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#### DYNAMIC RESPONSE OF NONUNIFORM STRUCTURES

#### TO CLASSES OF PRESSURE FIELDS

Milt G. Cottis KMS Technology Center 7810 Burnet Avenue Van Nuys, California 91405

> October 1971 Final Report

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The computer codes presented in Section 3.0 were written by Mr. R. Janda of the Computing Group, KMS Technology Center. The NASTRAN calculation of the sample problem (Section 4.0) was carried out at Goddard Space Flight Center by Mr. G. Jones under the direction of Mr. J. P. Young, Technical Monitor for the study.

## TABLE OF CONTENTS

	ACKNOWLEDGMENTS	iii
	LIST OF SYMBOLS	• <b>v</b>
1.0	PROBLEM DEFINITION AND APPROACH	1
2.0	ANALYSIS	5
	2.1 Basic Equations	5
	2.2 The Impulse Response Function	9
	2.3 The Input Function	13
	2.4 Response Calculation	18
	2.4.1 Response to Deterministic Excitation	18
	2.4.2 Response to Random Excitation	22
3.0	COMPUTER CODE - USER'S GUIDE	32
	3.1 Curve-Fitting Routine for Structural Mode Shapes (FITMSC)	32
	3.2 Response to Deterministic Excitation (DEXCYL)	48
	3.3 Response to Random Excitation (RANCYL)	72
4.0	SAMPLE PROBLEM - COMPARISON WITH NASTRAN CODE	107
5.0	CONCLUDING REMARKS	152
	REFERENCES	155
	APPENDIX - Evaluation of $P_{pr}(L)$ , $S_{qs}(2\pi)$	<b>A</b> 1

## LIST OF SYMBOLS

a n	structural damping in the nth mode
$G(r, r_o; t-t_o)$	impulse response function
L	length of cylindrical shell
M <sub>n</sub>	modal mass
m, n	mode numbers in circumferential and axial directions, respectively
p(r, t)	input function
Q(r-r';t-t')	pressure cross-correlation function
$\mathbf{r}$	spatial variable
R	nominal radius of cylindrical shell
<b>t</b> .	temporal variable
U(x)	unit step function
w(r, t)	structural displacement response
W(r, r', t-t')	response cross-correlation function
x	x-x'
2	axial coordinate
Z.	zz'
δ(x)	delta function
θ	circumferential angle

θ-θ'

t-t'

θ

### LIST OF SYMBOLS (continued)

nth structural mode shape frequency variable (rad/sec) nth modal frequency denotes complex conjugate denotes absolute value of x denotes double sum over n and m

denotes Fourier transform of w

The following convention is adopted for one-dimensional Fourier transforms:

vi

 $\hat{f}(\omega) = \int_{-\infty}^{\infty} dt e^{-i\omega t} f(t)$ 

 $\psi_{n}(\mathbf{x})$ 

Ŵ

 $\omega_{n}$ 

x

 $\sum_{n, m}$ 

w

×

 $f(t) = (2\pi)^{-1} \int_{-\infty}^{\infty} d\omega e^{i\omega t} \hat{f}(\omega)$ 

#### PROBLEM DEFINITION AND APPROACH

In view of the advances made in recent years in the development of aero and space vehicles, as well as naval vessels, an enormous amount of literature has been produced on the subject of structural dynamics (Reference 1). The behavior of structures when excited by the various pressure fields which are encountered in operation is crucial to the proper design of such vehicles and to the operation of on-board systems. By and large, available calculations of structural response follow one of two basic procedures: Analytical methods are employed in cases where the structure can be idealized to a sufficiently simple one and where the excitation can be represented by a relatively simple function; when the structure is complex (nonuniform), numerical techniques are used of which the most common involves the construction of a discrete structural model which approximates the original continuous structure (discrete element approach, Reference 2).

It is the purpose of the study reported herein to bridge the gap between those two approaches, that is, to use that portion of the discrete element approach (or, other numerical technique) which analytical methods cannot handle, in combination with an analytical calculation of the dynamic response. Inasmuch as the free vibrations of a complex structure cannot, in general, be established, analytically, this portion of the calculation is left to numerical techniques. Once results to the eigenvalue problem are available, however, analytical methods are used to complete the dynamic response calculation. This study employs the impulse response, or Green's function technique.

Two pieces of information are required in the application of the impulse response method: the impulse response function appropriate

1.0

to the structure at hand and an appropriate input function which describes the spatial-temporal distribution of pressure over the structure. The impulse response function can always be written in the form of an eigenfunction expansion, so that, knowledge of the structural mode shapes and normal frequencies suffices (References 3, 4). For complex structures of given geometry (i.e., describable in a given coordinate system), this study assumes parametric forms for the associated mode shapes, where the arbitrary parameters can be fixed once the numerical solution to the eigenvalue problem is available. These parametric forms are used in the expression for the impulse response function which, in turn, is used in the analytical calculation of the dynamic response. On the other hand, input functions are also parameterized in such a way that a whole class of functions can be considered simultaneously in the response calculation. This class represents most physically realizable pressure fields of practical concern. The result is a "bank" of response solutions where the arbitrary parameters can be fixed once (a) the numerical values for the mode shapes at a number of discrete points and values for the associated normal frequencies are available, and (b) a particular input function is given.

In any given application, this procedure constitutes, in effect, a hybrid calculation of structural response: the structure is discretized and the eigenvalue problem is solved by the use of appropriate computer codes; however, the calculation of the dynamic response does

\*In practical terms, the expansion of the Green's function in terms of structural mode shapes is generally valid if the damping is small. The assumption that such an expansion is possible is analogous to the assumption made for discrete systems with regard to the existence of a matrix which diagonalizes both M<sup>-1</sup>K and M<sup>-1</sup>C, where M, K, C are the mass, spring and damping matrices, respectively (see Ref. 5).

not proceed numerically, but rather, the results of the eigenvalue routine are used to define values for the arbitrary parameters in the analytical response solutions. The above procedure is depicted in Figure 1. This study has applied it to one-dimensional structures (beams) and circular cylindrical shells in the case of either deterministic or random excitation.

Section 2.0 presents the fundamental equations employed by the impulse response method, the parametric forms for the structural mode shapes (impulse response function) and for the input function and the calculation of the response due to both deterministic and random pressure fields. Section 3.0 details the computer codes based on the analytical results and Section 4.0 applies the tools developed in this study to a specific engineering problem. The identical problem is also solved with the use of the NASTRAN code and the results of the two approaches are compared. NASTRAN is a general-purpose digital computer program designed to analyze the behavior of elastic structures under a range of loading conditions using a finite-element displacement method approach. A wide range of analytical capability is built into NASTRAN including modal analysis and the determination of the response of structures due to random loads, which were the two features of NASTRAN used in this investigation. General remarks with regard to the method and results of this study follow in Section 5.0.



Approach in the calculation of the dynamic response of nonuniform structures. Figure 1.

#### 2.0 ANALYSIS

#### 2.1 Basic Equations

The linear displacement response of a structure obeys an equation of motion of the form

$$Q_{r,t} w(r,t) = p(r,t)$$

where  $Q_{r,t}$  is a linear differential operator in the spatial and temporal variables r and t, w(r,t) is the vibratory displacement response and p(r,t) the forcing, or input function which describes the spatial-temporal distribution of pressure over the structure. Two special cases of Equation (1) arise when p(r,t) is zero or an impulse:

(1)

(2)

(3)

(4)

$$Q_{r,t} w(r,t) = 0$$

$$Q_{r,t} G(r,r_{o};t-t_{o}) = \delta(r-r_{o}) \delta(t-t_{o})$$

Equation (2) defines the free vibrations of the structure, that is, its solution yields the appropriate eigenfunctions (mode shapes) and eigenvalues (normal frequencies). Equation (3) defines the impulse response, or Green's function for the structure. It is the response at position r at time t due to an impulse at position  $r_0$  at time  $t_0$ ; the impulse is represented by the product of delta functions.

Symbolically, the solution to Equation (1) is given by

$$w(r, t) = Q_{r, t}^{-1} p(r, t)$$

where  $Q_{r,t}^{-1}$  is the inverse of the operator  $Q_{r,t}$ , that is, an integral

F

operator. The kernel of this integral operator is the solution to Equation (3),  $G(r, r_0; t-t_0)$ . If initially the displacement and velocity responses are zero, Equation (4) has the explicit form

$$w(r, t) = \int_{S} dr_{o} \int_{o}^{t} dt_{o} G(r, r_{o}; t-t_{o}) p(r_{o}, t_{o})$$
(5)

where it is assumed that the operator  $Q_{r,t}$  is hermitian under the boundary conditions of the problem at hand, and where the spatial integration is over the surface of the structure, S. The Green's function is causal, that is,  $G(r, r_0; t-t_0) = 0$  for  $t < t_0$  and, therefore, the upper time limit in Equation (5) can be extended to  $+\infty$ . One can also extend the lower time limit to  $-\infty$  by incorporating a unit step function in the definition of the input function, that is, p(r,t) = p(r,t) U(t) where U(t) is defined as

U(t) = 0 for t < 0= 1 for t > 0

Then Equation (5) reads

$$w(\mathbf{r}, \mathbf{t}) = \int_{\mathbf{S}} d\mathbf{r}_{0} \int_{-\infty}^{\infty} d\mathbf{t}_{0} G(\mathbf{r}, \mathbf{r}_{0}; \mathbf{t} - \mathbf{t}_{0}) p(\mathbf{r}_{0}, \mathbf{t}_{0})$$
(6)

The Fourier transform of Equation (6) with respect to the time t is

$$\hat{\mathbf{w}}(\mathbf{r}, \omega) = \int_{\mathbf{S}} d\mathbf{r}_{o} \, \hat{\mathbf{G}}(\mathbf{r}, \mathbf{r}_{o}; \, \omega) \, \hat{\mathbf{p}}(\mathbf{r}_{o}, \omega)$$
(7)

where  $\hat{w}$ ,  $\hat{G}$ ,  $\hat{p}$  are the Fourier transforms of w, G, p, respectively. For a one-dimensional structure (beam) of length L, Equation (7) reads

$$\hat{\mathbf{w}}(\mathbf{x}, \boldsymbol{\omega}) = \int_{\mathbf{0}}^{\mathbf{L}} d\mathbf{x}_{\mathbf{0}} \, \hat{\mathbf{G}}(\mathbf{x}, \mathbf{x}_{\mathbf{0}}; \boldsymbol{\omega}) \, \hat{\mathbf{p}}(\mathbf{x}_{\mathbf{0}}, \, \boldsymbol{\omega})$$
(8)

while for a cylindrical shell of circular cross section and of length L,

$$\hat{\mathbf{w}}(\mathbf{z},\theta,\boldsymbol{\omega}) = R \int_{0}^{L} d\mathbf{z}_{0} \int_{0}^{2\pi} d\theta_{0} \hat{\mathbf{G}}(\mathbf{z},\theta,\mathbf{z}_{0},\theta;\boldsymbol{\omega}) \hat{\mathbf{p}}(\mathbf{z}_{0},\theta,\boldsymbol{\omega}) \qquad (9)$$

where R is the nominal radius and  $z, \theta$  are the axial coordinate and circumferential angle, respectively.

If the excitation is random, the response is given by an appropriate statistical average of Equation (6). The most general average of practical concern is the response cross-correlation function between two space-time points (r,t) and (r',t'); it is given by

$$\langle \mathbf{w}(\mathbf{r},\mathbf{t}) \mathbf{w}^{*}(\mathbf{r}',\mathbf{t}') \rangle = \int_{\mathbf{S}} d\mathbf{r}_{o} \int_{\mathbf{S}} d\mathbf{r}'_{o} \int_{-\infty}^{\infty} d\mathbf{t}_{o} \int_{-\infty}^{\infty} d\mathbf{t}'_{o} G(\mathbf{r},\mathbf{r}_{o};\mathbf{t}-\mathbf{t}_{o})$$

•  $G^{*}(r', r'; t'-t'_{o}) < p(r_{o}, t_{o}) p^{*}(r'_{o}, t'_{o}) >$ 

where (\*) denotes complex conjugate and  $\langle \cdots \rangle$  denotes the averaging process. The response autocorrelation, spatial correlation and mean square value result from Equation (10) by setting r = r', t = t' and the combination r = r', t = t', respectively. It is assumed that the pressure field is homogeneous in both space and time so that, the associated correlation function depends on the separation between the points (r,t) and (r',t'), that is

 $< p(r, t) p^{*}(r', t') > = Q(r-r'; t-t')$ 

(11)

(10)

Under these circumstances, the response correlation function is homogeneous in time, but not in space due to the finite extent of the structure, that is,

Using Equations (11), (12) in Equation (10) and taking the Fourier transform with respect to the variable  $\tau = t-t'$ , one obtains the response cross-spectral density:

$$\hat{W}(\mathbf{r},\mathbf{r}';\boldsymbol{\omega}) = \int_{\mathbf{G}} d\mathbf{r}_{o} \int_{\mathbf{G}} d\mathbf{r}'_{o} \hat{G}(\mathbf{r},\mathbf{r}_{o};\boldsymbol{\omega}) \hat{G}^{*}(\mathbf{r},\mathbf{r}_{o};\boldsymbol{\omega}) \hat{Q}(\mathbf{r}_{o}-\mathbf{r}'_{o};\boldsymbol{\omega})$$
(13)

where  $\hat{W}, \hat{Q}$  are the Fourier transforms of W,Q, respectively. The power spectral density results from Equation (13) by setting r = r'. In one dimension, Equation (13) reduces to

$$\hat{W}(\mathbf{x},\mathbf{x}';\omega) = \int_{0}^{L} d\mathbf{x}_{0} \int_{0}^{L} d\mathbf{x}_{0}' \hat{G}(\mathbf{x},\mathbf{x}_{0};\omega) \hat{G}'(\mathbf{x}',\mathbf{x}_{0}';\omega) \hat{Q}(\mathbf{x}_{0}-\mathbf{x}_{0}';\omega)$$
(14)

while, for a cylindrical shell

$$\hat{W}(z,\theta,z',\theta';\omega) = R^2 \int_{0}^{L} dz_{0} \int_{0}^{L} dz'_{0} \int_{0}^{2\pi} d\theta_{0} \int_{0}^{2\pi} d\theta'_{0} \hat{G}(z,\theta,z_{0},\theta_{0};\omega)$$

$$\cdot \hat{G}^{*}(z',\theta',z'_{0},\theta'_{0};\omega) \hat{Q}(z_{0}-z'_{0},\theta_{0}-\theta'_{0};\omega) \qquad (15)$$

The analytic evaluation of Equations (8), (9), (14) and (15) for a whole class of input functions p(r,t) and Q(r-r',t-t') is the purpose of this study. To do this, one must specify functional forms for the impulse response and input functions.

Under the assumption of small damping, the impulse response function can be written in the following form of an eigenfunction expansion (Ref. 3, 4)

$$G(\mathbf{r}, \mathbf{r}_{o}; t-t_{o}) = \sum_{n} (\mathbf{M}_{n}\omega_{n})^{-1} \psi_{n}(\mathbf{r}) \psi_{n}^{*}(\mathbf{r}_{o}) g_{n}(t-t_{o})$$
(16)  
and  $\stackrel{\wedge}{G}(\mathbf{r}, \mathbf{r}_{o}; \omega) = \sum_{n} (\mathbf{M}_{n}\omega_{n})^{-1} \psi_{n}(\mathbf{r}) \psi_{n}^{*}(\mathbf{r}_{o}) g_{n}^{*}(\omega)$   
$$g_{n}(t-t_{o}) = \exp[-a_{n}(t-t_{o})] \sin[\omega_{n}(t-t_{o})] U(t-t_{o})$$
(17)

where  $\psi_n(r)$  are the structural mode shapes, n denotes the set of mode numbers required to specify a given mode, and  $M_n$ ,  $\omega_n$ ,  $a_n$  are the modal masses, frequencies and damping, respectively. For uniform structures, the modal mass is a constant equal to the surface mass density and for most common structural geometries, the mode shapes  $\psi_n(r)$  and frequencies  $\omega_n$  are known from the analytic solution of the eigenvalue problem. In the case of nonuniform structures, the discrete element approach is usually employed to obtain values for  $M_n$ ,  $\omega_n$  and  $\psi_n(r_i)$  at a discrete number of points on the structure  $r_i$ . This study assumes that such values are available in a given application which involves either a beam or a cylindrical shell. It is further assumed that trigonometric interpolation can be used to define a curve through the values of  $\psi_n(r_i)$  at the spatial points  $r_i$ . The analytic forms of such trigonometric fits to mode-shape data are

$$\psi_{n}(\mathbf{x}) = \sum A_{p}^{n} \sin k_{p}^{n} \mathbf{x} + B_{p}^{n} \cos k_{p}^{n}$$

(18)

$$\psi_{nm}(z,\theta) = \sum_{p} \sum_{q} \left\{ A_{pq}^{nm} \cos k_{p}^{n} \sin k_{q}^{m} + B_{pq}^{nm} \sin k_{p}^{n} \cos k_{q}^{m} + C_{pq}^{nm} \cos k_{q}^{n} \cos k_{q}^{m} + D_{pq}^{nm} \sin k_{p}^{n} \sin k_{q}^{n} \sin k_{q}^{n} \right\}$$

$$+ C_{pq}^{nm} \cos k_{p}^{n} \cos k_{q}^{m} + D_{pq}^{nm} \sin k_{p}^{n} \sin k_{q}^{n} \theta \left\{ (19) \right\}$$

Values for the constant coefficients A, B, C, D and wave numbers k in the above expansions can be determined by an appropriate curvefitting routine (Section 3.1). Knowledge of these values, however, is not required for the analytic calculation of the dynamic response. Note that Equation (19) does not assume separability in the variables z and  $\theta$ , that is,  $\psi_{nm}(z,\theta) \neq \psi_n(z) \psi_n(\theta)$ . Use of the exponential forms for the trigonometric functions in Equation (19) results in the following form

$$\psi_{nm}(z,\theta) = \sum_{p} \sum_{q} \left\{ a_{pq}^{nm} \varphi_{p}(z) \varphi_{q}(\theta) + a_{pq}^{nm*} \varphi_{p}^{*}(z) \varphi_{q}^{*}(\theta) + b_{pq}^{nm*} \varphi_{p}(z) \varphi_{q}(\theta) \right\}$$

$$+ b_{pq}^{nm*} \varphi_{p}(z) \varphi_{q}^{*}(\theta) + b_{pq}^{nm} \varphi_{p}^{*}(z) \varphi_{q}(\theta) \right\}$$

$$(20)$$
where  $\varphi_{p}(z) = e^{ik_{p}^{n}z}$ 

$$m_{0}$$

$$\varphi_{\mathbf{q}}(\theta) = \mathbf{e}^{\mathbf{I}\mathbf{K}} \mathbf{q}$$

(21)

$$a_{pq}^{nm} = \frac{1}{4i} \left( A_{pq}^{nm} + B_{pq}^{nm} \right) + \frac{1}{4} \left( C_{pq}^{nm} - D_{pq}^{nm} \right)$$
$$b_{pq}^{nm} = \frac{1}{4i} \left( A_{pq}^{nm} - B_{pq}^{nm} \right) + \frac{1}{4} \left( C_{pq}^{nm} + D_{pq}^{nm} \right)$$

The curve-fitting routine developed in this study (Section 3.1) makes use of the following ordering for the trigonometric expansion given by Equation (19):

 $\psi = a_1 + a_2 \cos \theta \cos Z + a_3 \cos \theta \cos 2Z + ...$ 

+  $a_n \cos 0\theta \cos [(n-1)Z] + a_{n+1} \cos \theta \cos 0Z$ 

+  $a_{n+2} \cos \theta \cos Z$  + . . . +  $a_{2n} \cos \theta \cos [(n-1)Z]$ 

 $+ a_{(m-1)n+1} \cos [(m-1)\theta] \cos \theta + \ldots$ 

+ a  $\cos \left[ (m-1) \theta \right] \cos \left[ (n-1) Z \right]$ 

+  $a_{mn+1} \cos 0\theta \sin 0Z$  + . . . +  $a_{mn+n} \cos 0\theta \sin [(n-1)Z]$ 

+  $a_{2mn-n+1} \cos [(m-1)\theta] \sin \theta + .$ 

+  $a_{2mn} \cos [(m-1)\theta] \sin [(n-1)Z]$ 

+  $a_{3mn-n+1} \sin [(m-1) \theta] \cos \theta Z + ...$ 

+  $a_{3mn} \sin [(m-1)\theta] \cos [(n-1)Z]$ 

+  $a_{3mn+1}$  sin 0 $\theta$  sin 0Z + . . +  $a_{3mn+n}$  sin 0 $\theta$  sin[(n-1)Z]

 $+ a_{4mn-n+1} \sin[(m-1)\theta] \sin \theta + \ldots$ 

+  $a_{4mn}$  sin [(m-1)  $\theta$ ] sin [(n-1) Z]

where  $Z = \pi z/L$  and where the subscripts n,m bear no relationship to the mode numbers. Hence the indicies associated with a particular combination of trigonometric terms are given as follows (see Section 3.1 for notation):

> $\cos i\theta \ \cos jZ \rightarrow NA$   $\cos i\theta \ \sin jZ \rightarrow NOFZ \cdot NTHA + NA$   $\sin i\theta \ \cos jZ \rightarrow 2 \cdot NOFZ \cdot NTHA + NA$   $\sin i\theta \ \cos jZ \rightarrow 3 \cdot NOFZ \cdot NTHA + NA$ where  $NA = i \cdot NOFZ + j + 1$

Equation (16), with Equations (17), (18) and (20), defines the Green's function which is employed in Section 2.4 to derive analytic response solutions for beams and cylindrical shells. In a given application, all constants which appear in the above equations can easily be fixed once the numerical solution to the associated eigenvalue problem is available (Section 4.0). Note that with proper choice of the coefficients A, B, C, D in Equations (18) and (19), Equation (16) reduces to the Green's function appropriate to a uniform beam or cylindrical shell (Refs. 3, 6). For instance, using Equation (18) with p = 1,  $A_1 = (2/L)^{1/2}$ ,  $B_1 = 0$ ,  $k_1^n = n\pi/L$  in Equation (16) yields the impulse response function for a uniform beam. It follows that the response solutions of Section 2.4 are valid for both uniform and nonuniform beams and cylindrical shells.

