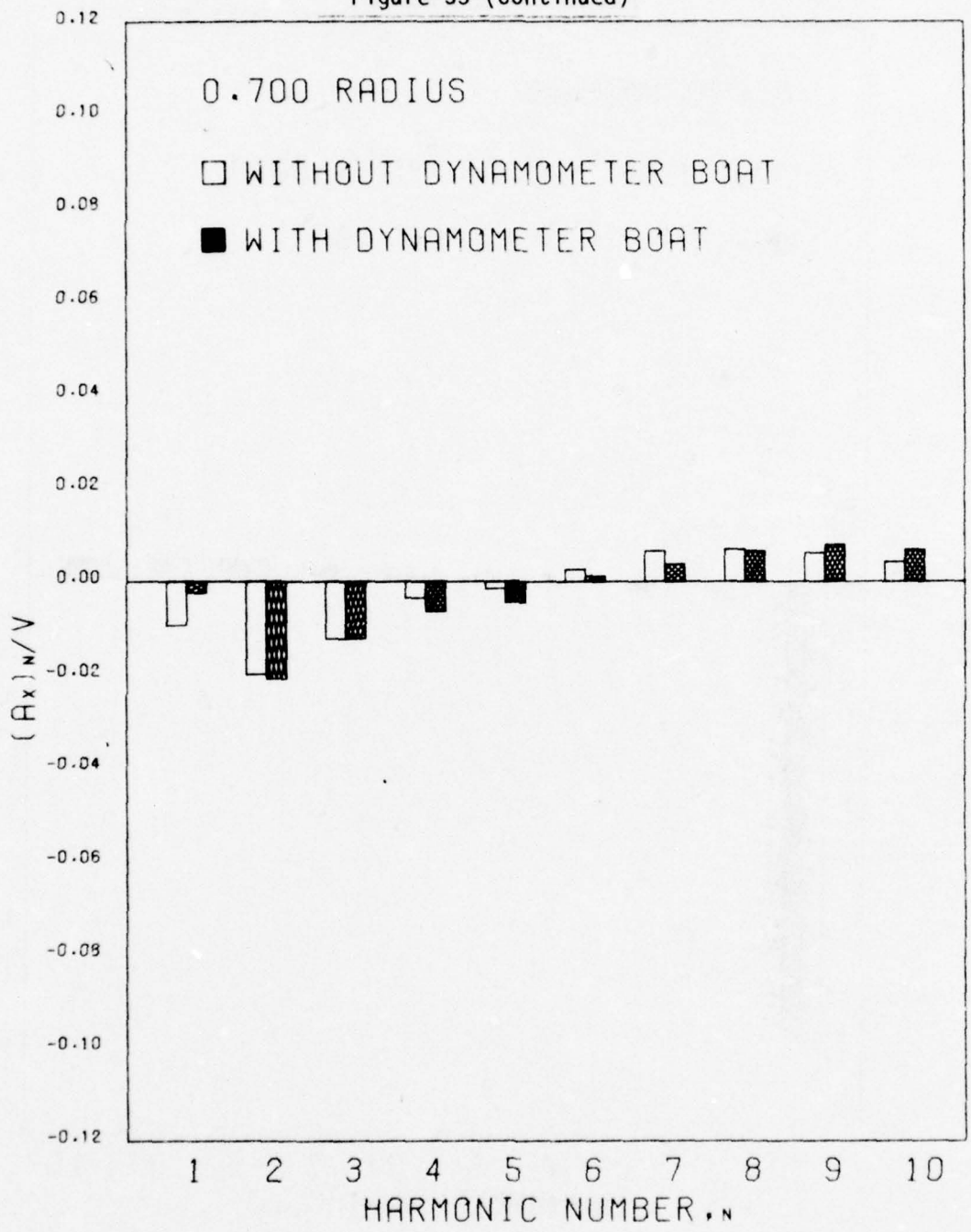


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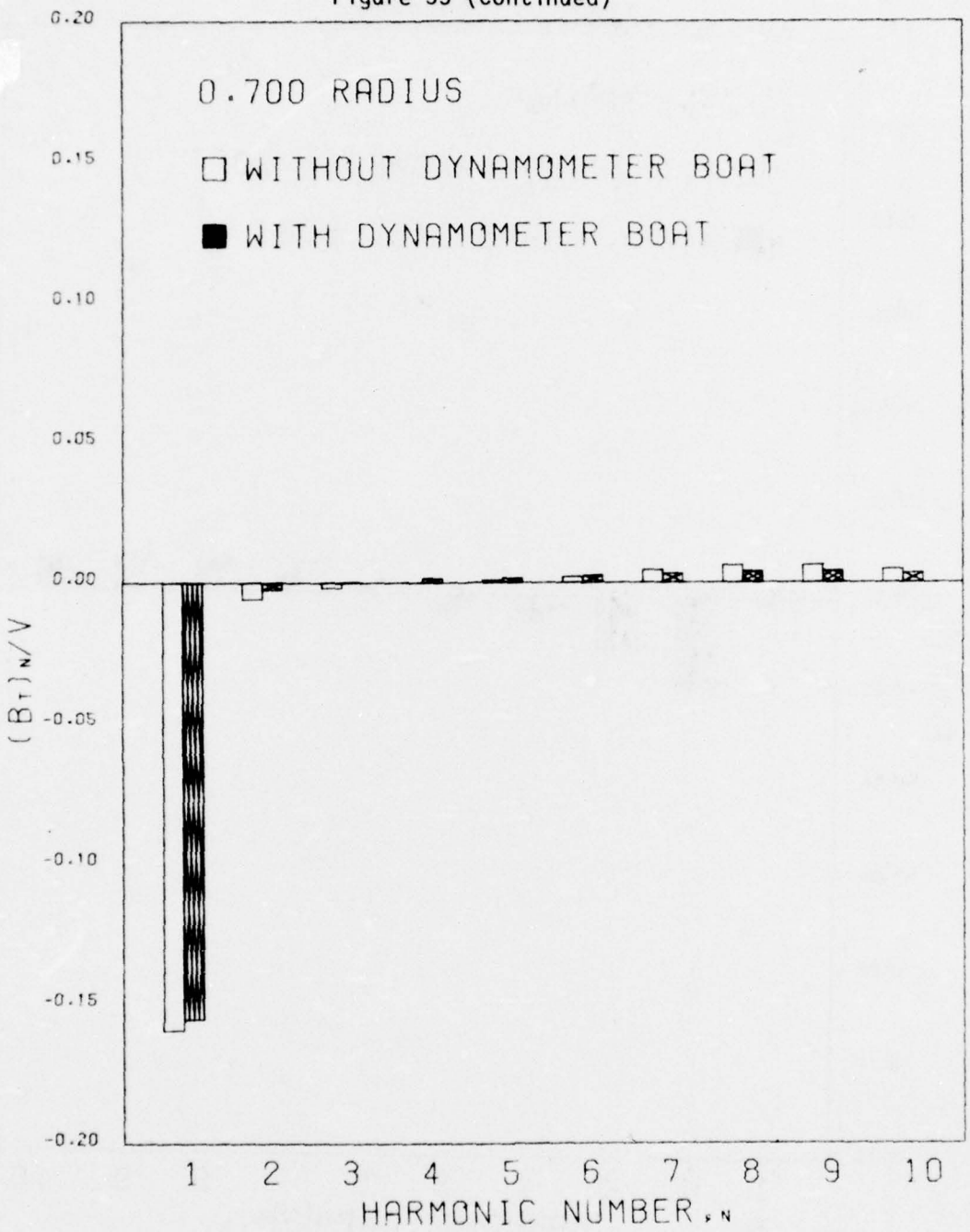


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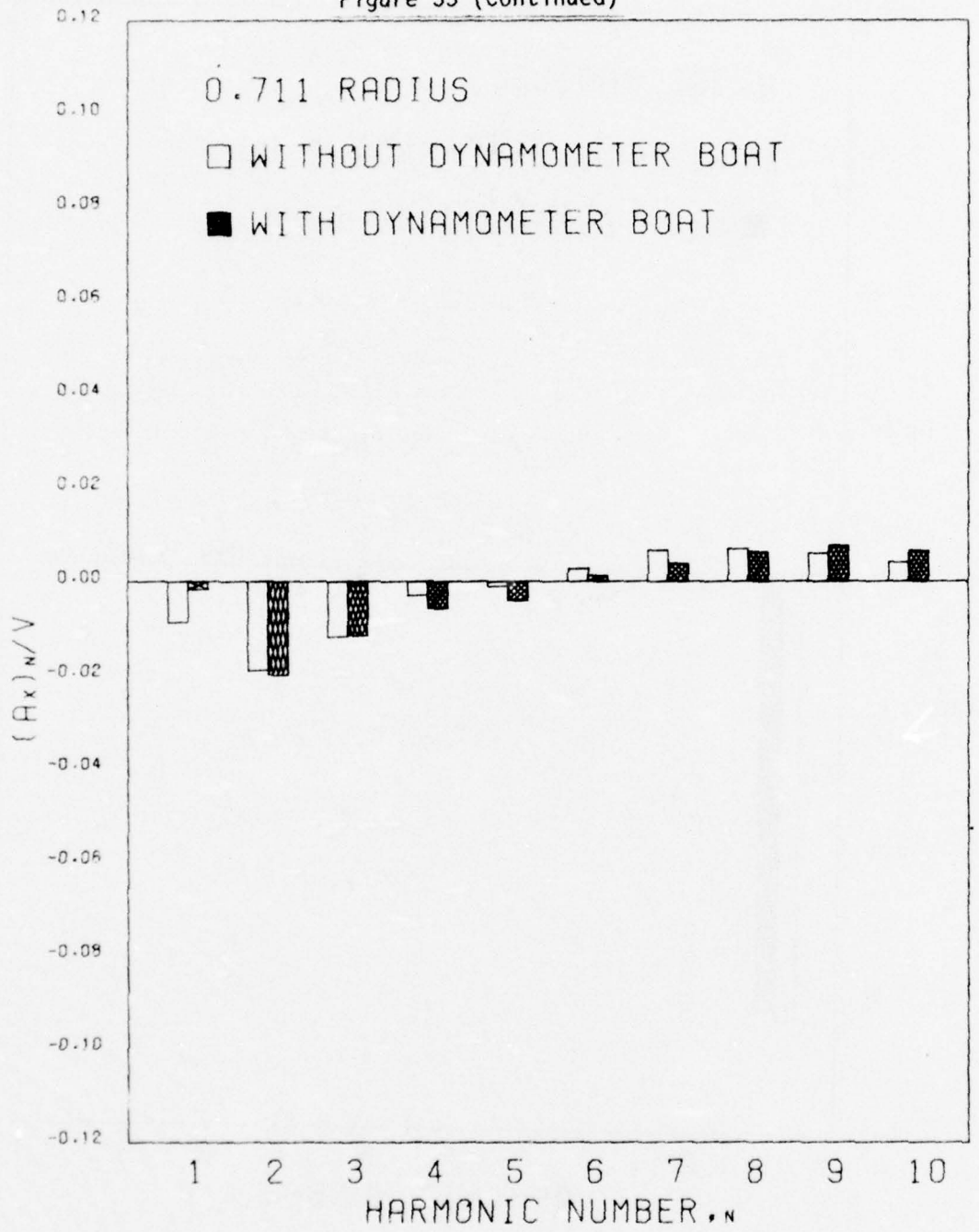


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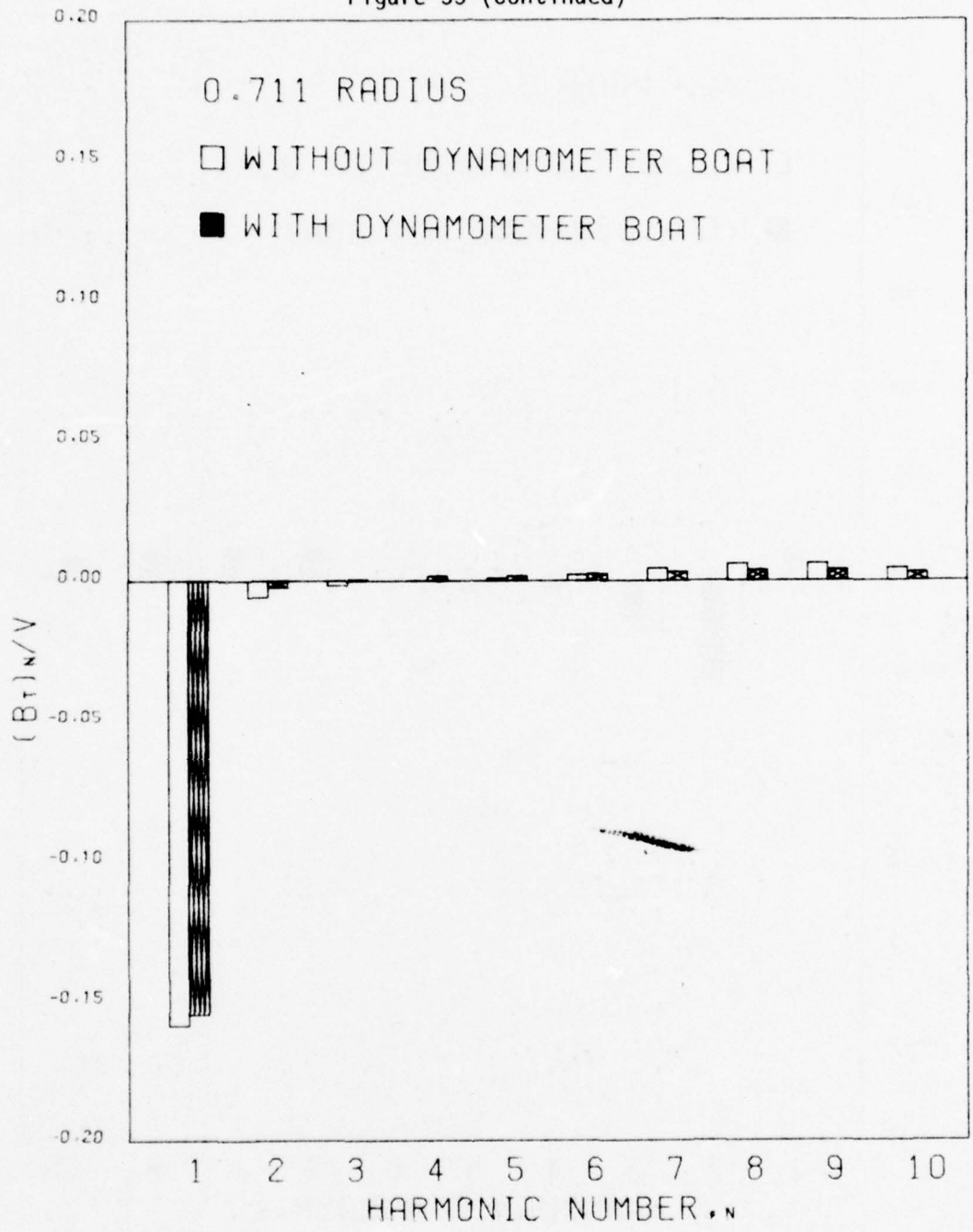


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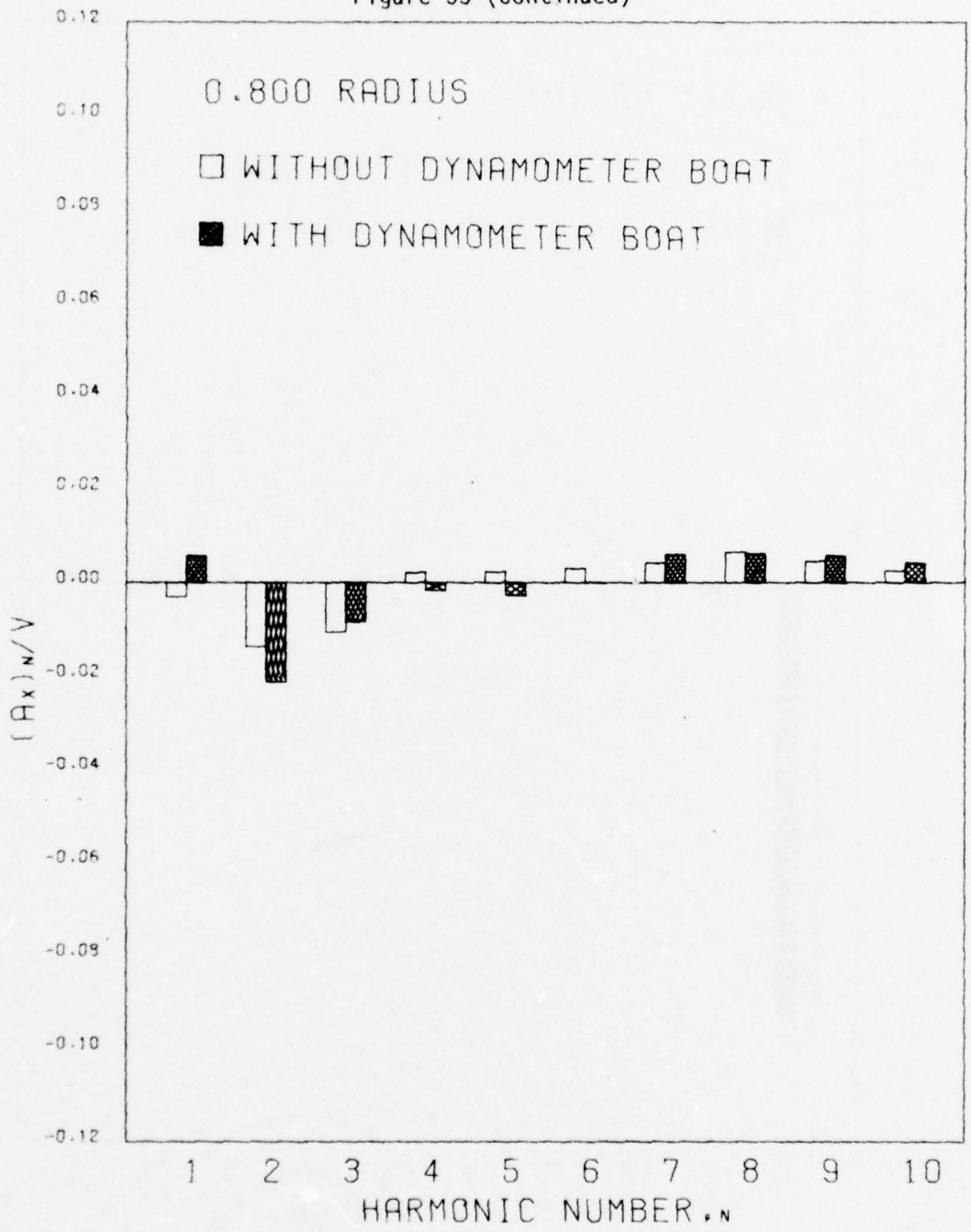


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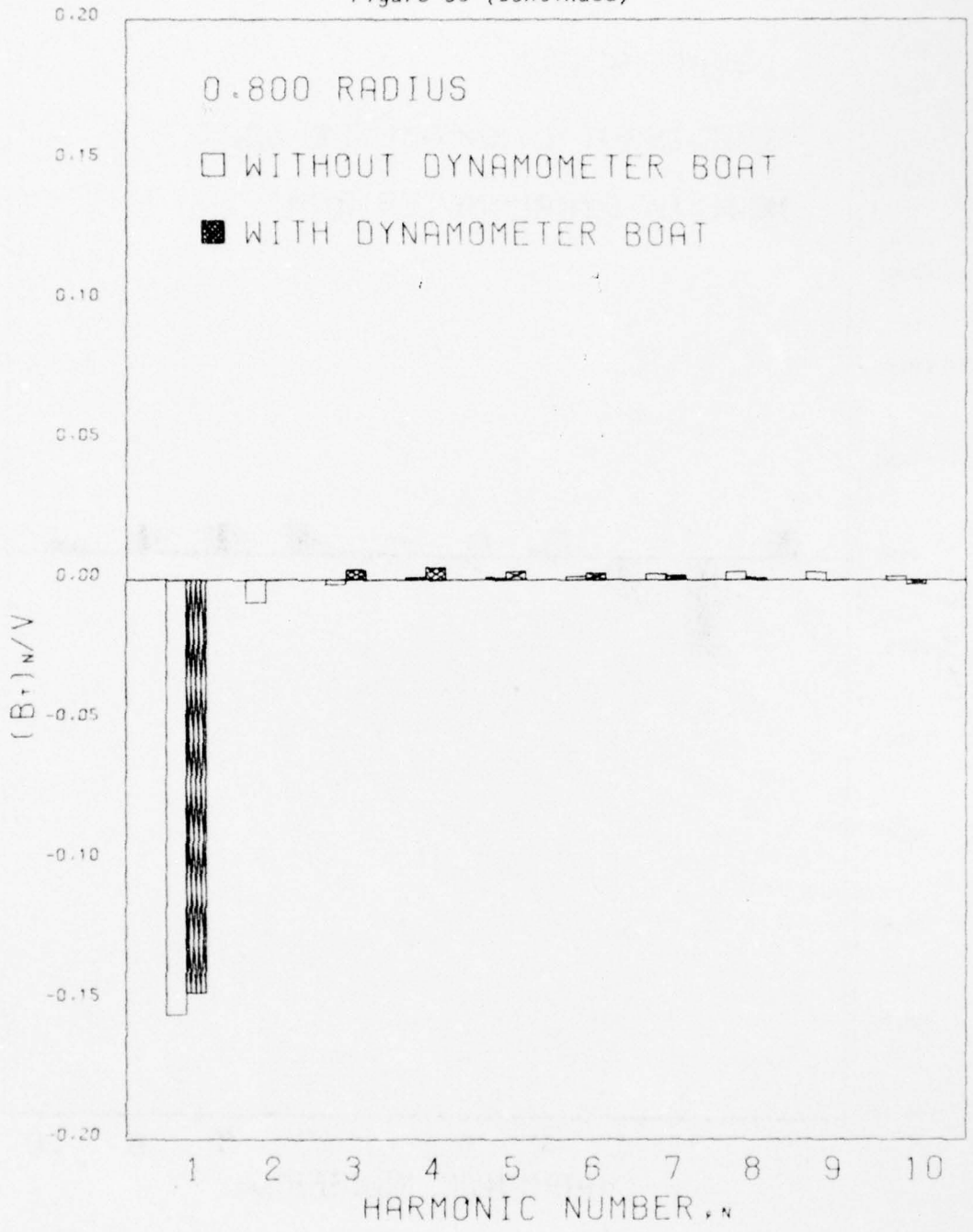


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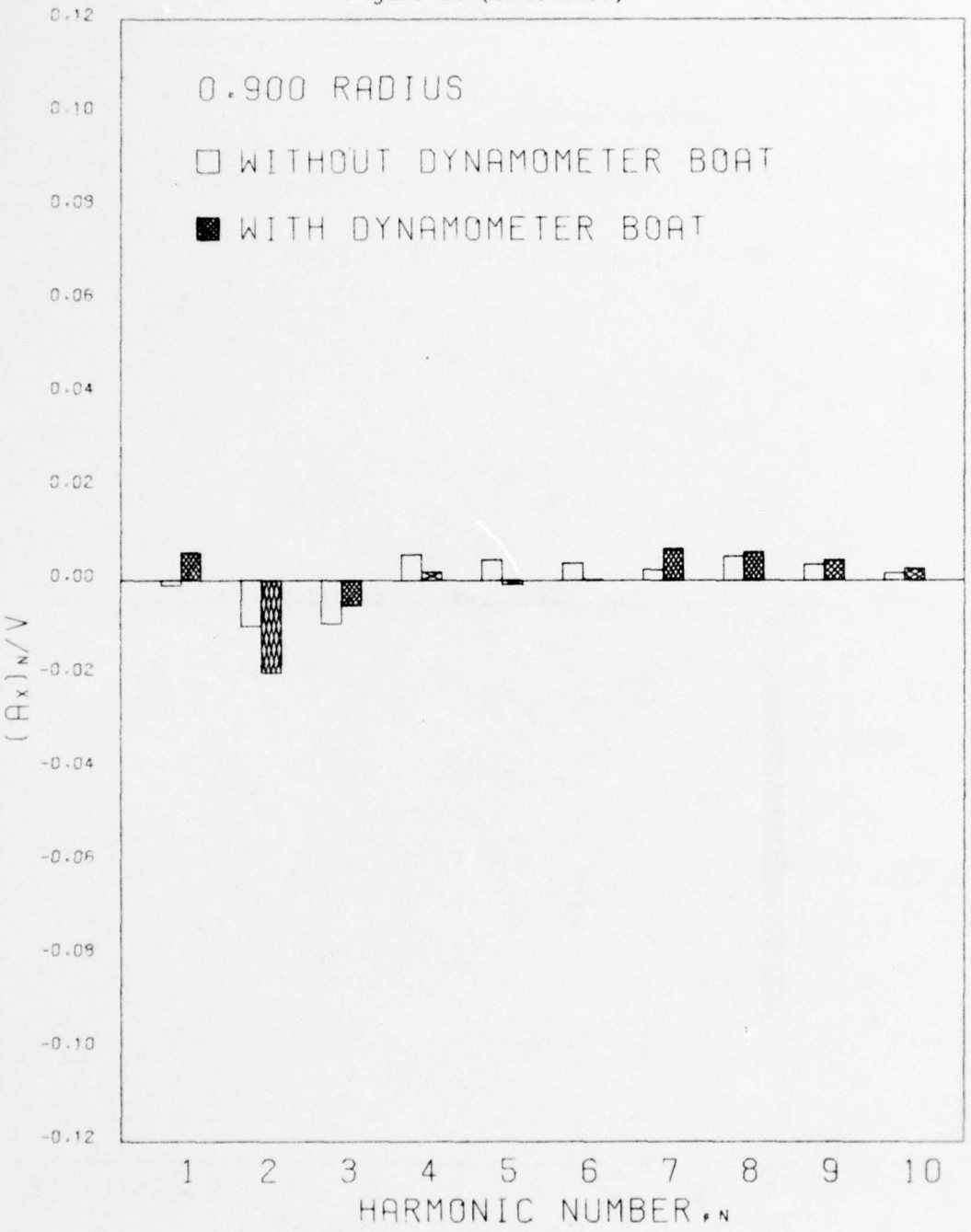


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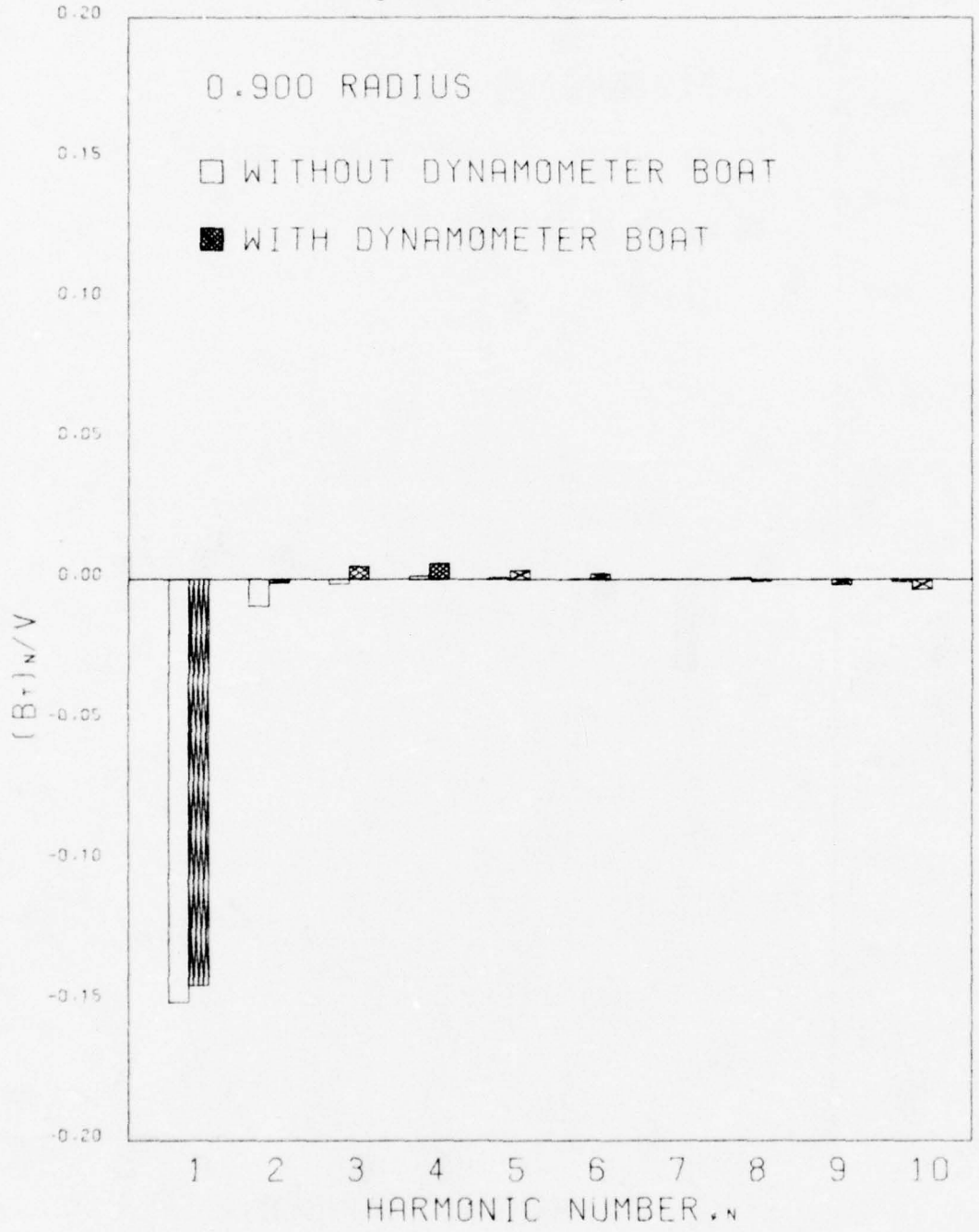


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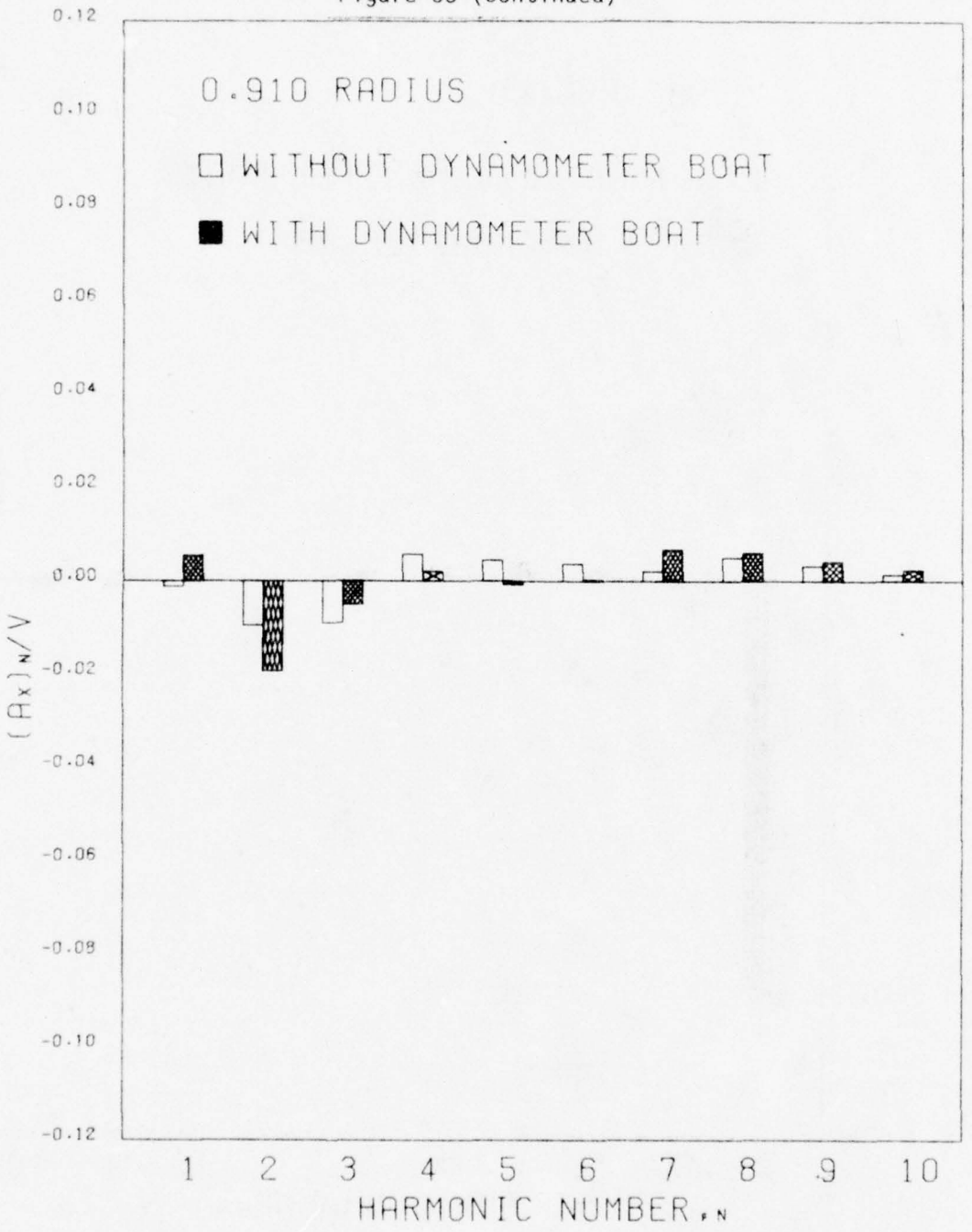


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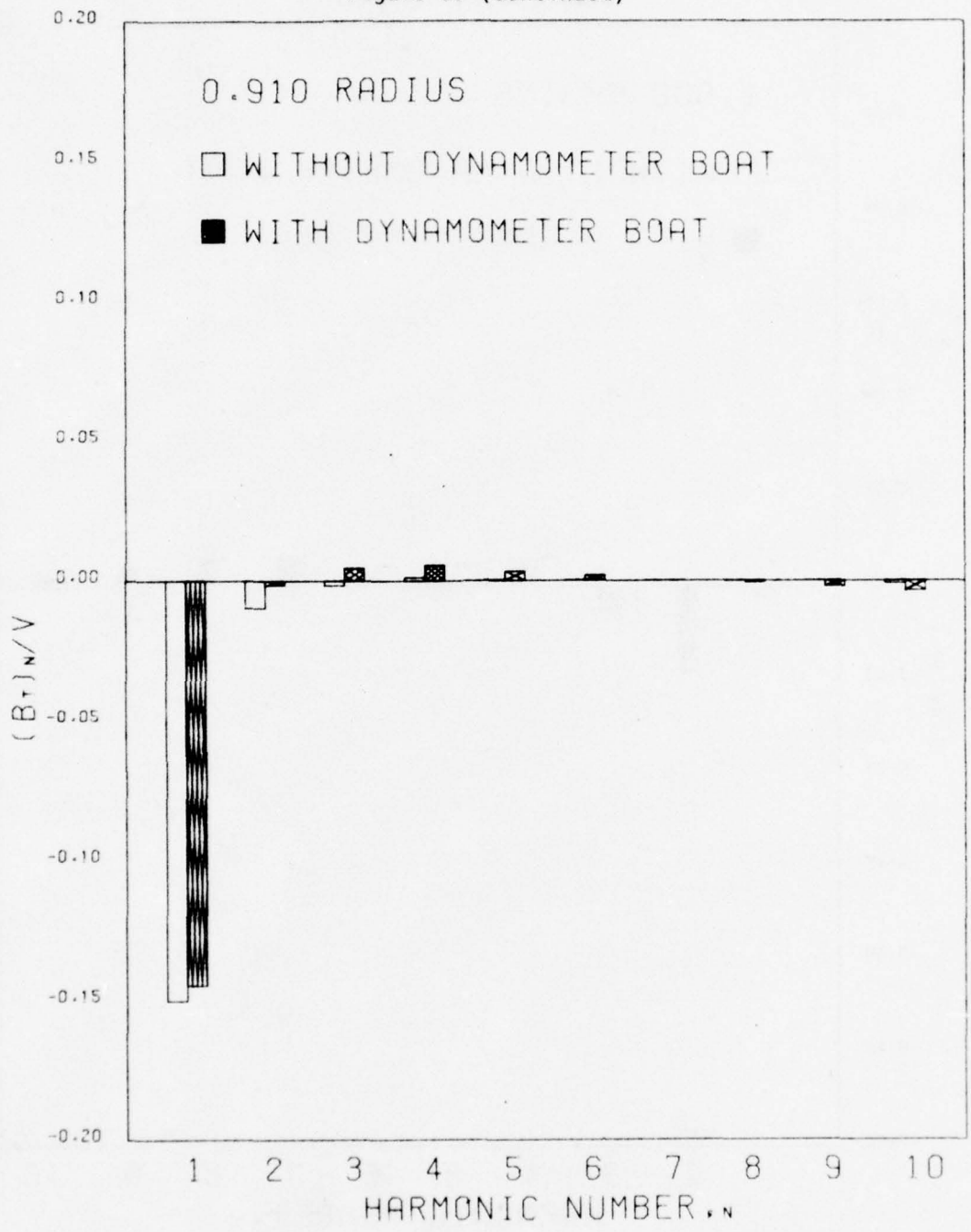


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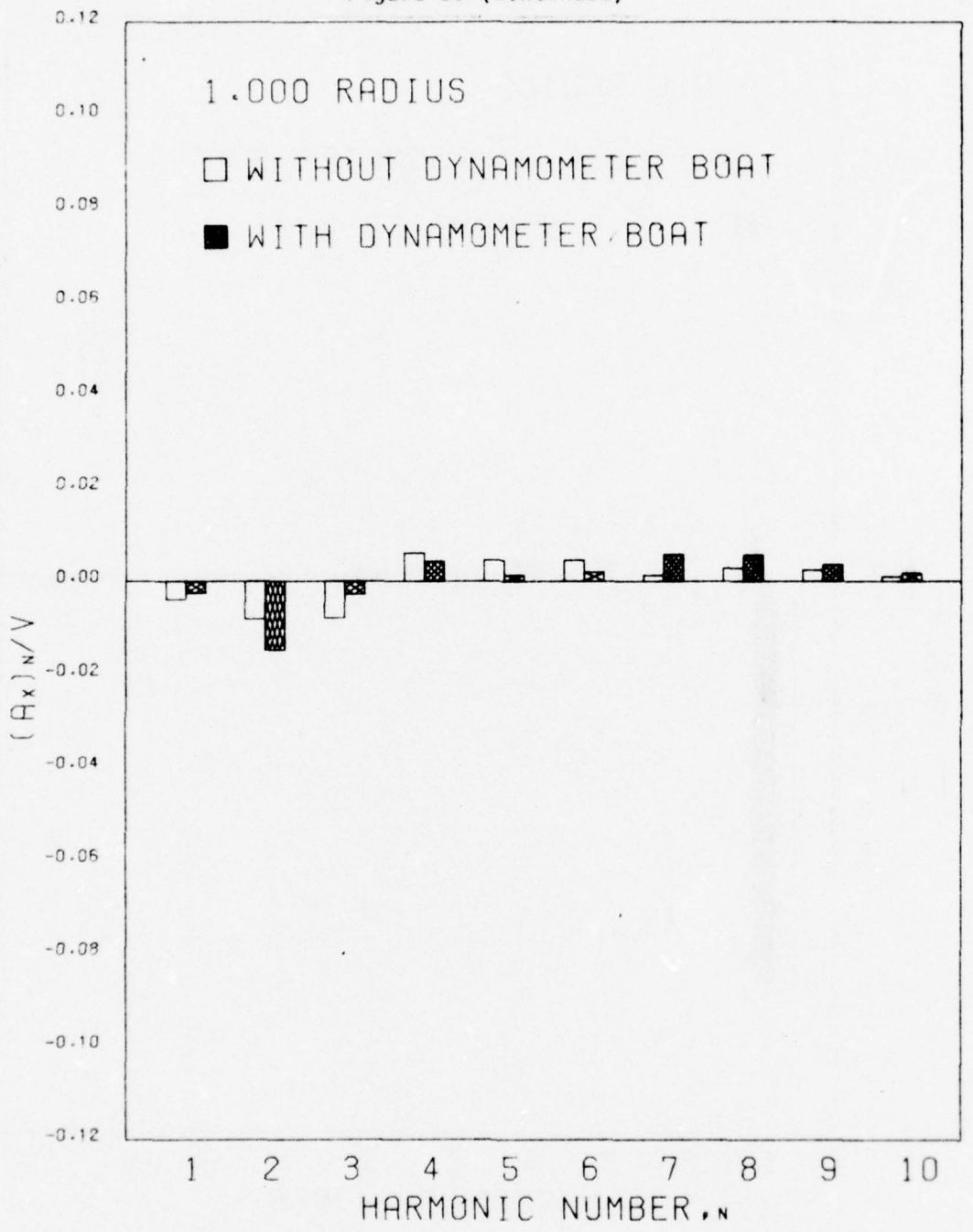


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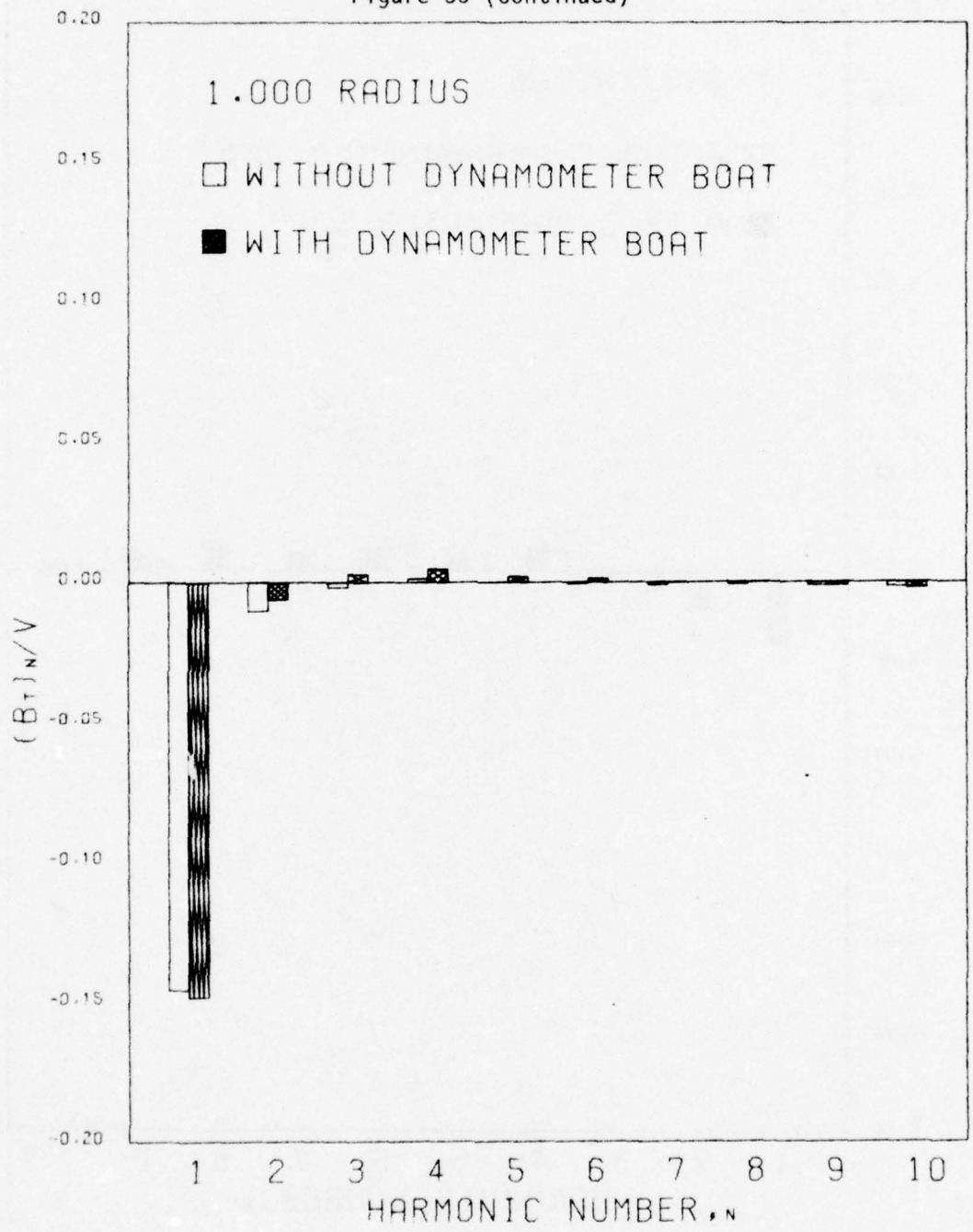


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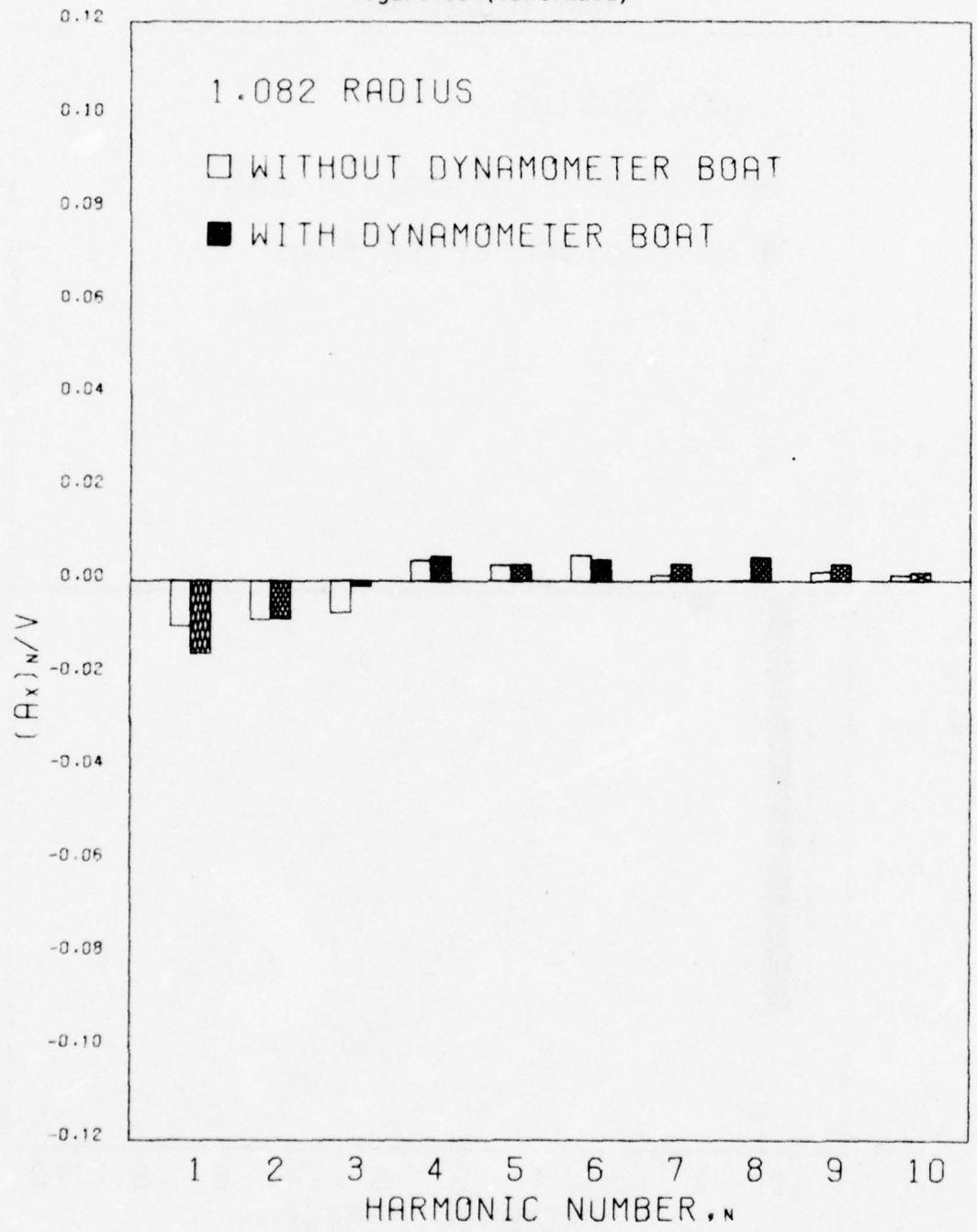


Figure 33 (Continued)

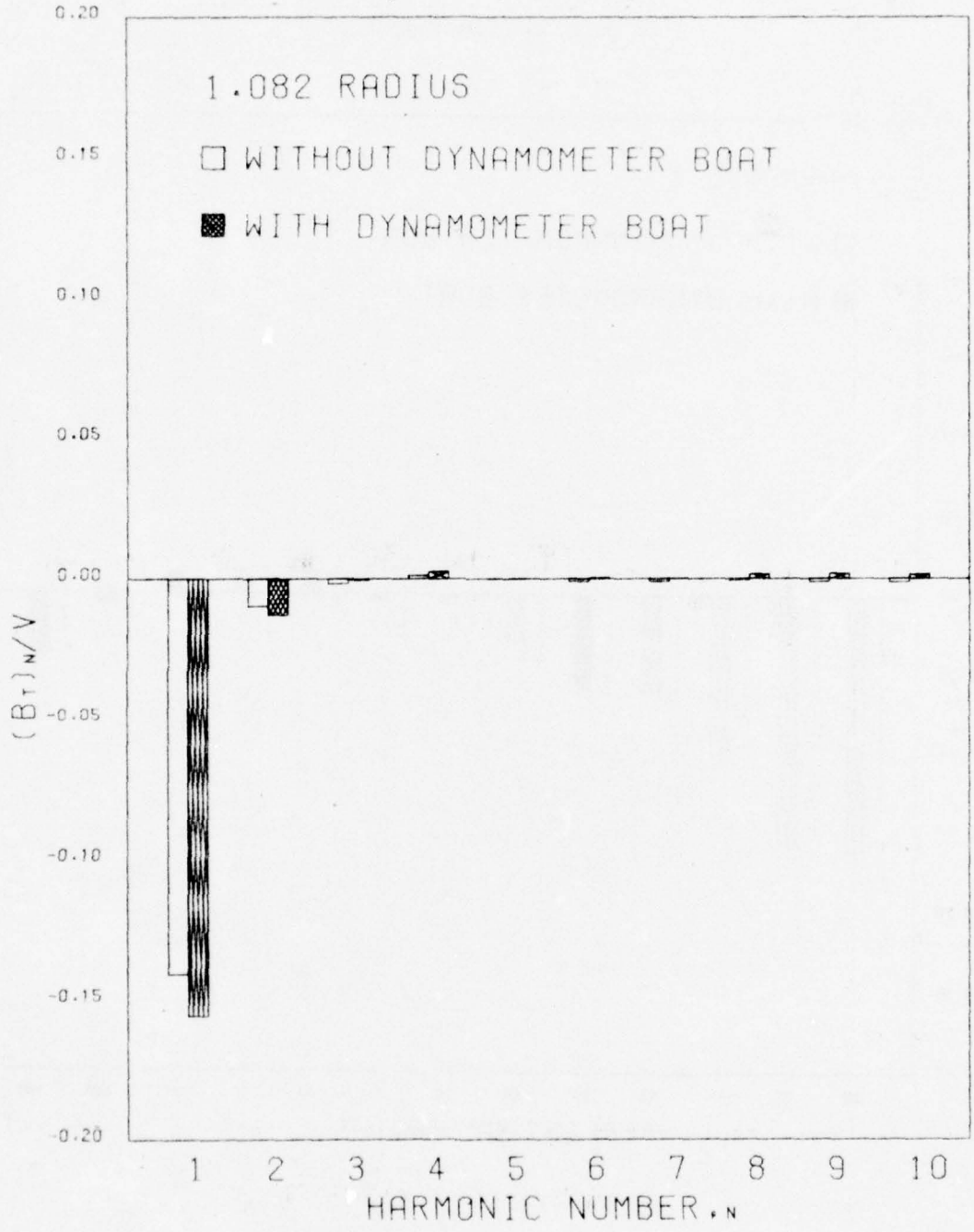


Figure 33 (Continued)

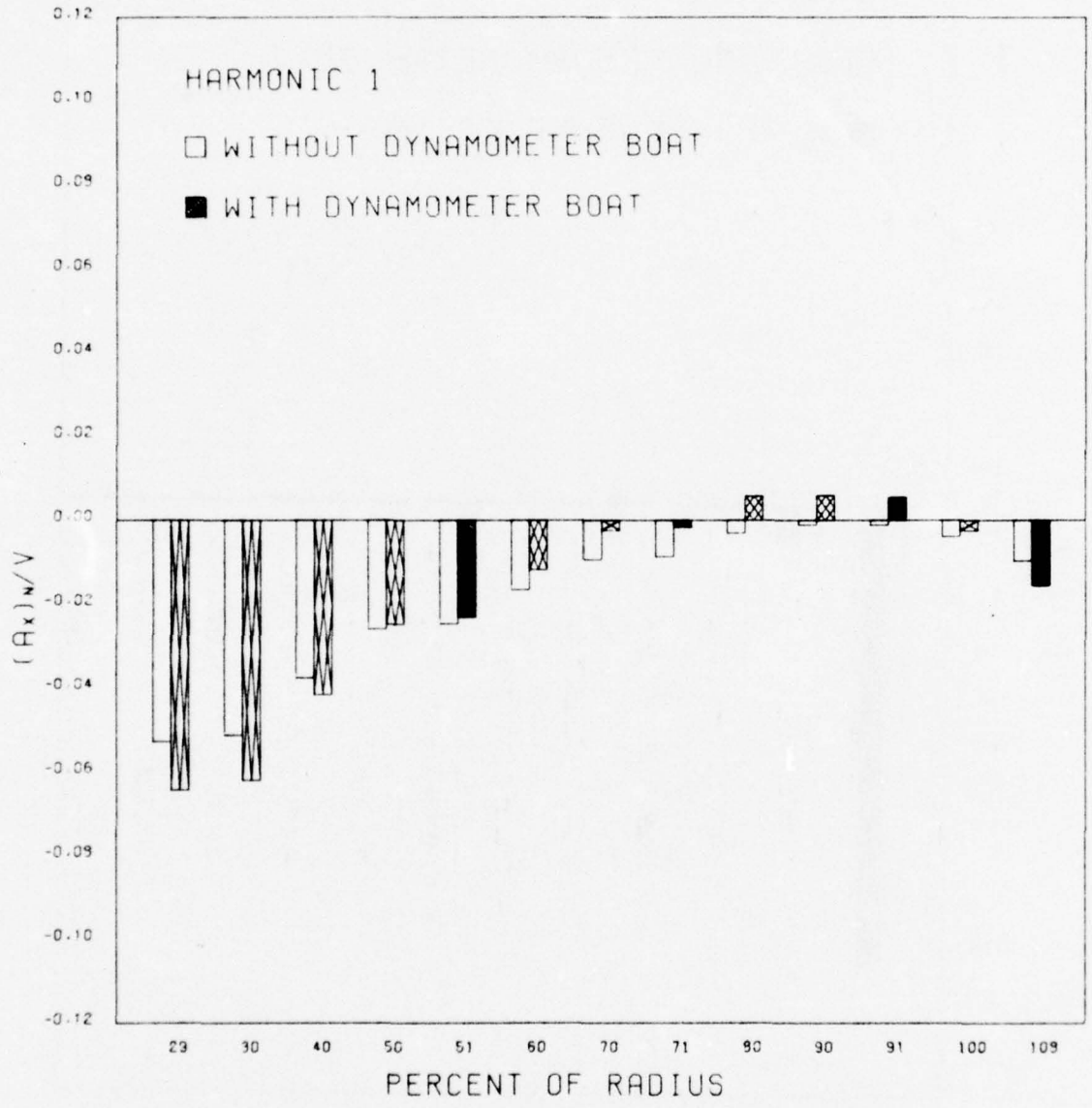


Figure 33 (Continued)

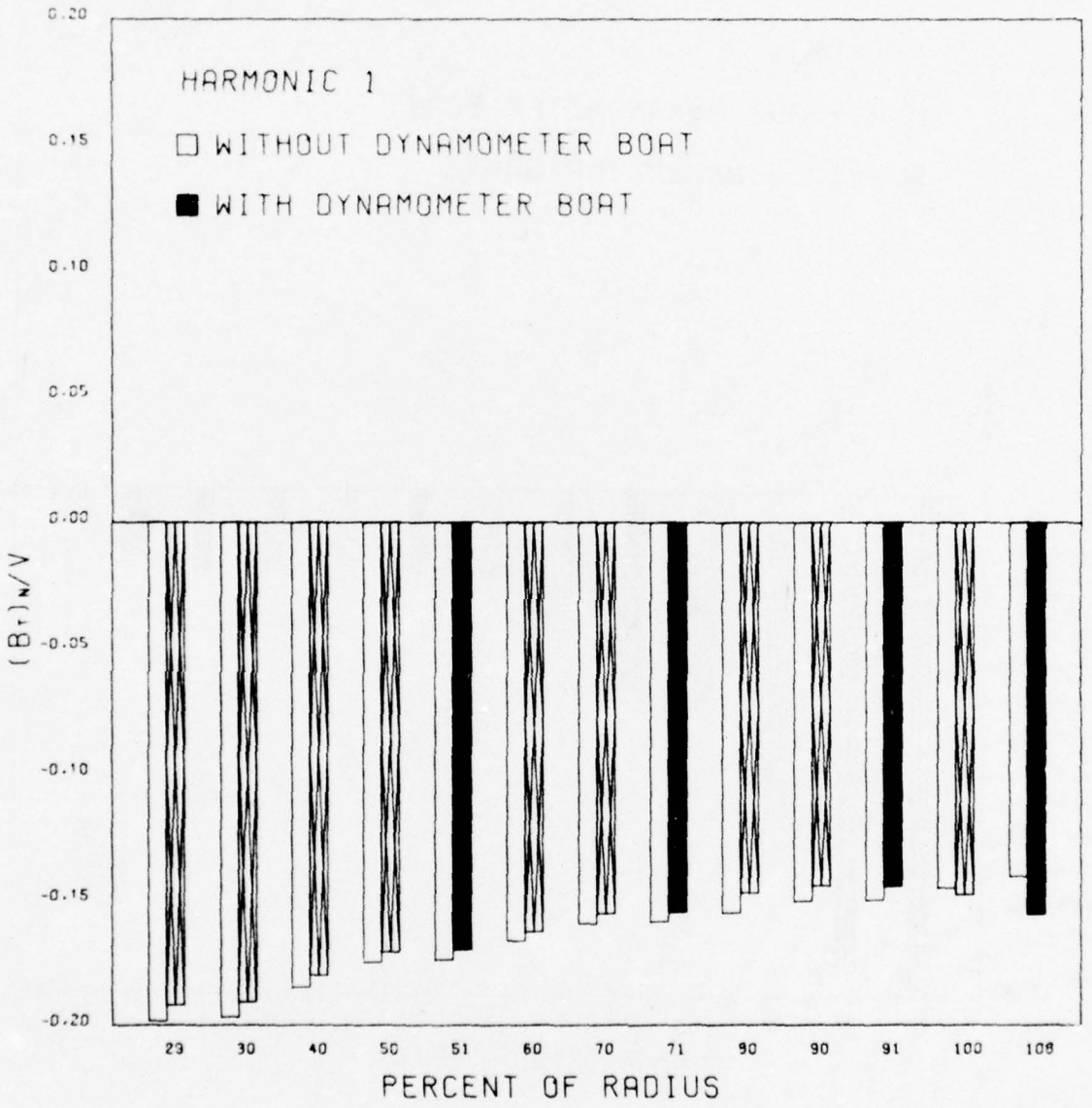


Figure 33 (Continued)

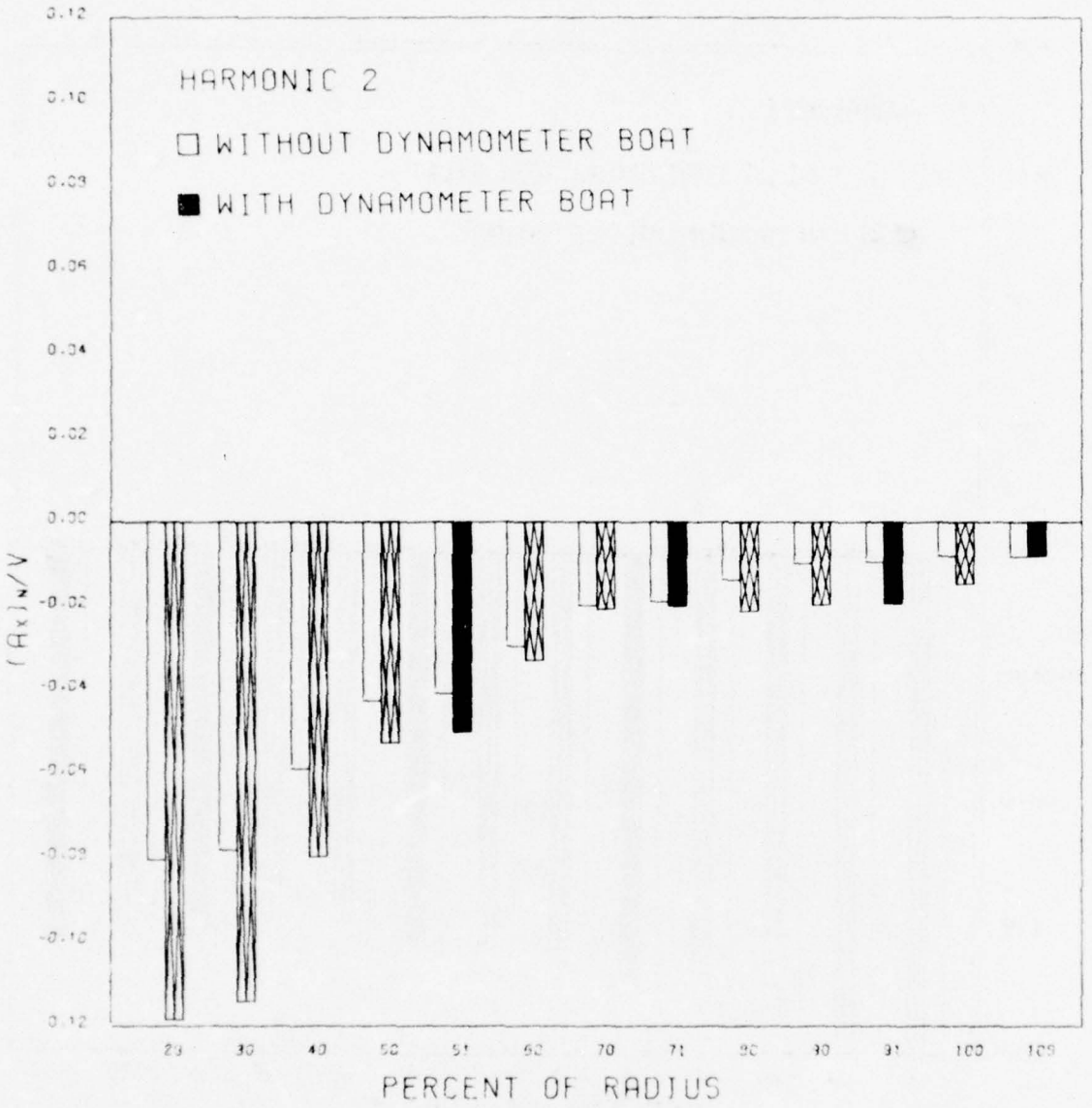


Figure 33 (Continued)

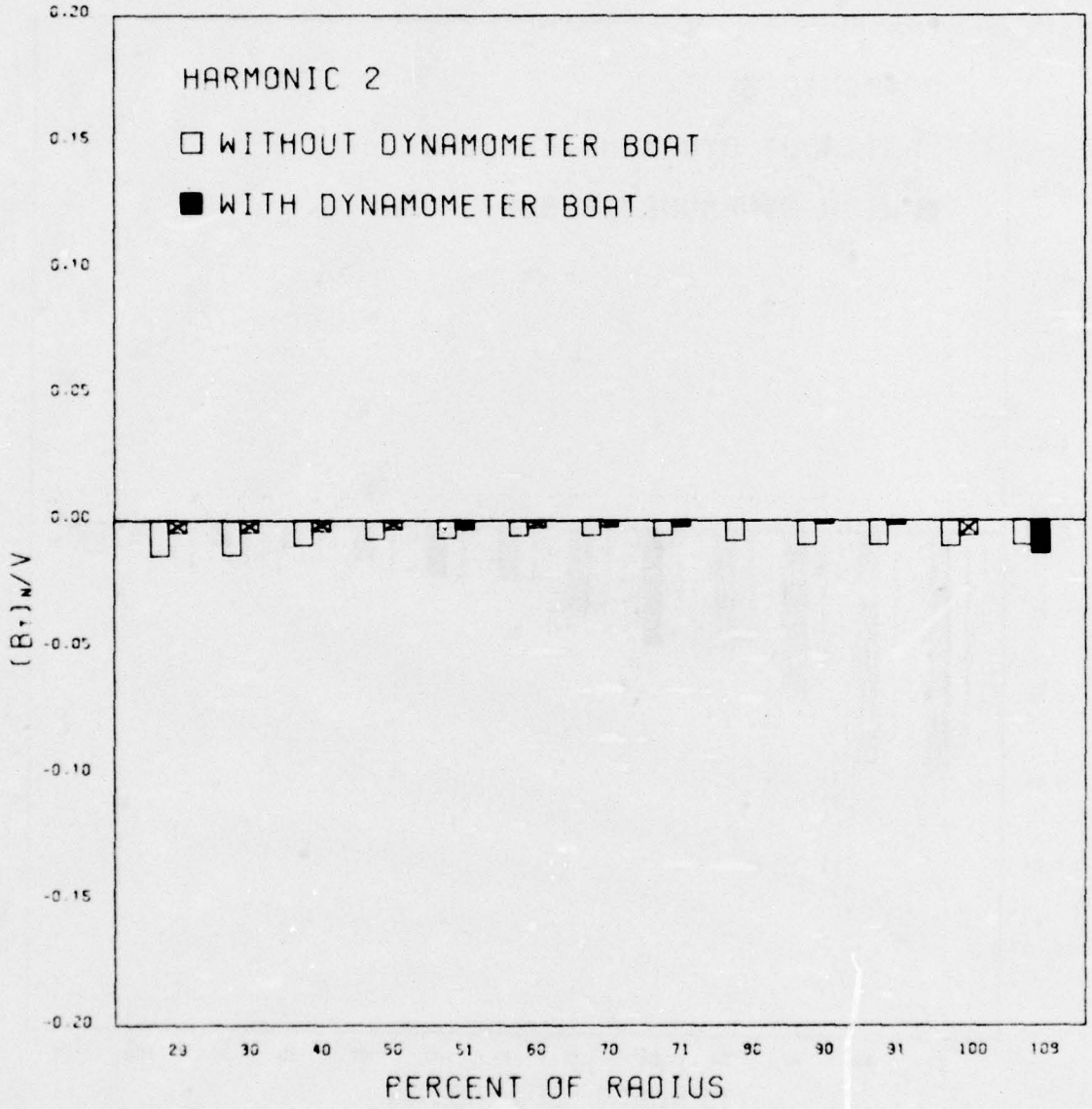


Figure 33 (Continued)

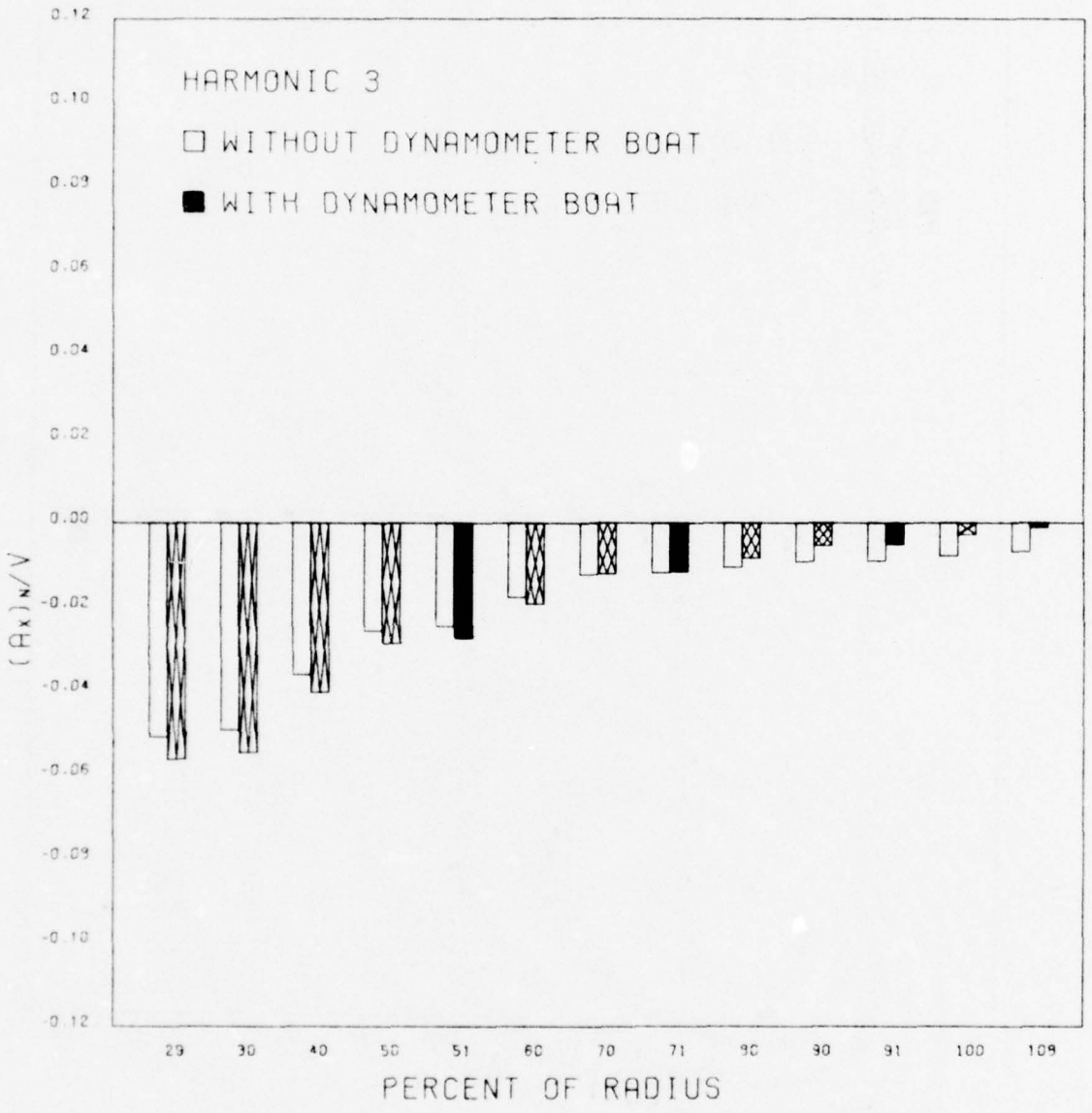


Figure 33 (Continued)

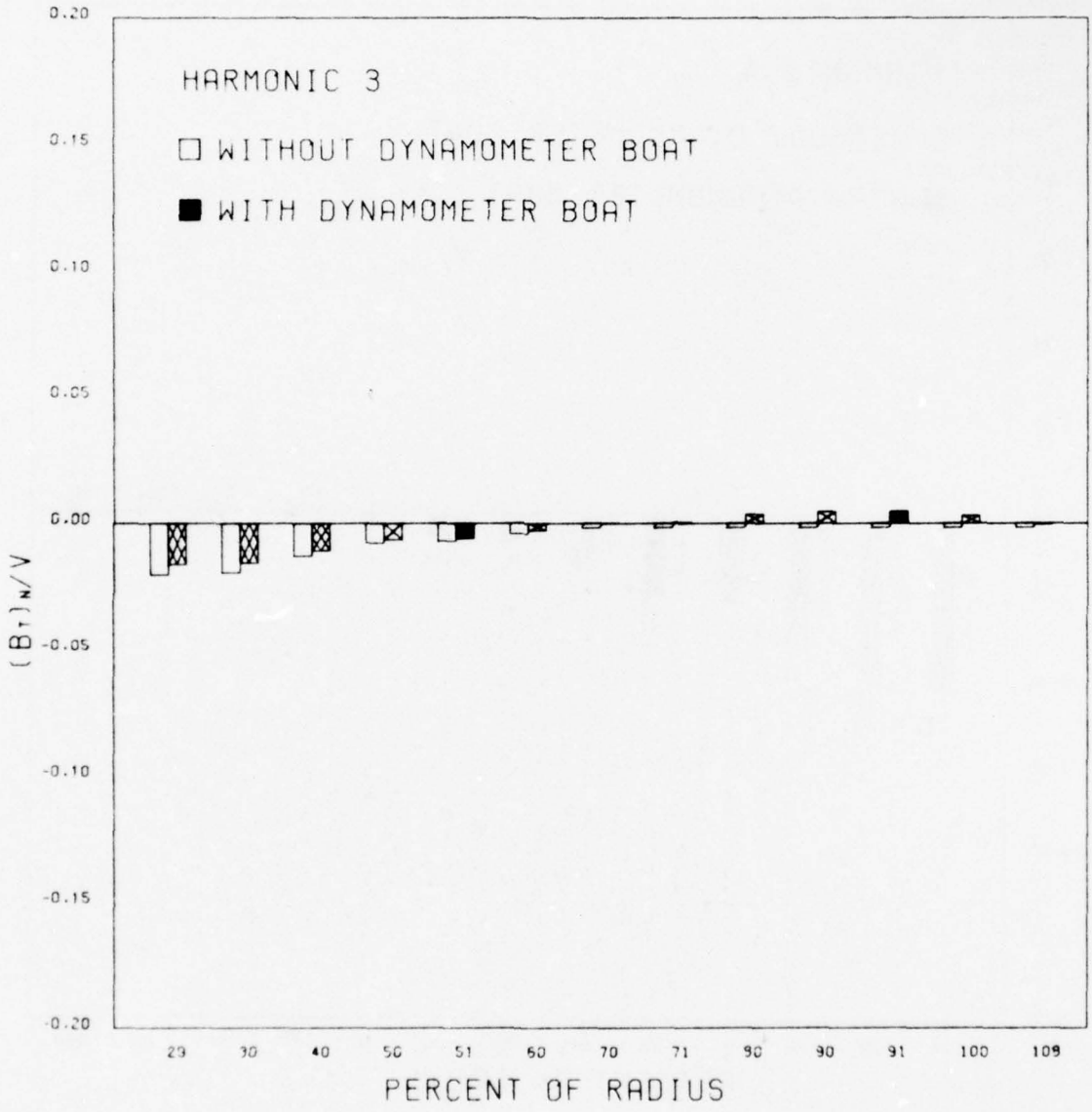


Figure 33 (Continued)

