

AD-752 468

PROGRAM SCORES - SHIP STRUCTURAL RESPONSE
IN WAVES

Alfred I. Raff

Oceanics, Incorporated

Prepared for:

Ship Structure Committee
Naval Ship Engineering Center

July 1972

DISTRIBUTED BY:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

AD752468

SSC-230

PROGRAM SCORES—SHIP STRUCTURAL RESPONSE IN WAVES

This document has been approved
for public release and sale; its
distribution is unlimited.

Reprinted by
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. Department of Commerce
705 G. L. P. A. 2151

D D C
RECEIVED
DEC 14 1972
RECEIVED
B. /

SHIP STRUCTURE COMMITTEE

1972

69

R

SHIP STRUCTURE COMMITTEE

AN INTERAGENCY ADVISORY
COMMITTEE DEDICATED TO IMPROVING
THE STRUCTURE OF SHIPS

MEMBER AGENCIES:

UNITED STATES COAST GUARD
NAVAL SHIP SYSTEMS COMMAND
MILITARY SEALIFT COMMAND
MARITIME ADMINISTRATION
AMERICAN BUREAU OF SHIPPING

ADDRESS CORRESPONDENCE TO:

SECRETARY
SHIP STRUCTURE COMMITTEE
U.S. COAST GUARD HEADQUARTERS
WASHINGTON, D.C. 20591

SR-174
1972

Dear Sir:

A major portion of the effort of the Ship Structure Committee program has been devoted to improving capability of predicting the loads which a ship's hull experiences.

This report contains details of a computer program, SCORES, which predicts these loads. Details of the development and verification of the program are contained in SSC-229, Evaluation and Verification of Computer Calculations of Wave-Induced Ship Structural Loads. Additional information on this program may be found in SSC-231, Further Studies of Computer Simulation of Slamming and Other Wave-Induced Vibratory Structural Loadings.

Comments on this report would be welcomed.

Sincerely,



W. F. REA, III
Rear Admiral, U. S. Coast Guard
Chairman, Ship Structure Committee

White Section	<input checked="" type="checkbox"/>
Blue Section	<input type="checkbox"/>
Justification	<input type="checkbox"/>
BY: [Signature]	
DATE: [Date]	
CLASSIFICATION: [Classification]	

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified

1 ORIGINATING ACTIVITY (Corporate author) Oceanics, Inc. Plainview, New York		20. REPORT SECURITY CLASSIFICATION Unclassified	
		21. GROUP	
3. REPORT TITLE Program SCORES -- Ship Structural Response in Waves			
4. DESCRIPTIVE NOTES (Type of report and inclusive dates)			
5. AUTHOR(S) (First name, middle initial, last name) A. I. Raff			
6. REPORT DATE July 1972		7a. TOTAL NO. OF PAGES 53	7b. NO. OF REFS
8a. CONTRACT OR GRANT NO. N00024-70-C-5076		9a. ORIGINATOR'S REPORT NUMBER(S)	
b. PROJECT NO.		9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) SSC-230	
c.			
d.			
10. DISTRIBUTION STATEMENT Unlimited			
11. SUPPLEMENTARY NOTES		12. SPONSORING MILITARY ACTIVITY Naval Ship Systems Command	
13. ABSTRACT <p>Information necessary for the use of the SCORES digital computer program is given. This program calculates both the vertical and lateral plane motions and applied loads of a ship in waves. Strip theory is used and each ship hull cross-section is assumed to be of Lewis form for the purpose of calculating hydrodynamic forces. The ship can be at any heading, relative to the wave direction. Both regular and irregular wave results can be obtained, including short crested seas (directional wave spectrum). All three primary ship hull loadings are computed, i.e. vertical bending, lateral bending and torsional moments.</p> <p>All the basic equations used in the analysis are given, as well as a description of the overall program structure. The input data requirements and format are specified. Sample input and output are shown. The Appendices include a description of the FORTRAN program organization, together with flowcharts and a complete cross-referenced listing of the source language.</p>			

Ta

SSC-230

Final Report
on
Project SR-174, "Ship Computer Response"
to the
Ship Structure Committee

PROGRAM SCORES - SHIP STRUCTURAL
RESPONSE IN WAVES

by

Alfred I. Raff
Oceanics, Inc.

under

Department of the Navy
Naval Ship Engineering Center
Contract No. N00024-70-C-5076

*This document has been approved for public release and
sale; its distribution is unlimited.*

U. S. Coast Guard Headquarters
Washington, D. C.
1972

ABSTRACT

Information necessary for the use of the SCORES digital computer program is given. This program calculates both the vertical and lateral plane motions and applied loads of a ship in waves. Strip theory is used and each ship hull cross-section is assumed to be of Lewis form for the purpose of calculating hydrodynamic forces. The ship can be at any heading, relative to the wave direction. Both regular and irregular wave results can be obtained, including short crested seas (directional wave spectrum). All three primary ship hull loadings are computed, i.e. vertical bending, lateral bending and torsional moments.

All the basic equations used in the analysis are given, as well as a description of the overall program structure. The input data requirements and format are specified. Sample input and output are shown. The Appendices include a description of the FORTRAN program organization, together with flowcharts and a complete cross-referenced listing of the source language.

CONTENTS

	<u>Page</u>
INTRODUCTION	1
METHOD OF ANALYSIS	1
VERTICAL PLANE EQUATIONS.	3
LATERAL PLANE EQUATIONS	8
WAVE SPECTRA EQUATIONS.	16
NON-DIMENSIONAL FORMS	19
PROGRAM ORGANIZATION	20
GENERAL	20
RESTRICTIONS.	21
RUNNING TIME.	22
DATA INPUT	22
UNITS	22
DATA CARD PREPARATION	23
SAMPLE INPUT.	30
PROGRAM OUTPUT	29
DESCRIPTION	29
SAMPLE OUTPUT	32
ERROR MESSAGES	37
ACKNOWLEDGEMENTS	37
APPENDIX A - PROGRAM DESCRIPTION.	38
APPENDIX B - FLOWCHARTS	40
APPENDIX C - LISTING.	52

SHIP STRUCTURE COMMITTEE

The SHIP STRUCTURE COMMITTEE is constituted to prosecute a research program to improve the hull structures of ships by an extension of knowledge pertaining to design, materials and methods of fabrication.

RADM W. F. Rea, III, USCG, Chairman
Chief, Office of Merchant Marine Safety
U. S. Coast Guard Headquarters

Capt. J. E. Rasmussen, USN
Head, Ship Systems Engineering
and Design Department
Naval Ship Engineering Center
Naval Ship Systems Command

Mr. E. S. Dillon
Chief
Office of Ship Construction
Maritime Administration

Mr. K. Morland, Vice President
American Bureau of Shipping

Capt. L. L. Jackson, USN
Maintenance and Repair Officer
Military Sealift Command

SHIP STRUCTURE SUBCOMMITTEE

The SHIP STRUCTURE SUBCOMMITTEE acts for the Ship Structure Committee on technical matters by providing technical coordination for the determination of goals and objectives of the program, and by evaluating and interpreting the results in terms of ship structural design, construction and operation.

NAVAL SHIP ENGINEERING CENTER

Mr. P. M. Palermo - Chairman
Mr. J. B. O'Brien - Contract Administrator
Mr. G. Sorkin - Member
Mr. H. S. Sayre - Alternate
Mr. I. Fioriti - Alternate

U. S. COAST GUARD

LCDR C. S. Loosmore, USCG - Secretary
CAPT C. R. Thompson, USCG - Member
CDR J. W. Kime, USCG - Alternate
CDR J. L. Coburn, USCG - Alternate

MARITIME ADMINISTRATION

Mr. F. Dashnaw - Member
Mr. A. Maillar - Member
Mr. R. Falls - Alternate
Mr. R. F. Coombs - Alternate

MILITARY SEALIFT COMMAND

Mr. R. R. Askren - Member
LTJG E. T. Powers, USNR - Member

AMERICAN BUREAU OF SHIPPING

Mr. S. G. Stiansen - Member
Mr. F. J. Crum - Member

OFFICE OF NAVAL RESEARCH

Mr. J. M. Crowley - Member
Dr. W. G. Rauch - Alternate

NAVAL SHIP RESEARCH & DEVELOPMENT CENTER

Mr. A. B. Stavovy - Alternate

NATIONAL ACADEMY OF SCIENCES - Ship Research Committee

Mr. R. W. Rumke, Liaison
Prof. R. A. Yagle, Liaison

SOCIETY OF NAVAL ARCHITECTS & MARINE ENGINEERS

Mr. T. M. Buermann, Liaison

BRITISH NAVY STAFF

Dr. V. Flint, Liaison
CDR P. H. H. Ablett, RCNC, Liaison

WELDING RESEARCH COUNCIL

Mr. K. H. Koopman, Liaison
Mr. C. Larson, Liaison

I. INTRODUCTION

This manual describes in detail the use of SCORES, which is a digital computer program for the calculation of the wave-induced motions and loads of a ship. Both the vertical and lateral plane motions are treated, so that results for vertical bending, lateral bending and torsional hull moments can be obtained. The principal assumptions of the method are that the motions are linear, can be solved by "strip theory" and that the ship sections can be approximated by "Lewis forms" for the purpose of calculating the hydrodynamic forces, that is, the required two-dimensional added mass and wave damping properties. Both regular or irregular waves can be specified, and for the latter multi-directional (short crested) seas are allowed.

SCORES was written in the FORTRAN IV language and checked out and run on the Control Data 6600 Computer using the SCOPE operating system (version 3.1.6). The program is unclassified.

The method of analysis used in SCORES is outlined below in Section II. All the equations of motion and loadings are given. In Section III, the organization of the SCORES program is discussed briefly. An explanation of input data card preparation is given in Section IV, and of program output in Section V. An example problem is shown. Error messages which can appear during program execution are described in Section VI.

The Appendices include a description of the FORTRAN program organization, flowcharts for each subprogram and a complete cross-referenced (to the flowcharts) listing of the source language.

II. METHOD OF ANALYSIS

The analysis used in SCORES was developed and investigated to some extent in work supported by the Ship Structure Committee.* The exposition to be given here will serve as a convenient listing of the equations, but for the full derivation and explanation of the analysis method, the references listed should be consulted.

*Kaplan, Paul, "Development of Mathematical Models for Describing Ship Structural Response in Waves," Ship Structure Committee Report SSC-193, January 1969 (AD 682591)

Kaplan, P., Sargent, T.P. and Raff, A.I., "An Investigation of the Utility of Computer Simulation to Predict Ship Structural Response in Waves," Ship Structure Committee Report SSC-197, June 1969 (AD 690229)

Kaplan, P., and Raff, A.I., "Evaluation and Verification of Computer Calculations of Wave-Induced Ship Structural Response." Ship Structure Committee Report SSC-229, July 1972.

The relationship between the water wave system and the ship coordinate axes system is shown in Figure 1. The wave propagation, at speed c , is considered fixed in space. The ship then travels, at speed V , at some angle, β with respect to the wave direction. The wave velocity potential, for simple deep-water waves, is then defined by:

$$\psi_w = -ace^{-kz'} \cos k (x' + ct) \quad (1)$$

where a = wave amplitude

c = wave speed

k = wave number = $\frac{2\pi}{\lambda}$

λ = wave length

z' = vertical coordinate, from undisturbed water surface positive downwards

x' = axis fixed in space

t = time

The x - y axes, with origin at G , the center of gravity of the ship, translate with the ship. The x' coordinate of a point in the x - y plane can be defined by:

$$x' = -(x+Vt) \cos \beta + y \sin \beta \quad (2)$$

Then, the surface wave elevation η (positive upwards) can be expressed as follows:

$$\eta = \frac{1}{g} \left(\frac{\partial \psi_w}{\partial t} \right)_{z'=0} = a \sin k (x' + ct) \quad (3)$$

since $c^2 = \frac{g}{k}$

where g = acceleration of gravity

In x - y coordinates we have:

$$\eta = a \sin k [-x \cos \beta + y \sin \beta + (c-V \cos \beta)t] \quad (4)$$

$$\dot{\eta} = \frac{D\eta}{Dt} = \left(\frac{\partial}{\partial t} - V \frac{\partial}{\partial x} \right) \eta (x, t)$$

$$\dot{\eta} = akc \cos k [-x \cos \beta + y \sin \beta + (c-V \cos \beta)t] \quad (5)$$

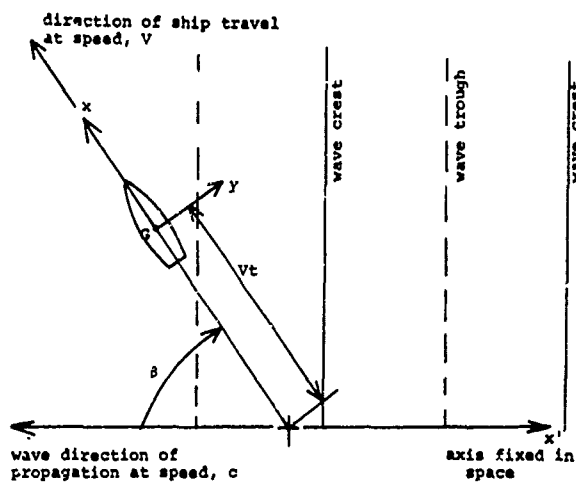


Fig. 1. Wave and Ship Axes Convention

$$\text{and } \ddot{\eta} = \frac{D\dot{\eta}}{Dt} = -akg \sin k [-x \cos \beta + y \sin \beta + (c-V \cos \beta)t] \quad (6)$$

The results of the equations of motion, etc., will be referenced to the wave elevation η at the origin of the x-y axes, that is:

$$\eta = a \sin k'(c-V \cos \beta) t \quad (7)$$

$$\text{or } \eta = a \sin \omega_e t$$

where

$$\omega_e = \frac{2\pi}{\lambda} (c-V \cos \beta) \quad (8)$$

and ω_e is known as the circular frequency of encounter.

A. Vertical Plane Equations

The coupled equations of motion for heave, z (positive downwards), and pitch, θ (positive bow-up), are given as:

$$m\ddot{z} = \int_{x_s}^{x_b} \frac{dz}{dx} dx + Z_w \quad (9)$$

$$I_Y \ddot{\theta} = - \int_{x_s}^{x_b} \frac{dZ}{dx} x dx + M_w \quad (10)$$

where

m = mass of ship

I_Y = mass moment of inertia of ship about y axis

$\frac{dZ}{dx}$ = local sectional vertical hydromechanic force on ship

x_s, x_b = coordinates of stern and bow ends of ship, respectively

Z_w, M_w = wave excitation force and moment on ship

The general hydromechanic force is taken to be:

$$\frac{dZ}{dx} = - \frac{D}{Dt} \left[A'_{33} (\dot{z} - x\dot{\theta} + V\theta) \right] - N'_z (\dot{z} - x\dot{\theta} + V\theta) - \rho g B^* (z - x\theta) \quad (11)$$

where

ρ = density of water

A'_{33} - local sectional vertical added mass

N'_z = local sectional vertical damping force coefficient

B^* = local waterline beam

and

$$N'_z = \rho g^2 \bar{A}^2 \omega_e^{-3} \quad (12)$$

with

\bar{A} = ratio of generated wave to wave amplitude for vertical motion-induced wave

Expanding the derivative, we obtain:

$$\frac{dz}{dx} = - A'_{33} (\ddot{z} - x\ddot{\theta} + 2V\dot{\theta}) - \left(N'_z - V \frac{dA'_{33}}{dx} \right) (\dot{z} - x\dot{\theta} + V\dot{\theta}) - \rho g B^* (z - x\theta) \quad (13)$$

The equations of motion, (9) and (10) are then transformed into the familiar form as follows:

$$a'\ddot{z} + b'\dot{z} + c'z - d\ddot{\theta} - e\dot{\theta} - g'\theta = Z_w \quad (14)$$

$$A\ddot{\theta} + B\dot{\theta} + C\theta - D\ddot{z} - E\dot{z} - G'z = M_w \quad (15)$$

The coefficients on the left hand sides are defined by:

$$\left. \begin{aligned} a' &= m + \int A'_{33} dx \\ b' &= \int N'_z dx - V \int d(A'_{33}) \\ c' &= \rho g \int B^* dx \\ d &= D = \int A'_{33} x dx \\ e &= \int N'_z x dx - 2V \int A'_{33} dx - V \int x d(A'_{33}) \\ g' &= \rho g \int B^* x dx - Vb \\ A &= I_y + \int A'_{33} x^2 dx \end{aligned} \right\} (16)$$

$$B = \int N'_z x^2 dx - 2V \int A'_{33} x dx - V \int x^2 d(A'_{33})$$

$$C = \rho g \int B^* x^2 dx - VE$$

$$E = \int N'_z x dx - V \int x d(A'_{33})$$

$$G' = \rho g \int B^* x dx$$

where all the indicated integrations are over the length of the ship.

The wave excitation, the right hand sides of Eqs. (14) and (15), is given by:

$$z_w = \int_{x_s}^{x_b} \frac{dz_w}{dx} dx \quad (17)$$

$$M_w = - \int_{x_s}^{x_b} \frac{dz_w}{dx} x dx \quad (18)$$

The local sectional vertical wave force acting on the ship section is represented as:

$$\frac{dz_w}{dx} = - \left[\rho g B^* \eta + \left(N'_z - V \frac{dA'_{33}}{dx} \right) \dot{\eta} + A'_{33} \ddot{\eta} \right] e^{-k\bar{h}} \quad (19)$$

where \bar{h} = mean section draft. Substituting the expressions for η , $\dot{\eta}$ and $\ddot{\eta}$ from Eq. (4), (5) and (6), with $y=0$ and applying the approximate factor for short wave lengths we obtain:

$$\frac{dz_w}{dx} = -ae^{-k\bar{h}} \left\{ \begin{aligned} & \left[(\rho g B^* = A'_{33} kg) \sin(-kx \cos \beta) + \right. \\ & kc \left(N'_z - V \frac{dA'_{33}}{dx} \right) \cos(-kx \cos \beta) \left. \right] \cos \omega_e t + \left[(\rho g B^* - A'_{33} kg) \right. \\ & \left. \cos(-kx \cos \beta) - kc \left(N'_z - V \frac{dA'_{33}}{dx} \right) \sin(-kx \cos \beta) \right] \sin \omega_e t \left. \right\} \cdot \\ & \frac{\sin \left(\frac{\pi B^*}{\lambda} \sin \beta \right)}{\frac{\pi B^*}{\lambda} \sin \beta} \end{aligned} \right. \quad (20)$$

The value of \bar{h} is approximated by:

$$\bar{h} = HC_s \quad (21)$$

where H = local section draft

C_s = local section area coefficient

The steady state solution of the equations of motion are obtained by conventional methods for second order ordinary differential equations, using complex notation. The solutions are expressed as:

$$z = z_0 \sin(\omega_e t + \delta) \quad (22)$$

$$\theta = \theta_0 \sin(\omega_e t + \epsilon)$$

where the zero subscripted quantities are the amplitudes and δ ϵ are the phase angle differences, i.e. leads with respect to the wave elevation in Eq. (7).

The local vertical loading is given by:

$$\frac{df_z}{dx} = -\epsilon m (\ddot{z} - x\ddot{\theta}) + \frac{dz}{dx} + \frac{dz_w}{dx} \quad (23)$$

where δm = local mass, per unit length.

Eq. (23) is simply the summation of inertial, hydrodynamic, hydrostatic and wave excitation forces. The latter terms are given in Eqs. (13) and (20). The vertical bending moment at location x_0 is then given by:

$$BM_z(x_0) = \int_{x_s}^{x_0} \text{or} \int_{x_0}^{x_b} (x-x_0) \frac{df_z}{dx} dx \quad (24)$$

and is expressed in a form similar to the motions, i.e.

$$BM_z = BM_{z0} \sin(\omega_e t + \sigma) \quad (25)$$

B. Lateral Plane Equations

The coupled equations of motion for sway, y (positive to starboard), yaw, ψ (positive bow-starboard), and roll, ϕ (positive starboard-down), are given as:

$$m\ddot{y} = \int_{x_s}^{x_b} \frac{dY}{dx} dx + Y_w \quad (26)$$

$$I_z \ddot{\psi} - I_{xz} \ddot{\phi} = \int_{x_s}^{x_b} \frac{dY}{dx} x dx + N_w \quad (27)$$

$$I_x \ddot{\phi} - I_{xz} \ddot{\psi} = \int_{x_s}^{x_b} \frac{dK}{dx} dx - mg \overline{GM} \phi + K_w \quad (28)$$

where I_z = mass moment of inertia of ship about z axis

I_x = mass moment of inertia of ship about x axis

I_{xz} = mass product of inertia of ship in x-z plane

- $\frac{dY}{dz}$ = local sectional lateral hydrodynamic force on ship
 $\frac{dK}{dx}$ = local sectional hydrodynamic rolling moment on ship
 Y_w, N_w, K_w = wave excitation force and moments on ship
 \overline{GM} = initial metacentric height of ship (hydrostatic).

The hydrodynamic force and moment are taken to be:

$$\begin{aligned} \frac{dY}{dx} = & - \frac{D}{Dt} \left[M_s (\dot{y} + x\dot{\psi} - V\psi) - F_{rs} \dot{\phi} \right] - N_s (\dot{y} + x\dot{\psi} - V\psi) + N_{rs} \dot{\phi} \\ & + \overline{OG} \frac{D}{Dt} (M_s \dot{\phi}) + \overline{OG} N_s \dot{\phi} \end{aligned} \quad (29)$$

$$\begin{aligned} \frac{dK}{dx} = & - \frac{D}{Dt} \left[I_r \dot{\phi} - M_{s\phi} (\dot{y} + x\dot{\psi} - V\psi) \right] - N_r \dot{\phi} + N_{s\phi} (\dot{y} + x\dot{\psi} - V\psi) \\ & - \overline{OG} \frac{D}{Dt} (M_{s\phi} \dot{\phi}) - \overline{OG} N_{s\phi} \dot{\phi} - \overline{OG} \frac{dY}{dx} \end{aligned} \quad (30)$$

where \overline{OG} = distance of ship C.G. from waterline, positive up

M_s = sectional lateral added mass

N_s = sectional lateral damping force coefficient

$M_{s\phi}$ = sectional added mass moment of inertia due to lateral motion

$N_{s\phi}$ = sectional damping moment coefficient due to lateral motion

I_r = sectional added mass moment of inertia

N_r = sectional damping moment coefficient

F_{rs} = sectional lateral added mass due to roll motion

N_{rs} = sectional lateral damping force coefficient due to roll motion

and the sectional added mass moments and damping moment coefficients are taken with respect to an axis at the waterline.

The additional roll damping moment to account for viscous and bilge keel effects is taken as a particular fraction of the critical roll damping, as follows:

$$N_R^* = \zeta_\phi C_C / L - N_R(\omega_\phi) \quad (31)$$

where N_R^* = sectional damping moment coefficient due to viscous and bilge keel effects

ζ_ϕ = fraction of critical roll damping (empirical data)

C_C = critical roll damping

L = ship length ($L = x_b - x_s$)

ω_ϕ = natural roll (resonant) frequency

$N_R(\omega_\phi)$ = value of N_R at frequency ω_ϕ .

The critical roll damping is expressed in terms of the natural roll frequency by:

$$C_C = 2 mg \overline{GM} \omega_\phi^{-1}$$

$$\text{with } \omega_\phi = \left[\frac{mg \overline{GM}}{(I_x + \int I_R(\omega_\phi) dx)} \right]^{\frac{1}{2}} \quad (32)$$

where the integral is over the ship length. The calculation of the natural roll frequency, ω_ϕ , as indicated above is carried out by means of successive approximation.

Expanding the derivatives, we obtain

$$\begin{aligned} \frac{dY}{dx} = & -M_s (\ddot{y} + x\ddot{\psi} - 2v\dot{\psi}) + \left(v \frac{dM_s}{dx} - N_s \right) (\dot{y} + x\dot{\psi} - v\psi) \\ & + \left(F_{rs} + \overline{OG} M_s \right) \ddot{\phi} + \left[N_{rs} + \overline{OG} N_s - v \left(\frac{dF_{rs}}{dx} + \overline{OG} \frac{dM_s}{dx} \right) \right] \dot{\phi} \\ \frac{dK}{dx} = & - \left[I_r + \overline{OG} \left(M_{s\phi} + F_{rs} + \overline{OG} M_s \right) \right] \ddot{\phi} + \left[v \left(\frac{dI_r}{dx} + \overline{OG} \frac{dM_{s\phi}}{dx} \right) \right] \dot{\phi} \end{aligned} \quad (33)$$

$$\begin{aligned}
& - \overline{OG} \left(N_{rs} + N_{s\phi} + \overline{OG} N_s \right) + \overline{OG} v \left(\frac{dF_{rs}}{dx} + \overline{OG} \frac{dM_s}{dx} \right) \\
& - \left[N_r \quad -N_r^* \right] \dot{\phi} + \left(M_{s\phi} + \overline{OG} M_s \right) (\dot{y} + x\dot{\psi} - 2V\dot{\psi}) \\
& + \left[N_{s\phi} + \overline{OG} N_s - v \left(\frac{dM_{s\phi}}{dx} + \overline{OG} \frac{dM_s}{dx} \right) \right] (\dot{y} + x\dot{\psi} - v\dot{\psi})
\end{aligned} \tag{34}$$

The equations of motion, (26), (27) and (28) are then transformed into this familiar form:

$$\begin{aligned}
& a_{11}\ddot{y} + a_{12}\dot{y} + a_{14}\dot{\psi} + a_{15}\ddot{\psi} + a_{16}\psi + a_{17}\ddot{\phi} + a_{18}\dot{\phi} = Y_w \\
& a_{21}\ddot{y} + a_{22}\dot{y} + a_{24}\dot{\psi} + a_{25}\ddot{\psi} + a_{26}\psi + a_{27}\ddot{\phi} + a_{28}\dot{\phi} = N_w \\
& a_{31}\ddot{y} + a_{32}\dot{y} + a_{34}\dot{\psi} + a_{35}\ddot{\psi} + a_{36}\psi + a_{37}\ddot{\phi} + a_{38}\dot{\phi} + a_{39}\phi = K_w
\end{aligned} \tag{35}$$

The coefficients on the left-hand sides are defined by:

$$\begin{aligned}
& a_{11} = m + \int M_s dx \quad , \quad a_{12} = \int N_s dx - v \int d(M_s) \quad , \\
& a_{14} = \int M_s x dx \quad , \quad a_{15} = \int N_s x dx - 2V \int M_s dx - v \int x d(M_s) \quad , \\
& a_{16} = -v a_{12} \quad , \quad a_{17} = - \int F_{rs} dx - \overline{OG} \int M_s dx \quad , \\
& a_{18} = - \int N_{rs} dx + \overline{OG} v \int d(M_s) - \overline{OG} \int N_s dx + v \int d(F_{rs}) \\
& a_{21} = \int M_s x dx \quad , \quad a_{22} = \int N_s x dx - v \int x d(M_s) \quad , \\
& a_{24} = I_z + \int M_s x^2 dx \quad , \quad a_{25} = \int N_s x^2 dx - 2V \int M_s x dx - v \int x^2 d(M_s) \quad , \\
& a_{26} = -v a_{22} \quad , \quad a_{27} = -I_{xz} - \int F_{rs} x dx - \overline{OG} \int M_s x dx \quad , \\
& a_{28} = - \int N_{rs} x dx + \overline{OG} v \int x d(M_s) - \overline{OG} \int N_s x dx + v \int x d(F_{rs}) \quad .
\end{aligned} \tag{36}$$

$$\tag{37}$$

$$\begin{aligned}
a_{31} &= -\int M_{S\phi} dx - \overline{OG} \int M_S dx \quad , \\
a_{32} &= -\int N_{S\phi} dx - \overline{OG} \int N_S dx + v \int d(M_{S\phi}) + v \overline{OG} \int d(M_S) \quad , \\
a_{34} &= -I_{xz} - \int M_{S\phi} x dx - \overline{OG} \int M_S x dx \quad , \\
a_{35} &= -\int N_{S\phi} x dx - \overline{OG} \int N_S x dx + v \int x d(M_{S\phi}) + v \overline{OG} \int x d(M_S) - 2va_{31} \quad , \\
a_{36} &= -va_{32} \quad , \\
a_{37} &= I_x + \int I_r dx + \overline{OG} \int M_{S\phi} dx + \overline{OG} \int F_{rs} dx + \overline{OG}^2 \int M_S dx \quad , \\
a_{38} &= \int (N_r + N_r^*) dx + \overline{OG} \int N_{S\phi} dx + \overline{OG} \int N_{rs} dx + \overline{OG}^2 \int N_S dx \\
&\quad - v \left[\int d(I_r) + \overline{OG} \int d(M_{S\phi}) + \overline{OG} \int d(F_{rs}) + \overline{OG}^2 \int d(M_S) \right] \quad , \\
a_{39} &= mg \overline{GM}
\end{aligned} \tag{38}$$

where all the indicated integrations are over the ship length.