#### The Input Function

2.3

It is assumed that the input functions in Equations (8), (9), (14) and (15) are separable in the variables, that is,

$$\hat{p}(\mathbf{x}, \boldsymbol{\omega}) = p_1(\mathbf{x}) \hat{p}_3(\boldsymbol{\omega})$$
(22)

$$\hat{p}(z, \theta, \omega) = p_1(z) p_2(\theta) \hat{p}_3(\omega)$$
(23)

$$\hat{Q}(\mathbf{x}-\mathbf{x}';\omega) = Q_1(\mathbf{x}-\mathbf{x}') \hat{Q}_3(\omega)$$
 (24)

$$\hat{\hat{Q}}(z-z', \theta-\theta'; \omega) = Q_1(z-z') Q_2(\theta-\theta') \hat{\hat{Q}}_3(\omega)$$
(25)

The above assumption is standard in structural response calculations, though not fundamental to the methodology developed in this study. If one were to relax it, however, the mathematical manipulations would become essentially unmanageable.

We adopt a classification scheme for pressure fields, whereby input functions are classified according to the analyticity of their spectra \*

<sup>\*</sup>By analyticity of the input function spectrum, we mean the nature of the singularities of the corresponding Fourier transform in the complex plane.

(Refs. 7, 8). This property is sufficiently general to allow the grouping of different input functions into a class, and yet provides sufficient information for the analytic calculation of the response. In particular, we consider input functions whose Fourier transforms have any number of poles of arbitrary order. In the case of deterministic excitation, the proper forms are

$$\hat{\mathbf{p}}_{1}(\mathbf{k}) = \mathbf{A}_{0}\delta(\mathbf{k}) + \sum_{j=1}^{\infty} \mathbf{B}_{j}e^{-i\mathbf{k}\mathbf{x}_{j}} + \sum_{\alpha=1}^{\infty} \sum_{\beta=1}^{\infty} \frac{\mathbf{C}_{\alpha,\beta}}{(\mathbf{k}-\mathbf{K}_{\alpha})^{\beta}}$$
(26)

$$\hat{p}_{3}(\omega) = H_{o}\delta(\omega) + \sum_{s=1}^{\infty} K_{s}e^{-i\omega t} + \sum_{\eta=1}^{\infty} \sum_{\sigma=1}^{\infty} \frac{N_{\eta,\sigma}}{(\omega - \nu_{\eta})^{\sigma}}$$
(27)

where k is the Fourier conjugate of the coordinate x, or z and  $\hat{p}_{1}(k)$  is the Fourier transform of  $p_{1}(x)$ , or  $p_{1}(z)$ . The first two terms in Equations (26), (27) have been included to account for the possibility of a discrete (delta function) and constant part of the spectrum. The last terms account for the singular portion of the spectrum in the complex k and  $\omega$  planes. It is composed of an arbitrary number of complex poles  ${}^{k}\alpha$ ,  $\nu_{\eta}$  of arbitrary order. The poles are located in the upper half-plane only, that is, they have a positive imaginary part; e.g.,  $\nu_{\eta} = \nu'_{\eta} + i\nu''_{\eta}$ ,  $\nu''_{\eta} \geq 0$ . The inverse Fourier transforms of Equations (26), (27) are given by

<sup>®</sup>Such functions are termed meromorphic.

\*\*Since  $p_3(t)$  is causal, i.e.,  $p_3(t) = 0$  for t < 0, the poles  $v_{\eta}$  must necessarily be in the upper  $\omega$  half-plane. Also, one can associate a step function with  $p_1(x)$  or  $p_1(z)$  since the integrations in Equations (8) and (9) start at zero and thus treat them as "causal" functions. This requires the poles  $\kappa$  to be located in the upper k half-plane.

$$p_{1}(\mathbf{x}) = \mathbf{A}_{o} + \sum_{j=1}^{B} \mathbf{B}_{j} \, \delta(\mathbf{x} - \mathbf{x}_{j}) + i \mathbf{U}(\mathbf{x}) \sum_{\alpha = 1}^{C} \sum_{\beta = 1}^{C} \frac{C_{\alpha,\beta}}{(\beta - 1)!} e^{i \kappa \alpha^{\mathbf{x}}} (i \mathbf{x})^{\beta - 1}$$
(28)

$$P_{3}(t) = H_{o} + \sum_{s=1}^{K} K_{s} \delta(t-t_{s}) + iU(t) \sum_{\eta=1}^{N} \sum_{\sigma=1}^{N} \frac{\eta_{\sigma}\sigma}{(\eta-1)!} e^{i\nu\eta^{t}} (it)^{\sigma-1}$$
(29)

where the  $(1/2 \pi)$  factor in the inversion formula has been absorbed in the constant coefficients.  $p_1(z)$  is given by Equation (28) with x replaced by z. In analogy to the above expressions, we assume the following form for the angular distribution of pressure.

$$\mathbf{p}_{2}(\boldsymbol{\theta}) = \mathbf{D}_{o} + \sum_{j'=1}^{\prime} \mathbf{E}_{j'} \delta(\boldsymbol{\theta}_{-}\boldsymbol{\theta}_{j'}) + \mathbf{i} \sum_{\boldsymbol{\alpha}'=1}^{\prime} \sum_{\boldsymbol{\beta}'=1}^{\prime} \frac{\mathbf{F}_{\boldsymbol{\alpha}',\boldsymbol{\beta}'}}{(\boldsymbol{\beta}'-1)!} \mathbf{e}^{\mathbf{i}\,\boldsymbol{\kappa}_{\boldsymbol{\alpha}'}\boldsymbol{\theta}}(\mathbf{i}\,\boldsymbol{\theta}\,)^{\boldsymbol{\beta}'-1} (30)$$

Thus, in the spatial-temporal variables, the class of input functions considered in this study includes a constant, a series of impulses and combinations of trigonometric functions, exponential functions and polynomials in the variables. This class of functions adequately represents physically realizable pressure fields of practical concern. In any given application, values for the constants in Equations (28) - (30) can easily be assigned (Section 2.4.1).

In the case of random excitation, the correlation functions are required to be even functions of the variables. That is,

\* $p_2(\theta)$  is defined in the interval 0 to  $2\pi$  and, therefore, possesses a truncated Fourier transform which is analytic everywhere. The constants  $\kappa_{n'}$  are not associated with singularities of the spectrum.

 $Q_{1}(X) = Q_{1}(|X|)$   $Q_{1}(Z) = Q_{1}(|Z|)$   $Q_{2}(\Theta) = Q_{2}(|\Theta|) \text{ for } |\Theta| \leq \pi$   $= Q_{2}(2\pi - |\Theta|) \text{ for } |\Theta| > \pi$   $Q_{3}(\tau) = Q_{3}(|\tau|)$ 

where  $X = x \cdot x'$ ,  $Z = z \cdot z'$ ,  $\Theta = \theta \cdot \theta'$ ,  $\tau = t \cdot t'$ . The condition on  $Q_2(\Theta)$  also guarantees that the same value for the correlation is obtained at  $\Theta = 0$  and  $\Theta = 2\pi$ . In terms of the spectra, the above conditions require that the singularities exist in both the upper and lower half-planes. Accordingly, the class of correlation functions analogous to the deterministic input functions given by Equations (26) - (30) is

(31)

2)

$$\hat{Q}_{1}(k) = A_{0}\delta(k) + A_{1} + \sum_{\alpha=1}\sum_{\beta=1}\frac{B_{\alpha,\beta}}{(k-\kappa_{\alpha})^{\beta}} + \sum_{\gamma=1}\sum_{\epsilon=1}\frac{C_{\gamma,\epsilon}}{(k-\kappa_{\gamma})^{\epsilon}}$$
(3)

$$\hat{Q}_{3}(\omega) = H_{0}\delta(\omega) + H_{1} + \sum_{\eta=1} \sum_{\sigma=1} \frac{N_{\eta,\sigma}}{(\omega-\nu_{\eta})^{\sigma}} + \sum_{\xi=1} \sum_{\rho=1} \frac{M_{\xi,\rho}}{(\omega-\nu_{\xi})^{\rho}}$$
(33)

$$Q_{1}(X) = A_{0} + A_{1}\delta(X) + iU(X) \sum_{\alpha=1}^{\infty} \sum_{\beta=1}^{\infty} \frac{B_{\alpha,\beta}}{(\beta-1)!} e^{i\kappa \alpha} (iX)^{\beta-1}$$

$$- iU(-X) \sum_{\gamma=1} \sum_{\epsilon=1}^{C} \frac{C_{\gamma,\epsilon}}{(\epsilon-1)!} e^{i\kappa_{\gamma}X} (iX)^{\epsilon-1}$$
(34)

# $Q_{3}(\tau) = H_{0} + H_{1}\delta(\tau) + iU(\tau)\sum_{\eta=1}\sum_{\sigma=1}\frac{N_{\eta,\sigma}}{(\sigma-1)!}e^{i\nu\eta\tau}(i\tau)^{\sigma-1}$

# $- iU(-\tau) \sum_{\xi=1} \sum_{\rho=1} \frac{M_{\xi,\rho}}{(\rho-1)!} e^{i\nu_{\xi}\tau} (i\tau)^{\rho-1}$ (35)

(36)

# $Q_2(\Theta) = D_0 + D_1 \delta(\Theta) + \sum_{\eta=1} \sum_{\sigma=0} E_{\eta,\sigma} e^{i\kappa \eta \Theta} \Theta^{\sigma}$

where k is the Fourier conjugate of X, or Z,  $\omega$  is the Fourier conjugate of  $\tau$ , and where the  $(1/2\pi)$  factor in the inversion formula has again been absorbed in the constant coefficients.  $Q_1(Z)$  is given by Equation (34) with X replaced by Z. The poles  $\kappa$ ,  $\nu$  are in the upper half-planes,  $\alpha$ ,  $\eta$ that is, they have positive imaginary parts, while the poles  $\kappa_{\gamma}, \nu_{F}$  are in the lower half-planes, that is, they have negative imaginary parts. Thus, in the spatial-temporal variables, the class of random pressure fields considered in this study is represented by correlation functions which may be constant (representing a perfectly correlated field), delta functions (representing a purely random field), or various combinations of trigonometric functions, exponential functions and polynomials in the variables. The arbitrary constants which appear in Equations (32) - (36) can easily be fixed in engineering applications (Section 4.0). A priori knowledge of values for these constants is not necessary, however, in order to proceed with the analytic evaluation of the response.

**Response Calculation** 2.4

Response to Deterministic Excitation 2.4.1

With Equations (16) and (22), Equation (8) reads

$$\hat{\mathbf{w}}(\mathbf{x}, \boldsymbol{\omega}) = \hat{\mathbf{p}}_{3}(\boldsymbol{\omega}) \sum_{n} (\mathbf{M}_{n} \boldsymbol{\omega}_{n})^{-1} \hat{\mathbf{g}}_{n}(\boldsymbol{\omega}) \psi_{n}(\mathbf{x}) \int_{\mathbf{0}}^{\mathbf{L}} d\mathbf{x}_{0} \psi_{n}^{*}(\mathbf{x}_{0}) \mathbf{p}_{1}(\mathbf{x}_{0}) \quad (37)$$

where  $\overset{\Lambda}{g}_{n}(\omega)$  is the Fourier transform of Equation (17) given by

Using Equation (18) in exponential form,

$$\hat{w}(\mathbf{x}, \omega) = \hat{p}_{3}(\omega) \sum_{n} (\mathbf{M}_{n} \omega_{n})^{-1} \hat{g}_{n}(\omega) \quad \psi(\mathbf{x}) \sum_{p} \left\{ a_{p}^{n} \mathbf{I}_{1}(\mathbf{x}_{1}, \mathbf{x}_{2}) + a_{p}^{n*} \mathbf{I}_{2}(\mathbf{x}_{1}, \mathbf{x}_{2}) \right\}$$
(39)
where
$$a_{p}^{n} = \frac{B^{n}}{2} + \frac{A^{n}}{2i}$$

where

$$I_{1}(\mathbf{x}_{1}, \mathbf{x}_{2}) = \int_{\mathbf{x}_{1}}^{\mathbf{x}_{2}} d\mathbf{x}_{0} \, \boldsymbol{\varphi}_{p}(\mathbf{x}_{0}) \, p_{1}(\mathbf{x}_{0})$$
(40)

$$I_{2}(\mathbf{x}_{1}, \mathbf{x}_{2}) = \int_{\mathbf{x}_{1}}^{\mathbf{x}_{2}^{*}} d\mathbf{x}_{0} \ \varphi_{p}^{*}(\mathbf{x}_{0}) \ p_{1}(\mathbf{x}_{0})$$
(41)

where  $\varphi_{\rm p}({\rm x})$  is given by Equation (21) with z replaced by x. The limits in Equations (40), (41) have been set at arbitrary values  $x_1, x_2$  to allow for the possibility of truncation of  $p_1(x)$ . If the pressure field extends over the entire length of the beam, then  $x_1 = 0$ ,  $x_2 = L$ ; if it extends to a point b < L, then  $x_1 = 0$ ,  $x_2 = b$ ; if it extends from a point a > 0 to a point b < L, then  $x_1 = a$ ,  $x_2 = b$ ; and, finally, if the pressure is distributed from a point a > 0 to a point b > L, then  $x_1 = a$ ,  $x_2 = L$ . With Equation (28), the evaluation of Equation (40) is straightforward yielding the result

$$I_{1}(\mathbf{x}_{1},\mathbf{x}_{2}) = \frac{A_{o}}{ik_{p}} \begin{pmatrix} ik_{p}\mathbf{x}_{1} & ik_{p}\mathbf{x}_{2} \\ e & -e \end{pmatrix} + \sum_{j} B_{j} e^{ik_{p}\mathbf{x}_{j}}$$

$$\sum_{\alpha} \sum_{\beta} \frac{(-1)^{\beta-1} C_{\alpha,\beta}}{(k_{p} + \kappa_{\alpha})^{\beta}} \sum_{r=0}^{\beta-1} \frac{1}{r!} \left[ \left\{ -ix_{2} (k_{p} + \kappa_{\alpha}) \right\}^{r} e^{i(k_{p} + \kappa_{\alpha})x_{2}} \right\}^{r} \right]$$

$$-\left\{-i\mathbf{x}_{1}\left(\mathbf{k}_{p}+\boldsymbol{\kappa}_{\alpha}\right)\right\}^{\mathbf{r}}\left[e^{i\left(\mathbf{k}_{p}+\boldsymbol{\kappa}_{\alpha}\right)\cdot\mathbf{x}_{1}}\right]$$
(42)

where, for clarity in notation, we have dropped the superscript n from the wave numbers  $k_p$ .  $I_2(x_1, x_2)$  is given by Equation (42) with  $k_p$  replaced by  $-k_p$ . Equation (39), with (38) and (42), gives the <u>beam solution</u> for the class of input functions considered in this study.

In the case of a cylindrical shell, Equation (9) with Equations (16), (20), (28) and (30) takes the form

$$\hat{w}(z,\theta,\omega) = \hat{p}_{3}(\omega) R \sum_{n,m} (M_{nm}\omega_{nm})^{-1} \hat{g}_{nm}(\omega) \psi_{nm}(z,\theta)$$

$$\cdot \sum_{p} \sum_{q} \left\{ a_{pq}^{nm} I_{1}(z_{1},z_{2}) I_{1}(\theta_{1}) + a_{pq}^{nm*} I_{2}(z_{1},z_{2}) I_{2}(\theta_{1}) + b_{pq}^{nm*} I_{1}(z_{1},z_{2}) I_{2}(\theta_{1}) + b_{pq}^{nm} I_{2}(z_{1},z_{2}) I_{1}(\theta) \right\}$$

$$(43)$$

where  $I_1(z_1, z_2)$ ,  $I_2(z_1, z_2)$  are given by Equations (40), (41) and (42) with  $x_1, x_2$  replaced by  $z_1, z_2$ , and where

$$I_{1}(\theta_{1}) = \int_{0}^{\theta_{1}} d\theta_{0} \varphi_{q}(\theta_{0}) p_{2}(\theta_{0})$$
(44)

$$I_{2}^{(\theta_{1})} = \int_{0}^{0} d\theta_{0} \varphi_{q}^{*}(\theta_{0}) p_{2}^{(\theta_{0})}$$
(45)

The upper limit in Equations (44), (45) has been set at an arbitrary angle  $\theta_1$  to allow for the possibility of truncation of  $p_2(\theta)$ . If the pressure field is distributed over the entire shell circumference, then  $\theta_1 = 2\pi$ ; if it is truncated at some angle  $a < 2\pi$ , then  $\theta_1 = a$ . Since the integrand in Equation (44) is identical

in form to that of Equation (40), it follows that  $I_1(\theta_1)$  is given by Equation (42) under the following substitutions [see also Equations (28) and (30)]:  $x_1 \rightarrow 0$ ,  $x_2 \rightarrow \theta_1$ ,  $k \rightarrow k_q$ ,  $A \rightarrow D_o$ ,  $B_j \rightarrow E_j$ ,  $x_j \rightarrow \theta_j$ ,  $C_{\alpha,\beta} \rightarrow F_{\alpha',\beta'}$ ,  $\kappa_{\alpha} \rightarrow \kappa_{\alpha'}$ .  $I_2(\theta_1)$  is obtained from  $I_1(\theta_1)$  by substituting  $k_q$  by  $-k_q$ . Equation (43) with (42) under the above substitutions gives the <u>cylindrical shell solution</u> for the class of pressure fields considered.

Equations (39) and (43) constitute a "bank" of deterministic response solutions for the class of input functions given by Equations (26) - (30). A particular response solution results once an input function belonging to the above class is specified. For instance, consider a beam loaded by a pressure field whose frequency spectrum is constant and whose spatial distribution over the entire length of the beam has the form

$$\hat{p}(x, \omega) = P_0 e^{-0.5x} (x^2 + 1)$$

Comparison with Equation (27) yields

$$H_{o} = t_{s} = N_{\eta, r} = 0, \text{ all } s, \eta, r$$
$$K_{s} = 1 = P_{o}$$

$$K_s = 0$$
, all  $s \neq 1$ 

On the other hand, expanding the  $\beta$  sum in Equation (28),

$$p_{1}(\mathbf{x}) = \mathbf{A}_{o} + \sum_{j=1}^{\mathbf{B}} \mathbf{B}_{j} \delta(\mathbf{x}-\mathbf{x}_{j}) + \mathbf{U}(\mathbf{x}) \sum_{\alpha=1}^{\mathbf{a}} e^{\mathbf{i} \kappa_{\alpha} \mathbf{x}} \left\{ \mathbf{i} \mathbf{C}_{\alpha, 1} + \mathbf{i} \mathbf{C}_{\alpha, 2} (\mathbf{i} \mathbf{x}) + \frac{\mathbf{i} \mathbf{C}_{\alpha, 3}}{2} (\mathbf{i} \mathbf{x})^{2} + \dots \right\}$$

so that, by direct comparison we conclude

$$A_{o} = B_{j} = 0, \text{ all } j$$

 $\kappa_{\alpha=1} = 0.5i$ 

$$\kappa_{\alpha} = 0, \text{ all } \alpha \neq 1$$
  
 $C_{1,1} = -i; C_{1,2} = 0; C_{1,3} = 2i$   
 $C_{\alpha,\beta} = 0, \text{ all } \alpha \neq 1, \beta > 3.$ 

Substitution of the above values and  $x_1 = 0$ ,  $x_2 = L$  in Equation (39) yields the corresponding analytic response solution. In terms of the computerized version of Equation (39), the user simply inputs the above values (along with the mode shape parameters appropriate to the case at hand) to the code to obtain numerical values of  $\hat{w}(x, \omega)$  at specified frequencies and positions (Section 3.2).