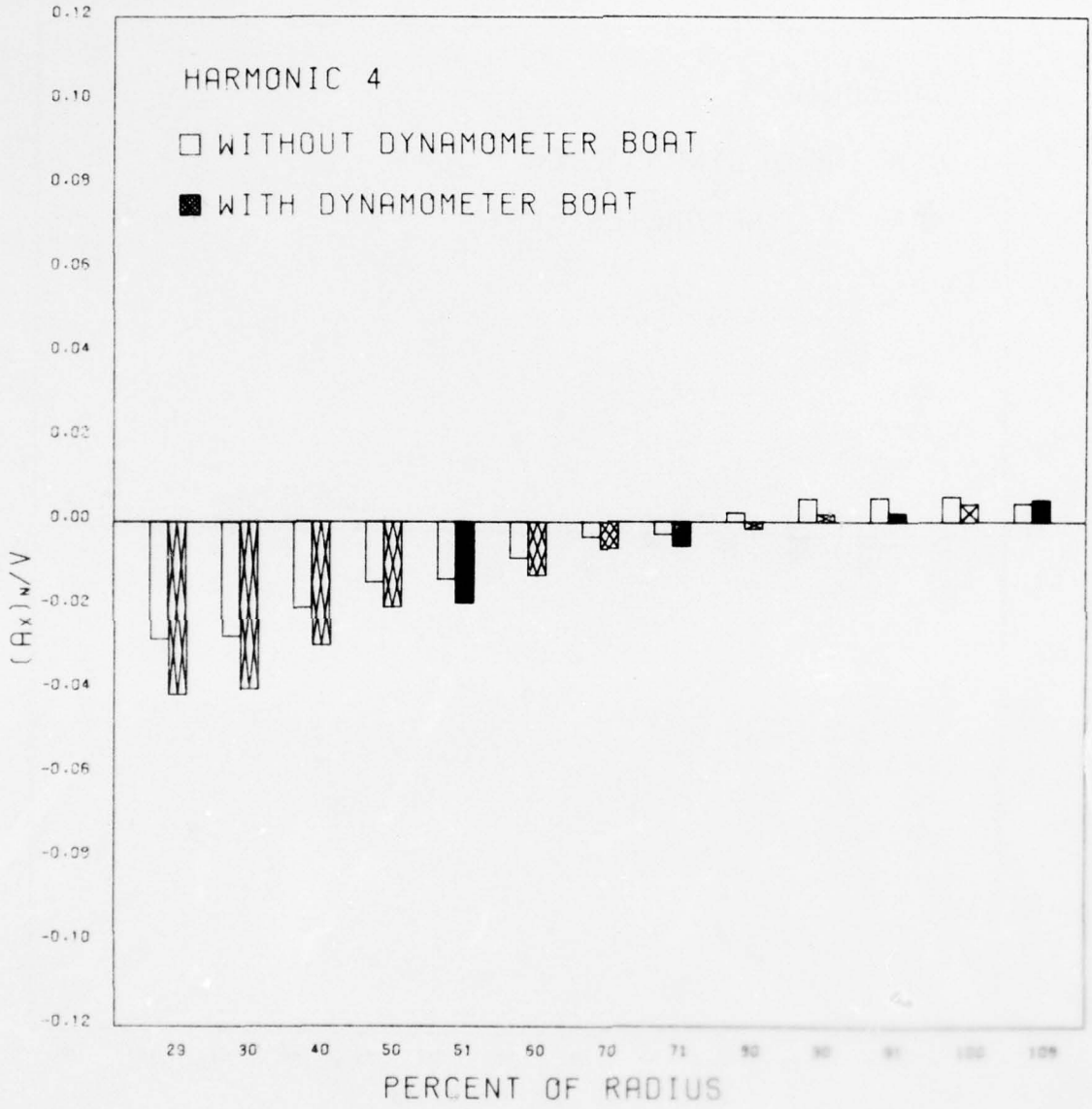


Figure 33 (Continued)

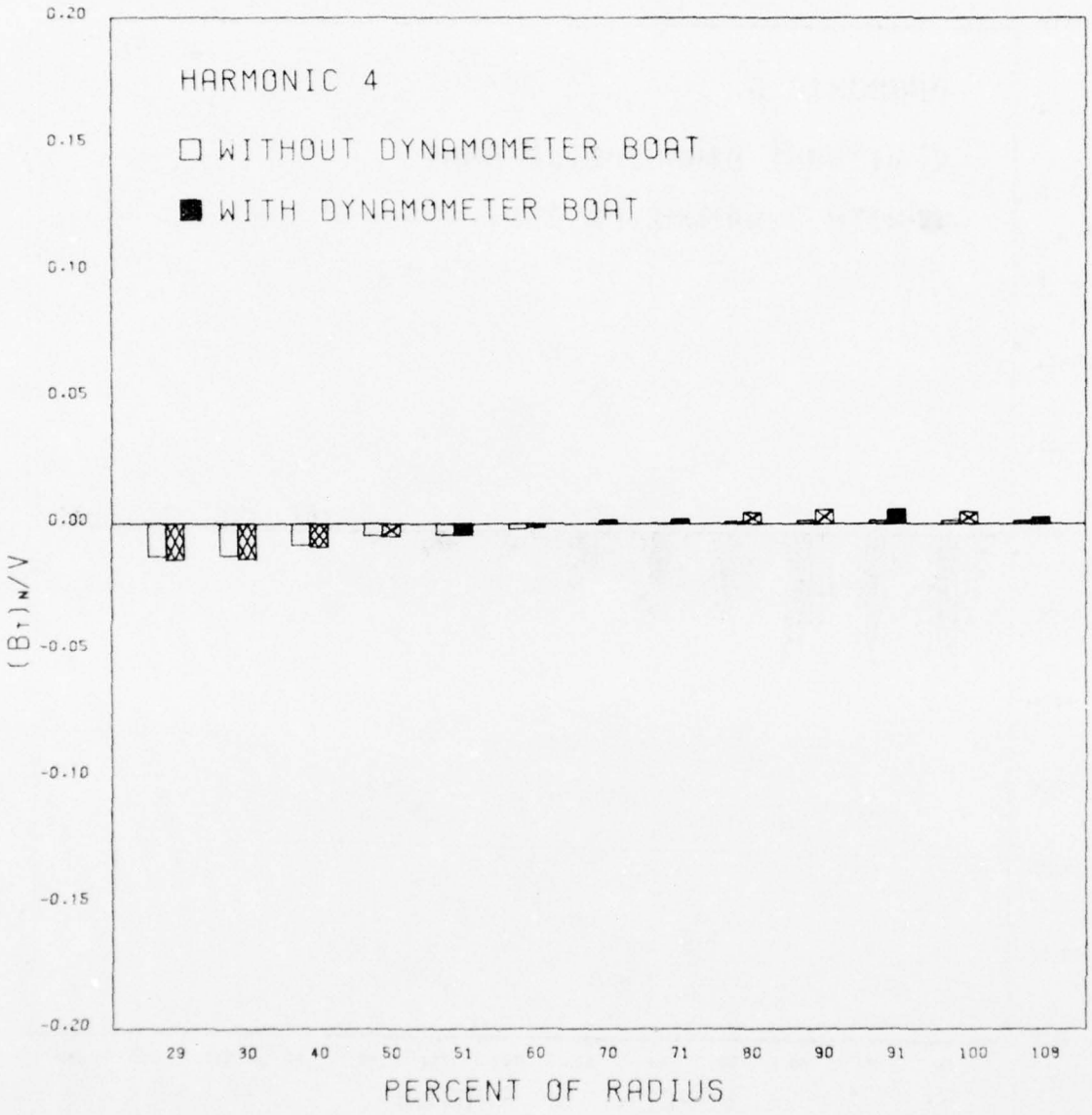


Figure 33 (Continued)

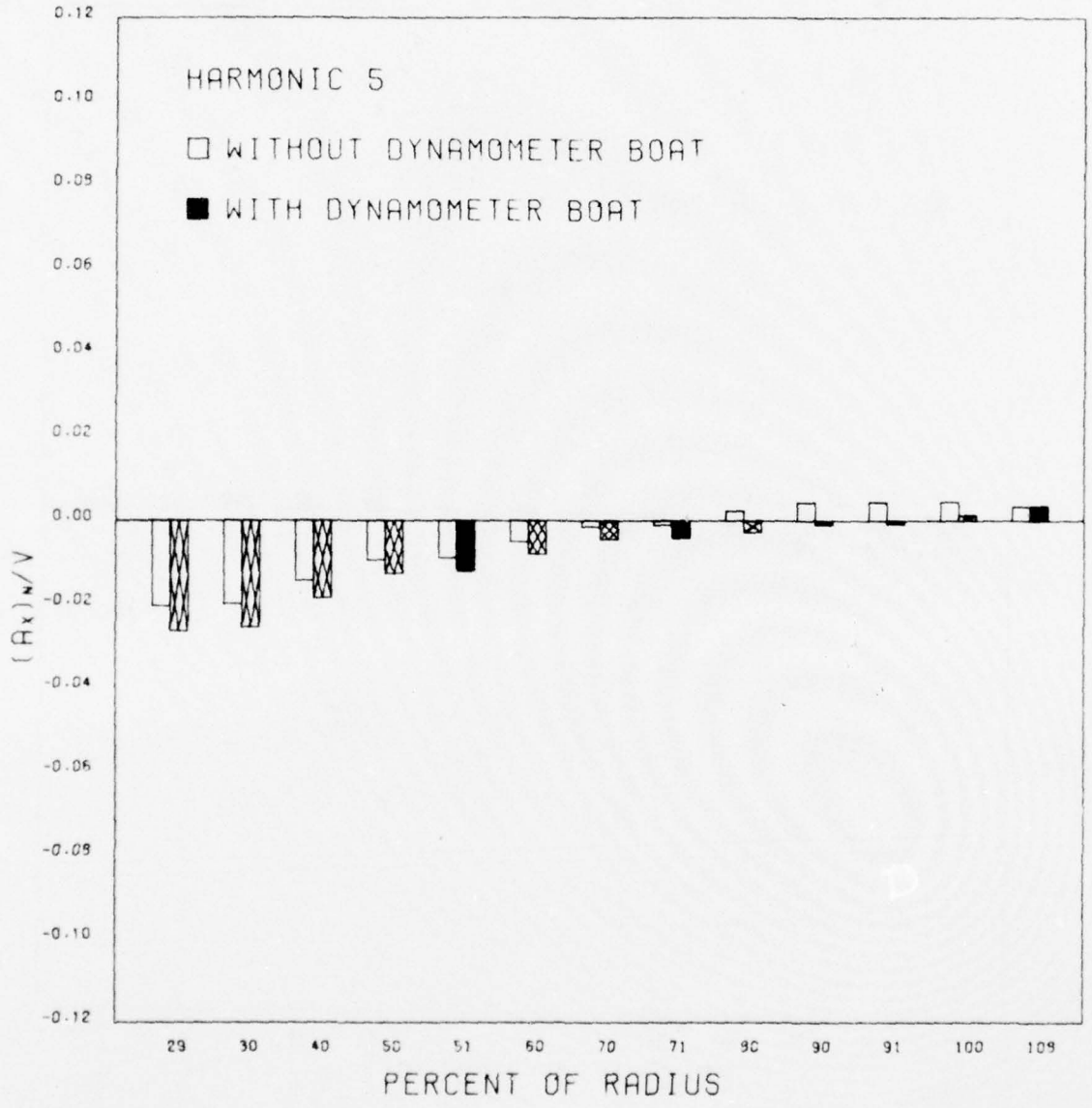


Figure 33 (Continued)

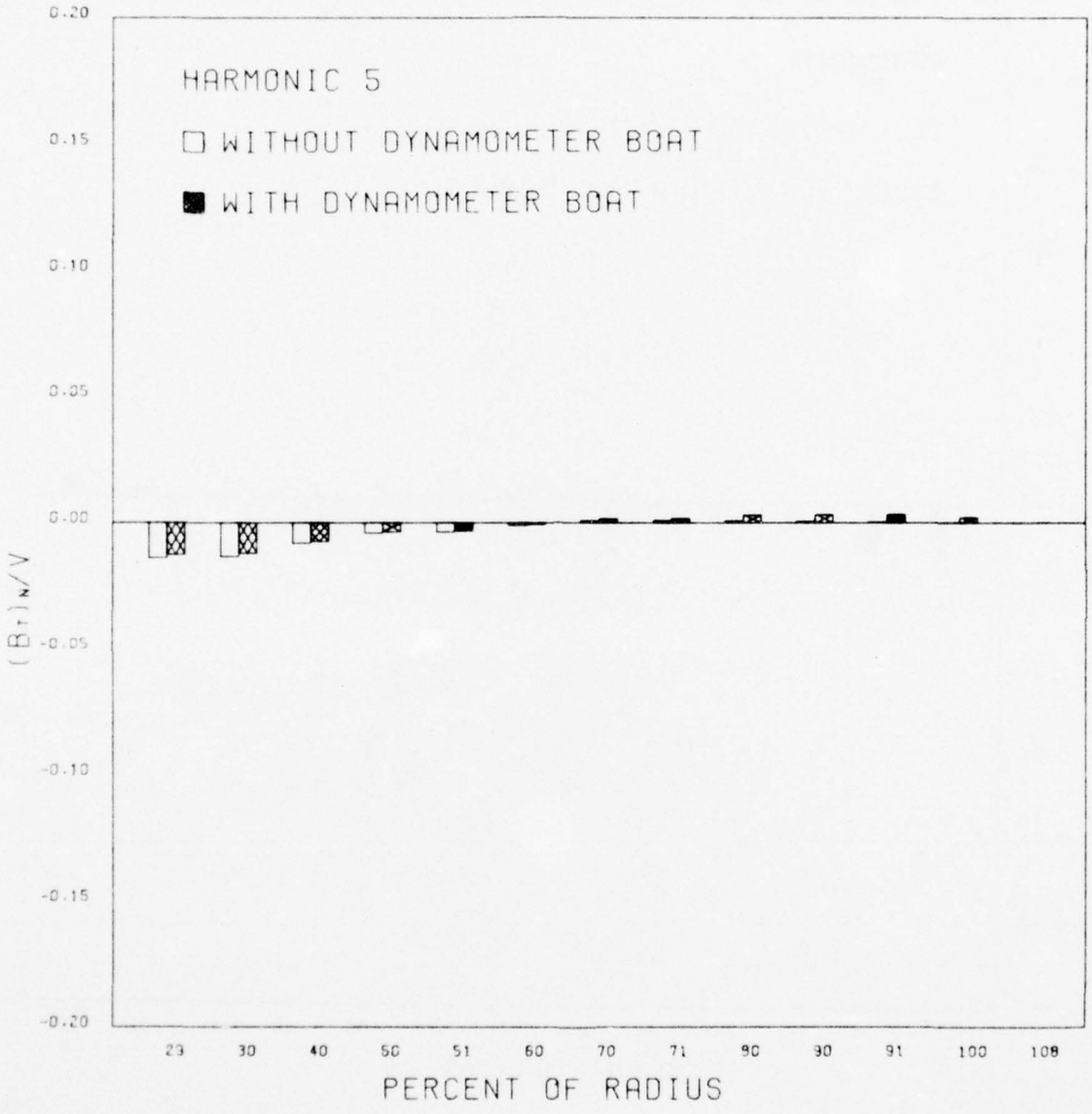


Figure 33 (Continued)

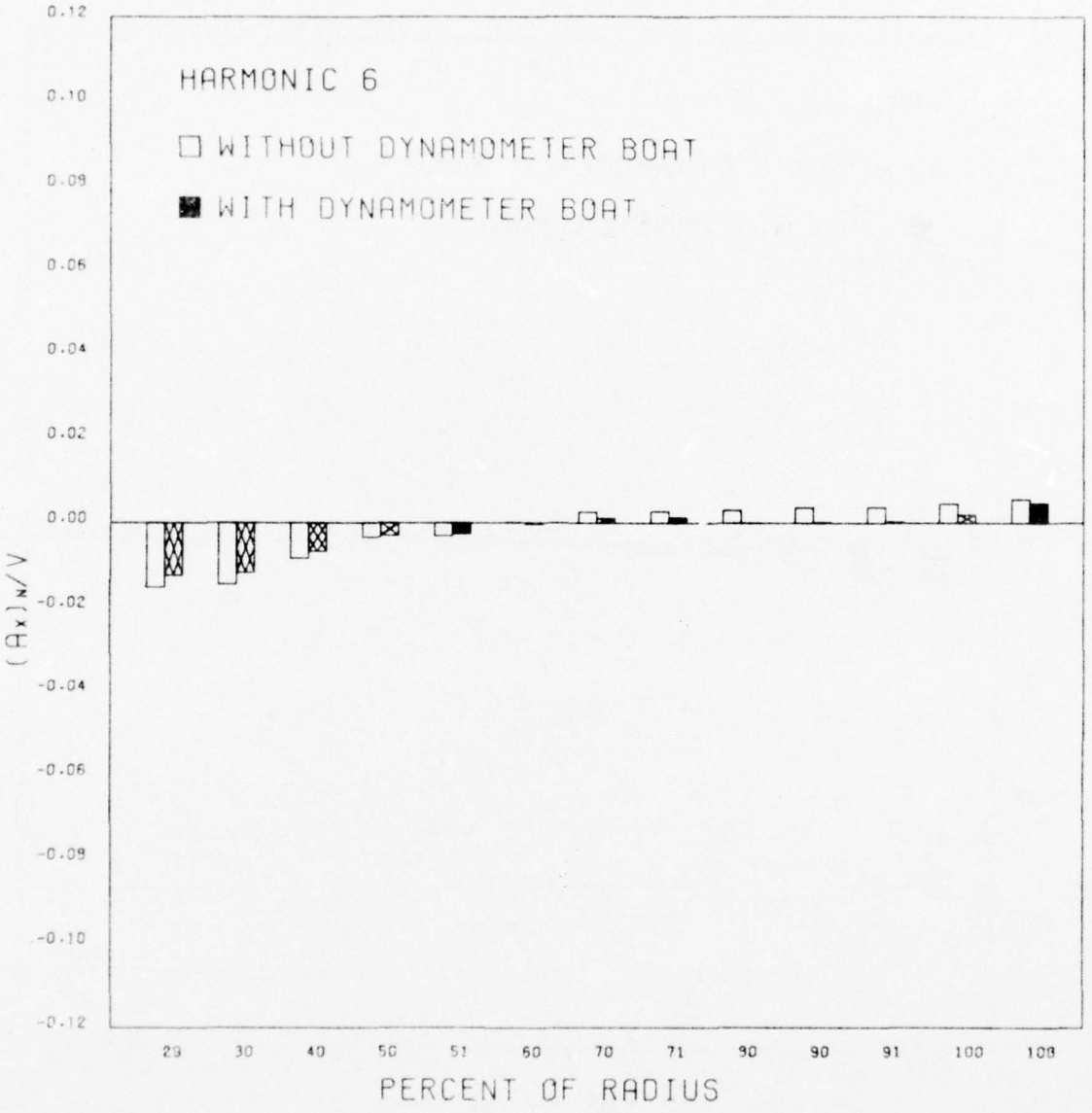


Figure 33 (Continued)

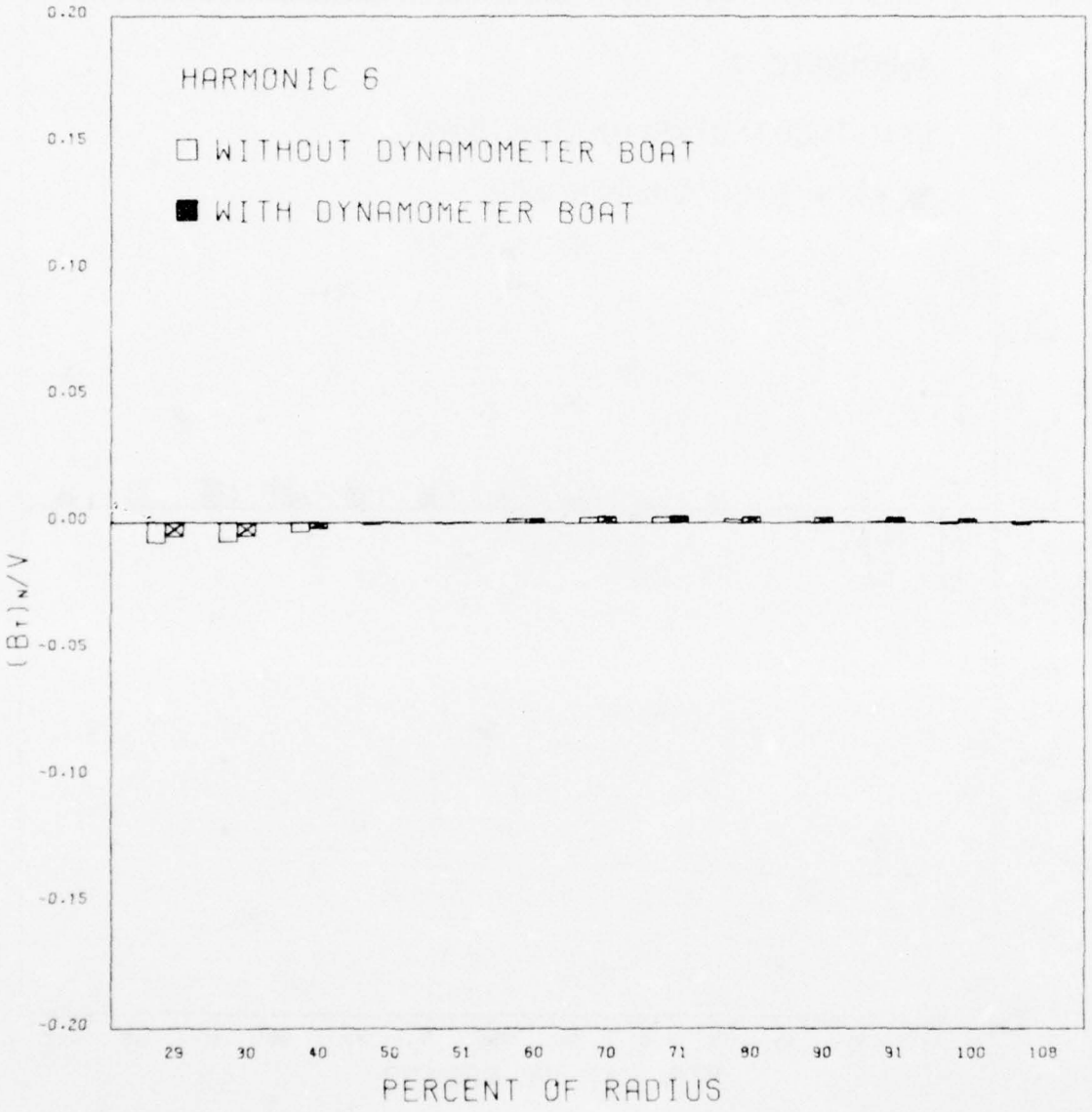


Figure 33 (Continued)

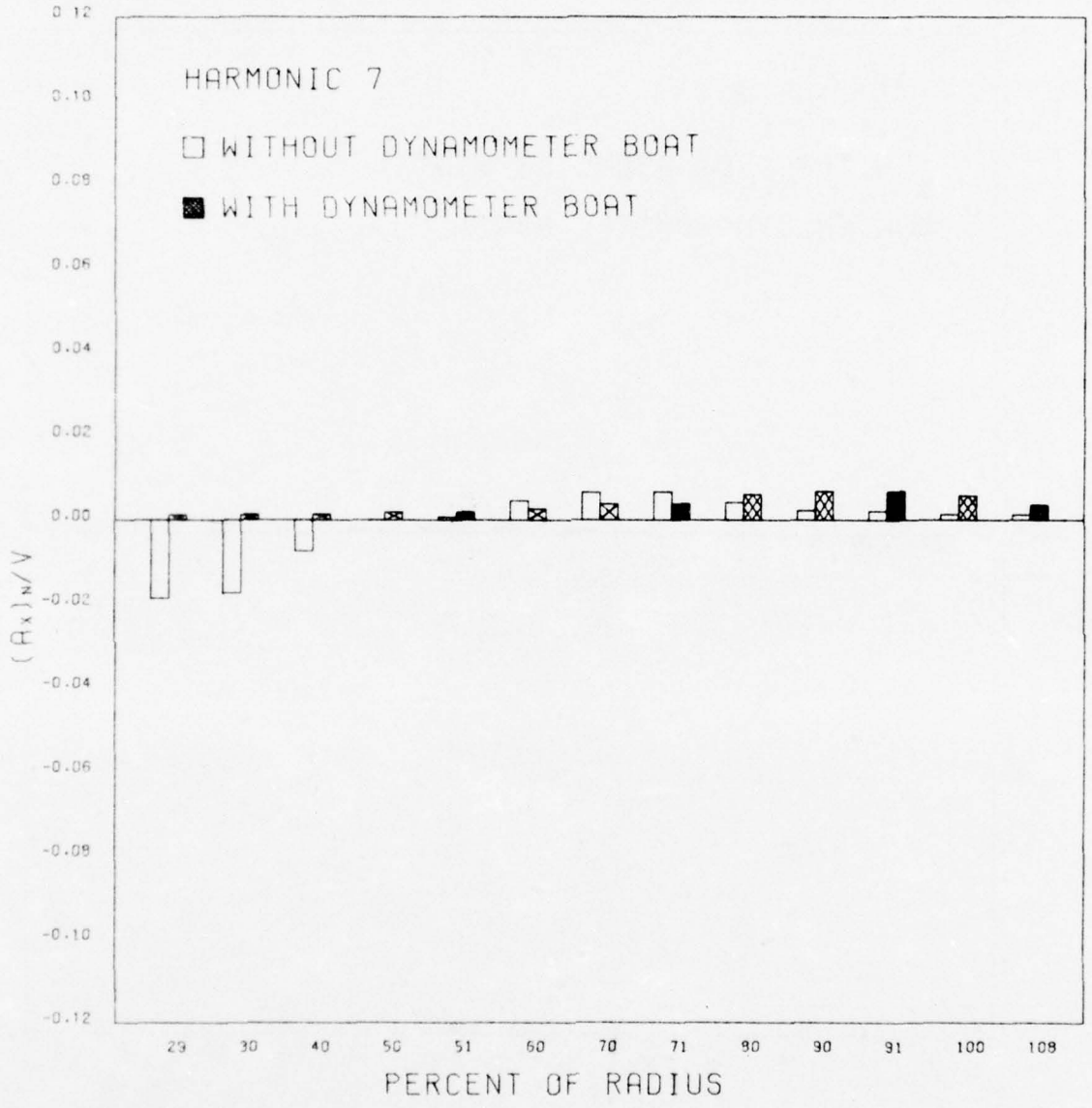


Figure 33 (Continued)

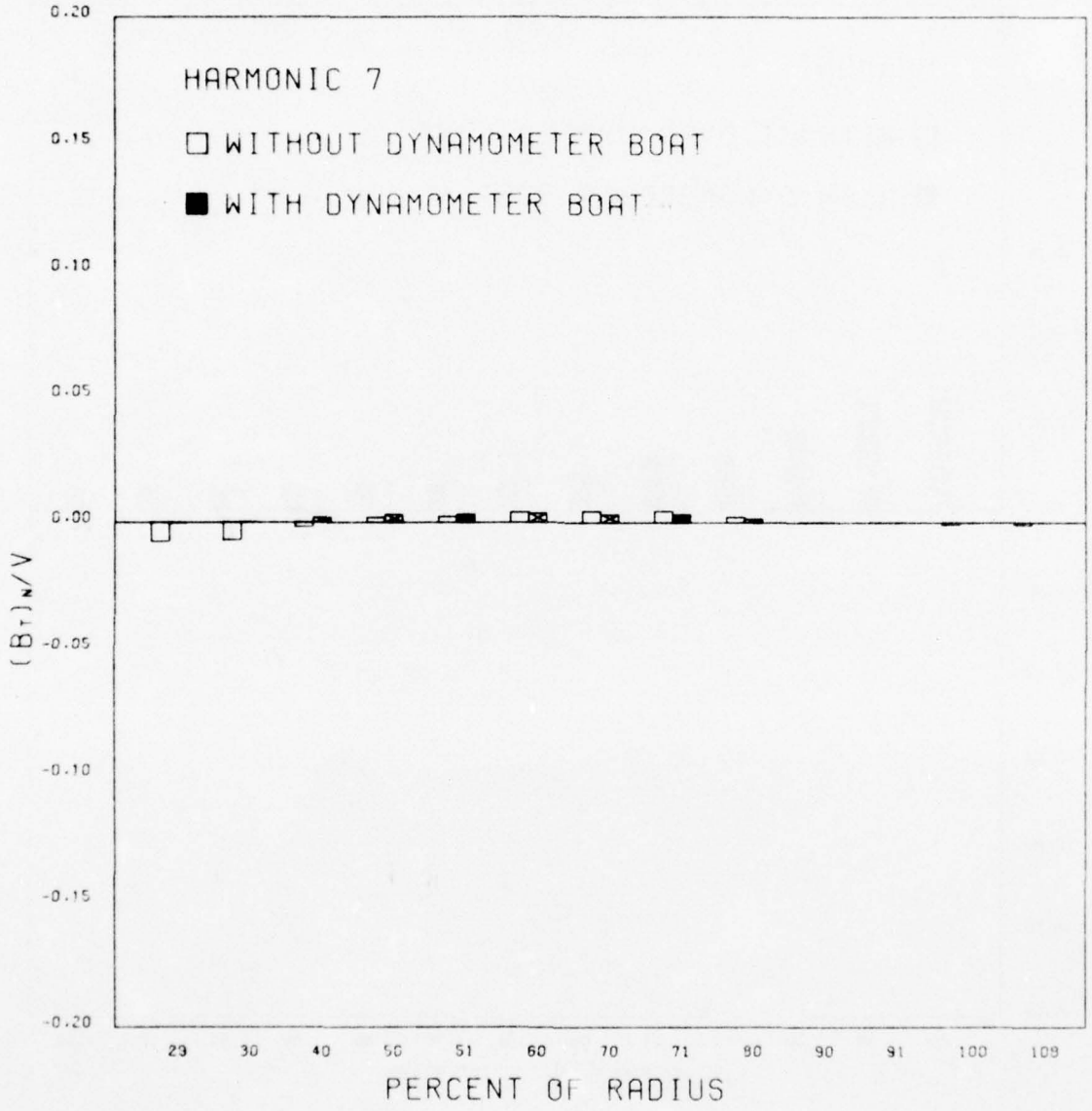


Figure 33 (Continued)

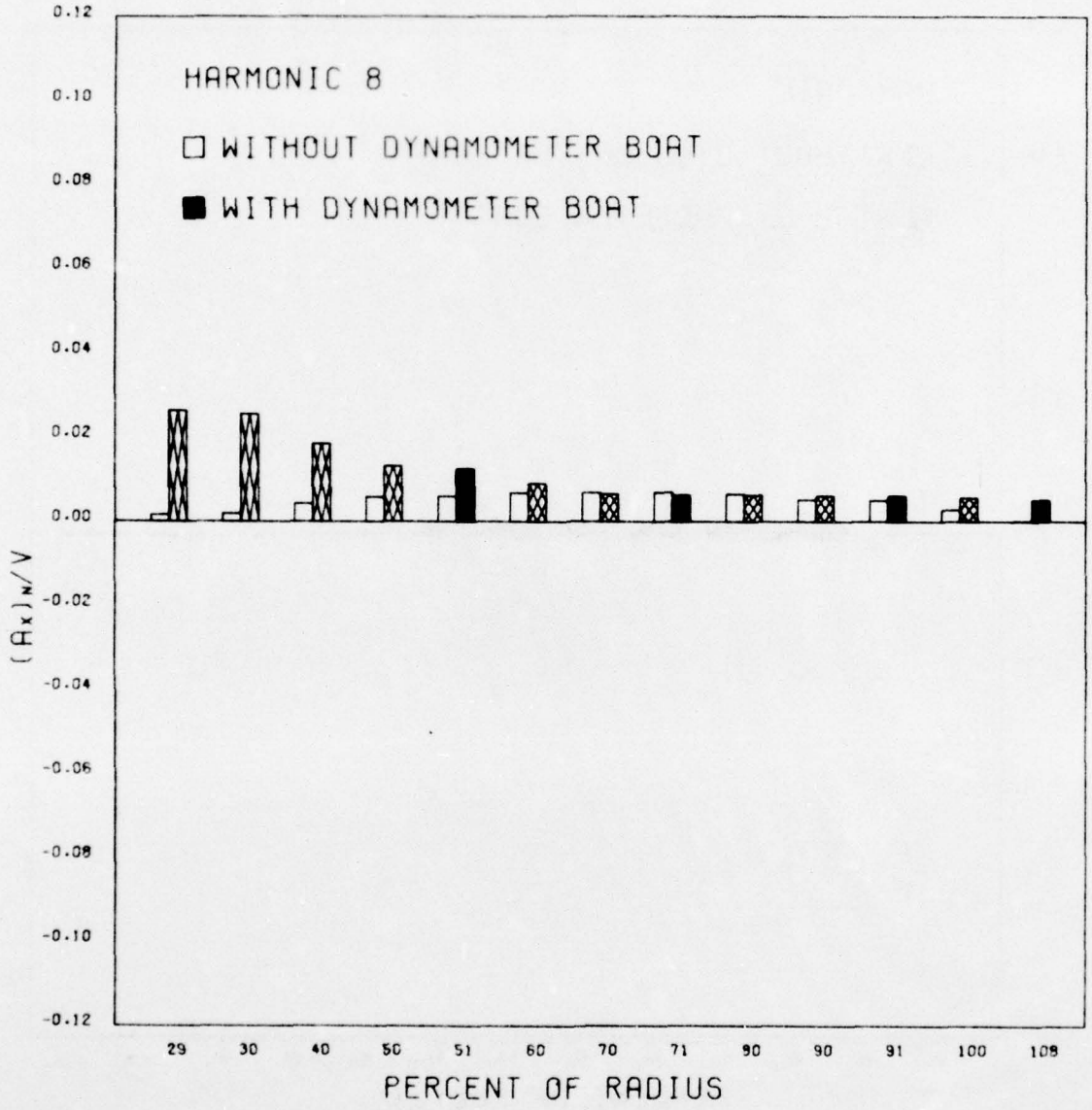


Figure 33 (Continued)

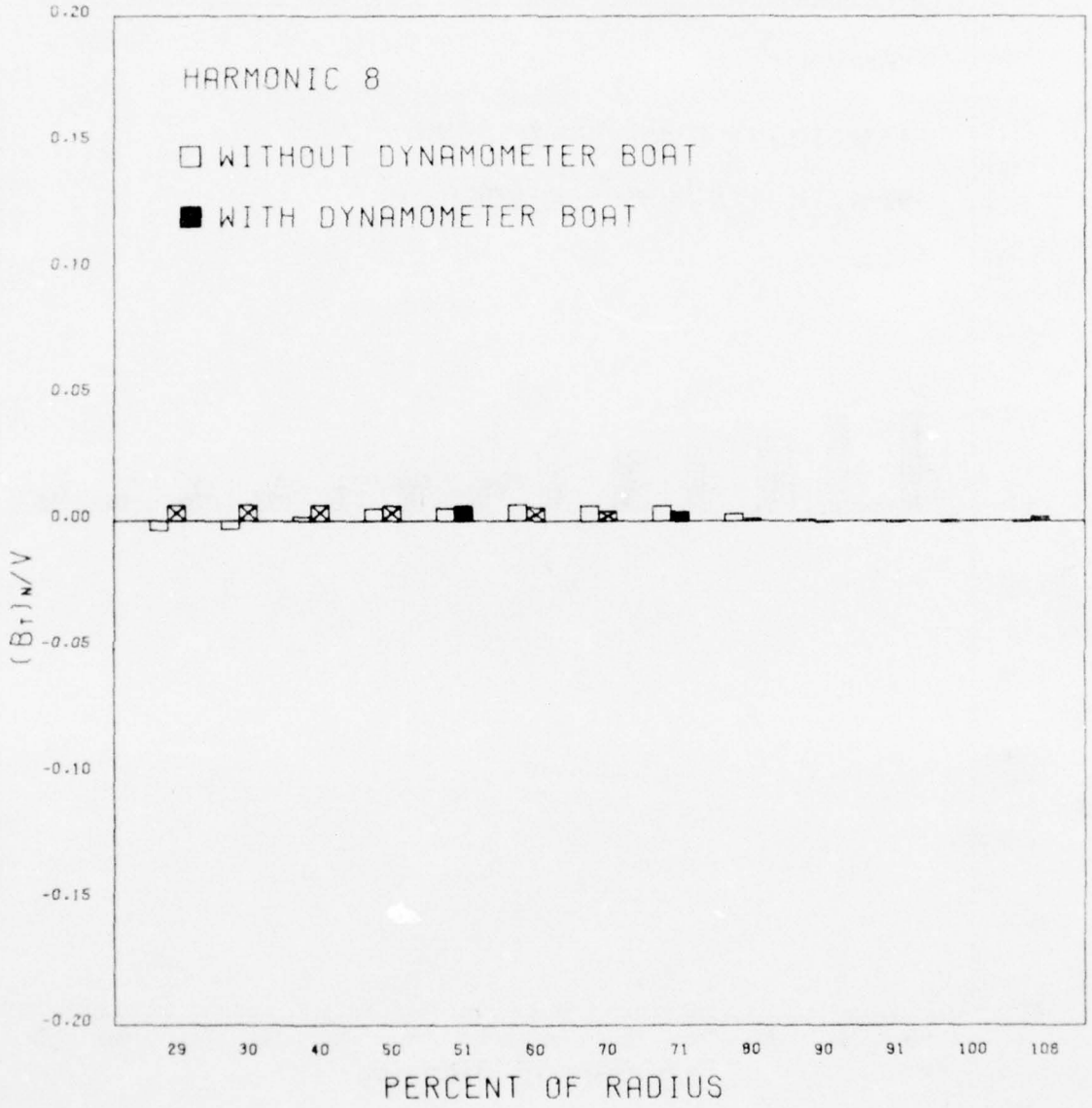


Figure 33 (Continued)

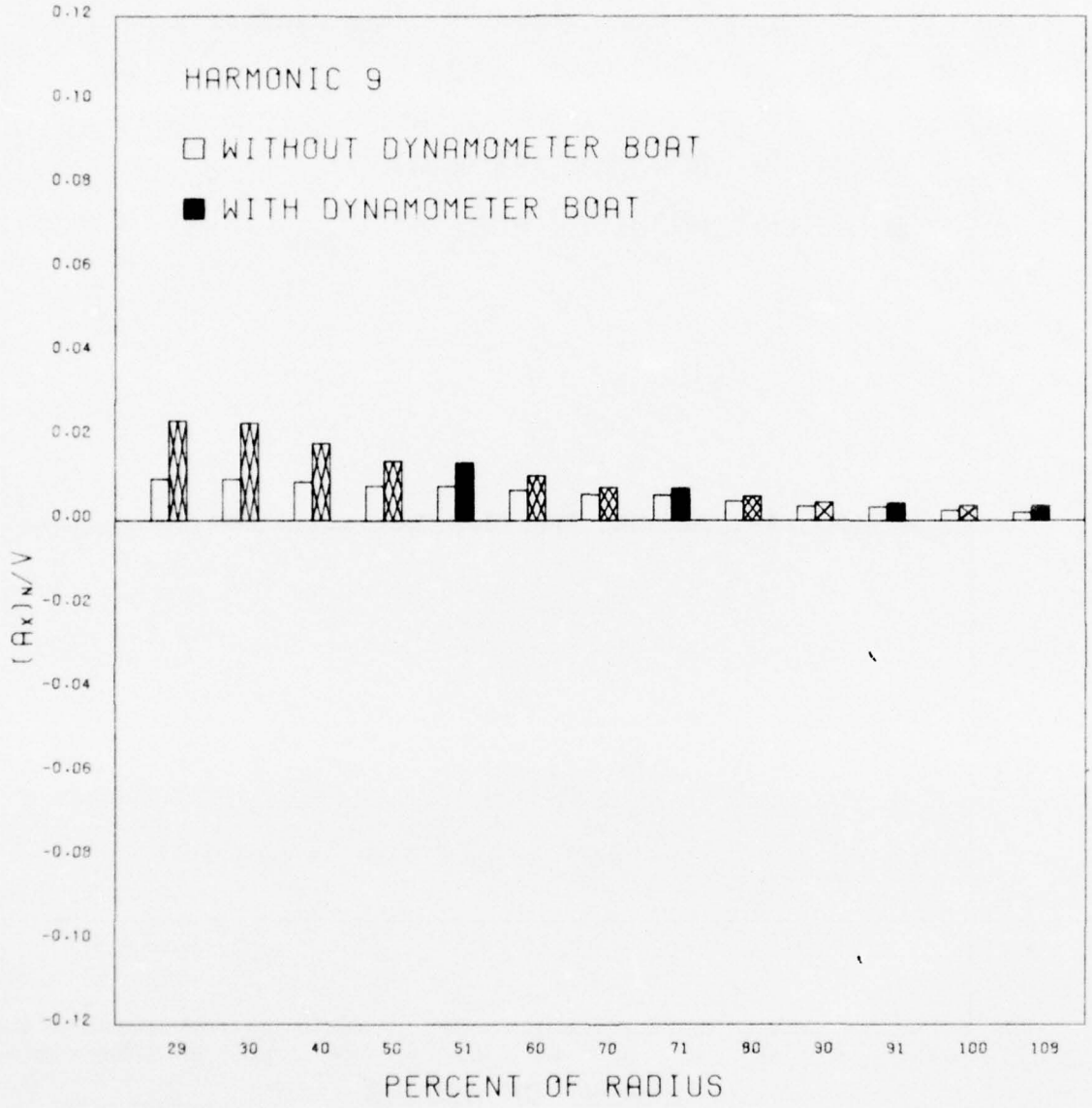


Figure 33 (Continued)

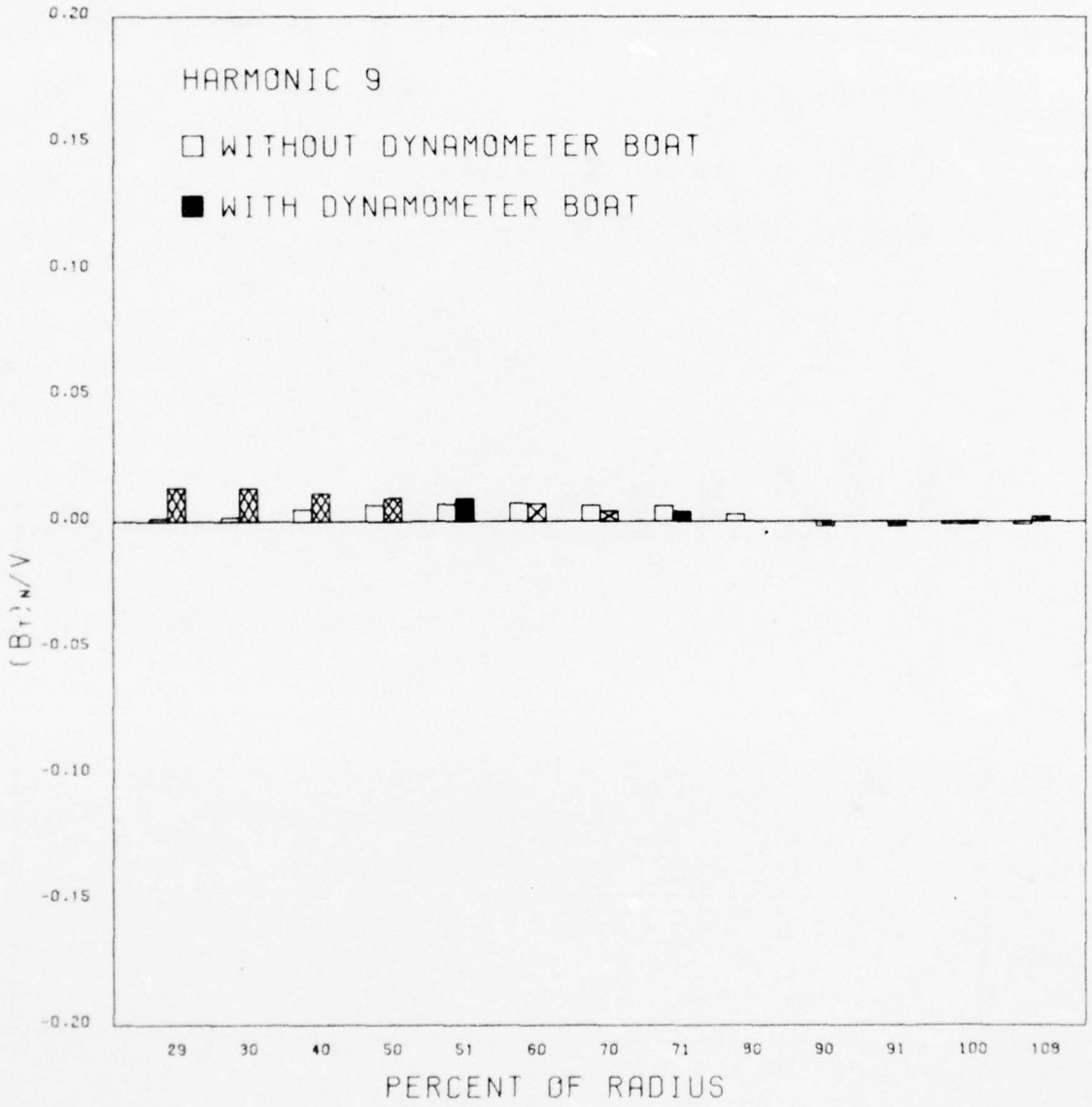


Figure 33 (Continued)

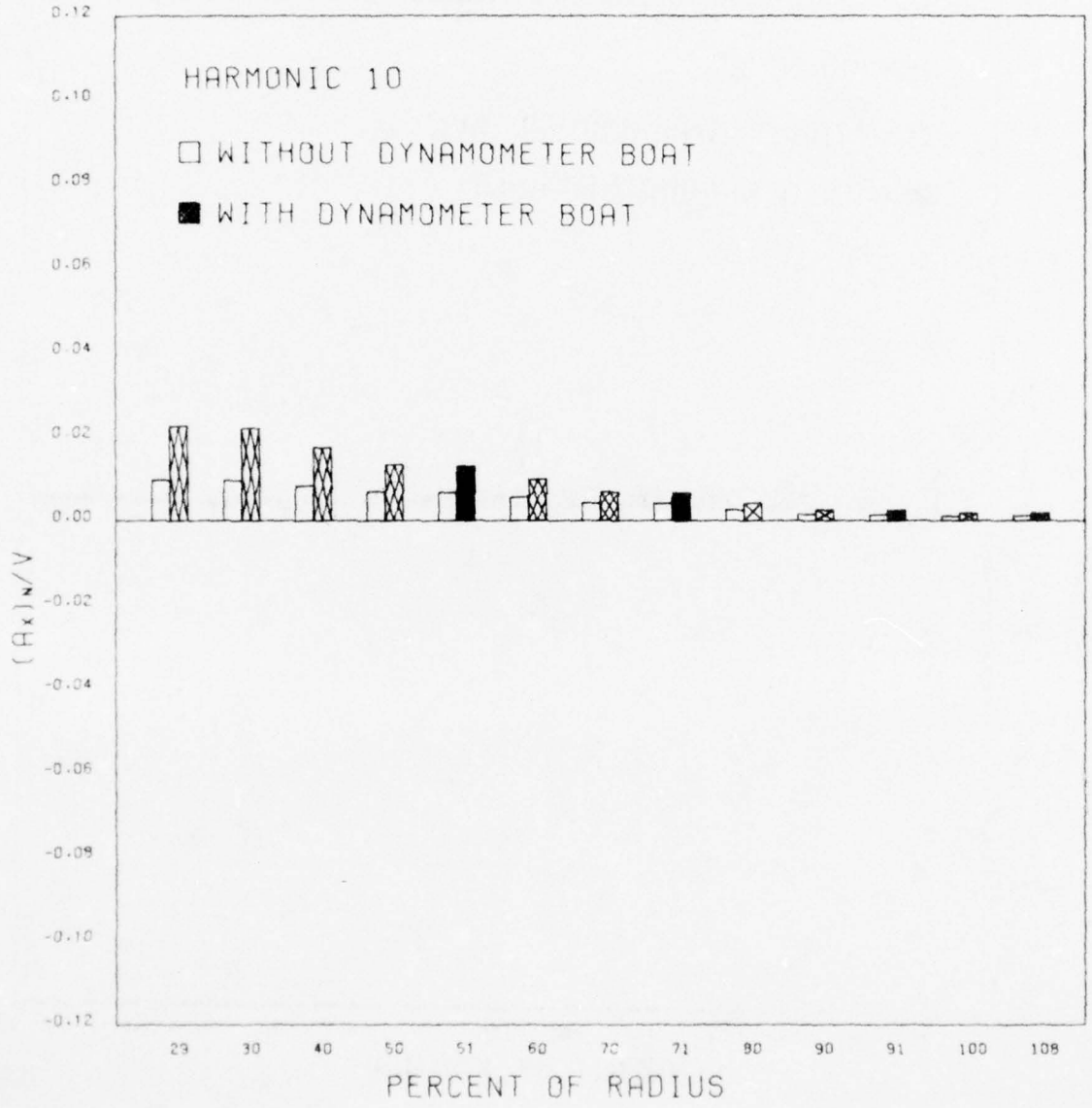
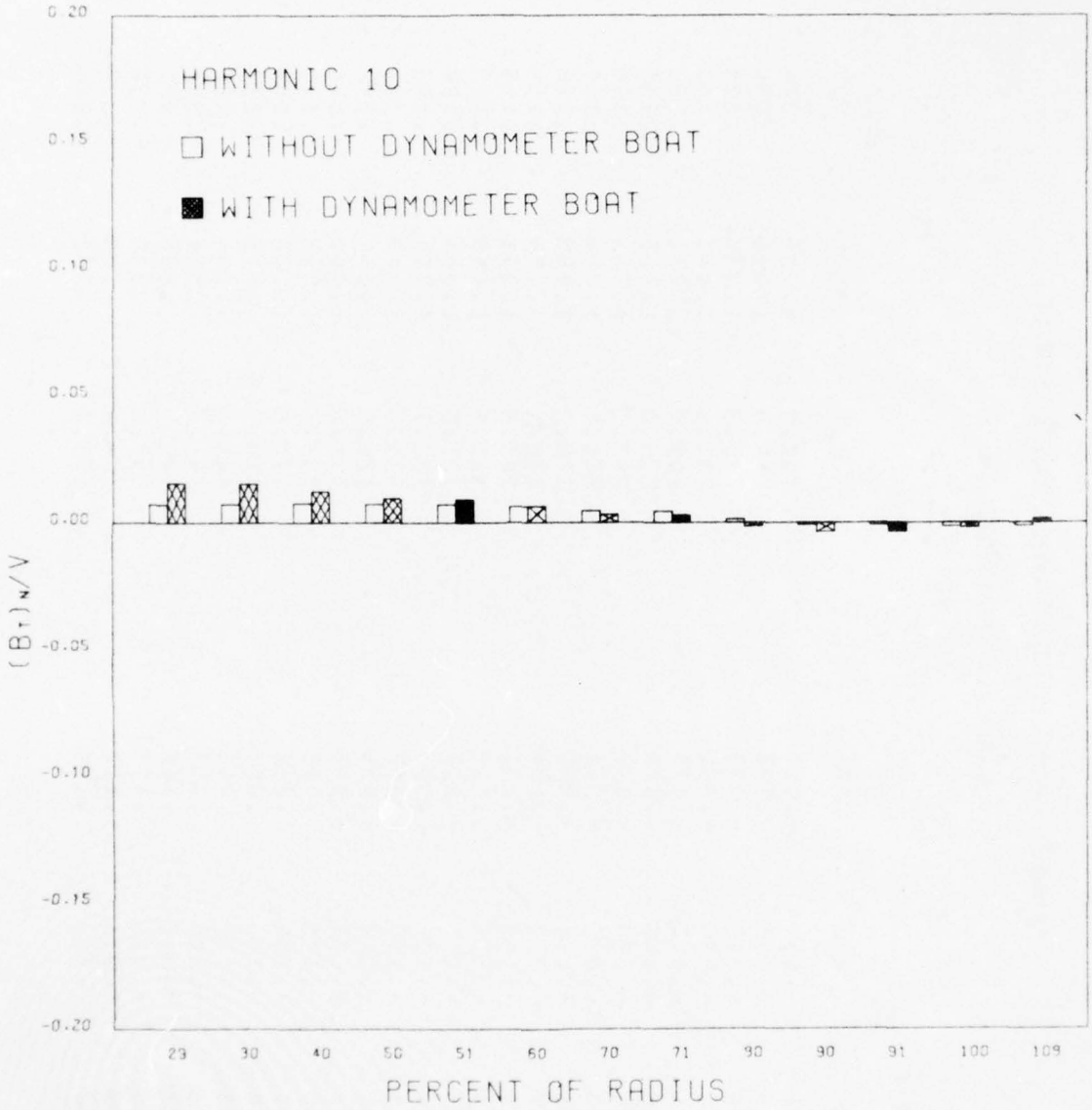


Figure 33 (Continued)



AD-A034 804 DAVID W TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CE--ETC F/G 13/10
EXPERIMENTAL UNSTEADY AND MEAN LOADS ON A CP PROPELLER BLADE ON--ETC(U)
OCT 76 R J BOSWELL, J J NELKA , S B DENNY

UNCLASSIFIED DTNSRDC-76-0125 NL

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## TABLE 9 – WAKE WITHOUT DYNAMOMETER BOAT

### TABLE 9a – MEASURED DATA

r/R = 0.512

| $\theta_w$ | $V_x/V$ | $V_t/V$ | $V_r/V$ | $\theta_w$ | $V_x/V$ | $V_t/V$ | $V_r/V$ |
|---|---|---|---|---|---|---|---|
| 1.0 | .926 | .011 | -.013 | 207.0 | 1.025 | .074 | .106 |
| 4.8 | .925 | -.008 | -.023 | 214.9 | 1.026 | .094 | .098 |
| 6.8 | .924 | -.012 | -.033 | 230.9 | 1.033 | .128 | .076 |
| 14.8 | .921 | -.054 | -.071 | 239.1 | 1.041 | .142 | .062 |
| 16.9 | .924 | -.054 | -.077 | 247.0 | 1.051 | .152 | .047 |
| 18.8 | .936 | -.043 | -.079 | 255.0 | 1.040 | .163 | .032 |
| 20.8 | .939 | -.029 | -.077 | 263.1 | 1.053 | .166 | .017 |
| 22.8 | .913 | -.033 | -.071 | 271.1 | 1.064 | .168 | .001 |
| 24.8 | .811 | -.101 | -.090 | 279.2 | 1.063 | .166 | -.015 |
| 26.5 | .857 | -.202 | -.124 | 295.4 | 1.054 | .154 | -.047 |
| 28.8 | .963 | -.198 | -.131 | 303.5 | 1.051 | .143 | -.061 |
| 31.0 | 1.040 | -.155 | -.119 | 311.5 | 1.048 | .128 | -.075 |
| 32.5 | 1.039 | -.135 | -.112 | 321.6 | 1.041 | .107 | -.091 |
| 42.7 | 1.034 | -.126 | -.085 | 323.7 | 1.044 | .103 | -.094 |
| 54.6 | 1.045 | -.145 | -.062 | 325.6 | 1.045 | .100 | -.097 |
| 66.9 | 1.041 | -.163 | -.035 | 329.5 | 1.040 | .097 | -.101 |
| 78.7 | 1.053 | -.170 | -.008 | 331.6 | 1.042 | .100 | -.101 |
| 90.7 | 1.048 | -.171 | .015 | 333.5 | 1.043 | .110 | -.103 |
| 102.8 | 1.041 | -.166 | .040 | 337.5 | 1.040 | .149 | -.112 |
| 114.8 | 1.040 | -.154 | .061 | 339.5 | .975 | .178 | -.124 |
| 126.9 | 1.033 | -.137 | .081 | 341.5 | .845 | .107 | -.090 |
| 138.8 | 1.028 | -.115 | .097 | 343.7 | .844 | -.002 | -.050 |
| 166.8 | 1.022 | -.045 | .118 | 345.5 | .893 | -.021 | -.030 |
| 174.9 | 1.026 | -.021 | .119 | 347.4 | .935 | -.006 | -.021 |
| 191.0 | 1.020 | .030 | .118 | 349.6 | .945 | .012 | -.019 |
| 199.0 | 1.022 | .052 | .113 | 353.8 | .932 | .018 | -.016 |

TABLE 9a – (Continued)

r/R = 0.711

| $\theta_w$ | $V_x/V$ | $V_t/V$ | $V_r/V$ | $\theta_w$ | $V_x/V$ | $V_t/V$ | $V_r/V$ |
|---|---|---|---|---|---|---|---|
| 5.9 | .988 | -.040 | -.088 | 202.0 | .995 | .075 | .145 |
| 10.6 | .992 | -.051 | -.098 | 226.0 | .993 | .123 | .115 |
| 17.8 | 1.007 | .017 | -.121 | 237.9 | 1.000 | .140 | .092 |
| 18.5 | 1.006 | .015 | -.122 | 249.9 | 1.008 | .153 | .065 |
| 21.9 | .851 | -.018 | -.107 | 273.9 | 1.015 | .162 | .003 |
| 23.8 | .872 | -.179 | -.122 | 285.9 | 1.011 | .157 | -.029 |
| 25.8 | .986 | -.167 | -.138 | 298.0 | 1.011 | .145 | -.060 |
| 27.8 | 1.021 | -.127 | -.129 | 322.0 | 1.010 | .102 | -.111 |
| 28.4 | 1.022 | -.126 | -.128 | 330.0 | .993 | .135 | -.129 |
| 30.0 | 1.022 | -.106 | -.125 | 332.3 | .991 | .155 | -.134 |
| 38.3 | 1.025 | -.110 | -.110 | 333.9 | .931 | .184 | -.113 |
| 48.2 | 1.028 | -.130 | -.087 | 334.0 | .905 | .184 | -.113 |
| 58.2 | 1.031 | -.143 | -.060 | 336.0 | .864 | .022 | -.082 |
| 82.1 | 1.032 | -.155 | .008 | 338.0 | .930 | -.039 | -.101 |
| 94.2 | 1.030 | -.150 | .040 | 340.2 | .979 | .001 | -.111 |
| 106.2 | 1.024 | -.140 | .069 | 342.0 | .973 | .026 | -.110 |
| 130.4 | 1.016 | -.104 | .116 | 344.1 | .962 | .033 | -.098 |
| 142.4 | 1.018 | -.078 | .133 | 346.0 | .960 | .032 | -.087 |
| 178.0 | 1.007 | .017 | .155 | 358.1 | .972 | -.023 | -.064 |
| 190.1 | .999 | .048 | .154 | 358.8 | .968 | -.020 | -.063 |

TABLE 9a – (Continued)

r/R = 0.910

| $\theta_w$ | $V_x/V$ | $V_t/V$ | $V_r/V$ | $\theta_w$ | $V_x/V$ | $V_t/V$ | $V_r/V$ |
|---|---|---|---|---|---|---|---|
| 2.5 | .982 | -.004 | -.094 | 186.6 | 1.008 | .034 | .160 |
| 3.3 | .990 | -.004 | -.092 | 194.7 | 1.007 | .052 | .156 |
| 6.5 | .988 | -.021 | -.099 | 202.7 | 1.003 | .071 | .150 |
| 7.5 | .988 | -.024 | -.101 | 210.9 | .995 | .089 | .142 |
| 10.6 | .999 | -.033 | -.109 | 218.6 | .999 | .104 | .131 |
| 13.5 | 1.001 | -.037 | -.112 | 226.7 | 1.001 | .118 | .119 |
| 20.5 | 1.026 | -.026 | -.114 | 234.8 | 1.002 | .130 | .105 |
| 22.5 | 1.029 | .026 | -.112 | 250.9 | 1.005 | .150 | .070 |
| 24.7 | .887 | .048 | -.115 | 258.9 | 1.013 | .157 | .051 |
| 26.4 | .812 | -.128 | -.110 | 266.9 | 1.019 | .161 | .031 |
| 28.5 | .914 | -.155 | -.140 | 274.9 | 1.024 | .165 | .010 |
| 30.4 | .985 | -.096 | -.125 | 283.1 | 1.031 | .163 | -.010 |
| 32.7 | .990 | -.083 | -.124 | 291.1 | 1.031 | .159 | -.030 |
| 38.4 | .997 | -.089 | -.111 | 307.3 | 1.023 | .142 | -.073 |
| 42.4 | .995 | -.098 | -.100 | 315.3 | 1.022 | .128 | -.093 |
| 58.5 | 1.000 | -.127 | -.054 | 323.3 | 1.024 | .108 | -.110 |
| 66.4 | 1.011 | -.134 | -.028 | 327.2 | 1.022 | .097 | -.117 |
| 74.4 | 1.023 | -.136 | -.004 | 329.3 | 1.024 | .094 | -.118 |
| 82.5 | 1.021 | -.137 | .016 | 331.3 | 1.030 | .098 | -.121 |
| 90.4 | 1.012 | -.132 | .035 | 333.5 | 1.026 | .121 | -.132 |
| 98.5 | 1.007 | -.127 | .054 | 335.2 | 1.024 | .183 | -.152 |
| 106.5 | 1.005 | -.121 | .072 | 337.2 | .837 | .116 | -.115 |
| 114.7 | .986 | -.113 | .092 | 339.2 | .878 | -.077 | -.113 |
| 122.6 | .996 | -.101 | .105 | 341.5 | 1.036 | .005 | -.116 |
| 130.6 | .996 | -.088 | .120 | 343.2 | 1.031 | .049 | -.117 |
| 138.6 | .997 | -.074 | .131 | 345.2 | 1.024 | .064 | -.112 |
| 154.5 | .997 | -.042 | .151 | 347.2 | 1.023 | .065 | -.106 |
| 162.6 | 1.003 | -.025 | .156 | 355.3 | 1.005 | .042 | -.091 |
| 170.7 | 1.009 | -.005 | .160 | 359.1 | .976 | .020 | -.091 |
| 178.6 | 1.010 | .015 | .163 | 359.3 | .998 | .027 | -.090 |

TABLE 9a – (Continued)

r/R = 1.082

| $\theta_w$ | $V_x/V$ | $V_t/V$ | $V_r/V$ |
|---|---|---|---|
| 7.9 | .987 | -.045 | -.128 |
| 12.0 | 1.000 | -.050 | -.129 |
| 19.7 | .993 | -.052 | -.119 |
| 20.0 | 1.000 | -.050 | -.118 |
| 21.7 | 1.012 | -.019 | -.118 |
| 23.6 | .960 | .050 | -.111 |
| 24.0 | .916 | .066 | -.113 |
| 25.5 | .875 | -.123 | -.116 |
| 25.9 | .807 | -.185 | -.125 |
| 28.0 | .983 | -.136 | -.143 |
| 29.9 | .983 | -.097 | -.139 |
| 31.9 | .980 | -.089 | -.135 |
| 39.9 | .969 | -.104 | -.114 |
| 45.9 | .967 | -.117 | -.093 |
| 53.8 | .971 | -.133 | -.068 |
| 53.8 | .969 | -.131 | -.070 |
| 61.9 | .988 | -.142 | -.044 |
| 69.8 | 1.008 | -.148 | -.018 |
| 77.8 | .980 | -.152 | .007 |
| 77.9 | 1.024 | -.149 | .007 |
| 85.7 | .993 | -.149 | .027 |
| 93.9 | .995 | -.145 | .046 |
| 101.9 | .995 | -.139 | .065 |
| 118.3 | .994 | -.121 | .101 |
| 126.2 | .993 | -.110 | .117 |
| 134.4 | .999 | -.098 | .129 |
| 142.5 | .987 | -.082 | .145 |
| 158.4 | 1.005 | -.050 | .160 |
| 166.3 | 1.011 | -.033 | .165 |
| 174.5 | 1.010 | -.014 | .170 |
| 182.5 | 1.006 | .004 | .169 |
| 190.6 | 1.002 | .023 | .166 |
| 198.4 | 1.002 | .039 | .161 |
| 214.5 | .995 | .069 | .146 |
| 222.5 | .995 | .082 | .135 |
| 230.6 | 1.001 | .094 | .120 |
| 238.9 | 1.001 | .106 | .105 |
| 246.7 | 1.003 | .114 | .090 |
| 254.8 | 1.009 | .120 | .072 |
| 263.0 | 1.010 | .126 | .051 |
| 271.3 | .997 | .134 | .027 |
| 271.3 | 1.009 | .132 | .027 |
| 279.2 | 1.011 | .133 | .008 |
| 287.3 | 1.034 | .131 | -.016 |
| 295.4 | 1.016 | .128 | -.040 |
| 303.5 | 1.020 | .121 | -.062 |
| 311.6 | 1.017 | .109 | -.087 |
| 319.7 | 1.008 | .093 | -.110 |
| 323.7 | .997 | .084 | -.121 |
| 325.6 | .998 | .080 | -.126 |
| 329.7 | .989 | .069 | -.135 |
| 331.6 | 1.001 | .075 | -.138 |
| 333.6 | 1.015 | .113 | -.135 |
| 335.6 | .844 | .194 | -.100 |
| 337.8 | .887 | -.109 | -.082 |
| 339.6 | .983 | -.011 | -.130 |
| 341.6 | 1.004 | .036 | -.130 |
| 343.7 | 1.008 | .043 | -.131 |
| 347.7 | .999 | .040 | -.131 |
| 355.7 | .980 | .029 | -.124 |
| 359.7 | .961 | .004 | -.119 |

## TABLE 9b – INTERPOLATED VALUES OF $V_x/V$

| $\theta_w$ | r/R = 0.289 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|
| 0.0 | .830 | .836 | .883 | .922 | .952 | .972 | .985 | .986 | .977 |
| 2.5 | .805 | .812 | .873 | .921 | .956 | .979 | .987 | .986 | .977 |
| 5.0 | .783 | .792 | .863 | .919 | .960 | .985 | .988 | .986 | .981 |
| 7.5 | .771 | .780 | .857 | .917 | .961 | .988 | .990 | .990 | .988 |
| 10.0 | .767 | .776 | .854 | .915 | .960 | .989 | .995 | .997 | .997 |
| 12.5 | .695 | .709 | .823 | .911 | .974 | 1.010 | 1.006 | 1.001 | .999 |
| 15.0 | .639 | .657 | .801 | .910 | .986 | 1.028 | 1.018 | 1.006 | .998 |
| 17.5 | .717 | .731 | .837 | .919 | .979 | 1.015 | 1.020 | 1.016 | 1.005 |
| 20.0 | 1.145 | 1.130 | 1.020 | .947 | .909 | .908 | .980 | 1.023 | 1.026 |
| 22.5 | 1.299 | 1.273 | 1.071 | .933 | .858 | .847 | .959 | 1.026 | 1.032 |
| 25.0 | .431 | .456 | .652 | .797 | .893 | .938 | .898 | .870 | .860 |
| 27.5 | .424 | .456 | .705 | .882 | .987 | 1.019 | .908 | .854 | .876 |
| 30.0 | .935 | .941 | .983 | 1.011 | 1.024 | 1.023 | .993 | .975 | .973 |
| 32.5 | 1.039 | 1.040 | 1.042 | 1.039 | 1.034 | 1.024 | 1.007 | .993 | .983 |
| 35.0 | 1.033 | 1.034 | 1.038 | 1.038 | 1.033 | 1.025 | 1.009 | .995 | .983 |
| 37.5 | 1.028 | 1.029 | 1.035 | 1.036 | 1.033 | 1.026 | 1.012 | .998 | .984 |
| 40.0 | 1.021 | 1.023 | 1.031 | 1.035 | 1.033 | 1.027 | 1.013 | .998 | .982 |
| 42.5 | 1.015 | 1.016 | 1.028 | 1.034 | 1.034 | 1.027 | 1.012 | .997 | .981 |
| 45.0 | 1.017 | 1.018 | 1.030 | 1.035 | 1.035 | 1.028 | 1.012 | .996 | .980 |
| 47.5 | 1.022 | 1.023 | 1.033 | 1.038 | 1.036 | 1.029 | 1.013 | .996 | .980 |
| 50.0 | 1.028 | 1.029 | 1.038 | 1.041 | 1.038 | 1.030 | 1.013 | .996 | .980 |
| 52.5 | 1.035 | 1.036 | 1.042 | 1.043 | 1.040 | 1.031 | 1.014 | .997 | .981 |
| 55.0 | 1.040 | 1.041 | 1.045 | 1.045 | 1.041 | 1.031 | 1.015 | .999 | .984 |
| 57.5 | 1.038 | 1.038 | 1.044 | 1.044 | 1.041 | 1.032 | 1.016 | 1.000 | .987 |

TABLE 9b – (Continued)

| $\theta_w$ | r/R = 0.289 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|
| 60.0 | 1.036 | 1.037 | 1.042 | 1.043 | 1.040 | 1.032 | 1.017 | 1.003 | .991 |
| 62.5 | 1.035 | 1.036 | 1.041 | 1.042 | 1.040 | 1.033 | 1.019 | 1.006 | .996 |
| 65.0 | 1.035 | 1.036 | 1.040 | 1.041 | 1.039 | 1.033 | 1.020 | 1.010 | 1.002 |
| 67.5 | 1.040 | 1.040 | 1.042 | 1.042 | 1.039 | 1.033 | 1.023 | 1.014 | 1.007 |
| 70.0 | 1.052 | 1.052 | 1.049 | 1.045 | 1.039 | 1.033 | 1.025 | 1.018 | 1.012 |
| 72.5 | 1.066 | 1.065 | 1.056 | 1.048 | 1.040 | 1.033 | 1.028 | 1.022 | 1.014 |
| 75.0 | 1.078 | 1.076 | 1.063 | 1.051 | 1.041 | 1.033 | 1.030 | 1.024 | 1.015 |
| 77.5 | 1.087 | 1.085 | 1.068 | 1.054 | 1.042 | 1.033 | 1.030 | 1.024 | 1.014 |
| 80.0 | 1.090 | 1.088 | 1.070 | 1.055 | 1.042 | 1.033 | 1.030 | 1.024 | 1.012 |
| 82.5 | 1.087 | 1.085 | 1.068 | 1.054 | 1.042 | 1.033 | 1.029 | 1.022 | 1.010 |
| 85.0 | 1.081 | 1.080 | 1.065 | 1.053 | 1.042 | 1.033 | 1.028 | 1.019 | 1.007 |
| 87.5 | 1.074 | 1.073 | 1.062 | 1.051 | 1.042 | 1.032 | 1.026 | 1.016 | 1.005 |
| 90.0 | 1.067 | 1.066 | 1.058 | 1.050 | 1.041 | 1.032 | 1.023 | 1.013 | 1.003 |
| 92.5 | 1.061 | 1.060 | 1.054 | 1.048 | 1.040 | 1.031 | 1.021 | 1.011 | 1.002 |
| 95.0 | 1.057 | 1.056 | 1.052 | 1.046 | 1.039 | 1.031 | 1.020 | 1.010 | 1.001 |
| 97.5 | 1.054 | 1.053 | 1.050 | 1.045 | 1.038 | 1.030 | 1.018 | 1.008 | 1.000 |
| 100.0 | 1.053 | 1.052 | 1.048 | 1.043 | 1.036 | 1.028 | 1.017 | 1.008 | 1.000 |
| 102.5 | 1.053 | 1.053 | 1.048 | 1.042 | 1.035 | 1.027 | 1.017 | 1.008 | 1.000 |
| 105.0 | 1.056 | 1.055 | 1.049 | 1.042 | 1.034 | 1.026 | 1.015 | 1.007 | 1.000 |
| 107.5 | 1.056 | 1.055 | 1.049 | 1.041 | 1.033 | 1.024 | 1.012 | 1.003 | .998 |
| 110.0 | 1.052 | 1.052 | 1.047 | 1.041 | 1.033 | 1.023 | 1.007 | .997 | .993 |
| 112.5 | 1.048 | 1.048 | 1.046 | 1.041 | 1.033 | 1.022 | 1.002 | .991 | .989 |
| 115.0 | 1.046 | 1.046 | 1.045 | 1.041 | 1.033 | 1.021 | .999 | .987 | .986 |
| 117.5 | 1.048 | 1.048 | 1.045 | 1.040 | 1.031 | 1.020 | 1.000 | .989 | .988 |

TABLE 9b – (Continued)

| $\theta_w$ | r/R = 0.289 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|
| 120.0 | 1.051 | 1.050 | 1.045 | 1.038 | 1.030 | 1.019 | 1.003 | .993 | .990 |
| 122.5 | 1.053 | 1.052 | 1.045 | 1.037 | 1.028 | 1.018 | 1.005 | .996 | .993 |
| 125.0 | 1.051 | 1.050 | 1.043 | 1.035 | 1.027 | 1.018 | 1.006 | .997 | .993 |
| 127.5 | 1.047 | 1.047 | 1.040 | 1.034 | 1.026 | 1.017 | 1.005 | .997 | .994 |
| 130.0 | 1.044 | 1.043 | 1.038 | 1.032 | 1.025 | 1.017 | 1.004 | .997 | .994 |
| 132.5 | 1.039 | 1.039 | 1.036 | 1.031 | 1.025 | 1.017 | 1.004 | .997 | .995 |
| 135.0 | 1.035 | 1.035 | 1.033 | 1.030 | 1.025 | 1.018 | 1.005 | .997 | .995 |
| 137.5 | 1.031 | 1.031 | 1.031 | 1.029 | 1.025 | 1.018 | 1.006 | .997 | .994 |
| 140.0 | 1.026 | 1.026 | 1.028 | 1.028 | 1.024 | 1.018 | 1.006 | .998 | .992 |
| 142.5 | 1.020 | 1.021 | 1.025 | 1.026 | 1.024 | 1.019 | 1.007 | .997 | .991 |
| 145.0 | 1.016 | 1.017 | 1.023 | 1.025 | 1.024 | 1.019 | 1.007 | .997 | .991 |
| 147.5 | 1.013 | 1.014 | 1.021 | 1.024 | 1.023 | 1.019 | 1.006 | .997 | .991 |
| 150.0 | 1.011 | 1.012 | 1.020 | 1.023 | 1.023 | 1.018 | 1.006 | .997 | .993 |
| 152.5 | 1.010 | 1.011 | 1.019 | 1.022 | 1.022 | 1.018 | 1.005 | .997 | .994 |
| 155.0 | 1.011 | 1.012 | 1.019 | 1.022 | 1.021 | 1.017 | 1.005 | .998 | .996 |
| 157.5 | 1.014 | 1.015 | 1.019 | 1.021 | 1.021 | 1.017 | 1.005 | .999 | .999 |
| 160.0 | 1.018 | 1.018 | 1.021 | 1.021 | 1.020 | 1.016 | 1.006 | 1.001 | 1.002 |
| 162.5 | 1.023 | 1.023 | 1.023 | 1.022 | 1.019 | 1.015 | 1.007 | 1.003 | 1.004 |
| 165.0 | 1.030 | 1.030 | 1.026 | 1.022 | 1.018 | 1.014 | 1.008 | 1.005 | 1.006 |
| 167.5 | 1.039 | 1.038 | 1.030 | 1.023 | 1.017 | 1.013 | 1.009 | 1.007 | 1.008 |
| 170.0 | 1.049 | 1.048 | 1.035 | 1.025 | 1.017 | 1.012 | 1.009 | 1.009 | 1.009 |
| 172.5 | 1.059 | 1.057 | 1.040 | 1.026 | 1.017 | 1.010 | 1.010 | 1.010 | 1.010 |
| 175.0 | 1.067 | 1.065 | 1.044 | 1.028 | 1.016 | 1.009 | 1.010 | 1.010 | 1.010 |
| 177.5 | 1.071 | 1.068 | 1.045 | 1.027 | 1.015 | 1.008 | 1.009 | 1.010 | 1.010 |

TABLE 9b – (Continued)

| $\theta_w$ | r/R = 0.289 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|
| 180.0 | 1.074 | 1.071 | 1.046 | 1.027 | 1.013 | 1.006 | 1.008 | 1.010 | 1.009 |
| 182.5 | 1.075 | 1.072 | 1.046 | 1.026 | 1.012 | 1.004 | 1.007 | 1.009 | 1.008 |
| 185.0 | 1.076 | 1.073 | 1.045 | 1.024 | 1.010 | 1.003 | 1.006 | 1.008 | 1.008 |
| 187.5 | 1.078 | 1.074 | 1.045 | 1.023 | 1.009 | 1.001 | 1.006 | 1.008 | 1.007 |
| 190.0 | 1.079 | 1.076 | 1.045 | 1.022 | 1.007 | .999 | 1.005 | 1.008 | 1.006 |
| 192.5 | 1.083 | 1.079 | 1.047 | 1.023 | 1.006 | .998 | 1.004 | 1.007 | 1.006 |
| 195.0 | 1.088 | 1.083 | 1.049 | 1.023 | 1.006 | .997 | 1.004 | 1.007 | 1.006 |
| 197.5 | 1.092 | 1.087 | 1.051 | 1.024 | 1.006 | .997 | 1.002 | 1.006 | 1.005 |
| 200.0 | 1.096 | 1.091 | 1.053 | 1.025 | 1.006 | .996 | 1.001 | 1.005 | 1.004 |
| 202.5 | 1.099 | 1.094 | 1.056 | 1.026 | 1.006 | .995 | 1.000 | 1.003 | 1.003 |
| 205.0 | 1.102 | 1.097 | 1.057 | 1.027 | 1.006 | .995 | .998 | 1.000 | 1.001 |
| 207.5 | 1.103 | 1.098 | 1.059 | 1.028 | 1.007 | .994 | .996 | .998 | .998 |
| 210.0 | 1.104 | 1.099 | 1.059 | 1.029 | 1.007 | .994 | .994 | .995 | .996 |
| 212.5 | 1.106 | 1.101 | 1.061 | 1.029 | 1.006 | .993 | .994 | .995 | .996 |
| 215.0 | 1.110 | 1.105 | 1.062 | 1.029 | 1.006 | .993 | .995 | .997 | .996 |
| 217.5 | 1.114 | 1.109 | 1.064 | 1.030 | 1.006 | .993 | .996 | .998 | .997 |
| 220.0 | 1.118 | 1.112 | 1.066 | 1.031 | 1.006 | .993 | .997 | .999 | .998 |
| 222.5 | 1.121 | 1.115 | 1.068 | 1.032 | 1.007 | .993 | .998 | 1.000 | .999 |
| 225.0 | 1.123 | 1.117 | 1.070 | 1.033 | 1.008 | .994 | .998 | 1.001 | 1.000 |
| 227.5 | 1.125 | 1.119 | 1.071 | 1.034 | 1.009 | .995 | .998 | 1.001 | 1.001 |
| 230.0 | 1.126 | 1.120 | 1.073 | 1.036 | 1.010 | .996 | .999 | 1.001 | 1.002 |
| 232.5 | 1.128 | 1.122 | 1.075 | 1.038 | 1.012 | .997 | 1.000 | 1.002 | 1.002 |
| 235.0 | 1.130 | 1.125 | 1.077 | 1.040 | 1.014 | .999 | 1.000 | 1.002 | 1.002 |
| 237.5 | 1.133 | 1.127 | 1.080 | 1.043 | 1.017 | 1.001 | 1.001 | 1.002 | 1.002 |