The wave excitation, the right-hand sides of Eqs. (35) is given by:

$$Y_w = \int_{x_s}^{x_b} \frac{dY_w}{dx} dx \tag{39}$$

$$N_w = \int_{x_s}^{x_b} \frac{dY_w}{dx} x dx \tag{40}$$

$$K_w = \int_{x_s}^{x_b} \frac{dK_w}{dx} dx \tag{41}$$

The local sectional lateral force and rotational moment due to the waves acting on the ship are represented as:

$$\frac{dy_w}{dx} = \left[(\rho S + M_s) \frac{Dv_w}{Dt} - v_w \frac{dM_s}{dx} + N_s v_w + k \left(-M_{s\phi} \frac{Dv_w}{Dt} + v \frac{dM_{s\phi}}{dx} v_w \right) \right] \cdot \frac{\sin \left(\frac{\pi B^*}{\lambda} \sin \beta \right)}{\frac{\pi B^*}{\lambda} \sin \beta} \quad (42)$$

$$\frac{dk_w}{dx} = \left[- \frac{D}{Dt} (M_{s\phi} v_w) + \rho \left(\frac{B^{*3}}{12} - S \bar{z} \right) \frac{Dv_w}{Dt} - N_{s\phi} v_w \right] \frac{\sin \left(\frac{\pi B^*}{\lambda} \sin \beta \right)}{\frac{\pi B^*}{\lambda} \sin \beta} - \overline{OG} \frac{dy_w}{dx} \quad (43)$$

where v_w = lateral orbital wave velocity

S = local section area

\bar{z} = local sectional center of buoyancy, from waterline

The lateral wave orbital velocity is obtained as follows:

$$v_w = - \frac{\partial \phi_w}{\partial y}$$

$$v_w = - akc e^{-k\bar{h}} \sin \beta \sin k \left[-x \cos \beta + y \sin \beta + (c - v \cos \beta) t \right] \quad (44)$$

and then we have:

$$\frac{Dv_w}{Dt} = - akc e^{-k\bar{h}} \sin \beta \cos k \left[-x \cos \beta + y \sin \beta + (c - v \cos \beta) t \right] \quad (45)$$

After substituting these expressions and expanding terms, we obtain

$$\frac{dy_w}{dx} = T_1 \cos \omega_e t + T_2 \sin \omega_e t \quad (46)$$

$$\text{with } T_1 = T_3 \left[gT_4 \cos T_6 + c T_5 \sin T_6 \right]$$

$$T_2 = T_3 \left[-gT_4 \sin T_6 + c T_5 \cos T_6 \right]$$

$$T_3 = -ake^{-k\bar{h}} \sin \beta \left[\frac{\sin \left(\frac{\pi B^*}{\lambda} \sin \beta \right)}{\frac{\pi B^*}{\lambda} \sin \beta} \right]$$

$$T_4 = \rho S + M_s - kM_{s\phi}$$

$$T_5 = N_s - V \frac{dM_s}{dx} + k V \frac{dM_{s\phi}}{dx}$$

$$T_6 = -kx \cos \beta$$

$$\text{and } \frac{dK_w}{dx} = T_7 \cos \omega_e t + T_8 \sin \omega_e t \quad (47)$$

$$\text{with } T_7 = T_3 \left[g T_9 \cos T_6 + c T_{10} \sin T_6 \right]$$

$$T_8 = T_3 \left[-g T_9 \sin T_6 + c T_{10} \cos T_6 \right]$$

$$T_9 = \rho \left(\frac{B^{*3}}{12} - S\bar{z} \right) - M_{s\phi} - \overline{OG} T_4$$

$$T_{10} = N_{s\phi} + V \frac{dM_{s\phi}}{dx} - \overline{OG} T_5$$

The steady-state solution of the equations of motion are expressed as:

$$y = y_0 \sin (\omega_e t + \kappa) \quad (48)$$

$$\psi = \psi_0 \sin (\omega_e t + \alpha) \quad (49)$$

$$\phi = \phi_0 \sin (\omega_e t + \nu) \quad (50)$$

where the zero-subscripted quantities are the amplitudes and κ , α and ν are phase angle leads with respect to the wave elevation.

The local lateral and rotational loadings are given by:

$$\frac{df_y}{dx} = -\delta m (\ddot{y} + x\ddot{\psi} - \zeta\ddot{\phi}) + \frac{dY}{dx} + \frac{dY_w}{dx} \quad (51)$$

$$\begin{aligned} \frac{dm_x}{dx} = & -\delta m \cdot \gamma^2 \ddot{\phi} + \delta m \zeta (\ddot{y} + x\ddot{\psi}) + \rho g \left(\frac{B^*{}^3}{12} - S\bar{z} - S\bar{O}G \right) \phi - g\delta m \zeta \phi \\ & + \frac{dK}{dx} + \frac{dK_w}{dx} \end{aligned} \quad (52)$$

where ζ = local center of gravity (relative to ship C.G.)
positive down

γ = local mass gyradius in roll

and the hydrodynamic and wave excitation terms are given in Eqs. (33), (34), (46), and (47).

The lateral bending and torsional moments at location x_0 are then:

$$BM_y(x_0) = \left[\int_{x_s}^{x_0} \text{ or } \int_{x_0}^{x_b} \right] (x-x_0) \frac{df_y}{dx} dx \quad (53)$$

$$TM_x(x_0) = \left[\int_{x_s}^{x_0} \text{ or } \int_{x_0}^{x_b} \right] \frac{dm_x}{dx} dx \quad (54)$$

and again they are expressed in this form:

$$BM_y = BM_{y0} \sin (\omega_e t + \tau) \quad (55)$$

$$TM_x = TM_{x0} \sin (\omega_e t + \nu)$$

The requirement on the local vertical mass center is:

$$\int_{x_s}^{x_b} \delta m \cdot \zeta dx = 0 \quad (56)$$

Similarly, the requirement on the local roll gyradius is:

$$\int_{x_s}^{x_b} \delta m y^2 dx = I_x \quad (57)$$

The product of inertia in the x-z plane is defined by:

$$I_{xz} = \int_{x_s}^{x_b} \delta m x \zeta dx \quad (58)$$

C. Wave Spectra Equations

The wave spectrum for calculations in irregular seas is considered to be a separable function of wave frequency and direction as follows:

$$S(\omega, \mu) = S_1(\omega) S_2(\mu) \quad \text{for } 0 < \omega < \infty \quad (59)$$

$$\text{and } -\frac{\pi}{2} \leq \mu \leq \frac{\pi}{2}$$

where $S(\omega, \mu)$ = directional spectrum of the seaway (short crested sea spectrum)

ω = circular wave frequency

μ = wave direction relative to predominant direction

$S_1(\omega)$ = frequency spectrum (long crested sea spectrum)

$S_2(\mu)$ = spreading function

The SCORES program includes various spectra that can be chosen as desired. However, in all cases, the following relationship between the spectrum, or spectral density, and the wave elevations, or amplitudes, is used:

$$\overline{a^2} = \int_0^{\infty} \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} S(\omega, \mu) d\omega d\mu \quad (60)$$

where $\overline{a^2}$ = mean squared wave amplitude.

Since we impose:

$$\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} S_2(\mu) d\mu = 1.0 \quad (61)$$

we then have:

$$\overline{a^2} = \int_0^{\infty} S_1(\omega) d\omega \quad (62)$$

Additional statistical properties are formulated from the mean squared amplitude:

$$a_{\text{rms}} = \sqrt{\overline{a^2}} \quad (63)$$

$$a_{\text{avg}} = 1.25 a_{\text{rms}} \quad (64)$$

$$a_{1/3} = 2.0 a_{\text{rms}} \quad (65)$$

$$a_{1/10} = 2.55 a_{\text{rms}} \quad (66)$$

where

a_{rms} = root-mean-squared wave amplitude

a_{avg} = average (statistical) wave amplitude

$a_{1/3}$ = significant (average of 1/3 highest)
wave amplitude

$a_{1/10}$ = average of 1/10 highest wave amplitude.

Neumann Spectrum (1953)

This frequency spectrum (as used) is given by:

$$S_1(\omega) = 0.000827 g^2 \pi^3 \omega^{-6} e^{-2g^2 \omega^{-2} U^{-2}} \quad (67)$$

where U = wind speed

The constant is one half that originally specified by Neumann so that this spectrum satisfies Eq. (62). Thus, originally the Neumann spectrum required only a factor of $\sqrt{2}$ in Eq. (65), instead of 2.0.

Pierson-Moskowitz (1964)

This is given by:

$$S_1(\omega) = 0.0081 g^2 \omega^{-5} e^{-.74g^4 \omega^{-4} U^{-4}} \quad (68)$$

and was derived on the basis of fully arisen seas.

Two Parameter (1967)

$$S_1(\omega) = \underline{A} \cdot \underline{B} \omega^{-5} e^{-\underline{B} \omega^{-4}} \quad (69)$$

where $\underline{A} = 0.25 H_{1/3}^2$

$$\underline{B} = (0.817 \frac{2\pi}{\tilde{T}})^4$$

$H_{1/3}$ = significant wave height (=2.0 $a_{1/3}$)

\tilde{T} = mean wave period

This spectrum is usually used in conjunction with "observed" wave height and period, which are then taken to be the significant height and mean period. This spectrum is similar to that adopted by the I.S.S.C. (1967) as "nominal", except that it is expressed in circular wave frequency instead of frequency in cycles per second.

Uni-Directional Spreading (Long Crested Seas)

This is obviously:

$$S_2(\mu) = \delta(\mu) \text{ (delta function)} \quad (70)$$

Cosine-Squared Spreading

$$S_2(\mu) = \frac{2}{\pi} \cos^2 \mu \quad (71)$$

Responses

All of the motions and moments calculated are considered to be linear and the principle of wave superposition is assumed. Thus for each response a spectrum is calculated by:

$$S_i(\omega, \mu) = [T_i(\omega, \mu)]^2 S(\omega, \mu) \quad (72)$$

where $T_i(\omega, \mu)$ = response amplitude operator (amplitude of response per unit wave amplitude)

We then have, similar to the wave amplitude:

$$\begin{aligned} \overline{a_i^2} &= \int_0^{\infty} \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} S_i(\omega, \mu) d\omega d\mu \\ &= \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} S_2(\mu) \left[\int_0^{\infty} [T_i(\omega, \mu)]^2 S_1(\omega) d\omega \right] d\mu \end{aligned} \quad (73)$$

where $\overline{a_i^2}$ = mean squared response amplitude.

Eqs. (63) - (66) then apply to each response.

D. Non-dimensional Forms

Frequency parameter: $\xi_t = \frac{\omega e^2}{g} H$

Non-dimensional linear motion (heave, sway): $\frac{\text{motion amplitude}}{a}$

Non-dimensional angular motion (pitch, yaw, roll): $\frac{\text{motion amplitude}}{2\pi a/\lambda}$

Non-dimensional moment: $\frac{BM_z \text{ (or } BM_y \text{ or } TM_x)}{\rho g B^* L^2 a}$

Non-dimensional shear: $\frac{\text{Shear Force}}{\rho g B^* L a}$

III. PROGRAM ORGANIZATION

A. General

In general, the SCORES computer program has been arranged and organized to both keep a) the coding simple and flexible (for possible future modification) and b) the running times low (for obvious reasons). Thus, precision of computation has not been of major priority in program development. This approach is considered reasonable at the present time because precise correlation (to less than about 5%) with independent data (model or full-scale experiments) is not envisioned, and the theoretical analysis itself is an approximation.

Aside from the actual coding and data structure in the program, which will not be discussed here (see Appendices A, B and C of this report), this approach manifests itself primarily in two aspects. The first is the precision with which the local, or two-dimensional, sectional added mass and damping characteristics or properties, are calculated. For vertical oscillation, the method of Grim* is used. For the two-dimensional properties in lateral and roll oscillations, the method of Tasai** has been programmed. In general, these methods can be carried out to increasing degrees of numerical accuracy. For practical purposes of keeping running time reasonable, these calculations have been limited. For example in the lateral and roll computations, the infinite series of terms representing the velocity potential is truncated to nine terms and only 15 points along the Lewis form contour are used for least square approximation purposes. While the full range of section properties and frequencies has not been explored in detail, results on the order of 1% accuracy or better are obtained for average sections over a wide frequency range.

* Grim, O., "Die Schwingungen von schwimmenden, zweidimensionalen Körpern," HSWA Report No. 1171, September 1959.

Grim, O., and Kirsch, M., private communication, September 1967.

**Tasai, F., "Hydrodynamic Force and Moment Produced by Swaying and Rolling Oscillation of Cylinders on the Free Surface," Reports of Research Institute for Applied Mechanics, Kyushu University Japan, Vol. IX, No. 35, 1961

The second aspect of program organization is related to the above. While the computations of the two-dimensional properties are limited as described, they still are relatively lengthy. That is at a particular condition of ship speed, wave angle and wave length, the bulk of the computation time would be devoted to these calculations rather than the formation of the coefficients, wave excitation, solution of ship motions and the resulting calculation of applied moments. Therefore, it was decided that rather than calculate for each frequency at each cross-section the above mentioned two-dimensional properties, instead the two-dimensional properties are calculated first at 25 values of frequency over a wide range and then interpolated (or extrapolated) for each subsequent frequency. The results of the initial calculation over the frequency range are saved in the computer memory for the calculations at hand, and can also be saved on a permanent disc file (or magnetic tape storage), for later usage. In this way, a large range of ship speeds and headings can be run, each over the appropriate frequency range, without excessively high running times. The interpolation procedure used is a six-point continued fraction method which gives results that are generally well within 1%.

In other respects, the SCORES program is organized in a fairly straightforward manner. The input consists of:

- a) basic data which specify the hull form and weight distribution and
- b) conditional data which specify the speeds and wave parameters.

Repeated sets of conditional data can be run with the same basic data, that is, for the same defined ship. A fair amount of input data verification is incorporated into the program.

B. Restrictions

The main restrictions in the program concern the following items:

Maximum no. of ship cross-sections.....	21
(stations 0 to 20)	
Maximum no. of wave angles (in one run).....	25
Maximum no. of wave lengths (in one run)....	51
Maximum no. of sea states (in one run).....	10

The core storage requirement is about 25,000 cells as compiled on the CDC 6600. This includes the program instructions, data storage and system routines to handle input-output system control and provide mathematical functions. It would be possible to decrease this core requirement via program overlay and linkage techniques, should the need arise. However, it probably would be relatively difficult to fit the program within a 12K core restraint.

The word length on the CDC 6600 is 60 bits. No loss in overall computational accuracy would be expected if this were reduced, as in other digital computers, to 36 bits.

A special system subroutine called DATE is used which provides the current date. This is used only in the heading on the output.

C. Running Time

The following approximate times are for running under the SCOPE operating system on the CDC 6600 computer.

Program compilation (RUN compiler).....10.0 secs.

Program loading into core..... 1.0 secs.

Calculation of TDP* Array (21 sections,
both vertical and lateral modes)..... 25 secs.

Calculate motions, moments at one condition,
(21 sections, both vertical and lateral
modes)..... 0.14 secs.

Calculate spectral response, for each
spectrum, for each condition..... 0.006 secs.

Thus, for a run with two ship speeds, 7 headings (at 30° increments from head to following seas), 21 wave frequencies (to adequately cover the spectral energy bands) and 5 sea states, the incremental time once the program was compiled, loaded and the TDP Array was calculated, would be estimated as follows:

$$(2) \quad (7) \quad (21) \quad [0.14 + (5) (0.006)] = 50 \text{ secs.}$$

IV. DATA INPUT

This section of the manual describes the details of data card input to the SCORES program.

A. Units

For calculations in regular waves, there are no inherent units assigned to any of the variables in the program. Thus, the user is free to choose any desired set as long as they are consistent for all input parameters. The units are established by the input values of water density and gravity acceleration. Some typical units are shown below.

*Two-dimensional properties

Water Density	lbs./cu. ft.	tons/cu. ft.	metric ton/cu. meter
Gravity Accel.	ft./sec. ²	ft./sec. ²	meter/sec. ²
Resultant Unit System	ft.-lbs.-sec.	ft.-tons-sec.	meter-metric ton-sec.

Wave direction angles are always specified in degrees, rather than radians.

However, for spectral calculations in irregular waves, using either the Neumann or Pierson-Moskowitz spectra, the SCORES program assumes ft.-sec. units, full scale. The input wind speeds used to specify spectral intensities, or sea states, are then assumed to be in knots.

The following input data description indicates typical consistent units for all parameters. Other systems of units could be used, as noted above.

B. Data Card Preparation

Every data card defines several parameters which are required by the program; each of these parameters must be input according to a specific format. "I" format (integer) means that the value is to be input without a decimal point and packed to the right of the specified field. "F" format (floating point) requires that the data be input with a decimal point; the number can appear anywhere in the field indicated. "A" format (alphanumeric) indicates that certain alphabetic characters or title information must be entered in the appropriate card columns.

If the field is left blank for either "I" or "F" format, a value of zero (0) is assigned to the parameter. Thus, parameters not required by the program for a particular problem need not be specified.

The card order of the data deck must follow the order in which they are described below. Cards which must be present in every run, regardless of options, are marked with an asterisk (*). The first eight types of cards are considered the basic data set, while subsequent cards are the conditional data set(s).

1) Title Card (*)

<u>Columns</u>	<u>Format</u>	<u>Entry</u>
1-80	A	Any alphanumeric title information, used to label job output

The first 30 columns are used as a label for the TDP array file. Thus, subsequent runs using the file must duplicate these first 30 columns which are then checked against the file label before using the data. This avoids inadvertent use of an incorrect TDP file.

2) Option Control Card (*)

<u>Columns</u>	<u>Format</u>	<u>Entry</u>
1-2	I	Integration option control tag
3-4	I	Moment option control tag
5-6	I	Mass dist. option control tag
7-8	I	Wave spectra option control tag
9-10	I	Degrees of freedom option control tag
11-12	I	Directionality option control tag
13-14	I	TDP file option control tag
15-16	I	Moment closure option control tag
17-18	I	Output form option control tag
19-20	I	Torsion axis option control tag
21-22	I	Number of ship segments

Each option control tag is given a value of 0, 1, 2 or 3 where the meaning of each is given in the table below. The last entry of the card, the number of ship segments, corresponds to the even number of equal length segments, or strips, into which the ship hull is divided lengthwise for purposes of calculation.

OPTION CONTROL TAG INTERPRETATION

<u>Letter Code</u>	<u>Tag Descriptor</u>	<u>Options Available</u>
A	Integration	0: Simple summation 1: Trapezoidal rule
B	Moment	0: Calc. motions only, use summary mass properties 1: Calc. motions only, use mass dist. 2: Calc. moments, use mass dist.
C	Mass dist.	0: Input masses 1: Input weights
D	Wave spectra	0: Regular waves 1: Neumann spectra 2: Pierson-Moskowitz spectra 3: Two parameter spectra

(continued on next page)

OPTION CONTROL TAG INTERPRETATION, Continued

Letter Code	Tag Descriptor	Options Available
E	Degrees of freedom	0: Vertical plane only 1: Vertical and lateral plane 2: Lateral plane only
F	Directionality	0: Uni-directional waves 1: Cos-sq. wave spreading
G	TDP file	0: Generate TDP file, write on file (Tape 10) 1: Read TDP file, (Tape 10), print out TDP data 2: Read TDP file, (Tape 10), no print-out
H	Moment closure	0: Suppress closure calcs. 1: Calc. and print out closure results
I	Output form	0: Dimensional 1: Non-dimensional
J	Torsion axis	0: Center of gravity 1: Waterline

3) Length Card (*)

<u>Columns</u>	<u>Format</u>	<u>Entry</u>
11-20	F	Ship length (ft.)
21-30	F	Water density (tons/cu.ft.)
31-40	F	Acceleration of gravity (ft./sec. ²)
41-50	F	Ship displacement (tons)

The entries on this card are self descriptive and determine the units to be used for all other parameters, except as noted earlier.

4) Hull Form Cards (*)

<u>Columns</u>	<u>Format</u>	<u>Entry</u>
1-10	F	Section waterline breadth (ft.)
11-20	F	Section area coefficient (-)
21-30	F	Section draft (ft.)
31-40	F	Section centroid (ft.)

One card is used for each section to be specified, in order along the ship length starting at the bow. For example, if the number of segments is 10, and the integration option tag is 0, then 10 hull form cards are required which correspond to the hull at stations 1/2, 1 1/2, 2 1/2, ..., 8 1/2, 9 1/2. If the integration tag is 1, then 11 hull form cards are required at stations 0, 1, 2, 3 9, 10.

The entries for sectional waterline breadth, area coefficient and draft are straightforward. The fourth entry, the section centroid, is measured downwards from the waterline. If no entries are given and the centroids are needed for lateral plane motions calculations, approximate centroids are then calculated based on the area coefficient and draft (using a two-dimensional version of the Moorish Approximation).

5) Lateral Plane Card

<u>Columns</u>	<u>Format</u>	<u>Entry</u>
1-10	F	Ship vertical center of gravity (ft.)
11-20	F	Radius of gyration in roll (ft.)

This card is used only if the degrees of freedom option tag is 1 or 2, indicating lateral plane calculations. The ship vertical c.g. is measured from the waterline, positive upwards.

6) Summary Mass Properties Card

<u>Columns</u>	<u>Format</u>	<u>Entry</u>
1-10	F	Radius of gyration, longitudinal (ft.)
11-20	F	Longitudinal center of gravity (ft.)

This card is used only if the moment option tag is 0. The longitudinal center of gravity is measured from amidships, positive forwards.

7) Sectional Mass Properties Cards

<u>Column</u>	<u>Format</u>	<u>Entry</u>
1-10	F	Segment weight, or mass (tons, or tons-sec ² /ft.)
11-20	F	Segment vert. c.g. (ft.)
21-30	F	Segment roll gyradius (ft.)

These cards are used only if the moment option tag is 1 or 2, in lieu of the summary mass properties card above. One card is used for each section to be specified, in a similar manner as the hull form cards described earlier.

The first entry on each card is the segment weight, or mass, depending on whether the mass dist. option tag is 1, or 0,

respectively. The second entry, the segment vertical center of gravity, necessary only for lateral bending moment calculations, is measured, positive downwards, with respect to the ship's overall vertical center, as specified on the lateral plane data card above. Since it is required that the vertical mass moment integral satisfy the specified overall v.c.g., the input segment v.c.g.'s are shifted by an equal amount, up or down as necessary to exactly balance the vertical moment for the hull. This minimizes the effort required to obtain precise balance in input data preparation. The third card entry, the segment roll gyradius, is needed only for torsional moment calculations. If no entries are given the overall ship value is used at each segment.

8) Moment Station Card (*)

<u>Column</u>	<u>Format</u>	<u>Entry</u>
1-10	I	First station for moment calculations
11-20	I	Last station for moment calculations
21-30	I	Increment between stations

The parameters on this card determine where along the ship hull the moment calculations are to be performed. Station numbers are defined as zero at the forward end of the first segment, increasing to N, the number of segments, at the after end of the last segment. If the calculations are required only at one station, then the first two entries on the card should be equal to that station number.

The moment results at only one station are stored for subsequent irregular seas spectral calculations. In the calculations over a range of stations at which moments are calculated (and printed), then only the results at midships are stored for the subsequent spectral calculations.

9) Run Control Card (*)

<u>Columns</u>	<u>Format</u>	<u>Entry</u>
1-10	F	Run control tag and wave amplitude (ft.)
11-20	F	Initial wave length, or frequency (ft. or rad./sec.)
21-30	F	Final wave length, or frequency (ft. or rad./sec.)
31-40	F	Increment in wave length, or frequency (ft. or rad./sec.)
41-50	F	Initial ship speed (ft./sec.)
51-60	F	Final ship speed (ft./sec.)
61-70	F	Increment in ship speed (ft./sec.)

The first entry, the run control tag, determines program continuity:

Run Control Tag	Action
Greater than 0.0	Continue calculations, using this as wave amplitude
0.0 (or blank)	Stop calculations; read new basic data set
Less than 0.0	Stop program execution

Thus, if the run control tag is not greater than 0.0, then the remaining parameters on the card are irrelevant. A blank card, for example, is used to stop calculations and proceed to read a complete new set of data starting with the title card, 1) above. This parameter is also used as the wave amplitude, and is usually set to 1.0.

The next three entries determine the wave lengths to be used in the calculations. If the wave spectra option control tag is 0, indicating regular waves, then these entries are the initial, final and increment in wave length. If the wave spectra option control tag is greater than 0, indicating irregular wave calculations, then these entries are the initial, final and increment in wave frequency. The increments should always be positive, so that wave length, or frequency, increases from initial to final value.

The last three entries are similar parameters for ship speed. If calculations are required at only one value, then the initial and final values should both be set equal to it.

10) Roll Damping Card

<u>Column</u>	<u>Format</u>	<u>Entry</u>
1-10	F	Fraction of critical roll damping (empirical data)

This card is used only if the degrees of freedom option control tag is 1 or 2 indicating lateral plane motions calculations are included. The calculated wave damping in roll, at the natural roll frequency, is increased so that the total damping is the specified fraction of critical damping. The additional roll damping thus determined initially is then used for all subsequent calculations.

11) Wave Angle Card (*)

<u>Column</u>	<u>Format</u>	<u>Entry</u>
1-10	F	Initial wave angle, degrees
11-20	F	Final wave angle, degrees
21-30	F	Increment in wave angle, degrees

These entries specify the wave direction angles to be used in the calculations and are always given in degrees. For calculations with uni-directional waves, the meaning of the parameters is as indicated. If the directionality option control

tag is greater than 0, indicating calculations for a directional wave spectrum, then only two choices exist. If the initial wave angle is 180.0 the calculations proceed for head seas only, including the wave directionality. If the initial wave angle is not 180.0 the calculations proceed for all angles from following seas to head seas, in steps according to the wave angle increment specified.

In both cases the integrations with respect to wave angle use the same increment, as specified.

12) Wave Spectra Card(s)

<u>Columns</u>	<u>Format</u>	<u>Entry</u>
1-10	I	No. of sea states (wave spectra)
11-15	F	First spectra parameter
16-20	F	Second spectra parameter
21-25	F	Third spectra parameter
(5 col. fields)	F	:
56-60	F	Tenth spectra parameter

This card is used only for calculations in irregular seas (wave spectra option control tag is greater than 0). The first entry specifies the number of sea states (spectra) to be used (maximum 10). For both the Neumann and Pierson-Moskowitz spectra (wave spectra option control tag equals 1 or 2), the parameters to be specified are the wind speed, in knots, for each sea state. For the two parameter spectrum (option tag equals 3), the parameters on this card are the significant wave heights for each sea state. A second card is then used which contains the mean periods for each corresponding sea state, as the spectral parameter entries specified above.

C. Sample Input Deck

A sample input card deck listing is given on the next page. The units are meters, metric tons and seconds.

V. PROGRAM OUTPUT

A. Description

The printed output from the SCORES program depends on the option control tags set as input. Each output section will be described, though in any given run not all sections will be printed. Each section starts a new page and is labeled with the title information and date.

The first part of the output is a listing of the basic input data as processed. This defines the hull form and weight distribution. Then the conditional data cards are printed out. For irregular seas cases, the wave spectra will then be printed, together with internally generated wave statistics. If the TDP array is calculated diagnostic messages concerning these calculations may then appear.

The next output will be the listing of the two-dimensional properties (TDP array) for each station and each frequency. If the data is being read from file, this output can be suppressed. For lateral plane calculations, the natural roll frequency and roll damping information will then be printed.

Then, the vertical and/or lateral plane responses will be printed out with all frequencies, or wave lengths, for a given ship speed and wave angle, on the same page. For irregular seas calculations, this will be followed by a print-out of the response spectra and statistics (long crested seas). These pages will be repeated for each wave angle at the initial ship speed. Then directional seas calculations results will be output, if specified. The output is, of course, then repeated for additionally specified ship speeds.

B. Sample Output

A sample output listing, in abbreviated form, is given following the sample input listing.

Sample Input Card Deck Listing

```

SERIFS 60 HULL FORM, 0.10 BLOCK (TND HPT. NO. 100 5) OCEANICS PROJECT NO. 1093
 1 2 1 3 1 0 1 1 1 120
00.00      193.0      1.025      9.80855  44176.4
00.00      .0      00.00
14.39      .872      11.03
22.88      .894      11.03
26.58      .929      11.03
27.54      .970      11.03
27.57      .991      11.03
27.57      .994      11.03
27.57      .994      11.03
27.57      .994      11.03
27.57      .994      11.03
27.57      .994      11.03
27.57      .994      11.03
27.57      .994      11.03
27.57      .994      11.03
27.57      .994      11.03
27.57      .994      11.03
27.57      .994      11.03
27.57      .994      11.03
27.57      .994      11.03
27.57      .994      11.03
27.24      .921      11.03
25.94      .851      11.03
23.46      .759      11.03
19.63      .627      11.03
13.87      .419      11.03
4.41       .53      1.10
-1.0985    A.96025
240.6
481.3
1203.2
2406.3
3850.1
4090.7
4331.4
4331.4
3368.8
1684.4
1684.4
1443.8
2195.4
3290.7
3633.6
3465.1
3146.3
1955.1
721.9
481.3
120.3
   10   10   1
1.0    0.3157  1.3079  0.0451  6.5257  6.5257  1.0
0.10
10.0    170.0   20.0
      1  A.4
      10.0
-1.0

```

Sample Input Listing

SERIES 60 HULL FORM, 0.00 BLOCK (TNO RPT. NO. 100 S) OCEANICS PROJECT NO. 1093 SEP 24, 1970

OPTION CONTROL TAGS = A H C D E F G H I J

1 2 1 3 1 0 1 1 1 1

NO. OF STATIONS = 20

BASIC INPUT DATA

LENGTH = 193.00 DENSITY = 1.025000
 DISPL. = 48126.40 GRAVITY = 9.806650

STATION	HEAM	AREA COEF.	DRAFT	Z-BAR	WEIGHT	ZETA	GYR.ROLL
0.00	0.0000	0.0000	0.0000	0.0000	240.6000	0.0000	8.9602
1.00	14.3900	.8720	11.0300	5.0444	481.3000	0.0000	8.9602
2.00	22.8400	.8940	11.0300	5.1257	1203.2000	0.0000	8.9602
3.00	26.5800	.9290	11.0300	5.2547	2406.3000	0.0000	8.9602
4.00	27.5400	.9700	11.0300	5.4047	3850.1000	0.0000	8.9602
5.00	27.5700	.9910	11.0300	5.4810	4090.7000	0.0000	8.9602
6.00	27.5700	.9940	11.0300	5.4920	4331.4000	0.0000	8.9602
7.00	27.5700	.9940	11.0300	5.4920	4331.4000	0.0000	8.9602
8.00	27.5700	.9940	11.0300	5.4920	3368.8000	0.0000	8.9602
9.00	27.5700	.9940	11.0300	5.4920	1684.4000	0.0000	8.9602
10.00	27.5700	.9940	11.0300	5.4920	1684.4000	0.0000	8.9602
11.00	27.5700	.9940	11.0300	5.4920	1443.8000	0.0000	8.9602
12.00	27.5700	.9930	11.0300	5.4897	2195.8000	0.0000	8.9602
13.00	27.5700	.9890	11.0300	5.4744	3290.7000	0.0000	8.9602
14.00	27.5700	.9680	11.0300	5.3977	3633.6000	0.0000	8.9602
15.00	27.2600	.9210	11.0300	5.2244	3465.1000	0.0000	8.9602
16.00	25.9400	.8510	11.0300	4.9675	3148.3000	0.0000	8.9602
17.00	23.4600	.7580	11.0300	4.6255	1955.1000	0.0000	8.9602
18.00	19.4300	.6270	11.0300	4.1434	721.9000	0.0000	8.9602
19.00	13.8700	.4190	11.0300	3.3780	481.3000	0.0000	8.9602
20.00	4.4100	.5300	1.1000	.3777	120.3000	0.0000	8.9602

OG = -1.099 GYRANTUS.ROLL = 8.960

CALCULATE MOMENTS AT STATION 10

DERIVED RESULTS

DISPL. (WTS.) = 48126.50

LONG. C.G. = 4.716 (FWD. OF MIDSHIPST)

DISPL. (VOL.) = 48077.53

LONG. C.G. = 4.825 (FWD. OF MIDSHIPST)

LONG. GYRADIUS = 46.159 GM = 1.978

SERIES 60 HULL FORM, 0.00 BLOCK (TNO RPT. NO. 100 S) OCEANICS PROJECT NO. 1093 SEP 24, 1970

CONDITIONAL INPUT DATA CARD PRINT OUT

1.0000 .3157 1.3079 .0491 6.4257 6.5257 1.0000
 .1000
 - 10.0000 170.0000 20.0000
 1 8.0 -0.0 -0.0 -0.0 -0.0 -0.0 -0.0 -0.0 -0.0
 10.0 -0.0 -0.0 -0.0 -0.0 -0.0 -0.0 -0.0 -0.0 -0.0

SERIES 60 HULL FORM, 0.00 BLOCK (TNO RPT. NO. 100 S) OCEANICS PROJECT NO. 1093 SEP 24, 1970

WAVE SPECTRAL DENSITY, TWO PARAMETER, ISSC 1967 SPECTRA

SIG.MT. 4.400
 MN.PER. 10.000

SPECTRA NO. 1

WAVE FREQ.