#### 2.4.2 Response to Random Excitation

The response cross-spectral density for a beam is given by Equations (14), (16) and (24) as

$$\hat{\mathbf{W}}(\mathbf{x},\mathbf{x}';\omega) = \hat{\mathbf{Q}}_{3}(\omega) \sum_{\mathbf{n}} \frac{\psi_{\mathbf{n}}(\mathbf{x}) \hat{\mathbf{g}}_{\mathbf{n}}(\omega)}{M_{\mathbf{n}} \omega_{\mathbf{n}}} \sum_{\mathbf{n}'} \frac{\psi_{\mathbf{n}'}(\mathbf{x}') \hat{\mathbf{g}}_{\mathbf{n}'}(-\omega)}{M_{\mathbf{n}'} \omega_{\mathbf{n}'}}$$
$$\cdot \int_{\mathbf{0}}^{\mathbf{L}} d\mathbf{x}_{\mathbf{0}} \int_{\mathbf{0}}^{\mathbf{L}} d\mathbf{x}_{\mathbf{0}} \psi_{\mathbf{n}}^{*}(\mathbf{x}_{\mathbf{0}}) \psi_{\mathbf{n}}(\mathbf{x}'_{\mathbf{0}}) \mathbf{Q}_{1}(\mathbf{x}_{\mathbf{0}}-\mathbf{x}'_{\mathbf{0}})$$

Using Equation (18),

$$\hat{W}(\mathbf{x}, \mathbf{x}'; \omega) = \hat{Q}_{3}(\omega) \sum_{n} \frac{\psi_{n}(\mathbf{x}) \hat{g}_{n}(\omega)}{M_{n}\omega_{n}} \sum_{n'} \frac{\psi_{n'}(\mathbf{x}') \hat{g}_{n'}(\omega)}{M_{n'}\omega_{n'}} \\
\cdot \sum_{p} \sum_{r} \left\{ h_{1}I(\mathbf{k}_{p}^{n}, \mathbf{k}_{r}^{n'}) + h_{1}^{*}I(-\mathbf{k}_{p}^{n}, -\mathbf{k}_{r}^{n'}) + h_{2}I(\mathbf{k}_{p}^{n}, -\mathbf{k}_{r}^{n'}) + h_{2}^{*}I(-\mathbf{k}_{p}^{n}, \mathbf{k}_{r}^{n'}) \right\} (46)$$

$$h_{2} = a_{p}^{n} a_{r}^{n'*}$$

$$h_{2} = a_{p}^{n} a_{r}^{n'*}$$

$$I(k_{p}^{n}, k_{r}^{n'}) = \int_{0}^{L} dx_{0} \int_{0}^{L} dx'_{0} \varphi_{p}(x_{0}) \varphi_{r}(x'_{0}) \Omega_{1}(x_{0} - x'_{0})$$

$$The coefficients a_{p}^{n}, a_{r}^{n'} are defined in Equation (39) and \varphi_{p}(x) = exp (ik_{p}^{n}x), \varphi_{r}(x') = exp (ik_{r}^{n'}x').$$

$$(47)$$

where

Similarly, Equations (15), (16), (20) and (25) yield the response cross-spectral density for a cylindrical shell in the form

$$\begin{split} \hat{W}(z,\theta,z',\theta';\omega) &= \hat{Q}_{3}(\omega) R^{2} \sum_{n,m} \frac{\psi_{nm}(z,\theta) \hat{g}_{nm}(\omega)}{M_{nm}\omega_{nm}} \sum_{n',m'} \frac{\psi_{n'm'}(z',\theta') \hat{g}_{n'm'}(-\omega)}{M_{n'm'}\omega_{n'm'}\omega_{n'm'}} \\ &= \sum_{p,q} \sum_{r,s} \left\{ H_{1}I(k_{p}^{n},k_{r}^{n'},k_{q}^{m},k_{s}^{m'}) + H_{1}^{*}I(-k_{p}^{n},-k_{r}^{n'},-k_{q}^{m},-k_{s}^{m'}) \\ &+ H_{2}I(k_{p}^{n},-k_{r}^{n'},k_{q}^{m},-k_{s}^{m'}) + H_{2}^{*}I(-k_{p}^{n},k_{r}^{n'},-k_{q}^{m},k_{s}^{m'}) + H_{3}I(k_{p}^{n},-k_{r}^{n'},k_{q}^{m},k_{s}^{m'}) \\ &+ H_{3}^{*}I(-k_{p}^{n},k_{r}^{n'},-k_{q}^{m},-k_{s}^{m'}) + H_{4}^{*}I(k_{p}^{n},k_{r}^{n'},-k_{q}^{m},-k_{s}^{m'}) + H_{4}^{*}I(-k_{p}^{n},-k_{r}^{n'},k_{q}^{m},-k_{s}^{m'}) \\ &+ J_{1}I(-k_{p}^{n},-k_{r}^{n'},k_{q}^{m},k_{s}^{m'}) + J_{1}^{*}I(k_{p}^{n},k_{r}^{n'},-k_{q}^{m},-k_{s}^{m'}) + J_{2}I(-k_{p}^{n},k_{r}^{n'},k_{q}^{m},-k_{s}^{m'}) \\ &+ J_{2}I(k_{p}^{n},-k_{r}^{n'},-k_{q}^{m},k_{s}^{m'}) + J_{3}I(-k_{p}^{n},k_{r}^{n'},k_{q}^{m},k_{s}^{m'}) + J_{3}^{*}I(k_{p}^{n},-k_{r}^{n'},-k_{q}^{m},-k_{s}^{m'}) \\ &+ J_{4}I(-k_{p}^{n},-k_{r}^{n'},k_{q}^{m},-k_{s}^{m'}) + J_{4}^{*}I(k_{p}^{n},k_{r}^{n'},-k_{q}^{m},k_{s}^{m'}) \\ &+ J_{4}I(-k_{p}^{n},-k_{r}^{n'},k_{q}^{m},-k_{s}^{m'}) \\ &+ J_{4}I(-k_{p}^{n},-k$$

$$H_{1} = a_{pq}^{nm} a_{rs}^{n'm'}$$

$$J_{1} = b_{pq}^{nm} b_{rs}^{n'm'}$$

$$H_{2} = a_{pq}^{nm} a_{rs}^{n'm'*}$$

$$J_{2} = b_{pq}^{nm} b_{rs}^{n'm'*}$$

$$J_{3} = b_{pq}^{nm} a_{rs}^{n'm'}$$

$$J_{3} = b_{pq}^{nm} a_{rs}^{n'm'*}$$

$$H_{4} = a_{pq}^{nm} b_{rs}^{n'm'*}$$

$$J_{4} = b_{pq}^{nm} a_{rs}^{n'm'*}$$

where

$$I(k_{p}^{n}, k_{r}^{n'}, k_{q}^{m}, k_{s}^{m'}) = P_{pr}(L) S_{qs}(2\pi)$$

$$P_{pr}(L) = \int_{0}^{L} dz_{o} \int_{0}^{L} dz'_{o} \varphi_{p}(z_{o}) \varphi_{r}(z'_{o}) Q_{1}(z_{o}-z'_{o})$$

$$S_{qs}(2\pi) = \int_{0}^{2\pi} d\theta_{o} \int_{0}^{2\pi} d\theta'_{o} \varphi_{q}(\theta_{o}) \varphi_{s}(\theta'_{o}) Q_{2}(\theta_{o}-\theta'_{o})$$
(52)

49)

The constants in Equation (49) are defined in Equation (21) and  $\varphi_p(z) = \exp(ik_p^n z), \quad \varphi_r(z') = \exp(ik_r^n z), \quad \varphi_q(\theta) = \exp(ik_q^m \theta), \text{ and}$   $\varphi_s(\theta) = \exp(ik_s^m \theta).$  The summation symbols in Equation (48) denote a double summation, e.g.,  $\sum_{p,q}$  stands for  $\sum_{p} \sum_{q}$ . Noting that Equations (47) and (51) are identical [i.e.,  $I(k_p^n, k_r^n) = P_{pr}(L)$ ], it follows that the evaluation of both Equations (46) and (48) rests on performing the integrations in Equations (51) and (52) for the class of input functions given by Equations (34) and (36). This calculation is presented in detail in the Appendix. The results are












 $\left.\frac{(-1)^{\sigma-a}(\sigma-a)!}{\sigma^{-a+1}(k_{q}+k_{r})^{\sigma-a+1}}\right\}$ 

(28)

For simplicity in notation, the superscripts have been suppressed in the wave numbers k, that is

 $k_p \equiv k_p^n$ ,  $k_r \equiv k_r^{n'}$ ,  $k_q \equiv k_q^m$  and  $k_s \equiv k_s^{m'}$ 

Equation (53) in (46) yields the response cross-spectral density in parametric form for <u>a beam</u> excited by the class of input functions given by Equations (33), (34), while Equation (48), with Equations (53) - (58), gives the corresponding solutions for <u>a cylindrical shell</u> when the input function belongs to the class given by Equations (33), (34) and (36). The response power spectral density at position x on the beam, or position z,  $\theta$  on the shell, results by setting x = x'in (46) and z = z',  $\theta = \theta'$  in (48). The mean-square response can be obtained by further integrating the above equations over all frequencies.

If the analyst is given an input function which belongs to the class considered, values for the pressure field parameters can easily be specified and the particular analytic response solutions obtained from the above equations. On the other hand, the computerized version of the solutions provides means for obtaining numerical response values The section which follows describes the codes based on Equations (39), (43), (46) and (48).

COMPUTER CODE - USER'S GUIDE

3.1 Curve-Fitting Routine for Structural Mode Shapes (FITMSC)

3.1.1 Program Description

The FITMSC program fits the normal component of the structural mode shape as computed by a numerical code, such as NASTRAN. The fits are in the form of products of trigonometric functions. The code uses stepwise multiple regression to evaluate the coefficients of the fit.

3.1.2 Input

3.0

Section 3.1.9 presents the necessary input to be read into the code.

3.1.3 Governing Equations

The governing equations are given in Section 2.2.

3.1.4 Method of Solution

The calculation procedure is described in Section 2.0.

3.1.5 Restart

The code is set up to skip past as many sets of modal data as necessary in order to refit a particular mode shape. 3.1.6 Termination

The code will terminate when the number of modes to be fitted have been fitted. The termination occurs because of lack of additional input data.

3.1.7 Computer Conversion

The program was written in FORTRAN V. It was used extensively on the UNIVAC 1108 (EXEC 8).

To adapt this code to CDC 6600, or IBM 7090 or 360, the following changes must be made:

1. All control cards at the beginning of each subroutine must be eliminated and/or replaced with appropriate cards.

3.1.8 Equipment Requirements

The code uses logical units (15) from which the mode shapes are obtained. No other storage units are needed. The present form of the code needs approximately 32,000 cells to execute, most of which is used for the data itself. Tapes 5 and 6 are used for reading and writing, respectively. Two or three cards will be punched for each fit.

3.1.9 Program Input Requirements

A tape with the mode shape data must be mounted on logical unit 15. See Sec. 3.1.15 for the listing of the code to generate this data tape from NASTRAN card output.

## 3.1.10 Card Formats

NOTE: All integer variables must be right adjusted.

Floating point fields must contain a decimal which may be arbitrarily located in the field width.

## CARD GROUP 1

<u>Columns</u>	Description
1-5	ITEST, case number. (Integer)
6-10	LIMIT, maximum number of steps in the
	regression analysis. (Integer)
11-15	NZS, number of constant Z for which the modal
	data is given.
16-20	NTH, number of angles for which the modal data
	is given.
21-25	NPOLI, K <sub>n</sub> , number of terms in the fits in the
	spatial variable. (Integer)
26-30	NPOLK, $K_q$ , number of terms in the fits in the
	azimuthal variable.
31-35	ISKIP, number of modes on the data tape to be
	skipped. If ISKIP is zero, no modal data will be
	alrinnad

Columns	Description
1-10	EFIN, the F* value for entering a variable into
	the regression. (Floating point)
11-20	EFOUT, the F value for removing a variable from
	the regression. (Floating point)
21-30	THNOT, $\theta_0$ , the modal data is tabulated for
	various angles starting at $\theta_0$ . (Floating point)
31-40	DTH, $\Delta \theta$ , angular increments (in degrees) for
	the modal data is tabulated. (Floating point)
41-50	DELZ, $\Delta Z$ , spatial increments in Z (in inches)
	for the tabulation of the modal data. (Floating point
51-60	ZNOT, Z <sub>0</sub> , length of the cylinder in inches.
	(Floating point)

F - F test is a significance test.

The above card groups are repeated for each mode shape to be fitted.

3.1.11 Sample Input

The following is a listing of the input data used to fit all of the mode shapes for model 1 (Section 4.0). Sample 2 is input to fit modes 3, 4, and 8 only.

#### INPUT SAMPLE 1

1	-11	7	10	· 4 ·	. 4	Ð		
1.05		1.05		Ö.		36 .	22.	132.
2	11	7	10	4	4	0		
1.0.5	÷. •	1.05		0.		36.	22.	132.
3	11	7	10	6	2	0		
1.05		1.05		0.	· · ·	36.	22.	132.
4	11	7	10	6	2	0	· .	
1.05		1.85	. •	0.		36.	22 .	132.
5	11	- 7	10	6	2	Ó C	1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 -	
1.05		1.05		0.	• •	36.	22.	132.
6	- 11	7	10	4	4	0		
1.05		1.05		0.		36.	22.	132.
7	11	<b>7</b>	10	4	4	0		• •
1.05	1997 - 1997 1997 - 1997	1.05		0.		36.	22.	132.
8	11	7	10	6	3	<b>D</b>		· .
1.05		1.05	•	0.	·.	36.	22.	132.
9	11	7	10	6	3	0		· ·
1-05	• •	1.05		0.		36.	22.	132.
10	11	7	10	7	3	0		
1.05	• .	1+05		0.	·	36.	22.	132.
11	11	7	10	4	4	0		
1.05		1+05		0.		36.	22.	132.
12	11	7	10	4	4	0		• •
1.05		1.05	$\{ e_{k}, \dots, e_{k} \}$	0.		36.	22.	132.

#### INPUT SAMPLE 2

•	3	i <b>11</b> i	7	10	6	2	2		
	1.05		1.05		.0.		36.	22.	132.
	. 4	11	7	10	6	. 2	0		
	1.05	$\cdot$	1.05		0.		36.	22 .	132.
	8	11	7.	10	6	3	3		
	1.05		1.05		0.		36.	22.	132.
			· .		· •		. •. ·		÷

3.1.12	Description of Output
· ·	
Variable	Line 1
ITEST	
LIMIT	
NZS	
NTH	Input data, see Section 3.1.10
NPOLI	
NPOLK	
ISKIP	

Variable	Line 2				,
EFIN	· · ·			· · ·	na L
EFOUT				· · ·	
THNOT					
DTH	Input data,	see Section	3.1.10		
DELZ		· · ·			
ZNOT		, * .		· . ·	

Following the input is a printout of the pertinent information at each step of the regression. The last set of variable numbers and the values of the coefficients are punched on cards for later code runs.

A comparison is made and printed between the actual data and the predicted data (data calculated from the last set of coefficients). These columns are self-explanatory.

## 3.1.13 Code Expansion

Following is a listing of minimum storage requirements. NOTE: MAXN and MAXNP1 must be altered to the dimension sizes of X and A, respectively.

Minimum storage requirements:

- a) (MAXN, MAXNPl) cells per variable X
- b) MAXN cells per variable W, XBAR, SIG, IVAR, B, SB
- c) MAXNP1 cells per variable R
- d) NTH cells per variable THA
- e) NZS cells per variable ZHA
- f) (MAXNPl, MAXNPl) cells per variable A

NOTE:

1) MAXN  $\geq$  Number of modal data points.

2) MAXNP1  $\geq$  4 · NPOLI · NPOLK + 1

3.1.14 C

Code Listing

(following)

BASG+T 15+T+RJ3 SHD6 .P POLREG USES UNIVAC MULTIPLE REGRESSION TO FIT A 2-D POLY FOR COTTI! *afor*, IS POLREG COMMON X(200+86), W(200), XBAR (86), A (86,86), SIG(100), IVAR (86), B (86), 1 SB(86) + R(200) + THA(200) + ZHA(200) REWIND 15 MAXN=200 MAXNP1=86 1 READ (5+30) ITEST+LIMIT+NZS+NTH+NPOLI+NPOLK+ISKIP WRITE(6+35) ITEST+LIMIT+NZS+NTH+NPOLI+NPOLK+ISKIP NP1=4+(NPOLI+NPOLK)+1 NPL1=NP1-1 IF(ISKIP.E0.0) GO TO 210 00 211 I=1+ISKIP 211 READ (15) EI 21D READ (15) EI+MODE+NPTS+(X(J+NP1)+DUM1+DUM2+DUM3+DUM4+DUM5+J=1+ INPTS) READ (5+31) EFIN+EFOUT+THNOT+DTH+ DELZ+ZNOT WRITE(6,36) EFIN, EFOUT, THNOT, DTH. DELZ.ZNOT IW=0 THNOT=THNOT+\_01745 DTH=DTH+.01745 PI=3.14159265 DELZ=DELZ/ZNOT+PI ZNOT=PI TH=THNOT ---00 2 1=1+NTH THA(I)=TH 2 TH=TH+DTH ZZ=ZNOT 00 3 1=1+NZS ZHA(I)=ZZ 3 ZZ=ZZ-DELZ J=0 DO 200 I=1+NTH TH=THA(I) DO 200 L=1.NZS ZZ=ZHA(L) M0=0 J=J+1 -NO=NPOLI + NPOLK. NOP=2+NO NOR=3+NO D0 200 M=1+NPOLI TS=FLOAT(M-1)+TH TT=COS(TS) TL=SIN(TS) DO 200 K=1+NPOLK ARG=FLOAT(K-1)+ZZ TP=COS(ARG) TR=SIN(ARG) NOP=NOP+1 NOR=NOR+1

```
MO=MO+1
    NO=NO+1
     X(J+MO)=TT+TP
    X(J+NO)=TT+TR
    X(J+NOP)=TL+TP
200 X(J+NOR)=TL+TR
     IF(IN) 5+5+6
  6 READ (5+31) (W(I)+I=1+NPTS)
     WRITE(6.34) (W(I).I=1.NPTS)
   5 IND=0
     ISTEP=-1
   7 CALL RESTEM(X+NPTS+NP1+MAXN+MAXNP1+W+IW+EFIN+EFOUT+XBAR+A+SIG+CONS
   1.T. NVAR.FLEVEL.SY, NOIN.IVAR.B.SB.R.IND)
    IF (IND) 13+12+13
 13 ISTEP=ISTEP+1
  14 WRITE(6+39) ISTEP
     IF (NVAR) 18, 19, 19
 18 NVAR=-NVAR
     WRITE(6+130) NVAR
     GO TO 10
 19 WRITE(6,131) NVAR
 10 WRITE(6+132) FLEVEL+SY+CONST+(IVAR(I)+B(I)+SB(I)+I=1+NOIN)
    IF (ISTEP-LIMIT)7,24,24
 24 IND =-1
     GO TO 7
 12 WRITE(6+133)
     IST=1
     MCO=NOIN
     IF(IVAR(1)-1) 1210+1210+1211
1210 CONSTEB(1)+CONST
     TST=2
    MCO=MCO-1
1211 PUNCH 30, NPOLI, NPOLK, MCO, (IVAR(I), I=IST, NOIN)
    PUNCH 136+CONST+(B(I)+I=IST+NOIN)
    DO 29 1=1.NPTS
    DEV = X(I) + P(I) - R(I)
 29 WRITE(6+134) I+X(I+NP1)+R(I)+DEV
    GO TO 1
 30 FORMAT(1615)
 31 FORMAT(8E10.3)
  32 FORMAT(10HO RAW DATA)
 33 FORMAT(1X,10E12.5)
 34 FORMAT(19HO WEIGHTING FACTORS/(1X+10E12.5))
 35 FORMAT(9HIITEST = I5+11H+ LIMIT = I5+9H+ NZS = I5+ 9H+
                                                                 NTH = 15
   1+11H+
            NPOLI = 15+11H+ NPOLK = 15+11H+
                                               ISKIP = ISF
 36 FORMAT(EHDEFIN = E13.6+11H+ EFOUT = E13.6+11H+
                                                        THNOT = E13.6.
          DTH = E13.6/8HODELZ = E13.6.10H.
                                             ZNOT = E13.6)
   19H.
 39 FORMAT(11HO STEP NO. 13)
130 FORMAT(5X+17H VARIABLE REMOVED I3)
131 FORMAT(5X+19H VARIABLE ENTERING I3)
132 FORMAT(5X+7H FLEVEL+E13.6/5X+20H STANDARD ERROR OF Y+ E13.6/5X+
   19HCONSTANT +E13.6//15X.46H VARIABLE
                                              COEFFICIENT
                                                            STD ERROR OF
  1 COEFF / (17X+3H X 12+E16.5+E18.5))
133 FORMAT(30H1 PREDICTED VS ACTUAL RESULTS/8H OB. NO.+8X+7H ACTUAL+
```

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```

		•
. 1	10X+10H PREDICTED+ 9X+10H DEVIATION}	
134	FORMAT(15,E18.6,E18.6,E19.6)	
136	FORMAT(5E15.8)	
	END	
FOR.	SRESTEM	
•	SUBROUTINE RESTEM (X+N+NP1+MAXN+MAXNP1+W+IW+EFIN+EFOUT+XBAR+A+SIG CONST+NVAR+FLEVEL+SY+NOIN+IVAR+B+SB+R+IND}	REST
C C'	MULTIPLE REGRESSION PROGRAM	- RESTI
C	DIMENSION X(MAXN,1)+W(1)+XBAR(1)+A(MAXNP1+1)+SIG(1)+IVAR(1)+B(1)+ SB(1)+R(1)	REST
C	IND=0 UPON FIRST CALL TO SUBRT.	REST
C	TE (TAID) 175.100.160	- DFCT
1.00		REST
c		
C, A	TEST IF WEIGHTS ARE INPUT. IF NOT, SET W(J)=1.0WEIGHT SUM=N	REST
C	IF INPUT. NORMALIZE WEIGHTS SO THAT AVERAGE OF WEIGHTS IS 1.0	REST
	IF (IW) 101+101+102	REST
C	NOT INPUT	- RESTI
		-
-101	DO 103 1=1•N	REST
103	W(I) = I + U	NE211
-	50 10 104 TNDIT	NE21
102	INFUI TEMD-D ()	DECT:
	10 10 7 7 1 N	DECTI
105	TEMP:TEMP+W(T)	REST
	TEMPTTEMP/N	REST
	DO 106 [=1+N	REST
106	W(I)=W(I)/TEMP	REST
	COMPUTE MEAN OF EACH VARIABLE=XBAR	REST
		-
104	DO 114 J=1+NP1	RESTI
	XBAR(J)=U.U Do lig (T=1.)	REST
		RESIL
115	ΛΟΑΚΙJJ→ΛΟΑΚΙJJ▼₩Ι_J▼ΧΙ_4J] YRAD/ 1) = XRAR(.1) /N	RECIE
* ± * 	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	
	COMPUTE WEIGHTED RESIDUAL SUMS OF SQUARES AND CROSS PRODUCTS	REST
	DO 117 I=1+NP1	REST
	00 117 J=I+NP1	REST
	A(I+J)=0+0	RESTE
	DO 116 K=1+N	REST
116 117	A(I+J)=A(I+J)+W(K)+(X(K+I)-XBAR(I))+(X(K+J)-XBAR(J)) CONTINUE	RESTE
	COMPUTE STANDARD DEVIATION. SET DIAGONALS OF CORRELATION MTRX=1.	REST
· · · .		· .
	13	
. ·	47 · · · · · · · · · · · · · · · · · · ·	
. ' · '	42	• .
	42	• •

C	NORMALIZE, THEN EXPAND UPPER TRIANGULAR MATRIX TO FULL	RES
C	D0 120 I=1+NP1	- RES
•	SIG(I)=SQRT(A(I,I))	RES
120	A(I.I)=1.0	RES
•	NP=NPI-I	RES
•	DO 121 I=1+NP	RES
	II=I+1	RES
	D0 121 J=II • NP1	RES
	A(I+J)=A(I+J)/(SIG(I)+SIG(J))	RES
121	A(J,I)=A(I,J)	RES
Č	COMPUTE DEGREES OF FREEDOM	RES
	PHI=N-1.0	RES
с с	INITIALTZATION PROCEDURE FOR DETERMINING MOST SIGNIFICANT VARIABL	- ERES
C	TO BE ADDED TO REGRESSION	RES
с с	COMPUTE STANDARD ERROR OF DEPENDENT VARIABLE	RES
125	SY=SIG(NP1) + SORT(A(NP1, NP1)/PHI)	RES
C	ZERO COEFFICIENTS ARRAY	RES
L	DO 131 T-1+NP	RES
1 7 1	B(T):0.0	RES
	VMIN = +10 - F34	RES
	VHAXED	RES
	NMINED	RES
	NMAX=0	RES
•	NOINED	RES
	DO 150 I=1+NP	RES
с	60 TO 142	DEC
C		- ·
C C	COMPUTE VARIANCE	RES -
141	V=A(I+NP1)+A(NP1+I)/A(I+I)	RES
	IF (V) 142+150+143	RES
143	IF (V-VMAX) 150+150+144	,
144	VMAX=V	
	NMAX=I	RES
	GO TO 150	RES
( C	X(T) TS TN REGRESSIONCOMPUTE COFFETCIENT & AND STAND. EPPOR OF	- RES
C	COEFF.	RES
142	NOIN=NOIN+1	RES
	IVAR(NOIN)=I	RES
	B(NOIN)=A(I+NP1)+SIG(NP1)/SIG(I)	RES
	SB(NOIN)=SY+SQRT(A(I,I))/SIG(I)	RES
	IF (V-VMIN) 150+150+145	· ,
145	VMIN=V	· · · ·
	NMINEI	RES
· · ·		