TABLE 9b – (Continued)

| $\theta_w$ | r/R = 0.289 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|
| 240.0 | 1.138 | 1.132 | 1.084 | 1.046 | 1.019 | 1.003 | 1.002 | 1.002 | 1.002 |
| 242.5 | 1.145 | 1.139 | 1.089 | 1.050 | 1.022 | 1.004 | 1.003 | 1.002 | 1.002 |
| 245.0 | 1.150 | 1.144 | 1.093 | 1.054 | 1.024 | 1.006 | 1.004 | 1.003 | 1.002 |
| 247.5 | 1.148 | 1.142 | 1.093 | 1.054 | 1.026 | 1.008 | 1.005 | 1.003 | 1.003 |
| 250.0 | 1.133 | 1.127 | 1.084 | 1.050 | 1.025 | 1.009 | 1.006 | 1.005 | 1.005 |
| 252.5 | 1.117 | 1.113 | 1.075 | 1.046 | 1.024 | 1.011 | 1.008 | 1.007 | 1.007 |
| 255.0 | 1.106 | 1.102 | 1.069 | 1.043 | 1.024 | 1.012 | 1.010 | 1.009 | 1.009 |
| 257.5 | 1.113 | 1.109 | 1.073 | 1.045 | 1.025 | 1.013 | 1.012 | 1.012 | 1.011 |
| 260.0 | 1.127 | 1.122 | 1.081 | 1.050 | 1.027 | 1.014 | 1.014 | 1.014 | 1.013 |
| 262.5 | 1.142 | 1.137 | 1.091 | 1.055 | 1.030 | 1.015 | 1.016 | 1.016 | 1.014 |
| 265.0 | 1.157 | 1.150 | 1.100 | 1.060 | 1.032 | 1.015 | 1.018 | 1.018 | 1.014 |
| 267.5 | 1.170 | 1.163 | 1.107 | 1.064 | 1.034 | 1.016 | 1.020 | 1.020 | 1.014 |
| 270.0 | 1.181 | 1.173 | 1.114 | 1.068 | 1.035 | 1.016 | 1.021 | 1.021 | 1.014 |
| 272.5 | 1.187 | 1.180 | 1.117 | 1.069 | 1.036 | 1.016 | 1.022 | 1.023 | 1.015 |
| 275.0 | 1.191 | 1.183 | 1.119 | 1.069 | 1.035 | 1.016 | 1.023 | 1.024 | 1.017 |
| 277.5 | 1.195 | 1.186 | 1.120 | 1.069 | 1.034 | 1.015 | 1.024 | 1.027 | 1.020 |
| 280.0 | 1.196 | 1.188 | 1.120 | 1.068 | 1.033 | 1.014 | 1.024 | 1.029 | 1.024 |
| 282.5 | 1.198 | 1.189 | 1.119 | 1.067 | 1.031 | 1.013 | 1.024 | 1.030 | 1.029 |
| 285.0 | 1.197 | 1.188 | 1.118 | 1.065 | 1.030 | 1.012 | 1.023 | 1.031 | 1.033 |
| 287.5 | 1.194 | 1.185 | 1.116 | 1.064 | 1.029 | 1.012 | 1.023 | 1.031 | 1.035 |
| 290.0 | 1.189 | 1.180 | 1.113 | 1.062 | 1.028 | 1.012 | 1.023 | 1.031 | 1.033 |
| 292.5 | 1.183 | 1.175 | 1.109 | 1.060 | 1.028 | 1.012 | 1.023 | 1.030 | 1.030 |
| 295.0 | 1.177 | 1.169 | 1.106 | 1.059 | 1.027 | 1.012 | 1.024 | 1.029 | 1.026 |
| 297.5 | 1.171 | 1.163 | 1.103 | 1.058 | 1.027 | 1.012 | 1.023 | 1.028 | 1.025 |

TABLE 9b – (Continued)

| $\theta_w$ | r/R = 0.289 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|
| **300.0** | **1.163** | 1.156 | 1.099 | 1.056 | 1.028 | 1.013 | 1.022 | 1.027 | 1.024 |
| **302.5** | **1.154** | 1.148 | 1.095 | 1.055 | 1.028 | 1.014 | 1.021 | 1.025 | 1.024 |
| **305.0** | 1.146 | 1.140 | 1.091 | 1.054 | 1.029 | 1.015 | 1.020 | 1.024 | 1.023 |
| **307.5** | 1.139 | 1.133 | 1.088 | 1.053 | 1.029 | 1.016 | 1.020 | 1.023 | 1.022 |
| **310.0** | 1.133 | 1.127 | 1.085 | 1.052 | 1.029 | 1.016 | 1.020 | 1.022 | 1.021 |
| **312.5** | 1.125 | 1.120 | 1.080 | 1.050 | 1.028 | 1.017 | 1.020 | 1.022 | 1.020 |
| **315.0** | 1.116 | 1.111 | 1.074 | 1.046 | 1.027 | 1.016 | 1.020 | 1.022 | 1.020 |
| **317.5** | 1.113 | 1.108 | 1.072 | 1.044 | 1.025 | 1.015 | 1.021 | 1.023 | 1.019 |
| **320.0** | 1.118 | 1.113 | 1.073 | 1.043 | 1.023 | 1.013 | 1.021 | 1.024 | 1.018 |
| **322.5** | 1.139 | 1.132 | 1.083 | 1.046 | 1.021 | 1.009 | 1.021 | 1.024 | 1.015 |
| **325.0** | 1.167 | 1.159 | 1.096 | 1.049 | 1.018 | 1.003 | 1.018 | 1.023 | 1.014 |
| **327.5** | 1.177 | 1.169 | 1.099 | 1.047 | 1.014 | .998 | 1.016 | 1.022 | 1.012 |
| **330.0** | 1.189 | 1.180 | 1.103 | 1.046 | 1.009 | .994 | 1.018 | 1.027 | 1.015 |
| **332.5** | 1.233 | 1.220 | 1.122 | 1.050 | 1.004 | .984 | 1.011 | 1.028 | 1.029 |
| **335.0** | 1.621 | 1.583 | 1.287 | 1.071 | .936 | .881 | .987 | 1.029 | .988 |
| **337.5** | 1.248 | 1.236 | 1.136 | 1.050 | .976 | .916 | .858 | .833 | .841 |
| **340.0** | .812 | .821 | .888 | .937 | .966 | .977 | .944 | .935 | .955 |
| **342.5** | .591 | .605 | .722 | .821 | .901 | .964 | 1.015 | 1.038 | 1.033 |
| **345.0** | .765 | .771 | .824 | .873 | .917 | .956 | 1.000 | 1.023 | 1.024 |
| **347.5** | .959 | .956 | .941 | .936 | .941 | .957 | 1.000 | 1.022 | 1.020 |
| **350.0** | .984 | .981 | .957 | .946 | .946 | .957 | .998 | 1.019 | 1.015 |
| **352.5** | .950 | .948 | .939 | .938 | .945 | .959 | .995 | 1.013 | 1.009 |
| **355.0** | .901 | .903 | .914 | .928 | .944 | .962 | .992 | 1.006 | 1.001 |
| **357.5** | .863 | .867 | .898 | .924 | .947 | .966 | .987 | .994 | .987 |

## TABLE 9c – INTERPOLATED VALUES OF $V_T/V$

| $\theta_w$ | r/R = 0.289 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|
| 0.0 | .157 | .148 | .073 | .019 | -.014 | -.026 | .002 | .017 | .016 |
| 2.5 | .120 | .112 | .051 | .007 | -.021 | -.032 | -.012 | -.001 | -.004 |
| 5.0 | .087 | .081 | .031 | -.005 | -.028 | -.038 | -.022 | -.015 | -.019 |
| 7.5 | .082 | .076 | .025 | -.011 | -.035 | -.046 | -.030 | -.024 | -.030 |
| 10.0 | .043 | .038 | .001 | -.027 | -.044 | -.051 | -.037 | -.032 | -.037 |
| 12.5 | -.076 | -.074 | -.058 | -.046 | -.038 | -.033 | -.032 | -.036 | -.043 |
| 15.0 | -.216 | -.205 | -.121 | -.060 | -.022 | -.005 | -.025 | -.043 | -.057 |
| 17.5 | -.280 | -.265 | -.146 | -.059 | -.006 | .014 | -.021 | -.049 | -.064 |
| 20.0 | -.272 | -.256 | -.132 | -.042 | .013 | .034 | -.003 | -.032 | -.047 |
| 22.5 | .195 | .179 | .060 | -.022 | -.067 | -.076 | -.016 | .024 | .036 |
| 25.0 | .295 | .267 | .049 | -.100 | -.178 | -.188 | -.052 | .018 | .002 |
| 27.5 | -.413 | -.401 | -.298 | -.220 | -.167 | -.139 | -.153 | -.161 | -.160 |
| 30.0 | -.340 | -.329 | -.246 | -.182 | -.136 | -.108 | -.110 | -.109 | -.104 |
| 32.5 | -.214 | -.210 | -.170 | -.138 | -.114 | -.096 | -.087 | -.083 | -.084 |
| 35.0 | -.143 | -.141 | -.128 | -.117 | -.106 | -.097 | -.086 | -.081 | -.083 |
| 37.5 | -.095 | -.097 | -.105 | -.109 | -.110 | -.106 | -.093 | -.086 | -.088 |
| 40.0 | -.093 | -.094 | -.106 | -.114 | -.116 | -.113 | -.099 | -.092 | -.095 |
| 42.5 | -.118 | -.119 | -.124 | -.125 | -.123 | -.118 | -.105 | -.098 | -.101 |
| 45.0 | -.117 | -.118 | -.125 | -.128 | -.128 | -.124 | -.110 | -.104 | -.106 |
| 47.5 | -.115 | -.116 | -.126 | -.131 | -.132 | -.129 | -.115 | -.109 | -.111 |
| 50.0 | -.120 | -.121 | -.131 | -.136 | -.137 | -.133 | -.120 | -.114 | -.116 |
| 52.5 | -.129 | -.130 | -.137 | -.141 | -.141 | -.137 | -.124 | -.118 | -.121 |
| 55.0 | -.139 | -.140 | -.144 | -.146 | -.144 | -.140 | -.128 | -.122 | -.125 |
| 57.5 | -.147 | -.148 | -.150 | -.150 | -.148 | -.143 | -.131 | -.126 | -.129 |

TABLE 9c – (Continued)

| $\theta_w$ | r/R = 0.289 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|
| 60.0 | -.155 | -.155 | -.155 | -.154 | -.151 | -.146 | -.134 | -.129 | -.132 |
| 62.5 | -.162 | -.162 | -.160 | -.158 | -.154 | -.148 | -.136 | -.131 | -.134 |
| 65.0 | -.168 | -.168 | -.165 | -.161 | -.156 | -.150 | -.138 | -.133 | -.136 |
| 67.5 | -.173 | -.173 | -.169 | -.164 | -.158 | -.152 | -.140 | -.135 | -.138 |
| 70.0 | -.176 | -.175 | -.171 | -.166 | -.160 | -.153 | -.141 | -.135 | -.139 |
| 72.5 | -.178 | -.178 | -.173 | -.168 | -.162 | -.154 | -.141 | -.136 | -.139 |
| 75.0 | -.180 | -.180 | -.175 | -.169 | -.163 | -.155 | -.142 | -.136 | -.140 |
| 77.5 | -.182 | -.182 | -.176 | -.170 | -.164 | -.156 | -.142 | -.137 | -.141 |
| 80.0 | -.184 | -.184 | -.178 | -.171 | -.164 | -.156 | -.143 | -.137 | -.141 |
| 82.5 | -.187 | -.186 | -.179 | -.172 | -.164 | -.156 | -.143 | -.137 | -.140 |
| 85.0 | -.188 | -.187 | -.180 | -.172 | -.164 | -.155 | -.142 | -.136 | -.139 |
| 87.5 | -.189 | -.189 | -.181 | -.172 | -.164 | -.155 | -.140 | -.134 | -.138 |
| 90.0 | -.190 | -.189 | -.181 | -.172 | -.163 | -.153 | -.138 | -.132 | -.136 |
| 92.5 | -.192 | -.191 | -.181 | -.172 | -.162 | -.152 | -.137 | -.131 | -.135 |
| 95.0 | -.193 | -.192 | -.182 | -.171 | -.161 | -.151 | -.135 | -.129 | -.133 |
| 97.5 | -.194 | -.193 | -.181 | -.170 | -.159 | -.149 | -.134 | -.128 | -.132 |
| 100.0 | -.195 | -.193 | -.181 | -.169 | -.158 | -.147 | -.132 | -.126 | -.130 |
| 102.5 | -.195 | -.194 | -.180 | -.168 | -.156 | -.145 | -.130 | -.124 | -.128 |
| 105.0 | -.195 | -.193 | -.179 | -.166 | -.154 | -.142 | -.128 | -.122 | -.126 |
| 107.5 | -.194 | -.192 | -.177 | -.164 | -.151 | -.140 | -.126 | -.120 | -.124 |
| 110.0 | -.193 | -.191 | -.175 | -.161 | -.148 | -.137 | -.123 | -.118 | -.122 |
| 112.5 | -.192 | -.190 | -.173 | -.158 | -.145 | -.134 | -.121 | -.116 | -.119 |
| 115.0 | -.190 | -.188 | -.171 | -.155 | -.142 | -.131 | -.118 | -.113 | -.116 |
| 117.5 | -.188 | -.186 | -.168 | -.152 | -.139 | -.127 | -.114 | -.109 | -.113 |

TABLE 9c – (Continued)

| $\theta_w$ | r/R = 0.289 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|
| 120.0 | -.185 | -.183 | -.165 | -.149 | -.135 | -.123 | -.110 | -.105 | -.109 |
| 122.5 | -.183 | -.181 | -.162 | -.146 | -.131 | -.119 | -.106 | -.101 | -.105 |
| 125.0 | -.180 | -.178 | -.159 | -.142 | -.127 | -.115 | -.102 | -.097 | -.101 |
| 127.5 | -.178 | -.176 | -.155 | -.138 | -.123 | -.111 | -.098 | -.093 | -.098 |
| 130.0 | -.175 | -.173 | -.152 | -.134 | -.118 | -.106 | -.093 | -.089 | -.094 |
| 132.5 | -.173 | -.170 | -.148 | -.129 | -.114 | -.101 | -.089 | -.085 | -.090 |
| 135.0 | -.170 | -.168 | -.144 | -.125 | -.108 | -.096 | -.084 | -.080 | -.086 |
| 137.5 | -.168 | -.165 | -.140 | -.120 | -.103 | -.090 | -.079 | -.076 | -.081 |
| 140.0 | -.165 | -.162 | -.136 | -.115 | -.098 | -.085 | -.074 | -.071 | -.077 |
| 142.5 | -.162 | -.158 | -.132 | -.109 | -.092 | -.079 | -.069 | -.066 | -.072 |
| 145.0 | -.158 | -.155 | -.127 | -.104 | -.086 | -.073 | -.063 | -.061 | -.067 |
| 147.5 | -.155 | -.151 | -.122 | -.098 | -.080 | -.067 | -.058 | -.056 | -.062 |
| 150.0 | -.151 | -.148 | -.117 | -.092 | -.073 | -.060 | -.052 | -.051 | -.057 |
| 152.5 | -.148 | -.144 | -.112 | -.086 | -.067 | -.054 | -.046 | -.046 | -.052 |
| 155.0 | -.144 | -.140 | -.106 | -.080 | -.060 | -.047 | -.041 | -.041 | -.047 |
| 157.5 | -.140 | -.135 | -.101 | -.074 | -.053 | -.040 | -.035 | -.036 | -.042 |
| 160.0 | -.135 | -.131 | -.095 | -.067 | -.046 | -.033 | -.029 | -.030 | -.037 |
| 162.5 | -.130 | -.125 | -.089 | -.060 | -.039 | -.026 | -.023 | -.025 | -.032 |
| 165.0 | -.124 | -.119 | -.082 | -.053 | -.032 | -.020 | -.016 | -.019 | -.026 |
| 167.5 | -.117 | -.112 | -.075 | -.046 | -.025 | -.013 | -.010 | -.013 | -.020 |
| 170.0 | -.109 | -.105 | -.068 | -.039 | -.018 | -.006 | -.003 | -.006 | -.014 |
| 172.5 | -.101 | -.097 | -.060 | -.031 | -.011 | .001 | .003 | .000 | -.008 |
| 175.0 | -.093 | -.088 | -.052 | -.024 | -.004 | .008 | .010 | .007 | -.002 |
| 177.5 | -.082 | -.078 | -.043 | -.015 | .004 | .015 | .017 | .013 | .004 |

TABLE 9c – (Continued)

| $\theta_w$ | r/R = 0.289 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|
| 180.0 | -.072 | -.068 | -.034 | -.007 | .011 | .022 | .023 | .019 | .010 |
| 182.5 | -.061 | -.057 | -.024 | .001 | .018 | .028 | .029 | .025 | .016 |
| 185.0 | -.050 | -.046 | -.015 | .009 | .025 | .035 | .036 | .031 | .022 |
| 187.5 | -.039 | -.035 | -.006 | .017 | .033 | .041 | .041 | .037 | .027 |
| 190.0 | -.028 | -.025 | .003 | .025 | .039 | .047 | .047 | .042 | .033 |
| 192.5 | -.019 | -.015 | .012 | .032 | .046 | .053 | .053 | .048 | .038 |
| 195.0 | -.009 | -.006 | .020 | .039 | .052 | .059 | .059 | .053 | .044 |
| 197.5 | .000 | .004 | .028 | .046 | .058 | .065 | .065 | .059 | .049 |
| 200.0 | .011 | .014 | .036 | .053 | .065 | .070 | .071 | .065 | .055 |
| 202.5 | .022 | .024 | .045 | .060 | .071 | .076 | .076 | .071 | .060 |
| 205.0 | .032 | .034 | .053 | .067 | .077 | .081 | .082 | .077 | .066 |
| 207.5 | .042 | .044 | .061 | .074 | .083 | .087 | .088 | .083 | .071 |
| 210.0 | .051 | .053 | .069 | .081 | .088 | .092 | .093 | .088 | .076 |
| 212.5 | .060 | .062 | .076 | .087 | .094 | .097 | .099 | .093 | .081 |
| 215.0 | .068 | .070 | .083 | .093 | .100 | .103 | .104 | .098 | .086 |
| 217.5 | .076 | .078 | .090 | .099 | .105 | .108 | .109 | .103 | .090 |
| 220.0 | .084 | .085 | .097 | .105 | .110 | .112 | .113 | .108 | .094 |
| 222.5 | .091 | .092 | .103 | .111 | .115 | .117 | .118 | .112 | .099 |
| 225.0 | .098 | .099 | .109 | .116 | .120 | .121 | .122 | .116 | .103 |
| 227.5 | .105 | .106 | .115 | .121 | .124 | .125 | .126 | .120 | .107 |
| 230.0 | .112 | .113 | .121 | .126 | .129 | .129 | .130 | .124 | .110 |
| 232.5 | .120 | .120 | .126 | .131 | .133 | .133 | .134 | .128 | .114 |
| 235.0 | .126 | .127 | .132 | .135 | .137 | .136 | .137 | .131 | .118 |
| 237.5 | .133 | .133 | .137 | .139 | .140 | .140 | .141 | .135 | .121 |

TABLE 9c – (Continued)

| $\theta_w$ | r/R = 0.289 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|
| 240.0 | .138 | .139 | .141 | .143 | .144 | .143 | .144 | .138 | .124 |
| 242.5 | .142 | .143 | .145 | .146 | .147 | .146 | .147 | .141 | .127 |
| 245.0 | .147 | .147 | .149 | .150 | .149 | .148 | .150 | .144 | .130 |
| 247.5 | .152 | .152 | .153 | .153 | .152 | .151 | .153 | .147 | .133 |
| 250.0 | .160 | .159 | .158 | .157 | .155 | .153 | .156 | .150 | .135 |
| 252.5 | .167 | .167 | .163 | .160 | .158 | .155 | .158 | .153 | .138 |
| 255.0 | .174 | .173 | .168 | .163 | .160 | .157 | .160 | .155 | .140 |
| 257.5 | .176 | .175 | .169 | .165 | .161 | .159 | .162 | .157 | .142 |
| 260.0 | .176 | .175 | .170 | .166 | .162 | .160 | .164 | .159 | .144 |
| 262.5 | .176 | .175 | .170 | .166 | .163 | .161 | .165 | .160 | .145 |
| 265.0 | .177 | .176 | .171 | .167 | .164 | .162 | .166 | .161 | .147 |
| 267.5 | .179 | .179 | .173 | .168 | .164 | .162 | .166 | .162 | .149 |
| 270.0 | .182 | .181 | .174 | .168 | .165 | .162 | .167 | .164 | .150 |
| 272.5 | .184 | .183 | .175 | .169 | .164 | .162 | .168 | .165 | .152 |
| 275.0 | .184 | .183 | .175 | .168 | .164 | .162 | .168 | .166 | .152 |
| 277.5 | .184 | .183 | .174 | .167 | .163 | .161 | .168 | .166 | .152 |
| 280.0 | .183 | .182 | .173 | .166 | .162 | .160 | .167 | .165 | .152 |
| 282.5 | .182 | .181 | .172 | .165 | .161 | .159 | .166 | .164 | .151 |
| 285.0 | .181 | .180 | .171 | .164 | .159 | .158 | .165 | .163 | .150 |
| 287.5 | .180 | .179 | .169 | .162 | .158 | .156 | .163 | .162 | .149 |
| 290.0 | .180 | .178 | .168 | .160 | .155 | .154 | .162 | .160 | .148 |
| 292.5 | .178 | .177 | .166 | .158 | .153 | .151 | .160 | .159 | .147 |
| 295.0 | .177 | .176 | .164 | .155 | .150 | .149 | .157 | .157 | .145 |
| 297.5 | .175 | .173 | .161 | .152 | .147 | .146 | .155 | .154 | .144 |

TABLE 9c – (Continued)

| $\theta_w$ | r/R = 0.289 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|
| 300.0 | .183 | .180 | .162 | .149 | .142 | .139 | .150 | .152 | .142 |
| 302.5 | .193 | .190 | .164 | .146 | .135 | .132 | .146 | .149 | .139 |
| 305.0 | .202 | .198 | .166 | .143 | .129 | .124 | .141 | .146 | .137 |
| 307.5 | .209 | .204 | .166 | .138 | .122 | .117 | .135 | .142 | .134 |
| 310.0 | .211 | .206 | .164 | .134 | .116 | .110 | .130 | .138 | .130 |
| 312.5 | .209 | .203 | .160 | .129 | .110 | .105 | .125 | .134 | .126 |
| 315.0 | .199 | .194 | .153 | .123 | .106 | .101 | .121 | .129 | .121 |
| 317.5 | .182 | .177 | .142 | .118 | .103 | .099 | .117 | .123 | .115 |
| 320.0 | .155 | .152 | .128 | .112 | .102 | .099 | .113 | .117 | .109 |
| 322.5 | .120 | .119 | .111 | .106 | .103 | .103 | .111 | .111 | .101 |
| 325.0 | .076 | .078 | .091 | .100 | .106 | .108 | .108 | .103 | .093 |
| 327.5 | .021 | .026 | .066 | .095 | .113 | .119 | .109 | .098 | .085 |
| 330.0 | -.039 | -.030 | .041 | .092 | .124 | .135 | .115 | .096 | .080 |
| 332.5 | -.095 | -.082 | .022 | .097 | .143 | .161 | .131 | .107 | .092 |
| 335.0 | .232 | .224 | .164 | .125 | .106 | .108 | .148 | .177 | .189 |
| 337.5 | .710 | .673 | .383 | .170 | .032 | -.030 | .062 | .088 | .032 |
| 340.0 | .486 | .467 | .310 | .181 | .078 | .003 | -.051 | -.067 | -.045 |
| 342.5 | .115 | .111 | .080 | .056 | .039 | .030 | .030 | .033 | .038 |
| 345.0 | -.108 | -.103 | -.061 | -.024 | .006 | .031 | .054 | .063 | .059 |
| 347.5 | -.041 | -.040 | -.024 | -.007 | .010 | .027 | .054 | .065 | .059 |
| 350.0 | .047 | .044 | .025 | .015 | .013 | .019 | .047 | .061 | .056 |
| 352.5 | .095 | .090 | .049 | .021 | .008 | .008 | .037 | .053 | .051 |
| 355.0 | .128 | .120 | .062 | .022 | .000 | -.005 | .025 | .043 | .043 |
| 357.5 | .158 | .149 | .075 | .023 | -.008 | -.017 | .014 | .032 | .032 |

## TABLE 9d – INTERPOLATED VALUES OF $V_r/V$

| $\theta_w$ | r/R = 0.289 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|
| 0.0 | .090 | .084 | .034 | -.008 | -.041 | -.066 | -.077 | -.089 | -.105 |
| 2.5 | .106 | .098 | .038 | -.011 | -.048 | -.074 | -.081 | -.091 | -.106 |
| 5.0 | .104 | .097 | .033 | -.019 | -.057 | -.083 | -.087 | -.095 | -.109 |
| 7.5 | .078 | .071 | .014 | -.032 | -.066 | -.090 | -.093 | -.100 | -.113 |
| 10.0 | .046 | .040 | -.007 | -.046 | -.075 | -.095 | -.100 | -.107 | -.117 |
| 12.5 | .035 | .029 | -.020 | -.058 | -.086 | -.105 | -.106 | -.111 | -.119 |
| 15.0 | .034 | .027 | -.026 | -.068 | -.097 | -.115 | -.113 | -.113 | -.118 |
| 17.5 | .030 | .023 | -.032 | -.074 | -.103 | -.120 | -.116 | -.114 | -.117 |
| 20.0 | -.011 | -.015 | -.049 | -.076 | -.096 | -.109 | -.112 | -.114 | -.116 |
| 22.5 | .020 | .015 | -.031 | -.067 | -.094 | -.110 | -.111 | -.112 | -.113 |
| 25.0 | .020 | .012 | -.046 | -.090 | -.118 | -.132 | -.121 | -.114 | -.113 |
| 27.5 | -.121 | -.121 | -.127 | -.130 | -.132 | -.132 | -.127 | -.126 | -.131 |
| 30.0 | -.131 | -.130 | -.127 | -.125 | -.125 | -.125 | -.126 | -.129 | -.133 |
| 32.5 | -.096 | -.097 | -.105 | -.111 | -.116 | -.120 | -.121 | -.123 | -.128 |
| 35.0 | -.076 | -.077 | -.091 | -.101 | -.110 | -.116 | -.117 | -.120 | -.124 |
| 37.5 | -.060 | -.062 | -.080 | -.094 | -.104 | -.111 | -.112 | -.113 | -.117 |
| 40.0 | -.052 | -.054 | -.073 | -.088 | -.099 | -.106 | -.106 | -.107 | -.110 |
| 42.5 | -.048 | -.051 | -.069 | -.084 | -.094 | -.100 | -.099 | -.100 | -.102 |
| 45.0 | -.044 | -.046 | -.064 | -.079 | -.089 | -.095 | -.093 | -.093 | -.094 |
| 47.5 | -.041 | -.043 | -.060 | -.074 | -.083 | -.088 | -.087 | -.086 | -.086 |
| 50.0 | -.039 | -.041 | -.057 | -.069 | -.078 | -.082 | -.080 | -.079 | -.079 |
| 52.5 | -.039 | -.040 | -.054 | -.065 | -.072 | -.076 | -.073 | -.072 | -.072 |
| 55.0 | -.038 | -.040 | -.051 | -.060 | -.066 | -.069 | -.066 | -.065 | -.064 |
| 57.5 | -.036 | -.037 | -.048 | -.055 | -.060 | -.062 | -.059 | -.057 | -.057 |

TABLE 9d – (Continued)

| $\theta_w$ | r/R = 0.289 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|
| 60.0 | -.033 | -.034 | -.043 | -.050 | -.054 | -.055 | -.051 | -.049 | -.049 |
| 62.5 | -.030 | -.031 | -.039 | -.044 | -.047 | -.048 | -.044 | -.041 | -.041 |
| 65.0 | -.026 | -.027 | -.034 | -.039 | -.041 | -.041 | -.036 | -.033 | -.032 |
| 67.5 | -.023 | -.024 | -.030 | -.033 | -.035 | -.034 | -.028 | -.025 | -.024 |
| 70.0 | -.020 | -.020 | -.025 | -.028 | -.028 | -.027 | -.021 | -.017 | -.016 |
| 72.5 | -.017 | -.017 | -.020 | -.022 | -.022 | -.020 | -.014 | -.010 | -.008 |
| 75.0 | -.015 | -.015 | -.016 | -.016 | -.015 | -.012 | -.007 | -.003 | -.001 |
| 77.5 | -.013 | -.013 | -.012 | -.011 | -.008 | -.005 | -.000 | .004 | .006 |
| 80.0 | -.013 | -.013 | -.009 | -.006 | -.002 | .002 | .006 | .010 | .012 |
| 82.5 | -.015 | -.014 | -.007 | -.001 | .004 | .009 | .013 | .016 | .018 |
| 85.0 | -.015 | -.014 | -.005 | .003 | .010 | .015 | .019 | .022 | .024 |
| 87.5 | -.015 | -.014 | -.002 | .008 | .016 | .022 | .025 | .028 | .030 |
| 90.0 | -.016 | -.015 | .000 | .012 | .022 | .029 | .032 | .034 | .036 |
| 92.5 | -.015 | -.013 | .004 | .017 | .028 | .035 | .038 | .040 | .042 |
| 95.0 | -.013 | -.011 | .008 | .022 | .034 | .041 | .044 | .046 | .047 |
| 97.5 | -.011 | -.008 | .012 | .028 | .040 | .048 | .050 | .052 | .053 |
| 100.0 | -.008 | -.006 | .016 | .033 | .045 | .054 | .056 | .057 | .059 |
| 102.5 | -.006 | -.003 | .019 | .038 | .051 | .060 | .061 | .063 | .065 |
| 105.0 | -.004 | -.001 | .023 | .042 | .056 | .066 | .067 | .068 | .070 |
| 107.5 | -.002 | .001 | .026 | .046 | .061 | .071 | .073 | .074 | .076 |
| 110.0 | .000 | .003 | .030 | .051 | .066 | .077 | .079 | .081 | .082 |
| 112.5 | .003 | .006 | .033 | .055 | .071 | .082 | .085 | .087 | .088 |
| 115.0 | .005 | .009 | .037 | .059 | .076 | .087 | .090 | .092 | .094 |
| 117.5 | .007 | .011 | .040 | .063 | .081 | .092 | .095 | .097 | .098 |

TABLE 9d – (Continued)

| $\theta_w$ | r/R = 0.289 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|
| 120.0 | .009 | .013 | .043 | .067 | .085 | .097 | .099 | .101 | .103 |
| 122.5 | .011 | .015 | .047 | .071 | .090 | .102 | .103 | .105 | .107 |
| 125.0 | .014 | .018 | .050 | .075 | .094 | .106 | .108 | .109 | .112 |
| 127.5 | .018 | .022 | .054 | .079 | .098 | .110 | .112 | .114 | .117 |
| 130.0 | .021 | .025 | .057 | .083 | .102 | .114 | .117 | .119 | .121 |
| 132.5 | .023 | .027 | .060 | .086 | .106 | .118 | .121 | .123 | .125 |
| 135.0 | .025 | .029 | .063 | .090 | .109 | .122 | .124 | .126 | .128 |
| 137.5 | .027 | .031 | .066 | .093 | .113 | .126 | .128 | .129 | .132 |
| 140.0 | .029 | .033 | .068 | .096 | .116 | .129 | .131 | .133 | .136 |
| 142.5 | .031 | .036 | .071 | .098 | .119 | .132 | .134 | .136 | .140 |
| 145.0 | .034 | .038 | .073 | .101 | .122 | .135 | .137 | .140 | .144 |
| 147.5 | .036 | .040 | .075 | .103 | .124 | .138 | .140 | .143 | .147 |
| 150.0 | .038 | .042 | .077 | .106 | .126 | .140 | .143 | .146 | .150 |
| 152.5 | .040 | .044 | .079 | .108 | .129 | .143 | .146 | .149 | .152 |
| 155.0 | .041 | .045 | .081 | .109 | .131 | .145 | .148 | .151 | .155 |
| 157.5 | .042 | .046 | .082 | .111 | .132 | .147 | .150 | .153 | .156 |
| 160.0 | .042 | .046 | .083 | .112 | .134 | .148 | .152 | .154 | .158 |
| 162.5 | .042 | .047 | .084 | .113 | .136 | .150 | .153 | .156 | .159 |
| 165.0 | .042 | .047 | .084 | .114 | .137 | .151 | .154 | .157 | .161 |
| 167.5 | .042 | .047 | .085 | .115 | .138 | .152 | .155 | .158 | .162 |
| 170.0 | .042 | .046 | .085 | .115 | .138 | .153 | .156 | .159 | .163 |
| 172.5 | .042 | .046 | .085 | .116 | .139 | .154 | .157 | .161 | .165 |
| 175.0 | .042 | .047 | .085 | .116 | .139 | .154 | .158 | .162 | .166 |
| 177.5 | .043 | .047 | .086 | .116 | .139 | .155 | .159 | .162 | .166 |

TABLE 9d – (Continued)

| $\theta_w$ | r/R = 0.289 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|
| 180.0 | .043 | .047 | .086 | .116 | .139 | .155 | .159 | .162 | .166 |
| 182.5 | .042 | .047 | .086 | .116 | .139 | .155 | .158 | .162 | .165 |
| 185.0 | .042 | .047 | .085 | .116 | .139 | .154 | .158 | .160 | .164 |
| 187.5 | .041 | .046 | .085 | .116 | .139 | .154 | .156 | .159 | .163 |
| 190.0 | .041 | .046 | .085 | .115 | .138 | .153 | .155 | .158 | .162 |
| 192.5 | .041 | .046 | .084 | .114 | .137 | .152 | .154 | .157 | .161 |
| 195.0 | .040 | .045 | .083 | .113 | .135 | .150 | .153 | .155 | .159 |
| 197.5 | .039 | .044 | .081 | .111 | .133 | .148 | .151 | .154 | .158 |
| 200.0 | .038 | .043 | .080 | .109 | .131 | .146 | .149 | .152 | .156 |
| 202.5 | .037 | .042 | .078 | .107 | .129 | .143 | .147 | .150 | .154 |
| 205.0 | .036 | .040 | .076 | .105 | .127 | .141 | .144 | .148 | .152 |
| 207.5 | .034 | .038 | .074 | .103 | .124 | .139 | .142 | .145 | .149 |
| 210.0 | .032 | .036 | .072 | .100 | .122 | .136 | .139 | .143 | .147 |
| 212.5 | .030 | .034 | .069 | .098 | .119 | .133 | .136 | .140 | .144 |
| 215.0 | .027 | .032 | .067 | .095 | .116 | .130 | .133 | .136 | .141 |
| 217.5 | .025 | .029 | .064 | .092 | .113 | .127 | .129 | .132 | .137 |
| 220.0 | .022 | .026 | .061 | .089 | .110 | .123 | .126 | .129 | .133 |
| 222.5 | .020 | .024 | .058 | .086 | .106 | .120 | .122 | .125 | .130 |
| 225.0 | .018 | .022 | .055 | .082 | .102 | .116 | .118 | .121 | .126 |
| 227.5 | .016 | .020 | .052 | .079 | .098 | .111 | .114 | .117 | .122 |
| 230.0 | .014 | .018 | .050 | .075 | .094 | .107 | .110 | .113 | .117 |
| 232.5 | .013 | .016 | .046 | .071 | .089 | .102 | .105 | .109 | .113 |
| 235.0 | .011 | .014 | .043 | .067 | .085 | .097 | .101 | .104 | .108 |
| 237.5 | .008 | .012 | .040 | .062 | .080 | .092 | .096 | .099 | .104 |

TABLE 9d – (Continued)

| $\theta_w$ | r/R = 0.289 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|
| 240.0 | .006 | .009 | .036 | .058 | .075 | .087 | .090 | .094 | .099 |
| 242.5 | .003 | .006 | .032 | .053 | .070 | .081 | .085 | .089 | .094 |
| 245.0 | .000 | .003 | .028 | .049 | .064 | .075 | .079 | .083 | .088 |
| 247.5 | -.002 | .001 | .025 | .044 | .059 | .070 | .073 | .077 | .083 |
| 250.0 | -.004 | -.001 | .021 | .039 | .054 | .064 | .067 | .072 | .077 |
| 252.5 | -.005 | -.003 | .018 | .035 | .048 | .058 | .061 | .066 | .072 |
| 255.0 | -.006 | -.004 | .015 | .030 | .043 | .052 | .055 | .060 | .066 |
| 257.5 | -.006 | -.004 | .012 | .026 | .037 | .045 | .049 | .054 | .060 |
| 260.0 | -.006 | -.004 | .010 | .022 | .031 | .039 | .043 | .048 | .054 |
| 262.5 | -.006 | -.005 | .007 | .017 | .026 | .033 | .037 | .042 | .047 |
| 265.0 | -.007 | -.006 | .004 | .012 | .020 | .026 | .031 | .035 | .041 |
| 267.5 | -.008 | -.007 | .000 | .007 | .014 | .020 | .024 | .029 | .034 |
| 270.0 | -.009 | -.009 | -.003 | .003 | .008 | .013 | .018 | .022 | .027 |
| 272.5 | -.010 | -.010 | -.006 | -.002 | .002 | .006 | .011 | .016 | .020 |
| 275.0 | -.011 | -.011 | -.009 | -.007 | -.004 | -.000 | .004 | .009 | .014 |
| 277.5 | -.011 | -.011 | -.012 | -.012 | -.010 | -.007 | -.002 | .003 | .008 |
| 280.0 | -.011 | -.012 | -.015 | -.017 | -.016 | -.014 | -.008 | -.003 | .002 |
| 282.5 | -.012 | -.013 | -.018 | -.021 | -.022 | -.020 | -.014 | -.009 | -.005 |
| 285.0 | -.013 | -.014 | -.022 | -.026 | -.028 | -.027 | -.021 | -.015 | -.011 |
| 287.5 | -.014 | -.015 | -.025 | -.031 | -.034 | -.033 | -.027 | -.021 | -.018 |
| 290.0 | -.015 | -.016 | -.028 | -.036 | -.040 | -.040 | -.033 | -.028 | -.025 |
| 292.5 | -.016 | -.018 | -.031 | -.041 | -.046 | -.046 | -.039 | -.034 | -.032 |
| 295.0 | -.017 | -.019 | -.035 | -.045 | -.051 | -.053 | -.046 | -.041 | -.038 |
| 297.5 | -.018 | -.020 | -.037 | -.050 | -.057 | -.059 | -.052 | -.047 | -.045 |

TABLE 9d – (Continued)

| $\theta_w$ | r/R = 0.289 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|
| 300.0 | -.020 | -.022 | -.041 | -.054 | -.062 | -.065 | -.058 | -.054 | -.052 |
| 302.5 | -.023 | -.025 | -.044 | -.058 | -.067 | -.070 | -.065 | -.061 | -.059 |
| 305.0 | -.026 | -.029 | -.048 | -.062 | -.071 | -.075 | -.071 | -.067 | -.066 |
| 307.5 | -.030 | -.033 | -.052 | -.067 | -.076 | -.081 | -.076 | -.074 | -.073 |
| 310.0 | -.034 | -.036 | -.056 | -.071 | -.081 | -.086 | -.082 | -.080 | -.080 |
| 312.5 | -.037 | -.040 | -.060 | -.075 | -.085 | -.091 | -.088 | -.086 | -.087 |
| 315.0 | -.040 | -.043 | -.063 | -.079 | -.090 | -.096 | -.093 | -.092 | -.094 |
| 317.5 | -.042 | -.045 | -.067 | -.083 | -.095 | -.101 | -.099 | -.098 | -.100 |
| 320.0 | -.043 | -.046 | -.069 | -.087 | -.099 | -.106 | -.104 | -.103 | -.106 |
| 322.5 | -.042 | -.045 | -.071 | -.090 | -.104 | -.112 | -.109 | -.108 | -.112 |
| 325.0 | -.041 | -.044 | -.072 | -.094 | -.109 | -.117 | -.114 | -.113 | -.118 |
| 327.5 | -.037 | -.041 | -.073 | -.097 | -.114 | -.123 | -.118 | -.117 | -.122 |
| 330.0 | -.024 | -.029 | -.068 | -.098 | -.118 | -.128 | -.120 | -.118 | -.125 |
| 332.5 | -.023 | -.028 | -.068 | -.099 | -.120 | -.131 | -.126 | -.125 | -.130 |
| 335.0 | -.196 | -.190 | -.140 | -.108 | -.092 | -.093 | -.133 | -.151 | -.140 |
| 337.5 | -.174 | -.170 | -.137 | -.114 | -.100 | -.095 | -.110 | -.114 | -.102 |
| 340.0 | -.139 | -.138 | -.127 | -.119 | -.113 | -.111 | -.110 | -.113 | -.122 |
| 342.5 | .003 | -.001 | -.038 | -.068 | -.091 | -.106 | -.111 | -.116 | -.123 |
| 345.0 | .077 | .070 | .015 | -.030 | -.065 | -.091 | -.101 | -.112 | -.122 |
| 347.5 | .085 | .079 | .027 | -.016 | -.051 | -.077 | -.091 | -.104 | -.118 |
| 350.0 | .067 | .062 | .021 | -.015 | -.044 | -.068 | -.082 | -.097 | -.114 |
| 352.5 | .058 | .053 | .018 | -.013 | -.040 | -.062 | -.077 | -.093 | -.111 |
| 355.0 | .059 | .055 | .020 | -.011 | -.038 | -.060 | -.074 | -.090 | -.108 |
| 357.5 | .070 | .063 | .025 | -.009 | -.037 | -.060 | -.074 | -.089 | -.106 |

## TABLE 9e – HARMONICS OF $V_x/V$

r/R = 0.289

| n | $(A_x)_n/V$ | $(B_x)_n/V$ | $(V_x)_n/V$ | $(\phi_x^*)_n$ |
|---|---|---|---|---|
| 0 | 1.0555 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.0527 | -.0725 | .0896 | 216.0 |
| 2 | -.0805 | -.0259 | .0845 | 252.2 |
| 3 | -.0509 | -.0374 | .0632 | 233.7 |
| 4 | -.0279 | -.0173 | .0328 | 238.1 |
| 5 | -.0205 | -.0215 | .0297 | 223.7 |
| 6 | -.0153 | -.0127 | .0199 | 230.2 |
| 7 | -.0187 | -.0010 | .0187 | 267.0 |
| 8 | .0015 | .0099 | .0100 | 8.7 |
| 9 | .0099 | .0166 | .0193 | 30.8 |
| 10 | .0097 | .0141 | .0171 | 34.4 |
| 11 | .0092 | .0132 | .0161 | 35.0 |
| 12 | .0144 | .0012 | .0145 | 85.4 |
| 13 | .0139 | -.0111 | .0178 | 128.6 |
| 14 | .0103 | -.0186 | .0213 | 151.0 |
| 15 | .0083 | -.0231 | .0246 | 160.2 |
| 16 | .0076 | -.0318 | .0327 | 166.6 |

r/R = 0.3

| n | $(A_x)_n/V$ | $(B_x)_n/V$ | $(V_x)_n/V$ | $(\phi_x^*)_n$ |
|---|---|---|---|---|
| 0 | 1.0534 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.0511 | -.0681 | .0852 | 216.9 |
| 2 | -.0781 | -.0246 | .0819 | 252.5 |
| 3 | -.0493 | -.0353 | .0606 | 234.4 |
| 4 | -.0271 | -.0165 | .0318 | 238.6 |
| 5 | -.0199 | -.0204 | .0285 | 224.3 |
| 6 | -.0145 | -.0121 | .0189 | 230.3 |
| 7 | -.0174 | -.0009 | .0174 | 267.2 |
| 8 | .0018 | .0095 | .0096 | 10.9 |
| 9 | .0098 | .0159 | .0187 | 31.7 |
| 10 | .0095 | .0136 | .0166 | 35.0 |
| 11 | .0090 | .0128 | .0156 | 35.0 |
| 12 | .0139 | .0014 | .0140 | 84.2 |
| 13 | .0132 | -.0102 | .0167 | 127.8 |
| 14 | .0096 | -.0175 | .0199 | 151.1 |
| 15 | .0077 | -.0218 | .0231 | 160.5 |
| 16 | .0070 | -.0301 | .0309 | 167.0 |

TABLE 9e – (Continued)

r/R = 0.4

| n | $(A_x)_n/V$ | $(B_x)_n/V$ | $(V_x)_n/V$ | $(\phi_x^*)_n$ |
|---|---|---|---|---|
| 0 | 1.0364 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.0375 | -.0338 | .0504 | 228.0 |
| 2 | -.0588 | -.0143 | .0605 | 256.3 |
| 3 | -.0362 | -.0183 | .0405 | 243.2 |
| 4 | -.0205 | -.0104 | .0229 | 243.1 |
| 5 | -.0144 | -.0117 | .0185 | 230.8 |
| 6 | -.0084 | -.0068 | .0108 | 231.1 |
| 7 | -.0074 | .0001 | .0074 | 270.8 |
| 8 | .0042 | .0062 | .0075 | 33.8 |
| 9 | .0091 | .0103 | .0138 | 41.4 |
| 10 | .0082 | .0093 | .0124 | 41.5 |
| 11 | .0067 | .0095 | .0116 | 35.3 |
| 12 | .0095 | .0031 | .0100 | 72.1 |
| 13 | .0078 | -.0037 | .0085 | 115.9 |
| 14 | .0042 | -.0083 | .0093 | 153.0 |
| 15 | .0025 | -.0115 | .0118 | 167.6 |
| 16 | .0019 | -.0171 | .0172 | 173.6 |

r/R = 0.5

| n | $(A_x)_n/V$ | $(B_x)_n/V$ | $(V_x)_n/V$ | $(\phi_x^*)_n$ |
|---|---|---|---|---|
| 0 | 1.0229 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.0259 | -.0090 | .0275 | 250.8 |
| 2 | -.0426 | -.0069 | .0432 | 260.8 |
| 3 | -.0257 | -.0059 | .0263 | 257.0 |
| 4 | -.0143 | -.0057 | .0154 | 248.5 |
| 5 | -.0094 | -.0050 | .0107 | 241.9 |
| 6 | -.0036 | -.0027 | .0044 | 233.2 |
| 7 | -.0001 | .0008 | .0008 | 353.3 |
| 8 | .0058 | .0038 | .0069 | 56.9 |
| 9 | .0082 | .0060 | .0102 | 53.8 |
| 10 | .0068 | .0058 | .0090 | 49.7 |
| 11 | .0047 | .0067 | .0082 | 35.4 |
| 12 | .0056 | .0038 | .0068 | 55.5 |
| 13 | .0030 | .0007 | .0031 | 77.6 |
| 14 | -.0001 | -.0019 | .0019 | 182.6 |
| 15 | -.0015 | -.0042 | .0044 | 200.0 |
| 16 | -.0019 | -.0075 | .0079 | 194.3 |

**TABLE 9e – (Continued)**

r/R = 0.6

| n | $(A_x)_n/V$ | $(B_x)_n/V$ | $(V_x)_n/V$ | $(\phi_x^*)_n$ |
|---|---|---|---|---|
| 0 | 1.0129 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.0166 | .0061 | .0177 | 290.1 |
| 2 | -.0296 | -.0023 | .0297 | 265.6 |
| 3 | -.0177 | .0017 | .0177 | 275.6 |
| 4 | -.0087 | -.0024 | .0090 | 254.4 |
| 5 | -.0051 | -.0004 | .0051 | 265.9 |
| 6 | .0001 | .0003 | .0003 | 16.4 |
| 7 | .0046 | .0013 | .0047 | 74.2 |
| 8 | .0067 | .0021 | .0071 | 72.4 |
| 9 | .0072 | .0030 | .0078 | 67.4 |
| 10 | .0055 | .0032 | .0064 | 59.5 |
| 11 | .0030 | .0043 | .0053 | 34.8 |
| 12 | .0022 | .0037 | .0043 | 30.3 |
| 13 | -.0007 | .0028 | .0029 | 346.4 |
| 14 | -.0033 | .0017 | .0037 | 296.9 |
| 15 | -.0044 | .0003 | .0044 | 273.5 |
| 16 | -.0046 | -.0017 | .0049 | 250.3 |

r/R = 0.7

| n | $(A_x)_n/V$ | $(B_x)_n/V$ | $(V_x)_n/V$ | $(\phi_x^*)_n$ |
|---|---|---|---|---|
| 0 | 1.0065 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.0094 | .0116 | .0149 | 321.0 |
| 2 | -.0198 | -.0006 | .0198 | 268.3 |
| 3 | -.0122 | .0047 | .0131 | 291.2 |
| 4 | -.0035 | -.0007 | .0036 | 259.2 |
| 5 | -.0014 | .0023 | .0027 | 328.3 |
| 6 | .0025 | .0021 | .0033 | 50.1 |
| 7 | .0065 | .0015 | .0067 | 76.8 |
| 8 | .0069 | .0013 | .0070 | 79.7 |
| 9 | .0061 | .0013 | .0062 | 78.2 |
| 10 | .0042 | .0015 | .0044 | 69.7 |
| 11 | .0015 | .0025 | .0029 | 31.8 |
| 12 | -.0008 | .0027 | .0028 | 344.2 |
| 13 | -.0034 | .0028 | .0044 | 309.8 |
| 14 | -.0053 | .0024 | .0058 | 294.2 |
| 15 | -.0062 | .0017 | .0064 | 285.7 |
| 16 | -.0061 | .0008 | .0062 | 277.6 |

TABLE 9e – (Continued)

r/R = 0.8

| n | $(A_x)_n/V$ | $(B_x)_n/V$ | $(V_x)_n/V$ | $(\phi_x^*)_n$ |
|---|---|---|---|---|
| 0 | 1.0064 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.0030 | .0004 | .0031 | 276.8 |
| 2 | -.0137 | -.0038 | .0142 | 254.6 |
| 3 | -.0105 | -.0009 | .0106 | 264.9 |
| 4 | .0022 | -.0018 | .0028 | 129.8 |
| 5 | .0023 | .0013 | .0026 | 59.5 |
| 6 | .0029 | .0020 | .0036 | 55.6 |
| 7 | .0041 | .0013 | .0043 | 72.7 |
| 8 | .0069 | .0022 | .0069 | 71.3 |
| 9 | .0045 | .0019 | .0049 | 67.5 |
| 10 | .0025 | .0015 | .0029 | 58.4 |
| 11 | .0001 | .0012 | .0012 | 4.5 |
| 12 | -.0034 | -.0006 | .0034 | 260.5 |
| 13 | -.0049 | -.0019 | .0053 | 249.0 |
| 14 | -.0059 | -.0028 | .0065 | 244.4 |
| 15 | -.0064 | -.0024 | .0069 | 249.3 |
| 16 | -.0059 | -.0034 | .0068 | 240.2 |

r/R = 0.9

| n | $(A_x)_n/V$ | $(B_x)_n/V$ | $(V_x)_n/V$ | $(\phi_x^*)_n$ |
|---|---|---|---|---|
| 0 | 1.0047 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.0011 | -.0077 | .0078 | 188.3 |
| 2 | -.0098 | -.0061 | .0115 | 238.2 |
| 3 | -.0092 | -.0041 | .0101 | 246.2 |
| 4 | .0054 | -.0019 | .0057 | 109.2 |
| 5 | .0043 | .0013 | .0045 | 72.7 |
| 6 | .0035 | .0021 | .0041 | 59.6 |
| 7 | .0022 | .0012 | .0025 | 60.3 |
| 8 | .0051 | .0021 | .0055 | 68.1 |
| 9 | .0033 | .0018 | .0038 | 61.0 |
| 10 | .0014 | .0009 | .0017 | 56.3 |
| 11 | -.0007 | .0002 | .0007 | 289.1 |
| 12 | -.0051 | -.0023 | .0056 | 245.5 |
| 13 | -.0059 | -.0042 | .0072 | 234.5 |
| 14 | -.0059 | -.0052 | .0079 | 228.5 |
| 15 | -.0062 | -.0047 | .0078 | 233.2 |
| 16 | -.0059 | -.0054 | .0076 | 225.6 |

TABLE 9e – (Continued)

r/R = 1.0

| n | $(A_x)_n/V$ | $(B_x)_n/V$ | $(V_x)_n/V$ | $(\phi_x^*)_n$ |
|---|---|---|---|---|
| 0 | 1.0007 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.0039 | -.0109 | .0115 | 199.7 |
| 2 | -.0080 | -.0070 | .0106 | 229.1 |
| 3 | -.0079 | -.0036 | .0087 | 245.2 |
| 4 | .0059 | -.0006 | .0060 | 95.4 |
| 5 | .0045 | .0027 | .0052 | 59.0 |
| 6 | .0044 | .0024 | .0051 | 61.4 |
| 7 | .0012 | .0015 | .0019 | 39.2 |
| 8 | .0028 | .0006 | .0028 | 78.2 |
| 9 | .0024 | .0008 | .0025 | 70.7 |
| 10 | .0010 | -.0003 | .0011 | 115.9 |
| 11 | -.0007 | -.0006 | .0009 | 231.3 |
| 12 | -.0060 | -.0023 | .0064 | 248.8 |
| 13 | -.0063 | -.0035 | .0072 | 241.0 |
| 14 | -.0055 | -.0042 | .0069 | 232.8 |
| 15 | -.0057 | -.0043 | .0072 | 233.1 |
| 16 | -.0050 | -.0044 | .0066 | 228.9 |

## TABLE 9f – HARMONICS OF $V_t/V$

r/R = 0.289

| n | $(A_t)_n/V$ | $(B_t)_n/V$ | $(V_t)_n/V$ | $(\phi_t^*)_n$ |
|---|---|---|---|---|
| 0 | -.0089 | 0.0000 | 0.0000 | 0.0 |
| 1 | .0484 | -.1984 | .2042 | 166.3 |
| 2 | -.0035 | -.0141 | .0145 | 194.0 |
| 3 | .0109 | -.0203 | .0231 | 151.7 |
| 4 | .0055 | -.0132 | .0143 | 157.2 |
| 5 | .0113 | -.0140 | .0180 | 141.0 |
| 6 | .0120 | -.0080 | .0144 | 123.6 |
| 7 | .0112 | -.0077 | .0136 | 124.4 |
| 8 | .0051 | -.0038 | .0063 | 126.9 |
| 9 | -.0031 | .0011 | .0033 | 290.1 |
| 10 | -.0078 | .0071 | .0106 | 312.3 |
| 11 | -.0073 | .0117 | .0138 | 328.1 |
| 12 | -.0003 | .0158 | .0158 | 358.8 |
| 13 | .0102 | .0165 | .0194 | 31.6 |
| 14 | .0215 | .0147 | .0260 | 55.7 |
| 15 | .0291 | .0109 | .0311 | 69.5 |
| 16 | .0327 | .0077 | .0336 | 76.8 |

r/R = 0.3

| n | $(A_t)_n/V$ | $(B_t)_n/V$ | $(V_t)_n/V$ | $(\phi_t^*)_n$ |
|---|---|---|---|---|
| 0 | -.0086 | 0.0000 | 0.0000 | 0.0 |
| 1 | .0453 | -.1970 | .2021 | 167.0 |
| 2 | -.0033 | -.0136 | .0140 | 193.6 |
| 3 | .0103 | -.0195 | .0221 | 152.0 |
| 4 | .0053 | -.0127 | .0137 | 157.3 |
| 5 | .0107 | -.0134 | .0171 | 141.3 |
| 6 | .0113 | -.0075 | .0135 | 123.5 |
| 7 | .0105 | -.0070 | .0126 | 123.7 |
| 8 | .0047 | -.0032 | .0056 | 124.2 |
| 9 | -.0030 | .0016 | .0034 | 297.1 |
| 10 | -.0075 | .0072 | .0104 | 313.9 |
| 11 | -.0070 | .0114 | .0133 | 328.4 |
| 12 | -.0004 | .0150 | .0150 | 358.4 |
| 13 | .0095 | .0156 | .0182 | 31.4 |
| 14 | .0202 | .0137 | .0244 | 55.9 |
| 15 | .0275 | .0100 | .0292 | 70.0 |
| 16 | .0309 | .0069 | .0317 | 77.4 |

TABLE 9f – (Continued)

r/R = 0.4

| n | $(A_t)_n/V$ | $(B_t)_n/V$ | $(V_t)_n/V$ | $(\phi_t^*)_n$ |
|---|---|---|---|---|
| 0 | -.0061 | 0.0000 | 0.0000 | 0.0 |
| 1 | .0207 | -.1852 | .1863 | 173.6 |
| 2 | -.0016 | -.0099 | .0100 | 189.1 |
| 3 | .0057 | -.0129 | .0141 | 156.1 |
| 4 | .0034 | -.0083 | .0090 | 157.6 |
| 5 | .0055 | -.0081 | .0098 | 145.5 |
| 6 | .0057 | -.0035 | .0067 | 121.8 |
| 7 | .0049 | -.0018 | .0052 | 109.9 |
| 8 | .0016 | .0016 | .0022 | 45.3 |
| 9 | -.0025 | .0047 | .0053 | 331.8 |
| 10 | -.0048 | .0075 | .0089 | 327.5 |
| 11 | -.0045 | .0085 | .0096 | 332.3 |
| 12 | -.0011 | .0091 | .0091 | 353.2 |
| 13 | .0043 | .0079 | .0090 | 28.5 |
| 14 | .0102 | .0057 | .0116 | 60.8 |
| 15 | .0145 | .0028 | .0148 | 79.0 |
| 16 | .0170 | .0009 | .0170 | 86.9 |

r/R = 0.5

| n | $(A_t)_n/V$ | $(B_t)_n/V$ | $(V_t)_n/V$ | $(\phi_t^*)_n$ |
|---|---|---|---|---|
| 0 | -.0031 | 0.0000 | 0.0000 | 0.0 |
| 1 | .0026 | -.1750 | .1750 | 179.1 |
| 2 | -.0003 | -.0073 | .0073 | 182.3 |
| 3 | .0023 | -.0078 | .0081 | 163.6 |
| 4 | .0019 | -.0047 | .0051 | 157.7 |
| 5 | .0017 | -.0040 | .0043 | 156.5 |
| 6 | .0015 | -.0006 | .0017 | 112.2 |
| 7 | .0008 | .0019 | .0020 | 22.5 |
| 8 | -.0006 | .0047 | .0047 | 353.3 |
| 9 | -.0020 | .0064 | .0067 | 342.8 |
| 10 | -.0026 | .0072 | .0077 | 339.8 |
| 11 | -.0025 | .0059 | .0064 | 337.3 |
| 12 | -.0014 | .0043 | .0045 | 342.2 |
| 13 | .0006 | .0019 | .0020 | 17.5 |
| 14 | .0029 | -.0004 | .0029 | 97.9 |
| 15 | .0050 | -.0025 | .0056 | 116.5 |
| 16 | .0067 | -.0035 | .0075 | 117.5 |

TABLE 9f – (Continued)

r/R = 0.6

| n | $(A_t)_n/V$ | $(B_t)_n/V$ | $(V_t)_n/V$ | $(\phi_t^*)_n$ |
|---|---|---|---|---|
| 0 | .0004 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.0090 | -.1664 | .1667 | 183.1 |
| 2 | .0005 | -.0060 | .0060 | 174.9 |
| 3 | .0001 | -.0041 | .0041 | 179.2 |
| 4 | .0009 | -.0020 | .0022 | 156.0 |
| 5 | -.0007 | -.0011 | .0013 | 215.3 |
| 6 | -.0012 | .0012 | .0017 | 316.5 |
| 7 | -.0018 | .0039 | .0043 | 335.6 |
| 8 | -.0018 | .0062 | .0064 | 344.0 |
| 9 | -.0015 | .0069 | .0071 | 347.7 |
| 10 | -.0011 | .0062 | .0063 | 350.4 |
| 11 | -.0010 | .0036 | .0037 | 344.8 |
| 12 | -.0013 | .0007 | .0015 | 297.1 |
| 13 | -.0015 | -.0023 | .0028 | 214.0 |
| 14 | -.0016 | -.0046 | .0048 | 199.0 |
| 15 | -.0010 | -.0060 | .0061 | 189.6 |
| 16 | -.0001 | -.0062 | .0062 | 180.6 |

r/R = 0.7

| n | $(A_t)_n/V$ | $(B_t)_n/V$ | $(V_t)_n/V$ | $(\phi_t^*)_n$ |
|---|---|---|---|---|
| 0 | .0044 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.0140 | -.1595 | .1601 | 185.0 |
| 2 | .0009 | -.0059 | .0060 | 171.1 |
| 3 | -.0010 | -.0018 | .0021 | 208.4 |
| 4 | .0003 | -.0001 | .0003 | 112.2 |
| 5 | -.0019 | .0007 | .0020 | 289.7 |
| 6 | -.0024 | .0020 | .0031 | 310.0 |
| 7 | -.0028 | .0044 | .0052 | 327.4 |
| 8 | -.0020 | .0060 | .0063 | 341.3 |
| 9 | -.0010 | .0061 | .0061 | 350.4 |
| 10 | -.0000 | .0046 | .0046 | 359.7 |
| 11 | .0000 | .0015 | .0015 | .6 |
| 12 | -.0009 | -.0017 | .0020 | 207.4 |
| 13 | -.0022 | -.0048 | .0052 | 204.4 |
| 14 | -.0033 | -.0058 | .0075 | 205.6 |
| 15 | -.0036 | -.0077 | .0085 | 205.2 |
| 16 | -.0032 | -.0074 | .0080 | 203.4 |

## TABLE 9f – (Continued)

r/R = 0.8

| n | $(A_t)_n/V$ | $(B_t)_n/V$ | $(V_t)_n/V$ | $(\phi_t^*)_n$ |
|---|---|---|---|---|
| 0 | .0136 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.0081 | -.1553 | .1555 | 183.0 |
| 2 | .0002 | -.0081 | .0081 | 178.6 |
| 3 | .0001 | -.0017 | .0017 | 176.6 |
| 4 | .0003 | .0007 | .0008 | 25.5 |
| 5 | -.0008 | .0007 | .0010 | 312.8 |
| 6 | -.0013 | .0011 | .0017 | 312.1 |
| 7 | -.0012 | .0020 | .0024 | 328.6 |
| 8 | -.0006 | .0027 | .0028 | 347.0 |
| 9 | -.0006 | .0026 | .0027 | 346.5 |
| 10 | .0001 | .0013 | .0013 | 6.3 |
| 11 | .0003 | -.0006 | .0006 | 155.4 |
| 12 | .0003 | -.0026 | .0026 | 173.5 |
| 13 | .0000 | -.0047 | .0047 | 179.4 |
| 14 | .0001 | -.0061 | .0061 | 178.8 |
| 15 | -.0001 | -.0064 | .0064 | 180.6 |
| 16 | -.0000 | -.0058 | .0058 | 180.4 |

r/R = 0.9

| n | $(A_t)_n/V$ | $(B_t)_n/V$ | $(V_t)_n/V$ | $(\phi_t^*)_n$ |
|---|---|---|---|---|
| 0 | .0149 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.0036 | -.1507 | .1507 | 181.4 |
| 2 | .0002 | -.0096 | .0096 | 178.6 |
| 3 | .0007 | -.0018 | .0019 | 158.3 |
| 4 | .0004 | .0011 | .0012 | 18.0 |
| 5 | .0000 | .0005 | .0005 | 6.1 |
| 6 | -.0003 | .0003 | .0004 | 314.3 |
| 7 | -.0000 | .0002 | .0002 | 356.1 |
| 8 | .0004 | .0004 | .0006 | 41.5 |
| 9 | -.0001 | .0002 | .0002 | 318.8 |
| 10 | .0003 | -.0008 | .0009 | 160.5 |
| 11 | .0004 | -.0018 | .0019 | 166.7 |
| 12 | .0011 | -.0030 | .0031 | 160.1 |
| 13 | .0014 | -.0044 | .0046 | 162.2 |
| 14 | .0021 | -.0054 | .0058 | 158.5 |
| 15 | .0021 | -.0053 | .0057 | 158.4 |
| 16 | .0019 | -.0046 | .0049 | 157.5 |

**TABLE 9f – (Continued)**

r/R = 1.0

| n | $(A_t)_n/V$ | $(B_t)_n/V$ | $(V_t)_n/V$ | $(\phi_t^*)_n$ |
|---|---|---|---|---|
| 0 | .0072 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.0015 | -.1455 | .1455 | 180.6 |
| 2 | .0012 | -.0101 | .0102 | 173.4 |
| 3 | .0006 | -.0017 | .0018 | 161.4 |
| 4 | .0003 | .0012 | .0013 | 14.0 |
| 5 | .0003 | .0001 | .0003 | 74.2 |
| 6 | .0003 | -.0004 | .0005 | 144.0 |
| 7 | .0005 | -.0007 | .0010 | 138.4 |
| 8 | .0009 | -.0006 | .0011 | 126.1 |
| 9 | .0005 | -.0011 | .0011 | 156.4 |
| 10 | .0009 | -.0015 | .0017 | 163.2 |
| 11 | .0006 | -.0022 | .0023 | 164.7 |
| 12 | .0013 | -.0030 | .0032 | 155.9 |
| 13 | .0016 | -.0041 | .0044 | 158.4 |
| 14 | .0021 | -.0048 | .0052 | 156.0 |
| 15 | .0022 | -.0046 | .0051 | 154.0 |
| 16 | .0020 | -.0039 | .0044 | 153.5 |

## TABLE 9g – HARMONICS OF $V_r/V$

r/R = 0.289

| n | $(A_r)_n/V$ | $(B_r)_n/V$ | $(V_r)_n/V$ | $(\phi_r^*)_n$ |
|---|---|---|---|---|
| 0 | .0012 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.0264 | -.0002 | .0264 | 269.6 |
| 2 | .0225 | -.0016 | .0225 | 94.0 |
| 3 | .0155 | .0035 | .0159 | 77.1 |
| 4 | .0209 | .0041 | .0213 | 78.8 |
| 5 | .0225 | .0045 | .0230 | 78.6 |
| 6 | .0175 | .0052 | .0183 | 73.3 |
| 7 | .0136 | .0041 | .0142 | 73.2 |
| 8 | .0094 | .0023 | .0097 | 76.2 |
| 9 | .0064 | -.0002 | .0064 | 92.0 |
| 10 | .0023 | -.0019 | .0030 | 130.0 |
| 11 | -.0011 | -.0044 | .0046 | 194.1 |
| 12 | -.0037 | -.0072 | .0081 | 207.6 |
| 13 | -.0052 | -.0080 | .0096 | 213.0 |
| 14 | -.0050 | -.0063 | .0080 | 218.1 |
| 15 | -.0049 | -.0037 | .0062 | 232.9 |
| 16 | -.0041 | -.0001 | .0041 | 268.6 |

r/R = 0.3

| n | $(A_r)_n/V$ | $(B_r)_n/V$ | $(V_r)_n/V$ | $(\phi_r^*)_n$ |
|---|---|---|---|---|
| 0 | .0019 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.0311 | .0001 | .0311 | 270.1 |
| 2 | .0219 | -.0016 | .0220 | 94.3 |
| 3 | .0155 | .0032 | .0158 | 78.5 |
| 4 | .0205 | .0038 | .0208 | 79.5 |
| 5 | .0219 | .0042 | .0223 | 79.2 |
| 6 | .0171 | .0049 | .0177 | 74.1 |
| 7 | .0132 | .0038 | .0138 | 74.1 |
| 8 | .0092 | .0021 | .0094 | 77.1 |
| 9 | .0062 | -.0003 | .0062 | 92.8 |
| 10 | .0022 | -.0019 | .0029 | 130.6 |
| 11 | -.0010 | -.0043 | .0044 | 193.8 |
| 12 | -.0036 | -.0069 | .0077 | 207.7 |
| 13 | -.0050 | -.0077 | .0092 | 212.9 |
| 14 | -.0047 | -.0061 | .0077 | 218.0 |
| 15 | -.0047 | -.0036 | .0059 | 232.5 |
| 16 | -.0039 | -.0001 | .0039 | 267.9 |

## TABLE 9g – (Continued)

r/R = 0.4

| n | $(A_r)_n/V$ | $(B_r)_n/V$ | $(V_r)_n/V$ | $(\phi_r^*)_n$ |
|---|---|---|---|---|
| 0 | .0075 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.0691 | .0023 | .0691 | 271.9 |
| 2 | .0171 | -.0021 | .0172 | 96.9 |
| 3 | .0155 | .0001 | .0155 | 89.6 |
| 4 | .0173 | .0010 | .0173 | 86.6 |
| 5 | .0171 | .0014 | .0172 | 85.4 |
| 6 | .0134 | .0018 | .0135 | 82.3 |
| 7 | .0103 | .0012 | .0104 | 83.1 |
| 8 | .0072 | .0004 | .0072 | 86.5 |
| 9 | .0045 | -.0010 | .0046 | 101.8 |
| 10 | .0016 | -.0016 | .0023 | 135.8 |
| 11 | -.0006 | -.0030 | .0030 | 191.3 |
| 12 | -.0023 | -.0043 | .0049 | 208.3 |
| 13 | -.0030 | -.0048 | .0057 | 211.7 |
| 14 | -.0028 | -.0039 | .0048 | 216.0 |
| 15 | -.0026 | -.0025 | .0036 | 226.7 |
| 16 | -.0021 | -.0005 | .0022 | 256.8 |

r/R = 0.5

| n | $(A_r)_n/V$ | $(B_r)_n/V$ | $(V_r)_n/V$ | $(\phi_r^*)_n$ |
|---|---|---|---|---|
| 0 | .0123 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.0995 | .0038 | .0996 | 272.2 |
| 2 | .0126 | -.0023 | .0128 | 100.2 |
| 3 | .0149 | -.0021 | .0150 | 97.8 |
| 4 | .0146 | -.0009 | .0146 | 93.6 |
| 5 | .0133 | -.0006 | .0133 | 92.4 |
| 6 | .0104 | -.0003 | .0104 | 91.6 |
| 7 | .0079 | -.0005 | .0079 | 93.8 |
| 8 | .0055 | -.0007 | .0056 | 97.5 |
| 9 | .0032 | -.0014 | .0035 | 113.0 |
| 10 | .0011 | -.0014 | .0018 | 141.6 |
| 11 | -.0003 | -.0020 | .0020 | 187.5 |
| 12 | -.0013 | -.0024 | .0027 | 209.0 |
| 13 | -.0015 | -.0027 | .0030 | 209.0 |
| 14 | -.0013 | -.0022 | .0026 | 211.5 |
| 15 | -.0011 | -.0016 | .0019 | 213.9 |
| 16 | -.0008 | -.0007 | .0011 | 228.1 |

## TABLE 9g – (Continued)

r/R = 0.6

| n | $(A_r)_n/V$ | $(B_r)_n/V$ | $(V_r)_n/V$ | $(\phi_r^*)_n$ |
|---|---|---|---|---|
| 0 | .0161 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.1222 | .0048 | .1223 | 272.2 |
| 2 | .0084 | -.0023 | .0087 | 105.0 |
| 3 | .0137 | -.0033 | .0141 | 103.6 |
| 4 | .0123 | -.0021 | .0125 | 99.5 |
| 5 | .0104 | -.0016 | .0105 | 98.9 |
| 6 | .0081 | -.0015 | .0082 | 100.4 |
| 7 | .0059 | -.0015 | .0061 | 104.5 |
| 8 | .0041 | -.0014 | .0043 | 108.8 |
| 9 | .0022 | -.0016 | .0027 | 125.2 |
| 10 | .0008 | -.0012 | .0014 | 147.2 |
| 11 | -.0001 | -.0012 | .0012 | 182.6 |
| 12 | -.0006 | -.0011 | .0012 | 208.8 |
| 13 | -.0005 | -.0012 | .0013 | 201.2 |
| 14 | -.0003 | -.0010 | .0011 | 196.5 |
| 15 | .0000 | -.0009 | .0009 | 179.4 |
| 16 | .0002 | -.0007 | .0008 | 166.9 |

r/R = 0.7

| n | $(A_r)_n/V$ | $(B_r)_n/V$ | $(V_r)_n/V$ | $(\phi_r^*)_n$ |
|---|---|---|---|---|
| 0 | .0190 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.1373 | .0051 | .1374 | 272.1 |
| 2 | .0045 | -.0020 | .0050 | 114.0 |
| 3 | .0120 | -.0037 | .0125 | 107.2 |
| 4 | .0105 | -.0024 | .0108 | 102.8 |
| 5 | .0084 | -.0018 | .0086 | 102.1 |
| 6 | .0065 | -.0018 | .0067 | 105.2 |
| 7 | .0044 | -.0018 | .0048 | 111.8 |
| 8 | .0030 | -.0016 | .0034 | 118.0 |
| 9 | .0015 | -.0015 | .0021 | 135.4 |
| 10 | .0006 | -.0010 | .0011 | 151.3 |
| 11 | .0000 | -.0008 | .0008 | 178.7 |
| 12 | -.0002 | -.0004 | .0005 | 200.8 |
| 13 | .0001 | -.0004 | .0004 | 167.8 |
| 14 | .0003 | -.0004 | .0005 | 139.8 |
| 15 | .0006 | -.0005 | .0008 | 129.5 |
| 16 | .0007 | -.0006 | .0010 | 131.1 |

TABLE 9g – (Continued)

r/R = 0.8

| n | $(A_r)_n/V$ | $(B_r)_n/V$ | $(V_r)_n/V$ | $(\phi_r^*)_n$ |
|---|---|---|---|---|
| 0 | .0208 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.1400 | .0047 | .1401 | 271.9 |
| 2 | .0012 | -.0014 | .0018 | 139.6 |
| 3 | .0091 | -.0026 | .0094 | 105.9 |
| 4 | .0094 | -.0012 | .0095 | 97.0 |
| 5 | .0079 | -.0003 | .0079 | 92.1 |
| 6 | .0062 | -.0004 | .0062 | 93.2 |
| 7 | .0038 | -.0006 | .0038 | 99.3 |
| 8 | .0024 | -.0010 | .0026 | 111.7 |
| 9 | .0015 | -.0012 | .0019 | 127.3 |
| 10 | .0008 | -.0010 | .0012 | 141.7 |
| 11 | .0001 | -.0010 | .0010 | 173.9 |
| 12 | -.0001 | -.0010 | .0010 | 185.2 |
| 13 | -.0003 | -.0008 | .0009 | 201.2 |
| 14 | .0000 | -.0005 | .0005 | 177.9 |
| 15 | .0001 | -.0004 | .0004 | 161.8 |
| 16 | .0005 | -.0001 | .0005 | 105.5 |

r/R = 0.9

| n | $(A_r)_n/V$ | $(B_r)_n/V$ | $(V_r)_n/V$ | $(\phi_r^*)_n$ |
|---|---|---|---|---|
| 0 | .0220 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.1435 | .0039 | .1436 | 271.6 |
| 2 | -.0021 | -.0009 | .0023 | 247.5 |
| 3 | .0066 | -.0017 | .0068 | 104.2 |
| 4 | .0084 | -.0005 | .0084 | 93.4 |
| 5 | .0073 | .0006 | .0073 | 85.0 |
| 6 | .0055 | .0006 | .0055 | 83.8 |
| 7 | .0029 | .0002 | .0029 | 86.7 |
| 8 | .0016 | -.0004 | .0017 | 104.8 |
| 9 | .0010 | -.0007 | .0012 | 123.9 |
| 10 | .0005 | -.0007 | .0008 | 141.9 |
| 11 | -.0002 | -.0009 | .0009 | 192.4 |
| 12 | -.0001 | -.0011 | .0011 | 187.5 |
| 13 | -.0004 | -.0009 | .0010 | 204.1 |
| 14 | .0001 | -.0006 | .0006 | 170.2 |
| 15 | .0002 | -.0003 | .0004 | 149.3 |
| 16 | .0006 | .0001 | .0006 | 79.7 |