.316

.361 1.320

.406 8.610

.451 12.254

.496 12.954

.541 11.743

.586 9.824

.631 7.886

.676 6.204

.722 4.846

.767 3.782

.812 2.961

.857 2.331

.902 1.847

.947 1.476

.992 1.186

1.037 .961

1.082 .784

1.127 .644

1.173 .533

1.218 .443

1.263 .371

1.308 .313

MN. ST 4.298

R.P.S. 2.073

AVG. 2.539

STG. 4.146

AVI/10 5.277

Sample Output Listing, Continued

SLICES AND HULL FORM, 0.40 FLUX (TMD RPT., NO. 100 S) OCEANICS PROJECT NO. 1003 SEP 24 1970

Two-DIMENSIONAL SECTION PROPERTIES

FREQ. PARAM.	A-PRIME (33)	ALBARISO.	M-SUR(S)	M(S,PHI)	N(S,PHI)	I-SUR(R)	N-SUB(R)	F-SUB(R,S)	N-SUB(R,S)
STA 0.0	INFINITY	0.	0.	0.	0.	0.	0.	0.	0.
0.000	INFINITY	0.	0.	0.	0.	0.	0.	0.	0.
0.010	2.952E+01	2.194E+01	0.	6.848E+01	0.	2.254E+02	0.	6.848E+01	0.
0.020	2.184E+01	2.227E+01	0.	6.936E+01	0.	2.337E+02	0.	6.936E+01	0.
0.030	1.654E+01	1.342E+03	0.	7.128E+01	4.900E-02	2.337E+02	0.	7.128E+01	4.900E-02
0.040	1.313E+01	4.873E+03	0.	7.431E+01	2.632E-01	2.429E+02	0.	7.431E+01	2.632E-01
0.050	1.069E+01	2.119E-02	0.	7.867E+01	1.045E+00	2.554E+02	0.	7.867E+01	1.045E+00
0.100	6.937E+00	2.115E-02	0.	8.400E+01	2.977E+00	2.714E+02	0.	8.400E+01	2.977E+00
0.200	4.810E+00	6.350E-02	0.	8.925E+01	7.074E+00	2.861E+02	0.	8.925E+01	7.074E+00
0.300	3.610E+00	1.331E-01	0.	9.202E+01	1.415E+01	2.934E+02	0.	9.202E+01	1.415E+01
0.400	2.810E+00	2.627E-02	0.	9.513E+01	2.514E+01	2.934E+02	0.	9.513E+01	2.514E+01
0.500	2.210E+00	4.962E-01	0.	9.868E+01	3.714E+01	2.934E+02	0.	9.868E+01	3.714E+01
0.600	1.810E+00	1.180E-01	0.	1.024E+02	4.869E+01	2.934E+02	0.	1.024E+02	4.869E+01
0.700	1.510E+00	1.465E-01	0.	1.088E+02	5.227E+01	1.493E+02	0.	1.088E+02	5.227E+01
0.800	1.250E+00	2.011E-01	0.	1.169E+02	5.260E+01	1.493E+02	0.	1.169E+02	5.260E+01
0.900	1.050E+00	2.196E-01	0.	1.248E+02	4.894E+01	1.493E+02	0.	1.248E+02	4.894E+01
1.000	0.910E+00	2.196E-01	0.	1.328E+02	4.894E+01	1.493E+02	0.	1.328E+02	4.894E+01
1.100	0.780E+00	2.509E-01	0.	1.408E+02	4.894E+01	1.493E+02	0.	1.408E+02	4.894E+01
1.200	0.670E+00	2.130E-01	0.	1.488E+02	4.894E+01	1.493E+02	0.	1.488E+02	4.894E+01
1.300	0.580E+00	1.827E-01	0.	1.568E+02	4.894E+01	1.493E+02	0.	1.568E+02	4.894E+01
1.400	0.510E+00	1.414E-01	0.	1.648E+02	4.894E+01	1.493E+02	0.	1.648E+02	4.894E+01
1.500	0.450E+00	1.079E-01	0.	1.728E+02	4.894E+01	1.493E+02	0.	1.728E+02	4.894E+01
1.600	0.400E+00	0.775E-01	0.	1.808E+02	4.894E+01	1.493E+02	0.	1.808E+02	4.894E+01
1.700	0.360E+00	0.507E-01	0.	1.888E+02	4.894E+01	1.493E+02	0.	1.888E+02	4.894E+01
1.800	0.330E+00	0.248E-01	0.	1.968E+02	4.894E+01	1.493E+02	0.	1.968E+02	4.894E+01
1.900	0.310E+00	0.1310E-02	0.	2.048E+02	4.894E+01	1.493E+02	0.	2.048E+02	4.894E+01
2.000	0.300E+00	0.734E-03	0.	2.128E+02	4.894E+01	1.493E+02	0.	2.128E+02	4.894E+01
2.100	0.290E+00	5.237E-03	0.	2.208E+02	4.894E+01	1.493E+02	0.	2.208E+02	4.894E+01
2.200	0.280E+00	3.676E-03	0.	2.288E+02	4.894E+01	1.493E+02	0.	2.288E+02	4.894E+01
2.300	0.270E+00	2.537E-03	0.	2.368E+02	4.894E+01	1.493E+02	0.	2.368E+02	4.894E+01
2.400	0.260E+00	1.764E-03	0.	2.448E+02	4.894E+01	1.493E+02	0.	2.448E+02	4.894E+01
2.500	0.250E+00	1.261E-03	0.	2.528E+02	4.894E+01	1.493E+02	0.	2.528E+02	4.894E+01
2.600	0.240E+00	8.814E-04	0.	2.608E+02	4.894E+01	1.493E+02	0.	2.608E+02	4.894E+01
2.700	0.230E+00	6.003E-04	0.	2.688E+02	4.894E+01	1.493E+02	0.	2.688E+02	4.894E+01
2.800	0.220E+00	4.261E-04	0.	2.768E+02	4.894E+01	1.493E+02	0.	2.768E+02	4.894E+01
2.900	0.210E+00	3.066E-04	0.	2.848E+02	4.894E+01	1.493E+02	0.	2.848E+02	4.894E+01
3.000	0.200E+00	2.283E-04	0.	2.928E+02	4.894E+01	1.493E+02	0.	2.928E+02	4.894E+01
3.100	0.190E+00	1.742E-04	0.	3.008E+02	4.894E+01	1.493E+02	0.	3.008E+02	4.894E+01
3.200	0.180E+00	1.283E-04	0.	3.088E+02	4.894E+01	1.493E+02	0.	3.088E+02	4.894E+01
3.300	0.170E+00	9.403E-05	0.	3.168E+02	4.894E+01	1.493E+02	0.	3.168E+02	4.894E+01
3.400	0.160E+00	6.834E-05	0.	3.248E+02	4.894E+01	1.493E+02	0.	3.248E+02	4.894E+01
3.500	0.150E+00	5.003E-05	0.	3.328E+02	4.894E+01	1.493E+02	0.	3.328E+02	4.894E+01
3.600	0.140E+00	3.761E-05	0.	3.408E+02	4.894E+01	1.493E+02	0.	3.408E+02	4.894E+01
3.700	0.130E+00	2.831E-05	0.	3.488E+02	4.894E+01	1.493E+02	0.	3.488E+02	4.894E+01
3.800	0.120E+00	2.104E-05	0.	3.568E+02	4.894E+01	1.493E+02	0.	3.568E+02	4.894E+01
3.900	0.110E+00	1.556E-05	0.	3.648E+02	4.894E+01	1.493E+02	0.	3.648E+02	4.894E+01
4.000	0.100E+00	1.142E-05	0.	3.728E+02	4.894E+01	1.493E+02	0.	3.728E+02	4.894E+01
4.100	0.090E+00	8.314E-06	0.	3.808E+02	4.894E+01	1.493E+02	0.	3.808E+02	4.894E+01
4.200	0.080E+00	6.003E-06	0.	3.888E+02	4.894E+01	1.493E+02	0.	3.888E+02	4.894E+01
4.300	0.070E+00	4.403E-06	0.	3.968E+02	4.894E+01	1.493E+02	0.	3.968E+02	4.894E+01
4.400	0.060E+00	3.283E-06	0.	4.048E+02	4.894E+01	1.493E+02	0.	4.048E+02	4.894E+01
4.500	0.050E+00	2.403E-06	0.	4.128E+02	4.894E+01	1.493E+02	0.	4.128E+02	4.894E+01
4.600	0.040E+00	1.763E-06	0.	4.208E+02	4.894E+01	1.493E+02	0.	4.208E+02	4.894E+01
4.700	0.030E+00	1.283E-06	0.	4.288E+02	4.894E+01	1.493E+02	0.	4.288E+02	4.894E+01
4.800	0.020E+00	9.403E-07	0.	4.368E+02	4.894E+01	1.493E+02	0.	4.368E+02	4.894E+01
4.900	0.010E+00	6.834E-07	0.	4.448E+02	4.894E+01	1.493E+02	0.	4.448E+02	4.894E+01
5.000	0.000E+00	5.003E-07	0.	4.528E+02	4.894E+01	1.493E+02	0.	4.528E+02	4.894E+01

Sample Output Listing, Continued

STA 2U.C	INFINITY	0.	1.5184E-01	0.	-2.8796E-01	0.	6.3338E-01	0.	-2.8796E-01	0.
0.0000	2.3734E+00	1.4460E-03	1.5327E-01	4.1053E-05	-2.9162E-01	-9.0494E-05	6.7142E-01	2.0124E-04	-2.9162E-01	-2.8796E-01
0.0100	1.8118E+00	1.4355E-02	1.5687E-01	4.1950E-04	-2.9484E-01	-1.3757E-03	6.8095E-01	3.0561E-03	-2.9484E-01	-2.8796E-01
0.0600	1.2411E+00	4.0631E-02	1.6202E-01	3.3197E-03	-3.1172E-01	-7.4449E-02	7.1632E-01	1.6530E-02	-3.1172E-01	-2.8796E-01
0.1000	1.0357E+00	9.7287E-02	1.6791E-01	1.0910E-02	-3.2494E-01	-2.4492E-02	7.4630E-01	5.4985E-02	-3.2494E-01	-2.8796E-01
0.1500	8.7208E+00	1.9174E-01	1.7380E-01	2.6235E-02	-3.3391E-01	-2.5931E-02	7.6181E-01	1.3215E-01	-3.3391E-01	-2.8796E-01
0.2100	7.5914E-01	3.3088E-01	1.7962E-01	4.9498E-02	-3.3268E-01	-1.1373E-01	7.6572E-01	2.5972E-01	-3.3268E-01	-2.8796E-01
0.2800	6.1964E-01	5.1417E-01	1.8544E-01	7.9495E-02	-3.1871E-01	-1.8082E-01	7.8000E-01	4.1519E-01	-3.1871E-01	-2.8796E-01
0.3600	5.2309E-01	7.5951E-01	1.9111E-01	1.0640E-01	-2.9490E-01	-2.4827E-01	8.0343E-01	7.7101E-01	-2.9490E-01	-2.8796E-01
0.4500	4.2429E-01	1.0529E+00	1.9660E-01	1.2912E-01	-2.6703E-01	-3.0601E-01	8.1403E-01	1.1804E-01	-2.6703E-01	-2.8796E-01
0.5500	3.5394E-01	1.3486E+00	1.2965E-01	1.5560E-01	-2.4008E-01	-3.5008E-01	8.2411E-01	1.8928E-01	-2.4008E-01	-2.8796E-01
0.6700	3.3254E-01	1.8316E+00	1.0774E-01	1.6104E-01	-2.1492E-01	-4.0735E-01	8.3366E-01	2.8324E-01	-2.1492E-01	-2.8796E-01
0.8100	3.0997E-01	2.3474E+00	9.9745E-02	1.6716E-01	-1.9276E-01	-4.4229E-01	8.4131E-01	4.0233E-01	-1.9276E-01	-2.8796E-01
1.0100	2.8691E-01	3.0324E+00	9.3615E-02	1.4971E-01	-1.5575E-01	-4.3199E-01	8.4813E-01	5.8333E-01	-1.5575E-01	-2.8796E-01
1.2500	2.6425E-01	4.0324E+00	8.6679E-02	1.3955E-01	-1.5450E-01	-4.3575E-01	8.5399E-01	7.9737E-01	-1.5450E-01	-2.8796E-01
1.5500	2.4192E-01	5.1456E+00	8.2327E-02	1.2773E-01	-1.5831E-01	-4.2764E-01	8.5909E-01	9.4023E-01	-1.5831E-01	-2.8796E-01
2.0500	2.1119E-01	6.7768E+00	8.8252E-02	1.1544E-01	-1.6462E-01	-4.2065E-01	8.6443E-01	1.1644E-01	-1.6462E-01	-2.8796E-01
3.0000	1.6997E-01	1.1316E+01	8.9252E-02	1.0385E-01	-1.7106E-01	-4.1594E-01	8.6958E-01	1.7106E-01	-1.7106E-01	-2.8796E-01
4.0000	1.2484E-01	1.4781E+01	8.5198E-02	9.2595E-02	-1.7803E-01	-4.1302E-01	8.7471E-01	2.5778E-01	-1.7803E-01	-2.8796E-01
5.0000	9.5753E-02	1.8642E+01	8.4632E-02	8.1933E-02	-1.8444E-01	-4.1130E-01	8.7930E-01	3.7471E-01	-1.8444E-01	-2.8796E-01
7.0000	6.0624E-02	2.5607E+01	8.7497E-02	7.2513E-02	-1.9099E-01	-4.0928E-01	8.8308E-01	5.5396E-01	-1.9099E-01	-2.8796E-01
8.0000	4.1244E-02	3.5405E+01	8.8413E-02	6.4074E-02	-1.9574E-01	-4.0802E-01	8.8647E-01	7.8244E-01	-1.9574E-01	-2.8796E-01
10.0000	2.1994E-02	5.5704E+01	8.9443E-02	5.6094E-02	-2.0115E-01	-4.0682E-01	8.8943E-01	9.2975E-01	-2.0115E-01	-2.8796E-01

NATURAL HULL FREQUENCY = .37415
 CALCULATOR WAVE RAMPING IN HULL = 3.949E+02
 ADDITIONAL VISCOM RAMPING IN HULL = 3.502E+04

SERIES 60 MULL FORM, 9.80 FLUCK (TNO APT. NO. 100 S) OCCANICS PROJECT NO. 107? SEP 24, 1979
 SPEED = 6.5257 WAVE ANGLE = 10.00 DEG. VERTICAL PLANE RESPONSES (NON-DIMENSIONAL)

F R E Q U E N C I E S	WAVE	ENCOUNTER	WAVE	WAVE/SHIP	U E A V E	P I T C M	VERTICAL
	LENGTH	LENGTH	LENGTH	AMPL.	PHASE	AMPL.	REND.MT.
31570	25039	614.232	3.2033	6611	179.3	.8790	4.075E-03
35080	27549	473.314	2.6525	7756	178.8	.8080	6.543E-03
40590	29793	373.992	1.9376	6657	178.0	.7282	9.693E-03
45100	31771	302.934	1.5666	5308	176.7	.6252	1.306E-02
49610	33481	250.354	1.2977	3797	174.0	.5091	1.631E-02
54120	34926	210.371	1.0900	2263	167.4	.3841	1.895E-02
58630	36103	179.251	.9284	9661	142.6	.2591	2.026E-02
63140	37014	154.558	.8008	6723	159.5	.1449	1.988E-02
67650	37659	134.637	.6976	4676	310.0	.0523	1.674E-02
72160	38037	118.333	.6131	3381	230.8	.0359	1.237E-02
76670	38148	104.821	.5431	2400	168.0	.0256	1.237E-02
81180	37993	93.494	.4844	1653	115.1	.0199	6.793E-03
85690	37571	83.915	.4348	1240	98.7	.0173	2.144E-03
90200	36882	75.733	.3924	845	74.8	.0146	3.321E-03
94710	35927	68.692	.3559	6457	54.2	.0123	4.363E-03
99220	34706	62.590	.3243	4813	40.5	.0103	5.292E-04
1.03730	33217	57.285	.2967	3604	31.1	.0086	1.670E-03
1.08240	31443	52.593	.2725	2610	30.3	.0066	1.824E-03
1.12750	29441	48.469	.2511	1845	19.5	.0049	7.459E-04
1.17260	27153	44.613	.2322	1322	12.6	.0039	1.931E-03
1.21770	24599	41.555	.2153	9019	8.6	.0028	3.314E-03
1.26280	21777	38.639	.2002	6494	6.4	.0022	1.008E-03
1.30790	18490	36.021	.1866	4823	5.3	.0015	1.821E-03

Sample Output Listing, Continued

SERIES 60 HULL FORM, 0.40 FLUCK (TMO RPT. NO. 100 S) OCEANICS PROJECT NO. 1093 SEP 24 1970
 SPEED = 6.5257 WAVE ANGLE = 10.40 DEG. LATERAL PLANE RESPONSES (NON-DIMENSIONAL)

WAVE FREQUENCY	ENCOUNTER LENGTH	WAVE LENGTH	WAVE/SHIP LENGTH	S AMPL.	A AMPL.	Y AMPL.	W AMPL.	R AMPL.	O AMPL.	L AMPL.	I AMPL.	LATERAL BEND. AMPLITUDE	MT. PHASE	TORSIONAL MOMENT AMPLITUDE	MOMENT PHASE
.31570	.25039	614.237	1.2033	1.696	90.6	1.807	--4	.2474	-95.3	2.102E-04	97.0	2.362E-05	-146.1		
.36090	.27549	573.534	2.4525	1.522	91.8	1.790	.0	.2609	-97.2	3.938E-04	96.1	3.730E-05	-142.1		
.40590	.29793	1.9378	1.285	1.285	91.1	1.710	.5	.2675	-100.2	6.777E-04	95.1	5.440E-05	-144.1		
.45100	.31771	1.5686	0.990	1.1	91.3	1.567	1.1	.2593	-104.8	1.087E-03	94.4	7.296E-05	-143.1		
.49610	.33481	1.2972	0.651	1.090	91.4	1.362	1.8	.2235	-111.4	1.622E-03	94.0	8.786E-05	-143.1		
.54120	.34976	1.0960	0.299	88.4	1.104	2.7	1.483	-119.5	2.235E-03	94.0	8.903E-05	-144.1			
.58630	.36163	1.79251	.9288	0.045	-36.4	.0622	3.6	.0398	-117.5	2.823E-03	94.2	6.846E-05	-144.1		
.63140	.37614	1.5454	.8008	.288	-76.4	.0530	4.4	.0858	-121.8	3.219E-03	94.9	3.369E-05	-141.1		
.67650	.37459	1.34637	.6976	.431	-77.8	.0261	3.9	.1773	-120.0	3.311E-03	96.0	5.905E-05	-22.1		
.72160	.38037	1.18333	.6131	.439	-77.5	.0194	-13.6	.2224	-126.2	2.994E-03	97.6	1.158E-04	-4.1		
.76670	.38144	1.04821	.5431	.4320	-77.7	.0102	-15.4	.2166	-126.5	2.298E-03	100.0	1.611E-04	4.1		
.81180	.37983	.91494	.4844	.4121	-45.2	.0151	-16.0	.1651	-21.3	1.381E-03	103.4	1.795E-04	11.1		
.85690	.37577	.78315	.4348	.4100	130.1	.0187	-158.9	.0814	28.9	4.924E-04	108.5	1.602E-04	18.1		
.90200	.36442	.64692	.3924	.4241	121.6	.0086	-156.4	.0094	-170.1	1.207E-04	-71.3	3.040E-05	8.1		
.94710	.35927	.54594	.3559	.4260	120.3	.0010	-163.3	.0685	-135.7	1.992E-04	-34.8	2.688E-05	-92.1		
.99220	.34706	.42594	.3243	.4252	120.3	.0051	36.8	.0779	-119.9	1.992E-04	-34.8	2.688E-05	-92.1		
1.03730	.33217	.3265	.2967	.4209	-35.2	.0056	46.9	.0501	-110.0	2.077E-04	99.5	4.092E-05	-122.1		
1.08240	.31463	.22593	.2725	.4209	-35.2	.0056	46.9	.0501	-110.0	5.314E-04	126.5	3.038E-05	-144.1		
1.12750	.29461	.18449	.2511	.4248	-36.3	.0047	28.8	.0664	116.3	6.654E-04	138.4	1.879E-05	174.1		
1.17260	.27153	.14473	.2322	.4103	-53.6	.0047	113.9	.0116	104.0	5.206E-04	149.5	1.819E-05	98.1		
1.21770	.24599	.11555	.2153	.4213	173.5	.0069	-111.7	.0080	104.2	1.763E-04	138.3	2.649E-05	43.1		
1.26280	.21777	.84639	.2002	.4423	186.4	.0037	-113.8	.0029	104.3	1.888E-04	3.7	2.649E-05	52.1		
1.30790	.18466	.36021	.1866	.4235	157.0	.0044	47.2	.0009	-9.9	2.812E-04	-7.7	1.997E-05	48.1		

SERIES 60 HULL FORM, 0.40 FLUCK (TMO RPT. NO. 100 S) OCEANICS PROJECT NO. 1093 SEP 24 1970
 SPEED = 6.5257 WAVE ANGLE = 10.40 DEG. SHEAR AND MOMENT CLOSURE RESULTS

WAVE FREQUENCY	ENCOUNTER LENGTH	WAVE LENGTH	WAVE/SHIP LENGTH	S AMPL.	A AMPL.	Y AMPL.	W AMPL.	R AMPL.	O AMPL.	L AMPL.	I AMPL.	LATERAL BENDING SHEAR	MOMENT	TORSIONAL MOMENT
.31570	.25039	614.237	1.2033	1.696	90.6	1.807	--4	.2474	-95.3	2.102E-04	97.0	4.936E-13	6.415E-14	
.36090	.27549	573.534	2.4525	1.522	91.8	1.790	.0	.2609	-97.2	3.938E-04	96.1	5.935E-17	9.409E-14	
.40590	.29793	1.9378	1.285	1.285	91.1	1.710	.5	.2675	-100.2	6.777E-04	95.1	2.139E-13	6.568E-14	
.45100	.31771	1.5686	0.990	1.1	91.3	1.567	1.1	.2593	-104.8	1.087E-03	94.4	7.945E-13	5.875E-14	
.49610	.33481	1.2972	0.651	1.090	91.4	1.362	1.8	.2235	-111.4	1.622E-03	94.0	2.608E-13	6.542E-14	
.54120	.34976	1.0960	0.299	88.4	1.104	2.7	1.483	-119.5	2.235E-03	94.0	8.903E-05	4.618E-14		
.58630	.36163	1.79251	.9288	0.045	-36.4	.0622	3.6	.0398	-117.5	2.823E-03	94.2	4.568E-14	3.983E-14	
.63140	.37614	1.5454	.8008	.288	-76.4	.0530	4.4	.0858	-121.8	3.219E-03	94.9	1.639E-14	7.864E-14	
.67650	.37459	1.34637	.6976	.431	-77.8	.0261	3.9	.1773	-120.0	3.311E-03	96.0	1.952E-14	8.085E-14	
.72160	.38037	1.18333	.6131	.439	-77.5	.0194	-13.6	.2224	-126.2	2.994E-03	97.6	1.392E-14	7.864E-14	
.76670	.38144	1.04821	.5431	.4320	-77.7	.0102	-15.4	.2166	-126.5	2.298E-03	100.0	2.178E-14	3.905E-14	
.81180	.37983	.91494	.4844	.4121	-45.2	.0151	-16.0	.1651	-21.3	1.381E-03	103.4	4.448E-14	3.298E-14	
.85690	.37577	.78315	.4348	.4100	130.1	.0187	-158.9	.0094	-170.1	1.207E-04	-71.3	1.365E-13	2.198E-14	
.90200	.36442	.64692	.3924	.4241	121.6	.0086	-156.4	.0094	-170.1	1.207E-04	-71.3	0.087E-14	6.087E-14	
.94710	.35927	.54594	.3559	.4260	120.3	.0051	36.8	.0779	-119.9	1.992E-04	-34.8	1.748E-13	1.939E-13	
.99220	.34706	.42594	.3243	.4252	120.3	.0056	46.9	.0501	-110.0	2.077E-04	99.5	2.042E-17	1.048E-13	
1.03730	.33217	.3265	.2967	.4209	-35.2	.0056	46.9	.0501	-110.0	5.314E-04	126.5	4.012E-17	1.932E-13	
1.08240	.31463	.22593	.2725	.4209	-35.2	.0056	46.9	.0501	-110.0	6.654E-04	138.4	1.421E-17	3.067E-13	
1.12750	.29461	.18449	.2511	.4248	-36.3	.0047	113.9	.0116	104.0	5.206E-04	149.5	6.418E-18	3.067E-13	
1.17260	.27153	.14473	.2322	.4103	-53.6	.0047	113.9	.0116	104.0	5.206E-04	149.5	8.624E-18	2.199E-13	
1.21770	.24599	.11555	.2153	.4213	173.5	.0069	-111.7	.0080	104.2	1.763E-04	138.3	3.609E-13	3.067E-13	
1.26280	.21777	.84639	.2002	.4423	186.4	.0037	-113.8	.0029	104.3	1.888E-04	3.7	2.495E-17	9.469E-14	
1.30790	.18466	.36021	.1866	.4235	157.0	.0044	47.2	.0009	-9.9	2.812E-04	-7.7	6.333E-14	7.501E-14	

Sample Output Listing, Continued

SERIES 60 HULL FORM, 6.40 KLUCK (TNO RPT. NO. 100 S) OCEANICS PROJECT NO. 1993 SEP 24, 1970
 SPEED # A-2757 WAVE ANGLE = 10.00 DEG., SIG. WAVE HT. = 8.40, MEAN PERIOD = 10.00 RESPONSE (AMPLITUDE) SPECTRA

FREQ	ENCOUNTER	WAVE LENGTH	HEAVE	PITCH	SWAY	YAW	ROLL	VERT. G.M.	LAT. G.M.	TORSN. G.M.
.3150	.2509	114.23	2.66E-01	9.89E-02	1.03E-02	3.98E-03	7.46E-03	7.66E-08	2.28E-10	2.58E-12
.3680	.2143	61.33	2.00E+00	1.26E+00	7.71E-02	3.18E-02	1.31E-01	1.03E-06	6.65E-09	5.96E-11
.4050	.2070	37.80	3.81E+00	6.20E+00	1.22E-01	2.32E-01	5.70E-01	1.02E-05	5.08E-08	3.27E-10
.4510	.3171	302.93	3.45E+00	6.74E+00	1.20E-01	4.24E-01	1.10E+00	2.46E-05	1.80E-07	8.39E-10
.49610	.3341	250.34	1.86E+00	6.94E+00	5.49E-02	4.97E-01	1.33E+00	4.43E-05	4.39E-07	1.26E-09
.54120	.3497	210.37	6.01E-01	5.01E+00	1.04E-02	4.22E-01	7.56E-01	5.42E-05	7.54E-07	1.19E-09
.58530	.3613	179.25	9.86E-02	2.86E+00	1.99E-04	2.67E-01	6.28E-02	2.18E-05	1.08E-06	5.92E-10
.63140	.3704	154.46	4.41E-02	8.97E-01	6.55E-03	1.20E-01	3.15E-01	3.93E-05	1.05E-06	1.15E-10
.67650	.3745	134.44	9.75E-02	1.21E-01	1.15E-02	1.02E-02	1.39E+00	2.29E-05	8.75E-07	2.78E-10
.72160	.3837	118.33	9.29E-02	1.14E-02	9.30E-03	9.68E-04	2.21E+00	2.54E-06	5.51E-07	8.36E-10
.76670	.3818	104.82	4.38E-02	9.25E-02	3.88E-03	4.62E-03	2.09E+00	2.24E-06	2.27E-07	1.26E-09
.81180	.3793	93.50	7.80E-03	1.84E-01	4.34E-04	1.13E-02	1.19E+00	1.78E-07	7.27E-08	7.69E-10
.85690	.3751	83.92	4.58E-04	4.89E-02	2.34E-03	9.30E-03	2.84E-01	3.30E-07	7.27E-09	2.64E-10
.90200	.3682	75.73	3.65E-03	5.89E-03	1.07E-03	3.07E-03	3.70E-03	4.52E-07	2.23E-09	7.70E-11
.94710	.3597	68.69	3.08E-03	2.96E-03	7.97E-04	3.72E-05	2.37E-01	1.78E-07	6.07E-09	1.10E-11
.99220	.3476	62.59	5.26E-04	6.97E-03	2.74E-05	1.02E-03	2.37E-01	4.22E-09	5.33E-10	2.00E-11
1.03730	.3327	57.27	6.75E-05	2.78E-03	2.12E-05	2.10E-03	9.68E-03	3.44E-08	2.84E-09	1.12E-11
1.08240	.3143	49.47	8.21E-05	1.24E-03	3.46E-04	1.17E-03	1.64E-03	2.55E-08	1.85E-09	2.25E-12
1.12750	.2941	40.47	6.80E-05	5.33E-04	5.66E-05	1.67E-03	1.40E-03	3.95E-08	1.77E-10	3.30E-12
1.17260	.2715	31.54	2.16E-04	1.23E-03	2.07E-04	1.59E-03	2.17E-03	3.95E-08	1.68E-10	1.60E-12
1.21770	.2459	24.59	1.01E-04	8.87E-04	6.66E-04	4.38E-04	2.47E-04	4.84E-09	3.10E-10	1.60E-12
1.26280	.2177	38.04	1.95E-04	3.92E-04	1.72E-04	6.82E-04	2.58E-05	1.33E-08	3.10E-10	1.60E-12
1.30790	.1860	36.02	5.53E-01	1.27E+00	2.01E-02	9.45E-02	3.44E-01	1.19E-05	2.39E-07	9.17E-19
		MIN. SD	7.43E-01	1.12E+00	1.41E-01	3.07E-01	7.37E-01	3.54E-03	4.88E-04	2.03E-05
		P.M.S.	9.10E-01	1.38E+00	1.73E-01	3.76E-01	9.83E-01	4.83E-03	5.97E-04	2.88E-05
		AVG.	1.48E+00	2.25E+00	2.83E-01	6.14E-01	1.47E+00	6.99E-03	9.74E-04	4.05E-05
		AVI/10	1.89E+00	2.67E+00	3.61E-01	7.82E-01	1.87E+00	8.79E-03	1.24E-03	5.18E-05

VI. ERROR MESSAGES

Various error messages may appear in the output and cause program termination. Each will be labeled with the subroutine which found the error, and possibly a brief note as to the type of error. Some messages give error numbers as explained below:

<u>Subroutine</u>	<u>Error No.</u>	<u>Explanation</u>
PRELIMB/C	0	Too many sections, wave lengths, wave angles, etc.
PRELIMB	1	Sum of weight distribution \neq displacement
PRELIMB	2	Hull volume inconsistent with displacement
PRELIMB	3	Longitudinal center of buoyancy \neq long. center of gravity
PRELIMC	4	Error in range or increment of variable conditions
PRELIMC	5	TDP calculation incomplete
PRELIMC	6	TDP file label \neq title data, col. 1-30

Errors in the calculation of the two-dimensional properties will be self explanatory. However, if an error is found in the energy balance check on the results of the two-dimensional lateral motion calculation the message is printed, but computations proceed. It has usually been found that such errors in the energy balance check have little influence on the calculated two-dimensional properties.