÷.,		
- 150 	CONTINUL	RESTEN
Č	COMPUTE CONSTANT	RESTEM
C	TEMP=0.0	RESTEM
×	00 151 I=1.NOIN	RESTEM
151	II = IVAR(I)	RESTEN
1.31	CONST =XBAR(NP1) - TEMP	RESIEN
	RETURN	
C	COMPUTE FLEVEL	RESTEM
160	FLEVEL=VMIN*PHI/A(NP1+NP1)	RESTEM
C	COMPARE F LEVELS	RESTEM
C	IF (EFOUT+FLEVEL) 153,153,152	<b>-</b> .
	KINMIN	
•	PHI=PHI-1.0	RESTEN
	NVAR	RESIEM
153	FLEVEL=VMAX+(PHI-1.)/(A(NP1+NP1)-VMAX)	RESTEM
	IF (EFIN-FLEVEL) 154+175+175	RESTEM
1.54	KENMAX	RESTEM
	PHI=PHI=1.U NVAR=K	RESTEN
C	CALCULATE NEW MATRIX	-
c		••• .
200	DC 210 I=1+NP1	
230	IF (I-K) 230,210,230 Do 200 (-1-1-NP)	DECTEM
2 5 0	$IF (J-K) 260 \cdot 240 \cdot 260$	RESIER
260	A(I,J) = A(I,J) - A(I,K) + A(K,J) / A(K,K)	RESTEM
240	CONTINUE	RESTEM
. 210	UQNIINUL DO 280 T-1-ND1	RESTEM
2	IF (I-K) 300+280+300	RESTER
300	$A(I \cdot K) = -A(I \cdot K) / A(K \cdot K)$	RESTEM
2 80	CONTINUE	RESTEM
'	DO 320 J=1+NP1	RESTEM
740	$\frac{1}{1} + \frac{1}{1} + \frac{1}$	RESTEM
. 320	CONTINUE	RESTEM
350	A(K+K)=1.0/A(K+K)	RESTEM
	GO TO 125	RESTEM
175	DO 178 J=1+N	RESTEM
	17. HP-U+U DO 177 T=1+NOTN	RESTER
	II=IVAR(I)	RESTEM
177	TEMP=TEMP + B(I) +X(J+II)	RESTEM
178	R(J)=CONST+TEMP	RESTEM

44

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,	· 1			•	· ·		
C	SET INDICT.	TO INDICAT	E END OF	COMPUTATION	HAS BEEN RE	ACHED	REST
C	IND=0			**********			REST
	RETURN						RESTE
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# 3.1.15 Suitable Data to Tape for FILMSC

(following)

AMAP+IS +ABS IN COTP AXOT APS 140 20 47

# END

33 FORMAT(19X,7E18.5) 10 WRITE(15) EI,MODE, INPTS) FND FILE 15 00 TO 1

- 9 READ (5, T7) T1(J),T?(J),T3(J),P1(J),P2(J),P3(J) 33 FORMAT(19X,7E18.5) 10 WRITE(15) EI,MODE,NPTS,(T1(J),T2(J),T3(J),P1(J),R2(J),R7(J),J=1,
- DO P.JE1.NPTS. DO P.JE1.NPTS. DO P.JE1.T1(J).T2(J).T3(J).P1(J).P2(J).P3(J).
- 37 FORMAT(12X,E15.4,9Y,TS)
- DO 12 LE1+NMODE PEAD (5+71) (DUM(T)+TE1+9)
- 70 FORMAT(1875)
- 1 PEAD (5.30) NOTS NODE

aASS+T 15+T+PJE aFOR+TE CDTP C TAKEE GODDARD CARD DATA AND PUTS IT ON TAPE FOP COTTIS DTMENSION DUM(10)+T1(400)+T2(400)+T3(400)+P1(400)+R2(400)+R3(400) 3.2 Response to Deterministic Excitation (DEXCYL)

#### 3.2.1 Program Description

The DEXCYL program computes the dynamic response of a cylinder or beam for a class of deterministic pressure fields. The structural mode shapes in the form of combinations of trigonometric functions with arbitrary constant coefficients are assumed. These coefficients are obtained from the computer code "FITMSC."

3.2.2 Input

Section 3.1.9 presents the necessary input to be read into the code.

3.2.3 Governing Equations

The governing equations are given in Section 2.4.1.

3.2.4 Method of Solution

The computational procedure is described in Section 2.0.

3.2.5 Restart

The code computes the response at prescribed positions and frequencies. Should a restart be necessary, it may be done without having to recalculate any of the previous data points. Each point is computed independently of previous points.

#### 3.2.6 Termination

The code will terminate when the input data has been exhausted.

#### 3.2.7 Computer Conversion

The program was written in FORTRAN V. It has been used extensively on the UNIVAC 1108 (EXEC 8). The only obvious changes necessary to adapt the code to CDC 6600 or IBM 7090 are the control cards. All control cards at the beginning of each subroutine must be eliminated and/or replaced with appropriate control cards.

#### 3.2.8 Equipment Requirements

The code uses no tape units other than 5 and 6 for input and output, respectively. Approximately 13,000 cells are needed to execute in the present form.

## 3.2.9 Program Input Requirements

NOTE: Certain real variable arrays were equivalenced to their complex counterparts to avoid the problem of format variation from machine to machine for complex variables.

3.2.10 Card Formats

#### NOTE: All integer variables must be right adjusted.

Floating point fields must contain a decimal which may be arbitrarily located in the field width.

Columns	Description
1-5	NTHA, the response is computed for a number of
	angular positions, $\theta$ , and a number of positions on
	the cylinder Z, NTHA is the number of $\theta$ 's.
	(Integer)
6-10	NOFZ, number of Z's for which the response
	is calculated. (Integer)
11-15	NFREQ, number of frequencies for which the
	response is computed. (Integer)
16-20	NMODES, number of mode shapes for which fit
	data is available. (Integer)
21-25	NBETA, number of $\beta$ terms in $p_1(Z)$ . (Integer)
26-30	NBETAP, number of $\beta'$ terms in $p_2(\theta)$ . (Integer)
31-35	NALP, number of $\alpha$ terms in $p_1(Z)$ . (Integer)
36-40	NALPP, number of $\alpha'$ terms in $p_2(\theta)$ . (Integer)
41-45	NJS, number of $B_j$ 's in $p_l(Z)$ . (Integer)
46-50	NJPS, number of $E_j$ 's in $p_2(\theta)$ . (Integer)
51-55	NSS, number of $K_s$ 's in $\hat{p}_3(w)$ . (Integer)
56-60	NETA, number of $v's$ in $\hat{p}_3(w)$ . (Integer)
61-65	NSIG, number of $\sigma$ 's in $\hat{p}_3(w)$ . (Integer)

CARD GROUP 2	
Columns	Description
1-10	ZNOT, length of the cylinder in inches. (Floating point)
11-20	RCYL, radius of the cylinder. (Floating point)
21-30	Z1 Z1-Z2 is the extent of the pressure field.
31-40	Z2 (Floating point)
41-50, 51-60	Z, positions along the cylinder for which the response will
61-70, 71-80	be computed. (Floating point, NOFZ numbers in all)

Columns	Description
1-10	THNOT, $\theta$ , extent of the pressure field in the
	azimuthal direction. (Floating point)
11-20, 21-30,	TTH, $\theta$ , angular values for which the response is
31-40, 41-50,	calculated. (Floating point, NTHA numbers in
51-60, 61-70,	all).
71-80	

NOTE: In the following three groups it is assumed the number of terms for each variable is one. If there are more terms the columns will be shifted appropriately.

Columns	Description
1-10, 11-20	AA, $A_0$ , constant pressure field term in $p_1(Z)$ , real part
	followed by imaginary part. (Floating point)
21-30, 31-40	BB, B, real component followed by the imaginary $I$
	component of B <sub>i</sub> . (Floating point) - there will be
	NJS successive paris of $B_i$ . If NJS = 0 two zero
	fields <u>must</u> be present.
41-50, 51-60	CC, C, real and imaginary components of $\alpha$ , $\beta$
	$C_{\alpha, \beta}$ . There will be NALP pairs of numbers
	for $\beta = 1$ , followed by NALP pairs of numbers
	for $\beta = 2$ , etc. If NALP = 0 there must be two
	fields containing zero. (Floating point)
61-70, 71-80	ZKALP, $K_{\alpha}$ , real and imaginary components of
	$K_{\alpha}$ . There must be NALP pairs of numbers.
	At least two fields (which may be zero) must be
	present. (Floating point)
New card, 1-10,	ZJP, $Z'_{i}$ , real and imaginary components of $Z'_{i}$ .
11-20	There must be at least two fields and up to NJPS
	pairs of numbers in all. (Floating point)

CARD GROUP 5	
Columns	Description
1-10, 11-20	DD, $D_0$ , constant pressure field term in $p_2(\theta)$ , real
	followed by the imaginary part. (Floating point)
21-30, 31-40	EE, $E'_i$ , real component followed by the imag-
	inary component of E <sub>i</sub> . (Floating point - there
	will be NJBS successive pairs of $\beta_1$ . If NJBS = 0
	two zero fields <u>must</u> be present)
<b>41-50, 51-60</b>	FF, F, , ,, real and imaginary components of
	$f_{\alpha}$ , $\beta$ . There will be NALPP pairs of numbers
	for $\beta' = 1$ , followed by NALPP pairs of numbers
	for $\beta' = 2$ etc. If NALPP = 0 two fields con-
	taining zero must be present. (Floating point)
51-70, 71-80	ZKALPP, K , real and imaginary components of $\alpha$
	$K_{\alpha}$ . There must be NALPP pairs of numbers.
	At least two fields (which may be zero) <u>must</u>
	be present. (Floating point)
New card, 1-10	THP, $\theta'_{j}$ , real: and imaginary components of
1-20	$\theta_{j}$ . There must be at least two fields and up
	to NJPS pairs of numbers in all. (Floating point)

Columns

#### Description

1-10

HCAP,  $H_0$ , constant pressure field term in  $p_3(\omega)$ . (Floating point)

11-20, 21-30

ZKS,  $K_s$ , real component followed by the imaginary component of  $K_s$ . (Floating point - there will be NSS successive pairs of  $K_s$ . If NSS = 0 two zero fields <u>must</u> be present.)

31-40

TS, t appearing in  $\hat{p}_3(w)$ . There must be at least one field (which may be zero) and up to NSS numbers. (Floating point)

41-50, 51-60

ZNN, N  $\eta$ ,  $\sigma$ , real and imaginary components of N  $\eta$ ,  $\sigma$ . There will be NSIG pairs of numbers for  $\eta = 1$  followed by NSIG pairs of numbers for  $\eta = 2$  etc. until the list of  $\eta$  is complete. If NSIG = 0 two fields containing zero must be present. (Floating point)

61-70, 71-80

ZNU, v, real and imaginary components of v.  $\eta$ There must be at least two fields and up to NETA pairs of numbers in all. (Floating point)

CARD	GROUP	7

Columns	Description					
			· · ·			
1-10, 11-20,	AMN1, $\alpha_{n m}$ ,	damping constants.	(Floating	point -		
21-30, 31-40,	NMODES num	bers in all)				
41-50, 51-60,	·	· · · ·				

61-70, 71-80

CARD GROUP 8	
Columns	Description
1-10, 11-20,	WMN, $\omega_n$ , modal frequency in cycles per second.
21-30, 31-40,	(Floating point - eight numbers per card, NMODES
41-50, 51-60,	in all.)
61-70, 71-80	
CARD GROUP 9	
Columns	Description
1-10, 11-20,	OM, $w$ frequencies for which the responses are
21-30, 31-40,	to be calculated. (Floating point - eight numbers
41-50, 51-60,	per card NFREQ in all.)
61-70, 71-80	

Columns	Description
1-10, 11-20,	ZMAS, M, modal mass. (Floating point -
21-30, 31-40,	eight numbers per card NMODES numbers in
41-50, 51-60,	all.)
61-70, 71-80	

CARD GROUP 1	
Columns	Description
1-5	NTH, number of $\theta$ terms in the fitting of the modal
	data. (Integer)
6-10	NKZ, number of Z terms in the fitting of the modal data. (Integer)
11-15	NCOE, number of non-zero terms in the fit, excluding the constant term.
16-20, 21-25,	MCO, index tagging the fit coefficients with the
26-30, 31-35,	appropriate trigonometric term. (Integer -
36-40, 41-45,	NCOE numbers in all)
46-50, 51-55,	
56-60, 61-65,	
66-70, 71-75,	
76-80	

Columns	Description
1-15	CON, constant term in the fits to the mode shapes. (Floating point)
15-30, 31-45, 46-60, 61-75	COE, fit coefficients to the mode shapes. (Floating point - NCOE numbers in all).

Card groups 11 and 12 are repeated once for each mode number. These two card groups are the direct output of the FITMSC computer code.

NOTE: To run the deterministic beam problem set:

1)	R = RCYL = 1
2)	$E_{i} = EE(1) + iEE(2) = 1+0i$
3)	NJPS = 1
4)	$F_{\alpha', \beta'} = FF(1) + iFF(2) = 0$
5)	$D_0 = DD(1) + iDD(2) = 0$
6)	NTH = 1 for all modes

3.2.11 Sample Input

The following is a listing of the input data used to obtain the sample output. It was the model 1 data (Section 4.0) as computed from FITMSC.

		• •	ı <i>:</i>	с., ,			. 1	· · · ·	
• • •	•	,* · ·				· · ·	· · · ·		
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	3.1415926	5 50.		0.	20.	4 <b>1</b> .	60.	80.	100.
1987) 1			•	160.	180.	200.	220.	240.	260.
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	5878779	-5263	621 •5	698155 Datzaz	.5654379	1.0898	90 •7388390	•673D767	.7642241
•	• //51001	-1+4790 6. A	1049 101 70	171557 75 E	1.0000094	• • • •		-	
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	9	<b>q</b> 4	30	32 6	2 64	0032 01	•••••		· • • • • • • • • • • • • • • • • • • •
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~ ~~	6	2	- E I						•••
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•	10586	593-03	4 95	46157-0	3 - 7925	5699+00	12295176-	01 .5 90 39	415+00
Mare e colona	91589	19-02							
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	4 4	11	5	7 1	22	24 26	30 39	54 56 .5	8
a		505-06	225	37380-01	2253	7106-01	-13347271-1	.85426	307+00
	. 112243	375-01	179	39.819-0	<b>*</b> . <b></b> 1133	12811-03	70 94 73 96-	.48112	981+00
- <sup>-</sup>	.20484	-02	1101	50 -01	5				

## 3.2.12 Description of Output

The input is printed immediately after it is read. No labels are printed. The order is the same as listed for the input cards.

Variable	Line l
FREQUENCY	$\boldsymbol{\omega}$ , frequency of the calculation.
THETA Z	θ   Coordinates of the point at which the dynamic Z   response is being computed.
RESPONSE	W, real and imaginary components of the dynamic response at $\theta$ , Z, and w.
Variable	Line 2
MAGNITUDE	$ W $ , magnitude of the dynamic response at $\theta$ , Z, and $\omega$ .
PHASE	$\phi, \ phase \ of \ the \ dynamic \ response \ at \ \theta, \ Z, \ and \ w.$

3.2.13 Sample Output

Following is a partial listing of a case run earlier. This is not the case run with the sample input. It corresponds to the sample case with  $a_{mn} = .02/\omega_{mn}$ .

***INPUT DATA*	• •	. 1	5 A.A.	· · ·			,	·	•
19 1 1	12 1	1	1	1 0	0	0	0	0	
•13200+03	.00000	•1320	0+03	66000	+02		· •		· .
.31416+01		•0000	)0	•20000	+02	.40000	+02	+60000+0	12
• 16000+03	·18000+03	. 2000	10+03	• 22000	+03	.24000	+03	•26000+0	)3
• 36000+03				1		÷			. • •
•00000	•00000		. 00	•00000		.10000	+01	.00000	
• 00000	•00000	+0000	00	. 00000		•10000	+01	. 00000	
.16000-01	•00000	•0000	00	.00000		.00000		.00000	
•20000-01	.2000001	•2000	10-01	• 20000	-01	•20000	-01	.20000-0	11
•20000-01	•20000-01						.*		
•14984+03	•14784+03	•1544	3+03	+15443	+03	+17017	+03	•18749+0	13
• 28036+03	+28036+03				, <sup>*</sup>		· ·		
•14984+03								· · ·	
•58788+00	•62636+00	•5698	12+00	+56544	+00	•10899	+01	•73884+0	10
·10214+01	•12061+01								
4 4 4	30 32	62	64		· · ·				
.64891715-05	75502460	+00 -	•25676	082-01		56394+	00	.20933483	1-01
4 4 4	30 32	62	64		· .			•	•
.11708251-03	• 63559545	+00 -	• 21614	622-01	- 779	66249+	00	.26513896	-01
6 2 3	9 22	46	· ·				- -		
18283015-04	<b>*</b> • 19143746	-01	•98810	329+00	•152	54598+	00		
6 2 3	22 33	45	i i	· .	,		•		
•12709915-03	•16226757	+00	.19080	996-01		01851+	00		
6 2 2	11 24						÷ . •	· · · ·	۰.
54830642-06		-01	•98730	116+00					
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<b>*</b> •10586593 <b>*</b> 03	49546157.	-03	• 79255	699+00	•122	95176-	01	+59039415	+00
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4 4 11	7 10	22	24 3			57	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	30 07070	. 0.2
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+44100000700			+4200/			473062	03	- 481130AL	
.20484000-02		-03	-11-27				U T	- 10142701	+ u u
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\*\*\*END OF INPUT DATA\*\*

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FREQUENCY = .149841+03, THETA = .0000000 , Z = .660000+02, RE MA FREQUENCY = .149841+03, THETA = .199962+02, Z = .660000+02, RE

•	•	•••	. •	•	•	•	(*) _ •	ال: •	•	•	• ~	<b>N</b> .a. ●	: • <b>M</b> • •	.51
PHASE B	419690-01 Phase =	•345552-02 Phase =	•454314-01 PHASE =	.419970-01 Phase =	341499-02 Pháse =	454083-01 PHASE =	42036-01 Phase-=	•339550-02 Phase =	•454046-01 Phase =	•420285-01 Phase =	335797-02 Phase =	-+453835-01 Phase =	420374-01 Phase =	•333465-02 Phase =
.509408-01.	.251220-01 .489133-01,	<ul> <li>207086-02</li> <li>403885-02</li> </ul>	230303-01 .509353-01.	251293-01 .489411-01,	211031-02 .461442-02,	.230148-01 .509077-01,	.251314-01 .489478-01,	•212444+02 •400533-02,	230089-01 .509018-01,	251461-01 -489767-01,	214973-02 .398714-02.	.229936-01 .508760-01,	.251486-01 .489857-01,	•215853-02 •397229-02 •
MAGNITUDE =	RESPONSE = Magnitude =	RESPONSE = Magnitude =	RESPONSE = Magnitude =	RESPONSE = Magnitude =	KESPONSE = Magnitude =	KESPONSE = Magnitude =	KESPONSE = Magnitude =	RESPONSE = MAGNITUDE =	RESPONSE = MAGNITUDE =	RESPONSE = . Magnitude =	KESPONSE = Magnitude =	RESPONSE = magnitude =	RESPONSE = Magnitude =	RESPONSE = MAGNITUDE =
	• \$ \$ 0000 + 0 2 •	• 660000+02 •	• 6 6 0 0 0 5 + 0 2 •	• 6 6 0 0 0 0 + 0 2 •	• 660000+02 •	• \$ \$ 0 0 0 0 + 0 2 •	• 6 6 0 0 0 0 + 0 2 •	• 6 6 3 0 0 0 + 0 2 ,	•660003+02,	• 6 6 0 0 0 0 + 0 2 ,	• 6 6 0 0 0 0 + 0 2 ,	• 6 6 0 0 0 0 + 0 2 ,	• 6 6 0 0 0 <del>0</del> 0 7 0 2 ,	•660000+02,
	2 =	- 7	= 2	= 2	r 7	= 2	2 =	= Z	8 2	11	# Z	2 8	# N	u 7
- - - - - - - - - - - - - - - - - - -	.399925+02,	.599887+02,	•799649+32,	•999811+02,	•119977+03.	•139974+03,	.159970+03,	•179966+03,	•199962+03,	•219958+03,	•239955+03,	• 259951+03,	•279947+03.	• 299943+03 •
•	11	, 	n	IJ	t)	11	H	N	Đ	N	1	0	10	H
•	THETA	THETA	THETA	THETA	THETA	THETA	THETA	THETA	THETA	THETA	THETA	THETA	THETA	THETA
	.149841+03,	•149841+03•	.149841+03.	.149841+03.	• 149841+03,	•149841+03,	•149841+03	•149841+03.	, 145841+03 <b>,</b>	•149841+03•	•149841+03.	•149841+03•	.149841+33.	.149841+03.
• .	= TCY =	H Č Č	۲C۲ =	11 	۶C ۲ =		∠CY =	%CY =	₿ >- 017	≈ NCY ≈	NCY =	n CY	n CY =	" 2 61

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•.			· . ·	· · · ·
3.2.14	Code Expansion		· .	-
•	Following is a list of	minimum stora	ge requirements.	
· · · · · · · · ·				, , , ,
		1	· · · · · ·	
AA	(2)			
AMNI	$(2 \cdot NMODES)$			
AMN2	$(2 \cdot NMODES)$	4		· · · · ·
ASM	(NTH NKZ)		•	· · · · ·
ASMST	(NTH, NKZ)	. ·		
BB	$(2 \cdot NIS)$		· · · · · ·	
BCAP	$(\mathbf{N}\mathbf{I}\mathbf{S})$			
BSM	(NTH, NKZ)	• • •	· · · · · · · · · · · · · · · · · · ·	
BSMST	(NTH, NKZ)	x		· ·
CC	$(2 \cdot NALP, NBETA)$			•
CCAP	(NALP. NBETA)			н
* CCAP	(NALP, NBETA)or C	CAP (NALPP.	NBETAP) whiches	ver is larger.
COE	(NCOE, NMODES)		, <u> </u>	
* COE	(NALP, NBETA) or (	COE (NALPP. I	NBETAP) whichev	er is larger.
* COEZ	(NALP) or COEZ (NA	LPP) whicheve	r is larger.	or to torgett
* COKP	(NALP. NBETA) or	COKP (NALPP.	NBETAP) which	ever is larger.
CON	(NMODES)		· · · · · · · · · · · · · · · · · · ·	
DD	(2)			·
ECAP	(NJPS)			
EE	(2 • NJPS)			
* FACT	(NBETA) or FACT (N	BETAP) which	ever is larger.	
FCAP	(NALPP NETAP)	• •		•
0 I 7	(2. NALPP NBETA	P)		· ·
GHAT	(NEREO NMODES)	- /		
MCO	(NCOE, NMODES)			
NCOEE	(NMODES)			
NKZ	(NMODES)			
NTH	(NMODES)			
OM	(NFREO)			
OMEGI	(NMODES)			
OMEG2	(NMODES)			
PHI	(NMODES)		· · · ·	
SRE	(NMODES)			
THP	(NJPS)		. ,	
TII	(NTH)			
TI2	(NTH)			• , •
TS	(NSS)			•
TTH	(NTHA)			
WMN	(NMODES)			·
·				

i.