TABLE 9g – (Continued)

r/R = 1.0

| n | $(A_r)_n/V$ | $(B_r)_n/V$ | $(V_r)_n/V$ | $(\phi_r^*)_n$ |
|---|---|---|---|---|
| 0 | .0227 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.1488 | .0027 | .1488 | 271.0 |
| 2 | -.0054 | -.0005 | .0054 | 265.0 |
| 3 | .0046 | -.0011 | .0048 | 103.5 |
| 4 | .0073 | -.0005 | .0073 | 94.3 |
| 5 | .0062 | .0008 | .0063 | 82.7 |
| 6 | .0041 | .0009 | .0042 | 77.6 |
| 7 | .0018 | .0005 | .0018 | 75.5 |
| 8 | .0004 | -.0000 | .0004 | 94.7 |
| 9 | -.0002 | -.0001 | .0002 | 242.6 |
| 10 | -.0003 | -.0000 | .0003 | 260.3 |
| 11 | -.0009 | -.0004 | .0010 | 246.1 |
| 12 | -.0003 | -.0007 | .0007 | 205.3 |
| 13 | -.0001 | -.0005 | .0005 | 189.9 |
| 14 | .0007 | -.0005 | .0009 | 129.3 |
| 15 | .0009 | -.0002 | .0009 | 103.5 |
| 16 | .0011 | -.0000 | .0011 | 90.3 |

## TABLE 10 – WAKE WITH DYNAMOMETER BOAT

### TABLE 10a – MEASURED DATA

$r/R = 0.512$

| $\theta_w$ | $V_x/V$ | $V_t/V$ | $V_r/V$ | $\theta_w$ | $V_x/V$ | $V_t/V$ | $V_r/V$ |
|---|---|---|---|---|---|---|---|
| .3 | .769 | .013 | -.032 | 180.8 | .868 | .013 | .081 |
| 4.2 | .778 | .006 | -.044 | 186.7 | .865 | .031 | .080 |
| 8.3 | .769 | -.011 | -.059 | 192.7 | .867 | .049 | .077 |
| 12.2 | .768 | -.027 | -.080 | 204.6 | .861 | .085 | .070 |
| 16.3 | .766 | -.007 | -.084 | 216.4 | .880 | .113 | .057 |
| 18.2 | .765 | .003 | -.083 | 228.1 | .893 | .137 | .041 |
| 20.4 | .730 | -.016 | -.087 | 240.0 | .905 | .156 | .022 |
| 22.3 | .655 | -.105 | -.100 | 252.1 | .908 | .172 | .001 |
| 24.2 | .701 | -.214 | -.136 | 263.8 | .920 | .175 | -.020 |
| 26.3 | .826 | -.184 | -.153 | 275.9 | .919 | .173 | -.043 |
| 28.3 | .888 | -.138 | -.142 | 288.0 | .918 | .165 | -.066 |
| 32.3 | .896 | -.102 | -.126 | 312.0 | .915 | .127 | -.105 |
| 36.2 | .899 | -.098 | -.119 | 324.0 | .920 | .103 | -.119 |
| 40.3 | .897 | -.105 | -.112 | 332.0 | .905 | .123 | -.121 |
| 44.3 | .898 | -.112 | -.107 | 333.9 | .902 | .149 | -.125 |
| 56.5 | .892 | -.135 | -.086 | 335.8 | .887 | .177 | -.134 |
| 68.5 | .904 | -.149 | -.062 | 335.9 | .857 | .180 | -.136 |
| 80.5 | .907 | -.156 | -.036 | 338.1 | .655 | .179 | -.147 |
| 92.5 | .909 | -.157 | -.013 | 339.8 | .645 | .074 | -.101 |
| 104.6 | .884 | -.153 | .009 | 341.8 | .686 | -.010 | -.060 |
| 116.5 | .893 | -.138 | .028 | 343.8 | .736 | -.017 | -.042 |
| 128.5 | .886 | -.120 | .046 | 346.0 | .772 | -0.000 | -.036 |
| 140.6 | .877 | -.096 | .060 | 347.8 | .784 | .017 | -.035 |
| 160.8 | .865 | -.045 | .077 | 349.8 | .788 | .024 | -.034 |
| 164.7 | .866 | -.034 | .078 | 353.9 | .782 | .030 | -.028 |
| 168.8 | .869 | -.022 | .079 | 358.1 | .772 | .023 | -.028 |

TABLE 10a – (Continued)

r/R = 0.711

| $\theta_w$ | $V_x/V$ | $V_t/V$ | $V_r/V$ | $\theta_w$ | $V_x/V$ | $V_t/V$ | $V_r/V$ |
|---|---|---|---|---|---|---|---|
| .5 | .849 | -.037 | -.076 | 138.3 | .877 | -.098 | .088 |
| 1.8 | .853 | -.036 | -.078 | 146.3 | .879 | -.079 | .096 |
| 2.6 | .858 | -.041 | -.077 | 154.2 | .884 | -.058 | .102 |
| 3.8 | .856 | -.045 | -.088 | 162.2 | .875 | -.039 | .107 |
| 6.6 | .862 | -.045 | -.091 | 170.2 | .878 | -.015 | .109 |
| 7.8 | .861 | -.052 | -.103 | 178.3 | .877 | .007 | .108 |
| 10.0 | .868 | -.052 | -.113 | 194.3 | .864 | .047 | .105 |
| 10.5 | .875 | -.055 | -.112 | 202.4 | .867 | .066 | .098 |
| 12.0 | .876 | -.060 | -.121 | 218.3 | .868 | .098 | .081 |
| 13.9 | .883 | -.052 | -.131 | 226.4 | .874 | .111 | .069 |
| 16.0 | .903 | -.025 | -.130 | 234.3 | .870 | .125 | .056 |
| 18.1 | .885 | .014 | -.126 | 242.3 | .881 | .133 | .039 |
| 20.0 | .799 | .031 | -.123 | 258.0 | .878 | .148 | .003 |
| 22.0 | .737 | -.046 | -.124 | 268.1 | .888 | .148 | -.021 |
| 24.0 | .797 | -.183 | -.148 | 278.0 | .892 | .146 | -.047 |
| 26.0 | .902 | -.144 | -.152 | 288.1 | .892 | .139 | -.071 |
| 28.0 | .911 | -.113 | -.149 | 306.1 | .890 | .114 | -.112 |
| 30.0 | .916 | -.101 | -.145 | 314.1 | .892 | .097 | -.126 |
| 32.0 | .913 | -.098 | -.140 | 322.2 | .899 | .082 | -.136 |
| 42.1 | .910 | -.120 | -.125 | 330.2 | .903 | .101 | -.152 |
| 48.0 | .909 | -.131 | -.112 | 332.3 | .888 | .142 | -.158 |
| 60.1 | .907 | -.151 | -.084 | 334.3 | .760 | .139 | -.135 |
| 66.0 | .908 | -.157 | -.069 | 336.2 | .737 | -.010 | -.112 |
| 72.1 | .908 | -.160 | -.054 | 338.2 | .797 | -.047 | -.112 |
| 78.1 | .907 | -.163 | -.037 | 340.3 | .844 | -.011 | -.118 |
| 84.0 | .908 | -.162 | -.022 | 342.5 | .841 | .014 | -.113 |
| 96.0 | .904 | -.158 | .008 | 346.4 | .839 | .014 | -.094 |
| 102.2 | .907 | -.153 | .022 | 350.5 | .842 | 0.000 | -.077 |
| 122.4 | .892 | -.128 | .063 | 354.5 | .848 | -.016 | -.069 |
| 130.4 | .892 | -.113 | .075 | | | | |

TABLE 10a – (Continued)

r/R = 0.910

| $\theta_w$ | $V_x/V$ | $V_t/V$ | $V_r/V$ |
|---|---|---|---|
| 4.3 | .892 | -.007 | -.109 |
| 8.2 | .897 | -.016 | -.120 |
| 12.3 | .904 | -.024 | -.127 |
| 16.0 | .911 | -.026 | -.133 |
| 17.8 | .917 | -.022 | -.133 |
| 20.2 | .939 | .007 | -.133 |
| 20.3 | .939 | .008 | -.136 |
| 21.8 | .898 | .066 | -.134 |
| 24.4 | .742 | .027 | -.132 |
| 28.4 | .905 | -.091 | -.158 |
| 32.3 | .901 | -.058 | -.153 |
| 36.3 | .904 | -.067 | -.146 |
| 40.3 | .906 | -.076 | -.138 |
| 44.1 | .905 | -.087 | -.131 |
| 48.4 | .899 | -.096 | -.120 |
| 52.2 | .906 | -.104 | -.109 |
| 56.3 | .907 | -.111 | -.099 |
| 60.3 | .907 | -.116 | -.085 |
| 66.1 | .908 | -.123 | -.069 |
| 78.0 | .921 | -.126 | -.035 |
| 84.3 | .915 | -.126 | -.020 |
| 90.1 | .926 | -.124 | -.007 |
| 96.2 | .926 | -.120 | .006 |
| 102.1 | .918 | -.115 | .016 |
| 108.2 | .909 | -.110 | .030 |
| 114.3 | .897 | -.104 | .043 |
| 120.2 | .900 | -.094 | .052 |
| 126.1 | .895 | -.086 | .064 |
| 132.6 | .883 | -.076 | .074 |
| 138.2 | .894 | -.065 | .080 |
| 144.4 | .887 | -.053 | .088 |
| 156.4 | .888 | -.028 | .098 |
| 168.5 | .894 | -0.000 | .104 |
| 180.6 | .879 | .031 | .107 |
| 192.5 | .884 | .060 | .103 |
| 204.4 | .890 | .086 | .093 |
| 216.1 | .892 | .109 | .080 |
| 239.9 | .906 | .148 | .040 |
| 246.1 | .909 | .156 | .027 |
| 251.7 | .919 | .161 | .015 |
| 257.9 | .936 | .165 | .003 |
| 263.6 | .930 | .167 | -.009 |
| 269.9 | .934 | .169 | -.024 |
| 282.3 | .923 | .168 | -.058 |
| 287.8 | .923 | .164 | -.071 |
| 294.2 | .928 | .157 | -.086 |
| 299.9 | .928 | .150 | -.101 |
| 306.2 | .928 | .140 | -.114 |
| 311.9 | .931 | .128 | -.127 |
| 316.4 | .926 | .118 | -.135 |
| 320.0 | .932 | .107 | -.140 |
| 324.0 | .935 | .096 | -.143 |
| 328.2 | .930 | .094 | -.148 |
| 332.0 | .923 | .174 | -.180 |
| 335.6 | .884 | -.056 | -.121 |
| 337.5 | .655 | -.033 | -.122 |
| 340.0 | .884 | .048 | -.134 |
| 343.7 | .910 | .063 | -.119 |
| 348.1 | .891 | .057 | -.105 |
| 352.2 | .890 | .046 | -.104 |
| 356.2 | .890 | .032 | -.102 |
| 359.8 | .892 | .010 | -.103 |
| 359.9 | .900 | .017 | -.103 |

TABLE 10a – (Continued)

r/R = 1.082

| $\theta_w$ | $V_x/V$ | $V_t/V$ | $V_r/V$ |
|---|---|---|---|
| 0.0 | .866 | 0.000 | -.124 |
| 10.0 | .879 | -.026 | -.127 |
| 17.8 | .898 | -.042 | -.124 |
| 21.2 | .835 | .047 | -.123 |
| 23.1 | .696 | -.181 | -.150 |
| 25.1 | .766 | -.137 | -.176 |
| 27.0 | .882 | -.089 | -.156 |
| 29.1 | .885 | -.084 | -.154 |
| 29.4 | .881 | -.083 | -.151 |
| 31.1 | .881 | -.087 | -.149 |
| 32.9 | .879 | -.092 | -.147 |
| 44.9 | .873 | -.121 | -.119 |
| 50.8 | .876 | -.135 | -.103 |
| 56.9 | .881 | -.143 | -.085 |
| 62.6 | .886 | -.152 | -.069 |
| 92.4 | .898 | -.152 | .012 |
| 104.8 | .897 | -.142 | .038 |
| 116.4 | .894 | -.128 | .061 |
| 128.6 | .896 | -.108 | .080 |
| 160.5 | .893 | -.047 | .115 |
| 172.6 | .902 | -.019 | .118 |
| 184.6 | .897 | .009 | .117 |
| 187.4 | .902 | .019 | .118 |
| 199.5 | .893 | .047 | .115 |
| 231.4 | .896 | .108 | .080 |
| 243.6 | .894 | .128 | .061 |
| 255.2 | .897 | .142 | .038 |
| 267.6 | .898 | .152 | .012 |
| 297.4 | .886 | .152 | -.069 |
| 303.1 | .881 | .143 | -.085 |
| 309.2 | .876 | .135 | -.103 |
| 315.1 | .873 | .121 | -.119 |
| 327.1 | .879 | .092 | -.147 |
| 328.9 | .881 | .087 | -.149 |
| 330.6 | .881 | .083 | -.151 |
| 330.9 | .885 | .084 | -.154 |
| 333.0 | .882 | .089 | -.156 |
| 334.9 | .766 | .137 | -.176 |
| 336.9 | .696 | .181 | -.150 |
| 338.8 | .835 | -.047 | -.123 |
| 342.2 | .898 | .042 | -.124 |
| 350.0 | .879 | .026 | -.127 |
| 360.0 | .866 | 0.000 | -.124 |

## TABLE 10b – INTERPOLATED VALUES OF $V_x/V$

| $\theta_w$ | r/R = 0.289 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|
| 0.0 | .640 | .647 | .709 | .763 | .809 | .846 | .881 | .896 | .888 |
| 2.5 | .632 | .641 | .709 | .767 | .815 | .852 | .881 | .894 | .887 |
| 5.0 | .626 | .635 | .709 | .770 | .819 | .856 | .882 | .892 | .887 |
| 7.5 | .599 | .610 | .694 | .764 | .819 | .859 | .885 | .896 | .890 |
| 10.0 | .566 | .578 | .678 | .760 | .823 | .867 | .891 | .900 | .894 |
| 12.5 | .547 | .561 | .670 | .759 | .826 | .873 | .894 | .904 | .905 |
| 15.0 | .487 | .504 | .644 | .755 | .838 | .891 | .903 | .908 | .910 |
| 17.5 | .492 | .509 | .646 | .756 | .838 | .892 | .910 | .916 | .911 |
| 20.0 | .771 | .767 | .743 | .739 | .756 | .794 | .890 | .938 | .929 |
| 22.5 | .587 | .590 | .617 | .651 | .691 | .738 | .830 | .859 | .817 |
| 25.0 | .378 | .403 | .595 | .734 | .820 | .852 | .790 | .750 | .742 |
| 27.5 | .702 | .713 | .801 | .863 | .901 | .913 | .875 | .857 | .865 |
| 30.0 | .871 | .873 | .890 | .902 | .911 | .916 | .919 | .914 | .900 |
| 32.5 | .845 | .849 | .875 | .894 | .907 | .912 | .909 | .902 | .891 |
| 35.0 | .862 | .864 | .883 | .897 | .906 | .910 | .910 | .904 | .891 |
| 37.5 | .867 | .869 | .885 | .897 | .906 | .910 | .911 | .906 | .892 |
| 40.0 | .863 | .865 | .883 | .896 | .905 | .910 | .913 | .907 | .892 |
| 42.5 | .864 | .866 | .883 | .896 | .905 | .910 | .913 | .907 | .892 |
| 45.0 | .864 | .866 | .884 | .897 | .905 | .909 | .911 | .905 | .890 |
| 47.5 | .858 | .860 | .881 | .896 | .905 | .909 | .908 | .901 | .888 |
| 50.0 | .857 | .860 | .879 | .894 | .904 | .908 | .909 | .903 | .890 |
| 52.5 | .859 | .862 | .879 | .893 | .902 | .908 | .911 | .907 | .894 |
| 55.0 | .858 | .860 | .877 | .891 | .901 | .907 | .911 | .908 | .896 |
| 57.5 | .859 | .861 | .878 | .891 | .901 | .907 | .911 | .908 | .897 |

TABLE 10b – (Continued)

| $\theta_w$ | r/R = 0.289 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|
| 60.0 | .867 | .869 | .883 | .894 | .902 | .907 | .911 | .908 | .898 |
| 62.5 | .874 | .876 | .887 | .897 | .903 | .907 | .911 | .908 | .898 |
| 65.0 | .882 | .884 | .893 | .900 | .905 | .908 | .911 | .908 | .900 |
| 67.5 | .893 | .893 | .898 | .903 | .906 | .908 | .912 | .910 | .902 |
| 70.0 | .902 | .902 | .903 | .905 | .906 | .908 | .914 | .913 | .904 |
| 72.5 | .910 | .910 | .907 | .906 | .906 | .908 | .916 | .917 | .907 |
| 75.0 | .917 | .916 | .910 | .906 | .905 | .907 | .918 | .919 | .910 |
| 77.5 | .922 | .921 | .912 | .907 | .905 | .907 | .919 | .921 | .912 |
| 80.0 | .919 | .918 | .912 | .907 | .906 | .907 | .917 | .919 | .910 |
| 82.5 | .918 | .918 | .912 | .908 | .907 | .908 | .915 | .916 | .909 |
| 85.0 | .923 | .922 | .914 | .910 | .907 | .908 | .915 | .916 | .909 |
| 87.5 | .934 | .932 | .919 | .911 | .906 | .907 | .919 | .921 | .913 |
| 90.0 | .944 | .941 | .923 | .911 | .905 | .905 | .922 | .926 | .916 |
| 92.5 | .946 | .943 | .923 | .910 | .904 | .904 | .922 | .928 | .918 |
| 95.0 | .931 | .929 | .914 | .905 | .901 | .903 | .922 | .927 | .917 |
| 97.5 | .908 | .907 | .901 | .899 | .899 | .904 | .920 | .925 | .916 |
| 100.0 | .881 | .881 | .886 | .892 | .898 | .905 | .918 | .922 | .913 |
| 102.5 | .855 | .857 | .873 | .886 | .897 | .906 | .916 | .918 | .910 |
| 105.0 | .842 | .844 | .865 | .882 | .896 | .905 | .913 | .914 | .908 |
| 107.5 | .846 | .848 | .868 | .883 | .896 | .904 | .910 | .910 | .905 |
| 110.0 | .853 | .855 | .872 | .886 | .896 | .902 | .906 | .905 | .901 |
| 112.5 | .862 | .864 | .878 | .888 | .896 | .900 | .901 | .900 | .898 |
| 115.0 | .876 | .877 | .885 | .891 | .895 | .898 | .898 | .897 | .896 |
| 117.5 | .889 | .889 | .891 | .893 | .894 | .896 | .898 | .898 | .897 |

TABLE 10b – (Continued)

| $\theta_w$ | r/R = 0.289 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|
| 120.0 | .896 | .895 | .893 | .892 | .892 | .893 | .898 | .900 | .898 |
| 122.5 | .895 | .895 | .892 | .891 | .891 | .892 | .897 | .899 | .898 |
| 125.0 | .884 | .884 | .886 | .889 | .891 | .893 | .895 | .896 | .896 |
| 127.5 | .871 | .872 | .880 | .886 | .891 | .893 | .892 | .892 | .893 |
| 130.0 | .861 | .863 | .875 | .884 | .890 | .892 | .887 | .886 | .890 |
| 132.5 | .865 | .867 | .876 | .882 | .887 | .888 | .883 | .883 | .888 |
| 135.0 | .882 | .882 | .881 | .881 | .882 | .883 | .884 | .887 | .891 |
| 137.5 | .899 | .898 | .887 | .880 | .877 | .878 | .886 | .892 | .895 |
| 140.0 | .900 | .898 | .886 | .878 | .875 | .876 | .886 | .893 | .895 |
| 142.5 | .888 | .887 | .880 | .876 | .874 | .876 | .884 | .890 | .893 |
| 145.0 | .872 | .872 | .872 | .873 | .875 | .878 | .882 | .886 | .890 |
| 147.5 | .857 | .858 | .865 | .870 | .875 | .880 | .882 | .886 | .889 |
| 150.0 | .844 | .845 | .858 | .868 | .876 | .882 | .883 | .885 | .889 |
| 152.5 | .834 | .836 | .853 | .866 | .876 | .883 | .884 | .886 | .889 |
| 155.0 | .831 | .833 | .851 | .865 | .875 | .883 | .885 | .887 | .890 |
| 157.5 | .840 | .841 | .854 | .864 | .873 | .880 | .885 | .888 | .891 |
| 160.0 | .852 | .852 | .858 | .864 | .870 | .877 | .885 | .890 | .893 |
| 162.5 | .863 | .863 | .863 | .865 | .869 | .874 | .884 | .892 | .895 |
| 165.0 | .866 | .866 | .865 | .866 | .869 | .875 | .885 | .893 | .897 |
| 167.5 | .869 | .868 | .867 | .868 | .871 | .876 | .886 | .893 | .898 |
| 170.0 | .867 | .867 | .867 | .869 | .872 | .877 | .885 | .892 | .897 |
| 172.5 | .864 | .865 | .867 | .870 | .873 | .878 | .883 | .889 | .896 |
| 175.0 | .861 | .861 | .865 | .869 | .873 | .877 | .880 | .885 | .892 |
| 177.5 | .857 | .858 | .864 | .869 | .873 | .877 | .878 | .882 | .889 |

TABLE 10b – (Continued)

| $\theta_w$ | r/R = 0.289 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|
| 180.0 | .856 | .857 | .863 | .868 | .872 | .875 | .876 | .879 | .887 |
| 182.5 | .858 | .859 | .863 | .866 | .870 | .873 | .874 | .878 | .886 |
| 185.0 | .863 | .863 | .864 | .865 | .868 | .871 | .873 | .879 | .888 |
| 187.5 | .871 | .871 | .867 | .865 | .866 | .868 | .872 | .880 | .891 |
| 190.0 | .883 | .882 | .872 | .866 | .864 | .866 | .872 | .881 | .893 |
| 192.5 | .895 | .893 | .877 | .868 | .863 | .864 | .873 | .883 | .894 |
| 195.0 | .896 | .893 | .877 | .867 | .862 | .864 | .874 | .884 | .894 |
| 197.5 | .889 | .883 | .874 | .865 | .862 | .864 | .876 | .886 | .893 |
| 200.0 | .882 | .881 | .869 | .863 | .862 | .865 | .878 | .887 | .892 |
| 202.5 | .875 | .874 | .866 | .862 | .862 | .866 | .879 | .889 | .893 |
| 205.0 | .876 | .874 | .866 | .862 | .862 | .866 | .880 | .890 | .893 |
| 207.5 | .887 | .885 | .872 | .865 | .863 | .866 | .881 | .890 | .894 |
| 210.0 | .900 | .898 | .881 | .869 | .865 | .866 | .881 | .890 | .894 |
| 212.5 | .915 | .912 | .889 | .874 | .867 | .867 | .881 | .891 | .894 |
| 215.0 | .930 | .927 | .899 | .879 | .869 | .867 | .881 | .891 | .895 |
| 217.5 | .942 | .938 | .906 | .883 | .871 | .867 | .882 | .892 | .895 |
| 220.0 | .947 | .943 | .910 | .887 | .873 | .869 | .884 | .893 | .896 |
| 222.5 | .951 | .947 | .913 | .889 | .876 | .872 | .885 | .895 | .897 |
| 225.0 | .956 | .951 | .917 | .892 | .878 | .873 | .887 | .896 | .898 |
| 227.5 | .966 | .961 | .922 | .895 | .879 | .873 | .888 | .898 | .900 |
| 230.0 | .982 | .976 | .931 | .898 | .879 | .872 | .889 | .899 | .901 |
| 232.5 | .998 | .992 | .939 | .902 | .879 | .870 | .889 | .901 | .902 |
| 235.0 | 1.008 | 1.001 | .945 | .904 | .880 | .871 | .891 | .902 | .903 |
| 237.5 | 1.008 | 1.001 | .946 | .907 | .883 | .874 | .893 | .904 | .904 |

TABLE 10b – (Continued)

| $\theta_w$ | r/R = 0.289 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|
| 240.0 | 1.003 | .996 | .945 | .908 | .886 | .877 | .896 | .906 | .904 |
| 242.5 | .993 | .987 | .942 | .909 | .889 | .881 | .898 | .906 | .904 |
| 245.0 | .995 | .989 | .943 | .909 | .889 | .882 | .899 | .908 | .905 |
| 247.5 | 1.001 | .995 | .945 | .910 | .889 | .881 | .901 | .911 | .907 |
| 250.0 | 1.011 | 1.004 | .950 | .911 | .888 | .880 | .904 | .915 | .911 |
| 252.5 | 1.025 | 1.018 | .956 | .912 | .887 | .879 | .908 | .921 | .915 |
| 255.0 | 1.046 | 1.037 | .966 | .916 | .886 | .878 | .913 | .929 | .921 |
| 257.5 | 1.064 | 1.054 | .975 | .919 | .886 | .878 | .917 | .935 | .926 |
| 260.0 | 1.066 | 1.056 | .977 | .922 | .889 | .879 | .917 | .934 | .925 |
| 262.5 | 1.061 | 1.052 | .977 | .924 | .892 | .882 | .916 | .931 | .923 |
| 265.0 | 1.056 | 1.047 | .976 | .925 | .895 | .885 | .916 | .930 | .922 |
| 267.5 | 1.050 | 1.041 | .973 | .925 | .896 | .887 | .918 | .932 | .923 |
| 270.0 | 1.046 | 1.037 | .971 | .925 | .897 | .889 | .921 | .934 | .924 |
| 272.5 | 1.038 | 1.030 | .968 | .924 | .898 | .890 | .920 | .933 | .922 |
| 275.0 | 1.030 | 1.023 | .964 | .923 | .899 | .891 | .919 | .930 | .921 |
| 277.5 | 1.023 | 1.016 | .962 | .922 | .899 | .892 | .917 | .928 | .918 |
| 280.0 | 1.018 | 1.012 | .960 | .922 | .900 | .892 | .916 | .925 | .916 |
| 282.5 | 1.015 | 1.009 | .958 | .922 | .900 | .892 | .914 | .923 | .915 |
| 285.0 | 1.014 | 1.008 | .958 | .922 | .900 | .892 | .914 | .923 | .914 |
| 287.5 | 1.015 | 1.008 | .958 | .921 | .900 | .892 | .915 | .923 | .914 |
| 290.0 | 1.016 | 1.010 | .958 | .921 | .899 | .892 | .916 | .925 | .914 |
| 292.5 | 1.019 | 1.012 | .958 | .921 | .898 | .891 | .918 | .927 | .915 |
| 295.0 | 1.020 | 1.013 | .959 | .920 | .897 | .891 | .919 | .928 | .915 |
| 297.5 | 1.020 | 1.013 | .958 | .920 | .897 | .890 | .919 | .929 | .915 |

TABLE 10b – (Continued)

| $\theta_w$ | r/R = 0.289 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|
| 300.0 | 1.019 | 1.012 | .958 | .919 | .897 | .890 | .919 | .928 | .914 |
| 302.5 | 1.018 | 1.011 | .957 | .919 | .896 | .890 | .919 | .928 | .913 |
| 305.0 | 1.017 | 1.010 | .956 | .918 | .896 | .890 | .919 | .928 | .912 |
| 307.5 | 1.018 | 1.011 | .957 | .918 | .896 | .890 | .921 | .930 | .912 |
| 310.0 | 1.019 | 1.011 | .957 | .918 | .896 | .890 | .922 | .931 | .912 |
| 312.5 | 1.018 | 1.011 | .957 | .919 | .897 | .891 | .922 | .931 | .911 |
| 315.0 | 1.017 | 1.010 | .958 | .921 | .899 | .893 | .921 | .928 | .908 |
| 317.5 | 1.017 | 1.010 | .959 | .923 | .902 | .895 | .922 | .928 | .909 |
| 320.0 | 1.017 | 1.011 | .960 | .924 | .903 | .897 | .926 | .933 | .912 |
| 322.5 | 1.010 | 1.004 | .957 | .924 | .905 | .900 | .929 | .935 | .914 |
| 325.0 | .977 | .973 | .942 | .920 | .909 | .907 | .932 | .935 | .914 |
| 327.5 | .948 | .946 | .927 | .915 | .909 | .909 | .930 | .932 | .912 |
| 330.0 | .950 | .947 | .925 | .910 | .903 | .903 | .926 | .930 | .913 |
| 332.5 | 1.041 | 1.032 | .960 | .911 | .882 | .876 | .916 | .933 | .921 |
| 335.0 | 1.461 | 1.424 | 1.128 | .916 | .787 | .741 | .868 | .918 | .871 |
| 337.5 | .415 | .435 | .589 | .697 | .758 | .773 | .693 | .656 | .673 |
| 340.0 | .256 | .280 | .474 | .631 | .750 | .833 | .866 | .883 | .886 |
| 342.5 | .487 | .499 | .603 | .694 | .771 | .835 | .894 | .924 | .924 |
| 345.0 | .652 | .658 | .707 | .753 | .796 | .835 | .878 | .905 | .915 |
| 347.5 | .717 | .720 | .750 | .779 | .808 | .836 | .870 | .893 | .902 |
| 350.0 | .722 | .725 | .756 | .785 | .812 | .839 | .871 | .889 | .890 |
| 352.5 | .701 | .706 | .745 | .781 | .814 | .842 | .876 | .890 | .881 |
| 355.0 | .670 | .676 | .729 | .774 | .813 | .845 | .879 | .890 | .874 |
| 357.5 | .653 | .660 | .718 | .768 | .810 | .845 | .881 | .893 | .876 |

## TABLE 10c – INTERPOLATED VALUES OF $V_t/V$

| $\theta_w$ | r/R = 0.289 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|
| 0.0 | .178 | .167 | .082 | .020 | -.018 | -.033 | -.005 | .012 | .012 |
| 2.5 | .172 | .161 | .076 | .014 | -.025 | -.041 | -.016 | -.000 | .002 |
| 5.0 | .161 | .151 | .069 | .009 | -.029 | -.046 | -.024 | -.010 | -.007 |
| 7.5 | .129 | .120 | .049 | -.002 | -.035 | -.048 | -.028 | -.015 | -.013 |
| 10.0 | .095 | .087 | .027 | -.016 | -.043 | -.053 | -.033 | -.021 | -.019 |
| 12.5 | .092 | .084 | .022 | -.022 | -.049 | -.059 | -.035 | -.024 | -.032 |
| 15.0 | .059 | .054 | .016 | -.012 | -.031 | -.039 | -.027 | -.026 | -.039 |
| 17.5 | -.037 | -.034 | -.013 | .000 | .006 | .004 | -.009 | -.022 | -.035 |
| 20.0 | -.131 | -.123 | -.059 | -.012 | .018 | .031 | .004 | .000 | .026 |
| 22.5 | -.016 | -.024 | -.085 | -.116 | -.117 | -.089 | .033 | .070 | .007 |
| 25.0 | -.088 | -.098 | -.173 | -.212 | -.214 | -.180 | -.044 | .009 | -.034 |
| 27.5 | -.183 | -.182 | -.172 | -.159 | -.142 | -.122 | -.088 | -.070 | -.070 |
| 30.0 | -.129 | -.129 | -.123 | -.116 | -.109 | -.102 | -.091 | -.085 | -.083 |
| 32.5 | -.061 | -.064 | -.087 | -.100 | -.104 | -.099 | -.070 | -.058 | -.067 |
| 35.0 | -.046 | -.049 | -.078 | -.096 | -.103 | -.101 | -.072 | -.062 | -.073 |
| 37.5 | -.042 | -.046 | -.077 | -.098 | -.107 | -.106 | -.080 | -.069 | -.080 |
| 40.0 | -.038 | -.043 | -.079 | -.102 | -.114 | -.114 | -.086 | -.075 | -.085 |
| 42.5 | -.036 | -.041 | -.080 | -.106 | -.120 | -.121 | -.093 | -.082 | -.092 |
| 45.0 | -.042 | -.047 | -.085 | -.111 | -.125 | -.126 | -.099 | -.089 | -.099 |
| 47.5 | -.048 | -.053 | -.090 | -.116 | -.129 | -.131 | -.104 | -.094 | -.104 |
| 50.0 | -.054 | -.059 | -.096 | -.121 | -.134 | -.135 | -.109 | -.099 | -.110 |
| 52.5 | -.060 | -.065 | -.101 | -.126 | -.138 | -.140 | -.114 | -.104 | -.115 |
| 55.0 | -.066 | -.070 | -.106 | -.130 | -.143 | -.144 | -.119 | -.109 | -.118 |
| 57.5 | -.070 | -.075 | -.110 | -.134 | -.147 | -.148 | -.122 | -.113 | -.122 |

TABLE 10c – (Continued)

| $\theta_w$ | r/R = 0.289 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|
| 60.0 | -.073 | -.077 | -.113 | -.138 | -.150 | -.151 | -.126 | -.116 | -.125 |
| 62.5 | -.076 | -.081 | -.117 | -.141 | -.153 | -.154 | -.128 | -.119 | -.129 |
| 65.0 | -.081 | -.085 | -.120 | -.144 | -.156 | -.157 | -.131 | -.122 | -.132 |
| 67.5 | -.085 | -.090 | -.123 | -.146 | -.158 | -.159 | -.133 | -.124 | -.134 |
| 70.0 | -.089 | -.094 | -.126 | -.148 | -.159 | -.160 | -.134 | -.125 | -.135 |
| 72.5 | -.092 | -.096 | -.129 | -.150 | -.161 | -.161 | -.135 | -.126 | -.136 |
| 75.0 | -.093 | -.097 | -.130 | -.152 | -.163 | -.162 | -.136 | -.126 | -.136 |
| 77.5 | -.093 | -.097 | -.131 | -.153 | -.164 | -.164 | -.136 | -.126 | -.136 |
| 80.0 | -.096 | -.100 | -.132 | -.154 | -.164 | -.164 | -.137 | -.126 | -.136 |
| 82.5 | -.100 | -.104 | -.135 | -.155 | -.164 | -.163 | -.137 | -.126 | -.136 |
| 85.0 | -.103 | -.107 | -.136 | -.155 | -.164 | -.163 | -.136 | -.126 | -.135 |
| 87.5 | -.105 | -.109 | -.137 | -.156 | -.164 | -.162 | -.136 | -.125 | -.134 |
| 90.0 | -.106 | -.110 | -.138 | -.156 | -.164 | -.161 | -.135 | -.124 | -.133 |
| 92.5 | -.107 | -.110 | -.138 | -.156 | -.163 | -.161 | -.134 | -.123 | -.131 |
| 95.0 | -.108 | -.112 | -.138 | -.155 | -.162 | -.159 | -.132 | -.121 | -.129 |
| 97.5 | -.110 | -.113 | -.139 | -.155 | -.161 | -.158 | -.130 | -.119 | -.127 |
| 100.0 | -.111 | -.115 | -.139 | -.154 | -.160 | -.156 | -.128 | -.117 | -.125 |
| 102.5 | -.113 | -.116 | -.139 | -.153 | -.158 | -.154 | -.126 | -.115 | -.123 |
| 105.0 | -.113 | -.116 | -.138 | -.152 | -.156 | -.151 | -.124 | -.113 | -.121 |
| 107.5 | -.111 | -.114 | -.136 | -.149 | -.153 | -.149 | -.122 | -.111 | -.119 |
| 110.0 | -.108 | -.111 | -.133 | -.146 | -.151 | -.146 | -.120 | -.109 | -.116 |
| 112.5 | -.104 | -.107 | -.129 | -.143 | -.147 | -.143 | -.117 | -.106 | -.114 |
| 115.0 | -.100 | -.103 | -.126 | -.139 | -.144 | -.140 | -.114 | -.103 | -.110 |
| 117.5 | -.095 | -.098 | -.121 | -.136 | -.141 | -.137 | -.110 | -.099 | -.106 |

TABLE 10c – (Continued)

| $\theta_w$ | r/R = 0.289 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|
| 120.0 | -.092 | -.095 | -.118 | -.132 | -.137 | -.133 | -.106 | -.094 | -.102 |
| 122.5 | -.090 | -.093 | -.115 | -.129 | -.133 | -.129 | -.102 | -.091 | -.098 |
| 125.0 | -.089 | -.092 | -.112 | -.125 | -.129 | -.124 | -.098 | -.088 | -.095 |
| 127.5 | -.088 | -.090 | -.110 | -.121 | -.124 | -.120 | -.095 | -.084 | -.091 |
| 130.0 | -.086 | -.088 | -.106 | -.117 | -.119 | -.115 | -.090 | -.080 | -.087 |
| 132.5 | -.082 | -.084 | -.102 | -.112 | -.115 | -.110 | -.086 | -.076 | -.083 |
| 135.0 | -.076 | -.078 | -.097 | -.107 | -.110 | -.105 | -.081 | -.071 | -.079 |
| 137.5 | -.070 | -.073 | -.091 | -.102 | -.105 | -.101 | -.076 | -.066 | -.074 |
| 140.0 | -.066 | -.068 | -.086 | -.097 | -.100 | -.095 | -.071 | -.062 | -.069 |
| 142.5 | -.062 | -.064 | -.081 | -.091 | -.094 | -.089 | -.066 | -.057 | -.064 |
| 145.0 | -.058 | -.060 | -.076 | -.085 | -.088 | -.083 | -.061 | -.052 | -.060 |
| 147.5 | -.055 | -.057 | -.071 | -.079 | -.081 | -.077 | -.055 | -.047 | -.055 |
| 150.0 | -.051 | -.053 | -.066 | -.073 | -.075 | -.070 | -.049 | -.042 | -.050 |
| 152.5 | -.047 | -.049 | -.061 | -.067 | -.068 | -.063 | -.043 | -.036 | -.045 |
| 155.0 | -.042 | -.043 | -.054 | -.060 | -.061 | -.057 | -.037 | -.031 | -.040 |
| 157.5 | -.033 | -.035 | -.047 | -.054 | -.055 | -.051 | -.032 | -.025 | -.034 |
| 160.0 | -.029 | -.026 | -.039 | -.047 | -.049 | -.045 | -.026 | -.020 | -.029 |
| 162.5 | -.017 | -.019 | -.032 | -.040 | -.042 | -.039 | -.020 | -.014 | -.023 |
| 165.0 | -.012 | -.014 | -.026 | -.033 | -.035 | -.031 | -.013 | -.008 | -.018 |
| 167.5 | -.007 | -.009 | -.019 | -.025 | -.027 | -.024 | -.007 | -.002 | -.012 |
| 170.0 | -.002 | -.004 | -.013 | -.018 | -.019 | -.016 | .000 | .004 | -.006 |
| 172.5 | .005 | .003 | -.006 | -.011 | -.012 | -.009 | .007 | .011 | .000 |
| 175.0 | .012 | .011 | .002 | -.004 | -.005 | -.002 | .014 | .017 | .006 |
| 177.5 | .021 | .020 | .010 | .004 | .002 | .004 | .020 | .024 | .012 |

TABLE 10c – (Continued)

| $\theta_w$ | r/R = 0.289 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|
| 180.0 | .030 | .029 | .018 | .011 | .009 | .011 | .027 | .030 | .018 |
| 182.5 | .040 | .038 | .026 | .019 | .016 | .017 | .033 | .036 | .024 |
| 185.0 | .051 | .049 | .035 | .027 | .023 | .024 | .039 | .042 | .031 |
| 187.5 | .061 | .059 | .044 | .034 | .030 | .030 | .045 | .049 | .038 |
| 190.0 | .072 | .069 | .053 | .042 | .036 | .036 | .051 | .054 | .045 |
| 192.5 | .082 | .080 | .062 | .049 | .043 | .042 | .057 | .060 | .051 |
| 195.0 | .093 | .091 | .071 | .057 | .050 | .048 | .063 | .066 | .056 |
| 197.5 | .105 | .102 | .080 | .065 | .057 | .054 | .069 | .072 | .062 |
| 200.0 | .116 | .113 | .090 | .073 | .063 | .060 | .074 | .077 | .067 |
| 202.5 | .127 | .124 | .099 | .081 | .070 | .066 | .080 | .082 | .072 |
| 205.0 | .137 | .134 | .107 | .088 | .076 | .072 | .085 | .088 | .077 |
| 207.5 | .146 | .142 | .115 | .094 | .082 | .077 | .090 | .093 | .082 |
| 210.0 | .154 | .150 | .121 | .101 | .087 | .082 | .095 | .098 | .087 |
| 212.5 | .162 | .158 | .128 | .106 | .093 | .087 | .100 | .103 | .092 |
| 215.0 | .169 | .165 | .134 | .112 | .098 | .092 | .105 | .107 | .097 |
| 217.5 | .177 | .173 | .141 | .118 | .103 | .097 | .110 | .112 | .102 |
| 220.0 | .186 | .181 | .148 | .123 | .108 | .101 | .114 | .117 | .106 |
| 222.5 | .194 | .190 | .154 | .129 | .112 | .105 | .118 | .121 | .111 |
| 225.0 | .202 | .197 | .161 | .134 | .116 | .109 | .122 | .125 | .115 |
| 227.5 | .208 | .203 | .166 | .139 | .121 | .113 | .127 | .130 | .119 |
| 230.0 | .211 | .207 | .170 | .143 | .126 | .118 | .131 | .134 | .124 |
| 232.5 | .214 | .210 | .174 | .147 | .130 | .122 | .135 | .138 | .128 |
| 235.0 | .219 | .214 | .178 | .151 | .134 | .126 | .139 | .141 | .132 |
| 237.5 | .226 | .221 | .183 | .155 | .137 | .129 | .142 | .145 | .136 |

TABLE 10c – (Continued)

| $\theta_w$ | r/R = 0.289 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|
| 240.0 | .234 | .229 | .188 | .159 | .140 | .131 | .145 | .148 | .139 |
| 242.5 | .243 | .238 | .195 | .163 | .143 | .134 | .148 | .152 | .143 |
| 245.0 | .249 | .244 | .199 | .167 | .146 | .136 | .151 | .155 | .147 |
| 247.5 | .254 | .248 | .203 | .170 | .149 | .139 | .153 | .158 | .149 |
| 250.0 | .257 | .251 | .206 | .173 | .152 | .142 | .156 | .160 | .152 |
| 252.5 | .259 | .253 | .208 | .175 | .154 | .144 | .158 | .162 | .154 |
| 255.0 | .258 | .252 | .209 | .177 | .156 | .146 | .159 | .164 | .156 |
| 257.5 | .256 | .251 | .209 | .177 | .157 | .148 | .161 | .165 | .158 |
| 260.0 | .257 | .252 | .209 | .178 | .158 | .149 | .161 | .166 | .160 |
| 262.5 | .258 | .252 | .210 | .178 | .158 | .149 | .162 | .167 | .161 |
| 265.0 | .259 | .254 | .210 | .178 | .158 | .149 | .162 | .168 | .162 |
| 267.5 | .261 | .255 | .211 | .178 | .157 | .148 | .162 | .168 | .164 |
| 270.0 | .262 | .256 | .211 | .178 | .157 | .148 | .162 | .169 | .165 |
| 272.5 | .262 | .256 | .210 | .177 | .156 | .148 | .162 | .169 | .166 |
| 275.0 | .261 | .255 | .210 | .177 | .156 | .147 | .162 | .169 | .167 |
| 277.5 | .260 | .254 | .209 | .175 | .155 | .146 | .161 | .169 | .167 |
| 280.0 | .259 | .254 | .208 | .174 | .153 | .145 | .160 | .169 | .167 |
| 282.5 | .258 | .252 | .206 | .173 | .152 | .144 | .159 | .168 | .167 |
| 285.0 | .257 | .251 | .204 | .171 | .150 | .142 | .157 | .166 | .166 |
| 287.5 | .255 | .249 | .202 | .169 | .148 | .140 | .155 | .164 | .165 |
| 290.0 | .251 | .245 | .199 | .166 | .145 | .137 | .152 | .161 | .163 |
| 292.5 | .247 | .241 | .196 | .163 | .142 | .135 | .149 | .158 | .161 |
| 295.0 | .243 | .237 | .192 | .159 | .139 | .132 | .146 | .156 | .158 |
| 297.5 | .239 | .233 | .188 | .156 | .136 | .128 | .143 | .153 | .155 |

TABLE 10c – (Continued)

| $\theta_w$ | r/R = 0.289 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|
| 300.0 | .235 | .229 | .184 | .152 | .132 | .124 | .139 | .149 | .152 |
| 302.5 | .231 | .225 | .180 | .148 | .128 | .120 | .136 | .146 | .148 |
| 305.0 | .227 | .221 | .176 | .143 | .123 | .116 | .131 | .142 | .144 |
| 307.5 | .223 | .218 | .172 | .139 | .118 | .111 | .126 | .137 | .140 |
| 310.0 | .220 | .214 | .168 | .134 | .113 | .106 | .121 | .131 | .135 |
| 312.5 | .214 | .208 | .162 | .128 | .108 | .100 | .116 | .126 | .130 |
| 315.0 | .202 | .196 | .152 | .120 | .101 | .095 | .110 | .121 | .124 |
| 317.5 | .193 | .188 | .144 | .114 | .095 | .089 | .104 | .114 | .118 |
| 320.0 | .184 | .178 | .138 | .109 | .091 | .084 | .097 | .106 | .110 |
| 322.5 | .178 | .173 | .134 | .106 | .088 | .081 | .091 | .099 | .103 |
| 325.0 | .187 | .182 | .136 | .103 | .082 | .073 | .082 | .091 | .096 |
| 327.5 | .167 | .162 | .127 | .101 | .084 | .076 | .084 | .090 | .092 |
| 330.0 | .185 | .180 | .137 | .109 | .096 | .097 | .137 | .149 | .127 |
| 332.5 | .088 | .090 | .112 | .128 | .139 | .145 | .152 | .144 | .118 |
| 335.0 | .212 | .211 | .196 | .171 | .136 | .093 | -.007 | -.032 | .028 |
| 337.5 | .745 | .711 | .430 | .212 | .056 | -.038 | -.061 | -.038 | .030 |
| 340.0 | .327 | .310 | .173 | .073 | .009 | -.017 | .038 | .050 | .007 |
| 342.5 | -.031 | -.031 | -.028 | -.020 | -.007 | .012 | .047 | .066 | .063 |
| 345.0 | -.020 | -.020 | -.018 | -.011 | .001 | .016 | .044 | .062 | .067 |
| 347.5 | .079 | .074 | .039 | .016 | .007 | .010 | .040 | .058 | .060 |
| 350.0 | .136 | .129 | .069 | .028 | .006 | .001 | .035 | .052 | .047 |
| 352.5 | .178 | .168 | .090 | .034 | .002 | -.008 | .030 | .045 | .031 |
| 355.0 | .203 | .192 | .101 | .036 | -.004 | -.018 | .023 | .037 | .018 |
| 357.5 | .203 | .191 | .098 | .031 | -.010 | -.025 | .012 | .026 | .009 |

TABLE 10d – INTERPOLATED VALUES OF $V_r/V$

| $\theta_w$ | r/R = 0.289 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|
| 0.0 | .034 | .030 | -.001 | -.028 | -.052 | -.072 | -.088 | -.102 | -.114 |
| 2.5 | .029 | .025 | -.007 | -.035 | -.059 | -.079 | -.092 | -.105 | -.116 |
| 5.0 | .023 | .019 | -.015 | -.043 | -.067 | -.087 | -.099 | -.110 | -.119 |
| 7.5 | .020 | .015 | -.021 | -.052 | -.077 | -.097 | -.109 | -.117 | -.123 |
| 10.0 | .015 | .010 | -.031 | -.065 | -.091 | -.110 | -.118 | -.123 | -.126 |
| 12.5 | .015 | .009 | -.039 | -.077 | -.105 | -.123 | -.126 | -.127 | -.127 |
| 15.0 | .025 | .018 | -.037 | -.080 | -.111 | -.130 | -.133 | -.132 | -.129 |
| 17.5 | .012 | .006 | -.041 | -.079 | -.107 | -.126 | -.132 | -.133 | -.130 |
| 20.0 | -.013 | -.017 | -.053 | -.082 | -.105 | -.122 | -.132 | -.135 | -.129 |
| 22.5 | -.047 | -.051 | -.079 | -.101 | -.118 | -.129 | -.130 | -.133 | -.137 |
| 25.0 | -.112 | -.114 | -.132 | -.144 | -.151 | -.152 | -.136 | -.134 | -.150 |
| 27.5 | -.146 | -.146 | -.147 | -.148 | -.149 | -.150 | -.151 | -.152 | -.153 |
| 30.0 | -.125 | -.125 | -.129 | -.134 | -.139 | -.144 | -.154 | -.158 | -.156 |
| 32.5 | -.111 | -.112 | -.118 | -.125 | -.131 | -.138 | -.148 | -.153 | -.152 |
| 35.0 | -.105 | -.106 | -.113 | -.120 | -.127 | -.134 | -.143 | -.148 | -.148 |
| 37.5 | -.098 | -.099 | -.108 | -.116 | -.123 | -.130 | -.139 | -.143 | -.143 |
| 40.0 | -.090 | -.091 | -.102 | -.111 | -.120 | -.127 | -.135 | -.139 | -.137 |
| 42.5 | -.086 | -.087 | -.098 | -.108 | -.116 | -.123 | -.131 | -.134 | -.132 |
| 45.0 | -.088 | -.089 | -.098 | -.105 | -.112 | -.118 | -.126 | -.129 | -.126 |
| 47.5 | -.088 | -.089 | -.095 | -.101 | -.107 | -.113 | -.120 | -.123 | -.119 |
| 50.0 | -.085 | -.086 | -.092 | -.097 | -.102 | -.107 | -.114 | -.115 | -.112 |
| 52.5 | -.082 | -.083 | -.088 | -.093 | -.097 | -.101 | -.107 | -.108 | -.105 |
| 55.0 | -.080 | -.080 | -.084 | -.088 | -.092 | -.096 | -.102 | -.103 | -.098 |
| 57.5 | -.075 | -.076 | -.080 | -.084 | -.087 | -.090 | -.095 | -.095 | -.091 |

TABLE 10d – (Continued)

| $\theta_w$ | r/R = 0.289 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|
| 60.0 | -.070 | -.071 | -.075 | -.079 | -.082 | -.084 | -.087 | -.086 | -.082 |
| 62.5 | -.067 | -.067 | -.071 | -.074 | -.076 | -.078 | -.080 | -.079 | -.075 |
| 65.0 | -.064 | -.065 | -.067 | -.069 | -.071 | -.071 | -.073 | -.072 | -.068 |
| 67.5 | -.061 | -.061 | -.063 | -.064 | -.065 | -.065 | -.067 | -.065 | -.061 |
| 70.0 | -.056 | -.056 | -.058 | -.059 | -.059 | -.059 | -.060 | -.058 | -.054 |
| 72.5 | -.051 | -.051 | -.053 | -.053 | -.053 | -.053 | -.053 | -.051 | -.046 |
| 75.0 | -.049 | -.049 | -.049 | -.048 | -.047 | -.046 | -.046 | -.044 | -.039 |
| 77.5 | -.048 | -.048 | -.045 | -.043 | -.041 | -.039 | -.039 | -.037 | -.032 |
| 80.0 | -.046 | -.046 | -.041 | -.037 | -.034 | -.032 | -.032 | -.030 | -.026 |
| 82.5 | -.045 | -.044 | -.038 | -.033 | -.029 | -.026 | -.027 | -.025 | -.020 |
| 85.0 | -.044 | -.043 | -.034 | -.028 | -.023 | -.020 | -.021 | -.019 | -.013 |
| 87.5 | -.043 | -.042 | -.032 | -.023 | -.017 | -.013 | -.015 | -.013 | -.008 |
| 90.0 | -.043 | -.042 | -.029 | -.019 | -.011 | -.007 | -.009 | -.008 | -.002 |
| 92.5 | -.043 | -.041 | -.026 | -.014 | -.006 | -.001 | -.003 | -.002 | .004 |
| 95.0 | -.043 | -.041 | -.023 | -.010 | -.000 | .005 | .002 | .003 | .009 |
| 97.5 | -.043 | -.040 | -.020 | -.005 | .005 | .011 | .007 | .008 | .014 |
| 100.0 | -.042 | -.040 | -.018 | -.001 | .011 | .017 | .012 | .012 | .018 |
| 102.5 | -.042 | -.039 | -.015 | .004 | .016 | .022 | .017 | .017 | .023 |
| 105.0 | -.040 | -.037 | -.011 | .008 | .021 | .028 | .022 | .022 | .028 |
| 107.5 | -.038 | -.035 | -.008 | .012 | .026 | .033 | .028 | .028 | .034 |
| 110.0 | -.037 | -.034 | -.006 | .016 | .030 | .039 | .034 | .034 | .040 |
| 112.5 | -.036 | -.032 | -.003 | .020 | .035 | .044 | .039 | .039 | .045 |
| 115.0 | -.035 | -.031 | -.000 | .023 | .040 | .049 | .044 | .044 | .049 |
| 117.5 | -.035 | -.031 | .002 | .027 | .044 | .054 | .048 | .048 | .053 |

TABLE 10d – (Continued)

| $\theta_w$ | r/R = 0.289 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|
| 120.0 | -.033 | -.029 | .005 | .031 | .049 | .058 | .052 | .051 | .057 |
| 122.5 | -.030 | -.026 | .009 | .035 | .053 | .063 | .057 | .056 | .062 |
| 125.0 | -.025 | -.021 | .013 | .038 | .056 | .066 | .062 | .062 | .067 |
| 127.5 | -.020 | -.016 | .017 | .042 | .060 | .070 | .066 | .066 | .071 |
| 130.0 | -.018 | -.014 | .020 | .045 | .063 | .074 | .070 | .070 | .075 |
| 132.5 | -.018 | -.014 | .021 | .048 | .067 | .078 | .074 | .074 | .078 |
| 135.0 | -.020 | -.015 | .022 | .051 | .071 | .082 | .077 | .076 | .081 |
| 137.5 | -.022 | -.017 | .023 | .054 | .075 | .086 | .080 | .079 | .084 |
| 140.0 | -.021 | -.015 | .025 | .056 | .078 | .089 | .083 | .082 | .087 |
| 142.5 | -.017 | -.012 | .028 | .059 | .080 | .092 | .086 | .085 | .090 |
| 145.0 | -.012 | -.007 | .032 | .062 | .083 | .094 | .089 | .088 | .093 |
| 147.5 | -.008 | -.003 | .035 | .064 | .085 | .096 | .092 | .091 | .096 |
| 150.0 | -.004 | .000 | .038 | .067 | .087 | .098 | .094 | .093 | .098 |
| 152.5 | -.001 | .003 | .041 | .069 | .089 | .100 | .096 | .095 | .101 |
| 155.0 | .001 | .006 | .043 | .071 | .091 | .102 | .097 | .097 | .102 |
| 157.5 | .002 | .007 | .044 | .073 | .092 | .104 | .099 | .098 | .104 |
| 160.0 | .003 | .007 | .045 | .074 | .094 | .105 | .100 | .100 | .106 |
| 162.5 | .002 | .007 | .045 | .075 | .095 | .106 | .102 | .101 | .107 |
| 165.0 | .002 | .007 | .046 | .075 | .096 | .107 | .103 | .102 | .108 |
| 167.5 | .004 | .008 | .046 | .076 | .096 | .108 | .104 | .103 | .109 |
| 170.0 | .006 | .010 | .048 | .076 | .097 | .108 | .104 | .104 | .110 |
| 172.5 | .009 | .013 | .049 | .077 | .097 | .108 | .105 | .105 | .110 |
| 175.0 | .012 | .017 | .051 | .078 | .097 | .108 | .106 | .106 | .111 |
| 177.5 | .016 | .020 | .053 | .078 | .096 | .107 | .106 | .106 | .111 |

TABLE 10d – (Continued)

| $\theta_w$ | r/R = 0.289 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|
| 180.0 | .018 | .022 | .054 | .078 | .096 | .107 | .106 | .107 | .111 |
| 182.5 | .017 | .021 | .053 | .078 | .096 | .107 | .106 | .107 | .111 |
| 185.0 | .016 | .020 | .053 | .078 | .096 | .107 | .105 | .106 | .111 |
| 187.5 | .014 | .018 | .051 | .077 | .096 | .107 | .104 | .105 | .110 |
| 190.0 | .011 | .015 | .049 | .076 | .095 | .106 | .103 | .104 | .110 |
| 192.5 | .007 | .012 | .047 | .074 | .094 | .105 | .102 | .103 | .109 |
| 195.0 | .006 | .010 | .046 | .073 | .092 | .104 | .100 | .101 | .108 |
| 197.5 | .006 | .010 | .045 | .072 | .091 | .102 | .098 | .099 | .106 |
| 200.0 | .007 | .011 | .045 | .071 | .089 | .100 | .096 | .097 | .104 |
| 202.5 | .007 | .011 | .044 | .069 | .087 | .097 | .093 | .094 | .102 |
| 205.0 | .006 | .010 | .042 | .067 | .085 | .095 | .091 | .092 | .100 |
| 207.5 | .003 | .007 | .040 | .065 | .082 | .093 | .088 | .089 | .097 |
| 210.0 | .000 | .004 | .037 | .062 | .080 | .090 | .086 | .087 | .095 |
| 212.5 | -.003 | .001 | .034 | .059 | .077 | .087 | .083 | .084 | .092 |
| 215.0 | -.007 | -.002 | .031 | .056 | .074 | .084 | .080 | .081 | .089 |
| 217.5 | -.010 | -.006 | .027 | .053 | .071 | .081 | .077 | .078 | .086 |
| 220.0 | -.013 | -.009 | .024 | .050 | .068 | .078 | .073 | .074 | .083 |
| 222.5 | -.016 | -.012 | .021 | .046 | .064 | .074 | .069 | .070 | .079 |
| 225.0 | -.019 | -.015 | .018 | .043 | .061 | .071 | .065 | .066 | .076 |
| 227.5 | -.022 | -.018 | .014 | .039 | .057 | .067 | .061 | .062 | .072 |
| 230.0 | -.026 | -.022 | .011 | .036 | .053 | .063 | .057 | .058 | .068 |
| 232.5 | -.029 | -.025 | .007 | .032 | .049 | .059 | .053 | .054 | .064 |
| 235.0 | -.032 | -.028 | .004 | .028 | .045 | .054 | .048 | .049 | .059 |
| 237.5 | -.033 | -.030 | .001 | .024 | .040 | .049 | .043 | .044 | .055 |

TABLE 10d – (Continued)

| $\theta_w$ | r/R = 0.289 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|
| 240.0 | -.034 | -.031 | -.002 | .020 | .035 | .044 | .037 | .039 | .050 |
| 242.5 | -.035 | -.032 | -.005 | .016 | .030 | .038 | .032 | .034 | .046 |
| 245.0 | -.036 | -.033 | -.008 | .012 | .025 | .033 | .026 | .029 | .041 |
| 247.5 | -.037 | -.034 | -.011 | .007 | .020 | .027 | .021 | .023 | .036 |
| 250.0 | -.038 | -.035 | -.014 | .003 | .015 | .021 | .015 | .018 | .031 |
| 252.5 | -.039 | -.036 | -.016 | -.001 | .009 | .016 | .010 | .013 | .025 |
| 255.0 | -.039 | -.036 | -.019 | -.005 | .004 | .010 | .005 | .008 | .021 |
| 257.5 | -.038 | -.037 | -.022 | -.010 | -.001 | .004 | -.001 | .003 | .016 |
| 260.0 | -.039 | -.037 | -.024 | -.014 | -.007 | -.002 | -.006 | -.002 | .011 |
| 262.5 | -.040 | -.039 | -.027 | -.019 | -.012 | -.008 | -.012 | -.007 | .006 |
| 265.0 | -.041 | -.040 | -.031 | -.023 | -.017 | -.014 | -.017 | -.013 | .000 |
| 267.5 | -.042 | -.041 | -.034 | -.028 | -.023 | -.020 | -.023 | -.019 | -.006 |
| 270.0 | -.043 | -.042 | -.037 | -.032 | -.029 | -.026 | -.030 | -.025 | -.012 |
| 272.5 | -.044 | -.043 | -.040 | -.037 | -.034 | -.033 | -.036 | -.032 | -.018 |
| 275.0 | -.045 | -.045 | -.043 | -.041 | -.040 | -.039 | -.043 | -.039 | -.025 |
| 277.5 | -.046 | -.046 | -.046 | -.046 | -.046 | -.046 | -.050 | -.046 | -.032 |
| 280.0 | -.048 | -.049 | -.050 | -.051 | -.051 | -.052 | -.057 | -.053 | -.039 |
| 282.5 | -.051 | -.051 | -.054 | -.055 | -.057 | -.058 | -.063 | -.059 | -.046 |
| 285.0 | -.053 | -.054 | -.057 | -.060 | -.062 | -.064 | -.069 | -.065 | -.052 |
| 287.5 | -.055 | -.056 | -.061 | -.065 | -.068 | -.069 | -.075 | -.071 | -.058 |
| 290.0 | -.056 | -.057 | -.064 | -.069 | -.073 | -.075 | -.080 | -.077 | -.065 |
| 292.5 | -.057 | -.058 | -.067 | -.073 | -.078 | -.081 | -.086 | -.083 | -.071 |
| 295.0 | -.058 | -.059 | -.070 | -.078 | -.084 | -.087 | -.092 | -.089 | -.078 |
| 297.5 | -.060 | -.061 | -.073 | -.082 | -.089 | -.093 | -.098 | -.096 | -.085 |

TABLE 10d – (Continued)

| $\theta_w$ | r/R = 0.289 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|
| 300.0 | -.061 | -.063 | -.076 | -.086 | -.094 | -.099 | -.104 | -.102 | -.091 |
| 302.5 | -.062 | -.064 | -.078 | -.090 | -.098 | -.104 | -.109 | -.107 | -.097 |
| 305.0 | -.063 | -.065 | -.081 | -.094 | -.103 | -.109 | -.114 | -.112 | -.103 |
| 307.5 | -.064 | -.066 | -.084 | -.097 | -.107 | -.114 | -.119 | -.118 | -.110 |
| 310.0 | -.067 | -.069 | -.087 | -.101 | -.111 | -.119 | -.124 | -.123 | -.116 |
| 312.5 | -.070 | -.073 | -.090 | -.104 | -.115 | -.123 | -.129 | -.129 | -.122 |
| 315.0 | -.075 | -.077 | -.094 | -.108 | -.119 | -.126 | -.133 | -.133 | -.128 |
| 317.5 | -.080 | -.082 | -.098 | -.111 | -.122 | -.129 | -.136 | -.137 | -.133 |
| 320.0 | -.083 | -.085 | -.101 | -.114 | -.125 | -.132 | -.138 | -.140 | -.138 |
| 322.5 | -.081 | -.084 | -.102 | -.116 | -.128 | -.136 | -.140 | -.142 | -.141 |
| 325.0 | -.071 | -.074 | -.098 | -.117 | -.131 | -.140 | -.142 | -.143 | -.143 |
| 327.5 | -.055 | -.059 | -.090 | -.115 | -.134 | -.145 | -.145 | -.146 | -.146 |
| 330.0 | -.063 | -.066 | -.093 | -.116 | -.135 | -.150 | -.164 | -.168 | -.163 |
| 332.5 | -.060 | -.064 | -.094 | -.119 | -.139 | -.155 | -.169 | -.173 | -.167 |
| 335.0 | -.145 | -.144 | -.136 | -.131 | -.127 | -.125 | -.120 | -.127 | -.148 |
| 337.5 | -.251 | -.245 | -.192 | -.153 | -.126 | -.111 | -.114 | -.121 | -.131 |
| 340.0 | -.067 | -.068 | -.082 | -.095 | -.106 | -.116 | -.129 | -.134 | -.129 |
| 342.5 | .075 | .067 | .004 | -.046 | -.085 | -.111 | -.121 | -.126 | -.127 |
| 345.0 | .095 | .087 | .021 | -.032 | -.072 | -.099 | -.107 | -.113 | -.120 |
| 347.5 | .069 | .062 | .011 | -.031 | -.063 | -.087 | -.096 | -.105 | -.116 |
| 350.0 | .040 | .036 | .000 | -.030 | -.056 | -.077 | -.090 | -.103 | -.116 |
| 352.5 | .029 | .025 | -.002 | -.027 | -.050 | -.070 | -.087 | -.102 | -.117 |
| 355.0 | .029 | .026 | -.000 | -.024 | -.047 | -.067 | -.085 | -.101 | -.116 |
| 357.5 | .033 | .030 | .001 | -.025 | -.048 | -.068 | -.085 | -.101 | -.115 |

## TABLE 10e – HARMONICS OF $V_x/V$

r/R = 0.289

| n | $(A_x)_n/V$ | $(B_x)_n/V$ | $(V_x)_n/V$ | $(\phi_x^*)_n$ |
|---|---|---|---|---|
| 0 | .8831 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.0644 | -.0778 | .1010 | 219.6 |
| 2 | -.1185 | -.0177 | .1198 | 261.5 |
| 3 | -.0563 | -.0143 | .0581 | 255.8 |
| 4 | -.0410 | -.0179 | .0448 | 246.4 |
| 5 | -.0263 | -.0011 | .0264 | 267.7 |
| 6 | -.0124 | .0072 | .0144 | 300.1 |
| 7 | .0012 | -.0010 | .0016 | 129.4 |
| 8 | .0263 | -.0014 | .0263 | 93.1 |
| 9 | .0237 | .0062 | .0245 | 75.3 |
| 10 | .0225 | .0081 | .0239 | 70.1 |
| 11 | .0283 | .0017 | .0284 | 86.6 |
| 12 | .0194 | -.0039 | .0197 | 101.5 |
| 13 | .0118 | -.0022 | .0120 | 100.8 |
| 14 | -.0011 | -.0122 | .0122 | 185.0 |
| 15 | .0044 | -.0198 | .0203 | 167.5 |
| 16 | -.0116 | -.0136 | .0179 | 220.4 |

r/R = 0.3

| n | $(A_x)_n/V$ | $(B_x)_n/V$ | $(V_x)_n/V$ | $(\phi_x^*)_n$ |
|---|---|---|---|---|
| 0 | .8823 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.0619 | -.0732 | .0959 | 220.2 |
| 2 | -.1142 | -.0167 | .1154 | 261.7 |
| 3 | -.0546 | -.0134 | .0563 | 256.2 |
| 4 | -.0398 | -.0169 | .0432 | 247.0 |
| 5 | -.0255 | -.0009 | .0255 | 267.9 |
| 6 | -.0118 | .0068 | .0136 | 300.1 |
| 7 | .0012 | -.0009 | .0015 | 125.4 |
| 8 | .0254 | -.0013 | .0255 | 92.9 |
| 9 | .0231 | .0059 | .0239 | 75.6 |
| 10 | .0219 | .0078 | .0233 | 70.5 |
| 11 | .0273 | .0016 | .0273 | 86.6 |
| 12 | .0187 | -.0037 | .0190 | 101.1 |
| 13 | .0112 | -.0021 | .0114 | 100.6 |
| 14 | -.0012 | -.0115 | .0116 | 185.8 |
| 15 | .0038 | -.0187 | .0191 | 168.5 |
| 16 | -.0114 | -.0129 | .0172 | 221.2 |

TABLE 10e – (Continued)

r/R = 0.4

| n | $(A_x)_n/V$ | $(B_x)_n/V$ | $(V_x)_n/V$ | $(\phi_x^*)_n$ |
|---|---|---|---|---|
| 0 | .8766 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.0416 | -.0375 | .0560 | 227.9 |
| 2 | -.0797 | -.0091 | .0802 | 263.5 |
| 3 | -.0404 | -.0064 | .0409 | 261.0 |
| 4 | -.0293 | -.0091 | .0307 | 252.8 |
| 5 | -.0185 | .0002 | .0185 | 270.7 |
| 6 | -.0068 | .0040 | .0079 | 300.3 |
| 7 | .0014 | .0003 | .0014 | 79.7 |
| 8 | .0185 | -.0002 | .0185 | 90.7 |
| 9 | .0183 | .0038 | .0187 | 78.3 |
| 10 | .0173 | .0048 | .0180 | 74.6 |
| 11 | .0187 | .0010 | .0187 | 87.1 |
| 12 | .0131 | -.0015 | .0132 | 96.7 |
| 13 | .0065 | -.0011 | .0066 | 99.7 |
| 14 | -.0020 | -.0064 | .0067 | 197.7 |
| 15 | -.0008 | -.0100 | .0101 | 184.8 |
| 16 | -.0096 | -.0078 | .0123 | 230.9 |

r/R = 0.5

| n | $(A_x)_n/V$ | $(B_x)_n/V$ | $(V_x)_n/V$ | $(\phi_x^*)_n$ |
|---|---|---|---|---|
| 0 | .8746 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.0249 | -.0116 | .0274 | 245.1 |
| 2 | -.0526 | -.0037 | .0527 | 266.0 |
| 3 | -.0286 | -.0013 | .0287 | 267.3 |
| 4 | -.0202 | -.0033 | .0205 | 260.9 |
| 5 | -.0126 | .0013 | .0127 | 275.6 |
| 6 | -.0030 | .0020 | .0036 | 303.8 |
| 7 | .0019 | .0012 | .0022 | 56.6 |
| 8 | .0131 | .0006 | .0131 | 87.2 |
| 9 | .0141 | .0023 | .0143 | 80.9 |
| 10 | .0133 | .0025 | .0135 | 79.3 |
| 11 | .0119 | .0005 | .0119 | 87.7 |
| 12 | .0084 | -.0001 | .0084 | 90.9 |
| 13 | .0027 | -.0005 | .0027 | 100.6 |
| 14 | -.0029 | -.0027 | .0040 | 226.5 |
| 15 | -.0043 | -.0037 | .0057 | 229.0 |
| 16 | -.0082 | -.0039 | .0091 | 244.5 |

## TABLE 10e – (Continued)

r/R = 0.6

| n | $(A_x)_n$ /V | $(B_x)_n$ /V | $(V_x)_n$ /V | $(\phi^*_x)_n$ |
|---|---|---|---|---|
| 0 | .8761 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.0118 | .0046 | .0127 | 291.4 |
| 2 | -.0330 | -.0003 | .0330 | 269.4 |
| 3 | -.0192 | .0018 | .0193 | 275.2 |
| 4 | -.0126 | .0006 | .0126 | 272.7 |
| 5 | -.0080 | .0021 | .0082 | 285.0 |
| 6 | -.0003 | .0009 | .0009 | 339.8 |
| 7 | .0026 | .0020 | .0033 | 51.9 |
| 8 | .0091 | .0012 | .0091 | 82.3 |
| 9 | .0107 | .0014 | .0107 | 82.7 |
| 10 | .0097 | .0010 | .0098 | 84.3 |
| 11 | .0068 | .0002 | .0069 | 88.4 |
| 12 | .0045 | .0006 | .0045 | 82.8 |
| 13 | -.0003 | -.0003 | .0004 | 231.2 |
| 14 | -.0037 | -.0006 | .0037 | 260.9 |
| 15 | -.0065 | .0001 | .0065 | 271.3 |
| 16 | -.0072 | -.0013 | .0073 | 259.6 |

r/R = 0.7

| n | $(A_x)_n$ /V | $(B_x)_n$ /V | $(V_x)_n$ /V | $(\phi^*_x)_n$ |
|---|---|---|---|---|
| 0 | .8812 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.0024 | .0110 | .0113 | 347.6 |
| 2 | -.0208 | .0009 | .0208 | 272.4 |
| 3 | -.0121 | .0029 | .0125 | 283.3 |
| 4 | -.0063 | .0024 | .0068 | 290.9 |
| 5 | -.0044 | .0029 | .0053 | 303.0 |
| 6 | .0011 | .0006 | .0013 | 60.2 |
| 7 | .0037 | .0027 | .0046 | 53.3 |
| 8 | .0065 | .0016 | .0067 | 76.5 |
| 9 | .0078 | .0011 | .0079 | 82.2 |
| 10 | .0068 | .0002 | .0068 | 88.6 |
| 11 | .0036 | .0001 | .0036 | 88.7 |
| 12 | .0014 | .0006 | .0016 | 68.7 |
| 13 | -.0025 | -.0004 | .0026 | 261.1 |
| 14 | -.0045 | .0000 | .0045 | 270.5 |
| 15 | -.0075 | .0016 | .0077 | 282.3 |
| 16 | -.0067 | -.0001 | .0067 | 269.6 |

## TABLE 10e – (Continued)

r/R = 0.8

| n | $(A_x)_n/V$ | $(B_x)_n/V$ | $(V_x)_n/V$ | $(\phi_x^*)_n$ |
|---|---|---|---|---|
| 0 | .8971 | 0.0000 | 0.0000 | 0.0 |
| 1 | .0058 | -.0007 | .0058 | 96.5 |
| 2 | -.0211 | -.0023 | .0212 | 263.9 |
| 3 | -.0083 | .0004 | .0083 | 272.4 |
| 4 | -.0015 | .0008 | .0017 | 299.3 |
| 5 | -.0027 | .0041 | .0049 | 326.9 |
| 6 | .0002 | .0024 | .0024 | 3.7 |
| 7 | .0062 | .0038 | .0072 | 58.3 |
| 8 | .0064 | .0016 | .0066 | 75.6 |
| 9 | .0058 | .0022 | .0062 | 69.4 |
| 10 | .0042 | .0006 | .0043 | 82.5 |
| 11 | .0032 | .0002 | .0032 | 85.6 |
| 12 | -.0004 | -.0012 | .0013 | 200.9 |
| 13 | -.0035 | -.0017 | .0039 | 244.3 |
| 14 | -.0050 | -.0027 | .0057 | 241.7 |
| 15 | -.0061 | -.0017 | .0063 | 254.7 |
| 16 | -.0065 | -.0013 | .0066 | 258.8 |

r/R = 0.9

| n | $(A_x)_n/V$ | $(B_x)_n/V$ | $(V_x)_n/V$ | $(\phi_x^*)_n$ |
|---|---|---|---|---|
| 0 | .9034 | 0.0000 | 0.0000 | 0.0 |
| 1 | .0059 | -.0070 | .0092 | 140.2 |
| 2 | -.0196 | -.0035 | .0199 | 259.8 |
| 3 | -.0053 | -.0011 | .0054 | 258.5 |
| 4 | .0019 | -.0001 | .0019 | 94.4 |
| 5 | -.0009 | .0040 | .0041 | 346.9 |
| 6 | .0002 | .0031 | .0031 | 3.9 |
| 7 | .0068 | .0038 | .0078 | 61.2 |
| 8 | .0061 | .0015 | .0062 | 76.1 |
| 9 | .0043 | .0025 | .0049 | 59.7 |
| 10 | .0024 | .0008 | .0026 | 71.1 |
| 11 | .0025 | .0004 | .0025 | 80.6 |
| 12 | -.0021 | -.0018 | .0027 | 229.5 |
| 13 | -.0044 | -.0019 | .0048 | 246.2 |
| 14 | -.0060 | -.0036 | .0070 | 238.9 |
| 15 | -.0057 | -.0030 | .0065 | 242.0 |
| 16 | -.0068 | -.0016 | .0070 | 256.6 |

TABLE 10e – (Continued)

$r/R = 1.0$

| n | $(A_x)_n/V$ | $(B_x)_n/V$ | $(V_x)_n/V$ | $(\phi_x^*)_n$ |
|---|---|---|---|---|
| 0 | .8984 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.0029 | -.0061 | .0068 | 205.0 |
| 2 | -.0151 | -.0024 | .0153 | 260.8 |
| 3 | -.0032 | -.0010 | .0034 | 252.2 |
| 4 | .0038 | -.0002 | .0038 | 93.1 |
| 5 | .0009 | .0025 | .0027 | 19.7 |
| 6 | .0016 | .0023 | .0028 | 34.4 |
| 7 | .0054 | .0024 | .0059 | 65.9 |
| 8 | .0053 | .0012 | .0054 | 77.6 |
| 9 | .0032 | .0018 | .0037 | 60.5 |
| 10 | .0014 | .0009 | .0017 | 57.4 |
| 11 | .0012 | .0006 | .0013 | 64.2 |
| 12 | -.0034 | -.0009 | .0036 | 254.8 |
| 13 | -.0052 | -.0009 | .0053 | 259.9 |
| 14 | -.0073 | -.0022 | .0076 | 253.5 |
| 15 | -.0067 | -.0019 | .0070 | 254.2 |
| 16 | -.0077 | -.0008 | .0077 | 264.0 |