VII. ACKNOWLEDGEMENTS

The SCORES program derives from earlier basic ship motion programs originally developed in the Department of Naval Architecture at M.I.T. in 1963-64, and subsequently updated at NSRDC. Thus, while the program concept is not wholly original, the increased level of both complexity and flexibility in Program SCORES results in a new generation program with little resemblance to its predecessors. However, the earlier work is acknowledged as the root source for the present development.

The initial phase of programming for Subroutine TDIR, the calculation of the lateral and rolling oscillation two-dimensional hydrodynamic forces based on the method of Tasai, was carried out by Dr. Y. K. Chung.

APPENDIX A & PROGRAM DESCRIPTION

The SCORES program, written in FORTRAN IV (RUN Fortran Version 2 under SCOPE Version 3 for CDC 6600 computer), is structured in a fairly conventional manner. The main program serves as a control for the job processing, calling various subroutines as required. The major program loops over ship speed, wave angle and wave frequency are established in the main program. Data are transferred among subroutines via labeled common blocks, each subroutine accessing those blocks specifically required. A special common block labeled PROGRAM is used and shared by many subroutines for storage of intermediate calculation data.

Subroutine PRELIMB reads, processes and stores the basic input data. Preliminary calculations are performed and the data are checked to some extent for self-consistency. Subroutine PRELIMC reads, stores and processes the conditional input data. Preliminary calculations are performed including spectral density calculations and print out (via Subroutine PAR) if required. Then the two-dimensional properties are obtained, either read from file or calculated via Subroutines CKLEW, ZIPSMO and TDLR.

Subroutine CKLEW simply calculates the two Lewis form parameters for each section and checks them against criteria to insure positive contours. If necessary, the section area coefficient is increased to satisfy the criterion. Subroutine ZIPSMO calculates the two-dimensional properties for vertical oscillation, while Subroutine TDLR does the same for the lateral and rolling modes. The latter routine follows both the method and the notation of Tasai. Subroutine MATPAC is used by ZIPSMO for solution of simultaneous equations.

If lateral plane computations are required, Subroutine ROLD is used to calculate the natural roll frequency and the additional roll damping, to approximately account for viscous effects.

The basic ship response calculations at a given condition are performed by calling Subroutines ALINT, COEFF, EXCITE, MOTION and BENDSH, sequentially. Subroutine ALINT finds and stores the value of each required two-dimensional property by continued fraction interpolation in frequency parameter (equal to circular frequency of encounter squared times draft divided by acceleration of gravity). Subroutines COEFF and EXCITE calculate the coefficients and excitation, respectively, in the equations of motion, which are then solved in Subroutine MOTION. Subroutine BENDSH then calculates the local loadings and integrated moments. Closure results are calculated, if required. Throughout all the calculations, subprogram function SINT is used as a simple integrator.

The ship responses at each speed and wave angle are printed out by Subroutine TNIRPA, including closure results if required. If irregular seas are used, Subroutine STATI then calculates and

prints the response spectra and statistics for long crested, or uni-directional, seas at the particular ship speed and wave angle. Only the integrated spectral response at each wave angle is saved, so that the response spectra for short crested seas are not available. For short crested seas results, Subroutine SPREAD is used after the full range of wave angles has been depleted. The integrated responses over wave angle are computed and printed.

After completion of the specified calculations, control reverts to Subroutine PRELIMC for additional cases with the same basic data, that is, the same ship. If no additional computations are required, normal program termination occurs in Subroutine PRELIMC upon input of a run control tag less than 0.0.

Only one special system subroutine is included in the program. This is referenced in the main program by CALL DATE (DTA, DTB) which provides the current date in the argument variables as Hollerith data (DTA = MMMbDD,b19,DTB=YY).

Program SCORES - Input Data Card Summary

Card Number	Conditions (see legend below)	Parameters Entered	Format (& Columns)
1	*	Title information	A80
2	*	Option control tags; number of segments	11I2
3	*	Length; density; gravity; displacement	10X, 4F10
4	*	Breadth; area coeff.; draft; centroid (each station)	4F10
5	OT(E)>0	VCG; roll gyradius (ship)	2F10
6	OT(B)=0	Long. gyradius; LCG	2F10
7	OT(B)>0	Weight; VCG; roll gyradius (each station).	3F10
8	*	First sta.; last sta.; increment for moment calcs.	3I10

9	*	Run control tag; initial, final and increment in wavelength, or frequency; initial, final and increment in speed	7F10
10	OT(E)>0	Fraction of critical roll damping	F10
11	*	Initial, final and increment in wave angle	3F10
12	OT(D)>0	No. of spectra; parameters....	I10, 10F5
	OT(D)=3	Additional corresponding parameters	10X, 10F5

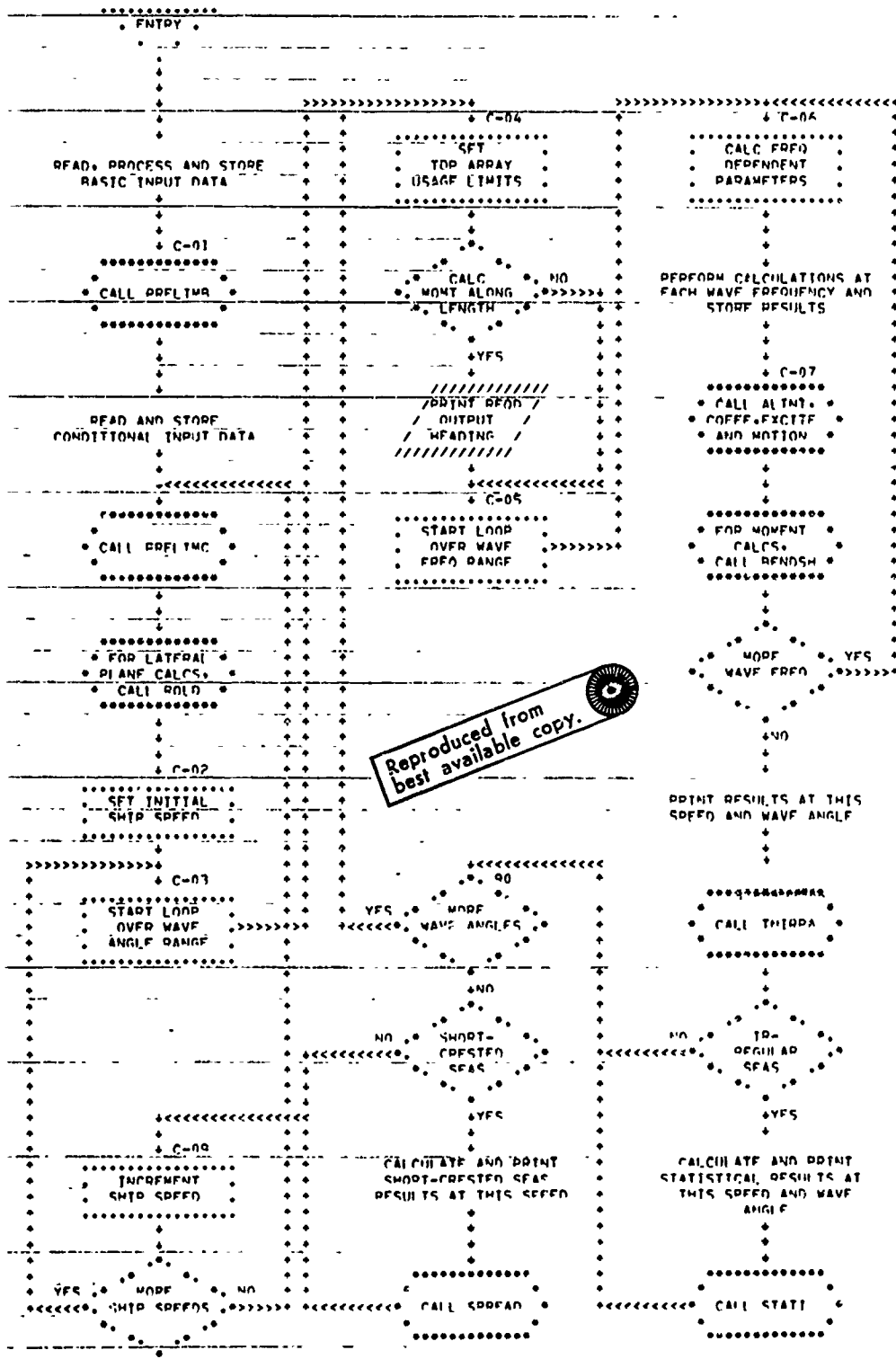
Legend for conditions: * = always necessary in data deck.

OT(-)>- necessary only if Option Tag indicated meets condition shown.

APPENDIX B - FLOWCHARTS

Flowcharts follow for the main program and each subroutine. The references given on the flowcharts, such as C-01 etc. (above and on the right of the symbolic outlines) correspond to numbered comment cards included with the FORTRAN source program, and listed in the next appendix.

FLOWCHART FOR MAIN PROGRAM



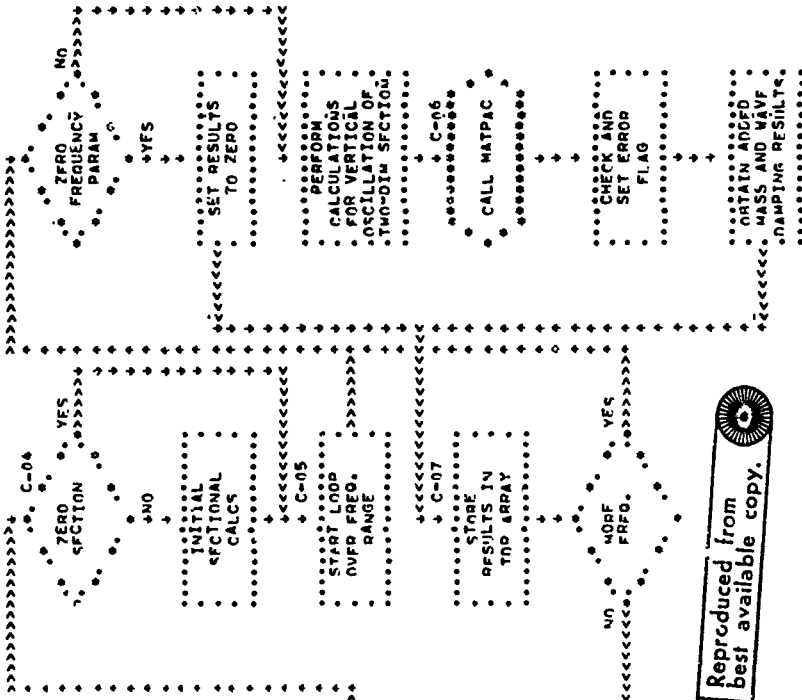
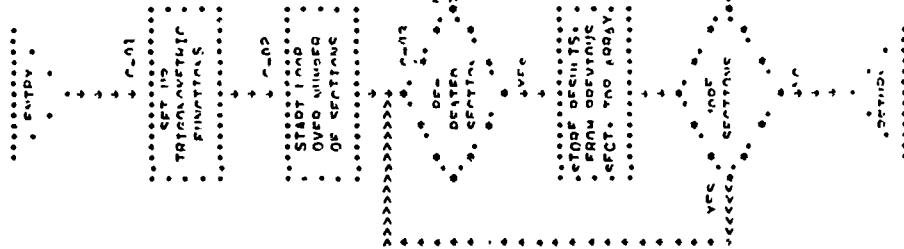
Reproduced from best available copy.

FLOWCHART FOR SIARFUJTHE PFLIMB

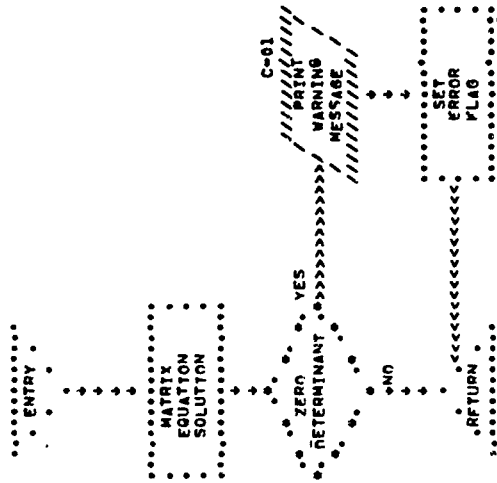


Reproduced from best available copy.

FLOWCHART FOR SUBROUTINE ZTPSMN

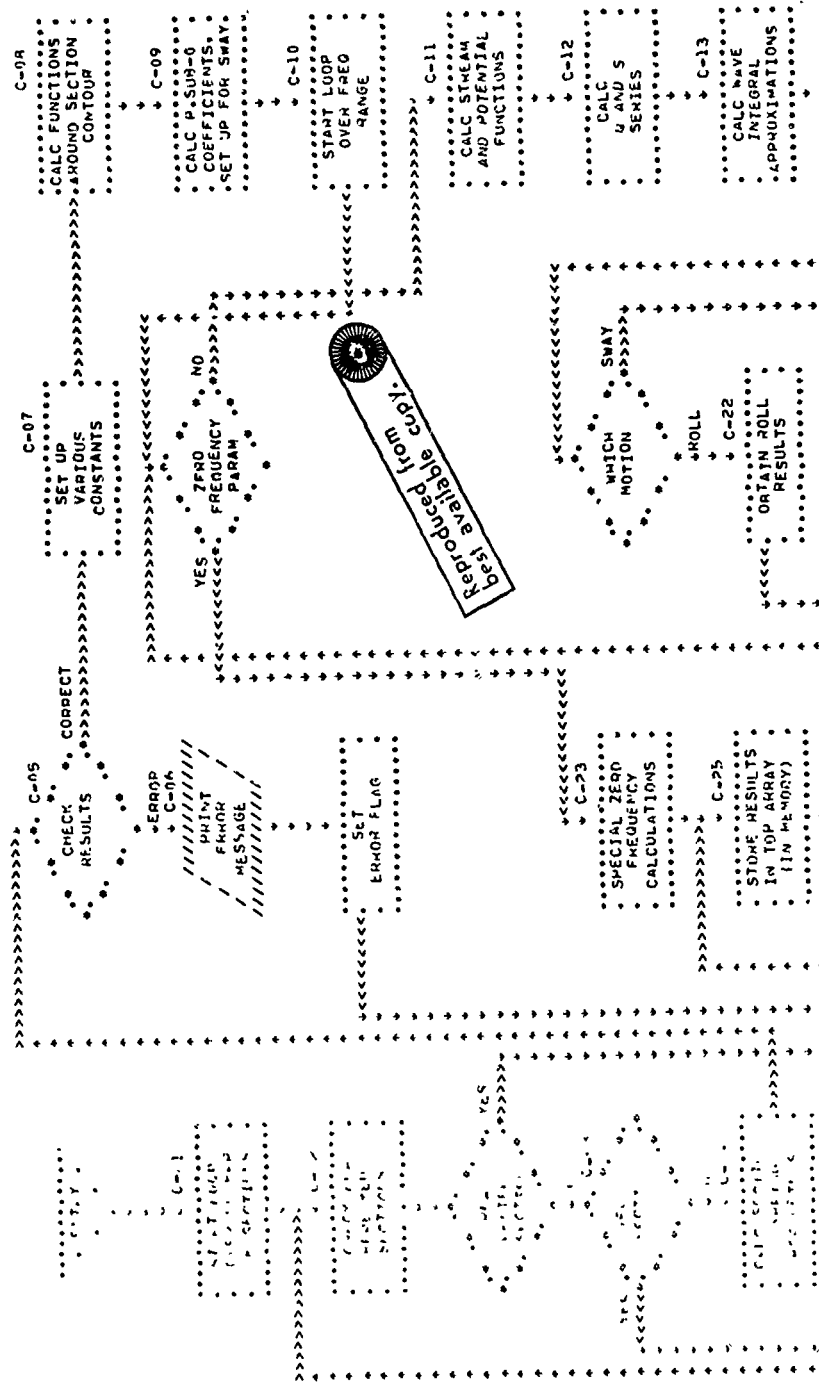


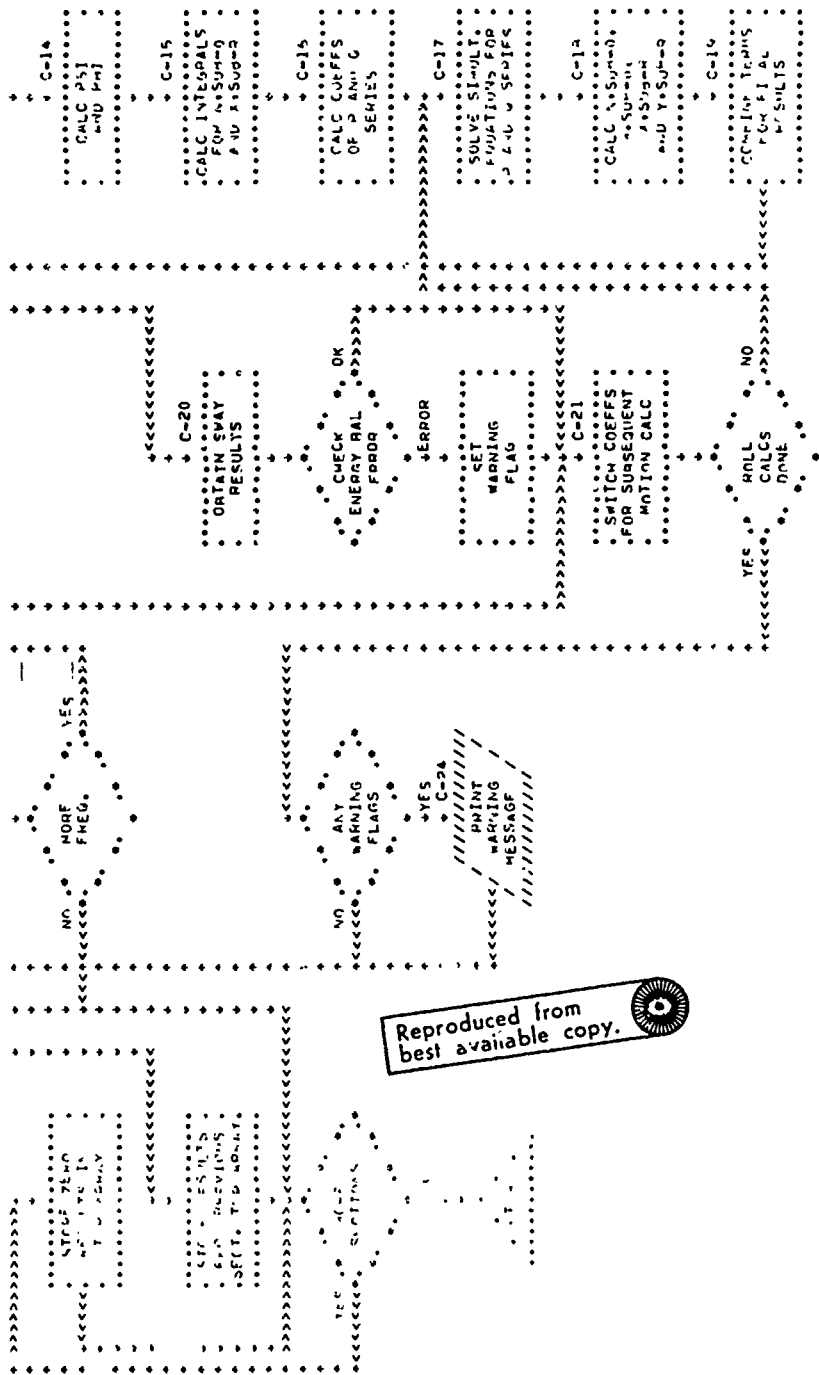
FLOWCHART FOR SUBROUTINE MATPAC



Reproduced from best available copy.

FIGURE 4 FOR TRANSDUCER DATA

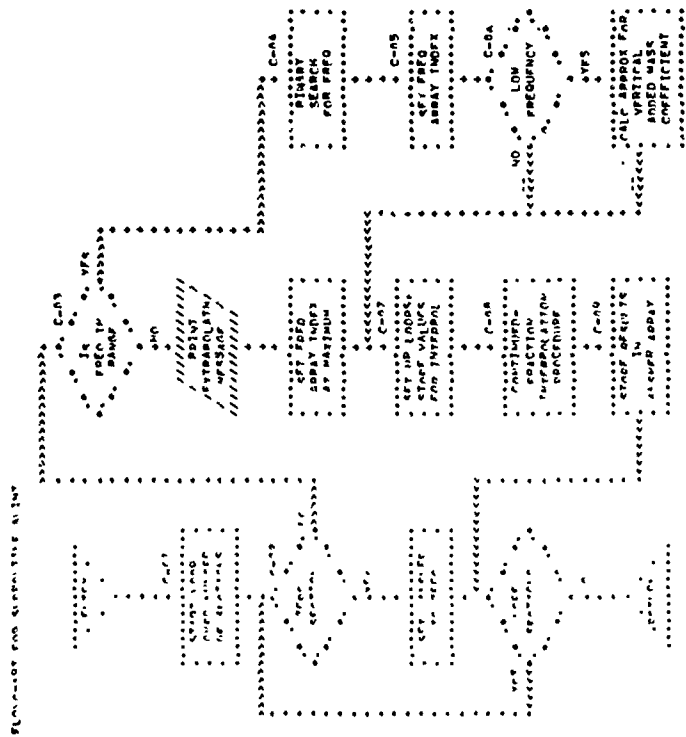
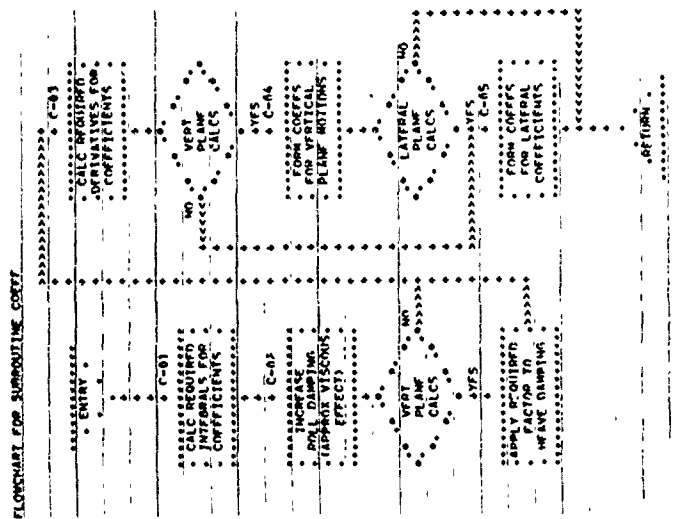




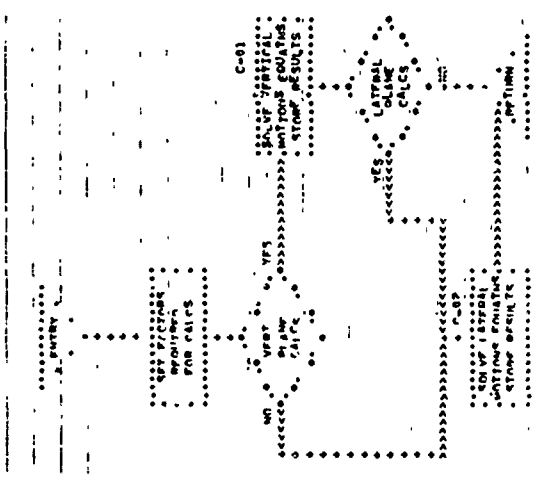
Reproduced from best available copy.