	Z	(NOFZ)
:	Z11	(NBETA) or FACT (NBETAP) whichever is larger.
:	Z22	(NBETA) or FACT (NBETAP) whichever is larger.
	ZII	(NKZ)
	ZI2	(NKZ)
	ZJP	(NJS)
	ZKA	(NALP)
	ZKALP	$(2 \cdot \text{NALP})$
•	ZKALPP	(2 · NALPP)
	ZKAP	(NALPP)
	ZKKS	(NSS)
•	ZKP	(NKZ)
	ZKQ	(NTH)
	ZKS	(2 • NSS)
	ZMAS	(NMODES)
	ZNCAP	(NSIG, NETA)
·	ZNN	(2 • NSIG, NETA)
	ZNU	(2 • NETA)
	ZNUCAP	(NETA)
		,

NOTE: The following variables must be dimensioned the same to avoid errors in subroutine FINDI: (CCAP and FCAP), (FF and CC). These arrays must be based on the largest values of (NALP, NALPP) and (NBETA, NBETAP). The present form of the code allows up to ten values for NALP, NALPP, NBETA, and NBETAP.

Variables tagged by an (\*) are located in subroutine

FINDI.

3.2.15 Code Listing

(following)

	······································	· · · · · · · · · · · · · · · · · · ·	· · · · · · · · · · · · · · · · · · ·			
	· I.	· Í		· · · .		
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, 	COMPLEX	ACAP . PCAP . CC	AP.DCAP.EC	LAP. ECAP. RES	PS. 7KA.	7KAP,
•	1 ZNCAP+	TNUCAP . OMEG	1 . OME67 .	PHAT, GHAT,	CN . CM	
-	2.45M. BSN	4.•	<u> <u> </u></u>	. <u>7.12. 111. 11</u>	Za SMRa SMa CR	1. CB2
	STARKS STOR		2.(.2.11) - B.B.(	HOL COAPLIN	.101	1. DD(2).
	1 FCAP(20)	). FF(40). F	CAP(10+10)	• FF(20+10)•	7KA(2(	]) •
		11. 7K.AP (	. ZKALPP (	( <b>0</b> -). • .	TS ( 40)	(10.10).
	3 2NN (20+	10), 7NUCAP (	20) + 7NU(4	n) + 04541(50	). AMN1(100).	OME 62 (50) +
	-4 -4 MN2 (101	1)+ ZKKS(-20)	. ZKS(40).	7(100) + TTH	(100) + WMN (50)	• QM ( 50 )
	5 . 7 MAS ( 50)	)+ASM(10+10)	•R54(10+10	1) • MCO (15 • 20)	• NTH (50) • NK7 (5	(0) + CON (50)
the star were able a result and the second by	7. ACMST1	► \$403.4 N-66667-8-864. 101-101-771/0	50), 717(5		4.0	501.
	A PHT (50)	6HAT(25+30)	•7 JP (-2 []) • 1	HP (30)	n na uz kie e na zana na	· · · · · · · · · · · · · · · · · · ·
	EQUIVALEN	NCE LACAP.AA	) . (BCAP . P	30+ 4003) + (8	1% (DCAP+00)+	(FCAP+EE)+
			5.)	ALP	7KALPP).	
	2 (ZNCAP+)	ZNN). (ZNUCA	P+ZNU1+ (C	MFRI. AMNII.	(0M5G2+AMN2), .	
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<pre>&gt;&gt; (LL +NM) = 1) /NK7(NMN+1) &gt;&gt; (L-1+NTH(NM)) + 1 &gt;&gt; (L-1+NTH(NM)) &gt;&gt; (MCO(LL+NM) = 1+NK7(NM)) +1 +1 +1 -(LL+NM) +(L+2+L3+L4+L</pre>	• <sup>44</sup> • L L		· · · · · · · · · · · · · · · · · · ·			• • • • • • • • • • • • • • • • • • •
<pre>1)/NTH(NM)+1 P(L-1+NTH(NM)) )(MCO(LL+NM)-1+NK7(NM)) +1 +1 -1 -(LL+NM) (+L+CP)(3+L4+L+CP) (+L4)=ASM(L3+L4)+CP (L3+L4)=ASM(L3+L4)+CP (L3+L4)=ASMST(L3+L4)+CP (L3+L4)=CB) 7</pre>	• <sup>44</sup> • L L		· · · · · ·	· · · · · · · · · · · · · · · · · · ·		· • • • • • • • • • • • • • • • • • • •
<pre>P(L-1+NTH(NM)) D(MCO(LL+NM)-1+NK7(NM)) +1 +1 T(LL+NM) K+71) NM+L1+L7+L3+L4+L K4+4+10+11)+M K+L4)=ASM(L3+L4)+CP L3+L4)=BSM(L3+L4)+CP L3+L4)=BSMST(L3+L4)+CP L3+L4)=BSMST(L3+L4)+CP L3+L4)=CB T</pre>	• * • LL		· · · · · · · · · · · · · · · · · · ·	· · · · · · · · · · · · · · · · · · ·		مر بیرید می بر بیرید می بر بر بر
)(MCO(LL+NM)-1+NK7(NM)) +1 -(LL+NM) :F+71) NM+L1+L7+L3+L4+L K4+4+10+11)+M :+L4)=ASM(L3+L4)+CP :L3+L4)=ASM(L3+L4)+CP :L3+L4)=ASMST(L3+L4)+CP :L3+L4)=ASMST(L3+L4)+CP	• <sup>14</sup> • L L		· · · · · ·	· · · · · · · · · · · · · · · · · · ·		<b></b>
+1 -(LL+NM) (A+9+10+11)+M (+4)=ASM(L3+L4)+C9 (+4)=ASM(L3+L4)+C9 (+3+L4)=ASM(L3+L4)+C9 (+3+L4)=ASMST(L3+L4)+C9 (+3+L4)=ASMST(L3+L4)+C8 (+3+L4)=ASMST(L3+L4)+C8	• * • LL		·······	· · · · · · · · · · · · · · · · · · ·		••••••••••••••••••••••••••••••••••••••
+1 +1 -(LL+NM) -(LL+NM) -(L+7) NM+L1+L7+L3+L4+L -(4+9+10+11)+M -(4)=ASM(L3+L4)+C9 -(13+L4)=ASM(L3+L4)+C9 -(13+L4)=ASMST(L3+L4)+C8 -7	• * • L L		•	· · · · · · · · · · · · · · · · · · ·		
+1 +1 (LL +NM) (A+9+10+11) +M (+L4) = ASM(L 3+L4) + CP (L3+L4) = ASM(L 3+L4) + CP (L3+L4) = ASMST(L3+L4) + CP (L3+L4) = RSMST(L3+L4) + CB (7	• 4 • L L				•	
+1 -(LL+NM) (G+71) NM+L1+L7+L3+L4+L (A9+9+10+11) +M (+L4)=ASM(L3+L4)+C9 (L3+L4)=ASM(L3+L4)+C9 (L3+L4)=ASMST(L3+L4)+C9 (L3+L4)=BSMST(L3+L4)+C9 (13+L4)=BSMST(L3+L4)+C9	• <sup>4</sup> • L L		· · · · · · ·			
-(LL+NM) -(LL+NM) A9+9+10+11)+M A+L4)=ASM(L3+L4)+C9 A+L4)=ASM(L3+L4)+C9 L3+L4)=ASM(L3+L4)+C9 L3+L4)=ASMST(L3+L4)+C9 L3+L4)=BSMST(L3+L4)+C9 7	• 4 • L L		•	· · · · · · · · · · · · · · · · · · ·		
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3+L4)=85M(L3+L4)+CP (L3+L4)=85M5T(L3+L4)+CP (L3+L4)=85M5T(L3+L4)+CP (L3+L4)=85M5T(L3+L4)+CP	• · · · · · · · · · · · · · · · · · · ·			and the second	۰.	· · ·
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1	- 19-50-19-19-19-01+0195 - SMR±SMR+45M(IF+I ↓+RSMST(IP+ILT)≠7I	T) * 7 <u>1   (TP) * T</u> [ <u>1(IP) * TT</u> 2(TT)		T(TP+TT)+ )#212(IP)	7T2(TP)*** *TI1(TT)	2(11)	•
1 C	ПО БП []=]+N]HN SMR=SMR+4SM(IF+I ↓+RSMST(IP+IT)±7I WPITF(6+35) []-I	T) * 7]](TP) *T] [1[]P) *TT7(TT) T+SM5+ASM(]P+	1 ( IT ) + ASM S + BSM ( TP • I ' ( T ) • 7 I ] ( TC	T(TP+TT)+ T)+ZI2(IP) P)+TT1(TT)	717(TP)*TT *TI1(TT) •ASMST(TP+	2(TT) TT)+	
	10 60 112100000 SMR = SMR + 45M(IP+I + 85MST(IP+IT) + 71 WPITE(6+35) IP+T (712(IP)+TT2(IT);	T)*7[](TP)*T] [1(IP)*TT7(TT) T*SM5*A5M(IP* RSMST(IP*IT)*	1(IT) +ASMS +BSM(TP+I TT)+711(TC 711(IP)+T	T(TP+TT)+ )*ZI2(IP) )+TI1(TT) I2(IT)+PSM	712(10)**** ********************************	2(TT) TT)•	• • •
1 2 03	10 50 1111 • 0 40 SMP=SMP+4SM(IF • 1 + 8SMST(IP • 1 + 7) * 71 WPITE(5 • 35) IP • 1 712(IP) • TT 2(TT) • CONTINUE	T)*7[](TP)*T] 1(IP)*TT2(TT) T+SM5+ASM(IP+ RSMST(IP+IT);	1(IT) + ASMS + BSM(TP+I' TT) + 7 I1(TC 7 I1(IP) + T'	T(TP+TT)+ )*212(IP) )+TI1(TT) 12(IT)+PSM	7[2(TP)*TT *TI1(TT) *ASMST(TP* (IP+IT)	2(TT) TT)•	
C 1 C 1 C 1	10 50 1121+0140 SMR=SMR+45M(IF+I +85MST(IP+IT)*7I WPITE(5+35) IP+I 7I2(IP)+TT2(IT)+ CONTINUE SRE(NM)=SMR+2CYL	T)*711(TP)*T1 1(IP)*TT2(TT) T+SM9+ASM(IP) BSMST(IP+IT);	1(IT) +ASMS +BSM(TP+I) TT)+7I1(TC 7I1(IP)+T	T (TP + TT )+" T) * ZI 2 (IP) + P) + T I (TT) + I2 (IT) + ASM	7[2(TP)*TT *TI1(TT) *ASMST(TP* (IP * IT)	2(TT) TT)-	• • • • •
C 1 	10 50 11110000000 SMR = SMR + 45M(IF+I + RSMST(IP+LT) = 7I WRITE(5+35) IP+I (7I2(IP)+TT2(TT)) CONTINUE SRE(NM) = SMR+DCYL CONTINUE	T)*7[](TP)*T] 1(IP)*TT2(TT) T+SMS+ASM(IP RSMST(IP+IT);	11(IT) +ASMS +BSM(TP+I) (TT)+7I1(TC 7T1(IP)+T)	T (TP+TT)+" ")*ZI2(IP) ")+TI1(TT) "2(IT)+PSM	717(TP)*TT *T11(TT) *ASMST(TP* (IP+IT)	2(TT) TT)•	•
C 1 	10 50 1121 • 019 SMR = SMR + 45M (IF • I + 85MST (IP • LT) * 7 I WPITE (5 • 35) IP • I (712(TP) • TT 2(TT) • CONTINUE SRE(NM) = SMR * 2074 CONTINUE WRITE 46 • 37)	T)*7[](TP)*T] 1(IP)*TT2(TT) T+SM5+ASM(IP BSMST(IP+IT);	11(IT) +ASMS +BSM(TP+I) (TT)+7I1(T 7T1(TP)+T)	T (TP + TT)+ ) * ZI 2 (IP) ) • T I (TT) (2 (IT) • PSM	717(TP)*TT +TI1(TT) +ASMST(TP+ (IP+IT)	2(TT) TT)•	•
C 1 C 1 FO	110       A11       1101       A11       14         SMR = SMR + ASM(IF + I       ASMST(IP + LT) + 7 I       47         WPITF(6,35)       IP + I         VPITF(6,35)       IP + I         712(TP) + TT 2(TT) +         ONTTNUE         SRE(NM) = SMB + DCYL         ONTTNUE         WRITE(6,37)         WRITE(6,37)         P0       200         TR = 1 + NOF7	T)*2[1(TP)*T] 1(IP)*TT2(TT) T+SMS+ASM(IP+ RSMST(IP+IT);	1(IT) +ASMS +BSM(TP+I' TT)+711(TC 711(TP)+T'	T (TP + TT)+ ) * ZI 2 (IP) ) • T I (TT) (2 (IT) • 95M	717(TP)*TT +TI1(TT) +ASMST(TP+ (IP+IT)	2(TT) TT)•	
	10       A1       1101 + N14         SMR = SMR + ASM(IF + I         + RSMST(IP + IT) + 7 I         WPITF(S, 35)       IP + I         7I2(IP) + TT2(IT) +         ONTTNUE         SRE(NM) = SMB + DCYL         ONTTNUE         WRITF(S, 37)         WRITF(S, 37)         PO         PO         PR = 1 + NOF7         77=7(IR) * CO	T)*7[1(TP)*T] 1(IP)*TT2(TT) T*SM5*ASM(IP RSMST(IP*IT);	1(IT) +ASMS +BSM(TP+I) TT)+7I1(TP 7I1(IP)+T	T (TP+TT)+ ) * ZI 2 (IP) ) * T 1 (TT) (2 (IT) * ASM	717(TP)*TT *TI1(TT) *ASMST(TP* (IP + IT)	2(TT)	
C 1 C 1 FO 100	10       61       110       61       110       61         SMP = SMP + ASM(IF + I       11       71       11       11       11       11         WPITE(5,35)       10	T)*711(TP)*T1 1(IP)*TT2(TT) T+SM9+ASM(IP+ RSMST(IP+IT);	1(IT) +ASMS +BSM(TP+I) TT)+7I1(TC 7I1(IP)+T	T (TP+TT)+ ) * ZI 2 (IP) ) * T I (TT) [2 (IT) * ASM	7[7(TP)*TT *TI1(TT) *ASMST(TP* (IP * IT)	2(TT) TT).	
	10       40       110       40       14         SMR = SMR + ASM(IF + I         4       ASMST(IP + LT) + 7I         WRITE(5,35)       10 + I         712(19)       11 2(17)         00NTINUE       SMR + DCYL         00NTINUE       MRITE(6,37)         WRITE(6,37)       10         77=7(18)       400         D0       210       18 10         P1       210       10         NTHA       14       14	T)*7[](TP)*T] 1(IP)*TT2(TT) T+SM5+ASM(IP RSMST(IP+IT);	1(IT) +ASMS +BSM(TP+I) TT)+7I1(T 7I1(IP)+T	T (TP+TT)+ ) * ZI 2 (IP) ) * T 1 (TT) [2 (IT) * PSM	7[7(TP)*TT +TI1(TT) +ASMST(TP+ (IP+IT)	2(TT) TT).	· · · · · · · · · · · · · · · · · · ·
C 1 	100       A11       101       A11       14         SMR ± SMR + ASM(IF + I         SMR ± SMR + ASM(IF + I         WPITF(S+35)       IP + I         VPITF(S+35)       IP + I         712(IP) + TT2(IT) +         CONTINUE         SRE(MM) ± SMR + DCYL         CONTINUE         WRITFLS+37.         PO         2727(IR) + CO         PO	T) * 711 (TP) *T1 1(IP) *TT2(TT) T+SM5+ASM(IP RSMST(IP+IT);	1 ( 1 T ) + A S M S + H S M ( T P • I Y 7 T ) • 7 I 1 ( T P 7 T 1 ( I P ) • T Y	T (TP + TT)+ ) * ZI 2 (IP) ) + T I (TT) (2 (IT) + PSM	7[7(TP)*TT +TI1(TT) +ASMST(TP+ (IP+IT)	2(TT) TT).	
C 1 60 100	10       A1       110       A1       110       A1       110         SMR ± SMR ± ASM(IF + I       ASM ST(IP + LT) ± 7 I       WPITF(S + 35)       IP + I         WPITF(S + 35)       IP + I       (17 + I)       IP + I         VPITF(S + 35)       IP + I       (17 + I)         CONTINUE       SRE(MM) ± SMR ± DCYL       ONTINUE         VRITELS + 37.       IP + I + NOF7         72±7(IR) ± CO       IP + I + NOF7         72±7(IR) ± CO       PO + 21(I + UR + 1) + NMOD         PO + 207       NM ± 1 + NMOD         PST ± CON(NM)       IN + I	T)*7[](TP)*T] 1(IP)*TT2(TT) T+SM5+ASM(IP RSMST(IP+IT);	1(IT) +ASMS +BSM(TP+I) TT)+7I1(TC 7T1(IP)+T	T (TP + TT)+ ) * ZI 2 (IP) ) + T I (TT) (2 (IT) + PSM	7[7(TP)*TT +TI1(TT) +ASMST(TP+ (IP+IT)	2(TT) TT).	
C 1 	10       A1       101       A1       101       A1       40         SMR = SMR + ASM(IF + I       ASM(IF + I)       40       10       41         WRITE(6,35)       IP + I       71       40       10       41         CONTINUE       SRE(MM) = SMR + DCYL       CONTINUE       10	T) * 711 (TP) *T1 1(IP) *TT2(TT) T+SMS+ASM(IP RSMST(IP+IT);	1(IT) +ASMS +BSM(TP+I) (TT)+7I1(T 7I1(IP)+T)	T (TP + TT)+ ) * ZI 2 (IP) ) • T I (TT) (2 (IT) • PSM	7[7(TP)*TT +TI1(TT) +ASMST(TP+ (IP+IT)	2(TT) TT).	
	100       A11       101       A11       101         SMR = SMR + ASM(IF + I         ARSMST(IP+LT) + 7I         WPITF(S+35)       IP+I         VPITF(S+35)       IP+I         CONTINUE         TRE(NM) = SMR + DCYL         CONTINUE         WRITF(A6+37)         PO       200         TF = 1 + NOFF7         77=7(JR) + CO         PO       21(I) UR = 1 + NOFF7         77=7(JR) + CO         PO       21(I) UR = 1 + NOFF7         77=7(JR) + CO         PO       21(I) UR = 1 + NOFF7         PO       21(I) UR = 1 + NOFF7         PO       21(I) UR = 1 + NOFF7         PO       21(I) UR = 1 + NOF7         PO       21(I) UR = 1 + NOF7         PO       21(I) UR = 1 + NOF7	T)*2[1(TP)*T] 1(IP)*TT2(TT) T+SMS+ASM(IP+ RSMST(IP+IT);	1(IT) +ASMS +BSM(TP+I) TT)+7I1(T 7T1(TP)+T	T (TP • TT) + T) * ZI 2 (IP) ) • T I (TT) (2 (IT) • PSM	7[7(TP)*TT +TI1(TT) +ASMST(TP, (IP + IT)	2(TT) TT).	
	100       A11       101       A11       101         SMR = SMR + ASM(IF + I         SMR = SMR + ASM(IF + I         WPITF(S, 35)       IP + I         WPITF(S, 35)       IP + I         CONTINUE         SRE(NM) = SMR + DCYL         CONTINUE         SRE(NM) = SMR + DCYL         CONTINUE         SRE(NM) = SMR + DCYL         CONTINUE         WRITELS + 37.         PO 200       TP = 1 + NOF7         ZZ=Z(TR) + CO         PO 210       JR = 1 + NOF7         THETTH(JR)         PO 200       RT = NOF7 (NM)         PO 200       RT = NOF7 (NM)         PO 200       RT = 1 + NOF7         PSIECON(NM)       NOF5 = NOF5 (NM)         PO 200       LT = 1 + NOF7	T) * 2[](TP) *T] 1(IP) *TT2(TT) T * SMS * ASM(IP RSMST(IP * IT) *	1(IT) +ASMS +BSM(TP+I) (TT)+7I1(TC 7I1(TP)+T)	T (TP • TT) + T) * ZI 2 (IP) ) • T I (TT) (2 (IT) • 9 SM	7[7(TP)*TT +TI1(TT) +ASMST(TP, (IP + IT)	2(TT) TT).	
	10       A1       110       A1       110       A1       110       A1       110 <th>T) * 211 (TP) *T1 1(IP) *TT2(TT) T * SMS * ASM(IP RSMST(IP * IT) * ES /NK7(NM) * 1</th> <th>1 (1T) + ASM ( + BSM (TP + T) (TT) + 7 I1 (TC 7 I1 (TP) + T)</th> <th>T (TP + TT)+ ) * ZI 2 (IP) ) • T I (TT) 2 (IT) • 95M</th> <th>7[7(TP)*TT +TI1(TT) +ASMST(TP+ (IP+IT)</th> <th>2(TT) TT).</th> <th></th>	T) * 211 (TP) *T1 1(IP) *TT2(TT) T * SMS * ASM(IP RSMST(IP * IT) * ES /NK7(NM) * 1	1 (1T) + ASM ( + BSM (TP + T) (TT) + 7 I1 (TC 7 I1 (TP) + T)	T (TP + TT)+ ) * ZI 2 (IP) ) • T I (TT) 2 (IT) • 95M	7[7(TP)*TT +TI1(TT) +ASMST(TP+ (IP+IT)	2(TT) TT).	
	100       A11       1101       A11       1101         SMR = SMR + ASM(IF + I         + RSMST(IP+LT) + 7I         WPITF(S,35)       IP+I         VPITF(S,35)       IP+I         7I2(IP)       TT2(IT)         ONTTNUE         SRE(NM)       SMB+DCYL         ONTTNUE         WRITF(G,37)         WRITF(G,37)         PO       200         TF1 <npf7< td="">         77=7(IR) *CO         PO       210         PO       210         PO       217         NME1       NME7         77=7(IR) *CO       PO         PO       217         PO       217         PO       217         NME1       NMOD         PO       217         NOF       NME1         NOF       NME1         NTH(DA)       1         NTH(NM) +       1</npf7<>	T) * 7[](TP) *T] 1(IP) *TT2(TT) T * SMS * ASM(IP RSMST(IP * IT) * SMST(IP * IT) * /NK7(NM) * 1 1 M) )	1 ( 1 T ) + A S M S 9 H S M ( T P • I Y 9 T 1 ( T P • T ) • T I ( T P 9 T 1 ( T P ) • T Y	T (TP + TT)+ ) * 2I 2 (IP) ) • T I (TT) 2 (IT) • 95M	7[7(TP)*TT +TI1(TT) +ASMST(TP+ (IP+IT)	2(TT) TT).	
	100       A11       101       A11       114         SMR = SMR + ASM(IF + I         SMR = SMR + ASM(IF + I         WPITF(S+35)       IP + I         WPITF(S+35)       IP + I         CONTINUE         SRE(MM) = SMR + DCYL         CONTINUE         WRITF(S+37)         PO	T) * 7[](TP) *T] h(IP) *TT2(TT) T * SMS * ASM(IP * RSMST(IP * IT) *	1 ( 1T ) + ASM S + BSM ( TP • I ) 7 T ) • 7 I 1 ( T 7 T 1 ( TP ) • T	T (TP + TT)+ ) * ZI 2 (IP) ) + T I (TT) (2 (IT) + 95M	7[7(TP)*TT +TI1(TT) +ASMST(TP+ (IP+IT)	2(TT) TT).	
C 1 60 100	10       A1       101       A1       101       A1       101         SMP = SMP + ASM(IF + I       ASM ST(IP + LT) + 7 I         WPITF(S+35)       IP + I         VPITF(S+35)       IP + I         POITF(S+35)       IP + I         POITF(S+1)	T) * 711 (TP) *T1 1.(IP) *TT2(TT) T+SMS+ASM(IP+ RSMST(IP+IT); /NK7(NM)+1 1 M); J-1+NK7(NM))	1 ( 1 T ) + A S M S + H S M ( T P • J Y • T T ) • 7 I ] ( T P • 7 I ] ( T P ) • T Y	T (TP + TT)+ ) * ZI 2 (IP) ) • T I (TT) 2 (IT) • PSM	7[7(TP)*TT +TI1(TT) +ASMST(TP+ (IP+IT)	2 ( T T ) T T ) •	
	10       A1       101       A1       101       A1       101       A1       101 <th>T) * 711 (TP) *T1 1.(IP) *TT2(TT) T * SMS * ASM(IP RSMST(IP * IT) * * /NK7(NM) + 1 1 M)) J-1 * NK7(NM) )</th> <th>1 ( 1T ) + ASM S + BSM ( TP + J 7 T ) + 7 I ] ( T 7 T ] ( TP ) + T</th> <th>T (TP + TT)+ ) * ZI 2 (IP) ) • T I (TT) 12 (IT) • PSM</th> <th>7[7(TP)*TT +TI1(TT) +ASMST(TP+ (IP+IT)</th> <th>2 ( T T ) T T ) •</th> <th></th>	T) * 711 (TP) *T1 1.(IP) *TT2(TT) T * SMS * ASM(IP RSMST(IP * IT) * * /NK7(NM) + 1 1 M)) J-1 * NK7(NM) )	1 ( 1T ) + ASM S + BSM ( TP + J 7 T ) + 7 I ] ( T 7 T ] ( TP ) + T	T (TP + TT)+ ) * ZI 2 (IP) ) • T I (TT) 12 (IT) • PSM	7[7(TP)*TT +TI1(TT) +ASMST(TP+ (IP+IT)	2 ( T T ) T T ) •	
	10       A1       101       A1       101         SMR = SMR + ASM(IF + I         + RSMST(IP + LT) + 7 I         WPITF(S, 35)       IP + I         712(TP) + TT2(TT) +         CONTINUE         TRE(MM) = SMR + DCYL         CONTINUE         TRE(TEL6+37)         WRITE(L6+37)         TO 200 TP = 1 + NOF7         77=7(TR) + CO         PO 21(1 UR T1 + NOF7         PO 21(1 UR T1 + NOF7         PSIECON(NM)         NOCS = NCOFF(NM)         PO 216         NTH(UR) +         NT(L-1) / NTH(MM) +         VIEL + NM         NTH(L-1) / NTH(MM) +         NOC (L + NM)         NOC (L + NM)         NOD (M	T) * 211 (TP) *T1 1(IP) *TT2(TT) T * SMS * ASM(IP RSMST(IP * IT) *	1 ( 1 T ) + A S M S + B S M ( T P + J Y 7 T ) + 7 I ] ( T P 7 T ] ( T P ) + T Y	T (TP • TT) + T) * ZI 2 (IP) ) • T I (TT) 2 (IT) • PSM	7[7(TP)*TT +TI1(TT) +ASMST(TP, (IP + IT)	2 ( T T ) T T ) •	
	100       A11       101       A11       101         SMR = SMR + ASM(IF + I         + BSMST(IP + LT) + 7 I         WPITF(S, 35)       IP + I         YPITF(S, 35)       IP + I	T) * 711 (TP) *T1 1(IP) *T72(TT) T * SMS * ASM(IP RSMST(IP * IT) * RSMST(IP * IT) * /NK7(NM) * 1 1 M)) J-1 * NK7(NM) *	1 ( 1 T ) + A S M S + B S M ( T P + J Y 7 T ) + 7 I ] ( T P 7 T ] ( T P ) + T Y	T (TP • TT) + T) * ZI 2 (IP) ) • T I (TT) 2 (IT) • 9 SM	7[7(TP)*TT +TI1(TT) +ASMST(TP+ (IP+IT)	2 ( T T ) T T ) •	
	100       A11       1101       A11         SMR = SMR + ASM(IF + I         HASMST(IP+LT) + 7I         WPITF(S+35)       IP+I         VPITF(S+35)       IP+I         VPITF(S+37)	T) * 711 (TP) *T1 1(IP) *TT2(TT) T * SMS * ASM(IP * RSMST(IP * IT) * ES /NK7(NM) + 1 1 M)) J-1 * NK7(NM) *	M • 1 1	T (TP • TT) + T) * ZI 2 (IP) ) • T I (TT) 2 (IT) • 95M	7[7(TP)*TT +TI1(TT) +ASMST(TP+ (IP+IT)	2 ( T T ) T T ) •	
C	100       A11       1101       A11         SMR = SMR + ASM(IF + I         ASMST(IP+LT) + 7I         WPITF(S+35)       IP+I         VPITF(S+35)       IP+I         VPITF(S+35)       IP+I         VPITF(S+35)       IP+I         POITF(S+35)       IP+I         VRITF(S+35)       IP+I         VRITF(S+35)       IP+I         VRITF(S+37)          PO       200       TF=1+NPF7         ZMRITF(S+37)           PO       200       TF=1+NPF7         ZMRITF(S+37)           PO       200       TF=1+NPF7         ZMRITF(S+37)           PO       200       TF=1+NPF7         ZMRITF(JA)           PO       200       TF=1+NPF7         ZMRITF(JA)           PO       200          PO       2017          PO       2015          PO       2015          PO       2015          PO       2015          PO	T) * 711 (TP) *T1 1(IP) *TT2(TT1 T * SMS * ASM(IP * RSMST(IP * IT) * PSMST(IP * IT) * 1 * L 2 * L 7 * L 4 * L * M	M +LL	T (TP + TT)+ T) * ZI 2 (IP) P) • T I (TT) Z (IT) • 95M	7[7(TP)*TT +TI1(TT) +ASMST(TP+ (IP+IT)	2 ( T T ) T T ) •	
	HO AN FIELENTH         SMRESMB+ASM(IF.I         SMRESMST(IP.LT)*71         WPITE(S.35) IP.T         WPITE(S.35) IP.T         TT2(TP).TT2(TT).         CONTINUE         SRE(NM)ESMB*DCYL         CONTINUE         WRITE(S.37)         PO 200 TP =1.NCF7         ZZZ7(TB)*CO         PO 210 JB =1.NTHA         THETTH(JA)         PO 210 JB =1.NTHA         THETTH(JA)         PO 217 NM =1.NTHA         NCCEENCOES(NM)         NCEENCOES(NM)         NCEENCOES(NM)         NCEENCOES(NM)         NCEENCOES(NM)         NCEENCOES(NM)         NCEENCOES(NM)         NE(EENCOES(N	T) * 711 (TP) *T1 1(IP) *TT2(TT1 T * SMS * ASM(IP * BSMST(IP * IT) * PSMST(IP * IT) * 1 * L ? * L ? * L 4 * L * M	M • LL	T (TP + TT)+ ) * ZI 2 (IP) ) + T I (TT) 2 (IT) + PSM	7[7(TP)*TT +TI1(TT.) +ASMST(TP+ (IP+IT)	2(TT) (TT).	
C	MO       AN       FIELENSH         SMR = SMR + ASM (IF + I         HASMST(IP+LT) + 7I         WPITE(S+35)       IP+I         7I2(TP) + TT2(TT) +         CONTINUE         CRE4NM) = SMR + DCYL         CONTINUE         PO 200 TP = 1 + NOFEZ         77=7 (JR) * CO         PO 210 JR 1 + NOFEZ         PSTECON(NM)         NCOS = NCOFE (NM)         PO 205 LI = 1 + NCOFE (NM)         PO 206 LI = 1 + NCOFE (NM)         NCOS = NCOFE (NM)	T) * 711 (TP) *T1 1(IP) *TT2(TT1 T * SMS * ASM(IP * BSMST(IP * IT) * PSMST(IP * IT) * NK7(NM) + 1 1 M) ) J-1 * NK7(NM) * 1 *L7 * L7 * L4 * L * M	M +LL	T (TP + TT)+ ) * ZI 2 (IP) ) • T I (TT) 2 (IT) • PSM	7[7(TP)*TT +TI1(TT) +ASMST(TP+ (IP+IT)	2 ( T T ) T T ) •	
C 100	<pre>MD AN [10] NIH: SMP = SMP + ASM(IF + I + RSMST(IP + LT) + 7 I WPITE(6,35) IP + I 712(TP) + TT2(TT) + CONTINUE TRE(MM) = SMB + DCYL CONTINUE WRITEL6+37) PO 200 TP = 1 + NOF7 77=7(TB) + CO PO 21(L JB = 1 + NOF7 PSTECON(NM) NOC5 = NCOF5(NM) PO 205 LL = 1 + NOF5 LT(MCO(LL + NM) + 1) MI(L = 1) / NTH(NM) + L1=MOD(MCO(LL + NM P1=L1 D2=L7 L3=L2+1 14=L1+1 WPITE(F + 31) NM + L GO = TO(2+3+4+5) + 3</pre>	T) * 711 (TP) *T1 1 ( IP) * TT2 (TT) T * SMS * ASM( IP * RSMST( IP * IT) * RSMST( IP * IT) * 1 * K 7 (NM) + 1 1 M) 1 * L 7 * L 7 * L 4 * L * M	<pre>1 ( IT ) + Λ S M S + B S M ( T P + I Y T ) + 7 I ] ( T P 7 I ] ( T P ) + T 7 I ] ( T P ) + T </pre>	T ( T P + T T ) + T ) * ZI 2 ( I P ) P ) • T I ( T T ) T 2 ( I T ) • P S M A	7[7(TP)*TT +TI1(TT) +ASMST(TP+ (IP+IT)	2 ( T T ) T T ) •	
C C C C C C	<pre>M9 %N [10] *NIH: SMP = SMP + 4SM (IF + I + RSMST(IP + LT) *7 I WPITE(6,35) IP + I 712(TP) *TT2(TT) * ONTTNUE TRE(NM) = SMB*DCYL CONTTNUE WRITE(6,37) P0 200 TP = 1 *NOF7 77=7(TB) *C0 P0 21(L JB = 1 *NOF7 P0 21(L JB = 1 *</pre>	T) * 711 (TP) *T1 1(IP) *TT2(TT) T * SMS * ASM(IP * RSMST(IP * IT) * RSMST(IP * IT) * PSMST(IP * IT) * NK7(NM) + 1 1 1 N) J-1 * NK7(NM) * 1 1 * * * * * * * * * * * * *	1 ( 1 T ) + Λ S M C + H S M ( T P + J Y • T T ) + 7 I ] ( T P • 7 T ] ( T P ) + T Y M + L L	T ( T P + T T ) + T ) * 2I 2 ( I P ) P ) • T I 1 ( T T ) T 2 ( I T ) • P S M 	7[7(TP)*TT +TI1(TT) ASMST(TP, (IP,IT)	2 ( T T ) T T ) •	