## TABLE 10f – HARMONICS OF $V_t/V$

r/R = 0.289

| n | $(A_t)_n/V$ | $(B_t)_n/V$ | $(V_t)_n/V$ | $(\phi_t^*)_n$ |
|---|---|---|---|---|
| 0 | .0730 | 0.0000 | 0.0000 | 0.0 |
| 1 | .0254 | -.1921 | .1938 | 172.5 |
| 2 | -.0020 | -.0048 | .0052 | 202.4 |
| 3 | .0137 | -.0163 | .0213 | 139.8 |
| 4 | .0086 | -.0145 | .0168 | 149.3 |
| 5 | .0129 | -.0127 | .0181 | 134.4 |
| 6 | .0098 | -.0054 | .0112 | 119.0 |
| 7 | .0088 | -.0003 | .0088 | 91.9 |
| 8 | .0052 | .0061 | .0080 | 40.3 |
| 9 | .0048 | .0133 | .0142 | 19.9 |
| 10 | .0024 | .0157 | .0158 | 8.6 |
| 11 | .0017 | .0160 | .0161 | 6.1 |
| 12 | .0032 | .0150 | .0153 | 12.1 |
| 13 | .0065 | .0110 | .0128 | 30.6 |
| 14 | .0077 | .0048 | .0090 | 58.1 |
| 15 | .0106 | -.0004 | .0106 | 92.3 |
| 16 | .0119 | -.0051 | .0130 | 113.1 |

r/R = 0.3

| n | $(A_t)_n/V$ | $(B_t)_n/V$ | $(V_t)_n/V$ | $(\phi_t^*)_n$ |
|---|---|---|---|---|
| 0 | .0685 | 0.0000 | 0.0000 | 0.0 |
| 1 | .0234 | -.1909 | .1923 | 173.0 |
| 2 | -.0019 | -.0047 | .0050 | 201.7 |
| 3 | .0130 | -.0157 | .0203 | 140.4 |
| 4 | .0081 | -.0139 | .0161 | 149.7 |
| 5 | .0122 | -.0121 | .0172 | 134.8 |
| 6 | .0093 | -.0051 | .0106 | 118.7 |
| 7 | .0083 | -.0000 | .0083 | 90.3 |
| 8 | .0049 | .0062 | .0079 | 38.4 |
| 9 | .0046 | .0131 | .0139 | 19.2 |
| 10 | .0022 | .0153 | .0155 | 8.3 |
| 11 | .0016 | .0156 | .0156 | 5.9 |
| 12 | .0030 | .0144 | .0147 | 11.8 |
| 13 | .0061 | .0105 | .0121 | 30.2 |
| 14 | .0072 | .0043 | .0084 | 59.0 |
| 15 | .0100 | -.0008 | .0100 | 94.4 |
| 16 | .0113 | -.0053 | .0125 | 115.2 |

## TABLE 10f – (Continued)

r/R = 0.4

| n | $(A_t)_n/V$ | $(B_t)_n/V$ | $(V_t)_n/V$ | $(\phi_t^*)_n$ |
|---|---|---|---|---|
| 0 | .0340 | 0.0000 | 0.0000 | 0.0 |
| 1 | .0076 | -.1803 | .1804 | 177.6 |
| 2 | -.0010 | -.0040 | .0041 | 194.2 |
| 3 | .0068 | -.0108 | .0128 | 147.7 |
| 4 | .0045 | -.0092 | .0102 | 153.8 |
| 5 | .0065 | -.0074 | .0098 | 138.8 |
| 6 | .0050 | -.0022 | .0054 | 113.9 |
| 7 | .0045 | .0019 | .0049 | 67.8 |
| 8 | .0025 | .0063 | .0068 | 21.9 |
| 9 | .0024 | .0112 | .0114 | 12.2 |
| 10 | .0011 | .0124 | .0124 | 5.3 |
| 11 | .0007 | .0117 | .0117 | 3.5 |
| 12 | .0015 | .0098 | .0099 | 8.6 |
| 13 | .0031 | .0061 | .0068 | 26.7 |
| 14 | .0038 | .0009 | .0039 | 76.9 |
| 15 | .0053 | -.0034 | .0063 | 123.1 |
| 16 | .0062 | -.0069 | .0092 | 138.1 |

r/R = 0.5

| n | $(A_t)_n/V$ | $(B_t)_n/V$ | $(V_t)_n/V$ | $(\phi_t^*)_n$ |
|---|---|---|---|---|
| 0 | .0100 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.0039 | -.1708 | .1709 | 181.3 |
| 2 | -.0004 | -.0034 | .0034 | 186.1 |
| 3 | .0023 | -.0065 | .0069 | 160.4 |
| 4 | .0018 | -.0050 | .0053 | 160.3 |
| 5 | .0022 | -.0036 | .0042 | 148.9 |
| 6 | .0017 | .0000 | .0017 | 89.8 |
| 7 | .0017 | .0030 | .0034 | 29.0 |
| 8 | .0008 | .0060 | .0060 | 7.3 |
| 9 | .0008 | .0090 | .0091 | 5.0 |
| 10 | .0003 | .0093 | .0094 | 2.0 |
| 11 | .0001 | .0081 | .0081 | .5 |
| 12 | .0003 | .0057 | .0057 | 3.5 |
| 13 | .0008 | .0024 | .0025 | 18.8 |
| 14 | .0013 | -.0018 | .0022 | 145.3 |
| 15 | .0017 | -.0052 | .0055 | 161.6 |
| 16 | .0023 | -.0076 | .0079 | 163.3 |

## TABLE 10f – (Continued)

r/R = 0.6

| n | $(A_t)_n/V$ | $(B_t)_n/V$ | $(V_t)_n/V$ | $(\phi_t^*)_n$ |
|---|---|---|---|---|
| 0 | -.0034 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.0112 | -.1626 | .1630 | 183.9 |
| 2 | .0001 | -.0028 | .0028 | 178.0 |
| 3 | -.0006 | -.0028 | .0029 | 191.4 |
| 4 | .0000 | -.0015 | .0015 | 179.5 |
| 5 | -.0008 | -.0006 | .0010 | 230.8 |
| 6 | -.0005 | .0015 | .0016 | 341.0 |
| 7 | -.0003 | .0034 | .0034 | 354.8 |
| 8 | -.0004 | .0051 | .0052 | 355.0 |
| 9 | -.0003 | .0066 | .0067 | 357.5 |
| 10 | -.0002 | .0063 | .0063 | 358.1 |
| 11 | -.0003 | .0047 | .0047 | 355.8 |
| 12 | -.0004 | .0021 | .0021 | 350.2 |
| 13 | -.0006 | -.0007 | .0009 | 223.4 |
| 14 | -.0004 | -.0038 | .0039 | 186.0 |
| 15 | -.0006 | -.0062 | .0062 | 185.5 |
| 16 | -.0004 | -.0075 | .0075 | 182.9 |

r/R = 0.7

| n | $(A_t)_n/V$ | $(B_t)_n/V$ | $(V_t)_n/V$ | $(\phi_t^*)_n$ |
|---|---|---|---|---|
| 0 | -.0062 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.0142 | -.1556 | .1562 | 185.2 |
| 2 | .0004 | -.0024 | .0024 | 171.3 |
| 3 | -.0018 | .0002 | .0018 | 276.5 |
| 4 | -.0009 | .0014 | .0017 | 328.7 |
| 5 | -.0023 | .0015 | .0027 | 303.5 |
| 6 | -.0017 | .0024 | .0029 | 324.2 |
| 7 | -.0014 | .0031 | .0034 | 335.7 |
| 8 | -.0011 | .0038 | .0039 | 344.0 |
| 9 | -.0009 | .0041 | .0041 | 348.2 |
| 10 | -.0005 | .0032 | .0032 | 351.5 |
| 11 | -.0005 | .0014 | .0015 | 339.4 |
| 12 | -.0007 | -.0009 | .0011 | 216.7 |
| 13 | -.0013 | -.0030 | .0033 | 202.6 |
| 14 | -.0012 | -.0051 | .0052 | 193.2 |
| 15 | -.0018 | -.0063 | .0066 | 195.5 |
| 16 | -.0018 | -.0065 | .0067 | 195.4 |

TABLE 10f – (Continued)

r/R = 0.8

| n | $(A_t)_n/V$ | $(B_t)_n/V$ | $(V_t)_n/V$ | $(\phi_t^*)_n$ |
|---|---|---|---|---|
| 0 | .0141 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.0107 | -.1473 | .1477 | 184.2 |
| 2 | .0006 | -.0002 | .0006 | 109.3 |
| 3 | .0001 | .0036 | .0036 | .8 |
| 4 | .0001 | .0043 | .0043 | .7 |
| 5 | -.0015 | .0029 | .0032 | 333.1 |
| 6 | -.0011 | .0022 | .0025 | 333.4 |
| 7 | -.0011 | .0012 | .0016 | 318.5 |
| 8 | -.0007 | .0007 | .0010 | 315.1 |
| 9 | -.0005 | -.0003 | .0006 | 236.2 |
| 10 | -.0001 | -.0017 | .0017 | 184.7 |
| 11 | -.0003 | -.0033 | .0033 | 185.0 |
| 12 | -.0001 | -.0046 | .0046 | 181.4 |
| 13 | -.0004 | -.0056 | .0057 | 184.6 |
| 14 | -.0004 | -.0060 | .0060 | 184.0 |
| 15 | -.0010 | -.0052 | .0053 | 190.6 |
| 16 | -.0012 | -.0037 | .0039 | 198.5 |

r/R = 0.9

| n | $(A_t)_n/V$ | $(B_t)_n/V$ | $(V_t)_n/V$ | $(\phi_t^*)_n$ |
|---|---|---|---|---|
| 0 | .0224 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.0070 | -.1446 | .1448 | 182.8 |
| 2 | .0003 | -.0013 | .0013 | 165.7 |
| 3 | .0009 | .0046 | .0047 | 10.9 |
| 4 | .0003 | .0055 | .0055 | 3.4 |
| 5 | -.0009 | .0032 | .0033 | 344.1 |
| 6 | -.0008 | .0019 | .0021 | 337.7 |
| 7 | -.0008 | .0001 | .0008 | 276.0 |
| 8 | -.0006 | -.0006 | .0008 | 223.2 |
| 9 | -.0003 | -.0020 | .0021 | 188.1 |
| 10 | -.0001 | -.0035 | .0035 | 181.9 |
| 11 | -.0002 | -.0048 | .0048 | 182.2 |
| 12 | .0000 | -.0055 | .0055 | 179.5 |
| 13 | .0000 | -.0059 | .0059 | 179.7 |
| 14 | -.0000 | -.0055 | .0055 | 180.3 |
| 15 | -.0004 | -.0040 | .0040 | 185.4 |
| 16 | -.0007 | -.0019 | .0020 | 201.2 |

TABLE 10f – (Continued)

r/R = 1.0

| n | $(A_t)_n/V$ | $(B_t)_n/V$ | $(V_t)_n/V$ | $(\phi_t^*)_n$ |
|---|---|---|---|---|
| 0 | .0158 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.0037 | -.1481 | .1482 | 181.4 |
| 2 | -.0004 | -.0060 | .0061 | 183.9 |
| 3 | .0003 | .0030 | .0030 | 6.5 |
| 4 | -.0002 | .0048 | .0049 | 357.1 |
| 5 | -.0008 | .0023 | .0024 | 341.1 |
| 6 | -.0009 | .0015 | .0017 | 329.3 |
| 7 | -.0007 | -.0000 | .0007 | 267.7 |
| 8 | -.0008 | .0002 | .0008 | 281.4 |
| 9 | -.0004 | -.0007 | .0008 | 207.6 |
| 10 | -.0005 | -.0017 | .0018 | 195.5 |
| 11 | -.0003 | -.0027 | .0027 | 186.0 |
| 12 | -.0003 | -.0031 | .0031 | 185.1 |
| 13 | .0000 | -.0036 | .0036 | 179.5 |
| 14 | -.0002 | -.0035 | .0035 | 183.0 |
| 15 | -.0001 | -.0027 | .0027 | 182.5 |
| 16 | -.0005 | -.0015 | .0016 | 198.2 |

## TABLE 10g – HARMONICS OF $V_r/V$

r/R = 0.289

| n | $(A_r)_n/V$ | $(B_r)_n/V$ | $(V_r)_n/V$ | $(\phi_r^*)_n$ |
|---|---|---|---|---|
| 0 | -.0333 | 0.0000 | 0.0000 | **0.0** |
| 1 | -.0231 | -.0026 | .0233 | **263.7** |
| 2 | .0258 | -.0030 | .0260 | 96.6 |
| 3 | .0159 | -.0033 | .0163 | 101.7 |
| 4 | .0244 | .0001 | .0244 | 89.7 |
| 5 | .0189 | .0000 | .0189 | 90.0 |
| 6 | .0133 | .0020 | .0134 | 81.5 |
| 7 | .0093 | .0008 | .0094 | 85.3 |
| 8 | .0057 | -.0014 | .0059 | 103.7 |
| 9 | .0013 | -.0013 | .0018 | 135.0 |
| 10 | -.0021 | -.0020 | .0029 | 227.0 |
| 11 | -.0058 | -.0036 | .0068 | 238.3 |
| 12 | -.0069 | -.0037 | .0078 | 241.4 |
| 13 | -.0094 | -.0053 | .0108 | 240.6 |
| 14 | -.0078 | -.0044 | .0089 | **240.5** |
| 15 | -.0089 | -.0027 | .0093 | **253.0** |
| 16 | -.0058 | -.0009 | .0058 | **260.8** |

r/R = 0.3

| n | $(A_r)_n/V$ | $(B_r)_n/V$ | $(V_r)_n/V$ | $(\phi_r^*)_n$ |
|---|---|---|---|---|
| 0 | -.0323 | 0.0000 | 0.0000 | **0.0** |
| 1 | -.0273 | -.0021 | .0274 | **265.6** |
| 2 | .0253 | -.0030 | .0254 | 96.8 |
| 3 | .0160 | -.0033 | .0164 | 101.7 |
| 4 | .0238 | -.0000 | .0238 | 90.1 |
| 5 | .0186 | -.0001 | .0186 | 90.5 |
| 6 | .0131 | .0017 | .0132 | 82.6 |
| 7 | .0092 | .0006 | .0092 | 86.4 |
| 8 | .0056 | -.0014 | .0058 | 104.2 |
| 9 | .0013 | -.0013 | .0019 | 133.8 |
| 10 | -.0019 | -.0019 | .0027 | 225.0 |
| 11 | -.0055 | -.0035 | .0065 | 237.8 |
| 12 | -.0066 | -.0036 | .0075 | 241.2 |
| 13 | -.0089 | -.0051 | .0103 | 240.6 |
| 14 | -.0074 | -.0042 | .0085 | 240.6 |
| 15 | -.0085 | -.0026 | .0089 | **252.8** |
| 16 | -.0055 | -.0009 | .0056 | **260.5** |

TABLE 10g – (Continued)

r/R = 0.4

| n | $(A_r)_n/V$ | $(B_r)_n/V$ | $(V_r)_n/V$ | $(\phi_r^*)_n$ |
|---|---|---|---|---|
| 0 | -.0244 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.0616 | .0017 | .0616 | 271.6 |
| 2 | .0207 | -.0028 | .0209 | 97.8 |
| 3 | .0168 | -.0033 | .0171 | 101.3 |
| 4 | .0194 | -.0013 | .0195 | 93.8 |
| 5 | .0154 | -.0013 | .0155 | 94.8 |
| 6 | .0112 | -.0004 | .0112 | 92.1 |
| 7 | .0082 | -.0009 | .0082 | 96.1 |
| 8 | .0051 | -.0017 | .0054 | 107.9 |
| 9 | .0020 | -.0015 | .0025 | 128.0 |
| 10 | -.0007 | -.0017 | .0019 | 201.8 |
| 11 | -.0032 | -.0025 | .0040 | 232.0 |
| 12 | -.0042 | -.0025 | .0049 | 238.8 |
| 13 | -.0056 | -.0032 | .0064 | 239.9 |
| 14 | -.0047 | -.0027 | .0054 | 240.7 |
| 15 | -.0051 | -.0018 | .0054 | 250.7 |
| 16 | -.0032 | -.0007 | .0033 | 257.7 |

r/R = 0.5

| n | $(A_r)_n/V$ | $(B_r)_n/V$ | $(V_r)_n/V$ | $(\phi_r^*)_n$ |
|---|---|---|---|---|
| 0 | -.0188 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.0888 | .0046 | .0889 | 273.0 |
| 2 | .0165 | -.0026 | .0168 | 99.1 |
| 3 | .0169 | -.0033 | .0172 | 101.2 |
| 4 | .0159 | -.0022 | .0161 | 97.9 |
| 5 | .0129 | -.0021 | .0131 | 99.1 |
| 6 | .0095 | -.0018 | .0097 | 100.8 |
| 7 | .0071 | -.0019 | .0074 | 104.6 |
| 8 | .0046 | -.0018 | .0049 | 111.5 |
| 9 | .0022 | -.0017 | .0028 | 126.9 |
| 10 | .0001 | -.0015 | .0015 | 175.0 |
| 11 | -.0015 | -.0017 | .0023 | 220.2 |
| 12 | -.0023 | -.0017 | .0029 | 234.1 |
| 13 | -.0030 | -.0018 | .0035 | 238.5 |
| 14 | -.0026 | -.0015 | .0030 | 241.1 |
| 15 | -.0024 | -.0011 | .0027 | 246.1 |
| 16 | -.0015 | -.0005 | .0015 | 250.9 |

TABLE 10g – (Continued)

r/R = 0.6

| n | $(A_r)_n/V$ | $(B_r)_n/V$ | $(V_r)_n/V$ | $(\phi_r^*)_n$ |
|---|---|---|---|---|
| 0 | -.0155 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.1090 | .0066 | .1092 | 273.5 |
| 2 | .0129 | -.0024 | .0131 | 100.4 |
| 3 | .0165 | -.0033 | .0168 | 101.3 |
| 4 | .0134 | -.0027 | .0136 | 101.5 |
| 5 | .0109 | -.0024 | .0112 | 102.7 |
| 6 | .0081 | -.0025 | .0085 | 107.3 |
| 7 | .0060 | -.0023 | .0065 | 111.2 |
| 8 | .0039 | -.0018 | .0043 | 115.1 |
| 9 | .0022 | -.0017 | .0028 | 128.6 |
| 10 | .0006 | -.0014 | .0015 | 157.9 |
| 11 | -.0004 | -.0012 | .0013 | 197.0 |
| 12 | -.0011 | -.0011 | .0015 | 224.1 |
| 13 | -.0012 | -.0008 | .0015 | 234.6 |
| 14 | -.0011 | -.0006 | .0013 | 242.9 |
| 15 | -.0006 | -.0005 | .0008 | 227.1 |
| 16 | -.0002 | -.0003 | .0003 | 206.9 |

r/R = 0.7

| n | $(A_r)_n/V$ | $(B_r)_n/V$ | $(V_r)_n/V$ | $(\phi_r^*)_n$ |
|---|---|---|---|---|
| 0 | -.0145 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.1221 | .0077 | .1224 | 273.6 |
| 2 | .0097 | -.0020 | .0099 | 102.0 |
| 3 | .0154 | -.0032 | .0158 | 101.7 |
| 4 | .0117 | -.0028 | .0121 | 103.6 |
| 5 | .0095 | -.0024 | .0098 | 104.4 |
| 6 | .0068 | -.0025 | .0073 | 110.1 |
| 7 | .0049 | -.0024 | .0054 | 115.6 |
| 8 | .0032 | -.0018 | .0036 | 119.1 |
| 9 | .0018 | -.0017 | .0025 | 133.7 |
| 10 | .0006 | -.0012 | .0013 | 154.9 |
| 11 | .0001 | -.0009 | .0009 | 172.6 |
| 12 | -.0004 | -.0008 | .0008 | 205.7 |
| 13 | -.0002 | -.0003 | .0004 | 214.6 |
| 14 | -.0002 | -.0000 | .0002 | 260.2 |
| 15 | .0005 | -.0001 | .0005 | 106.2 |
| 16 | .0007 | -.0001 | .0007 | 100.3 |

TABLE 10g – (Continued)

r/R = 0.8

| n | $(A_r)_n/V$ | $(B_r)_n/V$ | $(V_r)_n/V$ | $(\phi_r^*)_n$ |
|---|---|---|---|---|
| 0 | -.0195 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.1238 | .0084 | .1241 | 273.9 |
| 2 | .0082 | -.0017 | .0084 | 101.7 |
| 3 | .0136 | -.0034 | .0140 | 104.2 |
| 4 | .0118 | -.0026 | .0121 | 102.4 |
| 5 | .0089 | -.0019 | .0091 | 101.8 |
| 6 | .0058 | -.0012 | .0059 | 101.2 |
| 7 | .0033 | -.0016 | .0037 | 115.1 |
| 8 | .0023 | -.0017 | .0028 | 126.7 |
| 9 | .0007 | -.0017 | .0019 | 156.9 |
| 10 | -.0000 | -.0011 | .0011 | 182.2 |
| 11 | -.0003 | -.0011 | .0011 | 193.5 |
| 12 | -.0003 | -.0009 | .0010 | 200.3 |
| 13 | -.0003 | -.0005 | .0006 | 213.0 |
| 14 | -.0000 | .0000 | .0000 | 326.9 |
| 15 | .0006 | .0001 | .0006 | 81.4 |
| 16 | .0010 | .0001 | .0010 | 81.7 |

r/R = 0.9

| n | $(A_r)_n/V$ | $(B_r)_n/V$ | $(V_r)_n/V$ | $(\phi_r^*)_n$ |
|---|---|---|---|---|
| 0 | -.0201 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.1265 | .0073 | .1267 | 273.3 |
| 2 | .0049 | -.0012 | .0050 | 104.2 |
| 3 | .0116 | -.0030 | .0120 | 104.3 |
| 4 | .0115 | -.0020 | .0117 | 99.8 |
| 5 | .0084 | -.0012 | .0085 | 98.3 |
| 6 | .0050 | -.0002 | .0050 | 92.5 |
| 7 | .0024 | -.0009 | .0026 | 109.4 |
| 8 | .0015 | -.0014 | .0020 | 132.4 |
| 9 | -.0000 | -.0014 | .0014 | 181.2 |
| 10 | -.0007 | -.0009 | .0011 | 219.7 |
| 11 | -.0008 | -.0010 | .0013 | 219.1 |
| 12 | -.0007 | -.0009 | .0011 | 218.2 |
| 13 | -.0007 | -.0005 | .0009 | 232.6 |
| 14 | -.0002 | .0000 | .0002 | 276.1 |
| 15 | .0003 | .0002 | .0004 | 60.8 |
| 16 | .0009 | .0003 | .0009 | 74.1 |

TABLE 10g -- (Continued)

r/R = 1.0

| n | $(A_r)_n/V$ | $(B_r)_n/V$ | $(V_r)_n/V$ | $(\phi_r^*)_n$ |
|---|---|---|---|---|
| 0 | -.0153 | 0.0000 | 0.0000 | 0.0 |
| 1 | -.1312 | .0041 | .1312 | 271.8 |
| 2 | -.0007 | -.0006 | .0009 | 229.3 |
| 3 | .0096 | -.0017 | .0097 | 99.9 |
| 4 | .0105 | -.0010 | .0106 | 95.5 |
| 5 | .0079 | -.0006 | .0079 | 94.1 |
| 6 | .0044 | .0002 | .0044 | 87.9 |
| 7 | .0023 | -.0003 | .0023 | 97.8 |
| 8 | .0008 | -.0007 | .0011 | 130.5 |
| 9 | -.0004 | -.0008 | .0009 | 209.1 |
| 10 | -.0014 | -.0004 | .0015 | 253.0 |
| 11 | -.0015 | -.0006 | .0016 | 248.8 |
| 12 | -.0014 | -.0005 | .0015 | 249.9 |
| 13 | -.0013 | -.0003 | .0013 | 255.8 |
| 14 | -.0009 | .0000 | .0009 | 272.0 |
| 15 | -.0001 | .0002 | .0002 | 320.8 |
| 16 | .0004 | .0002 | .0005 | 66.5 |

## APPENDIX B

## DETAILED EXPERIMENTAL RESULTS

Figures 34 and 35 and Tables 11-20 present the measured experimental loads, including variation with blade angular position and harmonic analyses, for steady ahead operation near the self-propulsion point, quasi-steady crash forward, and quasi-steady crash astern. The data presented in Figures 34 and 35 are similar to those presented earlier, except that here all measured components of blade loading are given whereas Figures 22 and 24 were restricted to the one component $F_x$. The loads presented in Tables 11-20 are tabulated values of the data presented graphically in Figures 14-17, Figures 19-22, and Figures 34 and 35.



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Figure 34 - Harmonics of Loads for Quasi-Steady Crash Ahead

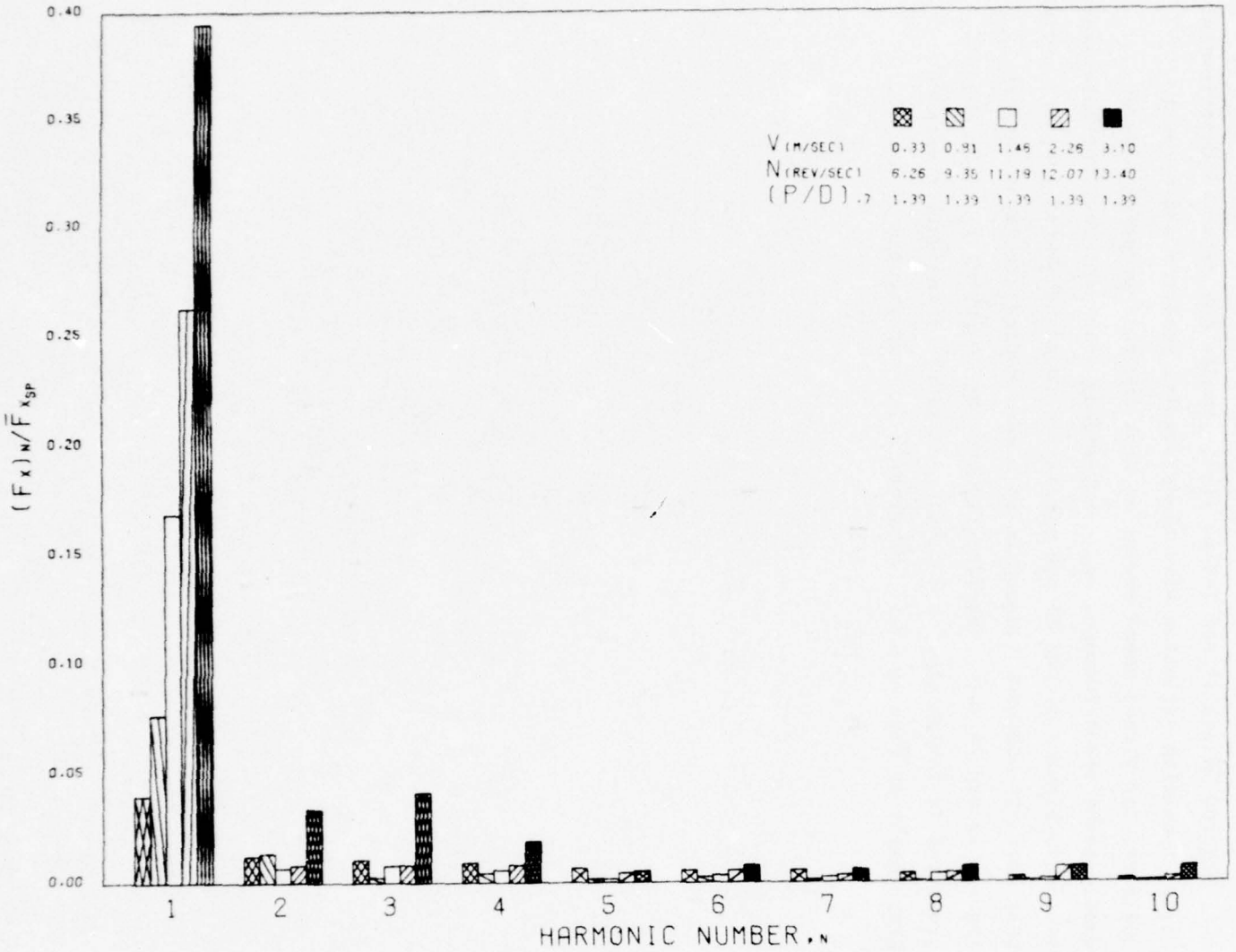


Figure 34 (Continued)

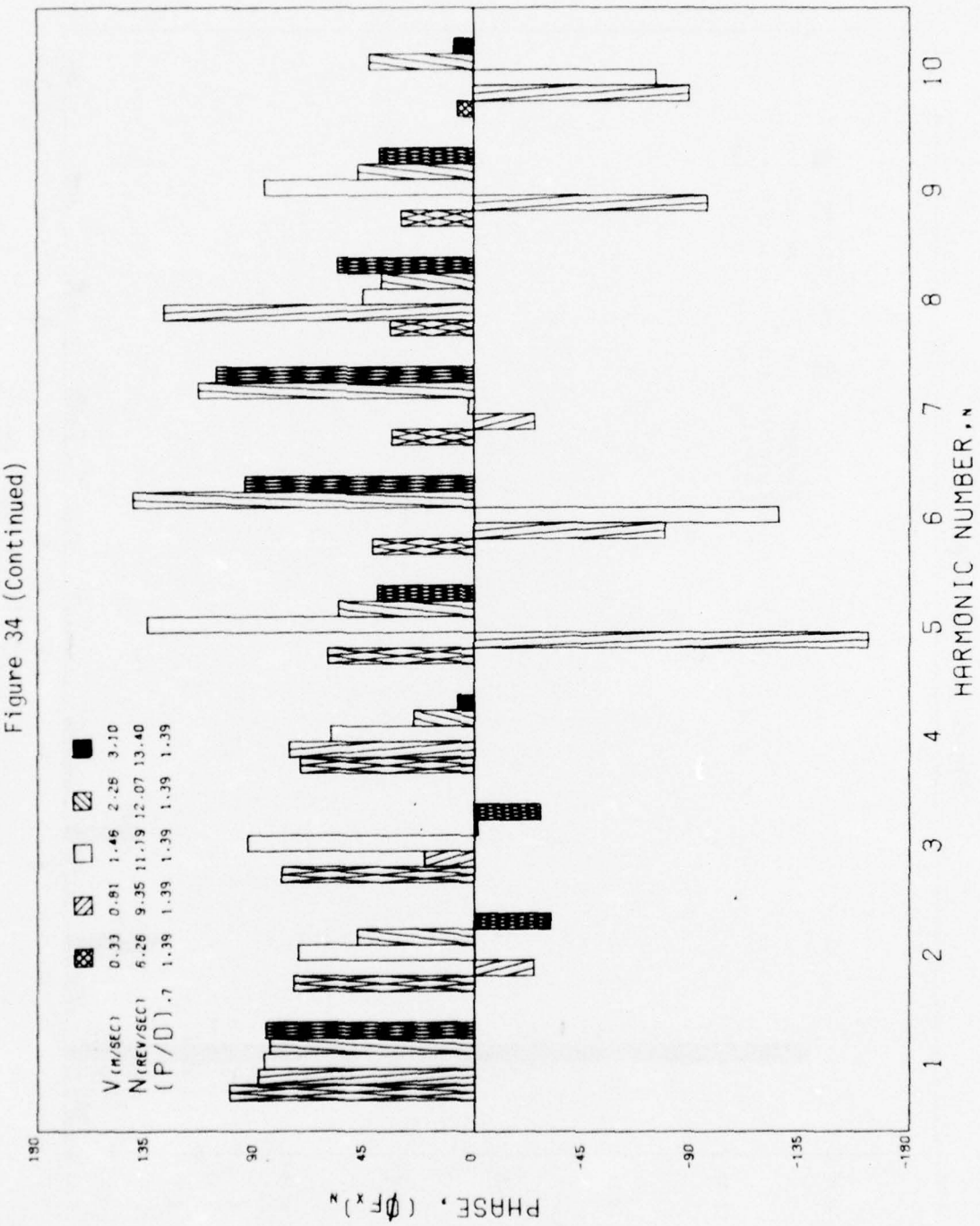
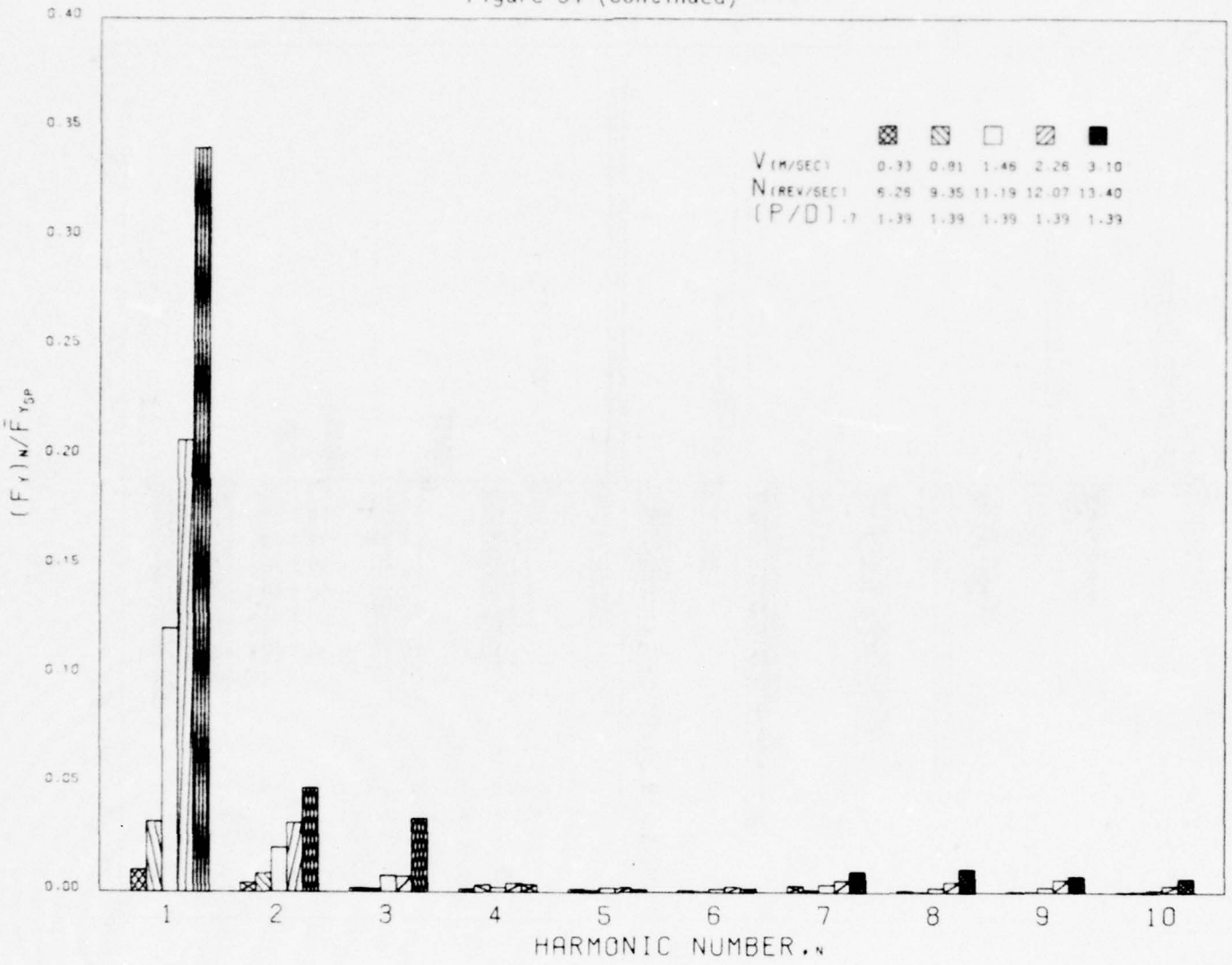


Figure 34 (Continued)



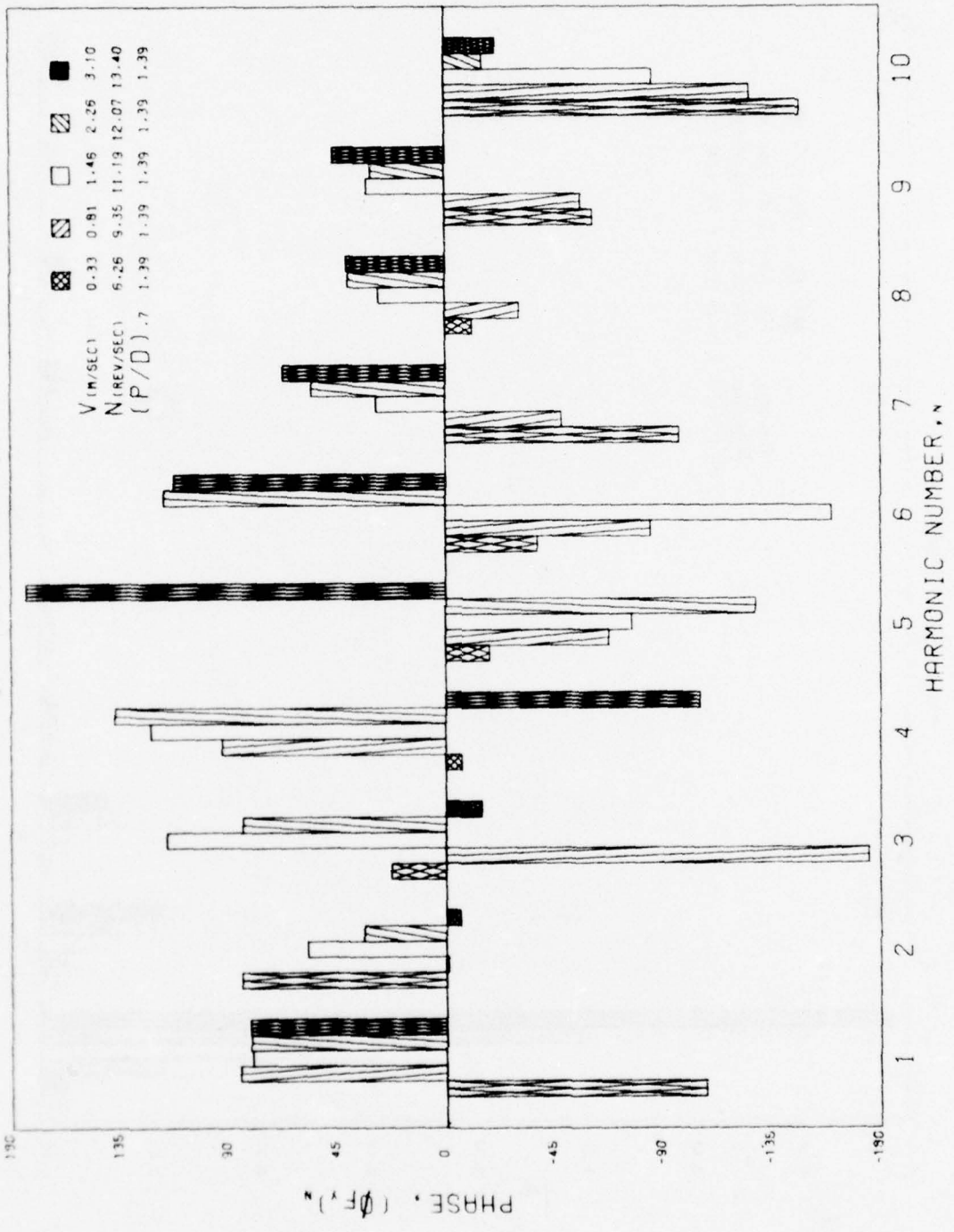
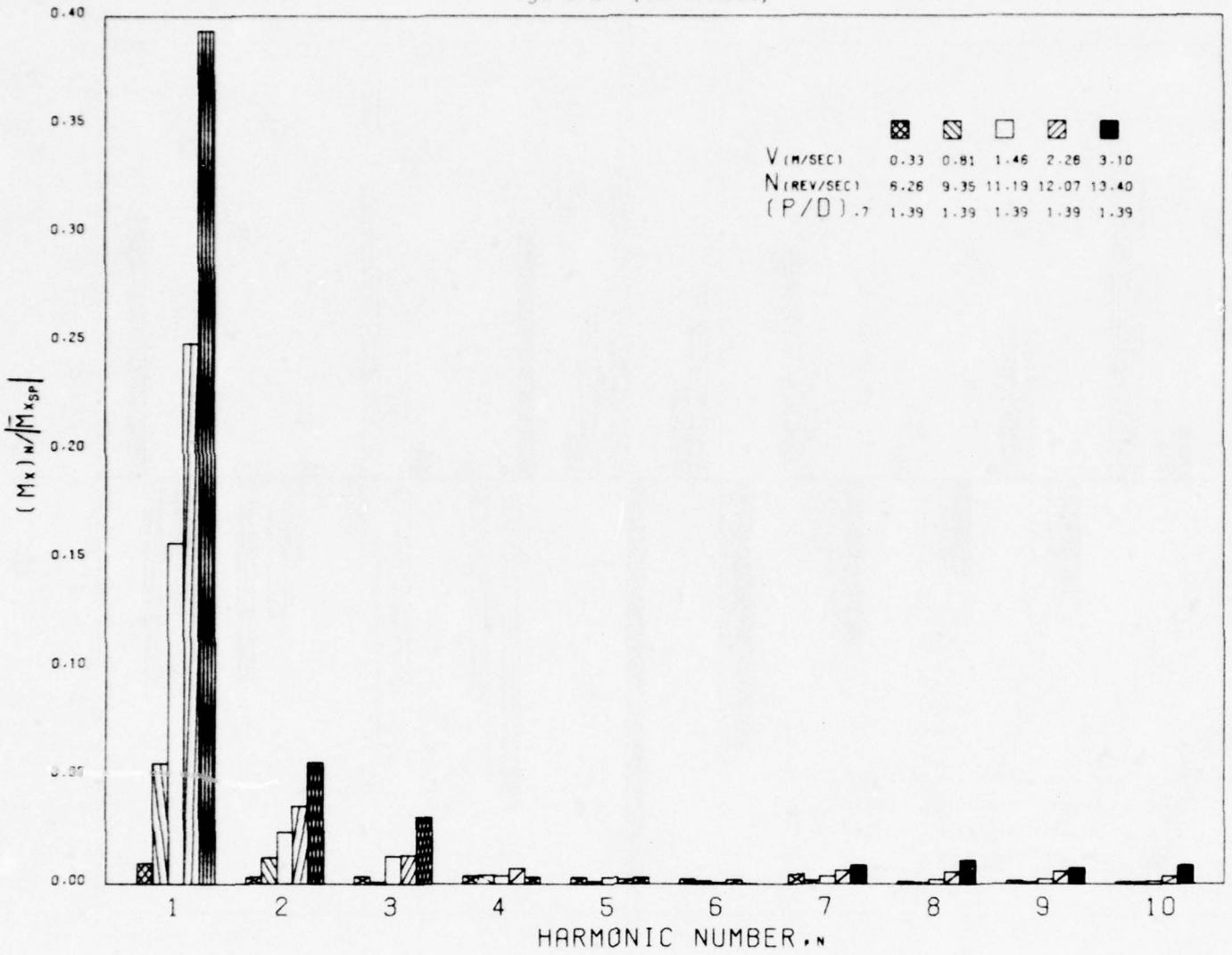



Figure 34 (Continued)

Figure 34 (Continued)



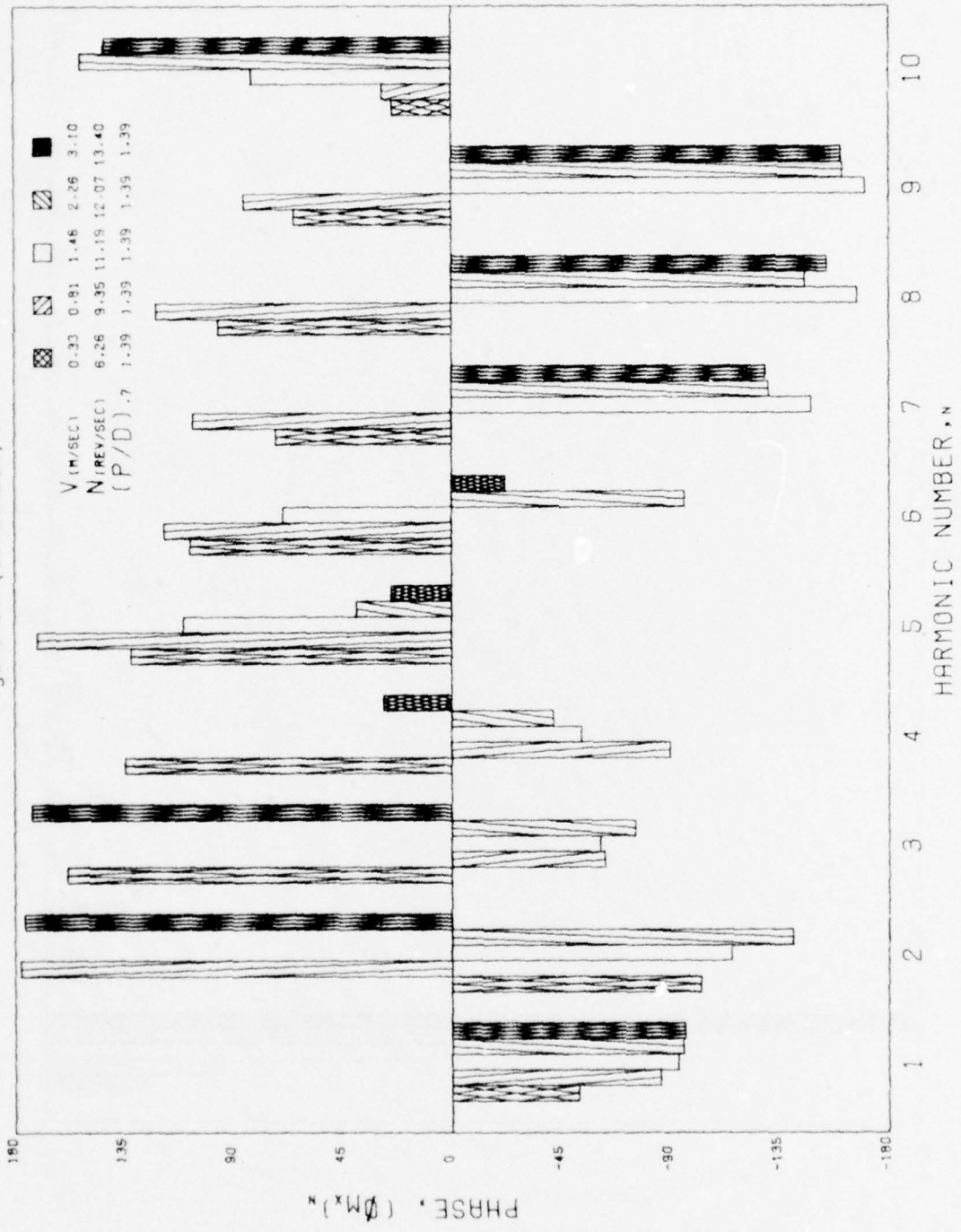



Figure 34 (Continued)

Figure 34 (Continued)

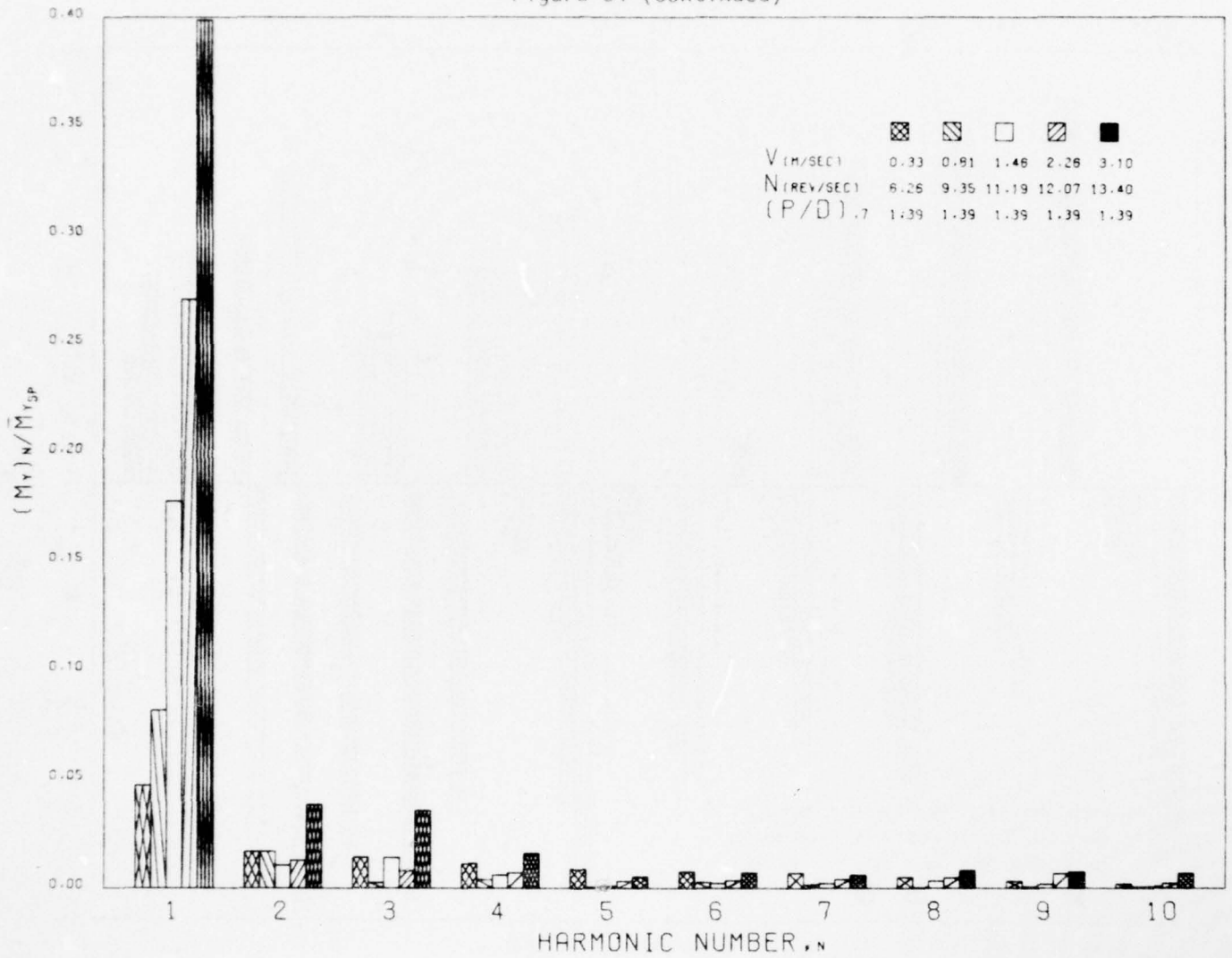


Figure 34 (Continued)

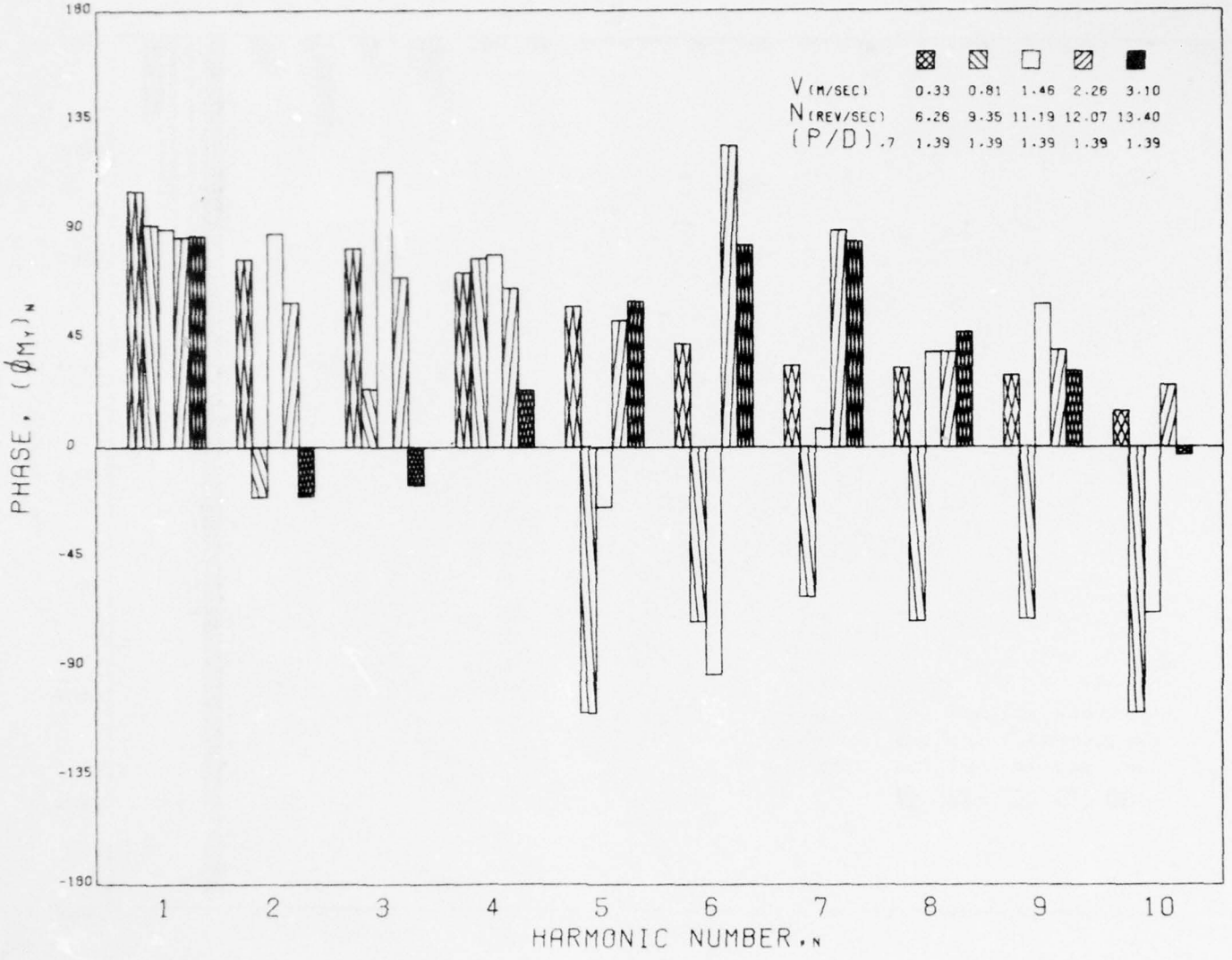


Figure 34 (Continued)

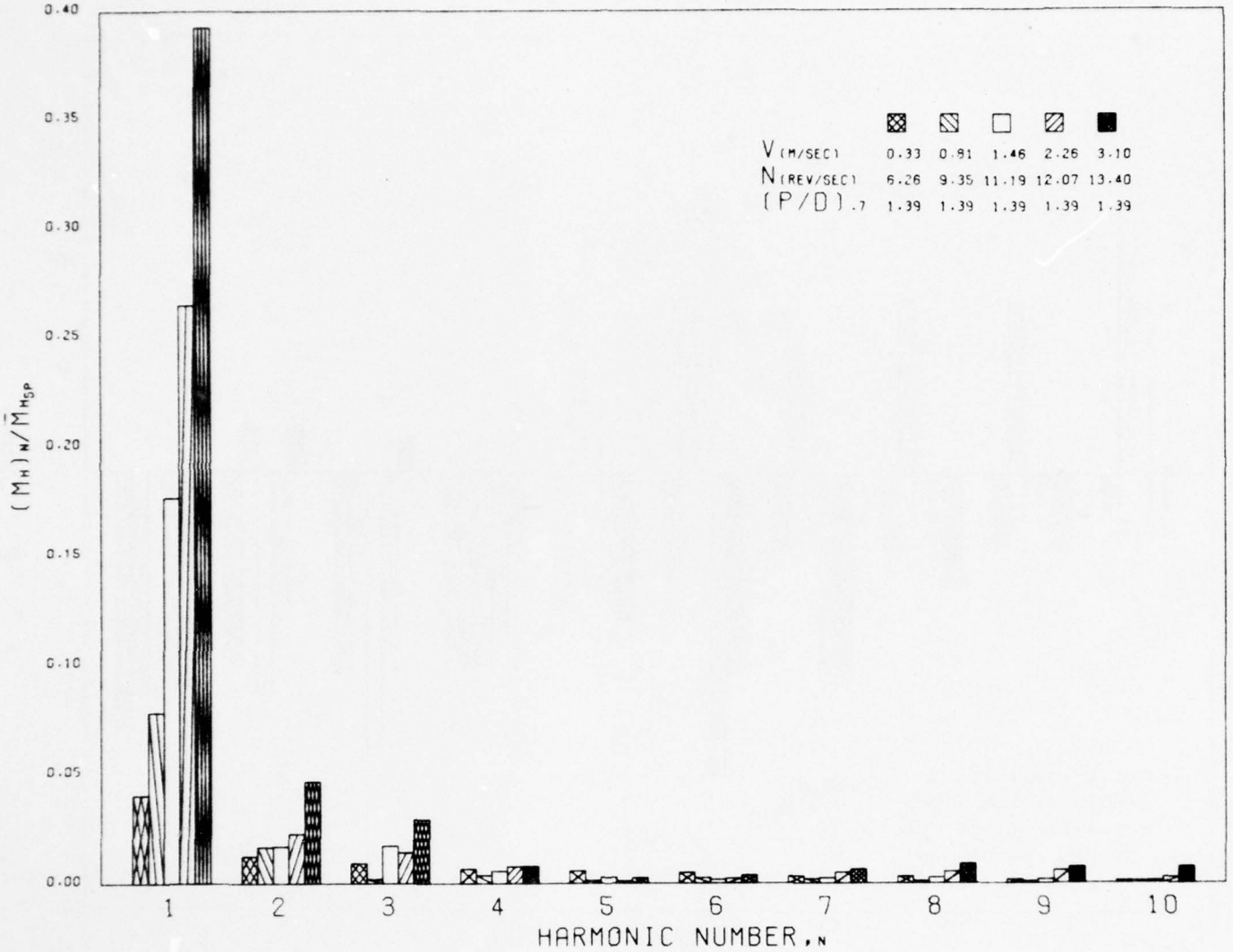


Figure 34 (Continued)

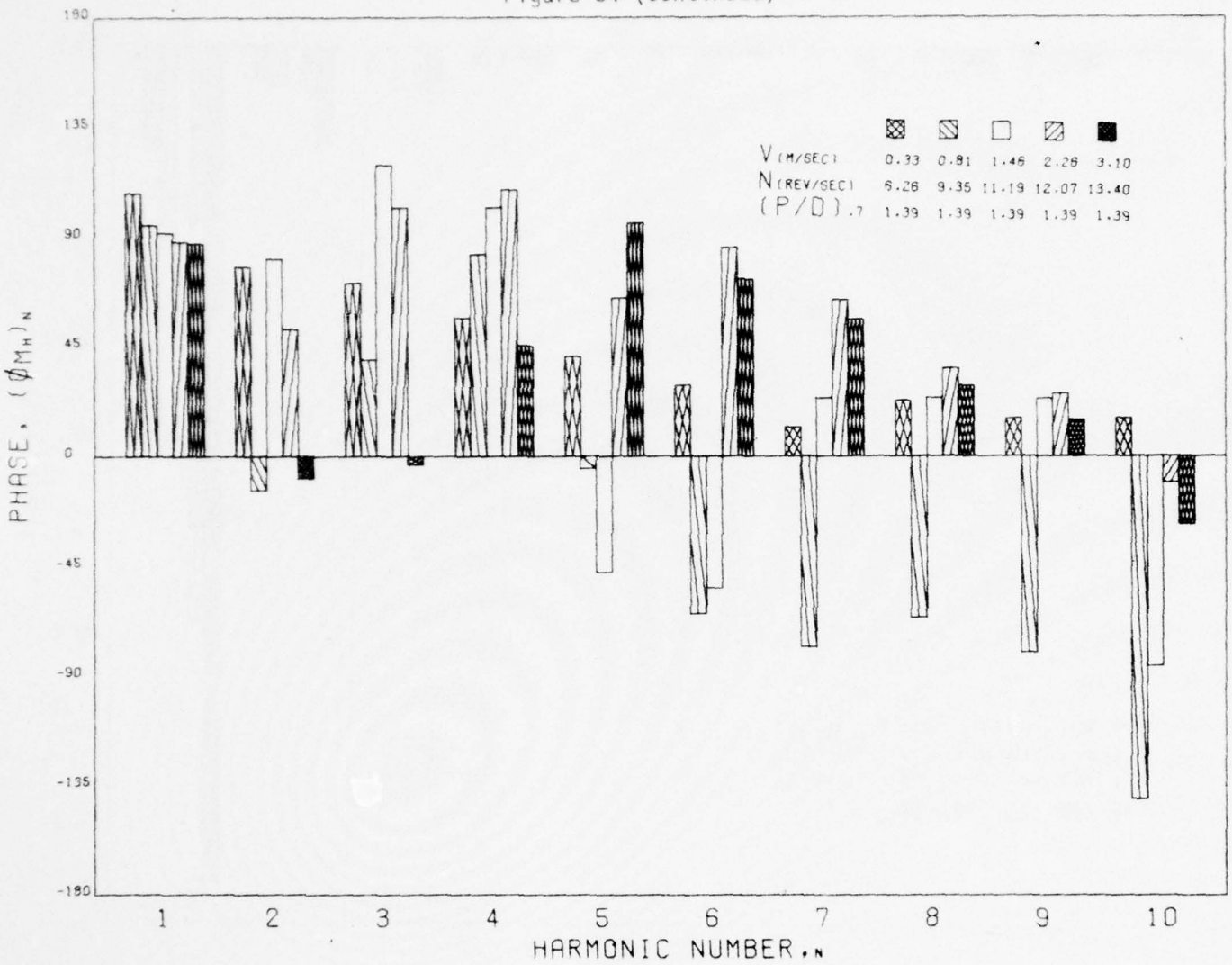


Figure 34 (Continued)

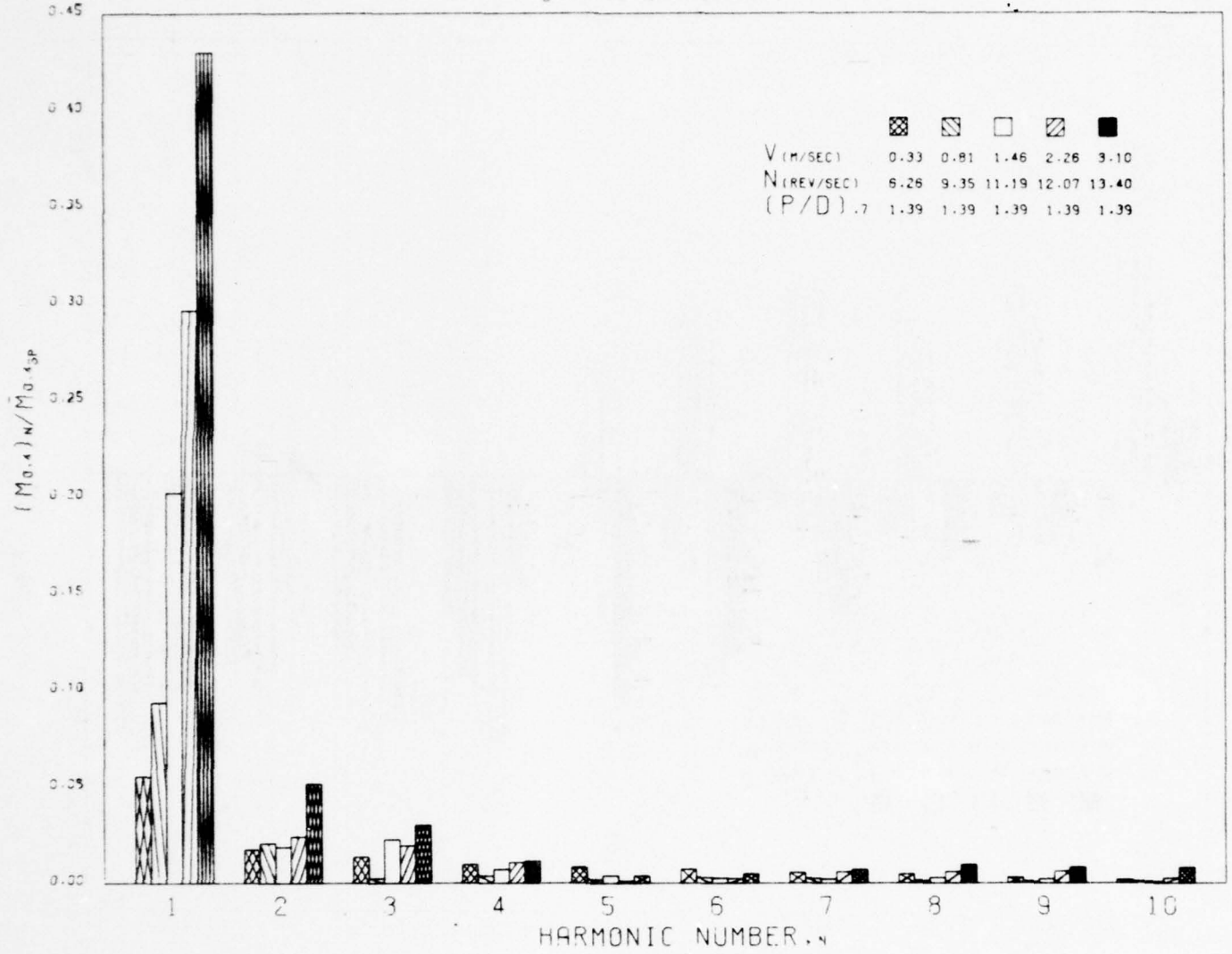


Figure 34 (Continued)

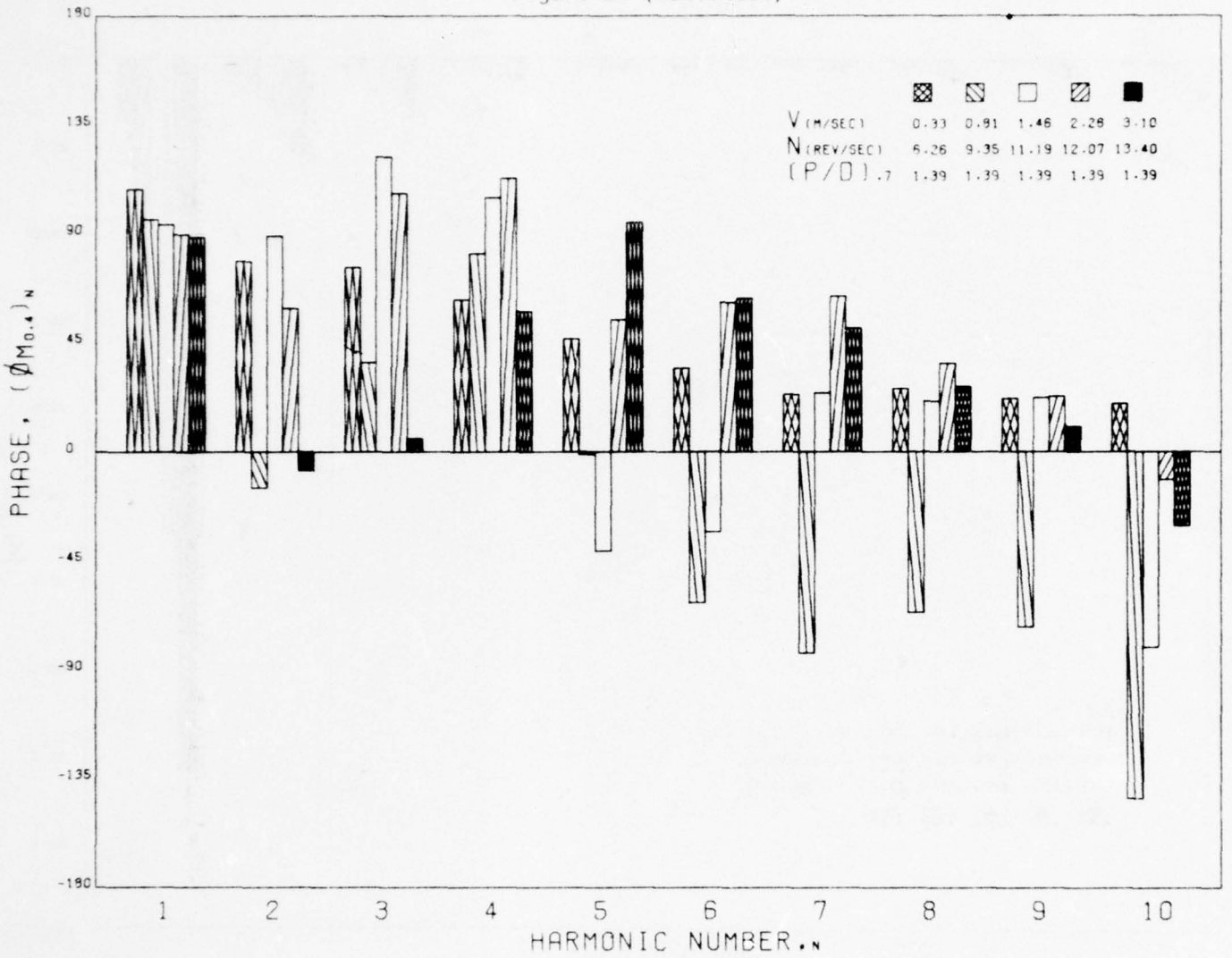
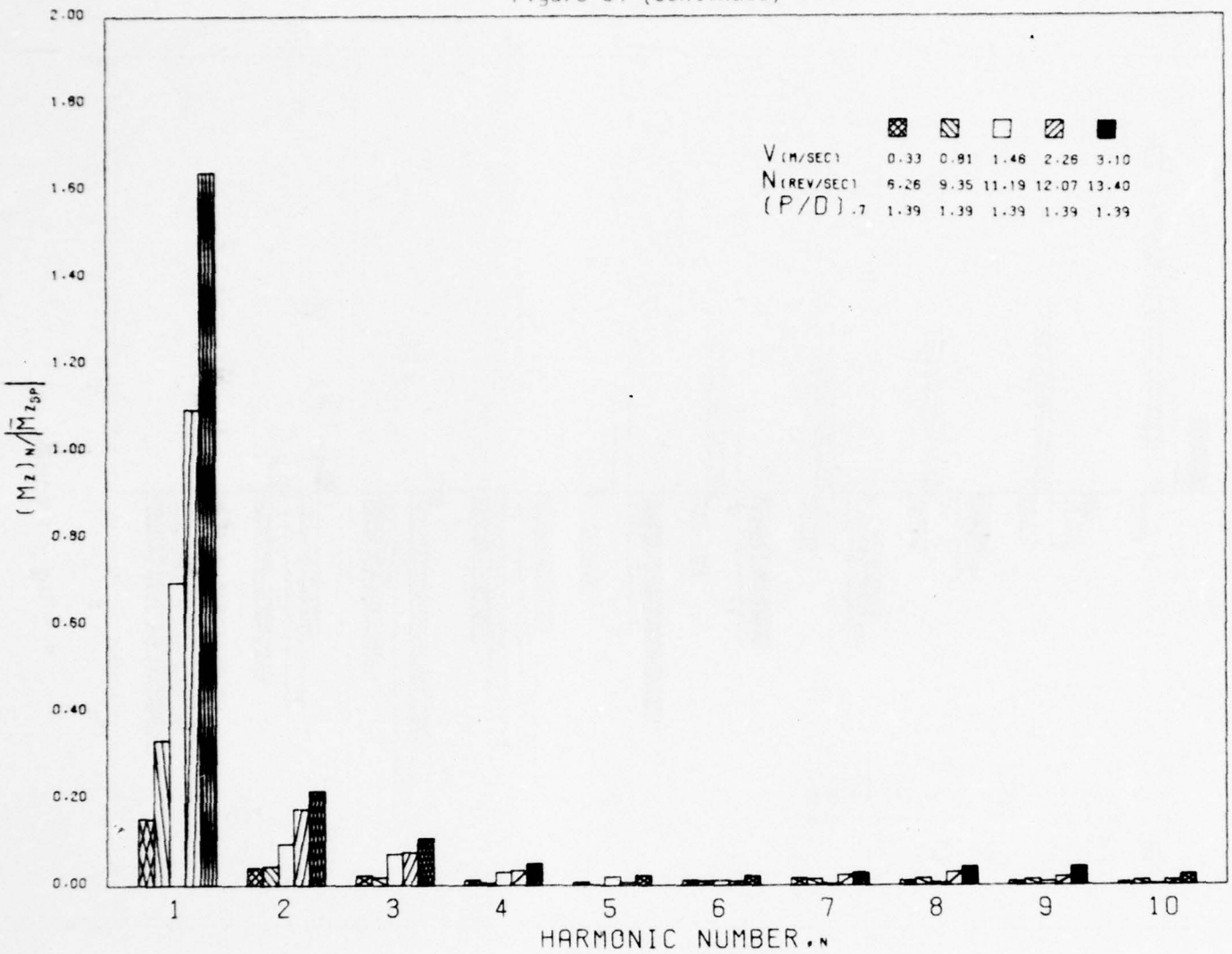


Figure 34 (Continued)