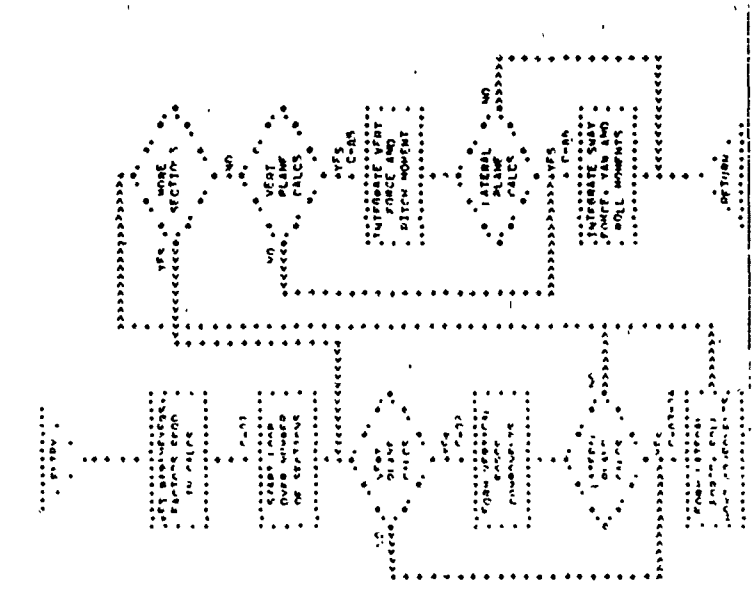
FLOWCHART FOR SUBROUTINE GOVT



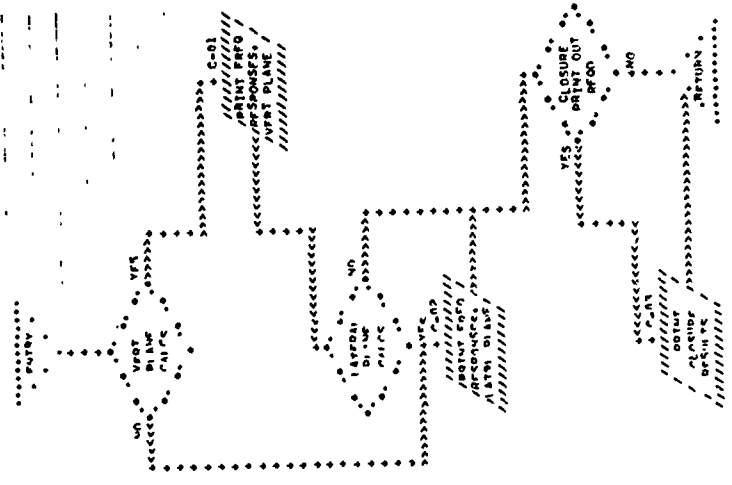
PROGRAM FOR COMPUTING WEIGHT



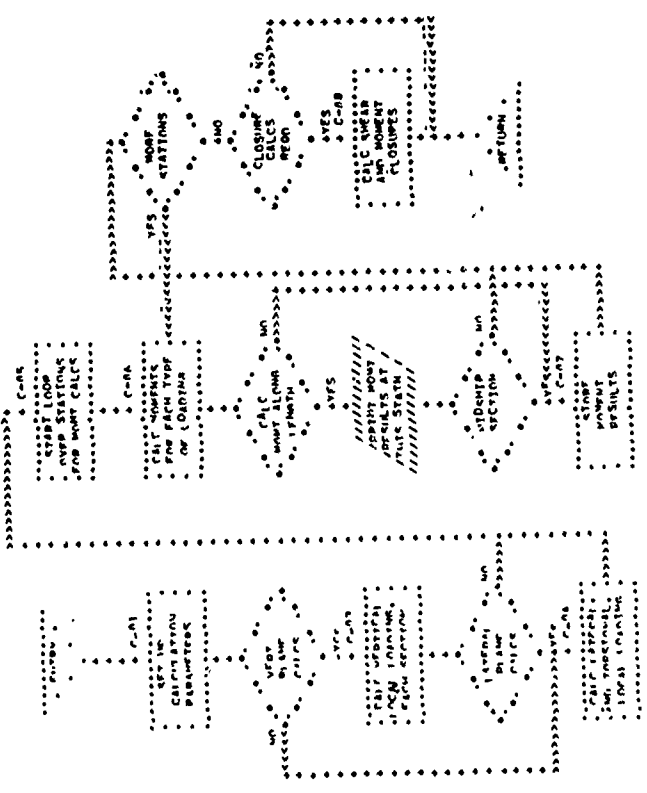
PROGRAM FOR COMPUTING FACTOR



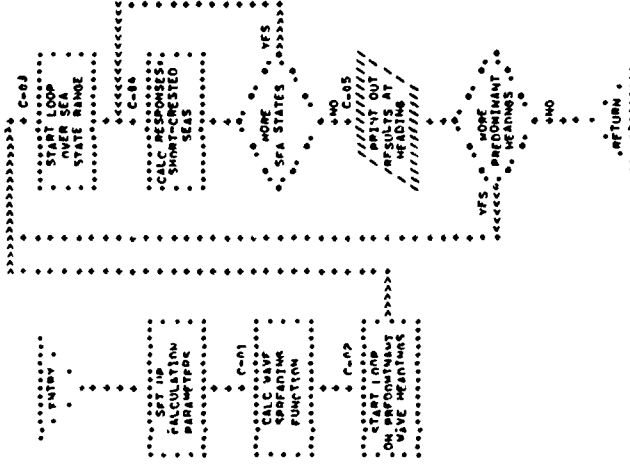
FLOWCHART FOR THE CLOSURE TIME



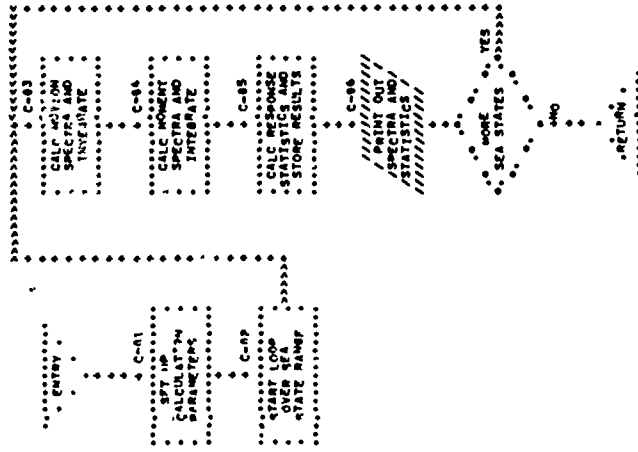
FLOWCHART FOR THE CLOSURE TIME



FLOWCHART FOR SUBROUTINE SPREAD



FLOWCHART FOR SUBROUTINE STATI



APPENDIX C - LISTING

The complete FORTRAN IV source deck listing for Program SCORES is given. The numbered comment cards, such as C-01 etc., are cross-referenced on the flowcharts in the previous section.

```

PROGRAM SCORES (INPUT,OUTPUT,TAPES=INPUT,TAPES=OUTPUT,TAPE10)

COMMON / / IDP(21,25,10)
COMMON / CONDA / P1,GMMA,GRAY,RO
COMMON / MMDT / MDA(14),DTA,DTB,IB,IC,ID,IE,IF,IG,IH,II,IJ,STS(8)
COMMON / BASDA / BPL,DISPL,THASS,VMERT,BSTAR(21),ARPA(21),
X SECDE(21),DRAFT(21),ZBAR(21),XI(21),XISO(21),
X DWZIGM(21),DMASS(21),ZWT(21),BRL(21),ZCO,VMERT,
X ZPERT,DM,MINKRI,MAXKRI,IMCRES,ROLNPP
COMMON / CASDA / NN,OMW(51),VVL(51),OMVE(51),VMIN,VMAX,DELY,
X NWA,WAD(25),VANBI,WANBA,OVANB,NUI,W(20),VLL(51)
COMMON / TDJH / NE,NEM,ANS(21,10),KL,KU,IO,IM
COMMON / MIND / IA,NS,DXI,V,WANB,OMEGA,NAVEN,CM,DIR(21,5),FAC(14)

DATA STS/OMW, 50,AMR,N,S,GMMA,0, VMERT, 0,GMVA1/10 /

C
C ** ** SPECIAL SYSTEM SUBROUTINE WHICH RETURNS CURRENT DATE ** **
CALL DATE (ITA,DTR)

C-01 READ, PROCESS AND STORE INPUT DATA
CALL PRELIM
90 CALL PRELIM
IF ( IE.GT.0 ) CALL ROLD

C-02 INITIALIZE SHIP SPEED
V = VMIN

C-03 LOOP OVER WAVE ANGLE RANGE
90 DO 90 I=1,MWA
WANA = WAD(I)*PI/180.0

C-04 GET THE ARRAY USAGE LIMITS
NL = 1
IF ( IE .GT. 1 ) NL = 3
NU = 10
IF ( IE .LT. 1 .OR. AMOD/WAD(IM),180.0).EQ.0.0 ) NU = 2
IF ( IM.LT.7 .OR. MAXKRI.EQ.MINKRI ) GO TO 70
PRINT 920,MDA,DTA,DTB
PRINT 921, V,WAD(IM)
IF ( I1.EQ.1 ) PRINT 924
PRINT 923

C-05 LOOP OVER WAVE FREQUENCY RANGE
70 DO 80 TO=1,NN
OMFA = OMW(IO)
WVFA = OMEGA*OMEGA/GRAY
VVL(10) = 2.0*PI/NAVEN
VLL(10) = VVL(10)/BPL

C-06 CALCULATE FREQUENCY PARAMETERS
CM = GRAY/OMEGA
WE = NAVEN*(CM-VOCOS(WANB))
OMWF(10) = WE
WFM = WE*WE/GRAY

PROGRAM SCORES (INPUT,OUTPUT,TAPES=INPUT,TAPES=OUTPUT,TAPE10)
(CONTINUED)

C-07 PERFORM CALCULATIONS AT EACH FREQUENCY
CALL ALINT
CALL COFFF
CALL EXCITE
CALL MOTION
IF ( I1.LT.7 ) GO TO 80
CALL REMDSH
GO CONTINUE

C-08 PRINT OUT RESULTS FOR THIS SPEED AND WAVE ANGLE
CALL TNIRPA
IF ( I0.EQ.0 ) GO TO 90
FAC = ((1.0/(DISPL*BPL)-1.0)*I1+1.0)**2
CALL STATI
90 CONTINUE
IF ( IF.LT.1 ) GO TO 100
CALL SPREAD

C-09 INCREMENT SHIP SPEED
100 V = V*DFLV
IF ( V.LT.VMAX .AND. VMIN.LE.VMAX ) GO TO 60
GO TO 50

920 FORMAT ( 1M1, 13A6, A2, 3E, A10, A2 )
921 FORMAT ( 9MSPEED = , F8.4, 6X, 13H WAVE ANGLE = ,
X F7.2, 21H DEG., MOMENT RESULTS )
923 FORMAT ( 1M0, 21E, 56H VERTICAL BEND, MT., LATERAL BEND, MT., TOPS
XIONAL MOMENT / 22M WAVE FREQ. STATION , 31ZOHAMPLITUDE PHASE
X ) /
924 FORMAT ( 1M0, 66X, 17H (NON-DIMENSIONAL) )
END

```

SUBROUTINE PRELIM

```

COMMON / CONDA / PI,GAHMA,GRAV,RO
COMMON / MMDT / MDA(14),DTA,DTB,IB,IC,ID,IE,IF,IG,IM,II,IJ,STS(5)
COMMON / BASDA / SPL,DISPL,THASS,YMERT,BSTAR(21),ARPA(21),
X SECOC(21),DRAFT(21),ZBAR(21),XI(21),XISO(21),
X DWEIGH(21),DMASS(21),ZWT(21),BRL(21),ZCB,XMERT,
X ZPERT,GM,MINKRI,MAXKRI,INCRS,ROLDPP
COMMON / MIMD / IA,NG,DXI,V,WANG,OMEGA,WAVEN,CM,DXI(21),S1,FAC,WA
COMMON / PROGRAM / STORAGE(436),V(21),STA(21),W(21)
PI = 3.1415926
IX = 0

```

C-01 READ (AND PROCESS) BASIC INPUT DATA

```

1 READ 901,MDA
2 READ 902, IA,IB,IC,ID,IE,IF,IG,IM,II,IJ,M
M = 4-IA
IF (M.GT.2) GO TO 961
M5 = M
DO 2 I=1,M
3 STAI(I) = I-0.50*(1.0-IA)
4 READ 903, SPL,GAHMA,GRAV,DISPL
5 READ 904, (BSTAR(I),SECOC(I),DRAFT(I),ZBAR(I)),I=1,M)
IF (ZBAR(21).GT.0.0 .OR. IE.LT.1) GO TO 4
DO 3 I=1,M
A = (1.0-2.0*SECOC(I))/A.0
IF (A .GT. 0.00) A = 0.00
3 ZBAR(I) = DRAFT(I)*A
4 IF (IE.LT.1) GO TO 12
5 READ 905, ZCB,RADRO
12 IF (TRAY.0) GO TO 10
6 READ 906, RADGRV,CBL
GO TO 11
10 READ 904, (DWEIGH(I),ZWT(I),BRL(I),A),I=1,M)
IF (BRL(21).GT.0.0 .OR. IF.LT.1) GO TO 11
DO A I=1,M
A BRL(I) = RADRO
11 READ 906, MINKRI,MAXKRI,INCRS

```

C-02 PRELIMINARY CALCULATIONS UPON BASIC INPUT DATA

```

RO = GAHMA/GRAV
DXI = SPL/M
IF (IB.GT.0) GO TO 13
THASS = DISPL/GRAV
XI(1) = (IB-IA)*DXI/2.0-CBL
YMERT = THASS*RADGRV+RADRO
GO TO 17
13 DO IA I=1,M
IF (IC.GT.0) GO TO 14
DWEIGH(I) = DWEIGH(I)*GRAV
14 DMASK(I) = DWEIGH(I)/(GRAV*DXI)
IF (IA.EQ.0) GO TO 15
IF (I.EQ.1) DMASS(1) = DMASK(1)*2.0
IF (I.EQ.M) DMASS(M) = DMASK(M)*2.0
15 V(I) = DMASK(I)*I-1
16 W(I) = DMASK(I)*ZWT(I)
THASS = SINT(IA,M,DMASS,DXI)
MISPL = THASS*GRAV
XI(1) = SINT(IA,M,Y,DXI)*DXI/THASS
CBL = (MPL-(1-IA)*DXI)/2.0-XI(1)
IF (IE.LT.1) GO TO 17
M5 = SINT(IA,M,W,DXI)
17 XMERT = THASS*RADRO+RADRO
DO 18 I=1,M
AREA(I) = BSTAR(I)*DRAFT(I)*SECOC(I)
V(I) = AREA(I)*I-1
W(I) = BSTAR(I)*3/2.0-AREA(I)*ZBAR(I)
F(I) = XI(I)*DXI*(I-1)
18 XISO(I) = XI(I)*XI(I)
CDIS = SINT(IA,M,AREA,DXI)*GAHMA
CPL = SINT(IA,M,Y,DXI)*DXI*GAHMA/CDIS*(SPL-(1-IA)*DXI)/2.0
IF (IE.GT.0) GM = SINT(IA,M,W,DXI)*GAHMA/CDIS-ZCB
ZPERT = 0.0
IF (IG.EQ.0) GO TO 20

```

C-03 CALCULATE LONGITUDINAL MASS MOMENT OF INERTIA

```

DO 19 I=1,M
19 V(I) = DMASK(I)*XISO(I)
YMERT = SINT(IA,M,Y,DXI)
RADGRV = SQRT(YMERT/THASS)
IF (IE.LT.1) GO TO 20
ZMTC = W5/THASS
DO 22 I=1,M
ZWT(I) = ZWT(I)-ZMTC
22 W(I) = DMASK(I)*ZWT(I)*XI(I)
ZPERT = SINT(IA,M,W,DXI)

```

C-04 PRINT OUT BASIC DATA (INCLUDING RESULTS OF PROCESSING)

```

20 PRINT 970,MDA,DTA,DTB
PRINT 802, IA,IB,IC,ID,IE,IF,IG,IM,II,IJ,M
PRINT 810
PRINT 803, SPL,GAHMA,DISPL,GRAV
PRINT 804, (BSTAR(I), BSTAR(I),SECOC(I),DRAFT(I),ZBAR(I),DWEIGH(I),
X ZWT(I),BRL(I)),I=1,M)
IF (IB.EQ.0) PRINT 806, CBL,RADGRV
IF (IE.GT.0) PRINT 805, ZCB,RADRO
IF (IG.EQ.0 .AND. MINKRI.EQ.MAXKRI) PRINT 807, MINKRI
PRINT 833
IF (IB.GT.0) PRINT 809, MISPL
PRINT 810, CBL,CDIS
IF (IB.GT.0) PRINT 808, CBL,RADGRV
IF (IE.GT.0) PRINT 808, GM

```

C-05 CHECK WTS. VOLUME, L.C.B. AGAINST DISPLACEMENT, L.C.B.

```

IF (IB.GT.0) GO TO 21
IF (ABS(MISPL-DISPL)/DISPL .GT. 0.02) GO TO 940
21 IF (ABS(CDIS-DISPL)/DISPL .GT. 0.02) GO TO 940
DISPL = CDIS
IF (ABS(CBL-CAL)/SPL .GT. 0.005) GO TO 940
RETURN

```

C-06 PARAD STOPS

```

940 TX = IX-1
940 IX = IX+1
950 IX = IX-1
951 PRINT 940, IX
STOP

```

```

902 FORMAT ( 25HCHOPTION CONTROL TABS = A B C D E F G H I J /
X 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 )
903 FORMAT ( 9HLENGTH = F10.2, 5X, 9HDENSITY = F11.4 /
X 5X, 9HDISPL. = F10.2, 4X, 9HGRAVITY = F11.6 )
904 FORMAT ( 7HSTATION BEAM AREA COEF. DRAFT Z-BAR WFI
X ZETA
X ZETA GRAV.ROLL / ( F7.2, 4F10.4, F12.4, 2F10.4 ) )
905 FORMAT ( 5H000 = F9.3, 5X, 15HGRADIUS,ROLL = F9.3 )
906 FORMAT ( 13H0LQW, C.B. = F8.3,40M (FWD. OF MIDSHIPS) LONG. 0
X VERTICUS = F9.3 )
907 FORMAT ( 48X, 24HCALCULATE MOMENTS AT STATION = I3 )
908 FORMAT ( 1M = F4X, 40M = F9.3 )
909 FORMAT ( 48X, 15HDISPL.(WTS.) = F10.2 )
910 FORMAT ( 13H0LQW, C.B. = F8.3,40M (FWD. OF MIDSHIPS) DISPL
X (VOLUME) = F10.2 )
930 FORMAT ( 17H0BASIC INPUT DATA )
933 FORMAT ( 14H0DERIVED RESULTS )
901 FORMAT ( 13A6, A2 )
902 FORMAT ( 11I2 )
903 FORMAT ( 10X, 3F10.5, F10.3 )
904 FORMAT ( 4F10.4 )
905 FORMAT ( 3I10 )
920 FORMAT ( 1M, 13A6, A2, 3X, A10, A2 )
940 FORMAT ( 39HSTOP IN SUBROUTINE PRELIM. ERROR NO. = I3 )
END

```

SUBROUTINE PRELIMC

```

COMMON / CONDA / PI,GAHMA,GRAV,RO
COMMON / MMDT / MDA(14),DTA,DTB,IB,IC,ID,IE,IF,IG,IM,II,IJ,STS(5)
COMMON / BASDA / SPL,DISPL,THASS,YMERT,BSTAR(21),ARPA(21),
X SECOC(21),DRAFT(21),ZBAR(21),XI(21),XISO(21),
X DWEIGH(21),DMASS(21),ZWT(21),BRL(21),ZCB,XMERT,
X ZPERT,GM,MINKRI,MAXKRI,INCRS,ROLDPP
COMMON / CASDA / NW,OW(51),VVL(51),OWE(51),VMIN,VMAX,DELV,
X WVA,WD(25),WAVEI,WANBA,OWANG,OWW,WD(21),VLL(51)
COMMON / MIMD / IA,NG,DXI,V,WANG,OMEGA,WAVEN,CM,DXI(21),S1,FAC,WA
COMMON / TDP / M,SBM(21),SBBB(21),NF,ONT(25)
COMMON / / TOP(21,25,10)
COMMON / PROGRAM / STORAGE(436),RSA(10),MOC(5)
DATA NF / 25 /
DATA ONT / 0.0, 0.01, 0.02, 0.06, 0.10, 0.15, 0.21, 0.28, 0.36,
X 0.45, 0.55, 0.67, 0.82, 1.01, 1.25, 1.55, 1.95, 2.45,
X 3.05, 3.8, 4.7, 5.8, 7.1, 8.7, 10.7 /

```

C-01 READ AND PRINT CONDITIONAL INPUT DATA CARDS

```

20 READ 907, WA,SVL,BVL,DELWL,VMIN,VMAX,DELV
IF (WA.CE.0) GO TO 27
27 PRINT 970,MDA,DTA,DTB
PRINT 832
PRINT 907, WA,SVL,BVL,DELWL,VMIN,VMAX,DELV
IF (IE.LT.1) GO TO 28
READ 907, ROLOPP
PRINT 907, ROLOPP
28 READ 907, WANBI,WANBA,DUANG
PRINT 907, WANBI,WANBA,DUANG
IF (ID.LT.1) GO TO 25
READ 908, NWI,(ND(I),I=1,10)

```

```

PRINT 909, NU1, (ND(I):I=1:10)
IF ( ID,NE.3 ) GO TO 25
READ 909, (ND(I):I=1:20)
PRINT 909, (ND(I):I=1:20)

C-03 INPUT DATA ERROR CHECK
25 IX = 0
IF ( MINKRI,NE,MAXKRI .AND, INCRES,LE,0 ) IX = 3
IF ( SWL,NE,BWL .AND, DELWL,LE,0.0 ) IX = 3
IF ( VMIN,NE,VMAX .AND, DELV,LE,0.0 ) IX = 3
IF ( WANG1,NE,WANG2 .AND, DWANG,LE,0.0 ) IX = 3
IF ( I,NE,0 ) GO TO 950

C-05 INITIALIZE (AND CHECK) INTERNAL PARAMETERS
M = 45
DET = 1.0
DDT = 1.0
IF ( NU1,GT,10 ) GO TO 951
NW = (RWL-SWL)/DELWL-1.001
IF ( NW,GT,51 ) GO TO 951
IF ( ID,LT,1 ) GO TO 30

C-06 PRELIMINARY CALCULATIONS FOR IRREGULAR WAVES
ND 22 I=1:NN
22 (NW(I)) = SWL*DELWL*(I-1)
CALL PAR
IF ( I,LT,1 ) GO TO 32
K = 80.001/DWANG
IF ( K,LT,2 ) K = 2
IF ( K,GT,12 ) K = 12
DWANG = 80.0/K
WANG1 = 180.0
IF ( WANG1-WANG2 .EQ, 0.0 ) GO TO 23
WANG1 = 0.0
GO TO 32
23 WANG1 = 90.0
GO TO 32

C-07 PRELIMINARY CALCULATIONS FOR REGULAR WAVES
30 ND 31 I=1:NN
31 (NW(I)) = SQRT(2.0*PI*GRAV/(SWL*DELWL*(I-1)))
32 WWA = (WANG1-WANG2)/DWANG*1.001
IF ( WWA,GT,25 ) GO TO 951
ND 31 I=1:NN
WAD(I) = WANG1-WANG2*(I-1)
33 CONTINUE

C-09 CALCULATE TWO-DIMENSIONAL SECTION PROPERTIES
AND CONVERT TO DIMENSIONAL RESULTS
40 IF ( ID,GT,0 ) GO TO 50
CALL CLEV
IF ( IE,GT,1 ) GO TO 42

C-10 VERTICAL OSCILLATIONS
CALL ZIRSHO (DET)
F2 = PI*RO/R,0
ND 44 J=1:M
FAC = F2*NSTAN(J)**2
ND 45 I=1:NF
45 TOP(J,I,1) = TOP(J,I,1)*FAC
IF ( IE,LT,1 ) GO TO 43

C-11 LATPVAL AND ROLLING OSCILLATIONS
42 CALL TOLR (DDT)
ND 44 J=1:M
ORNA = CONTINSTAR(J)/(2.0*ORAV)
IF ( RROD,LE,0.0 ) GO TO 46
RSA(I) = R0*WAD(I)
RSA(4) = RSA(3)/PROG
RSA(8) = RSA(3)*NSTAN(J)
RSA(16) = RSA(5)/RBOO
RSA(17) = RSA(5)*NSTAN(J)
RSA(18) = RSA(7)/RBOO
RSA(19) = RSA(5)
RSA(10) = RSA(4)
ND 44 I=1:NF
ND 44 K=1:10
44 TOP(J,I,K) = TOP(J,I,K)*RSA(K)
44 CONTINUE

C-12 WRITE TOP ARRAY ON FILE (TAPE10)
43 WRITE (17) (ND(I):I=1:5)
WRITE (18) ((TOP(J,I,K),J=1:M,I=1:NF),K=1:10)
IF ( OFF,EG,0.0,OR,DDT,EG,0.0 ) IX = 4

C-13 PRINT OUT TWO-DIMENSIONAL SECTION PROPERTIES
47 PRINT 907
ND 49 J=1:M
47A = J-0.5*(I+1A)

```

```

PRINT 909, K/T
48 PRINT 909, (NY(I):TOP(J,I,K),K=2:10)
K = (NY(I):TOP(J,I,K),K=1:10),J=2:NF)
GO TO 51

C-08 READ TOP ARRAY FROM FILE (TAPE10)
50 IF ( ID,GT,2 ) GO TO 51
READ (10) (MDC(I):I=1:5)
DO 49 I=1:5
IF ( MDC(I),NE,MDA(I) ) GO TO 949
52 CONTINUE
READ (10) ((TOP(J,I,K),J=1:M,I=1:NF),K=1:10)
IF ( ID,EG,1 ) GO TO 47
51 IA = 3
IF ( IX,NE,0 ) GO TO 950
PRINT 908

C-07 NO BACK FOR NEW BASIC INPUT DATA
1 CALL PRELIMR
GO TO 20

C-04 ERROR STOPS
940 IX = 5
450 IX = IX-1
951 PRINT 940, IX
IF ( IX,EG,6 ) PRINT 941, MDC
80 STOP

932 FORMAT ( /3#CONDITIONAL INPUT DATA CARD PRINT OUT /)
907 FORMAT ( 8F10.4)
908 FORMAT ( 110, 10F5.1 )
909 FORMAT ( 10X, 10F5.1 )
920 FORMAT ( 1M1, 13A9, A2, 3A, A10, A2)
940 FORMAT ( 3#MOSTP IN SUBROUTINE PRELIMR, ERROR NO. , I3)
941 FORMAT ( 15#TOP FILE LABEL , 5X, 5A6)
907 FORMAT ( 1M0,12#3#4#TWO-DIMENSIONAL SECTION PROPERTIES /AX+SHFREQ,
X/AX,12#PARAM, A-PRIME(33) A(BAR)50, M-SUB(5) N-SUB(5)
X(4,P(I)) W(5,P(I)) I-SUR(I) N-SUB(I) F-SUR(R,5) N-SUB(R,
X) )
908 FORMAT ( 4# STA , F5.1 )
909 FORMAT ( F10.4, 12# INFINITY , 9E12.4 / F10.4, 10E12.4 )
END

SUBROUTINE PAR
COMMON / CONDA / PI,GAHNA,GRAV,RO
COMMON / MMDT / MDA(14),DTA,DTR,IR,IC,ID,IE,IF,IG,IM,II,IJ,ISTS(5)
COMMON / CASOA / NW,OMH(51),WVL(51),OMNE(51),VMI,WMAI,DELV
X
COMMON / STAT / SPECH(10,51),WSD(8,10,25)
COMMON / PROGRAM / STORAGE(308),V(S1),MVST(10,5)
DIMENSION SPC(17)
DATA SPC/OMNEUMAN,OMN (105,6#3) (MA,OMLF) ,
X
OMPI,RSO,OMN,MOSSK,OMDITZ,OM(196#),
Y
AMTOD PA,BHRAHETE,6MR, ISS,6HC 1967/
Y
RSDIAR = GRAV*ORAV
COMET = 0.000877*63QUAR**0.5

C-01 CALCULATE WAVE SPECTRAL DENSITY AT EACH FREQUENCY
ND 40 K=1:NN
VOITH = OMH(K)*OMH(K)
OMSQ = OMH(K)*VOITH*VOITH

C-02 LOOP OVER WIND SPEED (OR SEA STATE) RANGE
DO 40 J=1:NU1
I = ND(I)*1.8888889
ND TO ( 10, 20, 30 ) , IO

C-3-4 NEUMANN SPECTRUM (1953) (HALF) SO THAT SIG. = 2 TIMES R.4+S.1
10 POWFR = (-2.0*OSQUAR/(VOITH*OMU))
SPECM(I,K) = (CONSTEXP(POWFR))/(OMSQ*OMH(K))
ND TO 40

C-3-4 PIETRON-MOSKOWITZ SPECTRUM (1966) FOR FULLY RISEN SEAS
20 POWFR = -.7*PIOSQUAR/(U*VOITH)**2
SPECM(I,K) = .COB1*OSQUAR*EXP(POWFR)/OMSQ
ND TO 40

C-3-4 TWO PARAMETER SPECTRUM, BASED ON SIGNIFICANT WAVE HEIGHT AND MEAN
WAVE PERIOD, SIMILAR TO I.S.S.C. NOMINAL (1967)
30 AA = 0.350*ND(I)*ND(I)
K = 1007
RR = (0.817*OD,0*PI/ND(K))**4
POWFR = -OB/(VOITH*VOITH)
SPECM(I,K) = AA*OB*EXP(POWFR)/OMSQ

40 CONTINUE
90 CONTINUE

```

```

C-05 INTEGRATE WAVE SPECTRA TO OBTAIN WAVE AMPLITUDE STATISTICS
NEL = OMW(3)+OMW(2)
DO AN K=1,NW1
DO SS L=1,NM
55 Y(L)=SPECM(K,L)
WVST(K,1) = SINT(Y(L),NM,Y+DEL)
WVST(K,2) = SORT(WVST(K,1))
WVST(K,3) = WVST(K,2)+1.2249
WVST(K,4) = WVST(K,2)+2.0
WVST(K,5) = WVST(K,2)+2.3482
60 CONTINUE

C-06 PRINT OUT WAVE SPECTRA AND AMPLITUDE STATISTICS
PRINT 920,MDA,DTA,DTB
ISS=ISS+1
IST=IST+3
PRINT 101, (SPC(I),I=ISS,ISS+1)
IF (ID.LT.3) PRINT 100, (WV(X),K=1,NW1)
IF (ID.LT.3) GO TO 51
PRINT 105, (WV(K),K=1,NW1)
I = 10*WV1
PRINT 106, (WV(X),K=1,NW1)
51 PRINT 107, (I,I=1,NW1)
PRINT 108
DO 99 I=1,NM
PRINT 102, (WV(I), (SPECM(K,I),K=1,NW1))
99 CONTINUE
PRINT 100
DO AN K=1,5
65 PRINT 103, STS(K), (WVST(L,K),L=1,NW1)
RETURN

100 FORMAT ( 1M )
101 FORMAT ( 1M,DT,23H WAVE SPECTRAL DENSITY, 4A6,8M SPECTRA )
102 FORMAT ( 1P12,3 )
103 FORMAT ( 6X, A6, 10P12,7 )
104 FORMAT ( 17X, 2A6P0R WAVE SPEEDS (KNOTS) OF / 12X, 10P12,3 )
105 FORMAT ( 9X, 7M10,MT, 4P8,3, 4P12,3 )
106 FORMAT ( 8X, 7M10,PER, 4P8,3, 4P12,3 )
107 FORMAT ( 14M SPECTRA NO. / 10, 9I12 )
108 FORMAT ( 13M WAVE PNO. )
920 FORMAT ( 1M, 17A6, A2, 3X, A10, A2 )
END

SUBROUTINE POLD
COMMON / CONDA / PI,66MMA,BRAY,RO
COMMON / BASDA / RPL,DISPL,THASS,THERT,BSTAR(21),ARPA(21),
X SECOE(21),DRAFT(21),ZBAR(21),XI(21),XISG(21),
X DUEIGM(21),DMASS(21),ZWT(21),BRL(21),ZCB,KNERT,
X ZPERT,GM,INWRI,MARKRI,INCRES,ROLNPP
COMMON / TDJH / WU,WHEN,ANS(21),KL,KU,IO,IM
COMMON / NIMO / I,ANS,DI1,V,WANB,OMEGA,WAVEN,CW,DIX(21,5),FACI,VA
COMMON / PROGRAM / STORAGE(167),V(21),W(21)

C-01 INITIALIZE PARAMETERS REQUIRED
NL = 7
NI = 8
WE = 0.5
WAI = 0.0

C-02 CALCULATE NATURAL ROLL FREQUENCY, INCLUDING ADDED INERTIA
2 WFX = WF
WF = SORT(DISPL*GM/(INERT+R1))
IF (ABS(WFX-NL-1.0) .LT. 0.01) GO TO 8
WEN = WFX/GWAV
CALL ALINT
DO 4 I=1,N5
V(I) = ANS(I,7)
W(I) = ANS(I,8)
WAI = SINT(I,AN,WDRI)
WAI = SINT(I,AN,WDRI)
DO TO 2

C-03 CALCULATE ADDITIONAL ROLL DAMPING
10 ROLNPP = 2.4*HOLNPP*DISPL*GM/WF -RMD
PRINT 50, WFX,WEN,ROLNPP
PRINT 50

** FORMAT ( //13X, 25HNATURAL ROLL FREQUENCY = .F10,4/ 4F, 3ANCALCU
X LATED WAVE DAMPING IN ROLL = .E14,4/ 3M ADDITIONAL VISCOUS DAMP
ING IN ROLL = .F14,4 )
END