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	PSImpsI+00S(D1*TH)*00F(LL+NM)*00S(D2*77)
	GALTO 206 - CONTRACTOR CONTRA
	PSI=PST+D3S(31+TH) *C05(LL+NM) *SIN(D2+27)
	GO TO 206 CONTRACTOR CONTRACT
4	PCI_PCI+STN(D] +TH) +COF(LL+NM) +COS(D2+72)
مربع با الموطيق بر مستوقو	and and an
. 5	PSI=PST+STN(01+TH)+00F(LL+NM)+STN(02+77)
205	CONTINUE
С	WRITEIS, 28) TR. JP. 77. TH. PST
207	DHT (NM) = DCT
	00 220 L3=1.NEPED
·	PHATEHCAP
· · · · · · · · · · · · · · · · · · ·	TE(NSS-17-1) 50 TO 224
	00 221 TS-1-MSC
	RHAT=RHAT+7KK5(TS) * CFXP(-OM(1 R) * CM*TS(TS))
270	TE(NETALT.1) GO TO 225
	DO 227 TTI-NETA
	CRI-1 // $OM(IRI-7MUCARITI)$
· · ·	
223 223	
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• ·	NU SNA NWII-NNANYES.
	SMESK+PH1 (NM) +(H40) (EP+NM) + SPF(NM) - see
. C	WOITE(6, KS) NM+LR+SM+GHAT(LB+NM) + CHE(NM)
	anna an an ann an ann ann an ann an ann an a
	PFSPS=SM#PHAT
<b></b>	
	AIN90(SEZDC)
	PHASE=1.5707963
	TE(Y,LT,D,) PHASE=PHASE+PT
· .	CO TO 242
	DHASE TATAN (Y/Y)
·	TE(X+Y) 240+241+241
	TE (X,LT,N,)PHASEIRHASE+PI
	60 TO 242
	PHASE TOHASE + DT
	TE(X.GT.D.) PHASE=PHASE+PT
2.42	WMAR=SQRT(X+++++2).
· · ·	TT 3TTHEON * TH
-	CMM = OM (LR) / PT.7
	PHASE-PHASE+THOON
اليين مراجبهم	WPTTE (6.36) OMM. JJ 3. 7 (JA) . RESPS. WMAC. PHASE
220	CONTINUE
<b>7.1.</b>	CONTINUE
200	CONTINUE
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	20 FORMAT(5515,2)
	31 FORMAT(1515)
	32 FORMAT ( 85 10. 31
	35 FORMAT(215+9512+5/(14+10F12+5))
•	36 EORMATL134 DEREOUENCY = E13.6. 11H. THETA = 513.5. ZH. Z = E13.6.
1	1 14H+ RESPONSE = 2F13.6773X+12HMAGNITUDE = E13.6+11H+ PHASE =
	37 FORMAT(24HD***END OF INPUT DATA***//)
	3.8 FORMOT(1.74.1 * * * TNR4) T., DATA * * * ).
	END .
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	SURPOUTINE FINDICER +71+72+ACAP+BCAP+CCAP+2KA+NALP+NBETA+FUNT+72F+
	COMPLEX
	17.22+711+5M+5M2+5M3+ACAP+BCAP+CCAP
	1+7KPT+FUNT
	DIMENSION 7KA(1).COEZ(20) + COKP(10) + COF(10+10) + EACT(11) +
	1 711(20) • 722(20) • CCAP(10 • 10) • PCAP(1) • 77P(1)
	13623800./
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	77=7K+7KA(T)
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	minimum dana (CNII). ()
	DD 10 JEL-NRETA
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	COF(I + J) = CN/COKP(I + J + 1) + CCAP(I + J)
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	DO 15 JEL+NRETA
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15 CONTINUE					
IS CONTINUE					·
13 SM7=0.					
$ZKPT=(D_{+})_{+}7K$			•	· · · · · · · · · · · · · · · · · · ·	
TE (NUS-LT.1) CO TO 20			· ·		,
BO 16 J-1-N IS					
SM3-SM3+RCAP(1)+CEXP(2)	(0T+770(J))		1997 - 19		
WRITE (E. TO) I. J. SM3. BC.	AP(.1) .7KPT.	779(1)			
18 CONTINUE					
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200 FUNT-FM2+SM3+ACAD+172-	711/04				
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$\begin{array}{cccccccccccccccccccccccccccccccccccc$	n. .02 .17 154.4314 280.3506 .5554379 1.005094 52 54 00 .255.76 54 1021514 11 .98810 15 .19080	1. .02 170.1672 1.099990 082-01 - 329+00 995-01 -	0. .02 .187.4918 .7388390 .51556394+00 .77966249+00 .16254598+00 .98501851+00	n. 	.n= .0. .02 258.45 .75427 .83-01 .96-01
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Response to Random Excitation (RANCYL)

3.3.1 Program Description

The RANCYL computer program computes the dynamic response of nonuniform beams and cylindrical shells for a class of random pressure fields. The structural mode shapes in the form of combinations of trigonometric functions with arbitrary constant coefficients are assumed. These coefficients are obtained from the computer code "FITMSC."

3.3.2 Input

3.3

Section 3.3.9 presents the necessary input to be read into the code.

3.3.3 Governing Equations

The governing equations are given in Section 2.4.2.

3. 3. 4 Method of Solution

The computational procedure is described in Section 2.0.

3.3.5 Restart

The code contains a restart feature. The first time the code is run, the quantity "ZJUNK" is punched on cards. ZJUNK is the double sum involving rerms like  $H_1^*$  I(-k, k, k, k, k). This part of the calculation represents the largest portion of the computation and hence is advantageous not to recalculate it if additional runs are to be performed.

## 3.3.6 Termination

The code will be terminated when the input data has been exhausted.

### 3.3.7 Computer Conversion

The program was written in FORTRAN V. It has been run and checked as thoroughly as is practical on the UNIVAC 1108 (EXEC 8). The code was designed to be as machine independent as possible. To run the codes on a CDC or IBM computer, the control cards at the beginning of each subroutine must be eliminated and/or replaced with appropriate control cards.

### 3.3.8 Equipment Requirements

The code uses no tape units other than 5 and 6 for input and output, respectively. The amount of core necessary to run is a strong function of the number of mesh points, modes, frequencies, etc. (See Section 3.3.14 for minimum storage requirements.) The present form of the code uses approximately 26,000 cells. There will be cards punched if ISHOT is less than or equal to 1. (See Section 3.3.9).

3.3.9 Program Input Requirements

NOTE: Certain real variable arrays were equivalenced to their complex counterparts to avoid the problem of format variation from machine to machine for complex variables.

### 3.3.10 Card Formats

NOTE: All integer variables must be right adjusted. Floating point fields must contain a decimal which may be arbitrarily located in the field width.

## CARD GROUP 1

Columns Description NTHA, the response is computed for the points 1-5 Z,  $\theta$ , Z',  $\theta'$ . Z and Z' use the same set of numbers.  $\theta$ ,  $\theta'$  use the same set of angles. NTHA is the number of angles in this set. 6-10 NOFZ, number of different values of Z (also Z') for which the response is calculated. (Integer) 11-15 NFREQ, number of frequencies for which the response is calculated. (Integer) 16-20 NMODES, number of mode shapes for which fit data is available. (Integer) 21-25 NBETA, number of  $\beta$  terms in  $Q_1(Z_0)$ . (Integer) NETA, number of  $\eta$  terms in  $Q_2(\theta_0)$ . (Integer) 26-30 NALP, number of a terms in  $Q_1(Z_0)$ . (Integer) 31-35 NKZET, number of  $\zeta$  terms in  $Q_2(\theta_0)$ . (Integer) 36-40 NGAM, number of  $\gamma$  terms in  $Q_1(Z_0)$ . (Integer) 41-45 NEPS, number of  $\varepsilon$  terms in  $Q_1(Z_0)$ . (Integer) 46-50 NLAM, obsolete 51-55

Columns	Description
56-60	NSIG, obsolete
61-65	NSS, number of $K_{s}$ 's in $\hat{Q}_{3}$ (w). (Integer)
66-70	NETA1, number of $\eta_1$ 's in $\hat{Q}_3$ (w). (Integer)
71-75	NSIG1, number of $v_{\sigma_1}$ terms in $\hat{Q}_3$ (w). (Integer)
76-80	NE TA2, number of $\eta_2$ 's in $\hat{Q}_3$ (w). (Integer)
Next Card, 1-5	NSIG2, number of $v_{\sigma_2}$ terms in $\hat{Q}_3(w)$ . (Integer)
6-10	ISHOT, constant: set equal to 1 for an initial run
	and set equal to 2 for a continuation run. If ISHOT=2
•	additional data (ZJUNK, See Card Group 13) will be
	required. (Integer)
11-15	NCROS, flag: If NCROS = 1 no cross terms will be
	evaluated in W. If NCROS = 0 all terms will be included
	in the summation for W.