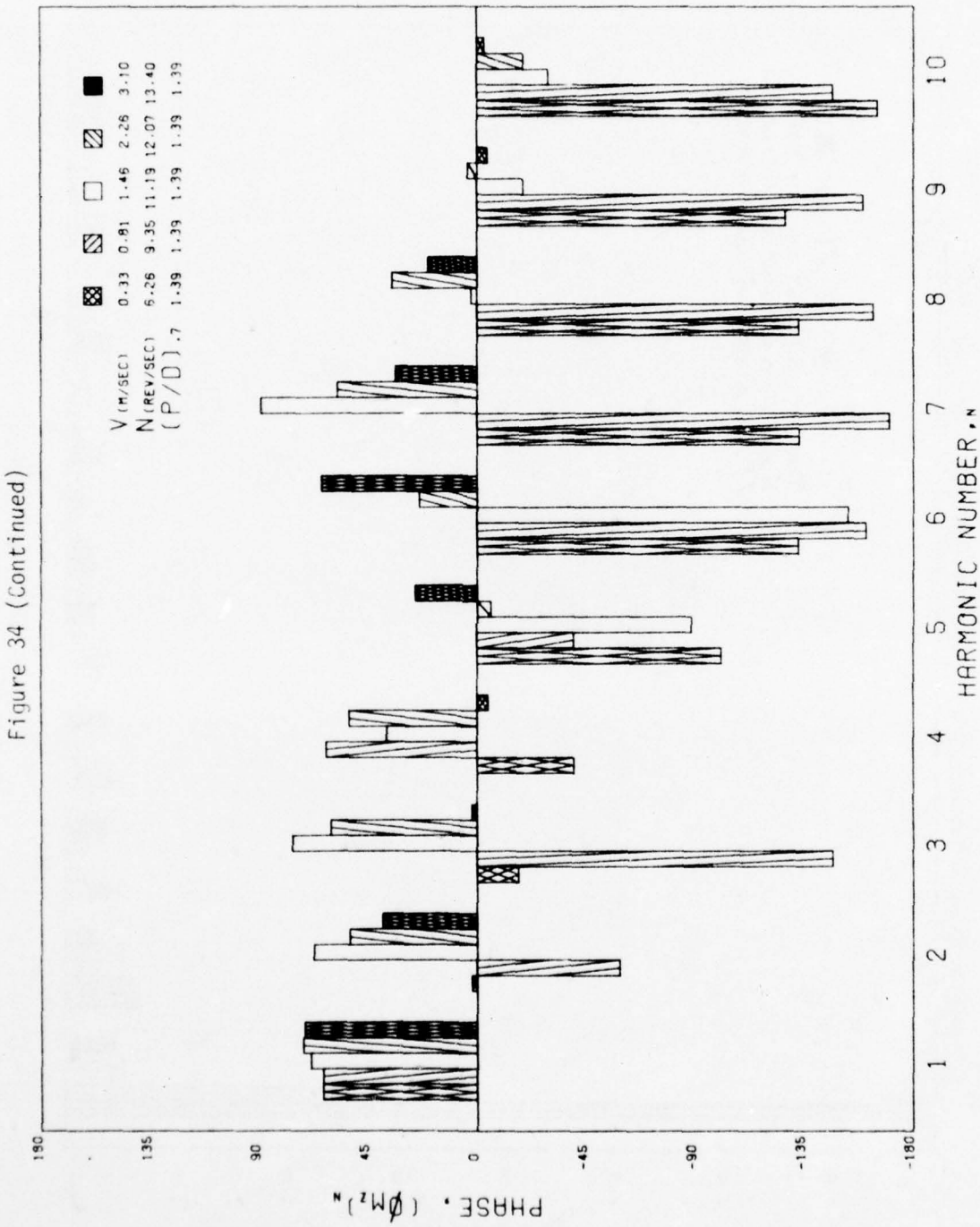
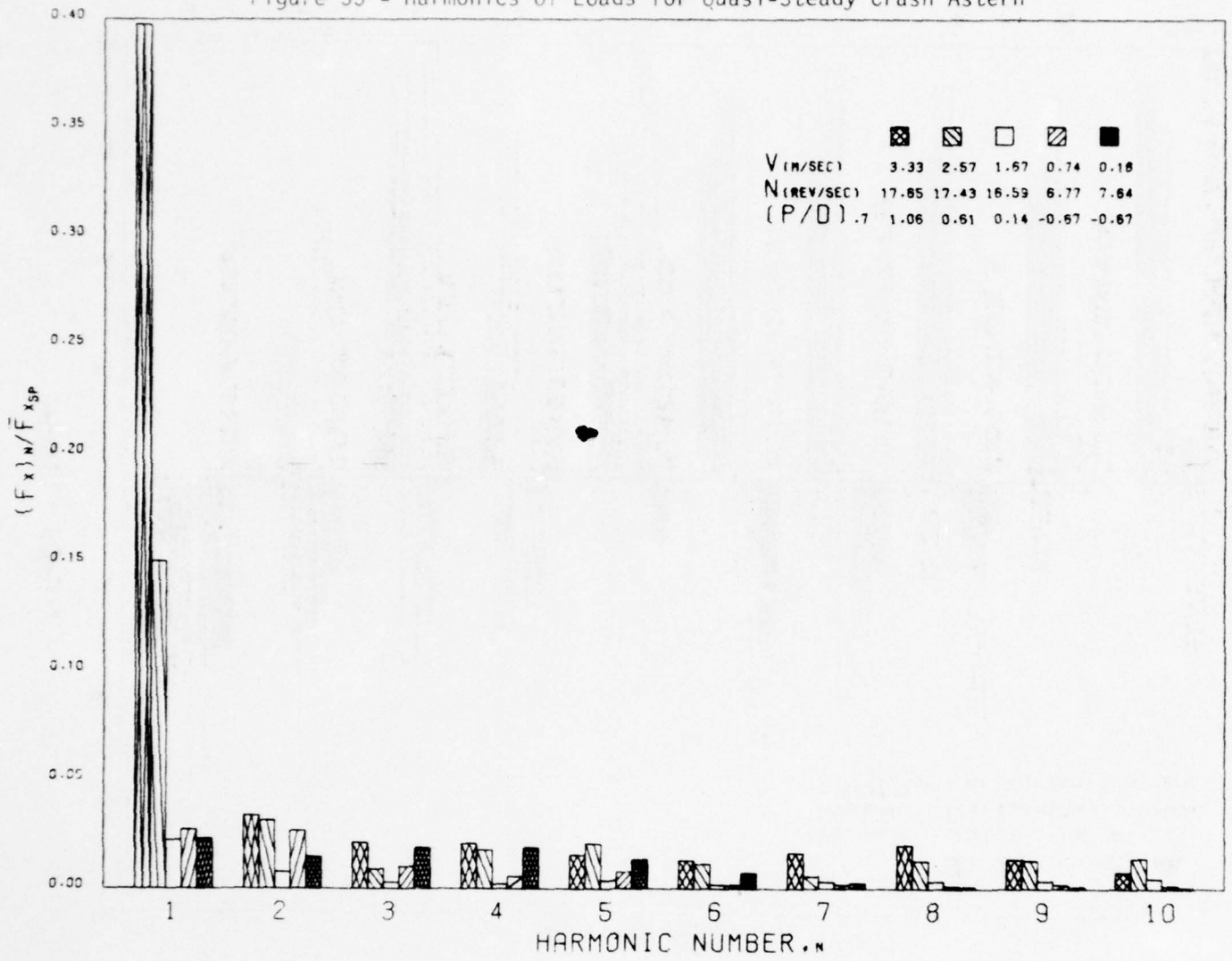



Figure 34 (Continued)

Figure 35 - Harmonics of Loads for Quasi-Steady Crash Astern



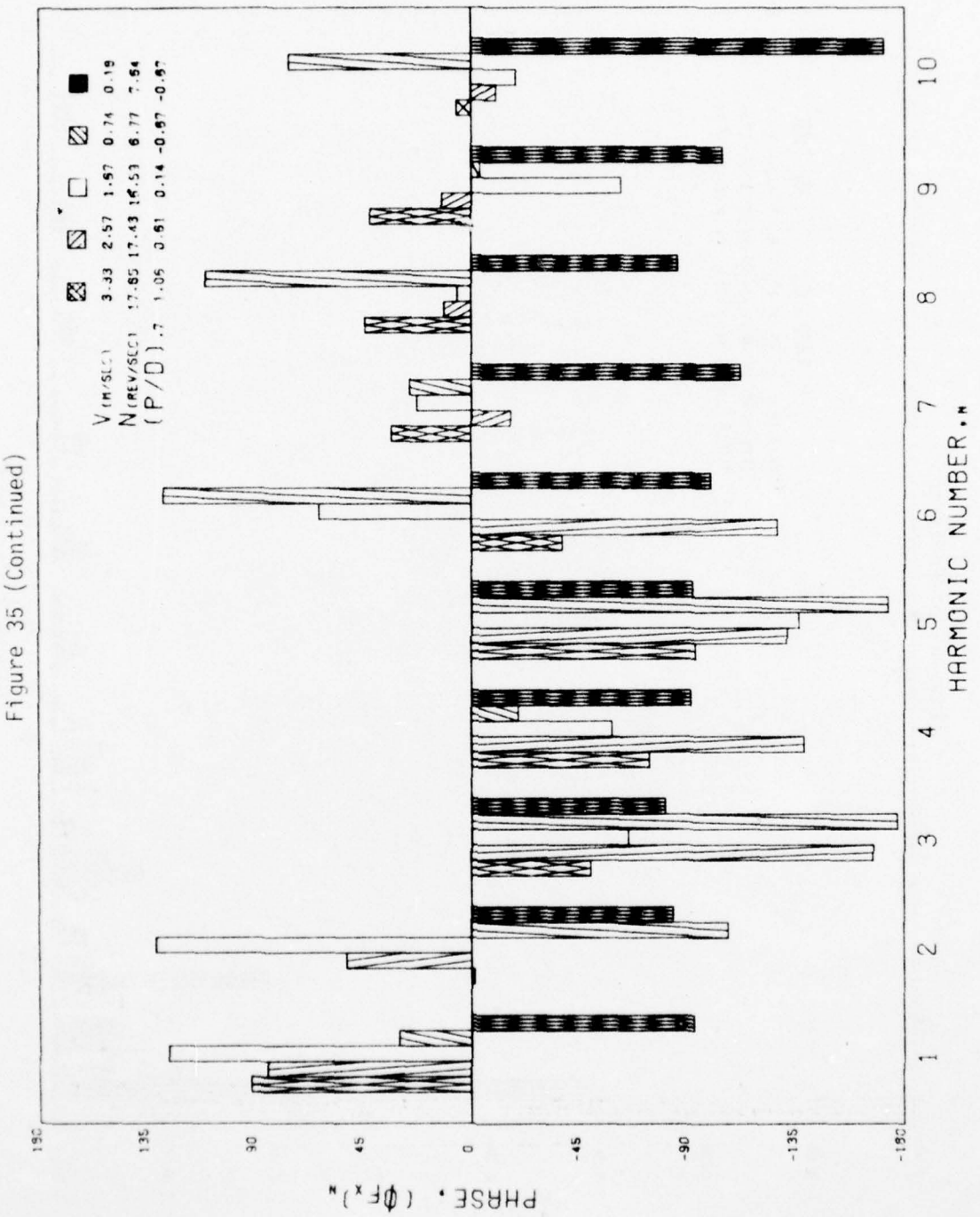



Figure 35 (Continued)

Figure 35 (Continued)

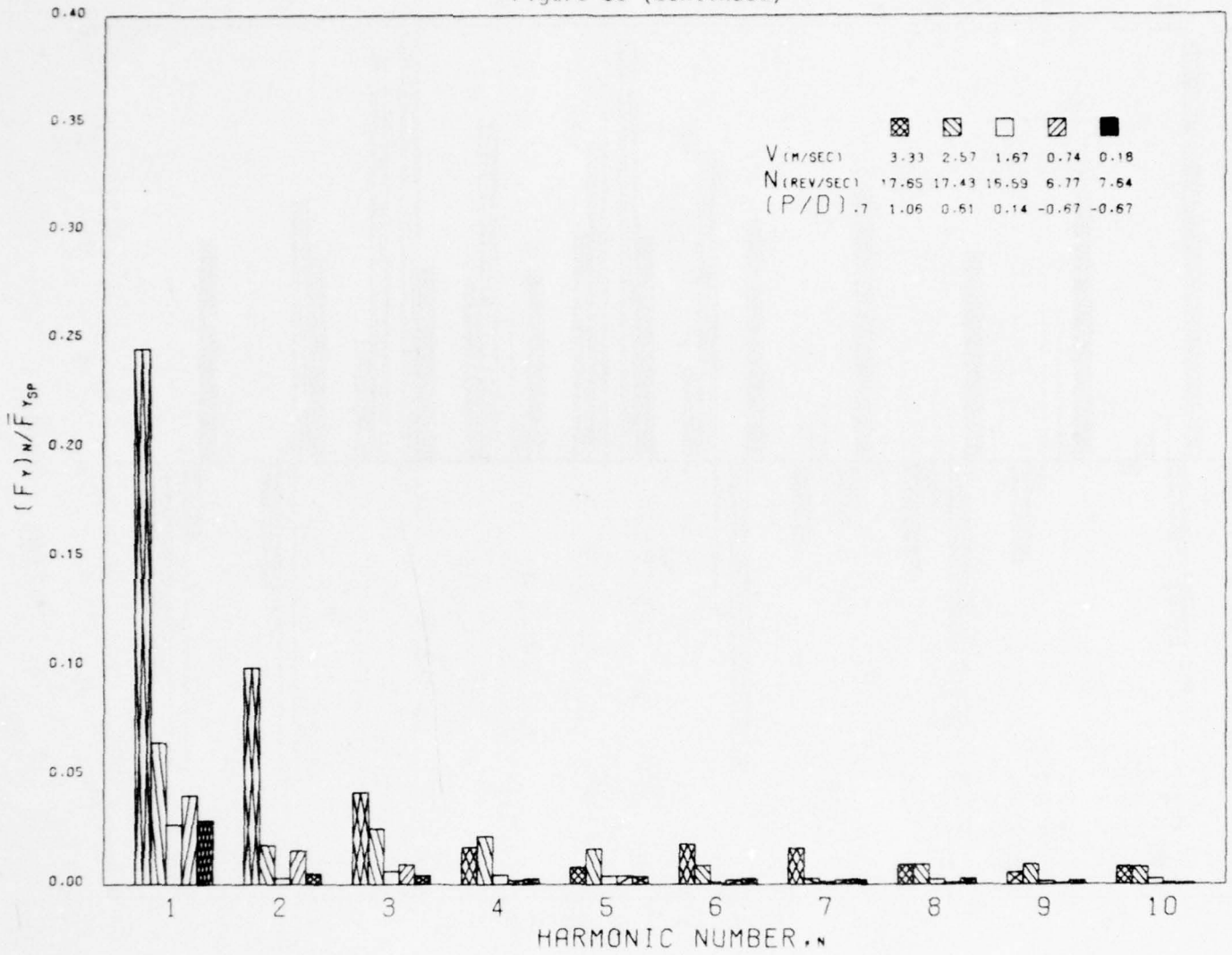


Figure 35 (Continued)

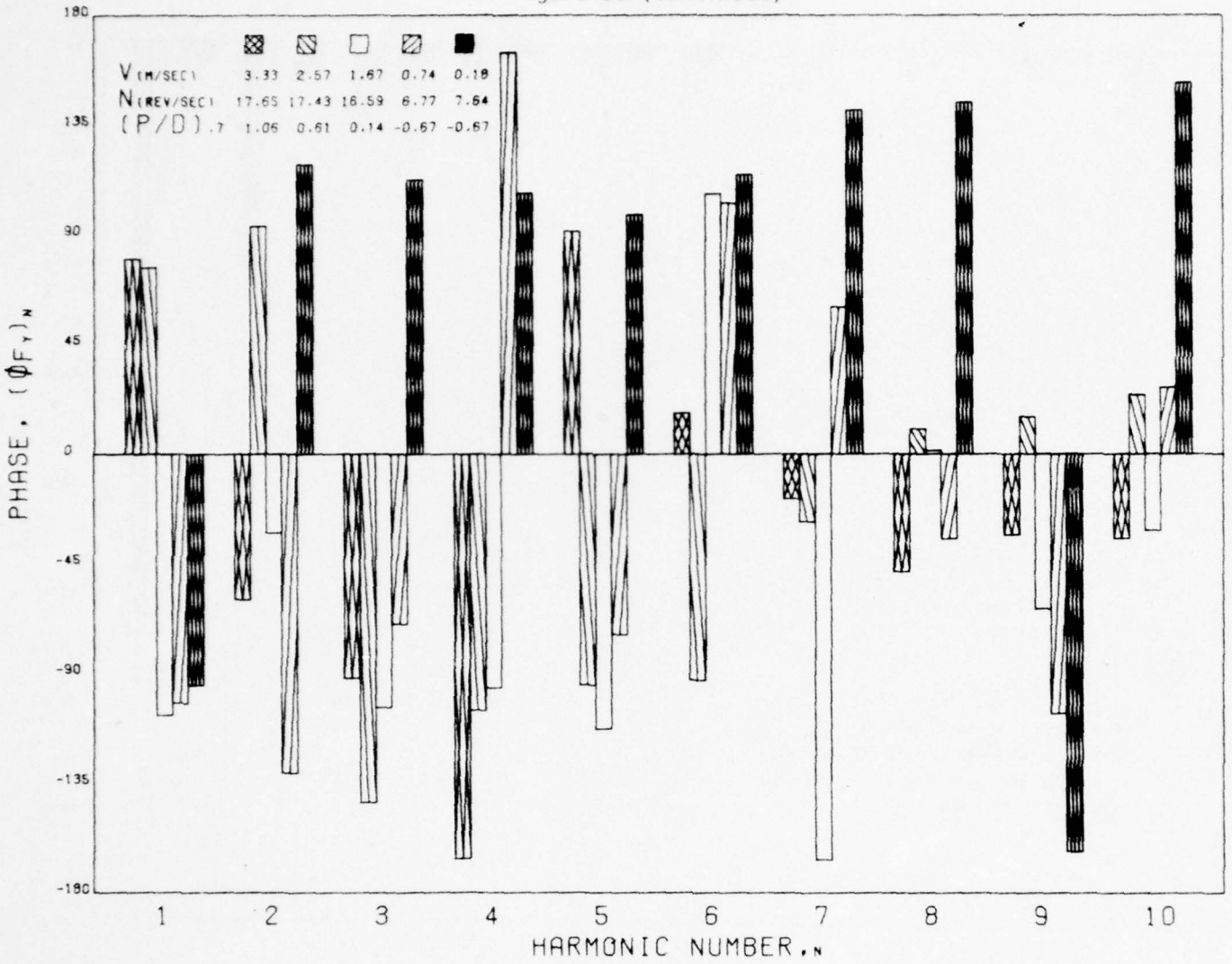
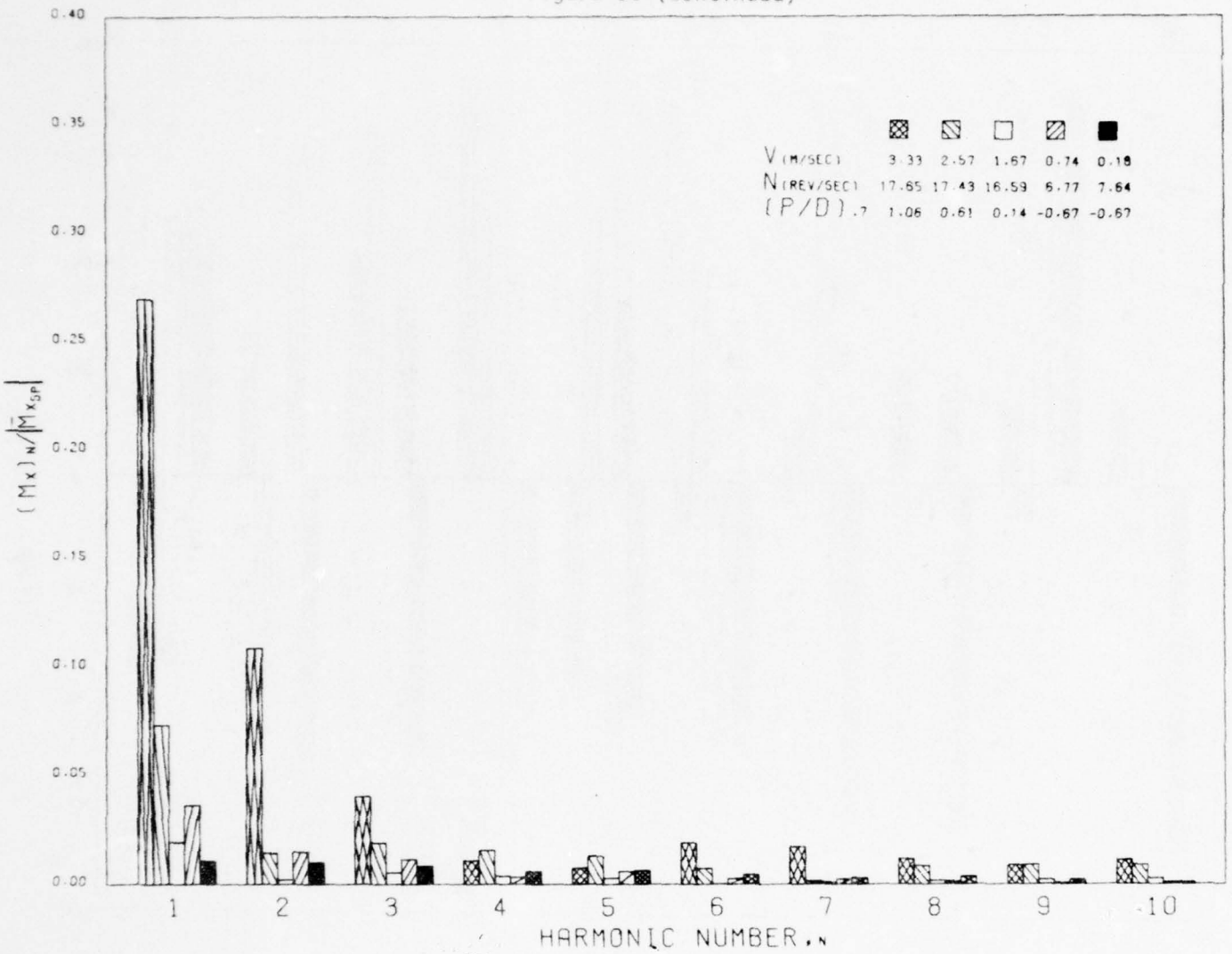


Figure 35 (Continued)



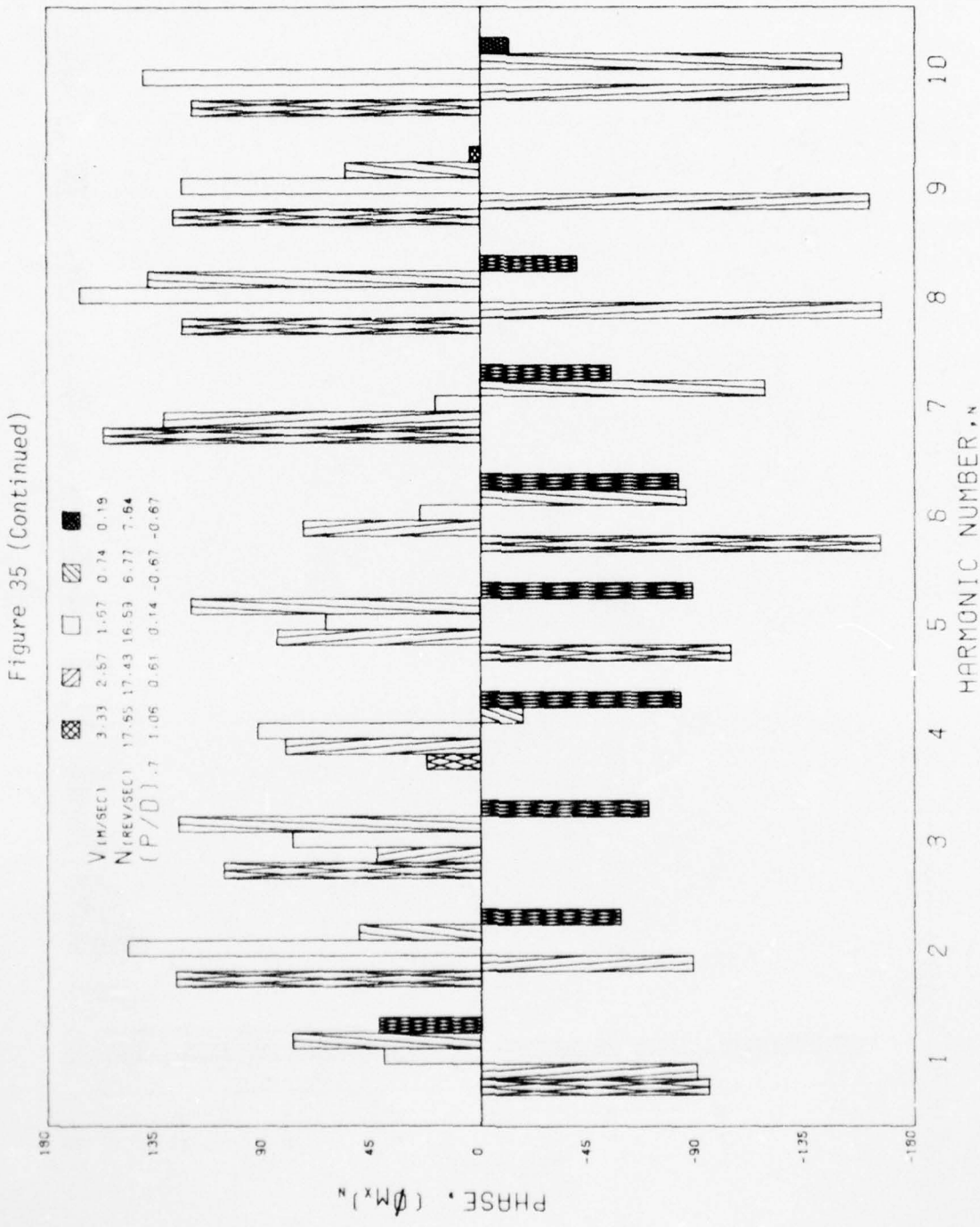
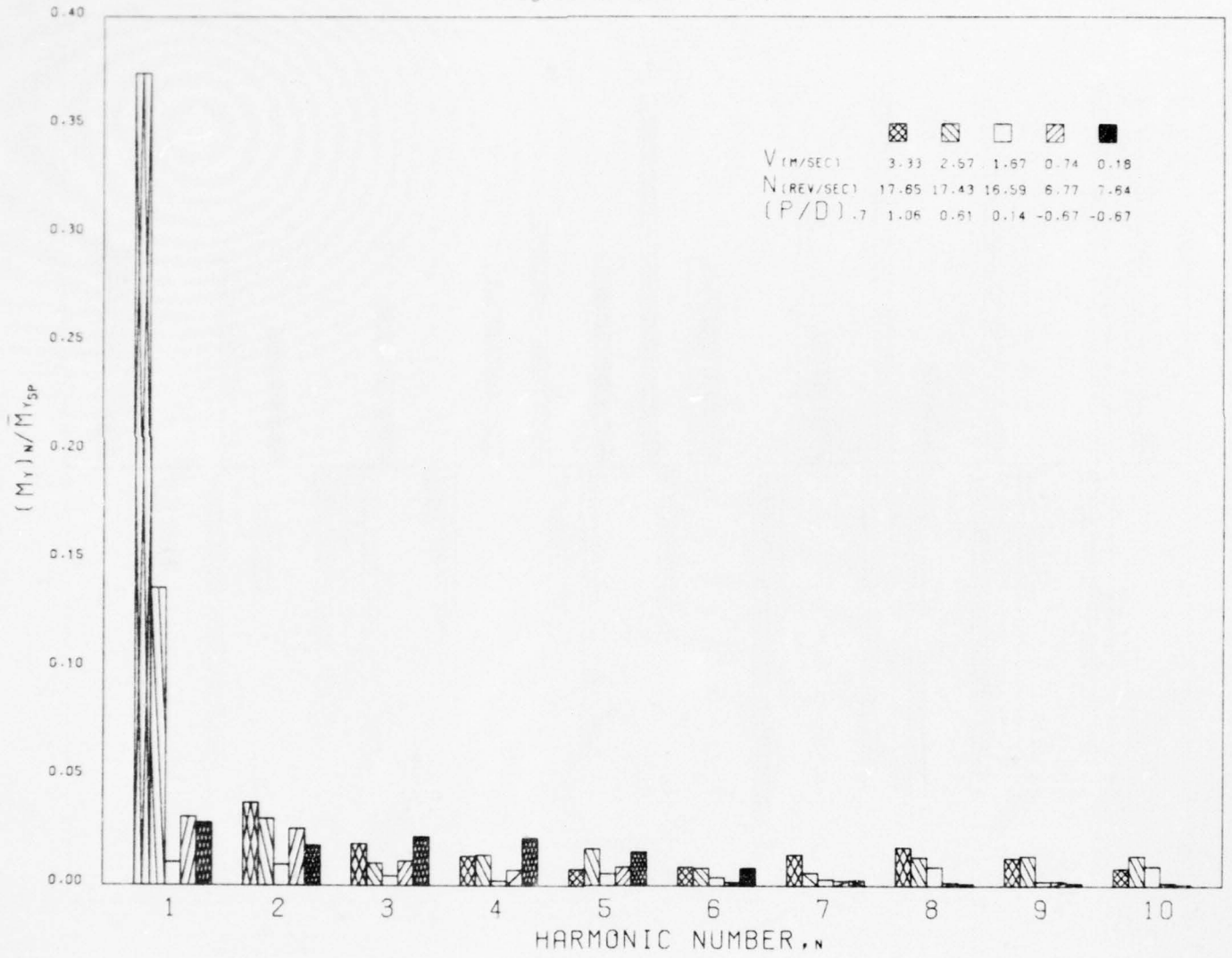



Figure 35 (Continued)

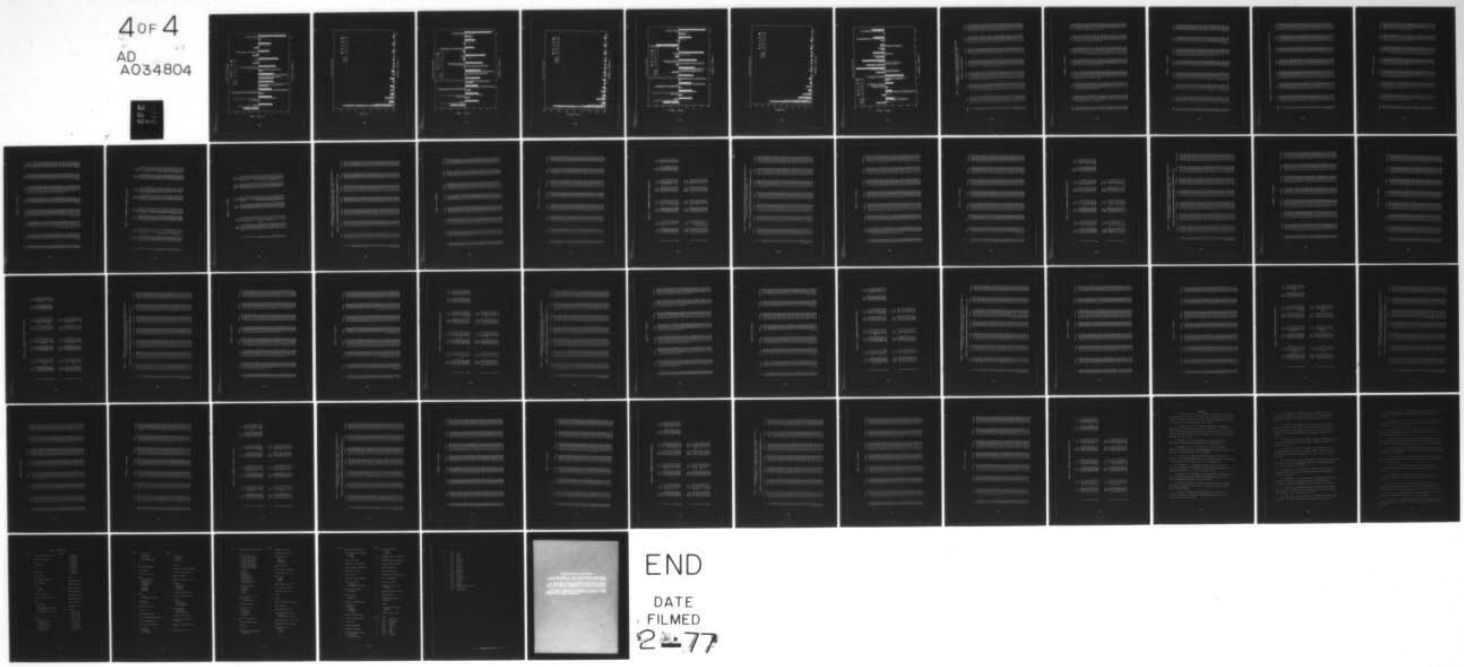
Figure 35 (Continued)



AD-A034 804 DAVID W TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CE--ETC F/G 13/10
EXPERIMENTAL UNSTEADY AND MEAN LOADS ON A CP PROPELLER BLADE ON--ETC(U)
OCT 76 R J BOSWELL, J J NELKA , S B DENNY

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Figure 35 (Continued)

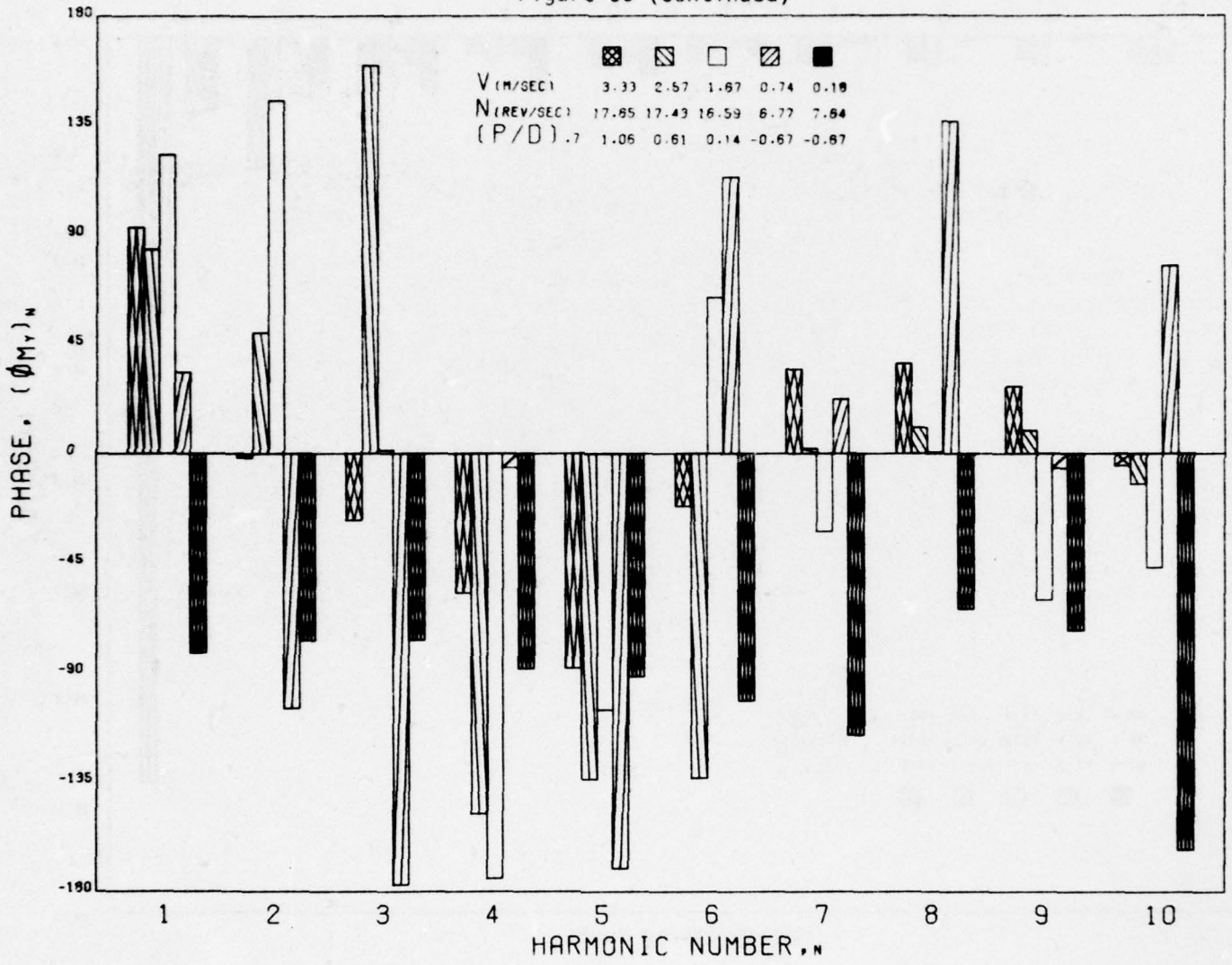


Figure 35 (Continued)

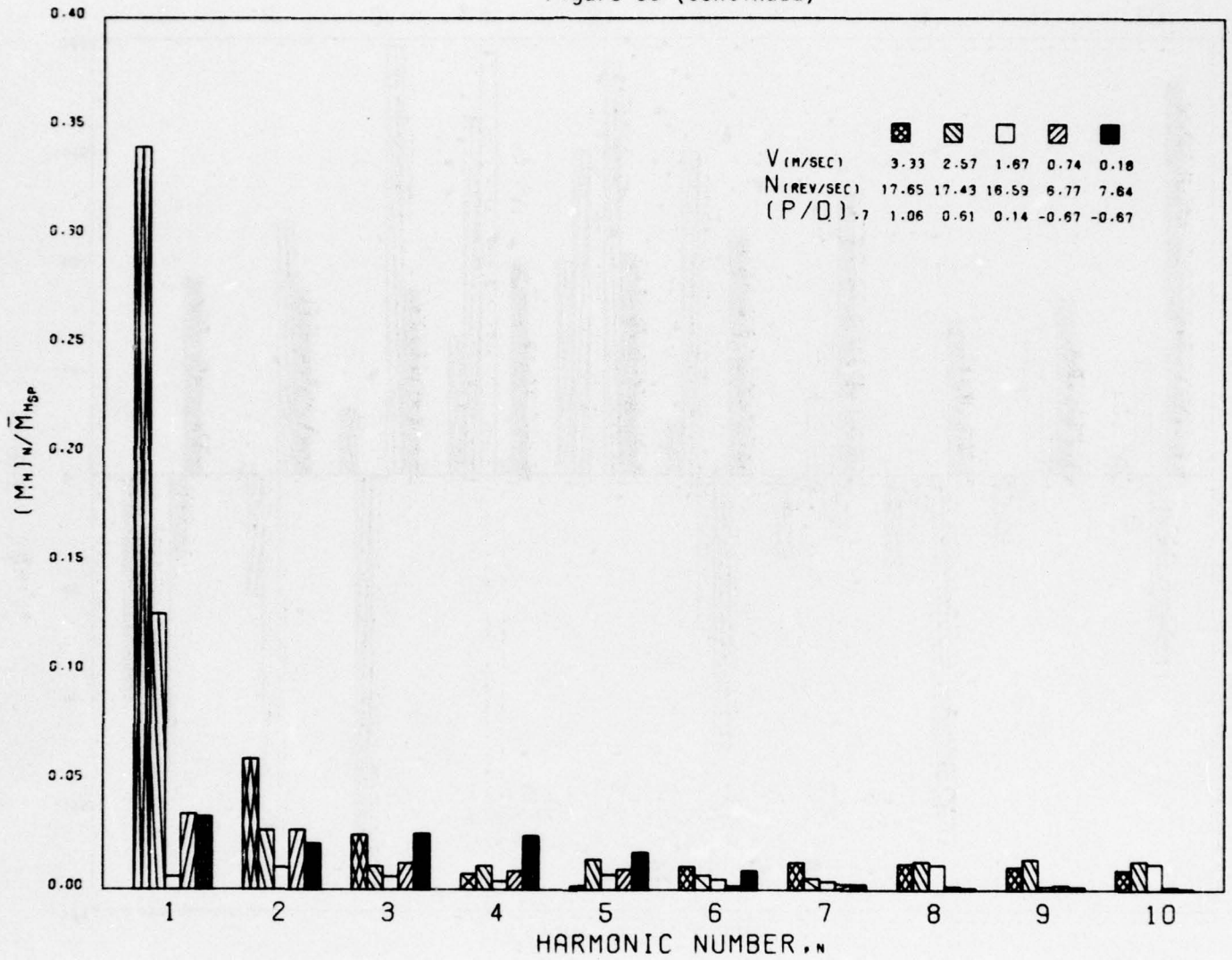


Figure 35 (Continued)

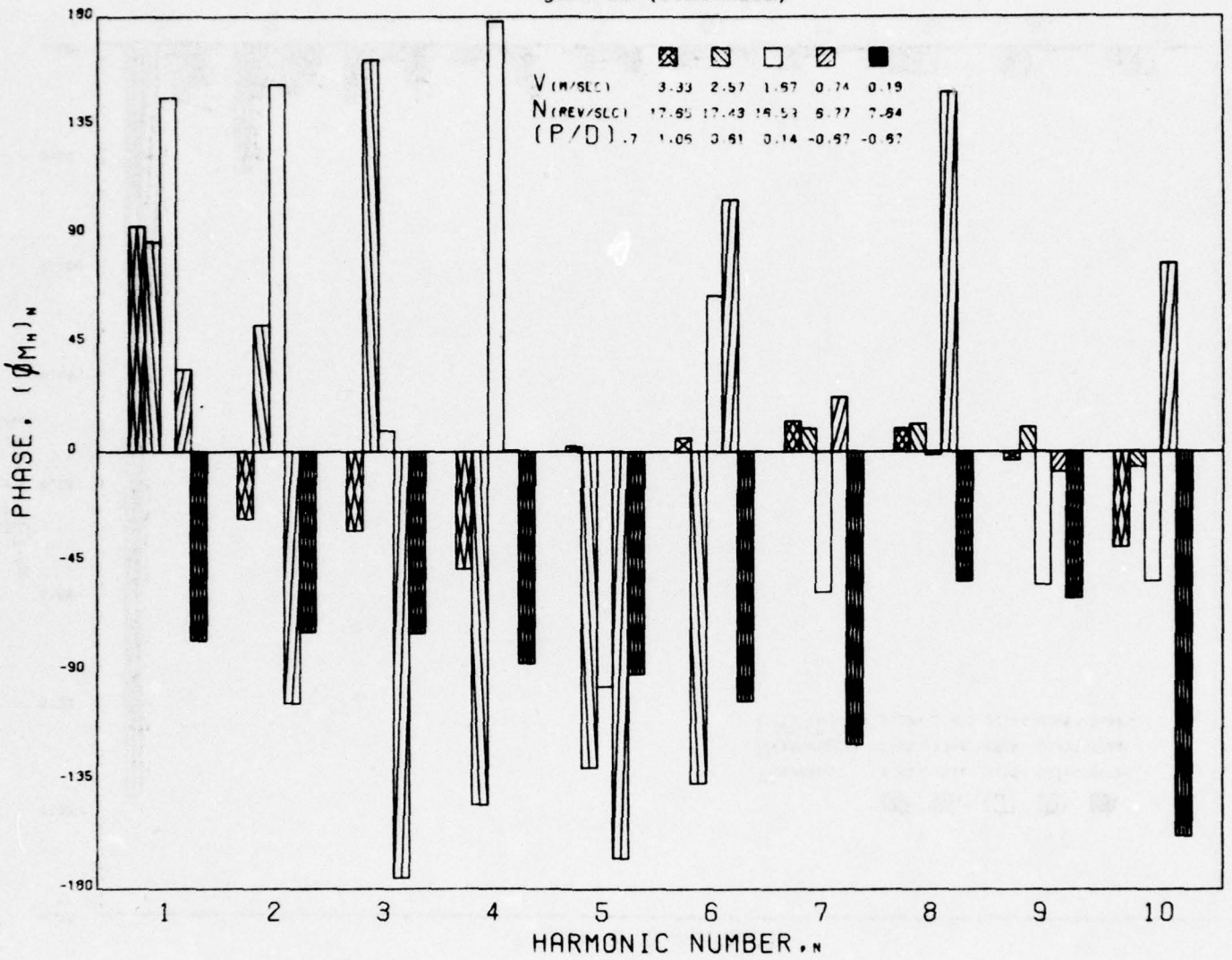


Figure 35 (Continued)

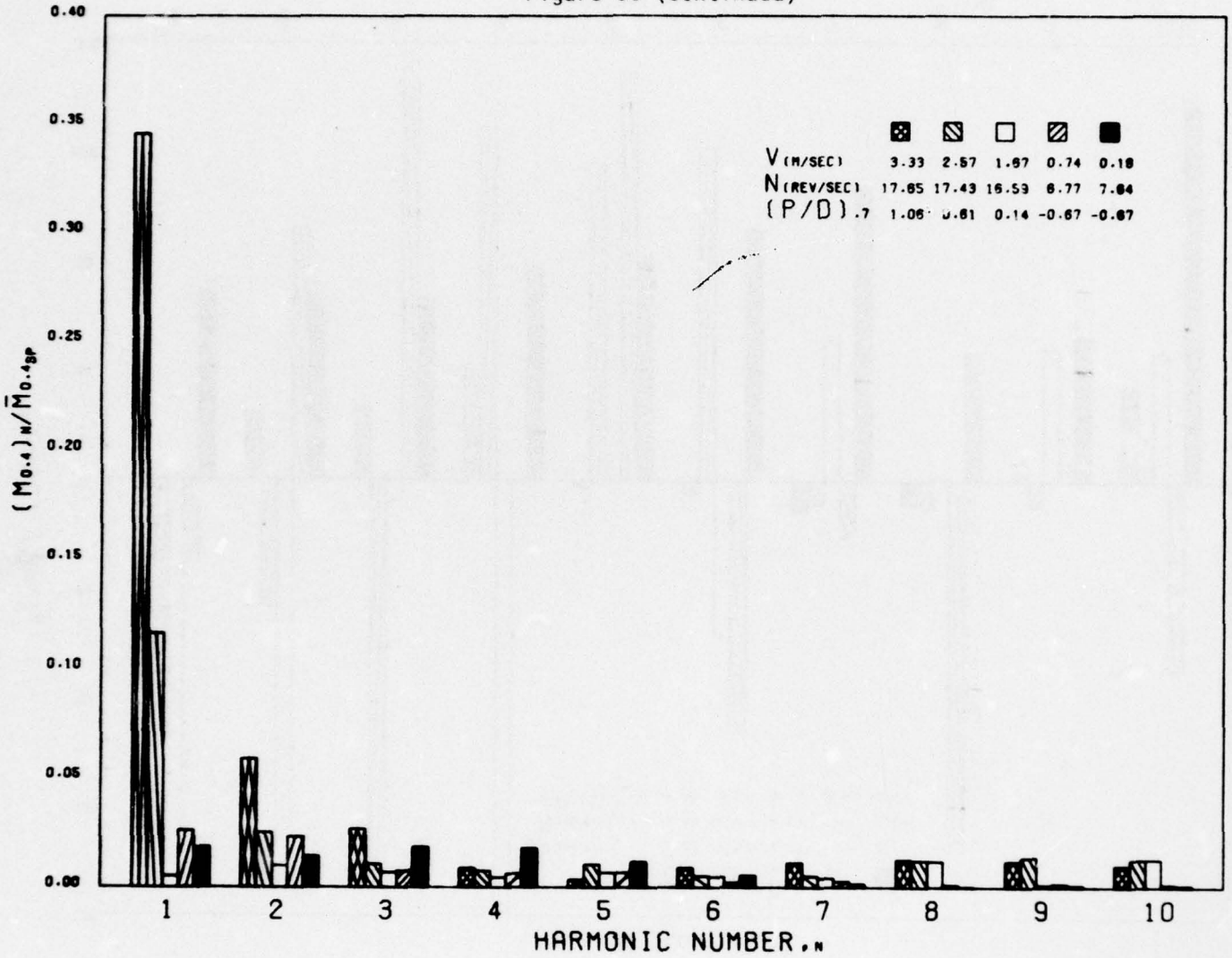


Figure 35 (Continued)

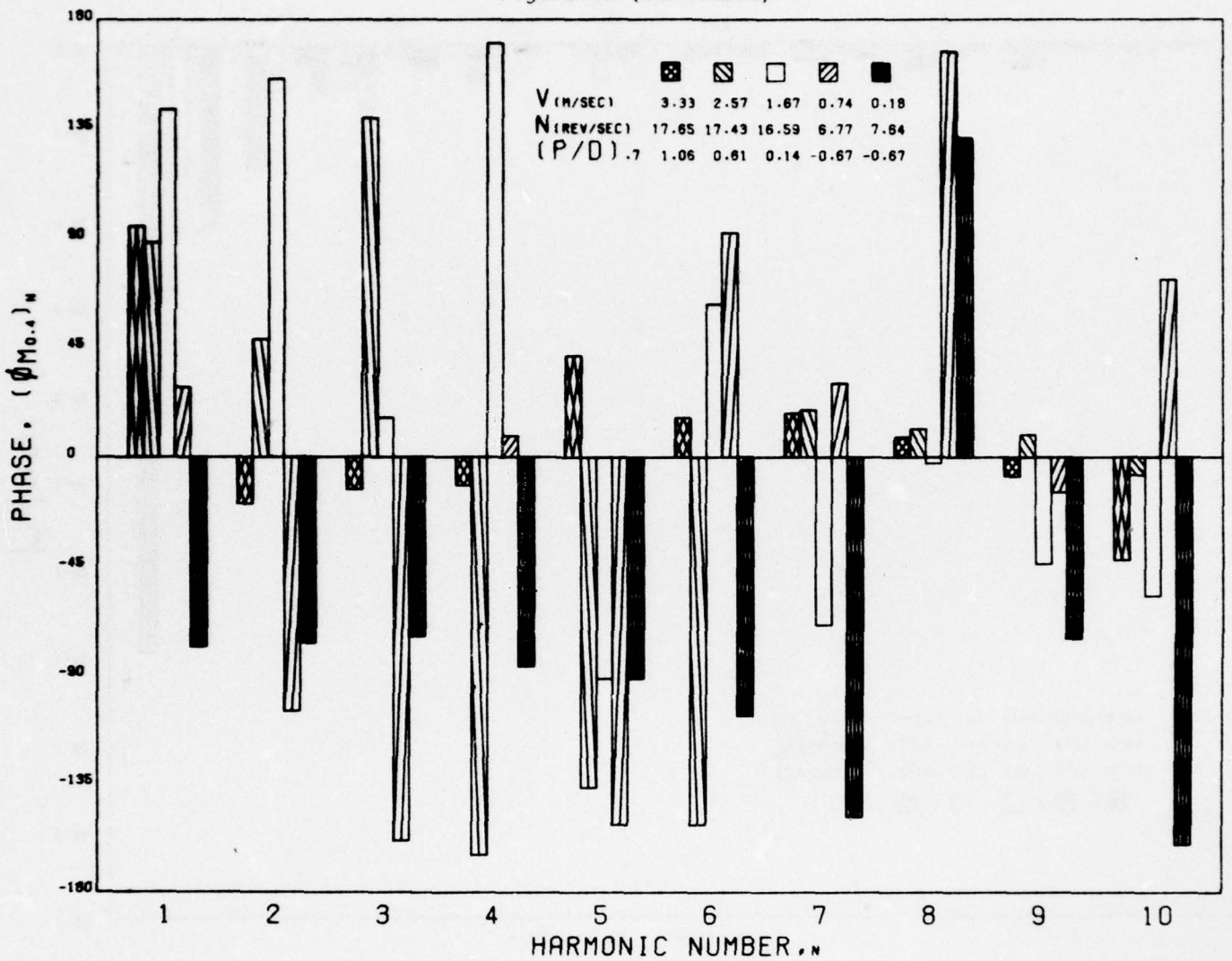


Figure 35 (Continued)

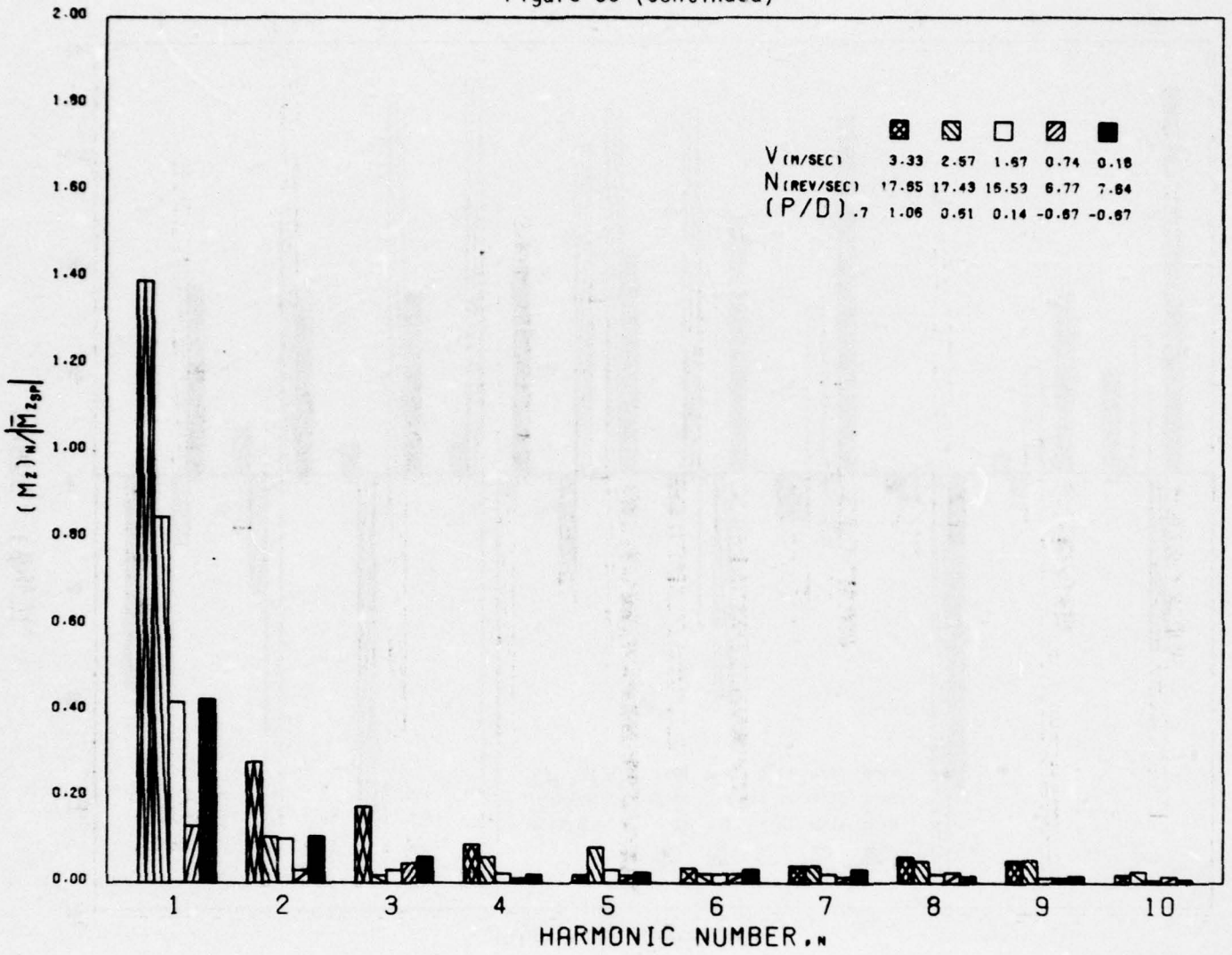
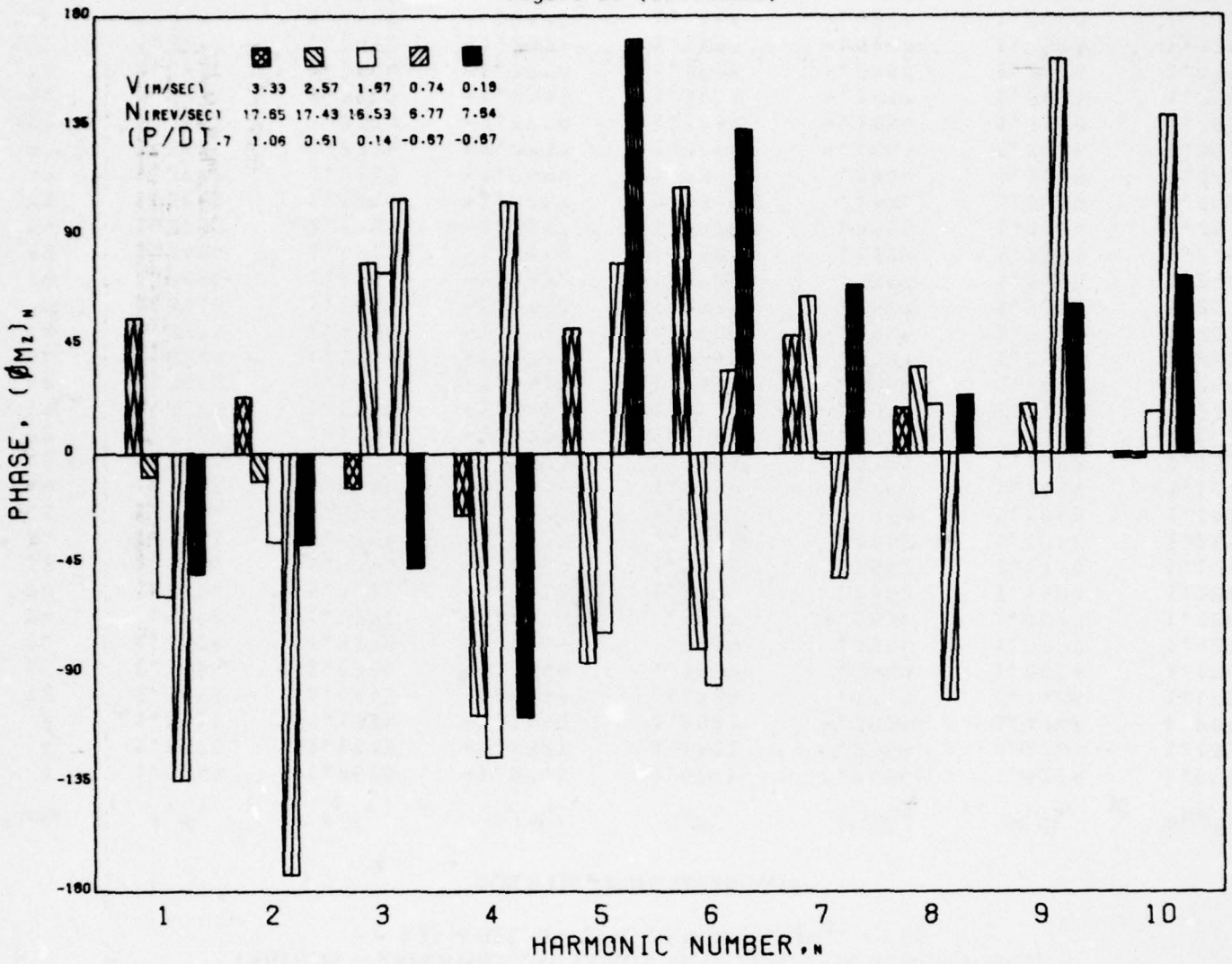


Figure 35 (Continued)



## TABLE 11 – EXPERIMENTAL LOADS NEAR SELF PROPULSION POINT. V = 3.33 M/SEC, n = 17.65 REV/SEC, $(P/D)_{0.7}$ = 1.06

### TABLE 11a – UNFILTERED DATA

| $\theta$ (deg) | $F_x/\bar{F}_x$ | $F_y/\bar{F}_y$ | $M_x/\lvert\bar{M}_x\rvert$ | $M_y/\bar{M}_y$ | $M_z/\lvert\bar{M}_z\rvert$ | $M_h/\bar{M}_h$ | $M_{0.4}/\bar{M}_{0.4}$ |
|---|---|---|---|---|---|---|---|
| 0 | 1.0249 | 1.0606 | -1.0741 | 1.0051 | .4454 | 1.0258 | 1.0157 |
| 4 | 1.0970 | 1.1035 | -1.1327 | 1.1011 | .2366 | 1.1264 | 1.1353 |
| 8 | 1.2017 | 1.1334 | -1.1463 | 1.2023 | -.3375 | 1.1942 | 1.2070 |
| 12 | 1.1653 | 1.0445 | -1.0449 | 1.1768 | -.1712 | 1.1466 | 1.1704 |
| 16 | 1.1004 | 1.0394 | -1.0546 | 1.0959 | .2740 | 1.0908 | 1.1001 |
| 20 | 1.0028 | 1.0239 | -1.0465 | .9979 | .0101 | 1.0222 | 1.0235 |
| 24 | .9902 | 1.0227 | -1.0475 | .9922 | -.0531 | 1.0223 | 1.0268 |
| 28 | 1.0794 | 1.0612 | -1.0912 | 1.0096 | .2852 | 1.1088 | 1.1240 |
| 32 | 1.1911 | 1.0944 | -1.1059 | 1.1945 | .2662 | 1.1775 | 1.1949 |
| 36 | 1.2582 | 1.0768 | -1.0727 | 1.2514 | .0412 | 1.1974 | 1.2159 |
| 40 | 1.2594 | 1.0997 | -1.1020 | 1.2323 | -.0913 | 1.1860 | 1.1906 |
| 44 | 1.2510 | 1.0954 | -1.0916 | 1.1989 | .2060 | 1.1464 | 1.1348 |
| 48 | 1.2550 | 1.1022 | -1.0933 | 1.2004 | .2391 | 1.1452 | 1.1313 |
| 52 | 1.3167 | 1.1252 | -1.1221 | 1.2541 | .0205 | 1.1898 | 1.1756 |
| 56 | 1.3778 | 1.1456 | -1.1421 | 1.3170 | .0072 | 1.2404 | 1.2314 |
| 60 | 1.3980 | 1.1468 | -1.1415 | 1.3446 | .3207 | 1.2622 | 1.2595 |
| 64 | 1.3808 | 1.1700 | -1.1721 | 1.3248 | .1087 | 1.2586 | 1.2507 |
| 68 | 1.3271 | 1.1756 | -1.1820 | 1.2775 | -.1040 | 1.2331 | 1.2236 |
| 72 | 1.3010 | 1.1644 | -1.1750 | 1.2571 | .1875 | 1.2206 | 1.2134 |
| 76 | 1.3098 | 1.1798 | -1.1926 | 1.2725 | .3759 | 1.2403 | 1.2366 |
| 80 | 1.3404 | 1.1922 | -1.2050 | 1.3101 | .1178 | 1.2735 | 1.2759 |
| 84 | 1.3790 | 1.2036 | -1.2117 | 1.3474 | .0066 | 1.2994 | 1.3033 |
| 88 | 1.3860 | 1.2084 | -1.2263 | 1.3518 | .1831 | 1.3089 | 1.3124 |
| 92 | 1.3772 | 1.2215 | -1.2494 | 1.3391 | .0944 | 1.3085 | 1.3083 |
| 96 | 1.3687 | 1.2224 | -1.2537 | 1.3294 | -.1668 | 1.3036 | 1.3021 |
| 100 | 1.3664 | 1.2333 | -1.2700 | 1.3284 | -.1984 | 1.3108 | 1.3093 |
| 104 | 1.3734 | 1.2513 | -1.2865 | 1.3409 | -.1852 | 1.3260 | 1.3265 |
| 108 | 1.3820 | 1.2404 | -1.2750 | 1.3525 | -.2960 | 1.3316 | 1.3359 |
| 112 | 1.3773 | 1.2482 | -1.2821 | 1.3496 | -.4163 | 1.3323 | 1.3363 |
| 116 | 1.3606 | 1.2461 | -1.2875 | 1.3348 | -.4251 | 1.3269 | 1.3312 |
| 120 | 1.3386 | 1.2365 | -1.2814 | 1.3119 | -.4862 | 1.3099 | 1.3127 |

TABLE 11a – (Continued)

| $\theta$ (deg) | $F_x/\bar{F}_x$ | $F_y/\bar{F}_y$ | $M_x/\lvert\bar{M}_x\rvert$ | $M_y/\bar{M}_y$ | $M_z/\lvert\bar{M}_z\rvert$ | $M_h/\bar{M}_h$ | $M_{0.4}/\bar{M}_{0.4}$ |
|---|---|---|---|---|---|---|---|
| 124 | 1.3167 | 1.2379 | -1.2898 | 1.2950 | -.6555 | 1.3052 | 1.3093 |
| 128 | 1.3035 | 1.2313 | -1.2857 | 1.2877 | -.7566 | 1.3023 | 1.3096 |
| 132 | 1.2940 | 1.2190 | -1.2707 | 1.2813 | -.7690 | 1.2937 | 1.3029 |
| 136 | 1.2801 | 1.2052 | -1.2541 | 1.2693 | -.8323 | 1.2803 | 1.2903 |
| 140 | 1.2628 | 1.1871 | -1.2347 | 1.2522 | -.9141 | 1.2621 | 1.2723 |
| 144 | 1.2415 | 1.1716 | -1.2180 | 1.2310 | -.9579 | 1.2419 | 1.2513 |
| 148 | 1.2155 | 1.1576 | -1.2059 | 1.2065 | -1.0363 | 1.2224 | 1.2317 |
| 152 | 1.1969 | 1.1418 | -1.1924 | 1.1912 | -1.1461 | 1.2039 | 1.2212 |
| 156 | 1.1819 | 1.1208 | -1.1696 | 1.1789 | -1.2233 | 1.1952 | 1.2088 |
| 160 | 1.1694 | 1.1033 | -1.1492 | 1.1655 | -1.2684 | 1.1782 | 1.1913 |
| 164 | 1.1463 | 1.0826 | -1.1301 | 1.1445 | -1.3476 | 1.1593 | 1.1735 |
| 168 | 1.1153 | 1.0596 | -1.1044 | 1.1114 | -1.4219 | 1.1266 | 1.1385 |
| 172 | 1.0863 | 1.0403 | -1.0813 | 1.0827 | -1.5111 | 1.0985 | 1.1092 |
| 176 | 1.0628 | 1.0224 | -1.0568 | 1.0612 | -1.5982 | 1.0749 | 1.0858 |
| 180 | 1.0441 | 1.0023 | -1.0375 | 1.0441 | -1.6427 | 1.0579 | 1.0698 |
| 184 | 1.0264 | .9752 | -1.0101 | 1.0306 | -1.6912 | 1.0421 | 1.0576 |
| 188 | .9926 | .9615 | -.9866 | .9970 | -1.7698 | 1.0084 | 1.0209 |
| 192 | .9473 | .9353 | -.9617 | .9517 | -1.7971 | .9696 | .9803 |
| 196 | .9074 | .9003 | -.9287 | .9127 | -1.8294 | .9336 | .9445 |
| 200 | .8759 | .8827 | -.9059 | .8847 | -1.9314 | .9070 | .9181 |
| 204 | .8648 | .8666 | -.8836 | .8751 | -2.0076 | .8922 | .9042 |
| 208 | .8508 | .8488 | -.8617 | .8625 | -2.0301 | .8760 | .8889 |
| 212 | .8254 | .8282 | -.8359 | .8373 | -2.0601 | .8491 | .8610 |
| 216 | .7918 | .7991 | -.8065 | .8025 | -2.1085 | .8153 | .8260 |
| 220 | .7558 | .7656 | -.7749 | .7658 | -2.1169 | .7804 | .7906 |
| 224 | .7311 | .7486 | -.7556 | .7428 | -2.1462 | .7585 | .7688 |
| 228 | .7164 | .7341 | -.7357 | .7287 | -2.1932 | .7411 | .7512 |
| 232 | .7076 | .7229 | -.7192 | .7227 | -2.2422 | .7314 | .7428 |
| 236 | .6923 | .7111 | -.7071 | .7079 | -2.2691 | .7176 | .7290 |
| 240 | .6690 | .6968 | -.6932 | .6813 | -2.2586 | .6935 | .7021 |

TABLE 11a – (Continued)

| $\theta$ (deg) | $F_x/\bar{F}_x$ | $F_y/\bar{F}_y$ | $M_x/\lvert\bar{M}_x\rvert$ | $M_y/\bar{M}_y$ | $M_z/\lvert\bar{M}_z\rvert$ | $M_h/\bar{M}_h$ | $M_{0.4}/\bar{M}_{0.4}$ |
|---|---|---|---|---|---|---|---|
| 244 | .6418 | .6821 | -.6794 | .6557 | -2.2818 | .6725 | .6808 |
| 248 | .6177 | .6539 | -.6584 | .6313 | -2.3297 | .6480 | .6553 |
| 252 | .6081 | .6677 | -.6584 | .6193 | -2.3593 | .6382 | .6433 |
| 256 | .6031 | .6545 | -.6355 | .6187 | -2.3282 | .6289 | .6356 |
| 260 | .5974 | .6454 | -.6237 | .6128 | -2.2955 | .6202 | .6269 |
| 264 | .5884 | .6380 | -.6167 | .6023 | -2.3218 | .6102 | .6158 |
| 268 | .5771 | .6192 | -.5952 | .5879 | -2.3591 | .5932 | .5995 |
| 272 | .5623 | .6217 | -.6004 | .5766 | -2.3309 | .5875 | .5924 |
| 276 | .5590 | .6302 | -.6046 | .5725 | -2.3080 | .5842 | .5970 |
| 280 | .5625 | .6600 | -.6272 | .5791 | -2.3327 | .5946 | .5958 |
| 284 | .5737 | .7036 | -.6673 | .5893 | -2.3593 | .6125 | .6096 |
| 288 | .5764 | .7590 | -.7176 | .5916 | -2.3092 | .6272 | .6181 |
| 292 | .5706 | .8042 | -.7581 | .5849 | -2.2682 | .6327 | .6174 |
| 296 | .5622 | .8572 | -.8115 | .5751 | -2.2822 | .6415 | .6190 |
| 300 | .5649 | .9096 | -.8589 | .5751 | -2.2555 | .6530 | .6234 |
| 304 | .5803 | .9247 | -.8756 | .5932 | -2.1857 | .6724 | .6446 |
| 308 | .6055 | .9574 | -.9204 | .6163 | -2.0182 | .7051 | .6763 |
| 312 | .6581 | .9826 | -.9344 | .6676 | -1.2101 | .7409 | .7132 |
| 316 | .7331 | 1.0279 | -1.0018 | .7550 | -.7547 | .8350 | .8199 |
| 320 | .8519 | 1.1047 | -1.0822 | .8400 | -1.6076 | .9048 | .8738 |
| 324 | .8415 | 1.0274 | -.9830 | .8290 | -1.6206 | .8598 | .8333 |
| 328 | .8257 | 1.0257 | -.9851 | .7973 | -.4287 | .8324 | .7952 |
| 332 | .8056 | .9973 | -.9572 | .7698 | -.3668 | .8016 | .7609 |
| 336 | .8171 | .9871 | -.9634 | .7881 | -1.1034 | .8247 | .7918 |
| 340 | .8980 | 1.0307 | -1.0346 | .8801 | -.7286 | .9244 | .9047 |
| 344 | .9777 | 1.1091 | -1.1289 | .9621 | .0401 | 1.0163 | .9996 |
| 348 | 1.0236 | 1.1076 | -1.1267 | 1.0102 | -.1553 | 1.0500 | 1.0393 |
| 352 | 1.0174 | 1.1235 | -1.1620 | 1.0009 | -.4759 | 1.0591 | 1.0461 |
| 356 | .9968 | 1.1496 | -1.1842 | .9706 | .1446 | 1.0391 | 1.0151 |
| 360 | 1.0249 | 1.0606 | -1.0741 | 1.0051 | .4454 | 1.0258 | 1.0157 |

## TABLE 11b – SIGNALS RECONSTRUCTED FROM FIRST TEN HARMONICS (Five for $M_z$)

| $\theta$ (deg) | $F_x/\bar{F}_x$ | $F_y/\bar{F}_y$ | $M_x/\lvert M_x\rvert$ | $M_y/\bar{M}_y$ | $M_z/\lvert\bar{M}_z\rvert$ | $M_h/\bar{M}_h$ | $M_{0.4}/\bar{M}_{0.4}$ |
|---|---|---|---|---|---|---|---|
| 0 | 1.0978 | 1.1247 | -1.1421 | 1.0967 | .3050 | 1.1157 | 1.1139 |
| 4 | 1.1163 | 1.1073 | -1.1181 | 1.1169 | .3743 | 1.1211 | 1.1234 |
| 8 | 1.1156 | 1.0824 | -1.0881 | 1.1186 | .4200 | 1.1126 | 1.1184 |
| 12 | 1.1008 | 1.0576 | -1.0615 | 1.1075 | .4437 | 1.0979 | 1.1067 |
| 16 | 1.0815 | 1.0398 | -1.0454 | 1.0926 | .4479 | 1.0851 | 1.0967 |
| 20 | 1.0687 | 1.0331 | -1.0423 | 1.0837 | .4358 | 1.0809 | 1.0945 |
| 24 | 1.0715 | 1.0380 | -1.0501 | 1.0880 | .4113 | 1.0878 | 1.1024 |
| 28 | 1.0938 | 1.0514 | -1.0634 | 1.1078 | .3783 | 1.1046 | 1.1186 |
| 32 | 1.1342 | 1.0687 | -1.0767 | 1.1409 | .3408 | 1.1271 | 1.1386 |
| 36 | 1.1859 | 1.0851 | -1.0860 | 1.1809 | .3026 | 1.1503 | 1.1578 |
| 40 | 1.2396 | 1.0982 | -1.0908 | 1.2206 | .2665 | 1.1704 | 1.1726 |
| 44 | 1.2876 | 1.1076 | -1.0933 | 1.2538 | .2352 | 1.1857 | 1.1824 |
| 48 | 1.3228 | 1.1151 | -1.0971 | 1.2772 | .2099 | 1.1967 | 1.1887 |
| 52 | 1.3436 | 1.1231 | -1.1054 | 1.2906 | .1911 | 1.2054 | 1.1943 |
| 56 | 1.3513 | 1.1332 | -1.1191 | 1.2964 | .1783 | 1.2139 | 1.2017 |
| 60 | 1.3501 | 1.1456 | -1.1366 | 1.2982 | .1702 | 1.2233 | 1.2120 |
| 64 | 1.3449 | 1.1591 | -1.1548 | 1.2991 | .1649 | 1.2338 | 1.2247 |
| 68 | 1.3398 | 1.1715 | -1.1706 | 1.3012 | .1599 | 1.2444 | 1.2382 |
| 72 | 1.3375 | 1.1813 | -1.1821 | 1.3055 | .1526 | 1.2543 | 1.2510 |
| 76 | 1.3392 | 1.1881 | -1.1899 | 1.3116 | .1405 | 1.2631 | 1.2621 |
| 80 | 1.3446 | 1.1930 | -1.1961 | 1.3190 | .1211 | 1.2715 | 1.2719 |
| 84 | 1.3528 | 1.1978 | -1.2037 | 1.3271 | .0929 | 1.2804 | 1.2814 |
| 88 | 1.3622 | 1.2045 | -1.2149 | 1.3355 | .0546 | 1.2906 | 1.2916 |
| 92 | 1.3713 | 1.2139 | -1.2297 | 1.3435 | .0057 | 1.3019 | 1.3027 |
| 96 | 1.3787 | 1.2252 | -1.2464 | 1.3504 | -.0533 | 1.3134 | 1.3140 |
| 100 | 1.3829 | 1.2365 | -1.2619 | 1.3553 | -.1216 | 1.3231 | 1.3238 |
| 104 | 1.3827 | 1.2454 | -1.2736 | 1.3567 | -.1976 | 1.3293 | 1.3303 |
| 108 | 1.3776 | 1.2501 | -1.2798 | 1.3541 | -.2795 | 1.3310 | 1.3326 |
| 112 | 1.3679 | 1.2499 | -1.2808 | 1.3473 | -.3651 | 1.3281 | 1.3307 |
| 116 | 1.3545 | 1.2458 | -1.2783 | 1.3369 | -.4524 | 1.3220 | 1.3256 |
| 120 | 1.3389 | 1.2393 | -1.2744 | 1.3244 | -.5394 | 1.3143 | 1.3191 |

TABLE 11b – (Continued)

| $\theta$ (deg) | $F_x/\bar{F}_x$ | $F_y/\bar{F}_y$ | $M_x/\lvert M_x\rvert$ | $M_y/\bar{M}_y$ | $M_z/\lvert\bar{M}_z\rvert$ | $M_h/\bar{M}_h$ | $M_{0.4}/\bar{M}_{0.4}$ |
|---|---|---|---|---|---|---|---|
| 124 | 1.3225 | 1.2319 | -1.2703 | 1.3112 | -.6247 | 1.3063 | 1.3123 |
| 128 | 1.3070 | 1.2245 | -1.2661 | 1.2983 | -.7070 | 1.2983 | 1.3054 |
| 132 | 1.2918 | 1.2165 | -1.2604 | 1.2856 | -.7858 | 1.2897 | 1.2978 |
| 136 | 1.2766 | 1.2069 | -1.2513 | 1.2727 | -.8609 | 1.2791 | 1.2881 |
| 140 | 1.2604 | 1.1943 | -1.2375 | 1.2585 | -.9327 | 1.2655 | 1.2752 |
| 144 | 1.2424 | 1.1760 | -1.2190 | 1.2423 | -1.0019 | 1.2486 | 1.2590 |
| 148 | 1.2228 | 1.1587 | -1.1974 | 1.2238 | -1.0692 | 1.2291 | 1.2400 |
| 152 | 1.2014 | 1.1377 | -1.1752 | 1.2038 | -1.1358 | 1.2085 | 1.2200 |
| 156 | 1.1798 | 1.1169 | -1.1543 | 1.1833 | -1.2026 | 1.1883 | 1.2004 |
| 160 | 1.1588 | 1.0977 | -1.1357 | 1.1632 | -1.2702 | 1.1693 | 1.1818 |
| 164 | 1.1386 | 1.0801 | -1.1185 | 1.1438 | -1.3392 | 1.1511 | 1.1639 |
| 168 | 1.1183 | 1.0633 | -1.1009 | 1.1243 | -1.4096 | 1.1322 | 1.1450 |
| 172 | 1.0969 | 1.0456 | -1.0806 | 1.1035 | -1.4812 | 1.1110 | 1.1237 |
| 176 | 1.0725 | 1.0256 | -1.0564 | 1.0801 | -1.5533 | 1.0864 | 1.0986 |
| 180 | 1.0445 | 1.0028 | -1.0287 | 1.0533 | -1.6252 | 1.0582 | 1.0701 |
| 184 | 1.0137 | .9778 | -.9993 | 1.0237 | -1.6958 | 1.0278 | 1.0395 |
| 188 | .9805 | .9523 | -.9707 | .9925 | -1.7638 | .9972 | 1.0089 |
| 192 | .9490 | .9281 | -.9448 | .9619 | -1.8283 | .9682 | .9801 |
| 196 | .9171 | .9063 | -.9221 | .9329 | -1.8883 | .9418 | .9540 |
| 200 | .8891 | .8865 | -.9012 | .9066 | -1.9431 | .9176 | .9298 |
| 204 | .8637 | .8674 | -.8798 | .8824 | -1.9922 | .8940 | .9061 |
| 208 | .8398 | .8473 | -.8557 | .8591 | -2.0356 | .8694 | .8811 |
| 212 | .8160 | .8248 | -.8281 | .8354 | -2.0736 | .8429 | .8541 |
| 216 | .7914 | .7999 | -.7980 | .8108 | -2.1067 | .8150 | .8257 |
| 220 | .7662 | .7741 | -.7683 | .7857 | -2.1356 | .7873 | .7978 |
| 224 | .7413 | .7499 | -.7421 | .7614 | -2.1613 | .7620 | .7725 |
| 228 | .7182 | .7297 | -.7218 | .7392 | -2.1848 | .7407 | .7514 |
| 232 | .6978 | .7149 | -.7077 | .7198 | -2.2079 | .7236 | .7345 |
| 236 | .6803 | .7049 | -.6979 | .7030 | -2.2285 | .7093 | .7199 |
| 240 | .6645 | .6976 | -.6891 | .6876 | -2.2503 | .6955 | .7058 |