```

```

FUNCTION SINT (INTN,J,Y,DXI)
C INTEGRATE THE FUNCTION Y(I), WHICH IS TABULATED FOR J POINTS AT
C FOUR-DISTANT INTERVALS OF DXI
C IF INTO = 0, USE SIMPLE SUMMATION TIMES DXI
C IF INTO = 1, USE TRAPEZOIDAL RULE

DIMENSION Y(1)
SUMA = 0.0
DO 10 I=1,J
SUMA = SUMA+Y(I)
IF ( INTO .EQ. 1 ) SUMA = SUMA-.Y(I)+Y(J))/2.0
INT = INT*SUMA
RETURN
END

SUBROUTINE CKLEW
COMMON / CONDA / PI,66MMA,BRAY,RO
COMMON / BASDA / RPL,DISPL,THASS,THERT,BSTAR(21),ARPA(21),
X SECOE(21),DRAFT(21),ZBAR(21),XI(21),XISG(21),
X DUEIGM(21),DMASS(21),ZWT(21),BRL(21),ZCB,KNERT,
X ZPERT,GM,INWRI,MARKRI,INCRES,ROLNPP
COMMON / TDJH / WU,WHEN,ANS(21),KL,KU,IO,IM
COMMON / NIMO / I,ANS,DI1,V,WANB,OMEGA,WAVEN,CW,DIX(21,5),FACI,VA
DATA ER1, ERD / 7MIN, 2HDE /
PIAR = PI*3.0/32.0

C-01 CHECK SECTION PARAMETERS AGAINST LEWIS FORM CRITERION
DO 1 I=1,M
SARR(I) = SECOE(I)
IF (DRAFT(I) .LE. 0.0) GO TO 11
SARR(I) = BSTAR(I) / (2.0*DRAFT(I))
IF (SARR(I) .LT. 0.0) GO TO 11
IF (SARR(I) .GT. 1.0) SARR(I) = 1.0

C-02 ZERO SECTION
11 SARR(I) = 0.0
DO TO 1

2 IF (SARR(I) .GE. PIAR*(2.0-SARR(I))) GO TO 9
SARR(I) = PIAR*(2.0-SARR(I))
GO TO 7
3 IF (SARR(I) .GE. PIAR*(2.0-1.0/SARR(I))) GO TO 5
SARR(I) = PIAR*(2.0-1.0/SARR(I))
7 PRINT 20, I, ER1, SECOE(I), SARR(I)
DO TO 1

5 IF (SARR(I) .LE. PI*(SARR(I)+1.0/SARR(I)+10.0)/32.0) GO TO 1
SARR(I) = PI*(SARR(I)+1.0/SARR(I)+10.0)/32.0
PRINT 20, I, ERD, SECOE(I), SARR(I)

1 CONTINUE
OPTION

20 FORMAT (4M SECTION I, 4M NOT VALID LEWIS FORM, SECTION AREA COEF
IF, 4E2, 12HCREASED FROM, F7, 4, 3M TO, F7, 4, 21H FOR T, 0, PROP. CALC.)
END

SUBROUTINE ZIPSMD (DET)
COMMON / TDJH / WU,WHEN,ANS(21),KL,KU,IO,IM
COMMON / NIMO / I,ANS,DI1,V,WANB,OMEGA,WAVEN,CW,DIX(21,5),FACI,VA
COMMON / PROGRAM / STORAGE(167), V(21), W(21)
C(11) = S(11), COP(11), SIP(11), SIK(4,5), SIKJ(4,4),
X SC(11), SPB(11), SOB(11), SSA(11), SPA(11), SNA(11),
X EPA(5,5), ZOA(5), EPB(5), B(10,11), EPK(5), POK(5)
DET = 1.0

C-01 SET UP TRIGONOMETRIC FUNCTIONS
DO 1 I=1,11
X(I) = 1
C(11) = COS(XI*0.147078)
S(11) = SIN(XI*0.147078)
COP(11) = COS(XI*0.471234)
SIP(11) = SIN(XI*0.471234)
DO 2 K=1,4
AK = K*2
AK = AK*0.157078
DO 3 J=1,5
A(I,J) = 1
4 S(I,K,J) = SIN(AK * (2.0*AI+1.0))
DO 7 J=1,4
S(J) = 1
END

```

```

7 SIK(JK,J)=SINI AK *2.0*AJ
2 CONTINUE

C-02 LOOP OVER NUMBER OF STATIONS
DO 100 K1=1,N5
IF (K1.EQ.1) GO TO 85

C-03 CHECK FOR CONSTANT SECTION PARAMETERS
KK = K1-1
IF (SBB(K1).NE.SBB(KK)) GO TO 85
IF (SBH(K1).NE.SBH(KK)) GO TO 85
NO AN IF 01*W
YDP(I1;F,1) = YDP(KK;F,1)
80 YDP(I1;F,2) = YDP(KK;F,2)
NO YN 1005

C-04 CHECK FOR ZERO SECTION
85 IF (SBB(K1).LF.0.0 .OR. SBH(K1).LE.0.0) GO TO 8A

SAM=3.14159*(SBB(K1)+.0-3.14159)*SBH(K1)/
1/(SBH(K1)-1.0)*(SBH(K1)+1.0)
X100=95103-1.<7070PSAN
IF (SVA) 11=12.12
11 WRITE (6,120) K1
120 FORMAT('7TH IN CORRECT PARAMETERS. ZIPSHO QUIT'S FOR STATION ',I3)
DET = 0.0
NO TO 1005

12 X12=9.35419+SQRT(SVA)
SAB=(SBH(K1)-1.0)/(SBH(K1)+1.0)+SAZ/SAN
SAB=SAZ/SAN-1.0
SAA=SA+SA-3.0=SB
SAAA=SA+SAA-3.0=SA+SB
S4Z=(1.0+SA)*0.33333+0.8667*SA+0.8267*SAA+0.8187*SAAA
S4V=0.0SB+0.2-0.1428*SA-0.8374*SAA+0.8187*SAAA
S4W=(1.0+SA)*0.8667+0.8267*SA+0.8187*SAA-0.0458
14(0.8266+0.8374*SA+0.8187*SAA)
S4J=(1.0+SA)*0.8267+0.8187*SA-0.0458(0.8374+0.8187*SA)
S4A=(1.0+SA)*0.8187+0.8267*SA+0.8187

C-05 LOOP OVER FREQUENCY RANGE
88 NO 1004 IF=1*W
SFRPA = ONT(IF)*SBH(K1)
IF (SFRPA .GT. 0.0) GO TO 3
SA = 0.0
KC = 8.0
NO TN 1003

3 QU=SPRZ /((1.0+SA+SB)
SF1 = SAZ-6.78544*W*(1.0+SA)
SF2 = SAN-0.78544*W*SB
S50=3.14159*SIN(SFRPA)
NO 15 10111
81=11
IX = SW*((1.0+SA)*CO(I)-SF*CO(I))
YV = SW*((1.0+SA)*SI(I)-SB*SIP(I))
FV=EXP(-VY)
CX=CSIKK
SIX=SI(KK)
S5R(1)=3.14159*SI*E*W
S5B(1)=3.14159*E*W
S5D(1)=S5R(1)-S5B(1)*(1.0+SI*0.1)
R5=OSORT(XI*IX+VY*YV)
8R1 = 8A
IF (ABS(VY) .GT. 1E-5) GO TO 13
NO 15 1008
NO TO 16
13 RC=ASIN(XX/8A)
14 RD=0
CORC=COS(BC)
CORC=CORCZ
SIBC=SIM(BC)
SIBC=SIBCF
IF (RA .GT. 6.0) GO TO 17
AMM = 2.8
20 RD=SD+SB1+CORCZ
RE=0-CORC+SIBC
RB1=SB1+BA*(AMM-1.0)/(AMM+AMM)
CORC1=CORC2+CORC-SIBC+SIBC
SIBC1=SIBC2+CORC-SIBC+CORCZ
CORC=CORC1
AMM=AMM+1.0
IF (RB1) (-0.001+8A) 71=21+20
21 RD=1-SD-ALON(1.781+8A)*E*W
RE=1-RE-BC1+E*W
BA=RD+CI-SE+SIX
8B=RD+CI+SD+SIX
NO TN 1008
17 RB1=1.0/8B1
NO 22 10115

```

```

AMM=AMM
RD=RD-CORC2+8A1
RE=RE-SIBC+8A1
8B1=8B1+AMM/8A
CORC1=CORC2+CORC-SIBC+SIBC
SIBC1=SIBC2+CORC-SIBC+CORCZ
CORC=CORC1

22 CONTINUE
8A=RD-3.1415926535*E*W*SIX
8B=RE-3.1415926535*E*W*CI
1000 S5A(I)=8B
S5A(I)=8A
15 CONTINUE
S5A0=S5A(1)
SFP1=0
SFO1=0
SQ=-0.05234
NO 25 10211
AT01
SQA(I)=S5A(1)-S4A0*(1.0-(AT-1.0)/10.0)
SQ=SQ
SFM=(1.0+SA)*S(I)+3.0*SB*SIP(I)*(C.157078-50)
SFO1=SFO1+SFP(I)*SFM
SFP1=SFP1+SFA(I)*SFM

25 CONTINUE
SFO1=SFO1-0.5*8B(11)*SFM
SFP1=SFP1-0.5*8B(11)*SFM
SFA(1)=S5A0
SFA(1)=S580
NO 27 K=1,4
KK=K-1
S1=8B
S2=8A
S3=8B
NO 28 J=1,5
ISIM=2*J
S1=8A+SDA(SUR)*SI(K,K,J)
S1=8B+SDA(SUR)*SIP(K,K,J)
2A CONTINUE
NO 29 J=1,4
IS1=2*J+1
S2=8B(SUR)*SI(K,K,J)
S2=8A(SUR)*SIP(K,K,J)
2B CONTINUE
SFA(KK) = (.26447+8B+0.133333+8B
21 SFA(KK,1)=0.26447+8A+0.133333+8A
SFA(1,2)=0.5W
SFA(2,2)=1.0+0.21221*8B
SFA(3,2)=1.0+0.02122*8B
SFA(4,2)=SAA-0.00606*8B
SFA(5,2)=SAAA-0.00253*8B
SFA(1,3)=0.33333*8B
SFA(2,3)=0.38107*8B
SFA(3,3)=1.0+0.13662*8B
SFA(4,3)=1.0+0.03388*8B
SFA(5,3)=SAA-0.00848*8B
SFA(1,4)=0.20*8B
SFA(2,4)=0.15144*8B
SFA(3,4)=0.1746*8B
SFA(4,4)=1.0+0.00666*8B
SFA(5,4)=SAA-0.02940*8B
SFA(1,5)=0.14228*8B
SFA(2,5)=0.00903*8B
SFA(3,5)=0.0674*8B
SFA(4,5)=0.11427*8B
SFA(5,5)=1.0+0.07428*8B
SFR(1)=1.0+SA+SB
SFR(2)=0.63662*(0.33333*(1.0+SA)-1.80*SB)
SFR(3)=0.31831*(0.06667+0.06667*SA+1.29571*SB)
SFR(4)=0.63662*(0.00952+0.00952*SA+0.11111*SB)
SFR(5)=0.31831*(0.00793+0.00793*SA+0.08182*SB)
NO 100 1015
NO 101 J=1,5
101 R1(I,J) = EPA(I,J)
R1(I,6) = EPA(I)
NO 107 J=7,10
107 R1(I,J) = -R1(J)
100 R1(I,11) = FPM(I)
NO 105 10010
1 = I-4
M(I,1) = EQA(I,J)
NO 104 J=2,4
104 R1(I,J) = 0.0
NO 104 10010
22 = J-4
104 R1(I,J) = EPA(I,J,J)
105 R1(I,11) = 0.0

```



```

C-06 CALL MATPAC
CALL MATPAC
IF (NOT.EQ.(0)) DET = 0.0
DO 34 I=1,5
  PFI(I) = B1(1,I)
  PFI(I) = B1(1,5,I)
  35 PFI(I) = B1(1,5,I)
  4PP=PP1(1)+SPFI-EOK(1)+SPFI-EOK(2)+SPFI-EOK(3)+SPFI
  1-EOK(4)+SPFI-EOK(5)+SPFI
  4C=CF/(A1*TSB*(1.0+SA*SB)+1.0+SA*SB)
  5A=1.414*0.5=C*ORT(EOK(1)+EOK(2)+EOK(3)+EOK(4))
C-07 4TORP RESULTS IN TDP ARRAY
1003 TDP(1,1:5) = SC
1004 TDP(1,1:5) = SAR+SAR
1009 CONTINUE
RETURN
END

SUBROUTINE MATPAC

COMMON / PROGRAM / STORAGE(10), DET,SPACE(10),A1(0:1),SPACK(10)
DET=1.

DO 4 J=1,9
  C=AK(A(J,J))
  J=J+1
DO 5 I=J,10
  D=AK(A(I,J))
  IF(C-D) S=S+D
  6 DET=DET
  DO 7 K=J,11
    R=AK(I,K)
    A(I,K)=AK(I,K)
  7 A(J,K)=D
  C=D
  8 CONTINUE
  IF(A(S,A(J,J))) ZU=ZU+15
  14 DO 4 I=J,10
    C=AK(A(I,J)/A(J,J))
    DO 4 K=J,11
      4 A(I,K)=A(I,K)-CONSTRA(J,K)
      IF(A(S,A(10,10))) ZU=ZU+18
  10 DO 12 I=1,10
    K = I-1
    KP1=K+1
    DO 13 J=KP1,10
      13 R=AK(K,J)/AK(J,1)
      12 A(K,I) = (A(K,I)-S)/AK(K,K)
  22 RETURN

C-01 PRINT WARNING MESSAGE
20 WRITE (A,30)
DET = 0
DO TO 22

30 FORMAT (3#XZERO DETERMINANT IN SUBR. MATPAC )
END

SUBROUTINE TOLR (DET)

C THIS SUBROUTINE PERFORMS THE CALCULATION OF THE POTENTIAL THEORY
C ADDED MASS AND WAVE DAMPING PROPERTIES OF TWO-DIMENSIONAL LEWIS
C FORMS IN LATERAL AND ROLL MOTION MODES. THE METHOD EMPLOYED IS
C THAT OF FUKUZO TAJI, "HYDRODYNAMIC FORCE AND MOMENT PRODUCED BY
C HEAVING AND ROLLING OSCILLATION OF CYLINDERS ON THE FREE SURFACE",
C IN REPORTS OF RESEARCH INSTITUTE FOR APPLIED MECHANICS, KYUSHU
C UNIVERSITY, JAPAN, VOLUME IX, NUMBER 38, 1961.

C SEE ALSO REPORT BY J. M. VUOSTI, "THE HYDRODYNAMIC COEFFICIENTS FOR
C HEAVING, HEAVING AND ROLLING CYLINDERS IN A FREE SURFACE", REPORT
C NO. 194 (IN ENGLISH) OF LABORATORIUM VOOR SCHIEPBOUWKUNDE,
C TECHNISCHE HOOGESCHOOL DELFT, THE NETHERLANDS, JANUARY 1968.

C PPARIANI 1970 - OCEANICS, INC. - A. I. RAFF
C PROJECT NO. 1093 (SSC-ERC PROJECT SR-174)

C BASIC INPUT AND OUTPUT VARIABLES
C MO = HALF-BREADTH TO DRAFT RATIO
C AIB = SECTION AREA COEFFICIENT
C VIB = NON-DIMENSIONAL FREQUENCY PARAMETER (OMEGA-SQUARED OVER
C GRAVITY, TIMES HALF-BREADTH)
C P(1) = ADDED MASS AND DAMPING RESULTANT ARRAY IN NON-DIMENSIONAL
C FORM ( AS IN VUOSTI, ABOVE )

```

```

C M = NO. OF TERMS IN P AND Q (POLYNOMIAL) SERIES (SET = 9)
C N = NO. OF POINTS ON CONTOUR FOR LEAST SQUARE FIT (SET = 15)
C N1 = NO. OF INTERVALS FOR X,SUB=0 AND X,SUB=N INTEGRATION (N1=N+1)

COMMON / TOR / NS,SBM(2),SBBB(2),NF,OLT(24)
COMMON / / TOP(2),S3(1)
COMMON / PROGRAM / STORAGE(10),A1(0:1),Y(16),Y1(16),R(8),S(0:10),
  COEFF1(16), COEFF2(16), SECT1( 9), SECT2( 9), PCO(16),
  P(0:10)+Z( 9)+Z1( 9)+RS(16)+VS(16)+P(0:0)
DIMENSION ERN(15)
DATA ERN /AMBERA:1, 6MVE CON, 6MTOUR ,
  6MILL-6E, 6MMAVED, 6MMATRIX,
  6M1 - 6, 6M3 CALC, 6M ERRDR,
  6MNEGATE, 6MVE FRE, 6MQUENCY,
  6MENERBT, 6M BAL., 6MERRON /
PI=3.1415927
DET = 1.0
TX = 0

C-01 LOOP OVER NUMBER OF STATIONS
DO 103 K1=1,NS
  MO = SBM(K1)
  910 = SBBB(K1)
  IF ( K1 .EQ. 1 ) GO TO 65

C-02 CHECK FOR CONSTANT SECTION PARAMETERS
  KK = K1-1
  IF ( SBBB(K1).NE.SBBB(KK) ) GO TO 65
  IF ( SBM(K1).NE.SBM(KK) ) GO TO 65
  DO RA IF=1,NF
  DO RB J=3,10
  80 TOP(1,1:5) = TOP(KK,1:5)
  GO TO 105

C-03 CHECK FOR ZERO SECTION
  85 IF ( S10-OT,0.0 .AND. MO,OT,0.0 ) GO TO 88
  DO RA IF=1,NF
  DO RB J=3,10
  86 TOP(1,1:5) = 0.
  GO TO 105

C-04 COMPUTE GEOMETRIC PARAMETERS A,SUB=1 AND A,SUB=3
  RA = 1.0+MO
  XR = XA+XA
  XC = 1.0-MO
  XN = XC+XC
  RR = RN/RN
  CC=1.4*PI*OH/(PI*RR)
  AA=CC-RR-3.
  RB=PI*(RR+CC)
  CC = CC-4.0*MO/XR
  43=(RR+SB*ORT(MO*RB+4.0*AA*CC))/(2.0*AA)
  A1 = -CC*(1.0+43)/XA
  A131=-A1+43
  AA17=A13*0.13
  TA3 = 3.0+43

C-05 CHECK THE RESULT
  IF (ABS(MO-A13)/(1.0-A1+43)) .GT. 10.E-6) GO TO 29
  IF (ABS(S10-OT*(1.0-A1+41-TA3*43))/(4.0*AA13)) .LT. 10.E-6)
  GO TO 30

C-06 PRINT RETURNES
  20 TX = 2
  90 IF ( TX=1 )
    PRINT 97, ERN(3*IX-2),ERN(3*IX-1),ERN(3*IX),MO,S10,X10
  DET = 0.0
  TX = 0
  DO TO 104

C-07 GET UP VARIOUS CONSTANT FACTORS
  30 N = 15
  N1 = N + 1
  PAC = N1
  PN = PI/(2.0*PAC)
  CC = PN/3.0
  MN = P
  M = 0
  MP = M+1
  CONST1 = -TA3*PI/4.0

C-08 CALCULATE FUNCTIONS OF THETA AROUND SECTION CONTOUR
  DO 98 I=1,N1
  PAC = 1
  99 = PN*PAC
  C5=COS(55)
  C7=COS(7.0*5)
  C9=COS(9.0*5)
  C11=COS(11.0*5)
  C13 = ((1.0+1.0*5-47*5T5)/413)
  Y0 = ((1.0-4.0*5+43*5T5)/A13)

```

```

IF (ABS(XO).LT.10.E-6) XO = 0.0
IF (ABS(YO).LT.10.E-6) YO = 0.0
IF (XO.LT. 0.0 .OR. YO.LT. 0.0) GO TO 90
X(I) = XO
Y(I) = YO
COEFF1(I) = (1.-A1)*SSS*TA3*STC
COEFF2(I) = (1.-A3)*A1*SIN(4.*SS) - 2.*A3*SIN(4.*SS)

C-09 CALCULATE P,SUR=0 COEFFICIENTS FOR SWAY AND ROLL
IF (I.FO.M) GO TO 32
A(I,1) = YO
A(I,2) = XO*AO*YO*YO=1.0
32 CONTINUE

C-10 LOOP OVER FREQUENCY RANGE
DO 144 I=1,NF
TIR = OMT(IF)OMN
IF (TIR) 95;TUN1
31 CONTINUE

C-11 CALCULATE STREAM AND POTENTIAL FUNCTIONS
DO 140 I=1,M1
TO = X(I)
YO = Y(I)
XK = XO*TO-YO*YO
YK = YI*YO
CKK = SIN(XK)
CCK = COS(XK)
PKV = EXP(-XK*YO)

C-12 CALCULATE Q AND S SERIES FOR WAVE INTEGRAL APPROXIMATIONS
IF (VO.NT. 0.0000001) GO TO 33
XI = PI/2.0
DO TO 34
33 XI = ATAN2(XO,YO)
34 XI = XIR*SORT(XI)
XK = XI
YK = XI
CCK = COS(XI)
SSS = SIN(XI)
CTK = CSS
CTK = SSS
3A DO = 90-FACTS
PK = PS-FACTS
TN = TN+1.0
XP = XR+IC/TN
XK = XB/XN
IF (XA.LT. 10.E-7) GO TO 37
XI = CS*CTS-SSS*STS
XIS = SS*CTS-CSS*STS
CTK = XI
DO TO 3A

C-13 WAVE INTEGRAL APPROXIMATIONS
37 XI = PKV*(QD*CKK+(PS-P)*CKK)
XK = PKV*(QD*SKK+(PS-P)*CKK)

C-14 COMBINE TERMS FOR PSI AND PHI
XK = XK*IB
PKV = EK*VP
Y(I) = EK*CKK
YI(I) = PKV*SKK + XA -YO/XK
PCO(I) = -EKV*SKK
PSO(I) = EKV*CKK - XK *XO/XK
40 CONTINUE

C-15 COMPUTE INTEGRALS FOR N,SUB=0 AND X,SUB=R EVALUATIONS
XA = PCO(M1)*COFF1(M1)
YA = PSO(M1)*COFF1(M1)
XC = PCO(M1)*COFF2(M1)
XN = PSO(M1)*COFF2(M1)
PP = -1.0
(A AN. 1) 01,M
DO = -PP
DO = 3.0*PP
XA = XA+DO*PCO(I)*COFF1(I)
XB = XB+DO*PSO(I)*COFF1(I)
YC = YC+DO*PCO(I)*COFF2(I)
YN = YN+DO*PSO(I)*COFF2(I)
V(I) = Y(I)-Y(M1)
45 V(I) = V(I)-V1(M1)

C-16 DETERMINE ALL COEFFICIENTS OF P AND Q SERIES
DO 1 I=1,M
95 = PN*FAC
AA = +1.0

```

```

PP = COS(SS)
PS = 2.*PP*PP-1.0
YP = PS
PO = 2.0*PS*PS-1.0
XI = SIN(SS)
XK = 2.*XI*PPH
XN = XI
XK = 2.0*XK*PS
QO = 0.0
DO 5A J=1,M,M
QO = QO + 2.0
95K = A1/(QO-2.0)
CKK = TA3/(QO+4.0)
XK = YK*PP-XK*XI
PK = PO*PS-XK*XX
A(I,J) = BK * (XIR/A13)*(YR/QO*PO*SKK-PP*CKK-AA*(1./QO-SKK-CKK))
VJ = PO
PO = PP
XK = XK
XK = XK*PS-YR*XX
IF (I.NE.M) GO TO 50
PK = QO*QO
EQ = (QO-2.0)/(QO+2.0)
FR = (QO+4.0)/(QO+6.0)
FS = (QO-1.0)/(QO+1.0)
9FC(I,J) = XIR*AA*(1.0/(EP+1.0) -A1/(EQ+1.0) -TA3/(FR+1.0)) *
(1.0-A1) *TA3*(-1.0/(EP+0.0) +A1/(EQ+0.0) +TA3/(FR+0.0))
9EC(I,J) = AA*(2.0*A1*(1.0+A3)/(ES+4.0) +8.0*A3/(ES-16.0))
50 AA = -A
55 CONTINUE

C-17 SOLVE SIMULTANEOUS EQUATIONS FOR P AND Q SERIES.
FORM M BY M COEFFICIENT MATRIX BY LEAST SQUARES METHOD
DO 7 I=1,M
DO 7 J=1,M
9(I,J)=0.
DO 8 K=1,M
9 7(I,J)+C(I,J)-A(K,I)*A(K,J)
7 9(I,J)=5(I,J)

C-17 FORM R.H.S. (M VECTOR) BY LEAST SQUARES METHOD
DO 4 I=1,M
7(I)=0.
7(I)=0.
DO 6 J=1,M
7(I)+Z(I)-A(J,I)*Y(I)
4 7(I)=7(I)-A(J,I)*Y(I)

C-17 INVERT COEFFICIENT MATRIX. IT REPLACES ORIGINAL MATRIX
DO 10 I=1,M
DO 10 J=1,M
9(I,J)=0.
9(I,J)=0.
DIV=C(I,I)
IF (ABS(DIV).LT. 10.E-16) GO TO 92
DO 8 K=1,M
9(I,J)+9(I,K)*DIV
DO 7 K=1,M
9(I,J)=9(I,K)*DIV
DO 9 K=1,M
9(I,J)=9(I,J)*DIV
10 CONTINUE

C-17 CALCULATE P,SUR=2M AND Q,SUR=2M SERIES
DO 11 I=1,M
O(I)=0.
O(I)=0.
DO 11 J=1,M
O(I)+P(I)+5(I,J)*Z(J)
11 O(I)=O(I)+5(I,J)*Z(J)

C-18 CALCULATE N,SUR=0 + M,SUB=0 , X,SUB=R AND Y,SUB=R
DO = 0.0
DO = 0.0
DO = 0.0
DO = 0.0
DO 1A J=2,M
DO = PP*(J)*SEC1(J)
PO = PO*(J)*SEC1(J)
DO = PP*(J)*SEC2(J)
DO = PS*(J)*SEC2(J)
AA = (-SS*CC*CONST1*PP(2))/A13-PP/AA13
PUN = (-SS*CC*CONST1*PP(2))/A13 -PP/AA13
YB = IC*CC*CONST2*(A1*P(2) -A3*P(3))+PP/AA13
YR = IC*CC*CONST2*(A1*Q(2) -A3*Q(3))+PS/AA13

```

```

C-19 COMBINE TERMS FOR FINAL RESULTS
PP = P(1)*P(1) + O(1)*O(1)
QQ = P(2)*P(1) + P(2)*O(1)
RR = P(2)*P(1) + P(2)*O(1)
SS = P(2)*P(1) + P(2)*O(1)
TT = P(2)*P(1) + P(2)*O(1)
IF (MM.CO,1) GO TO A7

C-20 QWAY RESULTS
XX = ABS(QD*2.0/(PI*PI)) -1.0
IF (XX.LT.0.025) GO TO A5
IF (ABS(QD-0.0348)/AMAX(ABS(PKO*P(1)),ABS(PNO*O(1))) .GT. 0.10)
  IX = 1
  GO TO A7
A5 XK = MO/(SIG*PP)
  R(1) = XK*PP
  R(2) = XK*PP
  XK = XK*QRT(4/A)
  R(3) = R(1)*K/R,0
  R(4) = XK*PS
  NO TO A7

C-21 SWITCH COEFFICIENTS FOR SUBSEQUENT ROLL OR QWAY CALC.
AA = A(1,1)
  KK = A(J,MP)
  A(I,MP) = A(I,1)
  A(I,1) = KK
  IF (MM.CO,1) GO TO A6
  NO TO A7

C-22 ROLL RESULTS
A7 XI = ABS(PS*0.0/(PI*PI)) -1.0
  XK = MO/(C.0*SIG*PP)
  R(1) = XK*PP
  R(2) = XK*PP
  R(3) = XK*PP
  R(4) = XK*QRT(4/A)
  R(5) = R(1)*K/R,0
  R(6) = XK*PS
  NO TO A8

C-23 ZERO FREQUENCY CALCULATIONS
  TA = 1.0-A1-A3
  IC = XA*XA
  R(1) = XI*(1.0-A1)*2+TA3*A3)/(4.0*MO*SIG*IC)
  R(2) = XI*(1.0-A1)*2+TA3*A3)/(4.0*MO*SIG*IC)
  R(3) = 2.0*MO/(SIG*TA3*A3)
  R(4) = -XC*TA/3.0
  R(5) = IC*(A1*(1.0-A3))*2-A.0*A3*(A1-A3*(A1+2.0))/9.0/(PI*A13)
  R(6) = R(3)
  NO TO A8
  R(1) = A.0
  NO TO A8

C-24 PRINT RETURN'S
  IF (IX.FO,0) GO TO 103
  IX = IX + 2
  IF (IX.LT.5) GO TO 93
  PRINT 97, FPH(3*IX-2)*ERN(3*IX-1)*ERN(3*IX)*MO*SIG*XI
  IF (IX.LT.5) GO TO 93
  PRINT 99, P, U
  PRINT 91, PNO,PNO,XR,YR
  IF (IX.LT.5) DET = 0.0
  IX = 0

C-25 STOP RESULTS IN COMMON ARRAY
  MM = 2
  DO A6 I=1,6
    J = I+2
  A9 TOP(K1,IF,J) = R(I)
  104 CONTINUE
  105 CONTINUE
  RETURN

  97 FORMAT (32HSTOP IN SUBROUTINE TOLR DUE TO , 3A6 / 30H PARAMETERS
  I= , MO = , F10.4, 3X, ABSIS = , F10.4, 3X, 6MXH = , F12.6)
  99 FORMAT ( 11H P SERIES = , 9E13.4 / 11H Q SERIES = , 9E13.4 )
  91 FORMAT (5H MO = , E12.4, 6H, MO = , E12.4, 6H, XR = , F12.4, 6H, YR = ,
  F12.4, 6H, E12.4)
  PNO
  END

SUBROUTINE ALINT
  C INTPROLATE ALL REQUIRED TWO-DIMENSIONAL PROPERTIES AT PARTICULAR
  C FREQUENCY. FOR ALL SECTIONS, USE CONTINUED FRACTION METHOD, WITH
  C SIX POINTS, THREE ON EACH SIDE OF GIVEN POINT. ADAPTED FROM
  C SUBROUTINES ACPI AND ATAN OF SYSTEM/300 SCIENTIFIC SUBROUTINE
  C PACKAGE, VERS. III, IBM PUR. NO. M20-0209-3 (1968).