CARD GROUP 2

Columns	Description
1-10	ZNOT, length of the cylinder in inches. (Floating point)
11-20, 21-30, 31-40, 41-50,	Z, the Z component of the points for which the cross spectral density of the response will be calculated.
51-60, 61-70,	All combinations of Z, Z', $\theta$ , $\theta'$ will be used,
71-80	where $Z'$ takes on the same set as Z. (Floating
•	point, NOFZ number in all)

CARD GROUP 3					
Columns	Description				
1-10	RCYL, radius of the cylinder in inches. (Floating				
	point)				
11-20, 21-30,	TTH, $\theta$ , angular values for which the cross				
31-40, 41-50,	spectral density of the response are calculated.				
51-60, 61-70	(Floating point, NTHA numbers in all.)				
71-80					

NOTE: In the following three groups it is assumed the number of terms for each variable is one. If there are more terms the columns will be shifted appropriately.

76

## CARD GROUP 4

Columns

### Description

1-10, 11-20

AA,  $A_0$ , constant pressure field term in  $Q_1(Z)$ , real part followed by imaginary part. (Floating point)

21-30, 31-40

AA1, real and imaginary parts of  $A_1$  used in  $Q_1(Z)$ . (Floating point)

41=50, 51-60

BB,  $B_{\alpha,\beta}$ , real and imaginary components of  $B_{\alpha,\beta}$ . There will be NALP pairs of numbers for  $\beta=1$ , followed by NALP pairs of numbers for  $\beta=2$ , etc. If NALP=0 there must be two fields containing zero. (Floating point, 2 x NALP x NBETA numbers in all.)

Columns

Description

61-70, 71-80

CC,  $C_{\gamma, \epsilon}$ , real and imaginary components of  $C_{\gamma, \epsilon}$ . There will be NGAM pairs of numbers for  $\epsilon$ =1, followed by NGAM pairs of numbers for  $\epsilon$ =2, etc. If NGAM=0 there must be two fields containing zero. (Floating point, 2 x NGAM x NEPS numbers in all.)

New Card 1-10, 11-20

ZKALP,  $K_{\alpha}$ , real and imaginary components of  $K_{\alpha}$ . There will be NALP pairs of numbers. (Floating point)

21-30, 31-40

ZKGM,  $K_{\gamma}$ , real and imaginary parts of K. There will be NGAM pairs of numbers. (Floating point)

CARD GROUP 5

Columns

### Description

1-10, 11-20

DD,  $D_0$ , constant pressure field term in  $Q_2(\theta)$ , real part followed by the imaginary part. (Floating point)

21-30, 31-40

DD1, real and imaginary parts of  $D_1$  used in  $Q_2(\theta)$ . (Floating point)

41-50; 51-60

EE,  $E_{\zeta, \eta}$ , real and imaginary components of  $E_{\zeta, \eta}$ . There will be NKZET pairs of numbers for  $\eta=1$ , followed by NKZET pairs of numbers for  $\eta=2$ , etc. If NKZET=0 there must be two fields containing zero. (Floating point, 2 x NKZET x NETA numbers in all.)

Columns	Description
61-70	ZKZETA, $K_{\zeta}$ , real and imaginary parts of $K_{\zeta}$ .
	There will be NKZET pairs of numbers. (Floating
	point)
CARD GROUP 6	
Columns	Description
1-10	HCAP, $H_0^{}$ , constant pressure term in $\hat{Q}_3^{}(\omega)$ .
	(Floating point)
11-20, 21-30	ZKS, K, real and imaginary parts of K. (Float-
	point there will be NSS successive pairs of
	$K_s$ . If NSS = 0 two zero fields must be present.)
31-40	TS, $t_{s}$ , appearing in $\hat{Q}_{3}(w)$ . There must be at
	least one field (which may be zero) and up to
	NSS numbers. (Floating point)
41-50, 51-60	ZNN, N, $\eta_1$ , $\sigma_1$ , real and imaginary components of
	N . There will be NSIG1 pairs of numbers for $\eta_1, \sigma_1$
	$\eta_1 = 1$ followed by NSIG1 pairs of numbers for $\eta_1 = 2$ ,
	etc. until the list of $\eta_1$ is complete. If NSIG1 = 0
	two fields containing zero must be present. (Float-
	ing point)
61-70, 71-80	ZNU, $\nu$ , real and imaginary components of $\nu$ .
	There must be at least two fields and up to NETA1
	pairs of numbers in all. (Floating point)

New Card

Columns

1-10, 11-20

ZMM, M , real and imaginary components of  $\eta_2, \sigma_2$ M . There will be NSIG2 pairs of numbers  $\eta_2, \sigma_2$ for  $\eta_2=1$  followed by NSIG2 pairs of numbers for  $\eta_2=2$ , etc. until the list of  $\eta_2$  is complete. If NSIG2=0 two fields containing zero must be present. (Floating point)

21-30, 31-40

ZMU, v, real and imaginary parts of v  $\eta_2$ There must be at least two fields and up to NETA2 pairs of numbers in all. (Floating point)

<u>CARD GROUP 7</u> <u>Columns</u> 1-10, 11-20, 21-30, 31-40, 41-50, 51-60, 61-70, 71-80

Description

Description

AMN1,  $\alpha_{nm}$ , damping constants. (Floating point-NMODES numbers in all)

CARD GROUP 8

Columns	Description
1-10, 11-20,	WMN, $w_{nm}$ , modal frequency in cycles per second.
21-30, 31-40,	(Floating point - eight numbers per card, NMODES
41-50, 51-60,	in all.)
41 70 71 90	

CARD GROUP 9		
Columns	Description	
1-10, 11-20,	OM, w frequencies for which the re	sponses are
21-30, 31-40,	to be calculated. (Floating point -	eight numbers
41-50, 51-60,	per card NFREQ in all.)	·
61-70, 71-80		

# CARD GROUP 10

Columns	Description
· · · ·	
1-10, 11-20,	ZMAS, M , modal mass. (Floating point
21-30, 31-40,	eight numbers per card NMODES numbers in all.)
41-50, 51-60,	
61-70, 71-80	
CARD GROUP 11	
Columns	Description
1-5	NTH, number of $\theta$ terms in the fitting of the modal
	data. (Integer)
6-10	NKZ, number of Z terms in the fitting of the
	modal data. (Integer)
11-15	NCOE, number of non-zero terms in the fit,
	excluding the constant term.
16-20, 21-25,	MCO, index tagging the fit coefficients with the
26-30, 31-35,	appropriate trigonometric term. (Integer -
36-40, 41-45,	NCOE numbers in all.)
46-50, 51-55,	
56-60, 61-65,	
66-70, 71-75,	
76-80	

CARD GROUP 12	
Columns	Description
1-15	CON, constant term in the fits to the mode shapes.
н н. Н	(Floating point)
15-30, 31-45,	COE, fit coefficients to the mode shapes. (Floating
46-60, 61-75	point NCOE numbers in all.)

Card groups 11 and 12 are repeated once for each mode number. These two card groups are the direct output of the FITMSC computer code.

### CARD GROUP 13

# Description

1-15, 16-30

Columns

ZJUNK, SA, summations involving terms like  $H_l^*I(K_p, K_q, K_r, K_s)$ . There will be NMODES groups of cards with each group consisting of NMODES numbers, 5 per card. (Floating point)

NOTE: Card Group 13 will be present only for continuation runs when ISHOT  $\geq 2$ . See Card Group 1.

NOTE: To run the random beam problem set

1)	$R = RCYL = 1/2\pi$
2)	$D_0 = D(1) + i \cdot D(2) = 1 + 0i$
3)	NKZET = 0
4)	$E_{c,n} = EE(1) + iDD(2) = 0$
4)	$D_0^{(3)} = DD(1) + iDD(2) = 0$
6)	NTH = 1 for all modes

3.3.11 Sample Input

The following is a listing of the input data used to obtain the sample output listed in Section 3.3.13. Model 1 fit data from FITMSC was used as input. Sample 1 is an initial run and sample 2 is a restart run.

# SAMPLE 1 INTITAL RUN

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.11224375-01	- 17934819-07	11332911-03	70947396-04	49112981+96
-20484 -02	1103003	•		•••••••••••••••••••••••••••••••••••••••
-51917104+03	.20000000	25507292-01	.19073486-05	-24443792-05
- 354 97442-14	• 54142372-05	.35527137-14	.14253103-05	- 34694477-17
-28285843-05	- 59389939-17	- 57879925-15	.0000000	69900039-07
- 0100000	34538900-09	- 0000000	45207499-07	.0000000
-56106725-01	26736174-18	.42572224-01	11630163-09	••••••••
- 26597324-01	74505806-08	-61963097+03	.0000000	10804297-74
- 35457749-14	-85471957-04	34694470-17	-114421685-05	34694470-17
- 57918587-05	• 6000000	- 64838254-94	-59388939-17	.19081074-07
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.10359292-01	-11358584-12	34553275-01	11518794-09	
-55519899-05	.0000000	.91800387-05	.00000000	.41866453+03
	59759068+00	.0000000	18881809-35	.88817842-15
39946752-05	•0000n000	29959612-25	.00000000	11280961+02
0000000	• 86053009+D1	.00000000	64937447-07	.00000000
23508185-04	13995749-13	.14586722-04	.0000000	
.48326910-05	.14210855-13	.83259181-04	71054274-14	.85095357+00
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	14203916-13	77697399-04	.28421739-13	85236939+01
.0000000	11293942+02	.00000000	98204112-08	.0000000
	• 0000000	.18294711-03	27547409-13	
.21759330-05	69398939-17	20208235-05	.00000000	18195811-05
.0000000	79583857-05	35527137-14	<b>.</b> 14426653 <b>+</b> 03	•0000000
49706685-05	71013579-14	.65237352-05	.00000000	.60091107-07
	-+25154474-07	.00000000	.52918745+01	.0000000
.37171139-05	.14432899-1*	67997038-05	86735174-18	
	14183099-13	99799539-06	.27755576-16	23245121-05
•14210855-13	21757120-05	.0000000	30602892-05	•00000000
	.0000000	41428340-02	.19626451-08	<b>.12379359-06</b>
•0000000	.32952348-07	•0°00000	97750167-07	-0000000
	•59398939 <del>-</del> 17	12667939+00	13877789-16	
79318651-05	14238610-13	58513522-04	•0000000	63395283-75
	-•76027782-04	.71088968-14	.45707555-05	.71088958-14
41428517-02	18626451-08	.78300469+03	.0000000	79778218-07
	•11751475-06	.0000000	.13980293-05	•0000000 <u>0</u> 0
.12999255+00	11367296-12	36532602+00	.46554760-09	
	• 00000000	.11795502-76	.00000000	11280970+02
•00000000	85236887+01	.0000000	.57579541-07	.00000000
•23033482-05	• 00000000	12959964-76	.0000000	72532459+03
,74575805-08	•13826454+0 <u>1</u>	.00000000	.29155202-05	.3552/13/-14
23913413-06	• 00000000	.22217379-96	.00000000	
.93470517-07	•73380000	35038372-38	.00000000	•86053038+01
• 0000000	11293952+02		31585376-07	
•82525837-117	•	-2:419093-36		21434949+00
	• /2×2/235+U3	- 24220745 05	16%/0818-05	•000000000
87648142-17		- FERTON OF	.00000000	
	• 10000010 10700077-07		-UUUUUUUU 52010770+01	
		•99960721710 20760775-00	00000000 00000000	2//395110_05
16163866-05	• CUBODUOU . _ 12071107 07	-21170730-56 RAARAAA	- 00000000 26700707+07	•2023213-02
	-*122,1121-02	- 19756025-DC	•26789797+83 0000000	•00000000
Erines	- • 00000000 19//29977-15	.10097261-01	•000000000 0000000	- 21858523-04
• 2970053%-01	■T2450205-T5	●★、ボタイミウエキウ★		• 5 # 6 9 6 9 5 9 - 6 4

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•13988810-17 -•10426783+00 •0000000 •84050091+93 •42578674-01 •0000000 *•12667398+00 •0000000	16220110 .7000000 28601637 .23941858 .69388939 .15757730 10408341 10983193	-03 .00 -07 .00 -06 .39 -1734 -03 .71 -1537 -06 .07	2000000 29865,50+00 1000000 5732599+01 579483-01 1019579-14 1071783+00 1000000	.25124913-05 .59894668-09 .65398529-07 .40046871-07 .11541538-09 45213664-05 .93132257-09 11558868-06	.14321877-13 99853210-07 .00000000 .18039935-04 .00000000 .78377914-07 .00000000
	29802322.	-37 .83	971035+33	11129305-06	
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a subset of the second s

The input is printed immediately after being read. No labels are printed. The order is the same as listed for the input cards.

# VARIABLE

Frequency	w, frequency of the calculation.			
Z	Z			
Theta	θ Coordinates of the two points for			
Z 1	Z' which the cross spectral density			
THETA 1	$\theta'$ ) of the response is computed.			
Magnitude	W (Z, $\theta$ , Z', $\theta'$ ) , magnitude of the cross spectral density of the response at two points on the cylinder			
PHASE	$\varphi$ , Phase associated with W(Z, $\theta$ , Z', $\theta$ ')			

# 3.3.13 Sample Output

The following sample case was run with the sample

87

# input as data.

· ·	1 .	· t	• • •				
• • • INPUT DATA •	• •		,			· · ·	
1 3 71	12 1	0 2	1 2	1 1	1	0 0	0
0 2 0						•	
•13200+03	•66000+02	•88000+0	2 •1100	0+03			
•50000+02	•00000		•				•
.00000	• 00000	•00000	•0000	0.000	000	50000+00	• •
• 0 0 0 0 0	•50000+00	•10000+0	0 •2500	0-01100	00+00	•25000+01	
• 0 0 0 0 0	•00000	•00000	•0000	0.10	000+01	.00000	
.16000-01	•00000	•00000	•0000	0.000	000	• • 0 0 0 0 0	
•00000	•00000					, 	
•10000-01	+10000-01	•10000-0	1. •1000	0-01 .100	00-01	•10000-01	
•10000-01	•10000-01	•					•
•14984+03	•14984+03	+15443+0	3 •1544	3+03 .170	017+03	•18749+03	
•28036+03	•28036+03						
•10000+03	•11000+03	•12000+0	3 •1300	0+03 +135	500+03	•14000+03	
14900+03	•15000+03	•15100+0	3 •1520	0+03 .153	300+03	+15400+03	
•16200+03	•16400+03	•16600+0	3 .1680	0+03 .169	900+03	•17000+03	
•17600+03	•17800+03	+18000+0	3 •1820	0+03 •184	400+03	•18600+03	•
•19200+03	+19400+03	•19600+0	3 .2000	0+03 +210	000+03	•22000+03	
+25400+03	+25600+03	+25800+0	3 .2600	0+03 .269	500+03	•27000+03	
+28000+03	•28200+03	+28400+0	3 .2860	0+03 .290	00+03	+30000+03	
+35000+03							
•58788+00	•62636+00	•56982+0	0 •5654	4+00 .108	399+01	+73884+00	
.10214+01	+10061+01						
4 4 4	30 32	62 64			•		
.64891715-05	-•755024604	•00 • 25	676082-01	-+6155639	74+00	.20933483-0	1
4 4 4	30 32	62 64					
•11708251-03	+ 635595454	0021	614622-01	-•7796624	19+00	.26513896-0	11
6 2 3	9 22	46			_		
•18283015-04	-•19143746-	•01 •98	810329+00	•1625459	78+00		
6 2 3	22 33	46				• · · ·	
.12709915-03	•162267574	•00 •19	080996-01	-•9850185	51+00		
6 2 2	11 24			•			
54830642-06	-+20595947-	01 98	730116+00				
4 4 4	26 28	58 60					
.16967466=05	•618431814	00 - 95	938868-02	•8301861	.4+00	12878921-0	11
4 4 5	22 26	28 58	60			****	
10586593-03	-•49546157-	03 -•792	255699+00	•1229517	6-01	.59039415+0	10
91589418-02	• • • • •						
6 3 3	14 33	69		<b>5</b> 3 6 7 6 9 6			
.15926782-09	•88414990=		517767+01	• 5 3 8 6 9 2 8	5+00		
6 3 3	33 50	69.					
14583651-08	+54168537+	0089	123033-02	•1009285	6+U1	· .	
7 3 2	17 39			•			•
<b>.</b>	-•107/044/-	01 •112	265665+01	20 54			
4 4 11	7 18	ZZ Z4	30 37	37 54	56		• •
22011810-00	•/[=====	04 -140	J/2/12=U3		.⇒+UU	-+ 4004/038*[	) 4
<b>*</b> •/6795498≠04	• 22655226=	01220	55272-01	•8607308	00+00	+11241908-0	11
2022H178-03	-+Y0219221-	04	<b>.</b>	10 00	<b>F</b> 44		
4 4 11		18 22	24 26	20 <u>3</u> 9	54		
• 22150605=06	• 2 2 5 3 / 3 8 0 -	U1 =•225	57106-01	+1334727	1-03	+ 05726307+0 40+1000+0	10
+11224375-01	=+1/934819=	03 -+113	532811-03	-+/094739	3-04	• 18112481+0	1U
•20484000 <del>+</del> 02	-•11030000-	03					

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1	1			•	DYNAMIC P	ESPON
FREGUENCY	7	THETA	Z1	THETAL	MAGNITUDE	P
,10000+C3	• FFTTT+( 2		.EECCC+E2	•CCCCC	.54C99-CE	-18
.11000+03	• EECCC+C2		• 8 8C CC +C 2	.0000	.45982-CE	.18
1111111			.11/00+03		25281-EE	31.
.1666+63	89186462				45887-06	.18:-
110000103	. 00rr(+r7		88100+02		19959-55	-18
111100403				.00000	22488-CE	-18
10000403				01000	25281-CE	.18
					.22488-66	-18
	1111000000				12864-06	.18
+1CCCC+C3	• 1 11 11 1 1 2				75268-66	-19
				.00000	673260°C0	-18
11666+63				00000	35097-06	. 18
		•••••••	• 1 1 2 2 2 3		63756_06	.18
•11666+C3	• 770000702 9300040702			.00000	-55178-66	.18
 311000403	. 890000+02	11111		nnerr	31884-18	1.8
-11000+03	+ COLLILZ	.0000			75097-06	18
11111111111	.11000+03				30884-06	.18
			-11(PF+F3	.01000	-17516-06	-18
.12000403			• I I C C · C J	.00000	.11772-05	.1.8
-12000+03	• 6 6 C C C C 2				.99725-06	19
17000-03				rrdrr	54822-06	.18
-12000+03	• 88000 · 02	-00000		.00006	.99725-66	.18
.12000+03	- 88515+62		-88555+12		85719-EF	.18
12000+03	- 830(0+02			.00.000	47684-66	.12
17000+03	•11000+03				-54822-LE	-18
.12000+03	.11010+03		- 880 CC +C 2	.0000	47684-06	.18
-12CCC+C3	.111100+03		-11([[+[3	.crrrc	26783-LE	-18:
.13000+03	.65CLC+C2	.00000	- 660 00 +0 2	.00000	22834-05	19
-17000+03	• 6 6 Г Г Г + Г 2		-88100+12	-01000	.19322-05	.18
.13000+03	• EECCC+C2	00333.	-110 66 +6 3	-00000	-10598-05	.18
-13666+63	•88FEC+E2		EFCCC+12		. 19322-05	.18
.13000+03	.88CLC+C2	.0000	-880 CC+C2		-16488-05	.18
-13CEE+C3	·88FEE+E2		-11/((+(-1)		.91073-06	.18
.13000+03	.11CCC+C3		- 6 F [ C + C 2	.00000	.10598-05	.18
.13000+03	•11000+03	. [ [ [ [ [	-88555+12	.00000	.91L73-E6	-12
.13000+03	.11000+03	.00000	• 111°CC +C 3	.00010.	-SC6C4-C6	.18
.13500+03	•E6CCC+C2		FELEC+C2	.00000	.37086-05	.18
.13500+03	.66CEC+C2	-CCCCC	-88L CC +C 2	.CLCLC	-31353-05	•18:
·1350C+C3	• E E C C C + C 2	.00000	-11/66+03		.17166-05	-18%
.135CC+C3	.89000+02		• 6 6 L C C + C 2	.00000	.31353-05	.18
·135CC+C3	.88000+02		.88CCC+L2		.2FE53-L5	. 181.
.135CC+C3	<b>.</b> 890£C+C2	.00000	•11CCC+C3	.00000	.14662-05	•191
+13500+03	•11CCC+C3	.[[[[	•86CCC+L2	11111	.17166-65	.191
.13500+03	.11000+03	00000	• 88E CC +C 2	.CLCCC	.14662-05	.19
13500+03	11000+03	.0000	11CC+C3	.ciccc	-8C989-CE	-181
.14000+03	.68000+02	.0000	• 6 6Ľ CC +C 2	.00000	.74385-05	•191
.14CCC+C3	•8£CCC+C2	•CCCCC	.88CCC+L2	.CCCLC	•E?792-C5	•1FI
14000+03	.88CCC+C2	.00000	•11C CC +C 3	.00000	.34284-05	. 181
•14CCC+C3	•88CLC+C2	.CCCC	• 6 E C C C + L 2	.00000	.62792-L5	.191
•14CCC+C3	.89000+02	.0000	•88LCC+C2	.00000	.53166-05	-181
•14666+63	• 98CCC+C2		.11CEC+03	.00000	·29105-05	131.
+14CCC+C3	.11CCC+C3	.00000	• 6 6C CC +C 2	.00000	•34284-C5	-1%
		and the second second				

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3.	3.	14		Code Expan	sion
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# The following is a list of minimum storage requirements

for running the code.