TABLE 11b – (Continued)

| $\theta$ (deg) | $F_x/\bar{F}_x$ | $F_y/\bar{F}_y$ | $M_x/\lvert M_x\rvert$ | $M_y/\bar{M}_y$ | $M_z/\lvert\bar{M}_z\rvert$ | $M_h/\bar{M}_h$ | $M_{0.4}/\bar{M}_{0.4}$ |
|---|---|---|---|---|---|---|---|
| 244 | .6491 | .6902 | -.6779 | .6719 | -2.2723 | .6799 | .6834 |
| 248 | .6327 | .6802 | -.6626 | .6550 | -2.2945 | .6615 | .6685 |
| 252 | .6154 | .6665 | -.6436 | .6372 | -2.3166 | .6413 | .6472 |
| 256 | .5984 | .6505 | -.6234 | .6202 | -2.3378 | .6220 | .6273 |
| 260 | .5842 | .6350 | -.6058 | .6064 | -2.3569 | .6065 | .6121 |
| 264 | .5747 | .6238 | -.5943 | .5978 | -2.3726 | .5974 | .6036 |
| 268 | .5709 | .6205 | -.5913 | .5949 | -2.3832 | .5949 | .6017 |
| 272 | .5714 | .6270 | -.5970 | .5960 | -2.3869 | .5975 | .6038 |
| 276 | .5737 | .6441 | -.6110 | .5981 | -2.3817 | .6020 | .6064 |
| 280 | .5743 | .6710 | -.6321 | .5977 | -2.3655 | .6058 | .6064 |
| 284 | .5709 | .7061 | -.6600 | .5931 | -2.3365 | .6081 | .6033 |
| 288 | .5639 | .7478 | -.6949 | .5852 | -2.2929 | .6104 | .5994 |
| 292 | .5567 | .7944 | -.7371 | .5778 | -2.2331 | .6165 | .5995 |
| 296 | .5550 | .8442 | -.7862 | .5768 | -2.1558 | .6307 | .6088 |
| 300 | .5647 | .8945 | -.8392 | .5877 | -2.0604 | .6557 | .6306 |
| 304 | .5898 | .9420 | -.8912 | .6133 | -1.9465 | .6910 | .6644 |
| 308 | .6299 | .9825 | -.9360 | .6523 | -1.8145 | .7326 | .7056 |
| 312 | .6805 | 1.0122 | -.9678 | .6992 | -1.6655 | .7739 | .7470 |
| 316 | .7340 | 1.0289 | -.9839 | .7461 | -1.5013 | .8084 | .7812 |
| 320 | .7818 | 1.0333 | -.9860 | .7853 | -1.3242 | .8319 | .8038 |
| 324 | .8181 | 1.0289 | -.9802 | .8125 | -1.1375 | .8447 | .8151 |
| 328 | .8415 | 1.0219 | -.9754 | .8281 | -.9447 | .8513 | .8203 |
| 332 | .8560 | 1.0190 | -.9799 | .8375 | -.7502 | .8594 | .8278 |
| 336 | .8688 | 1.0255 | -.9990 | .8488 | -.5583 | .8766 | .8459 |
| 340 | .8882 | 1.0429 | -1.0323 | .8699 | -.3736 | .9073 | .8793 |
| 344 | .9193 | 1.0685 | -1.0736 | .9050 | -.2006 | .9511 | .9276 |
| 348 | .9626 | 1.0963 | -1.1133 | .9529 | -.0431 | 1.0025 | .9845 |
| 352 | 1.0129 | 1.1186 | -1.1415 | 1.0072 | .0952 | 1.0527 | 1.0405 |
| 356 | 1.0611 | 1.1290 | -1.1515 | 1.0582 | .2118 | 1.0924 | 1.0858 |
| 360 | 1.0978 | 1.1247 | -1.1421 | 1.0967 | .3050 | 1.1157 | 1.1139 |

## TABLE 11c – HARMONIC CONTENT OF SIGNALS

| n | $\frac{(F_x)_n}{\bar{F}_x}$ | $(\phi_x)_n$ (deg) | $\frac{(F_y)_n}{\bar{F}_y}$ | $(\phi_y)_n$ (deg) | $\frac{(M_x)_n}{\lvert\bar{M}_x\rvert}$ | $(\phi_x)_n$ (deg) | $\frac{(M_y)_n}{\bar{M}_y}$ | $(\phi_y)_n$ (deg) |
|---|---|---|---|---|---|---|---|---|
| 1 | .3574 | 91.4 | .2453 | 80.0 | .2697 | -94.8 | .3737 | 92.8 |
| 2 | .0336 | -1.2 | .0992 | -59.7 | .1088 | 126.8 | .0380 | -1.7 |
| 3 | .0210 | -49.6 | .0421 | -92.0 | .0403 | 106.7 | .0192 | -27.4 |
| 4 | .0206 | -73.9 | .0168 | -166.1 | .0198 | 22.4 | .0133 | -57.3 |
| 5 | .0153 | -93.3 | .0076 | 91.2 | .0074 | -104.0 | .0077 | -88.2 |
| 6 | .0128 | -37.7 | .0182 | 15.8 | .0189 | -165.9 | .0086 | -21.6 |
| 7 | .0162 | 32.8 | .0162 | -18.3 | .0170 | 156.5 | .0141 | 34.5 |
| 8 | .0199 | 43.9 | .0091 | -48.3 | .0116 | 123.7 | .0175 | 36.8 |
| 9 | .0134 | 41.7 | .0055 | -33.2 | .0087 | 127.4 | .0127 | 27.4 |
| 10 | .0075 | 6.1 | .0079 | -34.7 | .0110 | 119.7 | .0079 | -5.0 |
| 11 | .0029 | -34.1 | .0067 | -54.7 | .0095 | 113.1 | .0027 | -64.2 |
| 12 | .0020 | 115.7 | .0042 | -96.9 | .0046 | 66.5 | .0034 | 125.6 |
| 13 | .0168 | 138.7 | .0070 | -175.1 | .0079 | 11.2 | .0188 | 135.4 |
| 14 | .0274 | 135.7 | .0078 | 138.0 | .0072 | -37.0 | .0304 | 131.1 |
| 15 | .0208 | 172.1 | .0072 | 152.4 | .0079 | -47.1 | .0230 | 167.9 |
| 16 | .0145 | 168.0 | .0064 | 137.5 | .0067 | -59.0 | .0155 | 164.6 |
| 17 | .0055 | 174.9 | .0036 | 95.8 | .0043 | -90.8 | .0060 | 171.1 |
| 18 | .0021 | 139.5 | .0019 | 121.8 | .0023 | -84.0 | .0026 | 145.4 |
| 19 | .0007 | -58.3 | .0006 | -148.1 | .0005 | 81.6 | .0006 | -95.5 |
| 20 | .0014 | -79.2 | .0026 | -129.3 | .0024 | 46.2 | .0012 | -104.1 |
| 21 | .0017 | -103.8 | .0021 | -143.9 | .0030 | 34.2 | .0018 | -118.9 |
| 22 | .0017 | -139.9 | .0021 | -171.5 | .0030 | 7.3 | .0017 | -151.9 |
| 23 | .0015 | 165.7 | .0023 | 145.7 | .0030 | -16.9 | .0015 | 160.0 |
| 24 | .0012 | 141.4 | .0010 | 175.8 | .0013 | -19.1 | .0012 | 137.0 |
| 25 | .0010 | 80.6 | .0005 | -154.4 | .0009 | 8.8 | .0008 | 72.9 |

TABLE 11c – (Continued)

| n | $\frac{(M_z)_n}{\lvert\bar{M}_z\rvert}$ | $(\phi_z)_n$ (deg) | $\frac{(M_h)_n}{\bar{M}_h}$ | $(\phi_h)_n$ (deg) | $\frac{(M_{0.4})_n}{\bar{M}_{0.4}}$ | $(\phi_{0.4})_n$ (deg) |
|---|---|---|---|---|---|---|
| 1 | 1.3923 | 55.8 | .3403 | 92.8 | .3451 | 94.8 |
| 2 | .2917 | 23.4 | .0599 | -27.6 | .0598 | -19.3 |
| 3 | .1771 | -14.0 | .0251 | -32.5 | .0267 | -13.3 |
| 4 | .0899 | -25.2 | .0071 | -48.2 | .0097 | -11.6 |
| 5 | .0180 | 31.3 | .0018 | 2.1 | .0035 | 41.3 |
| 6 | .0345 | 109.3 | .0105 | 5.6 | .0089 | 16.1 |
| 7 | .0394 | 48.1 | .0123 | 12.4 | .0112 | 17.9 |
| 8 | .0697 | 18.5 | .0118 | 9.6 | .0125 | 8.3 |
| 9 | .0514 | -.2 | .0103 | -3.5 | .0117 | -8.0 |
| 10 | .0194 | -2.2 | .0090 | -39.2 | .0097 | -42.2 |
| 11 | .0199 | -111.5 | .0056 | -73.1 | .0055 | -78.7 |
| 12 | .0208 | -102.4 | .0031 | 159.5 | .0043 | 148.6 |
| 13 | .0303 | -10.9 | .0154 | 142.8 | .0178 | 138.9 |
| 14 | .0496 | -2.3 | .0245 | 130.3 | .0283 | 128.1 |
| 15 | .0824 | -7.9 | .0190 | 159.1 | .0218 | 158.1 |
| 16 | .0721 | -15.1 | .0127 | 154.1 | .0142 | 154.1 |
| 17 | .0478 | -29.1 | .0048 | 150.1 | .0055 | 153.9 |
| 18 | .0256 | -32.9 | .0025 | 128.3 | .0028 | 132.1 |
| 19 | .0163 | 58.7 | .0006 | -100.6 | .0007 | -110.1 |
| 20 | .0570 | 64.6 | .0015 | -129.6 | .0014 | -139.4 |
| 21 | .0352 | 46.8 | .0026 | -136.5 | .0027 | -139.2 |
| 22 | .1296 | 24.2 | .0023 | -166.4 | .0024 | -169.1 |
| 23 | .1622 | 14.2 | .0022 | 165.7 | .0022 | 167.0 |
| 24 | .1850 | 18.3 | .0014 | 141.0 | .0015 | 136.2 |
| 25 | .1222 | 32.3 | .0005 | 119.8 | .0004 | 113.7 |

## TABLE 12 – EXPERIMENTAL LOADS DURING QUASI-STEADY CRASH FORWARD AT V = 0.33 M/SEC, n = 6.26 REV/SEC, $(P/D)_{0.7}$ = 1.39

### TABLE 12a – SIGNALS RECONSTRUCTED FROM FIRST TEN HARMONICS (Five for $M_z$)

| $\theta$ | $F_x/\bar{F}_{x_{SP}}$ | $F_y/\bar{F}_{y_{SP}}$ | $M_x/\lvert\bar{M}_{x_{SP}}\rvert$ | $M_y/\bar{M}_{y_{SP}}$ | $M_z/\lvert\bar{M}_{z_{SP}}\rvert$ | $M_h/\bar{M}_{h_{SP}}$ | $M_{0.4}/M_{0.4_{SP}}$ |
|---|---|---|---|---|---|---|---|
| 0 | .5045 | .4523 | -.5590 | .5700 | 2.0758 | .5937 | .6856 |
| 4 | .5177 | .4500 | -.5539 | .5869 | 2.0785 | .6028 | .7003 |
| 8 | .5249 | .4477 | -.5502 | .5959 | 2.0791 | .6072 | .7077 |
| 12 | .5265 | .4459 | -.5485 | .5974 | 2.0791 | .6076 | .7086 |
| 16 | .5240 | .4448 | -.5488 | .5936 | 2.0762 | .6054 | .7052 |
| 20 | .5198 | .4445 | -.5507 | .5876 | 2.0737 | .6025 | .7002 |
| 24 | .5158 | .4448 | -.5532 | .5823 | 2.0712 | .6003 | .6963 |
| 28 | .5135 | .4454 | -.5556 | .5795 | 2.0686 | .5999 | .6950 |
| 32 | .5134 | .4460 | -.5575 | .5797 | 2.0668 | .6012 | .6965 |
| 36 | .5149 | .4462 | -.5586 | .5821 | 2.0653 | .6038 | .7001 |
| 40 | .5172 | .4459 | -.5591 | .5855 | 2.0642 | .6067 | .7043 |
| 44 | .5192 | .4451 | -.5593 | .5883 | 2.0633 | .6091 | .7078 |
| 48 | .5202 | .4439 | -.5594 | .5895 | 2.0627 | .6105 | .7098 |
| 52 | .5200 | .4425 | -.5597 | .5890 | 2.0621 | .6108 | .7100 |
| 56 | .5188 | .4412 | -.5604 | .5872 | 2.0614 | .6103 | .7092 |
| 60 | .5171 | .4402 | -.5613 | .5849 | 2.0609 | .6097 | .7079 |
| 64 | .5154 | .4397 | -.5626 | .5828 | 2.0593 | .6093 | .7070 |
| 68 | .5141 | .4399 | -.5640 | .5814 | 2.0578 | .6094 | .7068 |
| 72 | .5133 | .4406 | -.5656 | .5808 | 2.0561 | .6100 | .7073 |
| 76 | .5131 | .4416 | -.5672 | .5808 | 2.0542 | .6108 | .7082 |
| 80 | .5134 | .4426 | -.5686 | .5811 | 2.0521 | .6116 | .7089 |
| 84 | .5140 | .4433 | -.5696 | .5815 | 2.0500 | .6121 | .7093 |
| 88 | .5148 | .4434 | -.5699 | .5819 | 2.0478 | .6123 | .7092 |
| 92 | .5160 | .4428 | -.5694 | .5823 | 2.0455 | .6122 | .7090 |
| 96 | .5171 | .4415 | -.5681 | .5830 | 2.0431 | .6120 | .7088 |
| 100 | .5181 | .4398 | -.5662 | .5837 | 2.0405 | .6117 | .7088 |
| 104 | .5186 | .4381 | -.5643 | .5844 | 2.0375 | .6115 | .7090 |
| 108 | .5185 | .4368 | -.5628 | .5848 | 2.0341 | .6113 | .7093 |
| 112 | .5180 | .4363 | -.5620 | .5848 | 2.0300 | .6111 | .7095 |
| 116 | .5169 | .4366 | -.5622 | .5842 | 2.0253 | .6110 | .7095 |
| 120 | .5154 | .4378 | -.5632 | .5832 | 2.0197 | .6108 | .7092 |

TABLE 12a – (Continued)

| $\theta$ | $F_x/\bar{F}_{x_{SP}}$ | $F_y/\bar{F}_{y_{SP}}$ | $M_x/\lvert\bar{M}_{x_{SP}}\rvert$ | $M_y/\bar{M}_{y_{SP}}$ | $M_z/\lvert\bar{M}_{z_{SP}}\rvert$ | $M_h/\bar{M}_{h_{SP}}$ | $M_{0.4}/M_{0.4_{SP}}$ |
|---|---|---|---|---|---|---|---|
| 124 | .5141 | .4396 | -.5648 | .5822 | 2.0132 | .6108 | .7089 |
| 128 | .5130 | .4416 | -.5664 | .5813 | 2.0060 | .6108 | .7086 |
| 132 | .5124 | .4434 | -.5677 | .5808 | 1.9980 | .6108 | .7083 |
| 136 | .5119 | .4448 | -.5684 | .5806 | 1.9896 | .6107 | .7081 |
| 140 | .5114 | .4456 | -.5681 | .5804 | 1.9807 | .6102 | .7076 |
| 144 | .5107 | .4458 | -.5672 | .5799 | 1.9717 | .6093 | .7066 |
| 148 | .5096 | .4456 | -.5657 | .5790 | 1.9627 | .6079 | .7050 |
| 152 | .5080 | .4452 | -.5639 | .5775 | 1.9540 | .6059 | .7028 |
| 156 | .5063 | .4448 | -.5623 | .5756 | 1.9455 | .6037 | .7002 |
| 160 | .5045 | .4448 | -.5610 | .5737 | 1.9374 | .6016 | .6976 |
| 164 | .5030 | .4453 | -.5604 | .5718 | 1.9297 | .5997 | .6951 |
| 168 | .5015 | .4464 | -.5604 | .5702 | 1.9222 | .5983 | .6931 |
| 172 | .5001 | .4481 | -.5611 | .5686 | 1.9148 | .5971 | .6913 |
| 176 | .4985 | .4503 | -.5623 | .5669 | 1.9073 | .5961 | .6895 |
| 180 | .4966 | .4527 | -.5637 | .5649 | 1.8997 | .5949 | .6875 |
| 184 | .4943 | .4551 | -.5650 | .5623 | 1.8916 | .5933 | .6850 |
| 188 | .4917 | .4570 | -.5657 | .5595 | 1.8830 | .5912 | .6818 |
| 192 | .4891 | .4583 | -.5656 | .5565 | 1.8739 | .5887 | .6783 |
| 196 | .4867 | .4589 | -.5645 | .5537 | 1.8643 | .5859 | .6746 |
| 200 | .4845 | .4588 | -.5628 | .5512 | 1.8543 | .5831 | .6710 |
| 204 | .4827 | .4584 | -.5608 | .5489 | 1.8442 | .5804 | .6677 |
| 208 | .4808 | .4579 | -.5591 | .5467 | 1.8342 | .5780 | .6647 |
| 212 | .4787 | .4578 | -.5582 | .5442 | 1.8246 | .5757 | .6617 |
| 216 | .4761 | .4582 | -.5583 | .5412 | 1.8157 | .5737 | .6589 |
| 220 | .4732 | .4594 | -.5594 | .5378 | 1.8077 | .5718 | .6558 |
| 224 | .4701 | .4611 | -.5611 | .5342 | 1.8009 | .5699 | .6528 |
| 228 | .4672 | .4629 | -.5625 | .5308 | 1.7957 | .5681 | .6497 |
| 232 | .4648 | .4645 | -.5636 | .5280 | 1.7909 | .5663 | .6469 |
| 236 | .4629 | .4654 | -.5639 | .5258 | 1.7877 | .5644 | .6443 |
| 240 | .4615 | .4656 | -.5623 | .5242 | 1.7854 | .5625 | .6418 |

TABLE 12a – (Continued)

| $\theta$ | $F_x/\bar{F}_{x_{SP}}$ | $F_y/\bar{F}_{y_{SP}}$ | $M_x/\lvert\bar{M}_{x_{SP}}\rvert$ | $M_y/\bar{M}_{y_{SP}}$ | $M_z/\lvert\bar{M}_{z_{SP}}\rvert$ | $M_h/\bar{M}_{h_{SP}}$ | $M_{0.4}/M_{0.4_{SP}}$ |
|---|---|---|---|---|---|---|---|
| 244 | .4603 | .4650 | -.5602 | .5227 | 1.7839 | .5603 | .6392 |
| 248 | .4590 | .4638 | -.5578 | .5209 | 1.7825 | .5578 | .6363 |
| 252 | .4573 | .4624 | -.5555 | .5188 | 1.7812 | .5552 | .6331 |
| 256 | .4555 | .4610 | -.5537 | .5162 | 1.7798 | .5526 | .6297 |
| 260 | .4536 | .4600 | -.5525 | .5135 | 1.7780 | .5502 | .6264 |
| 264 | .4521 | .4594 | -.5517 | .5111 | 1.7758 | .5481 | .6235 |
| 268 | .4511 | .4591 | -.5511 | .5094 | 1.7734 | .5465 | .6212 |
| 272 | .4502 | .4590 | -.5505 | .5084 | 1.7709 | .5453 | .6196 |
| 276 | .4501 | .4588 | -.5497 | .5077 | 1.7688 | .5443 | .6183 |
| 280 | .4496 | .4585 | -.5488 | .5070 | 1.7676 | .5432 | .6170 |
| 284 | .4487 | .4580 | -.5479 | .5057 | 1.7679 | .5419 | .6152 |
| 288 | .4474 | .4572 | -.5470 | .5039 | 1.7702 | .5403 | .6130 |
| 292 | .4460 | .4560 | -.5462 | .5017 | 1.7751 | .5385 | .6106 |
| 296 | .4449 | .4546 | -.5451 | .4998 | 1.7830 | .5367 | .6082 |
| 300 | .4440 | .4528 | -.5434 | .4986 | 1.7942 | .5352 | .6062 |
| 304 | .4449 | .4507 | -.5410 | .4982 | 1.8089 | .5339 | .6047 |
| 308 | .4454 | .4483 | -.5382 | .4982 | 1.8269 | .5325 | .6032 |
| 312 | .4451 | .4459 | -.5353 | .4972 | 1.8478 | .5306 | .6011 |
| 316 | .4432 | .4437 | -.5334 | .4942 | 1.8712 | .5277 | .5973 |
| 320 | .4389 | .4422 | -.5334 | .4882 | 1.8953 | .5240 | .5917 |
| 324 | .4326 | .4418 | -.5359 | .4795 | 1.9223 | .5197 | .5846 |
| 328 | .4255 | .4425 | -.5410 | .4698 | 1.9483 | .5160 | .5775 |
| 332 | .4196 | .4445 | -.5482 | .4615 | 1.9734 | .5144 | .5728 |
| 336 | .4173 | .4472 | -.5561 | .4580 | 1.9968 | .5162 | .5730 |
| 340 | .4209 | .4502 | -.5632 | .4619 | 2.0178 | .5225 | .5801 |
| 344 | .4309 | .4528 | -.5680 | .4743 | 2.0359 | .5334 | .5946 |
| 348 | .4467 | .4545 | -.5697 | .4946 | 2.0506 | .5480 | .6154 |
| 352 | .4663 | .4549 | -.5682 | .5201 | 2.0623 | .5645 | .6400 |
| 356 | .4867 | .4541 | -.5642 | .5466 | 2.0706 | .5805 | .6646 |
| 360 | .5045 | .4523 | -.5590 | .5700 | 2.0758 | .5937 | .6856 |

## TABLE 12b – HARMONIC CONTENT OF SIGNALS

| n | $\frac{(F_x)_n}{\bar{F}_{x_{SP}}}$ | $(\phi_x)_n$ (deg) | $\frac{(F_y)_n}{\bar{F}_{y_{SP}}}$ | $(\phi_y)_n$ (deg) | $\frac{(M_x)_n}{\lvert\bar{M}_{x_{SP}}\rvert}$ | $(\phi_x)_n$ (deg) | $\frac{(M_y)_n}{\bar{M}_{y_{SP}}}$ | $(\phi_y)_n$ (deg) |
|---|---|---|---|---|---|---|---|---|
| 1 | .0398 | 101.0 | .0098 | -107.7 | .0094 | -52.3 | .0471 | 105.5 |
| 2 | .0122 | 74.6 | .0042 | 84.5 | .0030 | -102.6 | .0165 | 77.5 |
| 3 | .0105 | 79.3 | .0016 | 22.5 | .0035 | 158.3 | .0140 | 81.7 |
| 4 | .0089 | 71.4 | .0015 | -6.8 | .0036 | 134.4 | .0110 | 71.7 |
| 5 | .0064 | 60.1 | .0015 | -18.1 | .0031 | 132.0 | .0086 | 57.7 |
| 6 | .0055 | 41.7 | .0007 | -37.9 | .0022 | 107.6 | .0075 | 42.3 |
| 7 | .0054 | 33.8 | .0028 | -96.7 | .0045 | 72.2 | .0069 | 33.4 |
| 8 | .0038 | 34.2 | .0006 | -11.2 | .0010 | 96.0 | .0050 | 32.5 |
| 9 | .0022 | 29.7 | .0004 | -61.2 | .0013 | 64.8 | .0032 | 29.4 |
| 10 | .0014 | 6.6 | .0003 | -146.7 | .0009 | 24.4 | .0019 | 14.7 |

| n | $\frac{(M_z)_n}{\lvert\bar{M}_{z_{SP}}\rvert}$ | $(\phi_z)_n$ (deg) | $\frac{(M_h)_n}{\bar{M}_{h_{SP}}}$ | $(\phi_h)_n$ (deg) | $\frac{(M_{0.4})_n}{\bar{M}_{0.4_{SP}}}$ | $(\phi_{0.4})_n$ (deg) |
|---|---|---|---|---|---|---|
| 1 | .1537 | 63.6 | .0404 | 107.9 | .0555 | 108.3 |
| 2 | .0392 | 2.1 | .0123 | 77.8 | .0174 | 78.6 |
| 3 | .0221 | -17.0 | .0091 | 71.1 | .0136 | 76.2 |
| 4 | .0122 | -39.9 | .0065 | 56.6 | .0097 | 62.6 |
| 5 | .0070 | -100.8 | .0055 | 40.8 | .0093 | 46.4 |
| 6 | .0115 | -132.4 | .0048 | 29.1 | .0072 | 34.4 |
| 7 | .0164 | -132.9 | .0032 | 11.9 | .0054 | 23.5 |
| 8 | .0111 | -132.7 | .0030 | 22.8 | .0046 | 25.8 |
| 9 | .0084 | -127.3 | .0016 | 15.4 | .0028 | 21.9 |
| 10 | .0050 | -165.1 | .0009 | 15.5 | .0016 | 19.5 |

## TABLE 13 – EXPERIMENTAL LOADS DURING QUASI-STEADY CRASH FORWARD AT V = 0.81 M/SEC, n = 9.35 REV/SEC, $(P/D)_{0.7}$ = 1.39

### TABLE 13a – SIGNALS RECONSTRUCTED FROM FIRST TEN HARMONICS (Five for $M_z$)

| $\theta$ | $F_x/\bar{F}_{x_{SP}}$ | $F_y/\bar{F}_{y_{SP}}$ | $M_x/\lvert\bar{M}_{x_{SP}}\rvert$ | $M_y/\bar{M}_{y_{SP}}$ | $M_z/\lvert\bar{M}_{z_{SP}}\rvert$ | $M_h/\bar{M}_{h_{SP}}$ | $M_{0.4}/M_{0.4_{SP}}$ |
|---|---|---|---|---|---|---|---|
| 0 | 1.0295 | .9561 | -1.1672 | 1.1540 | 4.1808 | 1.2091 | 1.3853 |
| 4 | 1.0333 | .9577 | -1.1699 | 1.1571 | 4.1950 | 1.2120 | 1.3882 |
| 8 | 1.0370 | .9594 | -1.1728 | 1.1600 | 4.2084 | 1.2149 | 1.3910 |
| 12 | 1.0410 | .9611 | -1.1761 | 1.1633 | 4.2210 | 1.2183 | 1.3945 |
| 16 | 1.0453 | .9631 | -1.1798 | 1.1672 | 4.2330 | 1.2223 | 1.3989 |
| 20 | 1.0497 | .9651 | -1.1836 | 1.1716 | 4.2444 | 1.2268 | 1.4040 |
| 24 | 1.0539 | .9672 | -1.1871 | 1.1760 | 4.2551 | 1.2313 | 1.4093 |
| 28 | 1.0575 | .9691 | -1.1902 | 1.1801 | 4.2653 | 1.2354 | 1.4142 |
| 32 | 1.0605 | .9706 | -1.1925 | 1.1836 | 4.2749 | 1.2388 | 1.4184 |
| 36 | 1.0625 | .9717 | -1.1942 | 1.1861 | 4.2839 | 1.2412 | 1.4214 |
| 40 | 1.0639 | .9722 | -1.1952 | 1.1876 | 4.2923 | 1.2427 | 1.4233 |
| 44 | 1.0647 | .9724 | -1.1958 | 1.1884 | 4.3001 | 1.2435 | 1.4242 |
| 48 | 1.0650 | .9721 | -1.1959 | 1.1885 | 4.3071 | 1.2438 | 1.4244 |
| 52 | 1.0651 | .9714 | -1.1958 | 1.1883 | 4.3132 | 1.2437 | 1.4242 |
| 56 | 1.0649 | .9705 | -1.1954 | 1.1880 | 4.3184 | 1.2435 | 1.4240 |
| 60 | 1.0645 | .9693 | -1.1949 | 1.1876 | 4.3224 | 1.2433 | 1.4240 |
| 64 | 1.0639 | .9682 | -1.1945 | 1.1874 | 4.3253 | 1.2435 | 1.4245 |
| 68 | 1.0635 | .9673 | -1.1944 | 1.1876 | 4.3269 | 1.2441 | 1.4257 |
| 72 | 1.0638 | .9667 | -1.1948 | 1.1885 | 4.3271 | 1.2454 | 1.4277 |
| 76 | 1.0646 | .9665 | -1.1957 | 1.1901 | 4.3258 | 1.2474 | 1.4304 |
| 80 | 1.0667 | .9669 | -1.1972 | 1.1927 | 4.3230 | 1.2499 | 1.4336 |
| 84 | 1.0701 | .9677 | -1.1990 | 1.1960 | 4.3186 | 1.2529 | 1.4371 |
| 88 | 1.0745 | .9687 | -1.2009 | 1.1998 | 4.3127 | 1.2559 | 1.4405 |
| 92 | 1.0794 | .9696 | -1.2024 | 1.2038 | 4.3053 | 1.2587 | 1.4434 |
| 96 | 1.0840 | .9703 | -1.2035 | 1.2074 | 4.2963 | 1.2610 | 1.4458 |
| 100 | 1.0877 | .9706 | -1.2042 | 1.2102 | 4.2858 | 1.2627 | 1.4476 |
| 104 | 1.0895 | .9706 | -1.2044 | 1.2120 | 4.2740 | 1.2639 | 1.4489 |
| 108 | 1.0903 | .9703 | -1.2044 | 1.2128 | 4.2608 | 1.2646 | 1.4500 |
| 112 | 1.0891 | .9699 | -1.2044 | 1.2126 | 4.2464 | 1.2650 | 1.4509 |
| 116 | 1.0867 | .9694 | -1.2045 | 1.2116 | 4.2309 | 1.2651 | 1.4518 |
| 120 | 1.0835 | .9690 | -1.2044 | 1.2101 | 4.2144 | 1.2650 | 1.4524 |

TABLE 13a – (Continued)

| $\theta$ | $F_x/\bar{F}_{x_{SP}}$ | $F_y/\bar{F}_{y_{SP}}$ | $M_x/\lvert\bar{M}_{x_{SP}}\rvert$ | $M_y/\bar{M}_{y_{SP}}$ | $M_z/\lvert\bar{M}_{z_{SP}}\rvert$ | $M_h/\bar{M}_{h_{SP}}$ | $M_{0.4}/M_{0.4_{SP}}$ |
|---|---|---|---|---|---|---|---|
| 124 | 1.0798 | .9685 | -1.2042 | 1.2081 | 4.1970 | 1.2645 | 1.4525 |
| 128 | 1.0762 | .9678 | -1.2037 | 1.2058 | 4.1789 | 1.2635 | 1.4519 |
| 132 | 1.0726 | .9670 | -1.2026 | 1.2032 | 4.1601 | 1.2618 | 1.4504 |
| 136 | 1.0692 | .9659 | -1.2011 | 1.2004 | 4.1407 | 1.2596 | 1.4491 |
| 140 | 1.0658 | .9646 | -1.1991 | 1.1973 | 4.1210 | 1.2570 | 1.4452 |
| 144 | 1.0625 | .9631 | -1.1969 | 1.1940 | 4.1009 | 1.2541 | 1.4418 |
| 148 | 1.0591 | .9616 | -1.1947 | 1.1905 | 4.0805 | 1.2510 | 1.4382 |
| 152 | 1.0557 | .9602 | -1.1924 | 1.1871 | 4.0600 | 1.2478 | 1.4345 |
| 156 | 1.0521 | .9588 | -1.1900 | 1.1834 | 4.0393 | 1.2444 | 1.4304 |
| 160 | 1.0483 | .9574 | -1.1875 | 1.1794 | 4.0185 | 1.2406 | 1.4259 |
| 164 | 1.0443 | .9561 | -1.1849 | 1.1750 | 3.9975 | 1.2364 | 1.4207 |
| 168 | 1.0398 | .9547 | -1.1820 | 1.1701 | 3.9762 | 1.2318 | 1.4150 |
| 172 | 1.0350 | .9534 | -1.1790 | 1.1647 | 3.9547 | 1.2267 | 1.4086 |
| 176 | 1.0298 | .9521 | -1.1760 | 1.1588 | 3.9329 | 1.2213 | 1.4019 |
| 180 | 1.0242 | .9510 | -1.1730 | 1.1528 | 3.9106 | 1.2158 | 1.3950 |
| 184 | 1.0184 | .9499 | -1.1701 | 1.1466 | 3.8879 | 1.2103 | 1.3881 |
| 188 | 1.0124 | .9488 | -1.1671 | 1.1403 | 3.8647 | 1.2047 | 1.3812 |
| 192 | 1.0063 | .9475 | -1.1638 | 1.1338 | 3.8412 | 1.1988 | 1.3740 |
| 196 | 1.0001 | .9458 | -1.1599 | 1.1272 | 3.8174 | 1.1926 | 1.3604 |
| 200 | .9936 | .9435 | -1.1554 | 1.1202 | 3.7934 | 1.1858 | 1.3582 |
| 204 | .9869 | .9405 | -1.1502 | 1.1128 | 3.7695 | 1.1786 | 1.3495 |
| 208 | .9800 | .9367 | -1.1445 | 1.1052 | 3.7461 | 1.1711 | 1.3406 |
| 212 | .9730 | .9326 | -1.1387 | 1.0975 | 3.7234 | 1.1636 | 1.3317 |
| 216 | .9662 | .9282 | -1.1331 | 1.0899 | 3.7019 | 1.1565 | 1.3232 |
| 220 | .9598 | .9239 | -1.1277 | 1.0828 | 3.6820 | 1.1498 | 1.3152 |
| 224 | .9538 | .9199 | -1.1226 | 1.0763 | 3.6642 | 1.1435 | 1.3078 |
| 228 | .9483 | .9164 | -1.1177 | 1.0703 | 3.6488 | 1.1375 | 1.3007 |
| 232 | .9438 | .9131 | -1.1128 | 1.0647 | 3.6364 | 1.1315 | 1.2935 |
| 236 | .9394 | .9103 | -1.1078 | 1.0593 | 3.6273 | 1.1254 | 1.2861 |
| 240 | .9355 | .9077 | -1.1028 | 1.0541 | 3.6216 | 1.1193 | 1.2785 |

TABLE 13a – (Continued)

| $\theta$ | $F_x/\bar{F}_{x_{SP}}$ | $F_y/\bar{F}_{y_{SP}}$ | $M_x/\lvert\bar{M}_{x_{SP}}\rvert$ | $M_y/\bar{M}_{y_{SP}}$ | $M_z/\lvert\bar{M}_{z_{SP}}\rvert$ | $M_h/\bar{M}_{h_{SP}}$ | $M_{0.4}/M_{0.4_{SP}}$ |
|---|---|---|---|---|---|---|---|
| 244 | .9319 | .9054 | -1.0981 | 1.0491 | 3.6197 | 1.1133 | 1.2710 |
| 248 | .9287 | .9036 | -1.0940 | 1.0447 | 3.6215 | 1.1080 | 1.2643 |
| 252 | .9261 | .9024 | -1.0911 | 1.0410 | 3.6270 | 1.1037 | 1.2588 |
| 256 | .9245 | .9020 | -1.0894 | 1.0385 | 3.6361 | 1.1009 | 1.2551 |
| 260 | .9239 | .9022 | -1.0890 | 1.0374 | 3.6486 | 1.0997 | 1.2532 |
| 264 | .9243 | .9031 | -1.0895 | 1.0377 | 3.6641 | 1.0998 | 1.2531 |
| 268 | .9256 | .9045 | -1.0907 | 1.0390 | 3.6823 | 1.1010 | 1.2544 |
| 272 | .9276 | .9061 | -1.0922 | 1.0412 | 3.7028 | 1.1028 | 1.2566 |
| 276 | .9299 | .9077 | -1.0938 | 1.0439 | 3.7250 | 1.1051 | 1.2594 |
| 280 | .9323 | .9094 | -1.0956 | 1.0468 | 3.7487 | 1.1076 | 1.2625 |
| 284 | .9348 | .9110 | -1.0976 | 1.0498 | 3.7733 | 1.1105 | 1.2561 |
| 288 | .9373 | .9128 | -1.1001 | 1.0529 | 3.7986 | 1.1137 | 1.2701 |
| 292 | .9401 | .9147 | -1.1030 | 1.0563 | 3.8241 | 1.1173 | 1.2745 |
| 296 | .9432 | .9167 | -1.1061 | 1.0599 | 3.8497 | 1.1211 | 1.2790 |
| 300 | .9467 | .9189 | -1.1091 | 1.0637 | 3.8750 | 1.1248 | 1.2834 |
| 304 | .9503 | .9209 | -1.1115 | 1.0676 | 3.9000 | 1.1281 | 1.2872 |
| 308 | .9545 | .9227 | -1.1131 | 1.0714 | 3.9245 | 1.1308 | 1.2903 |
| 312 | .9587 | .9241 | -1.1141 | 1.0751 | 3.9485 | 1.1330 | 1.2927 |
| 316 | .9630 | .9253 | -1.1148 | 1.0789 | 3.9718 | 1.1352 | 1.2952 |
| 320 | .9676 | .9265 | -1.1160 | 1.0832 | 3.9945 | 1.1380 | 1.2985 |
| 324 | .9727 | .9280 | -1.1182 | 1.0884 | 4.0166 | 1.1422 | 1.3036 |
| 328 | .9784 | .9301 | -1.1220 | 1.0948 | 4.0379 | 1.1483 | 1.3111 |
| 332 | .9850 | .9330 | -1.1275 | 1.1027 | 4.0585 | 1.1563 | 1.3211 |
| 336 | .9922 | .9365 | -1.1343 | 1.1116 | 4.0784 | 1.1658 | 1.3329 |
| 340 | .9998 | .9405 | -1.1417 | 1.1210 | 4.0975 | 1.1759 | 1.3455 |
| 344 | 1.0073 | .9445 | -1.1489 | 1.1302 | 4.1159 | 1.1856 | 1.3575 |
| 348 | 1.0142 | .9483 | -1.1552 | 1.1384 | 4.1333 | 1.1940 | 1.3678 |
| 352 | 1.0202 | .9515 | -1.1602 | 1.1451 | 4.1500 | 1.2007 | 1.3759 |
| 356 | 1.0253 | .9540 | -1.1641 | 1.1502 | 4.1658 | 1.2056 | 1.3815 |
| 360 | 1.0295 | .9561 | -1.1672 | 1.1540 | 4.1808 | 1.2091 | 1.3853 |

## TABLE 13b – HARMONIC CONTENT OF SIGNALS

| n | $\frac{(F_x)_n}{\bar{F}_{x_{SP}}}$ | $(\phi_x)_n$ (deg) | $\frac{(F_y)_n}{\bar{F}_{y_{SP}}}$ | $(\phi_y)_n$ (deg) | $\frac{(M_x)_n}{\lvert\bar{M}_{x_{SP}}\rvert}$ | $(\phi_x)_n$ (deg) | $\frac{(M_y)_n}{\bar{M}_{y_{SP}}}$ | $(\phi_y)_n$ (deg) |
|---|---|---|---|---|---|---|---|---|
| 1 | .0767 | 89.1 | .0323 | 85.3 | .0555 | -85.9 | .0816 | 91.6 |
| 2 | .0132 | -24.2 | .0083 | -.9 | .0119 | 177.7 | .0167 | -20.5 |
| 3 | .0024 | 20.6 | .0012 | -175.3 | .0009 | -63.0 | .0024 | 24.0 |
| 4 | .0042 | 76.3 | .0032 | 92.5 | .0039 | -89.9 | .0038 | 77.6 |
| 5 | .0018 | -162.8 | .0009 | -67.5 | .0011 | 170.7 | .0005 | -109.2 |
| 6 | .0024 | -78.6 | .0005 | -84.8 | .0013 | 118.1 | .0026 | -71.9 |
| 7 | .0010 | -25.0 | .0010 | -48.2 | .0015 | 106.3 | .0015 | -61.6 |
| 8 | .0003 | 127.6 | .0003 | -30.7 | .0007 | 121.5 | .0004 | -71.5 |
| 9 | .0005 | -96.4 | .0003 | -56.2 | .0007 | 85.3 | .0006 | -70.7 |
| 10 | .0006 | -89.0 | .0004 | -126.2 | .0008 | 28.3 | .0006 | -109.2 |

| n | $\frac{(M_z)_n}{\lvert\bar{M}_{z_{SP}}\rvert}$ | $(\phi_z)_n$ (deg) | $\frac{(M_h)_n}{\bar{M}_{h_{SP}}}$ | $(\phi_h)_n$ (deg) | $\frac{(M_{0.4})_n}{\bar{M}_{0.4_{SP}}}$ | $(\phi_{0.4})_n$ (deg) |
|---|---|---|---|---|---|---|
| 1 | .3346 | 63.5 | .0783 | 94.7 | .0937 | 95.7 |
| 2 | .0436 | -59.0 | .0165 | -17.9 | .0208 | -14.8 |
| 3 | .0181 | -147.0 | .0019 | 39.5 | .0025 | 36.6 |
| 4 | .0051 | 62.2 | .0036 | 82.7 | .0037 | 81.7 |
| 5 | .0013 | -39.9 | .0011 | -5.0 | .0019 | -1.0 |
| 6 | .0094 | -160.6 | .0024 | -64.4 | .0030 | -62.3 |
| 7 | .0139 | -170.2 | .0019 | -78.0 | .0025 | -83.1 |
| 8 | .0152 | -163.7 | .0009 | -66.8 | .0013 | -66.4 |
| 9 | .0125 | -159.3 | .0008 | -80.3 | .0009 | -72.3 |
| 10 | .0103 | -146.9 | .0008 | -140.5 | .0009 | -143.0 |

## TABLE 14 – EXPERIMENTAL LOADS DURING QUASI-STEADY CRASH FORWARD AT V = 1.46 M/SEC, n = 11.19 REV/SEC, $(P/D)_{0.7}$ = 1.39

### TABLE 14a – SIGNALS RECONSTRUCTED FROM FIRST TEN HARMONICS (Five for $M_z$)

| $\theta$ | $F_x/\bar{F}_{x_{SP}}$ | $F_y/\bar{F}_{y_{SP}}$ | $M_x/\lvert\bar{M}_{x_{SP}}\rvert$ | $M_y/\bar{M}_{y_{SP}}$ | $M_z/\lvert\bar{M}_{z_{SP}}\rvert$ | $M_h/\bar{M}_{h_{SP}}$ | $M_{0.4}/M_{0.4_{SP}}$ |
|---|---|---|---|---|---|---|---|
| 0 | 1.2304 | 1.2363 | -1.4527 | 1.3415 | 5.1659 | 1.4139 | 1.5824 |
| 4 | 1.2464 | 1.2482 | -1.4682 | 1.3594 | 5.2337 | 1.4318 | 1.6034 |
| 8 | 1.2607 | 1.2592 | -1.4820 | 1.3752 | 5.2964 | 1.4479 | 1.6222 |
| 12 | 1.2733 | 1.2667 | -1.4946 | 1.3893 | 5.3536 | 1.4627 | 1.6397 |
| 16 | 1.2844 | 1.2744 | -1.5070 | 1.4022 | 5.4049 | 1.4770 | 1.6565 |
| 20 | 1.2948 | 1.2822 | -1.5195 | 1.4147 | 5.4501 | 1.4913 | 1.6736 |
| 24 | 1.3049 | 1.2904 | -1.5326 | 1.4275 | 5.4892 | 1.5061 | 1.6915 |
| 28 | 1.3153 | 1.2994 | -1.5460 | 1.4409 | 5.5218 | 1.5214 | 1.7101 |
| 32 | 1.3260 | 1.3087 | -1.5592 | 1.4547 | 5.5479 | 1.5368 | 1.7288 |
| 36 | 1.3368 | 1.3177 | -1.5716 | 1.4683 | 5.5675 | 1.5515 | 1.7468 |
| 40 | 1.3467 | 1.3256 | -1.5823 | 1.4807 | 5.5804 | 1.5646 | 1.7629 |
| 44 | 1.3545 | 1.3316 | -1.5903 | 1.4910 | 5.5868 | 1.5753 | 1.7761 |
| 48 | 1.3604 | 1.3352 | -1.5965 | 1.4985 | 5.5869 | 1.5831 | 1.7858 |
| 52 | 1.3636 | 1.3361 | -1.5993 | 1.5028 | 5.5811 | 1.5878 | 1.7919 |
| 56 | 1.3643 | 1.3345 | -1.5994 | 1.5042 | 5.5700 | 1.5895 | 1.7945 |
| 60 | 1.3632 | 1.3311 | -1.5972 | 1.5034 | 5.5544 | 1.5888 | 1.7944 |
| 64 | 1.3614 | 1.3264 | -1.5932 | 1.5015 | 5.5350 | 1.5865 | 1.7923 |
| 68 | 1.3601 | 1.3215 | -1.5883 | 1.4996 | 5.5130 | 1.5835 | 1.7892 |
| 72 | 1.3605 | 1.3169 | -1.5831 | 1.4986 | 5.4892 | 1.5805 | 1.7858 |
| 76 | 1.3632 | 1.3131 | -1.5783 | 1.4992 | 5.4647 | 1.5781 | 1.7827 |
| 80 | 1.3679 | 1.3102 | -1.5741 | 1.5011 | 5.4402 | 1.5763 | 1.7802 |
| 84 | 1.3736 | 1.3079 | -1.5706 | 1.5039 | 5.4165 | 1.5752 | 1.7781 |
| 88 | 1.3798 | 1.3058 | -1.5675 | 1.5066 | 5.3939 | 1.5743 | 1.7762 |
| 92 | 1.3838 | 1.3034 | -1.5645 | 1.5082 | 5.3722 | 1.5732 | 1.7744 |
| 96 | 1.3849 | 1.3002 | -1.5614 | 1.5080 | 5.3516 | 1.5715 | 1.7723 |
| 100 | 1.3829 | 1.2963 | -1.5581 | 1.5057 | 5.3316 | 1.5692 | 1.7700 |
| 104 | 1.3771 | 1.2919 | -1.5546 | 1.5014 | 5.3113 | 1.5662 | 1.7676 |
| 108 | 1.3692 | 1.2871 | -1.5510 | 1.4959 | 5.2902 | 1.5630 | 1.7652 |
| 112 | 1.3601 | 1.2826 | -1.5476 | 1.4897 | 5.2674 | 1.5597 | 1.7630 |
| 116 | 1.3510 | 1.2784 | -1.5444 | 1.4837 | 5.2422 | 1.5565 | 1.7610 |
| 120 | 1.3429 | 1.2746 | -1.5411 | 1.4782 | 5.2140 | 1.5533 | 1.7587 |

TABLE 14a – (Continued)

| $\theta$ | $F_x/\bar{F}_{x_{SP}}$ | $F_y/\bar{F}_{y_{SP}}$ | $M_x/\lvert\bar{M}_{x_{SP}}\rvert$ | $M_y/\bar{M}_{y_{SP}}$ | $M_z/\lvert\bar{M}_{z_{SP}}\rvert$ | $M_h/\bar{M}_{h_{SP}}$ | $M_{0.4}/M_{0.4_{SP}}$ |
|---|---|---|---|---|---|---|---|
| 124 | 1.3361 | 1.2710 | -1.5375 | 1.4732 | 5.1825 | 1.5498 | 1.7557 |
| 128 | 1.3302 | 1.2673 | -1.5333 | 1.4693 | 5.1476 | 1.5456 | 1.7516 |
| 132 | 1.3246 | 1.2633 | -1.5283 | 1.4630 | 5.1096 | 1.5405 | 1.7460 |
| 136 | 1.3188 | 1.2588 | -1.5225 | 1.4566 | 5.0688 | 1.5342 | 1.7388 |
| 140 | 1.3116 | 1.2540 | -1.5163 | 1.4492 | 5.0260 | 1.5268 | 1.7303 |
| 144 | 1.3035 | 1.2492 | -1.5099 | 1.4406 | 4.9820 | 1.5189 | 1.7209 |
| 148 | 1.2944 | 1.2444 | -1.5035 | 1.4312 | 4.9376 | 1.5103 | 1.7111 |
| 152 | 1.2846 | 1.2398 | -1.4974 | 1.4214 | 4.8937 | 1.5016 | 1.7012 |
| 156 | 1.2745 | 1.2350 | -1.4911 | 1.4115 | 4.8509 | 1.4932 | 1.6913 |
| 160 | 1.2645 | 1.2298 | -1.4842 | 1.4016 | 4.8096 | 1.4844 | 1.6812 |
| 164 | 1.2544 | 1.2236 | -1.4763 | 1.3914 | 4.7701 | 1.4750 | 1.6706 |
| 168 | 1.2439 | 1.2163 | -1.4672 | 1.3807 | 4.7321 | 1.4648 | 1.6591 |
| 172 | 1.2329 | 1.2080 | -1.4569 | 1.3693 | 4.6955 | 1.4536 | 1.6465 |
| 176 | 1.2212 | 1.1992 | -1.4459 | 1.3571 | 4.6596 | 1.4416 | 1.6329 |
| 180 | 1.2089 | 1.1907 | -1.4352 | 1.3442 | 4.6238 | 1.4292 | 1.6188 |
| 184 | 1.1961 | 1.1832 | -1.4252 | 1.3310 | 4.5876 | 1.4169 | 1.6045 |
| 188 | 1.1835 | 1.1772 | -1.4165 | 1.3179 | 4.5504 | 1.4049 | 1.5904 |
| 192 | 1.1714 | 1.1724 | -1.4089 | 1.3053 | 4.5119 | 1.3935 | 1.5768 |
| 196 | 1.1599 | 1.1684 | -1.4018 | 1.2932 | 4.4720 | 1.3824 | 1.5634 |
| 200 | 1.1491 | 1.1643 | -1.3943 | 1.2815 | 4.4311 | 1.3714 | 1.5501 |
| 204 | 1.1387 | 1.1591 | -1.3858 | 1.2700 | 4.3898 | 1.3600 | 1.5363 |
| 208 | 1.1286 | 1.1522 | -1.3758 | 1.2584 | 4.3490 | 1.3480 | 1.5220 |
| 212 | 1.1185 | 1.1436 | -1.3645 | 1.2467 | 4.3100 | 1.3355 | 1.5074 |
| 216 | 1.1085 | 1.1339 | -1.3523 | 1.2350 | 4.2739 | 1.3229 | 1.4928 |
| 220 | 1.0989 | 1.1239 | -1.3402 | 1.2237 | 4.2421 | 1.3107 | 1.4787 |
| 224 | 1.0895 | 1.1144 | -1.3290 | 1.2131 | 4.2157 | 1.2993 | 1.4657 |
| 228 | 1.0811 | 1.1064 | -1.3190 | 1.2036 | 4.1956 | 1.2892 | 1.4542 |
| 232 | 1.0736 | 1.0999 | -1.3105 | 1.1953 | 4.1823 | 1.2803 | 1.4439 |
| 236 | 1.0671 | 1.0948 | -1.3031 | 1.1882 | 4.1758 | 1.2724 | 1.4349 |
| 240 | 1.0616 | 1.0908 | -1.2966 | 1.1821 | 4.1759 | 1.2655 | 1.4269 |

TABLE 14a – (Continued)

| $\theta$ | $F_x/\bar{F}_{x_{SP}}$ | $F_y/\bar{F}_{y_{SP}}$ | $M_x/\lvert\bar{M}_{x_{SP}}\rvert$ | $M_y/\bar{M}_{y_{SP}}$ | $M_z/\lvert\bar{M}_{z_{SP}}\rvert$ | $M_h/\bar{M}_{h_{SP}}$ | $M_{0.4}/M_{0.4_{SP}}$ |
|---|---|---|---|---|---|---|---|
| 244 | 1.0571 | 1.0875 | -1.2909 | 1.1769 | 4.1815 | 1.2594 | 1.4199 |
| 248 | 1.0538 | 1.0848 | -1.2861 | 1.1728 | 4.1918 | 1.2544 | 1.4140 |
| 252 | 1.0511 | 1.0826 | -1.2825 | 1.1699 | 4.2050 | 1.2507 | 1.4097 |
| 256 | 1.0501 | 1.0812 | -1.2804 | 1.1686 | 4.2196 | 1.2488 | 1.4075 |
| 260 | 1.0504 | 1.0810 | -1.2800 | 1.1690 | 4.2340 | 1.2488 | 1.4077 |
| 264 | 1.0521 | 1.0817 | -1.2809 | 1.1710 | 4.2470 | 1.2506 | 1.4099 |
| 268 | 1.0548 | 1.0831 | -1.2824 | 1.1742 | 4.2573 | 1.2533 | 1.4135 |
| 272 | 1.0574 | 1.0846 | -1.2836 | 1.1779 | 4.2644 | 1.2562 | 1.4174 |
| 276 | 1.0593 | 1.0853 | -1.2838 | 1.1811 | 4.2683 | 1.2584 | 1.4205 |
| 280 | 1.0614 | 1.0851 | -1.2827 | 1.1832 | 4.2692 | 1.2591 | 1.4220 |
| 284 | 1.0619 | 1.0840 | -1.2805 | 1.1838 | 4.2682 | 1.2585 | 1.4216 |
| 288 | 1.0618 | 1.0827 | -1.2783 | 1.1833 | 4.2667 | 1.2569 | 1.4198 |
| 292 | 1.0617 | 1.0822 | -1.2773 | 1.1821 | 4.2662 | 1.2553 | 1.4174 |
| 296 | 1.0625 | 1.0836 | -1.2785 | 1.1814 | 4.2686 | 1.2546 | 1.4156 |
| 300 | 1.0650 | 1.0875 | -1.2825 | 1.1819 | 4.2757 | 1.2555 | 1.4150 |
| 304 | 1.0693 | 1.0941 | -1.2890 | 1.1842 | 4.2892 | 1.2582 | 1.4160 |
| 308 | 1.0753 | 1.1026 | -1.2972 | 1.1883 | 4.3105 | 1.2622 | 1.4184 |
| 312 | 1.0839 | 1.1120 | -1.3056 | 1.1937 | 4.3405 | 1.2670 | 1.4215 |
| 316 | 1.0928 | 1.1211 | -1.3135 | 1.1998 | 4.3798 | 1.2719 | 1.4249 |
| 320 | 1.1014 | 1.1291 | -1.3201 | 1.2061 | 4.4282 | 1.2764 | 1.4281 |
| 324 | 1.1099 | 1.1359 | -1.3259 | 1.2124 | 4.4853 | 1.2809 | 1.4317 |
| 328 | 1.1183 | 1.1419 | -1.3318 | 1.2190 | 4.5502 | 1.2861 | 1.4364 |
| 332 | 1.1270 | 1.1481 | -1.3391 | 1.2267 | 4.6214 | 1.2932 | 1.4436 |
| 336 | 1.1369 | 1.1557 | -1.3491 | 1.2363 | 4.6975 | 1.3032 | 1.4544 |
| 340 | 1.1489 | 1.1655 | -1.3623 | 1.2487 | 4.7763 | 1.3166 | 1.4694 |
| 344 | 1.1623 | 1.1777 | -1.3786 | 1.2641 | 4.8575 | 1.3333 | 1.4887 |
| 348 | 1.1781 | 1.1929 | -1.3971 | 1.2821 | 4.9382 | 1.3527 | 1.5111 |
| 352 | 1.1953 | 1.2073 | -1.4165 | 1.3018 | 5.0172 | 1.3735 | 1.5352 |
| 356 | 1.2131 | 1.2224 | -1.4353 | 1.3221 | 5.0934 | 1.3943 | 1.5595 |
| 360 | 1.2304 | 1.2363 | -1.4527 | 1.3415 | 5.1658 | 1.4139 | 1.5824 |

## TABLE 14b – HARMONIC CONTENT OF SIGNALS

| n | $\frac{(F_x)_n}{\bar{F}_{x_{SP}}}$ | $(\phi_x)_n$ (deg) | $\frac{(F_y)_n}{\bar{F}_{y_{SP}}}$ | $(\phi_y)_n$ (deg) | $\frac{(M_x)_n}{\lvert\bar{M}_{x_{SP}}\rvert}$ | $(\phi_x)_n$ (deg) | $\frac{(M_y)_n}{\bar{M}_{y_{SP}}}$ | $(\phi_y)_n$ (deg) |
|---|---|---|---|---|---|---|---|---|
| 1 | .1686 | 36.6 | .1213 | 80.3 | .1571 | -93.2 | .1777 | 89.9 |
| 2 | .0067 | 72.6 | .0202 | 57.3 | .0237 | -115.1 | .0104 | 87.9 |
| 3 | .0078 | 93.2 | .0073 | 115.5 | .0127 | -61.2 | .0138 | 113.4 |
| 4 | .0056 | 58.9 | .0020 | 122.0 | .0037 | -53.3 | .0059 | 79.0 |
| 5 | .0015 | 134.7 | .0022 | -77.0 | .0029 | 110.3 | .0009 | -24.6 |
| 6 | .0032 | -125.6 | .0015 | -159.8 | .0006 | 69.3 | .0021 | -93.7 |
| 7 | .0023 | 2.2 | .0035 | 28.5 | .0035 | -147.9 | .0020 | 7.4 |
| 8 | .0037 | 45.5 | .0019 | 27.4 | .0021 | -166.9 | .0032 | 38.8 |
| 9 | .0014 | 86.0 | .0022 | 32.2 | .0021 | -170.3 | .0017 | 58.5 |
| 10 | .0007 | -75.2 | .0010 | -86.0 | .0012 | 82.1 | .0008 | -68.2 |

| n | $\frac{(M_z)_n}{\lvert\bar{M}_{z_{SP}}\rvert}$ | $(\phi_z)_n$ (deg) | $\frac{(M_h)_n}{\bar{M}_{h_{SP}}}$ | $(\phi_h)_n$ (deg) | $\frac{(M_{0.4})_n}{\bar{M}_{0.4_{SP}}}$ | $(\phi_{0.4})_n$ (deg) |
|---|---|---|---|---|---|---|
| 1 | .6971 | 68.7 | .1765 | 91.5 | .2023 | 93.7 |
| 2 | .0946 | 67.4 | .0168 | 81.0 | .0187 | 89.0 |
| 3 | .0713 | 76.2 | .0171 | 119.3 | .0227 | 121.7 |
| 4 | .0295 | 37.2 | .0055 | 102.0 | .0071 | 104.7 |
| 5 | .0194 | -88.3 | .0026 | -47.4 | .0039 | -40.9 |
| 6 | .0110 | -153.1 | .0016 | -53.9 | .0025 | -33.1 |
| 7 | .0035 | 89.0 | .0022 | 23.8 | .0021 | 24.0 |
| 8 | .0050 | 2.3 | .0025 | 23.9 | .0027 | 20.6 |
| 9 | .0072 | -19.1 | .0017 | 23.6 | .0021 | 22.1 |
| 10 | .0017 | -29.5 | .0009 | -86.1 | .0009 | -80.6 |

## TABLE 15 – EXPERIMENTAL LOADS DURING QUASI-STEADY CRASH FORWARD AT V = 2.26 M/SEC, n = 12.07 REV/SEC, $(P/D)_{0.7}$ = 1.39

### TABLE 15a – SIGNALS RECONSTRUCTED FROM FIRST TEN HARMONICS (Five for $M_z$)

| $\theta$ | $F_x/\bar{F}_{x_{SP}}$ | $F_y/\bar{F}_{y_{SP}}$ | $M_x/\lvert\bar{M}_{x_{SP}}\rvert$ | $M_y/\bar{M}_{y_{SP}}$ | $M_z/\lvert\bar{M}_{z_{SP}}\rvert$ | $M_h/\bar{M}_{h_{SP}}$ | $M_{0.4}/M_{0.4_{SP}}$ |
|---|---|---|---|---|---|---|---|
| 0 | 1.1145 | 1.2095 | -1.3664 | 1.1811 | 4.5820 | 1.2496 | 1.3632 |
| 4 | 1.1417 | 1.2310 | -1.3922 | 1.2110 | 4.6909 | 1.2788 | 1.3972 |
| 8 | 1.1627 | 1.2466 | -1.4119 | 1.2346 | 4.7905 | 1.3021 | 1.4246 |
| 12 | 1.1772 | 1.2572 | -1.4270 | 1.2517 | 4.8793 | 1.3201 | 1.4462 |
| 16 | 1.1866 | 1.2652 | -1.4402 | 1.2642 | 4.9565 | 1.3351 | 1.4644 |
| 20 | 1.1936 | 1.2733 | -1.4539 | 1.2747 | 5.0217 | 1.3494 | 1.4819 |
| 24 | 1.2008 | 1.2831 | -1.4697 | 1.2858 | 5.0749 | 1.3650 | 1.5007 |
| 28 | 1.2101 | 1.2952 | -1.4875 | 1.2989 | 5.1165 | 1.3824 | 1.5215 |
| 32 | 1.2216 | 1.3086 | -1.5060 | 1.3140 | 5.1470 | 1.4008 | 1.5433 |
| 36 | 1.2343 | 1.3216 | -1.5231 | 1.3297 | 5.1675 | 1.4187 | 1.5643 |
| 40 | 1.2465 | 1.3322 | -1.5369 | 1.3441 | 5.1791 | 1.4340 | 1.5824 |
| 44 | 1.2564 | 1.3391 | -1.5461 | 1.3555 | 5.1829 | 1.4453 | 1.5960 |
| 48 | 1.2635 | 1.3419 | -1.5506 | 1.3633 | 5.1801 | 1.4524 | 1.6046 |
| 52 | 1.2683 | 1.3413 | -1.5511 | 1.3681 | 5.1719 | 1.4558 | 1.6090 |
| 56 | 1.2728 | 1.3386 | -1.5488 | 1.3712 | 5.1592 | 1.4567 | 1.6103 |
| 60 | 1.2782 | 1.3348 | -1.5449 | 1.3747 | 5.1430 | 1.4566 | 1.6101 |
| 64 | 1.2868 | 1.3310 | -1.5403 | 1.3796 | 5.1240 | 1.4564 | 1.6095 |
| 68 | 1.2978 | 1.3275 | -1.5353 | 1.3865 | 5.1028 | 1.4567 | 1.6091 |
| 72 | 1.3109 | 1.3243 | -1.5301 | 1.3945 | 5.0797 | 1.4572 | 1.6087 |
| 76 | 1.3235 | 1.3210 | -1.5248 | 1.4022 | 5.0552 | 1.4575 | 1.6081 |
| 80 | 1.3333 | 1.3174 | -1.5196 | 1.4079 | 5.0292 | 1.4571 | 1.6068 |
| 84 | 1.3384 | 1.3136 | -1.5149 | 1.4103 | 5.0018 | 1.4556 | 1.6047 |
| 88 | 1.3381 | 1.3097 | -1.5110 | 1.4091 | 4.9730 | 1.4532 | 1.6022 |
| 92 | 1.3327 | 1.3060 | -1.5081 | 1.4048 | 4.9427 | 1.4504 | 1.5996 |
| 96 | 1.3239 | 1.3026 | -1.5060 | 1.3985 | 4.9107 | 1.4473 | 1.5973 |
| 100 | 1.3134 | 1.2995 | -1.5042 | 1.3916 | 4.8768 | 1.4443 | 1.5954 |
| 104 | 1.3030 | 1.2963 | -1.5021 | 1.3849 | 4.8409 | 1.4414 | 1.5937 |
| 108 | 1.2937 | 1.2929 | -1.4993 | 1.3789 | 4.8028 | 1.4384 | 1.5918 |
| 112 | 1.2856 | 1.2888 | -1.4954 | 1.3733 | 4.7623 | 1.4347 | 1.5890 |
| 116 | 1.2778 | 1.2841 | -1.4905 | 1.3673 | 4.7194 | 1.4301 | 1.5849 |
| 120 | 1.2698 | 1.2787 | -1.4848 | 1.3602 | 4.6740 | 1.4242 | 1.5790 |

TABLE 15a – (Continued)

| $\theta$ | $F_x/\bar{F}_{x_{SP}}$ | $F_y/\bar{F}_{y_{SP}}$ | $M_x/\lvert\bar{M}_{x_{SP}}\rvert$ | $M_y/\bar{M}_{y_{SP}}$ | $M_z/\lvert\bar{M}_{z_{SP}}\rvert$ | $M_h/\bar{M}_{h_{SP}}$ | $M_{0.4}/M_{0.4_{SP}}$ |
|---|---|---|---|---|---|---|---|
| 124 | 1.2597 | 1.2727 | -1.4785 | 1.3512 | 4.6262 | 1.4169 | 1.5712 |
| 128 | 1.2479 | 1.2662 | -1.4717 | 1.3402 | 4.5758 | 1.4092 | 1.5615 |
| 132 | 1.2342 | 1.2589 | -1.4642 | 1.3272 | 4.5233 | 1.3981 | 1.5502 |
| 136 | 1.2190 | 1.2510 | -1.4558 | 1.3126 | 4.4686 | 1.3867 | 1.5376 |
| 140 | 1.2023 | 1.2421 | -1.4462 | 1.2975 | 4.4120 | 1.3743 | 1.5238 |
| 144 | 1.1867 | 1.2324 | -1.4354 | 1.2819 | 4.3539 | 1.3611 | 1.5091 |
| 148 | 1.1706 | 1.2221 | -1.4236 | 1.2663 | 4.2946 | 1.3474 | 1.4939 |
| 152 | 1.1548 | 1.2116 | -1.4113 | 1.2507 | 4.2343 | 1.3334 | 1.4783 |
| 156 | 1.1390 | 1.2010 | -1.3989 | 1.2350 | 4.1736 | 1.3191 | 1.4624 |
| 160 | 1.1229 | 1.1904 | -1.3864 | 1.2190 | 4.1125 | 1.3047 | 1.4462 |
| 164 | 1.1062 | 1.1796 | -1.3737 | 1.2023 | 4.0515 | 1.2897 | 1.4293 |
| 168 | 1.0888 | 1.1683 | -1.3603 | 1.1849 | 3.9907 | 1.2739 | 1.4115 |
| 172 | 1.0708 | 1.1561 | -1.3458 | 1.1667 | 3.9302 | 1.2572 | 1.3926 |
| 176 | 1.0523 | 1.1430 | -1.3301 | 1.1478 | 3.8702 | 1.2394 | 1.3727 |
| 180 | 1.0335 | 1.1293 | -1.3134 | 1.1288 | 3.8106 | 1.2211 | 1.3520 |
| 184 | 1.0158 | 1.1156 | -1.2964 | 1.1100 | 3.7515 | 1.2026 | 1.3311 |
| 188 | .9985 | 1.1027 | -1.2799 | 1.0921 | 3.6927 | 1.1847 | 1.3107 |
| 192 | .9830 | 1.0910 | -1.2644 | 1.0752 | 3.6344 | 1.1676 | 1.2912 |
| 196 | .9683 | 1.0805 | -1.2501 | 1.0594 | 3.5765 | 1.1515 | 1.2727 |
| 200 | .9544 | 1.0705 | -1.2364 | 1.0444 | 3.5191 | 1.1360 | 1.2548 |
| 204 | .9409 | 1.0601 | -1.2222 | 1.0295 | 3.4626 | 1.1205 | 1.2369 |
| 208 | .9269 | 1.0482 | -1.2067 | 1.0143 | 3.4071 | 1.1044 | 1.2185 |
| 212 | .9124 | 1.0343 | -1.1895 | .9984 | 3.3531 | 1.0873 | 1.1993 |
| 216 | .8973 | 1.0185 | -1.1709 | .9819 | 3.3012 | 1.0696 | 1.1795 |
| 220 | .8820 | 1.0021 | -1.1519 | .9652 | 3.2518 | 1.0518 | 1.1598 |
| 224 | .8671 | .9862 | -1.1338 | .9492 | 3.2057 | 1.0348 | 1.1411 |
| 228 | .8535 | .9724 | -1.1179 | .9345 | 3.1635 | 1.0195 | 1.1240 |
| 232 | .8416 | .9614 | -1.1047 | .9217 | 3.1257 | 1.0062 | 1.1090 |
| 236 | .8321 | .9530 | -1.0939 | .9109 | 3.0927 | .9947 | 1.0959 |
| 240 | .8241 | .9465 | -1.0846 | .9017 | 3.0649 | .9846 | 1.0841 |

TABLE 15a – (Continued)

| $\theta$ | $F_x/\bar{F}_{x_{SP}}$ | $F_y/\bar{F}_{y_{SP}}$ | $M_x/\lvert\bar{M}_{x_{SP}}\rvert$ | $M_y/\bar{M}_{y_{SP}}$ | $M_z/\lvert\bar{M}_{z_{SP}}\rvert$ | $M_h/\bar{M}_{h_{SP}}$ | $M_{0.4}/M_{0.4_{SP}}$ |
|---|---|---|---|---|---|---|---|
| 244 | .8175 | .9407 | -1.0758 | .8938 | 3.0423 | .9754 | 1.0732 |
| 248 | .8116 | .9349 | -1.0671 | .8867 | 3.0249 | .9667 | 1.0631 |
| 252 | .8063 | .9287 | -1.0586 | .8805 | 3.0126 | .9589 | 1.0543 |
| 256 | .8020 | .9229 | -1.0512 | .8756 | 3.0050 | .9527 | 1.0476 |
| 260 | .7991 | .9186 | -1.0462 | .8728 | 3.0015 | .9491 | 1.0440 |
| 264 | .7983 | .9167 | -1.0444 | .8725 | 3.0017 | .9486 | 1.0440 |
| 268 | .7999 | .9174 | -1.0456 | .8749 | 3.0050 | .9509 | 1.0472 |
| 272 | .8034 | .9201 | -1.0488 | .8792 | 3.0112 | .9550 | 1.0522 |
| 276 | .8079 | .9235 | -1.0522 | .8841 | 3.0199 | .9593 | 1.0572 |
| 280 | .8121 | .9261 | -1.0543 | .8881 | 3.0311 | .9622 | 1.0604 |
| 284 | .8148 | .9269 | -1.0544 | .8901 | 3.0451 | .9630 | 1.0611 |
| 288 | .8157 | .9265 | -1.0533 | .8901 | 3.0623 | .9620 | 1.0597 |
| 292 | .8157 | .9264 | -1.0531 | .8892 | 3.0836 | .9610 | 1.0579 |
| 296 | .8166 | .9292 | -1.0564 | .8895 | 3.1099 | .9622 | 1.0585 |
| 300 | .8207 | .9371 | -1.0655 | .8933 | 3.1422 | .9678 | 1.0636 |
| 304 | .8300 | .9513 | -1.0811 | .9023 | 3.1819 | .9788 | 1.0744 |
| 308 | .8453 | .9712 | -1.1022 | .9169 | 3.2299 | .9947 | 1.0902 |
| 312 | .8657 | .9944 | -1.1256 | .9358 | 3.2874 | 1.0134 | 1.1087 |
| 316 | .8891 | 1.0175 | -1.1478 | .9564 | 3.3550 | 1.0319 | 1.1266 |
| 320 | .9122 | 1.0372 | -1.1657 | .9758 | 3.4331 | 1.0475 | 1.1413 |
| 324 | .9325 | 1.0514 | -1.1777 | .9918 | 3.5218 | 1.0587 | 1.1512 |
| 328 | .9486 | 1.0604 | -1.1851 | 1.0036 | 3.6205 | 1.0661 | 1.1573 |
| 332 | .9607 | 1.0665 | -1.1910 | 1.0126 | 3.7283 | 1.0722 | 1.1625 |
| 336 | .9714 | 1.0732 | -1.1993 | 1.0217 | 3.8438 | 1.0804 | 1.1708 |
| 340 | .9837 | 1.0841 | -1.2137 | 1.0342 | 3.9653 | 1.0942 | 1.1859 |
| 344 | 1.0005 | 1.1013 | -1.2361 | 1.0531 | 4.0905 | 1.1156 | 1.2100 |
| 348 | 1.0234 | 1.1251 | -1.2659 | 1.0792 | 4.2173 | 1.1447 | 1.2430 |
| 352 | 1.0519 | 1.1534 | -1.3001 | 1.1114 | 4.3430 | 1.1791 | 1.2824 |
| 356 | 1.0834 | 1.1828 | -1.3349 | 1.1467 | 4.4653 | 1.2154 | 1.3239 |
| 360 | 1.1145 | 1.2095 | -1.3664 | 1.1811 | 4.5820 | 1.2496 | 1.3632 |

## TABLE 15b – HARMONIC CONTENT OF SIGNALS

| n | $\frac{(F_x)_n}{\bar{F}_{x_{SP}}}$ | $(\phi_x)_n$ (deg) | $\frac{(F_y)_n}{\bar{F}_{y_{SP}}}$ | $(\phi_y)_n$ (deg) | $\frac{(M_x)_n}{\lvert\bar{M}_{x_{SP}}\rvert}$ | $(\phi_x)_n$ (deg) | $\frac{(M_y)_n}{\bar{M}_{y_{SP}}}$ | $(\phi_y)_n$ (deg) |
|---|---|---|---|---|---|---|---|---|
| 1 | .2627 | 84.2 | .2073 | 80.9 | .2490 | -95.1 | .2704 | 86.5 |
| 2 | .0078 | 48.2 | .0317 | 33.9 | .0357 | -140.4 | .0126 | 59.4 |
| 3 | .0080 | -1.4 | .0070 | 84.1 | .0132 | -75.5 | .0079 | 69.7 |
| 4 | .0080 | 25.0 | .0038 | 137.0 | .0070 | -41.7 | .0059 | 65.4 |
| 5 | .0043 | 55.7 | .0020 | -128.1 | .0021 | 39.1 | .0032 | 51.8 |
| 6 | .0053 | 140.7 | .0027 | 116.6 | .0020 | -95.6 | .0036 | 123.9 |
| 7 | .0031 | 113.7 | .0054 | 55.4 | .0060 | -130.3 | .0040 | 89.1 |
| 8 | .0042 | 38.1 | .0047 | 39.9 | .0055 | -145.4 | .0047 | 39.0 |
| 9 | .0058 | 47.5 | .0056 | 30.4 | .0056 | -160.9 | .0065 | 39.8 |
| 10 | .0023 | 42.9 | .0031 | -15.7 | .0035 | 152.6 | .0022 | 25.4 |

| n | $\frac{(M_z)_n}{\lvert\bar{M}_{z_{SP}}\rvert}$ | $(\phi_z)_n$ (deg) | $\frac{(M_h)_n}{\bar{M}_{h_{SP}}}$ | $(\phi_h)_n$ (deg) | $\frac{(M_{0.4})_n}{\bar{M}_{0.4_{SP}}}$ | $(\phi_{0.4})_n$ (deg) |
|---|---|---|---|---|---|---|
| 1 | 1.0961 | 71.8 | .2646 | 87.9 | .2963 | 89.6 |
| 2 | .1756 | 52.6 | .0227 | 52.1 | .0241 | 59.0 |
| 3 | .0756 | 60.3 | .0140 | 101.9 | .0195 | 106.5 |
| 4 | .0333 | 52.7 | .0076 | 109.3 | .0106 | 112.7 |
| 5 | .0064 | -5.7 | .0009 | 64.8 | .0011 | 54.3 |
| 6 | .0091 | 23.8 | .0022 | 85.4 | .0025 | 61.5 |
| 7 | .0233 | 57.6 | .0049 | 64.0 | .0058 | 64.1 |
| 8 | .0295 | 34.9 | .0052 | 35.8 | .0058 | 36.3 |
| 9 | .0191 | 3.8 | .0056 | 25.6 | .0061 | 22.7 |
| 10 | .0105 | -19.0 | .0024 | -10.9 | .0026 | -11.5 |

## TABLE 16 – EXPERIMENTAL LOADS DURING QUASI-STEADY CRASH FORWARD AT V = 3.10 M/SEC, n = 13.40 REV/SEC, $(P/D)_{0.7}$ = 1.39