```

```

COMMON / MASDA / BPL,DISPL,TMASS,YMERT,BSTAR(21),ARPA(21),
  X
  SECOE(21),DRAFT(21),ZBAR(21),XI(21),XISQ(21),
  X
  DVEIGM(21),DMASS(21),ZWT(21),ORL(21),ZCO,XMERT,
  X
  XZPERT,OM,MINKEI,MAXKEI,INCRS,ROLOFF
COMMON / TDR / MS,SBW(21),SABB(21),NF,OMT(25)
COMMON / / TOP(21,25,21)
COMMON / TDIR / ME,VEN,ANS(2,10),KL,KU,IG,IV
DIMENSION VAL(6),ARO(6)

C-01 LOOP OVER NUMBER OF STATIONS
  NO 20 XI=1,NS
  KM = KL
  X = ME*DRAFT(K1)

C-02 CHECK FOR ZERO SECT,ON
  IF ( DRAFT(K1) .GT. 0.0 ) GO TO 1
  NO 7 KOKM,KU
  7 ANS(1,K) = 0.0
  NO TO 20

C-03 CHECK IF X IS IN RANGE
  1 IF ( X .LE. OMT(NF) ) GO TO 5
  2 JJ = NF-3
  NO TO 4

C-04 BINARY SEARCH IN OMT ARRAY FOR X
  5 J = NF
  6 K = (J+1)/2
  IF ( X .GT. OMT(K) ) GO TO 6
  7 U = V
  8 V = W
  9 IF ( ABS(J-I) .GT. 1 ) GO TO 6
  10 JJ = I

C-05 OMT(JJ) IS JUST BELOW X IN ARRAY OMT
  IF ( JJ*3 .GT. NF ) GO TO 2
  IF ( JJ .GE. 3 ) GO TO 4
  IF ( JJ .GT. 1 .OR. KL .GT. 1 ) GO TO 3

C-06 FREQUENCY PARAMETER NEXT TO OMT(1) ZERO FREQUENCY
  KM = 2
  IF ( X .GT. 0.0 ) GO TO 31
  ANS(1,1) = 1.0P75
  NO TO 3
  33 XM = 1.0*BSTAR(V1)/(2.0*DRAFT(K1))
  ANS(K,1) = TOP(K1,21)*(0.73+ALOG(X*XM))/(0.23+ALOG(OMT(2)*XM))
  3 JJ = 3

C-07 SET UP LOOPS AND STORE VALUES FOR INTERPOLATION
  4 NO 1A KOKM,KU
  KK = JJ-3 +K/(K+JJ)
  NO 11 J=1,4
  IF ( KK=1
  VAL(I) = TOP(K1,IK+K)
  11 ARO(I) = OMT(IK)
  O1 = 1.0
  O2 = VAL(I)
  O3 = 0.0
  O4 = 1.0
  XMM = 1.E75

C-08 CONTINUED FRACTION INTERPOLATION LOOP
  NO 12 I=2,6
  JF = I-1
  NO 14 J=J+JE
  W = VAL(I)-VAL(J)
  IF ( W.NE.0.0 ) GO TO 14
  VAL(I) = 1.F75
  NO TO 17
  14 VAL(I) = (ARO(I)-ARO(J))/W
  13 CONTINUE
  KM = XMM
  O5 = VAL(I)*O2+(X-ARO(I-1))*O1
  O7 = VAL(I)*O2+(X-ARO(I-1))*O1
  IF ( O3.NE.0.0 ) GO TO 15
  XMM = 1.E75
  NO TO 17
  15 XMM = O3/O3
  17 IF ( ABS(1.0-XMM/XM) .LT. 0.02 ) GO TO 22
  O1 = O2
  O2 = O3
  O3 = O4
  12 CONTINUE

C-09 STOP RESULTS
  22 ANS(1,K) = XMM

```

1A CONTINUE
2A CONTINUE
RETURN
END

SUBROUTINE COEFF

```
COMMON / CONDA / PI, GAMMA, GRAV, RO  
COMMON / BASDA / BPL, DISPL, THASS, YNERT, BSTAR(21), ANPA(21),  
SECOC(21), DRAPT(21), ZBAR(21), XI(21), XISO(21),  
DWEIGH(21), DMASS(21), ZWT(21), BRL(21), ZCO, XNERT,  
XZPERT, SM, MINKRI, MAXKRI, INCRES, ROLNPF  
COMMON / TDIR / VE, WEN, ANS(21,10), KL, KU, IO, IW  
COMMON / MIND / IA, NS, DFI, V, WANG, OMEGA, WAVEN, CW, DIX(21,5), FAC, WA  
COMMON / EDWD / CV(12), CL(27), ZW, MW, YW, NW, KW  
COMMON / PROGRAM / STORAGE(442), P(10), FX(10), FXS(4), DP(5), DFX(5),  
DFXS(2), V(21)  
IT = 1A  
M = NS  
NZ = DTI  
TV = 2.00V
```

C-01 CALCULATE REQUIRED INTEGRALS OVER SHIP LENGTH

```
DO 10 K=KL, KU  
DO 7 I=1, M  
F(I) = ANS(I, K)  
F(K) = SINT(IT+M, Y, DX)  
IF ( K=1 ) ZCO, A ) GO TO 10  
DO 4 I=1, M  
V(I) = V(I)*X(I)  
FX(K) = SINT(IT+M, Y, DX)  
IF ( K=DTA ) GO TO 10  
DO 6 I=1, M  
V(I) = V(I)*X(I)  
FXS(K) = SINT(IT+M, Y, DX)  
10 CONTINUE  
PI = SINT(IT, M, BSTAR, DIX) * GAMMA  
DO 17 I=1, M  
17 V(I) = ASYAR(I) * X(I)  
XK1 = SINT(IT, M, Y, DIX) * GAMMA  
DO 14 I=1, M  
14 V(I) = V(I)*X(I)  
XK1 = SINT(IT, M, Y, DIX) * GAMMA
```

C-02 INCREASE ROLL DAMPING (TO ACCOUNT FOR VISCOUS EFFECTS)

```
F(4) = F(4) * ROLOPF  
IF ( KL, DT, 2 ) GO TO 19  
FAC = RO/SORT(MPH**3/GRAV)  
F(2) = F(2)*FAC  
F(7) = F(7)*FAC  
FXS(2) = FXS(2)*FAC
```

C-03 CALCULATE REQUIRED DERIVATIVES AND THEIR INTEGRALS

```
19 TV = 2.00D1  
MW = M-1  
DO 2A K=KL, KU, 2  
KK = (K-1)/2  
7IX(I, KK) = (ANS(I, K) - ANS(I, K+2)) / DX  
DIX(I, KK) = (ANS(I, K-1) - ANS(I, K)) / DX  
DO 22 I=2, MW  
22 DIX(I, KK) = (ANS(I-1, K) - ANS(I-1, K+1)) / DX  
DO 2A J=1, M  
2A V(I) = DIX(I, KK)  
DFX(K) = SINT(IT, M, Y, DX)  
IF ( KK, DT, 2 ) GO TO 20  
DO 24 I=1, M  
24 V(I) = V(I)*X(I)  
DFX(K) = SINT(IT, M, Y, DX)  
IF ( KK, DT, 2 ) GO TO 20  
DO 2A I=1, M  
26 V(I) = V(I)*X(I)  
DFXS(K) = SINT(IT, M, Y, DX)  
20 CONTINUE  
IF ( KL, DT, 2 ) GO TO 30
```

C-04 FORM COEFFICIENTS FOR VERTICAL PLANE MOTIONS (HEAVE + PITCH)

```
CV(1) = THASS*F(1)  
CV(2) = F(2)-V*DF(1)  
CV(3) = B1  
CV(4) = FX(1)  
CV(5) = FX(2)-V*DFX(1)-TV*F(1)  
CV(6) = B1-V*CV(2)  
CV(7) = YNERT*FXS(1)  
CV(8) = FX(2)-V*DFX(1)-TV*FX(1)  
CV(9) = B1-V*FX(2)-V*V*DFX(1)  
CV(10) = FX(1)
```

```
CV(11) = FX(2)-V*DFX(1)  
CV(12) = B1  
IF ( KULLT, 3 ) GO TO 40
```

C-05 FORM COEFFS. FOR LATERAL PLANE MOTIONS (SWAY, YAW + ROLL)

```
30 CV(11) = THASS*F(3)  
CL(2) = F(4)-V*DF(2)  
CL(3) = 0.7  
CL(4) = FX(3)  
CL(5) = FX(4)-V*DFX(2)-TV*F(3)  
CL(6) = -V*CL(2)  
CL(7) = -F(9)-ZCO*F(3)  
CL(8) = -F(10)-ZCO*CL(2)-V*DF(5)  
CL(9) = 0.0  
CL(10) = FX(3)  
CL(11) = FX(4)-V*DFX(2)  
CL(12) = 0.0  
CL(13) = YNERT*FXS(3)  
CL(14) = FXS(4)-V*DFXS(2)-TV*FX(3)  
CL(15) = -V*CL(11)  
CL(16) = -XZPERT*FX(9)-ZCO*FX(3)  
CL(17) = -FX(10)-ZCO*CL(11)-V*DFX(5)  
CL(18) = 0.0  
CL(19) = -F(5)-ZCO*F(3)  
CL(20) = -F(6)-ZCO*CL(2)+V*DF(3)  
CL(21) = 0.0  
CL(22) = -XZPERT*FX(5)-ZCO*FX(3)  
CL(23) = -FX(6)-ZCO*CL(11)-V*DFX(3)-TV*CL(10)  
CL(24) = -V*CL(20)  
CL(25) = XNERT*F(7)+ZCO*F(8)-ZCO*CL(19)  
CL(26) = F(8)-ZCO*CL(20)+ZCO*(F(10)-V*DF(5))-V*DF(4)  
CL(27) = DISPL*OH  
40 RETURN  
END
```

SUBROUTINE EXCITE

```
COMMON / CONDA / PI, GAMMA, GRAV, RO  
COMMON / BASDA / BPL, DISPL, THASS, YNERT, BSTAR(21), ANPA(21),  
SECOC(21), DRAPT(21), ZBAR(21), XI(21), XISO(21),  
DWEIGH(21), DMASS(21), ZWT(21), BRL(21), ZCO, XNERT,  
XZPERT, SM, MINKRI, MAXKRI, INCRES, ROLNPF  
COMMON / TDIR / VE, WEN, ANS(21,10), KL, KU, IO, IW  
COMMON / MIND / IA, NS, DFI, V, WANG, OMEGA, WAVEN, CW, DIX(21,5), FAC, WA  
COMMON / EDWD / CV(12), CL(27), ZW, MW, YW, NW, KW  
COMMON / BMDA / CXPST(21), CXMR(21), CBMM(5,3), SBMP(51,3)  
COMMON / PROGRAM / STORAGE(457), V(21), M(21)  
IT = 1A  
M = NS  
NZ = DTI  
MW = WAVEN  
CWAN = COS(WAN)  
SWAN = SIN(WAN)
```

C-01 CALCULATE WAVE EXCITATION AT EACH STATION

```
DO 11 I=1, NS  
XMR = UNPZ(I) * CWAN  
CXK = COS(XKC)  
SKK = SIN(XKC)  
FX = -EXP(-UNDRAPT(I) * SECOC(I)) * WA  
XZ = BSTAR(I) * MW * SWAN / ZI  
IF ( XZ, FOL, 0 ) GO TO 12  
FX = EXP(SIN(WAN) / XZ)  
12 IF ( KL, DT, 2 ) GO TO 10
```

C-02 FORM VERTICAL FORCE COMPONENTS

```
FKL = GAMMA * BSTAR(I) * MW * GRAV * ANS(I, 1)  
SKL = MW * CWAN * (ANS(I, 2) * FAC - V * DIX(I, 1))  
CX = ( FKL * SKK - SKL * CXK ) * EXY  
CY = ( FKL * CXK - SKL * SKK ) * EXY  
CXPT(I) = CMLY(CX, SK)  
IF ( KULLT, 3 ) GO TO 30
```

C-03 FORM LATERAL FORCE COMPONENTS

```
10 FKL = GRAV * (RO * AREA(I) * ANS(I, 3) - UNPANS(I, 5))  
SKL = CW * (ANS(I, 4) - V * DIX(I, 2) - UNV * V * DIX(I, 3))  
FXY = MW * EXY * SWAN  
CX = ( FKL * CXK - SKL * CXK ) * EXY  
CY = ( -FKL * SKK + SKL * CXK ) * EXY  
CXPL(I) = CMLY(CX, SK)
```

C-04 FORM ROLL MOMENT COMPONENTS

```
FKL = GRAV * (RO * BSTAR(I) * 0.3 / IZ - AREA(I) * ZBAR(I) - ANS(I, 5))  
F = -ZCO * FKL  
SKL = CW * (ANS(I, 4) - V * DIX(I, 3) - ZCO * SKL  
CX = ( FKL * CXK - SKL * SKK ) * EXY
```

```
PHITAJ = CALS(RA) * 57.295778  
PHIIOJ = ATN2(REAL(RA), AI * 40(RA)) * 57.295778  
20 RETURN  
END
```

```

4X = (-KX*SKX+SKX*CKX)*ERY
CXMR(1) = CMPLX(CX,SK)
30 CONTINUE
IF ( KU,GT,3 ) GO TO 40

C-05 INTEGRATE VERTICAL FORCE AND PITCH MOMENT
DO 39 I=1,N5
V(I) = REAL(CX*ST(I))
32 W(I) = AIMAG(CX*ST(I))
CX = -SINT(I)*W*DX
W = SINT(I)*W*DX
ZM = CMPLX(CX,SK)
DO 39 I=1,N5
V(I) = V(I)+X(I)
33 W(I) = W(I)+X(I)
CX = -SINT(I)*W*DX
W = SINT(I)*W*DX
W = CMPLX(CX,SK)
IF ( KU,LT,3 ) GO TO 50

C-06 INTEGRATE LATERAL FORCE, YAW MOMENT AND ROLL MOMENT
DO 42 I=1,N5
V(I) = REAL(CX*PL(I))
47 W(I) = AIMAG(CX*PL(I))
CX = -SINT(I)*W*DX
W = SINT(I)*W*DX
W = CMPLX(CX,SK)
DO 42 I=1,N5
V(I) = V(I)+X(I)
43 W(I) = W(I)+X(I)
CX = -SINT(I)*W*DX
W = SINT(I)*W*DX
W = CMPLX(CX,SK)
DO 42 I=1,N5
V(I) = REAL(CX*WR(I))
44 W(I) = AIMAG(CX*WR(I))
CX = -SINT(I)*W*DX
W = SINT(I)*W*DX
W = CMPLX(CX,SK)
90 RETURN
END

SUBROUTINE MOTION
COMMON / TDIR / VE,WE,ANS(21,10),KL,KU,IO,IV
COMMON / EQMO / CV(12),CL(27),ZM,MW,YM,NMKU
COMMON / MOTI / TA,TA,SAYA,RA
COMMON / MOTW / ZM(S),ZP(S),ZM(S),TP(S),SM(S),CP(S),YM(S),
X YP(S),RM(S),RP(S)
COMPLEX P,Q,R,S,T,U,V,W,X,ZM,MW,YM,NMKU,DEM
MFC = 0.0E+00
M = -VE
IF ( KU,GT,3 ) GO TO 10

C-01 VERTICAL MOTIONS COMPUTATIONS
P = CMPLX(CV(3)-WE*CV(1),W*CV(2))
Q = -CMPLX(CV(4)-WE*CV(5),W*CV(6))
R = -CMPLX(CV(12)-WE*CV(10),W*CV(11))
S = CMPLX(CV(9)-WE*CV(7),W*CV(8))
NFK = P+S-Q
ZA = (ZM+S-M*Q)/DEM
TA = (P+M*W-ZM)/DEM
ZM(1) = CARS(ZA)
ZM(10) = ATAN2(REAL(ZA),AIMAG(ZA))*57.295779
ZM(11) = CARS(TA)*57.295779
ZM(12) = ATAN2(REAL(TA),AIMAG(TA))*57.295779
IF ( KU,LT,3 ) GO TO 20

C-02 LATERAL MOTIONS COMPUTATIONS
DO 7 I=1,N5
P = CMPLX(PL(I)-WE*CL(1),W*CL(2))
Q = CMPLX(PL(4)-WE*CL(5),W*CL(6))
R = CMPLX(PL(9)-WE*CL(10),W*CL(11))
S = CMPLX(PL(12)-WE*CL(13),W*CL(14))
T = CMPLX(PL(15)-WE*CL(16),W*CL(17))
V = CMPLX(PL(18)-WE*CL(19),W*CL(20))
W = CMPLX(PL(21)-WE*CL(22),W*CL(23))
Y = CMPLX(PL(27)-W*CL(25),W*CL(26))
NFK = P+Q+R+S+T+V+W+Y
ZM = (Y+M*W+ZM)/DEM
TA = (P+M*W-ZM)/DEM
ZM(1) = CARS(ZA)
ZM(10) = ATAN2(REAL(ZA),AIMAG(ZA))*57.295779
ZM(11) = CARS(TA)*57.295779
ZM(12) = ATAN2(REAL(TA),AIMAG(TA))*57.295779

```

```

SUBROUTINE BENDSH
COMMON / CONDA / PI,BAMH,ORAV,RO
COMMON / MHD / MDA(14),DTA,DTR,IB,IC,ID,IE,IF,IG,IH,IJ,STS(5)
COMMON / NASDA / BPL,DISPL,YMASS,YMERT,BSTAR(21),ARPA(21),
X SECC(21),DRIFT(21),ZBAR(21),XI(21),I50(21),
X DMSHM(21),DMASS(21),ZUT(21),ORL(21),ZC0,IMENT,
X IZPERT,MINIKRI,MAXKRI,INCRES,ROLNPF
COMMON / TDIR / VE,WE,ANS(21,10),KL,KU,IO,IV
COMMON / MHD / I,NS,DI,V,PANB,ONEBA,MAVEN,CW,DIR(21,5),FAC,WA
COMMON / BMOA / CXST(21),CXPL(21),CXMR(21),SBMH(S,3),SBMP(S,3)
COMPLEX CXST,CXPL,CXMR
COMMON / MOTI / ZM,TR,SR,YR,RR
COMPLEX ZM,TR,SR,YR,RR
COMMON / PROGRAM / CLM(S,3),CLM(S,2),SPACE(80),QNM(3),SHP(3),
X BMH(3),RMP(3),WEI,ZRD,ZRCD,TRD,TRDD,SRD,SRDD,YRD,YRDD,RRD,
X RRD,CTFST(21,3),A,B
COMPLEX WEI,ZRD,TRD,TRDD,SRD,SRDD,YRD,YRDD,RRD,
X CTFST,A,B

C-01 GET UP CALCULATION PARAMETERS
WEI = CMPLX(0.0,-VE)
JL = (KL-S)*A
JI = (KU-S)*A
WM = DI/2.0
NT = NS-1

C-02 CALCULATE TOTAL LOCAL LOADINGS AT EACH STATION
IF ( KU,GT,3 ) GO TO 12

C-03 VERTICAL FORCE COMPONENTS
TRD = ZRD*WEI
TRD = TRD*E
ZRDD = ZRD*WEI
YRDD = YRD*WEI
DO 10 I=1,N5
CTF4T(I,1) = -(MMASS(I)-ANS(I,1))*(ZRD-XI(I))*TRDD -ANS(I,1)*
X 2.0*V*TRD -GAMMA*ASTAR(I)*(ZM-XI(I))*TR -ANS(I,2)*
X FAC-V*DX(I,1)*(ZRD-XI(I))*TRD-V*TRD -CXST(I)
IF ( KU,LT,3 ) GO TO 16

C-04 LATERAL FORCE AND TORSIONAL MOMENT COMPONENTS
DO 12 I=1,N5
YRD = YRD*WEI
TRD = TRD*E
YRDD = YRD*WEI
DO 14 I=1,N5
CTF4T(I,2) = -MMASS(I)*YRDD-XI(I)*YRDD-ZUT(I)*RRD(1)
X -ANS(I,3)*(SRDD-XI(I))*YRDD-2.0*V*YRD -ANS(I,4)*V*
X DIX(I,2)*SRDD-XI(I)*YRD-V*YR-ZC0*YRD -ANS(I,5)*
X ZC0*ANS(I,3)*YRDD -ANS(I,10)*V*DX(I,5)*YRD
X -CXPL(I)
CTF4T(I,3) = -DMASS(I)*(ORL(I)*ZRDD-ZUT(I))*SRDD-XI(I)*YRDD
X -GAV*RR(1)-GAMMA*INSTAR(I)*3/12*-AREA(I)*ZBAR(I)*
X ZC0)*RR -RRD*(ANS(I,7)+ZC0*(ANS(I,5)+ANS(I,9)+ZC0*ANS(I,3)))
X +ZC0*TPST(I,2)*J -RRD*(V*DX(I,4)+ZC0*DX(I,3)
X -DI*(I,5)+ZC0*DX(I,2)) -ZC0*(ANS(I,10)+ANS(I,6)
X +ZC0*ANS(I,4))-ANS(I,8)-HOLDP/BPL)*(SRDD-XI(I))*YRD-2.0*V*YRD
X (ANS(I,9)+ZC0*ANS(I,3))*(SRDD-XI(I))*YRD-V*YR
X (ANS(I,6)+ZC0*ANS(I,4)-V*DX(I,5)+ZC0*DX(I,2))*CXMR(I)
14 CONTINUE

C-05 LOOP OVER STATIONS FOR BENDING MOMENT CALCS.
16 KRIT = MINKRI
IF ( KRIT,GT,0 ) GO TO 18
IX = XI(1)*MM*(1.0-IA)
DO TN 16
18 IX = XI(KRIT)*MM*(1.0-IA)

C-06 LOOP OVER NUMBER OF TYPES OF LOADINGS
DO 18 I=1,N5
A = (0.0,0.0)
B = (0.0,0.0)
IF ( KRIT,EQ,0 ) GO TO 22
A = CTFCT(I,KRIT)/I
B = A*(I,1)-IX
IF ( KRIT,EQ,1 ) GO TO 22
DO 20 I=2,KRIT
20 A = CTFST(I,K)
20 B = CTFST(I,K)*XI(I)-IX

```

```

22 KK = KRIT+1.0A
  IF ( KK.GT.10 ) GO TO 26
  A = A-CTPST(NS,K)/(1-IA)
  R = B-CTPST(NS,K)/(1-IA)*(X(NS)-XX)
  IF ( KK.GT.10 ) GO TO 26
  DO 24 I=K,K+1
    I = A-CTPST(I,K)
  24 R = B-CTPST(I,K)*(X(I)-YX)
  2A IF ( K.FO.3 ) R = A
  SHM(K) = CAPS(A)*OHM
  SHM(I) = CAPS(A)*OHM
  SHM(X) = ATAN2(REAL(A)+AIMAG(A))*180.0/PI
  SHM(Y) = ATAN2(REAL(B)+AIMAG(B))*180.0/PI
  30 CONTINUE
  IF ( MAXKRI.EQ.4*MINKRI ) GO TO 31
  PRINT 9A, OMEGA,KRIT,(SHM(I),SHM(Y),I=1,3)
  IF ( KRIT.NE.(NS-1A)/2 ) GO TO 34

C-07 STONE RESULT
31 DO 32 K=JL,JU
  SRMM(I,O,K) = SHM(K)
  SRMP(I,O,K) = SHM(K)
  32 IF ( KRIT.GE.MAXKRI ) GO TO 3P
  KRIT = KRIT+INCRS
  DO 3A I=1,3
  3A IF ( I.NE.0 ) GO TO 60

C-0A CHECK SHEAR AND BENDING MOMENT CLOSURE
DO 40 K=1,2
  CLR(I,O,K) = 0.0
  CLR(I,O,K) = 0.0
  CLR(I,O,K) = 0.0
  DO 40 K=JL,JU
  A = (CTPST(I,K)-CTPST(NS,K))/(1-IA)
  R = (CTPST(I,K)*X(I)-CTPST(NS,K)*X(NS))/(1-IA)
  DO 40 I=2,NT
  A = A-CTPST(I,K)
  40 R = B-CTPST(I,K)*X(I)
  IF ( K.LT.3 ) GO TO 45
  R = A
  DO 40 I=50
  40 CLR(I,O,K) = CAPS(A)*DII/DISPL
  40 CLR(I,O,K) = CAPS(B)*DII/SBMM(I,O,K)
  40 RETURN
  90 FORMAT ( F9.4, I10, 3( E13.3, F7.0) )
  END

SUBROUTINE TNIRPA
COMMON / CONDA / PI,BAHMA,GRAY,RO
COMMON / MNDT / MDA(14),DTA,DTA,IB,IC,IO,IF,IF,IO,IM,II,IJ,STS(5)
COMMON / BASDA / BPL,DISPL,THASS,YNERT,OSTAR(2),ARPA(2),
  X
  SECDE(2),DRAFT(2),ZBAR(2),XI(2),XISO(2),
  ONEION(2),DMASS(2),ZUT(2),EBL(2),ZCO,KNERT,
  Y
  XZPL,OHM,MINKRI,MAXKRI,INCRS,ROL,NPF
COMMON / CASDA / NM,OHM(S),VUL(S),OMME(S),VMIN,VMAR,DELV,
  MFAWAD(25),WANGI,WAHBA,DAWANG,MWI,ND(20),WLL(S),
  I
COMMON / TDJR / WEN,EN,ANS(2),IO,KU,IO,IM
COMMON / MIPD / IA,NS,DXI,V,WANG,OMEGA,WAVENS,CU,DXI(2),S),FACWA
COMMON / MOTN / ZM(S),ZP(S),YM(S),TP(S),SM(S),AP(S),YM(S),
  Y
  VS(S),RM(S),RP(S)
COMMON / RMDA / CFPST(2),CPL(2),CXMP(2),SBMM(S),3),SBMP(S),3)
COMMON / EX CFPST,CPL,CXMP
COMMON / PROGRAM / CLSM(S),3),CLSH(S),2),SPACE(40),ZM(S),YM(S),
  X
  XM(S),VM(S)
  DIMENSION MDA(14),MDCP(4),MDCP(4), VM(S)
  DATA MDCP / OH ANP,OHM, PMA,ANSE /
  DATA MDCP / OH AN,OHM,ITOD,ANSE PMA,ANSE /
  DATA MDCP / OH AN,SHSHEAR,OH M,OHOMENT /
  TPI = 3.14159265
  WAM = 1.0/((1.0/WA-1.0)
  WC = (MS-1)/Z
  CL = 1.0/((OHM+OHPL*OHPL*OSTAR(NS)*WA)-1.0)*II+1.0
  IF ( KL.GT.2 ) GO TO 20

C-01 PRINT OUT FREQUENCY RESPONSE FUNCTIONS, VERTICAL PLANE
PRINT 920,MDA,DTA,DTB
PRINT 921, V=AD(IM)
PRINT 922
IF ( II.FO.1 ) PRINT 937
PRINT 927
PRINT 928
PRINT 929
PRINT 92A
PRINT 92B,MDCP,MDCP
PRINT 92C, MDCP,MDCP
DO 2A I=1,4M
  2A I = SHM(I)*OHM
  FNT = 1.0/((1.0/WUL(I)/TPI-1.0)
  YN(I) = YM(I)*FNT
  YN(I) = RM(I)*FNT
  VN(I) = SRMM(I)*FNT*OHM
  25 VN(I) = SRMM(I)*FNT*OHM
  PRINT 930, (OHM(I),OMME(I),VUL(I),WLL(I),ZM(I),SP(I),YM(I),VP(I),
  X
  XM(I),SBMP(I),I=1,4M)
  40 IF ( IM.LE.0 ) GO TO 60

C-02 PRINT OUT FREQUENCY RESPONSE FUNCTIONS, LATERAL PLANE
PRINT 920,MDA,DTA,DTB
PRINT 921, V=AD(IM)
PRINT 922
IF ( II.FO.1 ) PRINT 937
PRINT 927
PRINT 928
PRINT 929
PRINT 92A
PRINT 92B,MDCP,MDCP,MDCP(3),MDCP(4)
PRINT 92C, (OHM(I),OMME(I),VUL(I),WLL(I),ZM(I),SP(I),YM(I),VP(I),
  X
  XM(I),SBMP(I),I=1,4M)
  40 IF ( IM.LE.0 ) GO TO 60

C-03 PRINT OUT SHEAR AND MOMENT CLOSURE RESULTS
PRINT 920,MDA,DTA,DTB
PRINT 921, V=AD(IM)
PRINT 922
PRINT 927
PRINT 928
PRINT 929
PRINT 92A
PRINT 92B,MDCP,MDCP,MDCP(3),MDCP(4)
PRINT 92C, (OHM(I),OMME(I),VUL(I),WLL(I),ZM(I),SP(I),YM(I),VP(I),
  X
  XM(I),SBMP(I),I=1,4M)
  40 OBT=04
  520 FORMAT ( I10, I10, A2, 3( A10, A2 )
  521 FORMAT ( 9MSPEFD = , F8.4, 6( 13H WAVE ANGLE = , F7.2, 5H DEG. )
  522 FORMAT ( /A300 WAVE ENCOUNTER WAVE WAVE/SHIP )
  523 FORMAT ( I10, A2, 53M H E A V E * I T C H VERTICAL
  I R F A N , M T . )
  524 FORMAT ( 43M F R E Q U E N C I E S L E N G T H L E N G T H )
  525 FORMAT ( I10, A2, 3( 2A6, A4 ) )
  526 FORMAT ( I10, 7A3, 3A6, A3 / )
  527 FORMAT ( I10, A2, 8M S W A Y Y A W R O L
  Y I L A T E R A L R E N D . M T . T O R S I O N A L M O M E N T I )
  528 FORMAT ( I10, 9A1, 2( 3A6, A3 ) / )
  529 FORMAT ( I10, 4A1, 5A5 V E R T I C A L B E N D I N G L A T E R A L B E N D I N G
  X T O R S I O N A L )
  530 FORMAT ( 2F11.4, F11.3, F10.4, F8.4, F8.1, F8.4, F8.1, E13.3, F8.1 )
  531 FORMAT ( 2F11.5, F11.3, F10.4, F8.4, F8.1, F8.4, F8.1, F8.4, F8.1,
  F
  E17.2, F8.1, E13.3, F8.1 )
  532 FORMAT ( I10, A2, 10A6 / )
  533 FORMAT ( I10, A1, 32MSHEAR AND MOMENT CLOSURE RESULTS )
  534 FORMAT ( 2F11.4, F11.3, F10.4, 4E12.3 )
  535 FORMAT ( I10, 41E24M V E R T I C A L P L A N E R E S P O N S E S )
  536 FORMAT ( I10, 51E23M L A T E R A L P L A N E R E S P O N S E S )
  537 FORMAT ( I10, 7A2, 17M I N C O N - D I M E N S I O N A L )
  END

SUBROUTINE STATI
COMMON / MNDT / MDA(14),DTA,DTA,IB,IC,IO,IF,IF,IO,IM,II,IJ,STS(5)
COMMON / CASDA / NM,OHM(S),VUL(S),OMME(S),VMIN,VMAR,DELV,
  MFAWAD(25),WANGI,WAHBA,DAWANG,MWI,ND(20),WLL(S),
  I
COMMON / MIPD / IA,NS,DXI,V,WANG,OMEGA,WAVENS,CU,DXI(2),S),FACWA
COMMON / MOTN / ZM(S),ZP(S),YM(S),TP(S),SM(S),AP(S),YM(S),
  Y
  VS(S),RM(S),RP(S)
COMMON / RMDA / CFPST(2),CPL(2),CXMP(2),SBMM(S),3),SBMP(S),3)
COMMON / PROGRAM / CLSM(S),3),CLSH(S),2),SPACE(40),ZM(S),YM(S),
  X
  XM(S),VM(S)
  DIMENSION MDA(14),MDCP(4),MDCP(4), VM(S)
  DATA MDCP / OH ANP,OHM, PMA,ANSE /
  DATA MDCP / OH AN,OHM,ITOD,ANSE PMA,ANSE /
  DATA MDCP / OH AN,SHSHEAR,OH M,OHOMENT /
  TPI = 3.14159265
  WAM = 1.0/((1.0/WA-1.0)
  WC = (MS-1)/Z
  CL = 1.0/((OHM+OHPL*OHPL*OSTAR(NS)*WA)-1.0)*II+1.0
  IF ( KL.GT.2 ) GO TO 20

C-01 PRINT OUT FREQUENCY RESPONSE FUNCTIONS, VERTICAL PLANE
PRINT 920,MDA,DTA,DTB
PRINT 921, V=AD(IM)
PRINT 922
IF ( II.FO.1 ) PRINT 937
PRINT 927
PRINT 928
PRINT 929
PRINT 92A
PRINT 92B,MDCP,MDCP
PRINT 92C, MDCP,MDCP
DO 2A I=1,4M
  2A I = SHM(I)*OHM
  FNT = 1.0/((1.0/WUL(I)/TPI-1.0)
  YN(I) = YM(I)*FNT
  YN(I) = RM(I)*FNT
  VN(I) = SRMM(I)*FNT*OHM
  25 VN(I) = SRMM(I)*FNT*OHM
  PRINT 930, (OHM(I),OMME(I),VUL(I),WLL(I),ZM(I),SP(I),YM(I),VP(I),
  X
  XM(I),SBMP(I),I=1,4M)
  40 IF ( IM.LE.0 ) GO TO 60

C-02 PRINT OUT FREQUENCY RESPONSE FUNCTIONS, LATERAL PLANE
PRINT 920,MDA,DTA,DTB
PRINT 921, V=AD(IM)
PRINT 922
IF ( II.FO.1 ) PRINT 937
PRINT 927
PRINT 928
PRINT 929
PRINT 92A
PRINT 92B,MDCP,MDCP,MDCP(3),MDCP(4)
PRINT 92C, (OHM(I),OMME(I),VUL(I),WLL(I),ZM(I),SP(I),YM(I),VP(I),
  X
  XM(I),SBMP(I),I=1,4M)
  40 IF ( IM.LE.0 ) GO TO 60

C-03 PRINT OUT SHEAR AND MOMENT CLOSURE RESULTS
PRINT 920,MDA,DTA,DTB
PRINT 921, V=AD(IM)
PRINT 922
PRINT 927
PRINT 928
PRINT 929
PRINT 92A
PRINT 92B,MDCP,MDCP,MDCP(3),MDCP(4)
PRINT 92C, (OHM(I),OMME(I),VUL(I),WLL(I),ZM(I),SP(I),YM(I),VP(I),
  X
  XM(I),SBMP(I),I=1,4M)
  40 OBT=04
  520 FORMAT ( I10, I10, A2, 3( A10, A2 )
  521 FORMAT ( 9MSPEFD = , F8.4, 6( 13H WAVE ANGLE = , F7.2, 5H DEG. )
  522 FORMAT ( /A300 WAVE ENCOUNTER WAVE WAVE/SHIP )
  523 FORMAT ( I10, A2, 53M H E A V E * I T C H VERTICAL
  I R F A N , M T . )
  524 FORMAT ( 43M F R E Q U E N C I E S L E N G T H L E N G T H )
  525 FORMAT ( I10, A2, 3( 2A6, A4 ) )
  526 FORMAT ( I10, 7A3, 3A6, A3 / )
  527 FORMAT ( I10, A2, 8M S W A Y Y A W R O L
  Y I L A T E R A L R E N D . M T . T O R S I O N A L M O M E N T I )
  528 FORMAT ( I10, 9A1, 2( 3A6, A3 ) / )
  529 FORMAT ( I10, 4A1, 5A5 V E R T I C A L B E N D I N G L A T E R A L B E N D I N G
  X T O R S I O N A L )
  530 FORMAT ( 2F11.4, F11.3, F10.4, F8.4, F8.1, F8.4, F8.1, E13.3, F8.1 )
  531 FORMAT ( 2F11.5, F11.3, F10.4, F8.4, F8.1, F8.4, F8.1, F8.4, F8.1,
  F
  E17.2, F8.1, E13.3, F8.1 )
  532 FORMAT ( I10, A2, 10A6 / )
  533 FORMAT ( I10, A1, 32MSHEAR AND MOMENT CLOSURE RESULTS )
  534 FORMAT ( 2F11.4, F11.3, F10.4, 4E12.3 )
  535 FORMAT ( I10, 41E24M V E R T I C A L P L A N E R E S P O N S E S )
  536 FORMAT ( I10, 51E23M L A T E R A L P L A N E R E S P O N S E S )
  537 FORMAT ( I10, 7A2, 17M I N C O N - D I M E N S I O N A L )
  END

```

```

PRINT 925,MDAP,MDAP
PRINT 926,MDBP
DO 2A I=1,4M
  2A I = SHM(I)*OHM
  FNT = 1.0/((1.0/WUL(I)/TPI-1.0)
  YN(I) = YM(I)*FNT
  YN(I) = RM(I)*FNT
  VN(I) = SRMM(I)*FNT*OHM
  25 VN(I) = SRMM(I)*FNT*OHM
  PRINT 930, (OHM(I),OMME(I),VUL(I),WLL(I),ZM(I),SP(I),YM(I),VP(I),
  X
  XM(I),SBMP(I),I=1,4M)
  40 IF ( IM.LE.0 ) GO TO 40

C-02 PRINT OUT FREQUENCY RESPONSE FUNCTIONS, LATERAL PLANE
PRINT 920,MDA,DTA,DTB
PRINT 921, V=AD(IM)
PRINT 922
IF ( II.FO.1 ) PRINT 937
PRINT 927
PRINT 928
PRINT 929
PRINT 92A
PRINT 92B,MDAP,MDAP,MDAP
PRINT 92C, MDCP,MDCP
DO 2A I=1,4M
  2A I = SHM(I)*OHM
  FNT = 1.0/((1.0/WUL(I)/TPI-1.0)
  YN(I) = YM(I)*FNT
  YN(I) = RM(I)*FNT
  VN(I) = SRMM(I)*FNT*OHM
  25 VN(I) = SRMM(I)*FNT*OHM
  PRINT 930, (OHM(I),OMME(I),VUL(I),WLL(I),ZM(I),SP(I),YM(I),VP(I),
  X
  XM(I),SBMP(I),I=1,4M)
  40 IF ( IM.LE.0 ) GO TO 60

C-03 PRINT OUT SHEAR AND MOMENT CLOSURE RESULTS
PRINT 920,MDA,DTA,DTB
PRINT 921, V=AD(IM)
PRINT 922
PRINT 927
PRINT 928
PRINT 929
PRINT 92A
PRINT 92B,MDCP,MDCP,MDCP(3),MDCP(4)
PRINT 92C, (OHM(I),OMME(I),VUL(I),WLL(I),ZM(I),SP(I),YM(I),VP(I),
  X
  XM(I),SBMP(I),I=1,4M)
  40 OBT=04
  520 FORMAT ( I10, I10, A2, 3( A10, A2 )
  521 FORMAT ( 9MSPEFD = , F8.4, 6( 13H WAVE ANGLE = , F7.2, 5H DEG. )
  522 FORMAT ( /A300 WAVE ENCOUNTER WAVE WAVE/SHIP )
  523 FORMAT ( I10, A2, 53M H E A V E * I T C H VERTICAL
  I R F A N , M T . )
  524 FORMAT ( 43M F R E Q U E N C I E S L E N G T H L E N G T H )
  525 FORMAT ( I10, A2, 3( 2A6, A4 ) )
  526 FORMAT ( I10, 7A3, 3A6, A3 / )
  527 FORMAT ( I10, A2, 8M S W A Y Y A W R O L
  Y I L A T E R A L R E N D . M T . T O R S I O N A L M O M E N T I )
  528 FORMAT ( I10, 9A1, 2( 3A6, A3 ) / )
  529 FORMAT ( I10, 4A1, 5A5 V E R T I C A L B E N D I N G L A T E R A L B E N D I N G
  X T O R S I O N A L )
  530 FORMAT ( 2F11.4, F11.3, F10.4, F8.4, F8.1, F8.4, F8.1, E13.3, F8.1 )
  531 FORMAT ( 2F11.5, F11.3, F10.4, F8.4, F8.1, F8.4, F8.1, F8.4, F8.1,
  F
  E17.2, F8.1, E13.3, F8.1 )
  532 FORMAT ( I10, A2, 10A6 / )
  533 FORMAT ( I10, A1, 32MSHEAR AND MOMENT CLOSURE RESULTS )
  534 FORMAT ( 2F11.4, F11.3, F10.4, 4E12.3 )
  535 FORMAT ( I10, 41E24M V E R T I C A L P L A N E R E S P O N S E S )
  536 FORMAT ( I10, 51E23M L A T E R A L P L A N E R E S P O N S E S )
  537 FORMAT ( I10, 7A2, 17M I N C O N - D I M E N S I O N A L )
  END

SUBROUTINE STATI
COMMON / MNDT / MDA(14),DTA,DTA,IB,IC,IO,IF,IF,IO,IM,II,IJ,STS(5)
COMMON / CASDA / NM,OHM(S),VUL(S),OMME(S),VMIN,VMAR,DELV,
  MFAWAD(25),WANGI,WAHBA,DAWANG,MWI,ND(20),WLL(S),
  I
COMMON / MIPD / IA,NS,DXI,V,WANG,OMEGA,WAVENS,CU,DXI(2),S),FACWA
COMMON / MOTN / ZM(S),ZP(S),YM(S),TP(S),SM(S),AP(S),YM(S),
  Y
  VS(S),RM(S),RP(S)
COMMON / RMDA / CFPST(2),CPL(2),CXMP(2),SBMM(S),3),SBMP(S),3)
COMMON / PROGRAM / CLSM(S),3),CLSH(S),2),SPACE(40),ZM(S),YM(S),
  X
  XM(S),VM(S)
  DIMENSION MDA(14),MDCP(4),MDCP(4), VM(S)
  DATA MDCP / OH ANP,OHM, PMA,ANSE /
  DATA MDCP / OH AN,OHM,ITOD,ANSE PMA,ANSE /
  DATA MDCP / OH AN,SHSHEAR,OH M,OHOMENT /
  TPI = 3.14159265
  WAM = 1.0/((1.0/WA-1.0)
  WC = (MS-1)/Z
  CL = 1.0/((OHM+OHPL*OHPL*OSTAR(NS)*WA)-1.0)*II+1.0
  IF ( KL.GT.2 ) GO TO 20

C-01 PRINT OUT FREQUENCY RESPONSE FUNCTIONS, VERTICAL PLANE
PRINT 920,MDA,DTA,DTB
PRINT 921, V=AD(IM)
PRINT 922
IF ( II.FO.1 ) PRINT 937
PRINT 927
PRINT 928
PRINT 929
PRINT 92A
PRINT 92B,MDCP,MDCP
PRINT 92C, MDCP,MDCP
DO 2A I=1,4M
  2A I = SHM(I)*OHM
  FNT = 1.0/((1.0/WUL(I)/TPI-1.0)
  YN(I) = YM(I)*FNT
  YN(I) = RM(I)*FNT
  VN(I) = SRMM(I)*FNT*OHM
  25 VN(I) = SRMM(I)*FNT*OHM
  PRINT 930, (OHM(I),OMME(I),VUL(I),WLL(I),ZM(I),SP(I),YM(I),VP(I),
  X
  XM(I),SBMP(I),I=1,4M)
  40 IF ( IM.LE.0 ) GO TO 60

C-02 PRINT OUT FREQUENCY RESPONSE FUNCTIONS, LATERAL PLANE
PRINT 920,MDA,DTA,DTB
PRINT 921, V=AD(IM)
PRINT 922
IF ( II.FO.1 ) PRINT 937
PRINT 927
PRINT 928
PRINT 929
PRINT 92A
PRINT 92B,MDAP,MDAP,MDAP
PRINT 92C, MDCP,MDCP
DO 2A I=1,4M
  2A I = SHM(I)*OHM
  FNT = 1.0/((1.0/WUL(I)/TPI-1.0)
  YN(I) = YM(I)*FNT
  YN(I) = RM(I)*FNT
  VN(I) = SRMM(I)*FNT*OHM
  25 VN(I) = SRMM(I)*FNT*OHM
  PRINT 930, (OHM(I),OMME(I),VUL(I),WLL(I),ZM(I),SP(I),YM(I),VP(I),
  X
  XM(I),SBMP(I),I=1,4M)
  40 IF ( IM.LE.0 ) GO TO 60

C-03 PRINT OUT SHEAR AND MOMENT CLOSURE RESULTS
PRINT 920,MDA,DTA,DTB
PRINT 921, V=AD(IM)
PRINT 922
PRINT 927
PRINT 928
PRINT 929
PRINT 92A
PRINT 92B,MDCP,MDCP,MDCP(3),MDCP(4)
PRINT 92C, (OHM(I),OMME(I),VUL(I),WLL(I),ZM(I),SP(I),YM(I),VP(I),
  X
  XM(I),SBMP(I),I=1,4M)
  40 OBT=04
  520 FORMAT ( I10, I10, A2, 3( A10, A2 )
  521 FORMAT ( 9MSPEFD = , F8.4, 6( 13H WAVE ANGLE = , F7.2, 5H DEG. )
  522 FORMAT ( /A300 WAVE ENCOUNTER WAVE WAVE/SHIP )
  523 FORMAT ( I10, A2, 53M H E A V E * I T C H VERTICAL
  I R F A N , M T . )
  524 FORMAT ( 43M F R E Q U E N C I E S L E N G T H L E N G T H )
  525 FORMAT ( I10, A2, 3( 2A6, A4 ) )
  526 FORMAT ( I10, 7A3, 3A6, A3 / )
  527 FORMAT ( I10, A2, 8M S W A Y Y A W R O L
  Y I L A T E R A L R E N D . M T . T O R S I O N A L M O M E N T I )
  528 FORMAT ( I10, 9A1, 2( 3A6, A3 ) / )
  529 FORMAT ( I10, 4A1, 5A5 V E R T I C A L B E N D I N G L A T E R A L B E N D I N G
  X T O R S I O N A L )
  530 FORMAT ( 2F11.4, F11.3, F10.4, F8.4, F8.1, F8.4, F8.1, E13.3, F8.1 )
  531 FORMAT ( 2F11.5, F11.3, F10.4, F8.4, F8.1, F8.4, F8.1, F8.4, F8.1,
  F
  E17.2, F8.1, E13.3, F8.1 )
  532 FORMAT ( I10, A2, 10A6 / )
  533 FORMAT ( I10, A1, 32MSHEAR AND MOMENT CLOSURE RESULTS )
  534 FORMAT ( 2F11.4, F11.3, F10.4, 4E12.3 )
  535 FORMAT ( I10, 41E24M V E R T I C A L P L A N E R E S P O N S E S )
  536 FORMAT ( I10, 51E23M L A T E R A L P L A N E R E S P O N S E S )
  537 FORMAT ( I10, 7A2, 17M I N C O N - D I M E N S I O N A L )
  END

```

```

DO 7 L=1,NM
3 RSP(I,J) = 0.0
C-02 CALCULATE RESPONSE SPECTRA (AND INTEGRATE), FOR EACH SEA STATE
1 DO 10 K=1,NM1
C-03 VERTICAL AND LATERAL MOTIONS
70 7 L=1,NM
Y(L) = APEC(K,L)*RAN(L,J)**2/WAS
2 RSP(I,J) = Y(L)
4 RSD(I,K,IW) = SINT(I,NM)*DEL
IF ( I.E.LT.2 ) GO TO 9
C-04 ROLLING AND TORSIONAL MOMENTS
DO 8 I=1,NM
70 8 L=1,NM
Y(L) = (SPECK(L)*SRM(L,J)**2)*FAC/WAS
4 RSP(I,J) = Y(L)
4 RSD(I,K,IW) = SINT(I,NM)*DEL
C-05 CALCULATE RESPONSE STATISTICS
8 DO 10 L=1,NM
RST(L,1) = RSD(L,K,IW)
RST(L,2) = SORT(RST(L,1))
RST(L,3) = RST(L,2)*1.25
RST(L,4) = RST(L,2)*2.0
15 RST(L,5) = RST(L,2)*2.55
C-06 PRINT OUT RESPONSE SPECTRA AND STATISTICS
PRINT 920,MDA,DTA,OTR
PRINT 921,V,WIND(IW)
IF ( I.E.LT.3 ) PRINT 923,WDIK
IF ( I.E.LT.3 ) PRINT 925,WDIK,WDIK*10
PRINT 922
PRINT 924
PRINT 926,(OMV(I),OMV(I),VVL(I),(RSP(I,J,I=1,8),I=1,NM)
PRINT 928,(RST(L,I),L=1,5),I=1,5)
10 CONTINUE
RETURN
920 FORMAT ( 1M1, 13A6, A2, 3X, A10, A2)
921 FORMAT ( 8MSPEED = , F6.4, 8X, 13MWAVE ANGLE = , F7.2, 6M DEG.,
X 8AX, 28MRESPONSE (AMPLITUDE) SPECTRA )
922 FORMAT ( 33M WAVE 24COUNTER WAVE )
923 FORMAT ( 11M+5A2-13MIND SPEED = , F6.2, 7M KNOTS, )
924 FORMAT ( 33M F R E Q U E N C I E 7 LENGTH = 5X, 91MHEAVE
X PITCH S W A Y Y A W R O L L VERT.B.M. LAT.B.M
X, TORSHL.M. / )
925 FORMAT ( 1M1, 15M510, WAVE HT. = , F6.2, 16M, MEAN PERIOD = , F6.2 )
926 FORMAT ( 2F11.5, F11.2, 8C12.3 )
927 FORMAT ( 1M1, 2A6, A6, 8E12.3 / 4 27X, A6, 8E12.3 / )
END

```

```

20 CONTINUE
SPPI = SINT(1,NA*SPF,RMAX6)
C ZERO SRS ARRAY
DO 24 I=1,8
DO 25 J=1,10
DO 26 L=1,5
25 SRS(I,J,L) = 0.0
C-02 LOOP OVER PREDOMINANT WAVE HEADING ANGLES
DO 30 A= NM1,NM8
WHDS = WANGI*DWANG*(RM-1)
IF ( NM8.EQ.1 ) WHDS = 180.0
C-03 LOOP OVER WIND SPEED
DO 31 K=1,NM1
C-04 LOOP OVER RESPONSES
DO 50 J=K,JU
JJ = J
IF ( JJ.EQ.6 ) GO TO 50
C-05 INTERATION LOOP OVER WAVE ANGLE
30 DO 40 NM1,NA
IF ( NM8.EQ.1 ) 30 TO 32
NMH = NM
DO 40 TO 40
32 NMH = NM*(NM-NA+1)/2
IF ( NMH.EQ.NA ) NMH = 2*NA-NMH
IF ( NMH.LT.1 ) NMH = 2-NMH
40 Y(NH) = RSD(JJ,K,NMH)*SPF(NH)
SRS(JJ,K,1) = SINT(1,NA*Y,RWANG)/SPPI
IF ( NM8.EQ.1 ) SRS(JJ,K,1) = 2.0*SRS(JJ,K,1)
4RS(JJ,K,2) = SORT(SRS(JJ,K,1))
4RS(JJ,K,3) = SRS(JJ,K,2)*1.25
4RS(JJ,K,4) = SRS(JJ,K,2)*2.0
4RS(JJ,K,5) = SRS(JJ,K,2)*2.55
IF ( JJ.EQ.2 ) GO TO 50
JJ = 6
GO TO 30
50 CONTINUE
60 CONTINUE
C-05 PRINT OUT RESULTS AT EACH PREDOMINANT HEADING
PRINT 920, MDA,DTA,OTR
PRINT 921, V,WIND(IW)*STP(IF=2-),STP(IF=2)
PRINT 922
DO 70 K=1,NM1
PRINT 928, K,(RST(L,I),(SRS(J,K,L),J=1,8),L=1,5)
70 CONTINUE
80 CONTINUE
RETURN
920 FORMAT ( 1M1, 13A6, A2, 3X, A10, A2)
28MPREDOMINANT HEADING
921 FORMAT ( 8MSPEED = , F6.4, 8X, 13MWAVE ANGLE = , F7.2, 6M DEG.,
X0 ANGLE = , F7.2, 6M DEG., 30M SHORT-CREATED SEAS ( , 2A6, 26M SRE
XADING) RESPONSE STAT. / )
922 FORMAT ( 11X, 22M SPECTRA NO. STATISTEC = 5X, 91MHEAVE
X PITCH S W A Y Y A W R O L L VERT.B.M. LAT.B.M
X, TORSHL.M. / )
925 FORMAT ( 120, 7X, A6, 8E12.3 / 4 27X, A6, 8E12.3 / )
END

```

SHIP RESEARCH COMMITTEE
Maritime Transportation Research Board
National Academy of Sciences-National Research Council

The Ship Research Committee has technical cognizance of the inter-agency Ship Structure Committee's research program:

PROF. R. A. YAGLE, Chairman, *Prof. of Naval Architecture, University of Michigan*
DR. H. N. ABRAMSON, *Director, Dept. of Mechanical Sciences, Southwest Research Inst.*
MR. W. H. BUCKLEY, *Coordinator of Hydrofoil Struc. Res., Naval Ship R & D Center*
MR. E. L. CRISCUOLO, *Senior Non-destructive Testing Spec., Naval Ordnance Lab.*
DR. W. D. DOTY, *Research Consultant, U. S. Steel Corporation*
PROF. J. E. GOLDBERG, *School of Civil Engineering, Purdue University*
PROF. W. J. HALL, *Prof. of Civil Engineering, University of Illinois*
MR. J. E. HERZ, *Chief Structural Design Engineer, Sun Shipbuilding & Dry Dock Co.*
MR. G. E. KAMPSCHAEFER, JR., *Manager, Application Engineering, ARMCO Steel Corporation*
MR. R. C. STRASSER, *Director of Research, Newport News Shipbuilding & Dry Dock Co.*
CAPT R. M. WHITE, USCG, *Chief, Applied Engineering Section, U. S. Coast Guard Academy*
MR. R. W. RUMKE, *Executive Secretary, Ship Research Committee*

Advisory Group I, "Ship Response and Load Criteria" prepared the project prospectus and evaluated the proposals for this project.

DR. H. N. ABRAMSON, Chairman, *Director, Dept. of Mech. Sciences, Southwest Res. Inst.*
MR. W. H. BUCKLEY, *Coordinator of Hydrofoil Struc. Res., Naval Ship R & D Center*
PROF. A. M. FREUDENTHAL, *College of Engineering, George Washington University*
MR. R. G. KLINE, *Associate Research Consultant, U. S. Steel Corporation*
DR. M. K. OCHI, *Research Scientist, Naval Ship R & D Center*
MR. R. C. STRASSER, *Director of Research, Newport News Shipbuilding & Dry Dock Co.*
CAPT R. M. WHITE, USCG, *Chief, Applied Engineering Section, U. S. Coast Guard Academy*

The SR-174 Project Advisory Committee provided the liaison technical guidance, and reviewed the project reports with the investigator.

DR. H. N. ABRAMSON, Chairman, *Director, Dept. of Mech. Sciences, Southwest Res. Inst.*
MR. M. K. OCHI, *Research Scientist, Naval Ship R & D Center*
MR. R. C. STRASSER, *Director of Research, Newport News Shipbuilding & Dry Dock Co.*

SHIP STRUCTURE COMMITTEE PUBLICATIONS

These documents are distributed by the National Technical Information Service, Springfield, Va. 22161. These documents have been announced in the Clearinghouse Journal U.S. Government Research & Development Reports (USGRDR) under the indicated AD numbers.

- SSC-219, *Crack Propagation and Arrest in Ship and Other Steels* by G. T. Hahn, R. G. Hoagland, P. N. Mincer, A. R. Rosenfield, and M. Sarrate. 1971.
- SSC-220, *A Limited Survey of Ship Structural Damage* by S. Hawkins, G. H. Levine, and R. Jaggart. 1971.
- SSC-221, *Response of the Delta Test to Specimen Variables* by L. J. McGeady. 1971.
- SSC-222, *Catamarans - Technological Limits to Size and Appraisal of Structural Design Information and Procedures* by N. M. Maniar and W. P. Chiang. 1971.
- SSC-223, *Compressive Strength of Ship Hull Girders - Part II - Stiffened Plates* by H. Becker, A. Colao, R. Goldman, and J. Pczerycki. 1971.
- SSC-224, *Feasibility Study of Glass Reinforced Plastic Cargo Ship* by R. J. Scott and J. H. Sommella. 1971.
- SSC-225, *Structural Analysis of Longitudinally Framed Ships* by R. Nielson, P. Y. Chang, and L. C. Deschamps. 1972.
- SSC-226, *Tanker Longitudinal Strength Analysis - User's Manual and Computer Program* by R. Nielson, P. Y. Chang, and L. C. Deschamps. 1972.
- SSC-227, *Tanker Transverse Strength Analysis - User's Manual* by R. Nielson, P. Y. Chang, and L. C. Deschamps. 1972.
- SSC-228, *Tanker Transverse Strength Analysis - Programmer's Manual* by R. Nielson, P. Y. Chang, and L. C. Deschamps. 1972.
- SSC-229, *Evaluation and Verification of Computer Calculations of Wave-Induced Ship Structural Loads* by P. Kaplan and A. I. Raff. 1972.
- SSC-230, *Program JCORES -- Ship Structural Response in Waves* by A. I. Raff. 1972.
- SSC-231, *Further Studies of Computer Simulation of Slamming and Other Wave-Induced Vibratory Structural Loadings on Ships in Waves* by P. Kaplan and T. P. Sargent. 1972.