### TABLE 16a – SIGNALS RECONSTRUCTED FROM FIRST TEN HARMONICS (Five for $M_z$)

| $\theta$ | $F_x/\bar{F}_{x_{SP}}$ | $F_y/\bar{F}_{y_{SP}}$ | $M_x/\lvert\bar{M}_{x_{SP}}\rvert$ | $M_y/\bar{M}_{y_{SP}}$ | $M_z/\lvert\bar{M}_{z_{SP}}\rvert$ | $M_h/\bar{M}_{h_{SP}}$ | $M_{0.4}/M_{0.4_{SP}}$ |
|---|---|---|---|---|---|---|---|
| 0 | 1.0983 | 1.1372 | -1.2406 | 1.1494 | +.1859 | 1.1636 | 1.2701 |
| 4 | 1.1279 | 1.1623 | -1.2636 | 1.1816 | 4.2078 | 1.1910 | 1.3019 |
| 8 | 1.1452 | 1.1759 | -1.2759 | 1.2011 | +.4117 | 1.2073 | 1.3214 |
| 12 | 1.1515 | 1.1801 | -1.2818 | 1.2097 | +.4981 | 1.2159 | 1.3325 |
| 16 | 1.1505 | 1.1792 | -1.2864 | 1.2114 | +.5679 | 1.2215 | 1.3403 |
| 20 | 1.1471 | 1.1777 | -1.2940 | 1.2112 | 4.6225 | 1.2284 | 1.3494 |
| 24 | 1.1457 | 1.1794 | -1.3066 | 1.2128 | 4.6644 | 1.2386 | 1.3618 |
| 28 | 1.1479 | 1.1860 | -1.3236 | 1.2178 | 4.6959 | 1.2521 | 1.3773 |
| 32 | 1.1542 | 1.1968 | -1.3424 | 1.2261 | +.7197 | 1.2668 | 1.3936 |
| 36 | 1.1632 | 1.2100 | -1.3597 | 1.2358 | 4.7384 | 1.2803 | 1.4077 |
| 40 | 1.1730 | 1.2229 | -1.3733 | 1.2452 | 4.7541 | 1.2906 | 1.4180 |
| 44 | 1.1825 | 1.2336 | -1.3822 | 1.2536 | 4.7683 | 1.2974 | 1.4241 |
| 48 | 1.1931 | 1.2411 | -1.3870 | 1.2614 | 4.7823 | 1.3018 | 1.4277 |
| 52 | 1.2052 | 1.2456 | -1.3894 | 1.2703 | 4.7963 | 1.3059 | 1.4310 |
| 56 | 1.2210 | 1.2480 | -1.3908 | 1.2819 | 4.8100 | 1.3115 | 1.4361 |
| 60 | 1.2410 | 1.2495 | -1.3923 | 1.2971 | 4.8228 | 1.3194 | 1.4442 |
| 64 | 1.2648 | 1.2509 | -1.3943 | 1.3157 | +.8329 | 1.3295 | 1.4547 |
| 68 | 1.2903 | 1.2529 | -1.3967 | 1.3360 | 4.8393 | 1.3406 | 1.4666 |
| 72 | 1.3147 | 1.2559 | -1.3993 | 1.3558 | 4.8403 | 1.3516 | 1.4785 |
| 76 | 1.3355 | 1.2600 | -1.4025 | 1.3731 | 4.8344 | 1.3615 | 1.4893 |
| 80 | 1.3511 | 1.2652 | -1.4068 | 1.3870 | 4.8207 | 1.3704 | 1.4992 |
| 84 | 1.3613 | 1.2716 | -1.4130 | 1.3973 | +.7972 | 1.3786 | 1.5086 |
| 88 | 1.3671 | 1.2786 | -1.4210 | 1.4047 | 4.7646 | 1.3867 | 1.5182 |
| 92 | 1.3698 | 1.2854 | -1.4299 | 1.4101 | 4.7229 | 1.3947 | 1.5280 |
| 96 | 1.3705 | 1.2906 | -1.4380 | 1.4139 | 4.6721 | 1.4019 | 1.5371 |
| 100 | 1.3694 | 1.2930 | -1.4432 | 1.4159 | 4.6134 | 1.4071 | 1.5440 |
| 104 | 1.3661 | 1.2918 | -1.4441 | 1.4152 | 4.5480 | 1.4087 | 1.5473 |
| 108 | 1.3597 | 1.2867 | -1.4401 | 1.4111 | 4.4770 | 1.4062 | 1.5460 |
| 112 | 1.3495 | 1.2785 | -1.4322 | 1.4030 | 4.4016 | 1.3996 | 1.5401 |
| 116 | 1.3356 | 1.2684 | -1.4219 | 1.3912 | +.3232 | 1.3898 | 1.5306 |
| 120 | 1.3187 | 1.2577 | -1.4110 | 1.3767 | +.2424 | 1.3783 | 1.5189 |

TABLE 16a – (Continued)

| $\theta$ | $F_x/\bar{F}_{x_{SP}}$ | $F_y/\bar{F}_{y_{SP}}$ | $M_x/\lvert\bar{M}_{x_{SP}}\rvert$ | $M_y/\bar{M}_{y_{SP}}$ | $M_z/\lvert\bar{M}_{z_{SP}}\rvert$ | $M_h/\bar{M}_{h_{SP}}$ | $M_{0.4}/M_{0.4_{SP}}$ |
|---|---|---|---|---|---|---|---|
| 124 | 1.2999 | 1.2469 | -1.4005 | 1.3604 | 4.1602 | 1.3659 | 1.5061 |
| 128 | 1.2801 | 1.2359 | -1.3900 | 1.3429 | 4.0767 | 1.3530 | 1.4926 |
| 132 | 1.2595 | 1.2235 | -1.3780 | 1.3243 | 3.9921 | 1.3387 | 1.4775 |
| 136 | 1.2378 | 1.2083 | -1.3627 | 1.3041 | 3.9063 | 1.3219 | 1.4595 |
| 140 | 1.2137 | 1.1893 | -1.3428 | 1.2813 | 3.8191 | 1.3016 | 1.4380 |
| 144 | 1.1870 | 1.1666 | -1.3183 | 1.2555 | 3.7301 | 1.2776 | 1.4124 |
| 148 | 1.1575 | 1.1412 | -1.2905 | 1.2271 | 3.6391 | 1.2508 | 1.3838 |
| 152 | 1.1267 | 1.1150 | -1.2618 | 1.1973 | 3.5459 | 1.2227 | 1.3540 |
| 156 | 1.0953 | 1.0899 | -1.2343 | 1.1678 | 3.4507 | 1.1954 | 1.3249 |
| 160 | 1.0670 | 1.0670 | -1.2092 | 1.1401 | 3.3536 | 1.1700 | 1.2977 |
| 164 | 1.0411 | 1.0460 | -1.1861 | 1.1149 | 3.2552 | 1.1466 | 1.2725 |
| 168 | 1.0180 | 1.0257 | -1.1633 | 1.0917 | 3.1562 | 1.1241 | 1.2480 |
| 172 | .9965 | 1.0043 | -1.1387 | 1.0692 | 3.0574 | 1.1008 | 1.2225 |
| 176 | .9740 | .9803 | -1.1107 | 1.0458 | 2.9596 | 1.0753 | 1.1944 |
| 180 | .9513 | .9535 | -1.0793 | 1.0203 | 2.8636 | 1.0469 | 1.1633 |
| 184 | .9253 | .9251 | -1.0461 | .9924 | 2.7704 | 1.0165 | 1.1300 |
| 188 | .8974 | .8973 | -1.0137 | .9629 | 2.6804 | .9858 | 1.0962 |
| 192 | .8688 | .8724 | -.9847 | .9335 | 2.5941 | .9566 | 1.0638 |
| 196 | .8412 | .8521 | -.9606 | .9055 | 2.5116 | .9301 | 1.0342 |
| 200 | .8157 | .8363 | -.9409 | .8796 | 2.4330 | .9064 | 1.0072 |
| 204 | .7923 | .8235 | -.9236 | .8556 | 2.3581 | .8842 | .9816 |
| 208 | .7703 | .8115 | -.9061 | .8325 | 2.2866 | .8620 | .9556 |
| 212 | .7483 | .7978 | -.8861 | .8089 | 2.2181 | .8383 | .9280 |
| 216 | .7254 | .7812 | -.8629 | .7844 | 2.1524 | .8127 | .8987 |
| 220 | .7016 | .7618 | -.8373 | .7591 | 2.0893 | .7862 | .8687 |
| 224 | .6773 | .7409 | -.8114 | .7343 | 2.0286 | .7603 | .8400 |
| 228 | .6559 | .7206 | -.7874 | .7115 | 1.9704 | .7370 | .8144 |
| 232 | .6367 | .7024 | -.7665 | .6919 | 1.9150 | .7171 | .7927 |
| 236 | .6212 | .6866 | -.7487 | .6757 | 1.8627 | .7004 | .7744 |
| 240 | .6086 | .6727 | -.7325 | .6619 | 1.8143 | .6854 | .7579 |

TABLE 16a – (Continued)

| $\theta$ | $F_x/\bar{F}_{x_{SP}}$ | $F_y/\bar{F}_{y_{SP}}$ | $M_x/\lvert\bar{M}_{x_{SP}}\rvert$ | $M_y/\bar{M}_{y_{SP}}$ | $M_z/\lvert\bar{M}_{z_{SP}}\rvert$ | $M_h/\bar{M}_{h_{SP}}$ | $M_{0.4}/M_{0.4_{SP}}$ |
|---|---|---|---|---|---|---|---|
| 244 | .5975 | .6593 | -.7163 | .6491 | 1.7702 | .6706 | .7413 |
| 248 | .5863 | .6454 | -.6991 | .6359 | 1.7310 | .6549 | .7236 |
| 252 | .5742 | .6310 | -.6814 | .6218 | 1.6976 | .6387 | .7053 |
| 256 | .5617 | .6172 | -.6651 | .6080 | 1.6702 | .6234 | .6884 |
| 260 | .5504 | .6059 | -.6526 | .5963 | 1.6496 | .6116 | .6755 |
| 264 | .5427 | .5990 | -.6458 | .5889 | 1.6361 | .6050 | .6685 |
| 268 | .5398 | .5970 | -.6449 | .5868 | 1.6300 | .6042 | .6680 |
| 272 | .5423 | .5992 | -.6491 | .5898 | 1.6318 | .6076 | .6721 |
| 276 | .5483 | .6034 | -.6526 | .5958 | 1.6418 | .6128 | .6779 |
| 280 | .5553 | .6072 | -.6554 | .6021 | 1.6605 | .6170 | .6823 |
| 284 | .5602 | .6091 | -.6556 | .6065 | 1.6885 | .6187 | .6839 |
| 288 | .5640 | .6097 | -.6547 | .6097 | 1.7265 | .6187 | .6838 |
| 292 | .5669 | .6120 | -.6567 | .6105 | 1.7755 | .6203 | .6853 |
| 296 | .5703 | .6201 | -.6667 | .6156 | 1.8363 | .6277 | .6931 |
| 300 | .5811 | .6382 | -.6888 | .6281 | 1.9101 | .6447 | .7113 |
| 304 | .6020 | .6684 | -.7242 | .6508 | 1.9977 | .6728 | .7410 |
| 308 | .6341 | .7095 | -.7702 | .6839 | 2.0997 | .7102 | .7801 |
| 312 | .6753 | .7573 | -.8212 | .7244 | 2.2167 | .7524 | .8236 |
| 316 | .7209 | .8055 | -.8690 | .7670 | 2.3484 | .7934 | .8650 |
| 320 | .7649 | .8481 | -.9106 | .8064 | 2.4943 | .8282 | .9992 |
| 324 | .8028 | .8810 | -.9407 | .8386 | 2.6531 | .8545 | .9242 |
| 328 | .8323 | .9039 | -.9619 | .8630 | 2.8226 | .8737 | .9422 |
| 332 | .8551 | .9201 | -.9794 | .8824 | 3.0005 | .8904 | .9587 |
| 336 | .8755 | .9351 | -.9997 | .9020 | 3.1835 | .9106 | .9804 |
| 340 | .8989 | .9546 | -1.0281 | .9273 | 3.3680 | .9392 | 1.0128 |
| 344 | .9294 | .9825 | -1.0664 | .9619 | 3.5503 | .9782 | 1.0575 |
| 348 | .9682 | 1.0189 | -1.1126 | 1.0060 | 3.7265 | 1.0257 | 1.1121 |
| 352 | 1.0129 | 1.0605 | -1.1613 | 1.0560 | 3.8932 | 1.0767 | 1.1705 |
| 356 | 1.0583 | 1.1020 | -1.2057 | 1.1059 | 4.0471 | 1.1245 | 1.2253 |
| 360 | 1.0983 | 1.1372 | -1.2406 | 1.1494 | 4.1858 | 1.1636 | 1.2701 |

## TABLE 16b – HARMONIC CONTENT OF SIGNALS

| n | $\frac{(F_x)_n}{\bar{F}_{x_{SP}}}$ | $(\phi_x)_n$ (deg) | $\frac{(F_y)_n}{\bar{F}_{y_{SP}}}$ | $(\phi_y)_n$ (deg) | $\frac{(M_x)_n}{\lvert\bar{M}_{x_{SP}}\rvert}$ | $(\phi_x)_n$ (deg) | $\frac{(M_y)_n}{\bar{M}_{y_{SP}}}$ | $(\phi_y)_n$ (deg) |
|---|---|---|---|---|---|---|---|---|
| 1 | .3943 | 85.8 | .3408 | 81.3 | .3933 | -95.9 | .3986 | 87.0 |
| 2 | .0335 | -31.1 | .0478 | -5.9 | .0558 | 176.0 | .0383 | -20.1 |
| 3 | .0411 | -27.2 | .0338 | -14.7 | .0307 | 172.9 | .0355 | -15.6 |
| 4 | .0187 | 6.7 | .0034 | -105.0 | .0032 | 27.9 | .0157 | 23.5 |
| 5 | .0050 | 39.8 | .0012 | 173.7 | .0028 | 24.8 | .0052 | 59.8 |
| 6 | .0075 | 94.4 | .0017 | 112.5 | .0003 | -22.0 | .0078 | 82.9 |
| 7 | .0057 | 105.0 | .0093 | 67.1 | .0085 | -128.9 | .0059 | 84.6 |
| 8 | .0072 | 56.1 | .0107 | 40.6 | .0107 | -154.4 | .0080 | 47.0 |
| 9 | .0070 | 38.9 | .0073 | 46.1 | .0072 | -160.3 | .0073 | 31.1 |
| 10 | .0070 | 8.0 | .0063 | -20.9 | .0083 | 142.9 | .0067 | -3.3 |

| n | $\frac{(M_z)_n}{\lvert\bar{M}_{z_{SP}}\rvert}$ | $(\phi_z)_n$ (deg) | $\frac{(M_h)_n}{\bar{M}_{h_{SP}}}$ | $(\phi_h)_n$ (deg) | $\frac{(M_{0.4})_n}{\bar{M}_{0.4_{SP}}}$ | $(\phi_{0.4})_n$ (deg) |
|---|---|---|---|---|---|---|
| 1 | 1.6405 | 71.0 | .3924 | 87.2 | .4299 | 88.5 |
| 2 | .2166 | 38.9 | .0465 | -9.1 | .0515 | -7.7 |
| 3 | .1078 | 2.1 | .0292 | -3.4 | .0302 | 5.4 |
| 4 | .0497 | -4.5 | .0078 | 45.1 | .0113 | 57.7 |
| 5 | .0228 | 25.6 | .0024 | 95.6 | .0039 | 94.4 |
| 6 | .0210 | 64.2 | .0037 | 72.4 | .0049 | 63.2 |
| 7 | .0280 | 33.5 | .0063 | 55.9 | .0070 | 50.8 |
| 8 | .0409 | 20.1 | .0087 | 28.8 | .0094 | 26.7 |
| 9 | .0409 | -4.3 | .0072 | 14.7 | .0081 | 10.1 |
| 10 | .0232 | -3.1 | .0073 | -27.9 | .0080 | -30.5 |

## TABLE 17 – EXPERIMENTAL LOADS DURING QUASI-STEADY CRASH ASTERN AT V = 2.57 M/SEC, n = 17.43 REV/SEC, $(P/D)_{0.7}$ = 0.61

### TABLE 17a – SIGNALS RECONSTRUCTED FROM FIRST TEN HARMONICS (Five for $M_z$)

| $\theta$ | $F_x/\bar{F}_{x_{SP}}$ | $F_y/\bar{F}_{y_{SP}}$ | $M_x/\lvert\bar{M}_{x_{SP}}\rvert$ | $M_y/\bar{M}_{y_{SP}}$ | $M_z/\lvert\bar{M}_{z_{SP}}\rvert$ | $M_h/\bar{M}_{h_{SP}}$ | $M_{0.4}/M_{0.4_{SP}}$ |
|---|---|---|---|---|---|---|---|
| 0 | .4045 | .4896 | -.4200 | .3748 | -8.8959 | .3790 | .3192 |
| 4 | .4002 | .4781 | -.4136 | .3739 | -8.9514 | .3797 | .3230 |
| 8 | .3976 | .4603 | -.4002 | .3633 | -9.0079 | .3699 | .3161 |
| 12 | .3753 | .4415 | -.3845 | .3516 | -9.0613 | .3575 | .3057 |
| 16 | .3728 | .4288 | -.3732 | .3482 | -9.1083 | .3518 | .3006 |
| 20 | .3867 | .4284 | -.3724 | .3599 | -9.1469 | .3600 | .3077 |
| 24 | .4182 | .4432 | -.3854 | .3881 | -9.1767 | .3843 | .3288 |
| 28 | .4622 | .4720 | -.4110 | .4282 | -9.1986 | .4207 | .3605 |
| 32 | .5095 | .5092 | -.4441 | .4711 | -9.2149 | .4609 | .3952 |
| 36 | .5497 | .5471 | -.4770 | .5070 | -9.2289 | .4953 | .4242 |
| 40 | .5751 | .5784 | -.5044 | .5285 | -9.2445 | .5165 | .4407 |
| 44 | .5826 | .5984 | -.5202 | .5330 | -9.2658 | .5215 | .4425 |
| 48 | .5748 | .6062 | -.5248 | .5233 | -9.2966 | .5127 | .4321 |
| 52 | .5577 | .6044 | -.5212 | .5054 | -9.3399 | .4962 | .4154 |
| 56 | .5384 | .5978 | -.5145 | .4862 | -9.3974 | .4788 | .3987 |
| 60 | .5225 | .5910 | -.5095 | .4710 | -9.4694 | .4658 | .3872 |
| 64 | .5122 | .5866 | -.5087 | .4617 | -9.5547 | .4593 | .3822 |
| 68 | .5069 | .5850 | -.5119 | .4570 | -9.6509 | .4580 | .3824 |
| 72 | .5039 | .5841 | -.5166 | .4542 | -9.7543 | .4585 | .3842 |
| 76 | .5006 | .5812 | -.5193 | .4506 | -9.8603 | .4575 | .3845 |
| 80 | .4958 | .5741 | -.5175 | .4450 | -9.9643 | .4534 | .3815 |
| 84 | .4900 | .5624 | -.5103 | .4380 | -10.0614 | .4464 | .3757 |
| 88 | .4848 | .5475 | -.4993 | .4315 | -10.1479 | .4387 | .3692 |
| 92 | .4817 | .5321 | -.4871 | .4274 | -10.2207 | .4327 | .3643 |
| 96 | .4810 | .5198 | -.4765 | .4263 | -10.2781 | .4296 | .3623 |
| 100 | .4815 | .5091 | -.4691 | .4271 | -10.3199 | .4292 | .3629 |
| 104 | .4812 | .5030 | -.4650 | .4277 | -10.3472 | .4298 | .3646 |
| 108 | .4780 | .4993 | -.4627 | .4262 | -10.3623 | .4292 | .3652 |
| 112 | .4713 | .4962 | -.4603 | .4216 | -10.3685 | .4261 | .3634 |
| 116 | .4622 | .4923 | -.4566 | .4146 | -10.3694 | .4206 | .3592 |
| 120 | .4530 | .4874 | -.4514 | .4074 | -10.3688 | .4143 | .3540 |

TABLE 17a – (Continued)

| $\theta$ | $F_x/\bar{F}_{x_{SP}}$ | $F_y/\bar{F}_{y_{SP}}$ | $M_x/\lvert\bar{M}_{x_{SP}}\rvert$ | $M_y/\bar{M}_{y_{SP}}$ | $M_z/\lvert\bar{M}_{z_{SP}}\rvert$ | $M_h/\bar{M}_{h_{SP}}$ | $M_{0.4}/M_{0.4_{SP}}$ |
|---|---|---|---|---|---|---|---|
| 124 | .4462 | .4822 | -.4457 | .4020 | -10.3702 | .4091 | .3498 |
| 128 | .4430 | .4780 | -.4410 | .3999 | -10.3761 | .4065 | .3478 |
| 132 | .4430 | .4758 | -.4385 | .4005 | -10.3883 | .4067 | .3482 |
| 136 | .4441 | .4759 | -.4384 | .4020 | -10.4074 | .4081 | .3497 |
| 140 | .4435 | .4775 | -.4397 | .4019 | -10.4328 | .4085 | .3502 |
| 144 | .4391 | .4792 | -.4408 | .3984 | -10.4630 | .4061 | .3481 |
| 148 | .4308 | .4799 | -.4405 | .3910 | -10.4956 | .4003 | .3427 |
| 152 | .4194 | .4790 | -.4381 | .3813 | -10.5281 | .3921 | .3350 |
| 156 | .4085 | .4770 | -.4342 | .3718 | -10.5577 | .3835 | .3270 |
| 160 | .4004 | .4750 | -.4303 | .3649 | -10.5820 | .3769 | .3207 |
| 164 | .3963 | .4743 | -.4279 | .3614 | -10.5992 | .3734 | .3173 |
| 168 | .3952 | .4753 | -.4277 | .3605 | -10.6081 | .3724 | .3161 |
| 172 | .3947 | .4777 | -.4295 | .3598 | -10.6088 | .3720 | .3154 |
| 176 | .3915 | .4801 | -.4317 | .3566 | -10.6018 | .3697 | .3129 |
| 180 | .3846 | .4810 | -.4324 | .3493 | -10.5886 | .3637 | .3069 |
| 184 | .3730 | .4793 | -.4302 | .3388 | -10.5711 | .3539 | .2974 |
| 188 | .3592 | .4749 | -.4249 | .3248 | -10.5514 | .3418 | .2860 |
| 192 | .3460 | .4687 | -.4175 | .3126 | -10.5314 | .3300 | .2749 |
| 196 | .3361 | .4623 | -.4097 | .3035 | -10.5126 | .3206 | .2661 |
| 200 | .3303 | .4573 | -.4034 | .2982 | -10.4959 | .3146 | .2605 |
| 204 | .3271 | .4543 | -.3995 | .2951 | -10.4813 | .3109 | .2568 |
| 208 | .3237 | .4530 | -.3976 | .2914 | -10.4682 | .3071 | .2529 |
| 212 | .3171 | .4523 | -.3964 | .2843 | -10.4552 | .3006 | .2463 |
| 216 | .3057 | .4505 | -.3939 | .2726 | -10.4402 | .2899 | .2357 |
| 220 | .2901 | .4467 | -.3891 | .2571 | -10.4211 | .2757 | .2219 |
| 224 | .2729 | .4408 | -.3817 | .2406 | -10.3957 | .2602 | .2070 |
| 228 | .2579 | .4336 | -.3728 | .2265 | -10.3624 | .2465 | .1941 |
| 232 | .2474 | .4265 | -.3640 | .2173 | -10.3201 | .2370 | .1853 |
| 236 | .2423 | .4207 | -.3569 | .2135 | -10.2685 | .2323 | .1813 |
| 240 | .2409 | .4167 | -.3521 | .2130 | -10.2083 | .2310 | .1804 |

TABLE 17a – (Continued)

| $\theta$ | $F_x/\bar{F}_{x_{SP}}$ | $F_y/\bar{F}_{y_{SP}}$ | $M_x/\lvert\bar{M}_{x_{SP}}\rvert$ | $M_y/\bar{M}_{y_{SP}}$ | $M_z/\lvert\bar{M}_{z_{SP}}\rvert$ | $M_h/\bar{M}_{h_{SP}}$ | $M_{0.4}/M_{0.4_{SP}}$ |
|---|---|---|---|---|---|---|---|
| 244 | .2400 | .4142 | -.3493 | .2128 | -10.1411 | .2304 | .1802 |
| 248 | .2364 | .4124 | -.3474 | .2099 | -10.0693 | .2278 | .1780 |
| 252 | .2289 | .4105 | -.3453 | .2033 | -9.9956 | .2222 | .1730 |
| 256 | .2185 | .4083 | -.3425 | .1942 | -9.9232 | .2146 | .1660 |
| 260 | .2084 | .4064 | -.3396 | .1857 | -9.8547 | .2075 | .1598 |
| 264 | .2018 | .4056 | -.3376 | .1811 | -9.7924 | .2039 | .1570 |
| 268 | .2007 | .4068 | -.3376 | .1819 | -9.7377 | .2053 | .1588 |
| 272 | .2041 | .4097 | -.3397 | .1869 | -9.6911 | .2105 | .1642 |
| 276 | .2087 | .4131 | -.3428 | .1923 | -9.6518 | .2161 | .1699 |
| 280 | .2100 | .4150 | -.3447 | .1938 | -9.6182 | .2180 | .1717 |
| 284 | .2048 | .4137 | -.3435 | .1883 | -9.5876 | .2129 | .1667 |
| 288 | .1929 | .4086 | -.3379 | .1760 | -9.5571 | .2010 | .1551 |
| 292 | .1783 | .4009 | -.3290 | .1612 | -9.5234 | .1862 | .1406 |
| 296 | .1677 | .3940 | -.3199 | .1507 | -9.4836 | .1748 | .1295 |
| 300 | .1681 | .3915 | -.3145 | .1515 | -9.4356 | .1736 | .1279 |
| 304 | .1837 | .3966 | -.3166 | .1674 | -9.3779 | .1865 | .1396 |
| 308 | .2141 | .4102 | -.3277 | .1971 | -9.3108 | .2127 | .1637 |
| 312 | .2535 | .4307 | -.3465 | .2344 | -9.2355 | .2466 | .1946 |
| 316 | .2928 | .4537 | -.3690 | .2701 | -9.1547 | .2795 | .2238 |
| 320 | .3233 | .4740 | -.3896 | .2953 | -9.0720 | .3028 | .2434 |
| 324 | .3392 | .4875 | -.4040 | .3052 | -8.9917 | .3115 | .2488 |
| 328 | .3407 | .4923 | -.4096 | .3006 | -8.9184 | .3062 | .2410 |
| 332 | .3330 | .4900 | -.4076 | .2880 | -8.8565 | .2928 | .2260 |
| 336 | .3247 | .4843 | -.4017 | .2767 | -8.8098 | .2804 | .2128 |
| 340 | .3236 | .4796 | -.3967 | .2750 | -8.7809 | .2773 | .2097 |
| 344 | .3338 | .4792 | -.3965 | .2868 | -8.7710 | .2880 | .2208 |
| 348 | .3535 | .4832 | -.4019 | .3103 | -8.7799 | .3109 | .2447 |
| 352 | .3774 | .4892 | -.4106 | .3385 | -8.8058 | .3394 | .2748 |
| 356 | .3964 | .4927 | -.4182 | .3623 | -8.8458 | .3646 | .3021 |
| 360 | .4043 | .4896 | -.4200 | .3748 | -8.8959 | .3790 | .3192 |

## TABLE 17b – HARMONIC CONTENT OF SIGNALS

| n | $\frac{(F_x)_n}{\bar{F}_{x_{SP}}}$ | $(\phi_x)_n$ (deg) | $\frac{(F_y)_n}{\bar{F}_{y_{SP}}}$ | $(\phi_y)_n$ (deg) | $\frac{(M_x)_n}{\lvert\bar{M}_{x_{SP}}\rvert}$ | $(\phi_x)_n$ (deg) | $\frac{(M_y)_n}{\bar{M}_{y_{SP}}}$ | $(\phi_y)_n$ (deg) |
|---|---|---|---|---|---|---|---|---|
| 1 | .1503 | 84.6 | .0649 | 76.5 | .0733 | -89.7 | .1369 | 87.9 |
| 2 | .0310 | 51.9 | .0177 | 93.4 | .0142 | -88.0 | .0306 | 49.7 |
| 3 | .0088 | -167.2 | .0255 | -142.8 | .0189 | 43.1 | .0102 | 159.5 |
| 4 | .0175 | -139.2 | .0219 | -105.1 | .0156 | 81.0 | .0140 | -148.0 |
| 5 | .0204 | -131.1 | .0162 | -94.8 | .0128 | 84.3 | .0166 | -133.7 |
| 6 | .0112 | -127.2 | .0083 | -92.8 | .0072 | 73.5 | .0080 | -133.2 |
| 7 | .0055 | -16.3 | .0024 | -27.7 | .0014 | 131.4 | .0058 | 1.9 |
| 8 | .0127 | 11.3 | .0089 | 10.2 | .0093 | -166.5 | .0131 | 10.6 |
| 9 | .0128 | 12.4 | .0090 | 15.2 | .0088 | -161.4 | .0136 | 9.5 |
| 10 | .0139 | -10.5 | .0079 | 24.3 | .0087 | -152.9 | .0137 | -12.5 |

| n | $\frac{(M_z)_n}{\lvert\bar{M}_{z_{SP}}\rvert}$ | $(\phi_z)_n$ (deg) | $\frac{(M_h)_n}{\bar{M}_{h_{SP}}}$ | $(\phi_h)_n$ (deg) | $\frac{(M_{0.4})_n}{\bar{M}_{0.4_{SP}}}$ | $(\phi_{0.4})_n$ (deg) |
|---|---|---|---|---|---|---|
| 1 | .8486 | -9.3 | .1253 | 86.4 | .1162 | 88.2 |
| 2 | .1058 | -11.4 | .0271 | 51.9 | .0251 | 48.3 |
| 3 | .0172 | 78.5 | .0106 | 161.9 | .0105 | 139.4 |
| 4 | .0603 | -107.6 | .0108 | -145.2 | .0074 | -164.5 |
| 5 | .0819 | -86.0 | .0136 | -130.0 | .0105 | -136.4 |
| 6 | .0218 | -80.2 | .0066 | -135.7 | .0050 | -151.9 |
| 7 | .0391 | 64.3 | .0051 | 9.5 | .0050 | 19.1 |
| 8 | .0499 | 35.3 | .0129 | 11.3 | .0121 | 11.5 |
| 9 | .0528 | 19.7 | .0139 | 10.1 | .0134 | 9.2 |
| 10 | .0255 | -2.0 | .0131 | -6.5 | .0125 | -7.4 |

## TABLE 18 – EXPERIMENTAL LOADS DURING QUASI-STEADY CRASH ASTERN AT V = 1.67 M/SEC, $n$ = 16.59 REV/SEC, $(P/D)_{0.7}$ = 0.14

### TABLE 18a – SIGNALS RECONSTRUCTED FROM FIRST TEN HARMONICS (Five for $M_z$)

| $\theta$ | $F_x/\bar{F}_{x_{SP}}$ | $F_y/\bar{F}_{y_{SP}}$ | $M_x/\lvert\bar{M}_{x_{SP}}\rvert$ | $M_y/\bar{M}_{y_{SP}}$ | $M_z/\lvert\bar{M}_{z_{SP}}\rvert$ | $M_h/\bar{M}_{h_{SP}}$ | $M_{0.4}/M_{0.4_{SP}}$ |
|---|---|---|---|---|---|---|---|
| 0 | -.2686 | .2400 | -.2185 | -.4534 | -9.2938 | -.5012 | -.5061 |
| 4 | -.2719 | .2324 | -.2116 | -.4616 | -9.3373 | -.5129 | -.5183 |
| 8 | -.2775 | .2246 | -.2048 | -.4724 | -9.3823 | -.5272 | -.5328 |
| 12 | -.2827 | .2183 | -.1999 | -.4814 | -9.4272 | -.5385 | -.5438 |
| 16 | -.2850 | .2144 | -.1978 | -.4850 | -9.4707 | -.5426 | -.5474 |
| 20 | -.2831 | .2134 | -.1987 | -.4818 | -9.5118 | -.5384 | -.5424 |
| 24 | -.2774 | .2149 | -.2013 | -.4733 | -9.5499 | -.5278 | -.5315 |
| 28 | -.2695 | .2175 | -.2058 | -.4626 | -9.5851 | -.5151 | -.5187 |
| 32 | -.2616 | .2199 | -.2090 | -.4532 | -9.6177 | -.5046 | -.5086 |
| 36 | -.2563 | .2212 | -.2106 | -.4476 | -9.6485 | -.4990 | -.5035 |
| 40 | -.2537 | .2211 | -.2104 | -.4463 | -9.6785 | -.4985 | -.5036 |
| 44 | -.2534 | .2200 | -.2093 | -.4478 | -9.7090 | -.5012 | -.5069 |
| 48 | -.2538 | .2188 | -.2084 | -.4500 | -9.7408 | -.5045 | -.5104 |
| 52 | -.2537 | .2184 | -.2086 | -.4509 | -9.7748 | -.5060 | -.5121 |
| 56 | -.2509 | .2191 | -.2104 | -.4499 | -9.8115 | -.5053 | -.5116 |
| 60 | -.2469 | .2209 | -.2135 | -.4476 | -9.8507 | -.5035 | -.5102 |
| 64 | -.2427 | .2230 | -.2170 | -.4457 | -9.8919 | -.5024 | -.5097 |
| 68 | -.2389 | .2244 | -.2199 | -.4457 | -9.9339 | -.5036 | -.5116 |
| 72 | -.2378 | .2247 | -.2213 | -.4479 | -9.9754 | -.5071 | -.5155 |
| 76 | -.2392 | .2236 | -.2212 | -.4514 | -10.0146 | -.5116 | -.5200 |
| 80 | -.2422 | .2216 | -.2199 | -.4545 | -10.0496 | -.5147 | -.5224 |
| 84 | -.2449 | .2196 | -.2185 | -.4553 | -10.0786 | -.5144 | -.5212 |
| 88 | -.2459 | .2181 | -.2176 | -.4530 | -10.1002 | -.5104 | -.5162 |
| 92 | -.2442 | .2178 | -.2178 | -.4484 | -10.1132 | -.5041 | -.5094 |
| 96 | -.2403 | .2184 | -.2189 | -.4434 | -10.1170 | -.4994 | -.5037 |
| 100 | -.2356 | .2194 | -.2206 | -.4403 | -10.1117 | -.4960 | -.5021 |
| 104 | -.2322 | .2205 | -.2222 | -.4407 | -10.0979 | -.4983 | -.5054 |
| 108 | -.2315 | .2211 | -.2231 | -.4444 | -10.0768 | -.5041 | -.5122 |
| 112 | -.2333 | .2213 | -.2234 | -.4495 | -10.0501 | -.5105 | -.5187 |
| 116 | -.2387 | .2217 | -.2235 | -.4533 | -10.0197 | -.5136 | -.5210 |
| 120 | -.2442 | .2228 | -.2239 | -.4535 | -9.9877 | -.5106 | -.5164 |

TABLE 18a – (Continued)

| $\theta$ | $F_x/\bar{F}_{x_{SP}}$ | $F_y/\bar{F}_{y_{SP}}$ | $M_x/\lvert\bar{M}_{x_{SP}}\rvert$ | $M_y/\bar{M}_{y_{SP}}$ | $M_z/\lvert\bar{M}_{z_{SP}}\rvert$ | $M_h/\bar{M}_{h_{SP}}$ | $M_{0.4}/M_{0.4_{SP}}$ |
|---|---|---|---|---|---|---|---|
| 124 | -.2484 | .2249 | -.2251 | -.4492 | -9.9559 | -.5015 | -.5052 |
| 128 | -.2504 | .2281 | -.2271 | -.4419 | -9.9260 | -.4890 | -.4908 |
| 132 | -.2500 | .2317 | -.2296 | -.4348 | -9.8995 | -.4781 | -.4789 |
| 136 | -.2483 | .2349 | -.2320 | -.4316 | -9.8771 | -.4739 | -.4747 |
| 140 | -.2469 | .2369 | -.2337 | -.4347 | -9.8590 | -.4793 | -.4814 |
| 144 | -.2472 | .2374 | -.2343 | -.4445 | -9.8452 | -.4940 | -.4980 |
| 148 | -.2497 | .2368 | -.2342 | -.4587 | -9.8349 | -.5142 | -.5202 |
| 152 | -.2539 | .2358 | -.2339 | -.4731 | -9.8273 | -.5339 | -.5412 |
| 156 | -.2563 | .2358 | -.2341 | -.4836 | -9.8211 | -.5471 | -.5552 |
| 160 | -.2612 | .2374 | -.2356 | -.4872 | -9.8152 | -.5508 | -.5586 |
| 164 | -.2616 | .2412 | -.2385 | -.4837 | -9.8086 | -.5448 | -.5519 |
| 168 | -.2593 | .2466 | -.2424 | -.4752 | -9.8003 | -.5327 | -.5392 |
| 172 | -.2554 | .2527 | -.2465 | -.4654 | -9.7900 | -.5196 | -.5260 |
| 176 | -.2513 | .2582 | -.2499 | -.4579 | -9.7773 | -.5103 | -.5172 |
| 180 | -.2485 | .2623 | -.2521 | -.4549 | -9.7625 | -.5073 | -.5150 |
| 184 | -.2481 | .2644 | -.2529 | -.4563 | -9.7459 | -.5099 | -.5186 |
| 188 | -.2498 | .2649 | -.2525 | -.4604 | -9.7281 | -.5154 | -.5240 |
| 192 | -.2527 | .2644 | -.2517 | -.4644 | -9.7099 | -.5200 | -.5291 |
| 196 | -.2557 | .2639 | -.2508 | -.4659 | -9.6917 | -.5208 | -.5293 |
| 200 | -.2577 | .2639 | -.2505 | -.4643 | -9.6742 | -.5172 | -.5249 |
| 204 | -.2584 | .2646 | -.2505 | -.4604 | -9.6576 | -.5110 | -.5178 |
| 208 | -.2583 | .2659 | -.2507 | -.4563 | -9.6419 | -.5048 | -.5112 |
| 212 | -.2580 | .2673 | -.2509 | -.4538 | -9.6267 | -.5015 | -.5078 |
| 216 | -.2585 | .2684 | -.2506 | -.4542 | -9.6117 | -.5020 | -.5087 |
| 220 | -.2599 | .2689 | -.2501 | -.4568 | -9.5962 | -.5054 | -.5125 |
| 224 | -.2621 | .2690 | -.2496 | -.4600 | -9.5794 | -.5093 | -.5165 |
| 228 | -.2644 | .2689 | -.2491 | -.4620 | -9.5606 | -.5111 | -.5181 |
| 232 | -.2660 | .2689 | -.2488 | -.4614 | -9.5394 | -.5094 | -.5157 |
| 236 | -.2665 | .2691 | -.2486 | -.4583 | -9.5155 | -.5044 | -.5101 |
| 240 | -.2658 | .2694 | -.2482 | -.4539 | -9.4888 | -.4982 | -.5034 |

TABLE 18a – (Continued)

| $\theta$ | $F_x/\bar{F}_{x_{SP}}$ | $F_y/\bar{F}_{y_{SP}}$ | $M_x/\lvert\bar{M}_{x_{SP}}\rvert$ | $M_y/\bar{M}_{y_{SP}}$ | $M_z/\lvert\bar{M}_{z_{SP}}\rvert$ | $M_h/\bar{M}_{h_{SP}}$ | $M_{0.4}/M_{0.4_{SP}}$ |
|---|---|---|---|---|---|---|---|
| 244 | -.2647 | .2696 | -.2473 | -.4501 | -9.4599 | -.4935 | -.4987 |
| 248 | -.2637 | .2694 | -.2458 | -.4484 | -9.4293 | -.4920 | -.4977 |
| 252 | -.2635 | .2690 | -.2440 | -.4497 | -9.3979 | -.4941 | -.5005 |
| 256 | -.2645 | .2683 | -.2421 | -.4520 | -9.3670 | -.4983 | -.5054 |
| 260 | -.2663 | .2678 | -.2408 | -.4551 | -9.3374 | -.5022 | -.5096 |
| 264 | -.2686 | .2675 | -.2402 | -.4571 | -9.3103 | -.5041 | -.5112 |
| 268 | -.2713 | .2674 | -.2401 | -.4577 | -9.2865 | -.5034 | -.5097 |
| 272 | -.2743 | .2672 | -.2401 | -.4577 | -9.2665 | -.5017 | -.5069 |
| 276 | -.2761 | .2664 | -.2394 | -.4590 | -9.2503 | -.5015 | -.5056 |
| 280 | -.2829 | .2645 | -.2375 | -.4630 | -9.2379 | -.5051 | -.5085 |
| 284 | -.2886 | .2616 | -.2343 | -.4702 | -9.2295 | -.5133 | -.5164 |
| 288 | -.2944 | .2581 | -.2304 | -.4792 | -9.2214 | -.5245 | -.5276 |
| 292 | -.2992 | .2550 | -.2268 | -.4874 | -9.2157 | -.5350 | -.5385 |
| 296 | -.3014 | .2533 | -.2246 | -.4918 | -9.2101 | -.5408 | -.5447 |
| 300 | -.3001 | .2537 | -.2247 | -.4903 | -9.2040 | -.5394 | -.5435 |
| 304 | -.2954 | .2563 | -.2269 | -.4831 | -9.1966 | -.5308 | -.5351 |
| 308 | -.2884 | .2605 | -.2307 | -.4727 | -9.1878 | -.5183 | -.5229 |
| 312 | -.2819 | .2652 | -.2348 | -.4631 | -9.1775 | -.5069 | -.5118 |
| 316 | -.2775 | .2687 | -.2378 | -.4582 | -9.1664 | -.5016 | -.5072 |
| 320 | -.2770 | .2702 | -.2387 | -.4604 | -9.1554 | -.5051 | -.5114 |
| 324 | -.2806 | .2692 | -.2376 | -.4690 | -9.1457 | -.5165 | -.5235 |
| 328 | -.2868 | .2663 | -.2350 | -.4810 | -9.1388 | -.5316 | -.5389 |
| 332 | -.2929 | .2624 | -.2321 | -.4914 | -9.1361 | -.5443 | -.5514 |
| 336 | -.2963 | .2598 | -.2300 | -.4961 | -9.1388 | -.5495 | -.5560 |
| 340 | -.2955 | .2561 | -.2291 | -.4929 | -9.1479 | -.5449 | -.5504 |
| 344 | -.2904 | .2543 | -.2291 | -.4828 | -9.1641 | -.5321 | -.5366 |
| 348 | -.2825 | .2528 | -.2290 | -.4693 | -9.1874 | -.5159 | -.5198 |
| 352 | -.2748 | .2504 | -.2277 | -.4576 | -9.2174 | -.5026 | -.5064 |
| 356 | -.2695 | .2462 | -.2242 | -.4517 | -9.2537 | -.4971 | -.5013 |
| 360 | -.2686 | .2400 | -.2185 | -.4534 | -9.2938 | -.5012 | -.5061 |

## TABLE 18b – HARMONIC CONTENT OF SIGNALS

| n | $\frac{(F_x)_n}{\bar{F}_{x_{SP}}}$ | $(\phi_x)_n$ (deg) | $\frac{(F_y)_n}{\bar{F}_{y_{SP}}}$ | $(\phi_y)_n$ (deg) | $\frac{(M_x)_n}{\lvert\bar{M}_{x_{SP}}\rvert}$ | $(\phi_x)_n$ (deg) | $\frac{(M_y)_n}{\bar{M}_{y_{SP}}}$ | $(\phi_y)_n$ (deg) |
|---|---|---|---|---|---|---|---|---|
| 1 | .0222 | 125.9 | .0272 | -107.1 | .0193 | 40.2 | .0105 | 122.8 |
| 2 | .0076 | 131.1 | .0028 | -32.4 | .0019 | 146.7 | .0095 | 145.3 |
| 3 | .0028 | -65.0 | .0059 | -104.0 | .0051 | 78.2 | .0043 | 1.3 |
| 4 | .0019 | -58.5 | .0042 | -95.8 | .0036 | 92.4 | .0021 | -174.7 |
| 5 | .0036 | -135.9 | .0036 | -112.8 | .0029 | 64.2 | .0053 | -105.2 |
| 6 | .0017 | 63.1 | .0006 | 106.7 | .0002 | 25.1 | .0038 | 64.0 |
| 7 | .0030 | 22.6 | .0009 | -166.6 | .0010 | 18.6 | .0029 | -32.0 |
| 8 | .0033 | 5.6 | .0023 | 1.3 | .0016 | 166.2 | .0085 | .4 |
| 9 | .0035 | -62.0 | .0014 | -63.4 | .0020 | 123.9 | .0020 | -60.1 |
| 10 | .0047 | -18.6 | .0025 | -31.2 | .0025 | 139.7 | .0090 | -46.8 |

| n | $\frac{(M_z)_n}{\lvert\bar{M}_{z_{SP}}\rvert}$ | $(\phi_z)_n$ (deg) | $\frac{(M_h)_n}{\bar{M}_{h_{SP}}}$ | $(\phi_h)_n$ (deg) | $\frac{(M_{0.4})_n}{\bar{M}_{0.4_{SP}}}$ | $(\phi_{0.4})_n$ (deg) |
|---|---|---|---|---|---|---|
| 1 | .4201 | -58.7 | .0058 | 146.3 | .0051 | 142.9 |
| 2 | .1015 | -36.3 | .0100 | 151.6 | .0038 | 155.6 |
| 3 | .0295 | 74.6 | .0059 | 8.5 | .0067 | 16.2 |
| 4 | .0212 | -124.9 | .0037 | 178.0 | .0044 | 170.2 |
| 5 | .0296 | -73.5 | .0067 | -96.6 | .0067 | -91.1 |
| 6 | .0212 | -95.3 | .0047 | 63.8 | .0047 | 62.9 |
| 7 | .0203 | -2.3 | .0037 | -57.8 | .0042 | -68.9 |
| 8 | .0201 | 20.0 | .0113 | -1.3 | .0117 | -2.5 |
| 9 | .0117 | -16.8 | .0014 | -54.6 | .0009 | -43.7 |
| 10 | .0063 | 16.9 | .0119 | -53.2 | .0126 | -57.0 |

## TABLE 19 – EXPERIMENTAL LOADS DURING QUASI-STEADY CRASH ASTERN AT V = 0.74 M/SEC, n = 6.77 REV/SEC, $(P/D)_{0.7}$ = -0.67

### TABLE 19a – SIGNALS RECONSTRUCTED FROM FIRST TEN HARMONICS (Five for $M_z$)

| $\theta$ | $F_x/\bar{F}_{x_{SP}}$ | $F_y/\bar{F}_{y_{SP}}$ | $M_x/\lvert\bar{M}_{x_{SP}}\rvert$ | $M_y/\bar{M}_{y_{SP}}$ | $M_z/\lvert\bar{M}_{z_{SP}}\rvert$ | $M_h/\bar{M}_{h_{SP}}$ | $M_{0.4}/M_{0.4_{SP}}$ |
|---|---|---|---|---|---|---|---|
| 0 | -.4030 | .1609 | -.3022 | -.4459 | -2.6159 | -.4736 | -.2636 |
| 4 | -.4041 | .1547 | -.2958 | -.4467 | -2.6044 | -.4745 | -.2654 |
| 8 | -.4058 | .1483 | -.2888 | -.4480 | -2.5929 | -.4759 | -.2677 |
| 12 | -.4080 | .1418 | -.2815 | -.4498 | -2.5826 | -.4778 | -.2706 |
| 16 | -.4102 | .1358 | -.2745 | -.4516 | -2.5745 | -.4797 | -.2736 |
| 20 | -.4117 | .1307 | -.2684 | -.4528 | -2.5692 | -.4811 | -.2760 |
| 24 | -.4118 | .1266 | -.2635 | -.4529 | -2.5670 | -.4813 | -.2774 |
| 28 | -.4103 | .1237 | -.2600 | -.4516 | -2.5679 | -.4802 | -.2776 |
| 32 | -.4075 | .1221 | -.2580 | -.4491 | -2.5716 | -.4781 | -.2766 |
| 36 | -.4041 | .1215 | -.2572 | -.4463 | -2.5773 | -.4754 | -.2750 |
| 40 | -.4012 | .1218 | -.2576 | -.4438 | -2.5843 | -.4731 | -.2733 |
| 44 | -.3993 | .1230 | -.2590 | -.4421 | -2.5918 | -.4715 | -.2719 |
| 48 | -.3987 | .1249 | -.2613 | -.4416 | -2.5988 | -.4709 | -.2708 |
| 52 | -.3991 | .1274 | -.2642 | -.4418 | -2.6047 | -.4708 | -.2700 |
| 56 | -.3998 | .1305 | -.2677 | -.4421 | -2.6089 | -.4708 | -.2691 |
| 60 | -.3998 | .1337 | -.2713 | -.4418 | -2.6111 | -.4702 | -.2677 |
| 64 | -.3984 | .1369 | -.2747 | -.4405 | -2.6112 | -.4687 | -.2658 |
| 68 | -.3960 | .1397 | -.2776 | -.4383 | -2.6093 | -.4664 | -.2635 |
| 72 | -.3929 | .1417 | -.2797 | -.4355 | -2.6058 | -.4637 | -.2613 |
| 76 | -.3897 | .1432 | -.2808 | -.4327 | -2.6010 | -.4610 | -.2593 |
| 80 | -.3871 | .1441 | -.2814 | -.4305 | -2.5954 | -.4589 | -.2579 |
| 84 | -.3853 | .1450 | -.2819 | -.4289 | -2.5893 | -.4575 | -.2570 |
| 88 | -.3843 | .1462 | -.2828 | -.4279 | -2.5832 | -.4564 | -.2562 |
| 92 | -.3837 | .1481 | -.2845 | -.4271 | -2.5772 | -.4553 | -.2550 |
| 96 | -.3831 | .1508 | -.2874 | -.4261 | -2.5712 | -.4539 | -.2533 |
| 100 | -.3823 | .1542 | -.2913 | -.4249 | -2.5652 | -.4523 | -.2510 |
| 104 | -.3815 | .1580 | -.2959 | -.4240 | -2.5588 | -.4511 | -.2488 |
| 108 | -.3816 | .1616 | -.3006 | -.4242 | -2.5516 | -.4511 | -.2475 |
| 112 | -.3831 | .1646 | -.3049 | -.4262 | -2.5434 | -.4533 | -.2480 |
| 116 | -.3865 | .1668 | -.3084 | -.4305 | -2.5337 | -.4581 | -.2509 |
| 120 | -.3918 | .1681 | -.3107 | -.4369 | -2.5224 | -.4654 | -.2561 |

TABLE 19a – (Continued)

| $\theta$ | $F_x/\bar{F}_{x_{SP}}$ | $F_y/\bar{F}_{y_{SP}}$ | $M_x/\lvert\bar{M}_{x_{SP}}\rvert$ | $M_y/\bar{M}_{y_{SP}}$ | $M_z/\lvert\bar{M}_{z_{SP}}\rvert$ | $M_h/\bar{M}_{h_{SP}}$ | $M_{0.4}/M_{0.4_{SP}}$ |
|---|---|---|---|---|---|---|---|
| 124 | -.3982 | .1686 | -.3119 | -.4446 | -2.5095 | -.4742 | -.2630 |
| 128 | -.4045 | .1685 | -.3120 | -.4523 | -2.4952 | -.4831 | -.2702 |
| 132 | -.4096 | .1678 | -.3110 | -.4585 | -2.4798 | -.4904 | -.2767 |
| 136 | -.4125 | .1668 | -.3090 | -.4623 | -2.4679 | -.4949 | -.2814 |
| 140 | -.4130 | .1654 | -.3060 | -.4632 | -2.4483 | -.4963 | -.2840 |
| 144 | -.4113 | .1635 | -.3023 | -.4618 | -2.4336 | -.4950 | -.2845 |
| 148 | -.4093 | .1614 | -.2981 | -.4591 | -2.4210 | -.4922 | -.2839 |
| 152 | -.4073 | .1592 | -.2938 | -.4564 | -2.4107 | -.4893 | -.2831 |
| 156 | -.4067 | .1574 | -.2900 | -.4549 | -2.4034 | -.4874 | -.2829 |
| 160 | -.4077 | .1562 | -.2872 | -.4551 | -2.3992 | -.4871 | -.2836 |
| 164 | -.4101 | .1562 | -.2860 | -.4568 | -2.3982 | -.4885 | -.2851 |
| 168 | -.4133 | .1575 | -.2865 | -.4594 | -2.4001 | -.4909 | -.2870 |
| 172 | -.4166 | .1601 | -.2887 | -.4623 | -2.4043 | -.4935 | -.2888 |
| 176 | -.4196 | .1639 | -.2922 | -.4650 | -2.4100 | -.4960 | -.2901 |
| 180 | -.4223 | .1684 | -.2968 | -.4675 | -2.4164 | -.4983 | -.2909 |
| 184 | -.4252 | .1732 | -.3020 | -.4703 | -2.4226 | -.5009 | -.2918 |
| 188 | -.4290 | .1783 | -.3076 | -.4740 | -2.4277 | -.5045 | -.2933 |
| 192 | -.4343 | .1832 | -.3134 | -.4794 | -2.4310 | -.5099 | -.2961 |
| 196 | -.4413 | .1881 | -.3194 | -.4868 | -2.4320 | -.5176 | -.3006 |
| 200 | -.4496 | .1928 | -.3255 | -.4960 | -2.4304 | -.5273 | -.3068 |
| 204 | -.4586 | .1971 | -.3314 | -.5062 | -2.4262 | -.5385 | -.3143 |
| 208 | -.4672 | .2009 | -.3366 | -.5164 | -2.4197 | -.5499 | -.3222 |
| 212 | -.4743 | .2039 | -.3407 | -.5254 | -2.4113 | -.5603 | -.3298 |
| 216 | -.4792 | .2057 | -.3431 | -.5322 | -2.4018 | -.5684 | -.3362 |
| 220 | -.4815 | .2064 | -.3437 | -.5361 | -2.3917 | -.5735 | -.3407 |
| 224 | -.4811 | .2062 | -.3427 | -.5368 | -2.3817 | -.5750 | -.3429 |
| 228 | -.4784 | .2054 | -.3407 | -.5345 | -2.3724 | -.5730 | -.3425 |
| 232 | -.4736 | .2046 | -.3384 | -.5295 | -2.3643 | -.5679 | -.3396 |
| 236 | -.4672 | .2045 | -.3369 | -.5225 | -2.3576 | -.5603 | -.3344 |
| 240 | -.4596 | .2055 | -.3367 | -.5139 | -2.3524 | -.5508 | -.3273 |

TABLE 19a – (Continued)

| $\theta$ | $F_x/\bar{F}_{x_{SP}}$ | $F_y/\bar{F}_{y_{SP}}$ | $M_x/\lvert\bar{M}_{x_{SP}}\rvert$ | $M_y/\bar{M}_{y_{SP}}$ | $M_z/\lvert\bar{M}_{z_{SP}}\rvert$ | $M_h/\bar{M}_{h_{SP}}$ | $M_{0.4}/M_{0.4_{SP}}$ |
|---|---|---|---|---|---|---|---|
| 244 | -.4513 | .2077 | -.3381 | -.5046 | -2.3486 | -.5404 | -.3189 |
| 248 | -.4429 | .2108 | -.3410 | -.4951 | -2.3459 | -.5298 | -.3100 |
| 252 | -.4345 | .2143 | -.3445 | -.4860 | -2.3439 | -.5197 | -.3012 |
| 256 | -.4269 | .2177 | -.3481 | -.4778 | -2.3423 | -.5107 | -.2933 |
| 260 | -.4204 | .2203 | -.3507 | -.4708 | -2.3410 | -.5031 | -.2867 |
| 264 | -.4143 | .2217 | -.3520 | -.4650 | -2.3398 | -.4968 | -.2816 |
| 268 | -.4105 | .2219 | -.3518 | -.4603 | -2.3388 | -.4918 | -.2778 |
| 272 | -.4068 | .2210 | -.3503 | -.4565 | -2.3382 | -.4877 | -.2751 |
| 276 | -.4037 | .2194 | -.3481 | -.4531 | -2.3385 | -.4842 | -.2730 |
| 280 | -.4009 | .2176 | -.3457 | -.4499 | -2.3403 | -.4808 | -.2709 |
| 284 | -.3981 | .2159 | -.3437 | -.4468 | -2.3443 | -.4775 | -.2687 |
| 288 | -.3952 | .2147 | -.3426 | -.4436 | -2.3511 | -.4740 | -.2660 |
| 292 | -.3921 | .2142 | -.3423 | -.4402 | -2.3614 | -.4703 | -.2629 |
| 296 | -.3887 | .2142 | -.3429 | -.4365 | -2.3756 | -.4662 | -.2593 |
| 300 | -.3847 | .2148 | -.3441 | -.4324 | -2.3938 | -.4618 | -.2553 |
| 304 | -.3802 | .2155 | -.3454 | -.4279 | -2.4159 | -.4570 | -.2511 |
| 308 | -.3753 | .2160 | -.3464 | -.4231 | -2.4413 | -.4521 | -.2469 |
| 312 | -.3705 | .2160 | -.3468 | -.4184 | -2.4692 | -.4473 | -.2430 |
| 316 | -.3664 | .2151 | -.3462 | -.4145 | -2.4985 | -.4433 | -.2400 |
| 320 | -.3639 | .2130 | -.3445 | -.4121 | -2.5279 | -.4409. | -.2382 |
| 324 | -.3637 | .2097 | -.3418 | -.4118 | -2.5560 | -.4406 | -.2381 |
| 328 | -.3663 | .2053 | -.3381 | -.4139 | -2.5814 | -.4426 | -.2397 |
| 332 | -.3713 | .2001 | -.3339 | -.4182 | -2.6031 | -.4468 | -.2429 |
| 336 | -.3779 | .1944 | -.3295 | -.4241 | -2.6199 | -.4525 | -.2470 |
| 340 | -.3852 | .1887 | -.3252 | -.4305 | -2.6314 | -.4586 | -.2515 |
| 344 | -.3917 | .1831 | -.3210 | -.4363 | -2.6374 | -.4642 | -.2554 |
| 348 | -.3968 | .1776 | -.3169 | -.4407 | -2.6380 | -.4685 | -.2585 |
| 352 | -.4001 | .1723 | -.3126 | -.4435 | -2.6340 | -.4712 | -.2607 |
| 356 | -.4019 | .1668 | -.3078 | -.4450 | -2.6262 | -.4727 | -.2622 |
| 360 | -.4030 | .1609 | -.3022 | -.4459 | -2.6159 | -.4736 | -.2636 |

## TABLE 19b – HARMONIC CONTENT OF SIGNALS

| n | $\frac{(F_x)_n}{\bar{F}_{x_{SP}}}$ | $(\phi_x)_n$ (deg) | $\frac{(F_y)_n}{\bar{F}_{y_{SP}}}$ | $(\phi_y)_n$ (deg) | $\frac{(M_x)_n}{\lvert\bar{M}_{x_{SP}}\rvert}$ | $(\phi_x)_n$ (deg) | $\frac{(M_y)_n}{\bar{M}_{y_{SP}}}$ | $(\phi_y)_n$ (deg) |
|---|---|---|---|---|---|---|---|---|
| 1 | .0271 | 30.1 | .0406 | -102.4 | .0363 | 78.1 | .0314 | 33.4 |
| 2 | .0265 | -106.6 | .0152 | -130.7 | .0147 | 50.8 | .0261 | -104.6 |
| 3 | .0100 | -177.1 | .0089 | -69.8 | .0113 | 125.4 | .0112 | -177.2 |
| 4 | .0055 | -19.5 | .0018 | 164.6 | .0032 | -17.6 | .0071 | -5.7 |
| 5 | .0076 | -173.3 | .0041 | -74.0 | .0059 | 120.0 | .0094 | -170.6 |
| 6 | .0016 | 128.0 | .0021 | 102.6 | .0025 | -85.3 | .0016 | 113.6 |
| 7 | .0019 | 25.6 | .0019 | 60.2 | .0023 | -118.1 | .0022 | 22.4 |
| 8 | .0012 | 110.4 | .0006 | -34.9 | .0013 | 137.9 | .0014 | 136.4 |
| 9 | .0020 | -3.7 | .0005 | -106.5 | .0006 | 55.7 | .0020 | -6.1 |
| 10 | .0015 | 75.8 | .0006 | 27.4 | .0007 | -149.8 | .0014 | 77.2 |

| n | $\frac{(M_z)_n}{\lvert\bar{M}_{z_{SP}}\rvert}$ | $(\phi_z)_n$ (deg) | $\frac{(M_h)_n}{\bar{M}_{h_{SP}}}$ | $(\phi_h)_n$ (deg) | $\frac{(M_{0.4})_n}{\bar{M}_{0.4_{SP}}}$ | $(\phi_{0.4})_n$ (deg) |
|---|---|---|---|---|---|---|
| 1 | .1316 | -134.3 | .0346 | 33.8 | .0260 | 28.7 |
| 2 | .0296 | -173.0 | .0273 | -103.7 | .0231 | -104.7 |
| 3 | .0457 | 104.7 | .0120 | -175.5 | .0075 | -158.5 |
| 4 | .0104 | 103.2 | .0084 | .5 | .0062 | 8.7 |
| 5 | .0179 | 78.2 | .0092 | -167.6 | .0057 | -151.9 |
| 6 | .0206 | 33.8 | .0018 | 103.5 | .0021 | 92.0 |
| 7 | .0135 | -51.2 | .0026 | 22.3 | .0027 | 30.2 |
| 8 | .0247 | -101.3 | .0017 | 148.5 | .0011 | 166.8 |
| 9 | .0106 | 161.9 | .0021 | -8.3 | .0015 | -14.4 |
| 10 | .0153 | 139.4 | .0014 | 77.4 | .0011 | 72.9 |

## TABLE 20 – EXPERIMENTAL LOADS DURING QUASI-STEADY CRASH ASTERN AT V = 0.17 M/SEC, n = 7.64 REV/SEC, $(P/D)_{0.7} = -0.67$

### TABLE 20a – SIGNALS RECONSTRUCTED FROM FIRST TEN HARMONICS (Five for $M_z$)

| $\theta$ | $F_x/\bar{F}_{x_{SP}}$ | $F_y/\bar{F}_{y_{SP}}$ | $M_x/\lvert\bar{M}_{x_{SP}}\rvert$ | $M_y/\bar{M}_{y_{SP}}$ | $M_z/\lvert\bar{M}_{z_{SP}}\rvert$ | $M_h/\bar{M}_{h_{SP}}$ | $M_{0.4}/M_{0.4_{SP}}$ |
|---|---|---|---|---|---|---|---|
| 0 | -.4109 | .2155 | -.3991 | -.5068 | -4.4683 | -.5667 | -.3215 |
| 4 | -.4323 | .2199 | -.4106 | -.5324 | -4.5131 | -.5952 | -.3337 |
| 8 | -.4511 | .2256 | -.4230 | -.5553 | -4.5587 | -.6208 | -.3558 |
| 12 | -.4655 | .2309 | -.4342 | -.5734 | -4.6044 | -.6414 | -.3686 |
| 16 | -.4745 | .2345 | -.4420 | -.5857 | -4.6501 | -.6558 | -.3777 |
| 20 | -.4784 | .2354 | -.4452 | -.5918 | -4.6958 | -.6634 | -.3829 |
| 24 | -.4777 | .2331 | -.4435 | -.5924 | -4.7415 | -.6649 | -.3846 |
| 28 | -.4733 | .2283 | -.4380 | -.5885 | -4.7872 | -.6614 | -.3834 |
| 32 | -.4665 | .2221 | -.4304 | -.5815 | -4.8330 | -.6543 | -.3799 |
| 36 | -.4582 | .2157 | -.4228 | -.5728 | -4.8788 | -.6454 | -.3746 |
| 40 | -.4496 | .2105 | -.4172 | -.5637 | -4.9247 | -.6359 | -.3691 |
| 44 | -.4415 | .2072 | -.4144 | -.5551 | -4.9687 | -.6268 | -.3612 |
| 48 | -.4349 | .2059 | -.4145 | -.5479 | -5.0115 | -.6192 | -.3545 |
| 52 | -.4299 | .2062 | -.4167 | -.5424 | -5.0519 | -.6132 | -.3496 |
| 56 | -.4257 | .2073 | -.4198 | -.5386 | -5.0888 | -.6091 | -.3459 |
| 60 | -.4233 | .2083 | -.4223 | -.5365 | -5.1216 | -.6066 | -.3407 |
| 64 | -.4229 | .2085 | -.4235 | -.5356 | -5.1496 | -.6055 | -.3391 |
| 68 | -.4231 | .2078 | -.4232 | -.5357 | -5.1727 | -.6053 | -.3387 |
| 72 | -.4240 | .2062 | -.4216 | -.5363 | -5.1896 | -.6058 | -.3391 |
| 76 | -.4252 | .2041 | -.4195 | -.5372 | -5.2017 | -.6066 | -.3400 |
| 80 | -.4261 | .2022 | -.4176 | -.5381 | -5.2090 | -.6075 | -.3410 |
| 84 | -.4266 | .2009 | -.4164 | -.5388 | -5.2124 | -.6085 | -.3419 |
| 88 | -.4271 | .2000 | -.4160 | -.5395 | -5.2129 | -.6093 | -.3426 |
| 92 | -.4271 | .2000 | -.4163 | -.5399 | -5.2115 | -.6100 | -.3430 |
| 96 | -.4269 | .2003 | -.4169 | -.5400 | -5.2093 | -.6103 | -.3432 |
| 100 | -.4264 | .2008 | -.4174 | -.5397 | -5.2072 | -.6102 | -.3432 |
| 104 | -.4256 | .2012 | -.4173 | -.5391 | -5.2061 | -.6096 | -.3430 |
| 108 | -.4246 | .2012 | -.4168 | -.5380 | -5.2063 | -.6085 | -.3424 |
| 112 | -.4234 | .2011 | -.4159 | -.5366 | -5.2079 | -.6070 | -.3417 |
| 116 | -.4221 | .2009 | -.4149 | -.5351 | -5.2107 | -.6053 | -.3409 |
| 120 | -.4209 | .2010 | -.4142 | -.5337 | -5.2143 | -.6038 | -.3401 |

TABLE 20a – (Continued)

| $\theta$ | $F_x/\bar{F}_{x_{SP}}$ | $F_y/\bar{F}_{y_{SP}}$ | $M_x/\lvert\bar{M}_{x_{SP}}\rvert$ | $M_y/\bar{M}_{y_{SP}}$ | $M_z/\lvert\bar{M}_{z_{SP}}\rvert$ | $M_h/\bar{M}_{h_{SP}}$ | $M_{0.4}/M_{0.4_{SP}}$ |
|---|---|---|---|---|---|---|---|
| 124 | -.4193 | .2015 | -.4141 | -.5325 | -5.2179 | -.6025 | -.3395 |
| 128 | -.4190 | .2030 | -.4148 | -.5317 | -5.2296 | -.6017 | -.3391 |
| 132 | -.4184 | .2052 | -.4162 | -.5312 | -5.2217 | -.6012 | -.3389 |
| 136 | -.4178 | .2080 | -.4180 | -.5308 | -5.2204 | -.6008 | -.3388 |
| 140 | -.4174 | .2111 | -.4201 | -.5303 | -5.2161 | -.6002 | -.3385 |
| 144 | -.4167 | .2141 | -.4220 | -.5296 | -5.2086 | -.5994 | -.3381 |
| 148 | -.4160 | .2167 | -.4235 | -.5286 | -5.1978 | -.5984 | -.3375 |
| 152 | -.4152 | .2186 | -.4244 | -.5276 | -5.1840 | -.5972 | -.3369 |
| 156 | -.4145 | .2201 | -.4247 | -.5267 | -5.1678 | -.5960 | -.3364 |
| 160 | -.4139 | .2211 | -.4247 | -.5259 | -5.1498 | -.5952 | -.3361 |
| 164 | -.4136 | .2222 | -.4245 | -.5254 | -5.1310 | -.5946 | -.3363 |
| 168 | -.4133 | .2236 | -.4247 | -.5251 | -5.1120 | -.5943 | -.3366 |
| 172 | -.4130 | .2256 | -.4253 | -.5248 | -5.0934 | -.5940 | -.3369 |
| 176 | -.4124 | .2291 | -.4265 | -.5242 | -5.0758 | -.5934 | -.3369 |
| 180 | -.4116 | .2310 | -.4281 | -.5232 | -5.0593 | -.5923 | -.3363 |
| 184 | -.4104 | .2338 | -.4298 | -.5218 | -5.0439 | -.5907 | -.3353 |
| 188 | -.4091 | .2364 | -.4313 | -.5202 | -5.0290 | -.5887 | -.3339 |
| 192 | -.4075 | .2383 | -.4323 | -.5185 | -5.0142 | -.5867 | -.3325 |
| 196 | -.4065 | .2398 | -.4326 | -.5169 | -4.9987 | -.5848 | -.3314 |
| 200 | -.4055 | .2409 | -.4324 | -.5155 | -4.9819 | -.5832 | -.3306 |
| 204 | -.4045 | .2421 | -.4321 | -.5142 | -4.9631 | -.5818 | -.3302 |
| 208 | -.4032 | .2436 | -.4320 | -.5127 | -4.9419 | -.5802 | -.3298 |
| 212 | -.4016 | .2457 | -.4324 | -.5110 | -4.9180 | -.5784 | -.3290 |
| 216 | -.3997 | .2484 | -.4336 | -.5088 | -4.8918 | -.5760 | -.3276 |
| 220 | -.3976 | .2514 | -.4353 | -.5064 | -4.8637 | -.5732 | -.3257 |
| 224 | -.3958 | .2544 | -.4372 | -.5040 | -4.8344 | -.5704 | -.3234 |
| 228 | -.3944 | .2568 | -.4390 | -.5021 | -4.8052 | -.5680 | -.3214 |
| 232 | -.3939 | .2587 | -.4404 | -.5011 | -4.7770 | -.5665 | -.3200 |
| 236 | -.3942 | .2598 | -.4412 | -.5009 | -4.7510 | -.5661 | -.3195 |
| 240 | -.3950 | .2605 | -.4414 | -.5015 | -4.7282 | -.5665 | -.3193 |

TABLE 20a – (Continued)

| $\theta$ | $F_x/\bar{F}_{x_{SP}}$ | $F_y/\bar{F}_{y_{SP}}$ | $M_x/\lvert\bar{M}_{x_{SP}}\rvert$ | $M_y/\bar{M}_{y_{SP}}$ | $M_z/\lvert\bar{M}_{z_{SP}}\rvert$ | $M_h/\bar{M}_{h_{SP}}$ | $M_{0.4}/M_{0.4_{SP}}$ |
|---|---|---|---|---|---|---|---|
| 244 | -.3959 | .2609 | -.4412 | -.5023 | -4.7093 | -.5673 | -.3209 |
| 248 | -.3963 | .2613 | -.4407 | -.5028 | -4.5946 | -.5679 | -.3218 |
| 252 | -.3961 | .2618 | -.4403 | -.5025 | -4.6839 | -.5677 | -.3222 |
| 256 | -.3957 | .2624 | -.4398 | -.5015 | -4.6766 | -.5665 | -.3218 |
| 260 | -.3941 | .2627 | -.4393 | -.4999 | -4.6717 | -.5647 | -.3207 |
| 264 | -.3932 | .2628 | -.4387 | -.4985 | -4.6678 | -.5623 | -.3195 |
| 268 | -.3932 | .2625 | -.4380 | -.4979 | -4.6633 | -.5619 | -.3188 |
| 272 | -.3945 | .2619 | -.4373 | -.4987 | -4.6567 | -.5626 | -.3193 |
| 276 | -.3970 | .2613 | -.4369 | -.5013 | -4.6464 | -.5652 | -.3214 |
| 280 | -.4004 | .2607 | -.4366 | -.5052 | -4.6311 | -.5696 | -.3248 |
| 284 | -.4041 | .2603 | -.4367 | -.5097 | -4.6102 | -.5748 | -.3290 |
| 288 | -.4073 | .2600 | -.4368 | -.5139 | -4.5837 | -.5799 | -.3331 |
| 292 | -.4097 | .2595 | -.4366 | -.5169 | -4.5508 | -.5835 | -.3362 |
| 296 | -.4098 | .2585 | -.4356 | -.5177 | -4.5136 | -.5845 | -.3373 |
| 300 | -.4086 | .2567 | -.4334 | -.5158 | -4.4731 | -.5824 | -.3359 |
| 304 | -.4055 | .2541 | -.4301 | -.5112 | -4.4310 | -.5767 | -.3318 |
| 308 | -.4005 | .2510 | -.4258 | -.5039 | -4.3896 | -.5678 | -.3252 |
| 312 | -.3936 | .2476 | -.4210 | -.4940 | -4.3510 | -.5559 | -.3163 |
| 316 | -.3848 | .2444 | -.4161 | -.4821 | -4.3173 | -.5417 | -.3056 |
| 320 | -.3744 | .2416 | -.4116 | -.4687 | -4.2903 | -.5260 | -.2938 |
| 324 | -.3630 | .2392 | -.4075 | -.4547 | -4.2715 | -.5100 | -.2818 |
| 328 | -.3517 | .2368 | -.4036 | -.4414 | -4.2618 | -.4950 | -.2707 |
| 332 | -.3421 | .2340 | -.3994 | -.4302 | -4.2616 | -.4827 | -.2619 |
| 336 | -.3358 | .2303 | -.3950 | -.4230 | -4.2708 | -.4749 | -.2566 |
| 340 | -.3345 | .2258 | -.3905 | -.4215 | -4.2888 | -.4732 | -.2560 |
| 344 | -.3393 | .2210 | -.3867 | -.4266 | -4.3144 | -.4799 | -.2606 |
| 348 | -.3505 | .2167 | -.3846 | -.4389 | -4.3466 | -.4922 | -.2706 |
| 352 | -.3674 | .2138 | -.3857 | -.4575 | -4.3839 | -.5126 | -.2851 |
| 356 | -.3891 | .2133 | -.3905 | -.4810 | -4.4248 | -.5383 | -.3026 |
| 360 | -.4105 | .2155 | -.3991 | -.5068 | -4.4583 | -.5667 | -.3215 |

## TABLE 20b – HARMONIC CONTENT OF SIGNALS

| n | $\frac{(F_x)_n}{\bar{F}_{x_{SP}}}$ | $(\phi_x)_n$ (deg) | $\frac{(F_y)_n}{\bar{F}_{y_{SP}}}$ | $(\phi_y)_n$ (deg) | $\frac{(M_x)_n}{\lvert\bar{M}_{x_{SP}}\rvert}$ | $(\phi_x)_n$ (deg) | $\frac{(M_y)_n}{\bar{M}_{y_{SP}}}$ | $(\phi_y)_n$ (deg) |
|---|---|---|---|---|---|---|---|---|
| 1 | .0228 | -92.5 | .0292 | -94.9 | .0105 | 42.3 | .0287 | -81.8 |
| 2 | .0145 | -63.7 | .0049 | 118.8 | .0099 | -58.2 | .0193 | -76.8 |
| 3 | .0185 | -80.4 | .0040 | 112.4 | .0080 | -69.5 | .0224 | -76.5 |
| 4 | .0185 | -91.1 | .0023 | 107.0 | .0059 | -83.0 | .0218 | -88.4 |
| 5 | .0133 | -92.1 | .0034 | 98.1 | .0063 | -87.8 | .0154 | -91.6 |
| 6 | .0072 | -99.6 | .0025 | 114.5 | .0043 | -82.1 | .0080 | -101.4 |
| 7 | .0024 | -111.9 | .0020 | 141.0 | .0029 | -54.1 | .0025 | -115.6 |
| 8 | .0009 | -85.8 | .0025 | 144.2 | .0036 | -40.1 | .0010 | -63.8 |
| 9 | .0011 | -104.4 | .0017 | -163.2 | .0021 | 4.4 | .0011 | -72.5 |
| 10 | .0007 | -171.4 | .0006 | 152.1 | .0009 | -11.9 | .0007 | -162.7 |

| n | $\frac{(M_z)_n}{\lvert\bar{M}_{z_{SP}}\rvert}$ | $(\phi_z)_n$ (deg) | $\frac{(M_h)_n}{\bar{M}_{h_{SP}}}$ | $(\phi_h)_n$ (deg) | $\frac{(M_{0.4})_n}{\bar{M}_{0.4_{SP}}}$ | $(\phi_{0.4})_n$ (deg) |
|---|---|---|---|---|---|---|
| 1 | .4272 | -49.2 | .0333 | -77.7 | .0183 | -78.0 |
| 2 | .1081 | -37.0 | .0211 | -74.1 | .0141 | -76.5 |
| 3 | .0592 | -46.7 | .0255 | -74.7 | .0181 | -73.9 |
| 4 | .0191 | -109.1 | .0245 | -87.0 | .0176 | -85.9 |
| 5 | .0245 | 170.1 | .0170 | -91.4 | .0115 | -91.1 |
| 6 | .0305 | 133.0 | .0087 | -102.7 | .0054 | -106.5 |
| 7 | .0315 | 69.0 | .0026 | -120.4 | .0016 | -148.6 |
| 8 | .0157 | 23.5 | .0009 | -53.2 | .0004 | 131.2 |
| 9 | .0159 | 60.9 | .0013 | -60.3 | .0008 | -74.6 |
| 10 | .0077 | 72.2 | .0007 | -158.2 | .0008 | -160.3 |

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