VARIABLES IN MAIN CODE
(2) (2) (2 • NMODES) (2 • NMODES)
$\left\{ \begin{pmatrix} \text{NMODES} \\ \sum_{i=1}^{\text{NMODES}} \text{NTH(i), NKZ} \\ \max \end{pmatrix} \right\}$
(2 • NALP, NBETA) (NALP, NBETA)
$\left  \begin{pmatrix} \text{NMODES} \\ \sum_{i=1}^{\text{NMODES}} \text{NTH(i), NKZ} \\ & \text{max} \end{pmatrix} \right $
(2 • NGAM, NEPS) (NGAM, NEPS) (NCOEE , NMODES) max
(NMODES) (2) (2) (NKZET, NETA) (2 • NKZET, NETA)
(2 • NLAM, NSIG) (NFREQ, NMODES) (NFREQ, NMODES) (NCOEE, NMODES) (NMODES) (NMODES) (NMODES)

	OM	(NFREQ)
	OMEG1	(NMODES)
	OMEG2	(NMODES)
	Р	$(4 \cdot \text{NKZ}_{\text{max}} \cdot \text{NKZ}_{\text{max}})$
	PHI	(NOFZ • NTHA • NMODES)
	TS	(NSS)
	TTH	(NTHA)
	WMN	(NMODES)
	ZJUNK	(NMODES, NMODES)
	ZKA	(NALP)
	ZKALP	(2 • NALP)
	ZKGAM	(NGAM)
	ZKGM	$(2 \cdot NGAM)$
	ZKKS	(NSS)
	ZKP	(NKZ)
	<b>4</b> 1100	max'
	ZKPP	(NKZ) max
	ZKQ	(NTH max)
	ZKQQ	(NTH )
	ZKS	(2 • NSS)
	ZKZET	(NKZET)
	ZKZETA	(2 • NKZET)
*.	ZLC	(NB)
*	ZLCS	(NB) where NB
*	ZLI	(NB, NB) (
*	ZLL	(NB)
*	ZLLS	(NB, NB)
	ZMASQ	(NMODES)
	ZMCAP	(NSIG2, NETA2)
	ZMM	(2 • NSIG2, NETA2)
	ZMU	(2 • NETA2)
	ZMUCAP	(NETA2)
	ZNCAP	(NSIG1, NETA1)
	ZNU	(2 • NETA1)
	ZNUCAP	(NETA1)

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= 1 + maximum of

NBETA, NEPS, NETA, NSIG

# VARIABLES IN FINDI

*	BCAP	(NALP, NBETA) or (NKZET, NETA) whichever is lar	ger
<b>%</b>	CCAP	(NGAM, NEPS) or (NLAM, NSIG) whichever is larger	•
*	FACT	(NBETA) or (NETA) whichever is larger.	
*	.SM2	(NBETA) or (NETA) whichever is larger.	
*	SM4	(NBETA) or (NETA) whichever is larger.	
*	ZKA	(1)	
*	ZKGAM	(1)	
*	ZLC	(1)	
*	ZLG	(1) where NB is the largest of NBE is	A, NETA,
*	ZLH	(1) $($ NEPS	, NSIG $+1$
*	ZLI	(NB, 1)	
*	ZLL	(1)	
		J .	

NOTE (\*) variables may appear in Main and INIT.

NOTE: The following variables must be dimensioned the same to avoid errors in subroutine FINDI, (BCAP and ECAP). These arrays must be based on the largest of (NALP, NKZET), (NGAM, NLAM), (NBETA, NETA) and (NEPS, NSIG). The present form allows up to ten values for the above variables. The dimensions of ZLI should be based on the larger of (NBETA, NEPS, NETA, NSIG) + 1.

3.3.15 Code Listing

(following)

```
COMPLEX ACAP, BCAP, CCAP, DCAP, ECAP, RESPS, ZKA,
 1 ZNCAP, ZNUCAP, OMEG1, OMEG2, PHAT, GHAT, CN. CM
 2,ASM, USM, ASMST, BSMST, SM, CB1, CB2, GHATS
 3, ZKKS, ZJUNK, S2P, P, ZMCAP, ZMUCAP, AICAP, ZKGAM, DICAP, ZKZET,
 4 SM1
  COMMON /A1/NBETA, NEPS, NETA, NSIG
  (02+02)IJZ/2A/ NOMMOD
  COMMON ZLL (20), ZLC (20), ZLLS (20), ZLCS (20)
 1.7LLJ(20),7LCJ(20),7LLSJ(20),7LCSJ(20)
  DIMENSION AA(2), BCAP(10+10), BB(20,10), CCAP(10,10), CC(20,10), DD(2),
 1 ECAP(10,10),EE(20,10),ZKA(20),
 2 ZKALP(40) + TS(40) + ZNCAP(10,10) + ZMCAP(10,10) + ZMM(20,10) +
 3 ZNN(20,10), ZNUCAP(20), ZNU(40), OMEG1(50), AMN1(100), OMEG2(50),
 4 AMN2(100), ZKKS(20), ZKS(40), Z(100), TTH(100), WMN(50), OM(75)
 5, ZMAS(50), ASM(70, 10), BSM(70, 10), MCO(15, 20), NTH(50), NKZ(50), CON(50)
 6, COE (15, 30), NCOEE (30), ZKP (100), ZKQ (100), BSMST (70, 10)
 7.ASMST(70.10).
 8 PHI(100), GHAT(75,25), P(800), S2P(800), ZMUCAP(20), ZMU(40),
 9 ZJUNK(20,20), GHATS(75,25), ZKPP(50), ZKQQ(50), AA1(2),
 * ZKGM(40), ZKGAM(20), DD1(2), ZKZETA(40), ZKZET(20)
  EQUIVALENCE (ACAP, AA), (BCAP, BB), (CCAP, CC), (DCAP, DD), (ECAP, EE),
 1 (ZKKS+ZKS)+(ZKA+ZKALP)+(ZKGAM+ZKGM)+
 2 (ZNCAP,ZNN), (ZNUCAP,ZNU), (UMEG1,AMN1), (OMEG2,AMN2)
 3, (A1CAP, AA1), (D1CAP, DD1), (ZKZET, ZKZETA)
 4, (ZMCAP,ZMM), (ZMUCAP,ZMU)
  THNT=6.2831853
  THCON=57.29578
  CM = (0 . . 1 .)
  PI2=6.28318530
  PI=3.14159265
1 READ (5,31) NTHA, NOFZ, NFREQ, NMODES, NBETA, NETA, NALP, NKZET, NGAM,
 1 NEPS, NLAM, NSIG, NSS, NETA1, NSIGI, NETA2, NSIG2, ISHOT
 1.NCROS
  WRITE(6.38)
  WRITE(6,31) NTHA, NOFZ, NFREQ, NMODES, NBETA, NETA, NALP, NKZET, NGAM,
 1 NEPS, NLAM, NSIG, NSS, NETAL, NSIGI, NETA2, NSIG2, ISHOT
 1,NCROS
 LA=NALP#2
 LB=NBETA
 LD=2+NGAM
 LE=NEPS
  IF(LA \cdot LT \cdot 2) LA=2
  IF(L8.LT.1) L8=1
  IF(LD.LT.2) LD=2
  IF (LE.LT.1) LE=1
 READ (5,32) ZNOT+(Z(I),I=1,NOF2)
  WRITE(6,34) ZNOT,(Z(I),I=1,NOFZ)
 READ (5,32) RCYL, (TTH(1), I=1, NTHA)
 WRITE (6,34) RCYL, (TTH(I), I=1, NTHA)
 READ (5.32) AA, AA1, ((BB(L, J), L=1, LA), J=1, LB), ((CC(L1, L2), L1=1, LD),
1L2=1+LE) + (ZKALP(K) + K=1+LA) + (ZKGH(KK) + KK=1+LD)
 WRITE(6,34) AA,AA1,((BB(L,J),L=1,LA),J=1,LB),((CC(L1,L2),L1=1,LD),
1 L2=1+LE) + (ZKALP(K) + K=1+LA) + (ZKGM(KK) + KK=1+LD)
 LA=2#NKZET
```

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. ,		I A=2	,			·			
	IF (LB.LT.1)	LB=1			· •• •	· · .		- nu -	•
	READ (5+32)	DD,DD1,((EE(L	, J), L=1	•LA) • J=1	•LB)•				
مرمسر به را ا	1(ZKZETA(K) +	K=1,LA)						· · · · · · · · · · · · · · · · · · ·	
	WRITE(6,34)	DD, DD1, ((EE(L	,J),L=1	,LA),J=1	LB),			· · · · · · · · · · · · · · · · · · ·	
	1(ZKZETA(K))	K=1,LA)				۰.			
•	LJ=NS5					· ··· · ···			
	LB=NSIG1#2	ан сайтаа (1996). Сайтаа (1996)							
	IF(LJ.LT.I)	LJ=1			· · · ·	- •••• • • • •	·	······································	
	LK=2+LJ						f Manufacture and a state and a set from		· ****
	IF(LA+LT+1)	LA=1	•					· ·	· ·
	LC=2*LA				•			· · ·	
•		LB=2			· .		· · ·		
ینی وجنور مانه ا	LE=NEIA2		м н.	,	÷	2 - <u>1</u>	·· , ···		
• -	IF (LE +LT + 1)	LE=1	•						•
	LG=2*LE				·		بر برد میدونی در انداز اندا		
•	IF (LF.LT.2)	LF=2							•
•	READ (5,32)	HCAP + (ZKS(I) +	I=1,LK)	•(TS(J)•、	J=1,LJ),	((ZNN(L	•K)•L=1•	L8)	
	1,K=1,LA),(Z	$NU(M) \cdot M = 1 \cdot LC) \cdot$	((ZMM(L)	1,L2),L1=	=1,4LF),4L	2=1,LE)	• (ZMU(L3	).+L	
	23=1,LG)			1754 1	· 1 · · · · · ·	/ / 7		1.01	
	$\frac{WKIIE(0,34)}{3 \times 7} = 1 \times 1 \times 17$	$\frac{H(AP)(ZKS(1))}{N(1(M) + M + 1) + C}$	1=1+LN/	(13(J))	<u>]=[9[]]9</u>	2+1 LE	9KJ9L=19		*******
	198-1964/982 23=146)	NO(M/9M-14LU/9			-1,61,1,6	2-19261	JIZHU(L)	77C	*
•	LJ=2*NMODES	i							
	READ (5,32)	(AMN1(I)+I=2+	LJ+2)						
	WRITE(6,34)	(AMN1(I),I=2,	LJ+2)						
	READ (5,32)	(WMN(I), I=1, N	MODES)			· · · · · · · · · · · · · · · · · · ·	, 	-	
	WRITE(6,34)	(WMN(I),I=),NI	MODES				•		· .
<b>.</b>	REAU (5+32)	(UM(1), I=1, NF)	REUI						·
<b>•</b>	00 14 I=1.N	FREG FREG	REGI	•			· .		
14	OM(I) = PI2*0	M(I)	. Harak P		· · · · · · · · · · · · · · · · · · ·	· · · · ·		· · · · ·	
• •	J=0			·					
1999 - Ward Waginanan Ma	00 15 I=1.N	MODES				*** • . • . • . • . • . • . • . • . • .			
• · ·	WMN(I)=WMN(	I)#PI2	· .			· · ·	· · · · · · · ·	1 · · ·	
•	J=J+2	· · · · · · · · · · · · · · · · ·	• •						. 1
	AMN1 (J) = AMN	1(J) * WMN(I)						· ·· · ·	· · · · ·
	10 42 1=1.0	ТНА							
42	TTH(1) = TTH(	1)*.0174532925		······································					
	READ (5,32)	(ZMAS(I),I=1,	NMODES		· · · · ·				
	WRITE(6,34)	(ZMAS(I),I=1,	NMODES)				· . · ·		
	L=-1							·	
•	DO 20 I=1.N	MODES						• •	
	L=L+2					· · · · · · · · · · · · · · · · · · ·			
	AMINI(L)=WMN	(1) N(T)						• •	
20	AMN2(1+1)=4	•••• MN1 (1 + 1 )							
<b>.</b> .	RR2=RCYL ++2							· · · · ·	
,	DO 43 I=1.N	FREQ			· .			•	
· · · · · · · · · · · · · · · · · · ·	DO 43 NM=1.1	NMODES							
	GHATS(I,NM):	=1./((OM(I)+OME	EGI(NM))	#(OM(I)+	OMEG2 (N	M) ) +ZMA	S(NM))		
			· `. ·						• •
				94					•
· `	• • • •	· · · · · · · · · · · · · · · · · · ·						· · · · .	
						· · ,			· · .

· · · · ·	and the second	· · · · · · · · · · · · · · · · · · ·
· ··· · · · · · · · · · ·	<u> </u>	· · · · · · · · · · · · · · · · · · ·
43	GHAT(1.NM)=-1./((OM(I)-OMEG)	L (NM) ) * (OM (I) - OMEG2 (NM) ) *ZMAS (NM) )
	CALL INIT (ZNOT, ZLL, ZLC, ZLLJ)	
		//2LC3J/
	LC3=0	
	DO 102 NM=1,NMODES	
 D	READ (5,31) NTH(NM), NKZ(NM), WRITE(6,31) NTH(NM), NKZ(NM),	NCOE, (MCO(L,NM),L=1,NCOE) NCOE, (MCO(L,NM),L=1,NCOE)
1	WRITE (6.30) CON (NM) . (COF (1.1)	$(M) = 1 = 1 = N \cap F$
	CO=.25/SQRT(ZMAS(NM))	
	NCOEE (NM) =NCOE	
	IF (ISHOT.GT.1) GO TO 102	
)	NZS=NKZ(NM)	
•	NZS1 = NZS - 1	· · · · · · · · · · · · · · · · · · ·
	NIHS=NIH(NM)	
	$\frac{1}{10}$	
•	T=K+LC3	
	DO 110 J=1,NTHS	
•	ASMST(I,J) = (0.,0.)	
	BSMST(I+J)=(0++0+)	
	BSM (I,J) = (0.,0.)	
110	ASM  (I + J) = (0 + 0 + 0)	
· ·		
	ASM(LC3+1+1)=CA BSM(LC3+1+1)=CA	
	$DO = 6 + 1 = 1 \cdot NCOF$	
	L = (MCO(LL, NM) - 1) / NKZ(NM) + 1	
	M = (L - 1) / NTH(NM) + 1	
	L1=MOD(L-1,NTH(NM))	
	$L2=MOD(MCO(LL \cdot NM) - 1 \cdot NKZ(NM))$	
	DI=LI	
	CB=COE(LL • NM)	
ີ້	WRITE (6,31) NM, L1, L2, L3, L4, L	
	GO TO (8+9+10+11)+M	
8	ASM(L3+L4)=ASM(L3+L4)+CB	
	BSM(L3+L4) = BSM(L3+L4)+CB	
	ASMST(L3,L4) = ASMST(L3,L4) + CB	
	BSM51(L3+L4)=BSM51(L3+L4)+CB	
	CN=CM+CR	
	$\Delta SM(1,3+1,4) = \Delta SM(1,3+1,4) = CN$	· · · · · · · · · · · ·
	BSM(L3+L4)=BSM(L3+L4)+CN	
· · ·	A5M5T(L3,L4) = ASMST(L3,L4) + CN	
	BSMST(L3,L4)=BSMST(L3,L4)-CN	
	GO TO 7	
10	CN=CM*CB	
	ASM(L3+L4) = ASM(L3+L4) - CN	
· ·	BSM(LJ+L4)=BSM(LJ+L4)+CN	
•	ASM311L3+L4)=ASM51(L3+L4)+CN	
	and the second	
	· ·	95
•		این به محمد در در میت ۲۸۰۰ و برای مان مان م این از مان م

						•
				· · · ·		
	BSMST (1 3.1 4)=BSMST (1 3.1 4) +CN		<u></u>			
		· .				
- 11	ASM (L3+L4) = ASM (L3+L4) - CB	· · · · · · · · · · · · · · · · · · ·				
	BSM(L3,L4) = BSM(L3,L4) + CB					
	ASMST(L3,L4)=ASMST(L3,L4)-CB			· · · · · · · · · · · · · · · · · · ·		
	BSMST(L3,L4) = BSMST(L3,L4) + CB			~		
7	CONTINUE				· · ·	
6	CONTINUE					
·· ·· <del>·</del>	DO 18 IP=1+NZS1					
	L3=IP+1+LC3				. Santaria	
	DO 18 IT=1.NTHS1			1		
	<u>L4=IT+1</u>		د به مادور و مستحدات الروم برده و المادور مر مر روم			······································
	ASM(L3+L4)=ASM(L3+L4)*C0					1997 - 1997 -
	BSM(L3+L4) = BSM(L3+L4) + CO	• • • •		•	· · · · · · · · · · · · · · · · · · ·	in di second
	ASMST(L3,L4) = ASMST(L3,L4) * CO				۶	
18	BSMST(L3,L4) = BSMST(L3,L4) + CO				· · · · · ·	
	ASMSI(LC3+1+1) = ASM(LC3+1+1)					
	BSMS1(LC3+1+1)=BSM(LC3+1+1)					
					and the second sec	•
	IF (NZS+01+MAAR) MAAR=NZS					
100						
102	TEATSHOT LE 1) GO TO 199					
	DO 198 NM=1-NMODES			·		
198	READ (5.30) (7 IUNK (NM.NMM) .NMM	= I .NMODES	)			
1,0	60 TO 321	-191110025	•			
199	78=0.		ana kana ny kaominin' dia mampika dia mampika dia mangka dia mangka dia mangka dia mangka dia mangka dia mangka Tangga dia mangka dia ma	··· •· • • • • • • • • • • • • • • • •	، يې د الساعد، شد. ا	
• • •	D0 265 I=1.MAXK			. '		· . · ·
,.	ZKP(I) = ZB		· · · · ·	· · · · · · · ·	· · · · · · · · · · · · · · · · · · ·	سر <u>شرید. سر</u>
	ZKPP(I)=ZB	·				
265	ZB=ZB+CD		, , , , , , , , , , , , , , , , , , ,		an in an	
	00 201 I=1.MAXQ	10 A.		· ·		· · ·
	ZKQ(I) = FLOAT(I-1)		· ·	· · · ·		
201	ZKQQ(I) = ZKQ(I)					· ·
	IL=0					
	DO 202 I=1,MAXK					• •
	D0 204 M=1.2				· · ·	
	ZP=ZKP(I)	· · · · · · · · · · · · · · · · · · ·			·	· · · · · · · ·
	D0 203 L=1.2					· .
- <b>- - - - - - - - - -</b>	DO 203 J=1,MAXK	innar i stranis anni			• • • • · · ·	
	ZR=ZKPP(J)					
	CALL FINDI(ZP,ZR,ACAP,AICAP,BC	AP • CCAP • ZI	KANALPONI	BEIA,ZKGAN	INGAM,	
202	$\frac{1}{2} \frac{1}{2} \frac{1}$	LUJ	ere er			
203	2KPP(J) = -2KPP(J)					· .
204					i iii maa ahaa	
<i>L.</i> V <i>L</i>				· ·		
	$\frac{12-0}{12}$			·····		
	DO 724 $M=1.2$					
•			•	, ., ., ,		
	007231=1.2			. •		
•	00 $1 = 1 = 1 = 1 = 1 = 1 = 1 = 1 = 1 = 1$		· · · ·	-	· ••• ·	· · · ·
						. •
·						······································
-						
					• •	

		· · · · · · · · · · · · · · · · · · ·
		CADAECANA 7K7ETANK7ETANETA DI CODITA
	1ZLLS•ZLCS•ZLLSJ•ZLCSJ)	LAPJECAPJZKZEIJNKZEIJNEIAJPIJSZP(117)
723	ZKQQ(J) = -ZKQQ(J)	
724	ZKQ(I) = -ZKQ(I)	
722	CONTINUE	
	IN=0	
	NZ42=4+MAXK	
1 - I		
· :	TN2-0	
	NP=NK/(NM)	
ŧ,	NQ=NTH (NM)	
	IN3=0	
	IN1=0	
•	DO 301 NMM=1.NMODES	
	NR=NKZ (NMM)	
	NR2=MAXK+MAXK	
	NR3=NK2+MAXK	
	NQS=NTH(NMM)	
•••••••••••••••••••••••••••••••••••••••	SM-(0 -0 )	
·	IN2=0	
	DO 305 IP=1.NP	n na
	IP1=1N2	
	IM1=IN1	
	IM=IM+1	
•	DO 304 IR=1.NR	
		i de la mais estada de la companya d
	1711-1717MAAN 1012-1014NU2	
	TP13=1P1+NR3	
	IM1 = IM1 + 1	
•	IN3=0	
•	DO 303 IQ=1.NQ	
······································	IS1=IN3	
	DO 302 IS=1.NQS	
	IS1=IS1+1	
	ISI1=ISI+MAXQ	
	1512=151+NU52 1512=151+NU52	
······	1515-151 + NG55 SM=SM+ASM(IM-TO)+(ASM(TN)	- TS180 (10118520 (10114/SNCT (1M1-10180 (1011
· 1	)#S2P(TSE1) #8SM(TM1+TS)	\\\P11)\\S2P(IS1)\\SMST(IMI\IS1\\\CIMI\IS1\\CIMI\IS1\\\CIMI\IS1\\\CIMI\IS1\\\CIMI\IS1\\\CIMI\IS1\\\CIMI\IS1\\CIMI\IS1\\\CIMI\IS1\\\CIMI\IS1\\CIMI\IS1\\\CIMI\IS1\\CIMI\IS1\\CIMI\IS1\\CIMI\IS1\\CIMI\IS1\\\CIMI\IS1\\CIMI\IS1\\\CIMI\IS1\\T\T\IS1\\TINI\IS1\\TINI\IS1\\TI\IS1\\TI\IS1\\TINI\IS1\\TI\IS1\\TI\IS1\\TI\IS1\\TINI\IS1\\TI\IS1\\TI\IS1\\TI\IS1\\TI\IS1\\TI\IS1\\TI\IS1\\TI\IS1\\TI\IS1\\TI\IS1\\TI\IS1\\TI\IS1\\TI\IS1\\TI\IS1\\TI\
. 2	2P(1P1) #S2P(1S11)) +BSM(IM	10)*(BSM(IM1+IS)*P(IP13)*S2P(IS1)+
1.1.1	3 BSMST(IM1+IS) +P(IP12) +S2	2P(IS11)+ASM(IM1,IS)*P(1P12)*S2P(1S1)
: 4	4+ASMST(IM1+IS)#P(IP13)#S2	2P(IS11))+ASMST(IM,IQ)*(ASMST(IM1,IS)*
9	5P(IP13) #S2P(IS13) +ASM(IM1	• IS) #P(IP12) #S2P(IS12) +BSMST(IM1•IS) #P(
<u> </u>	51P12) #S2P(1513) +BSM(1M1+1	(S) *P(1P13) *S2P(1S12)) +BSMST(1M+1Q) *(BSMST
6	6(IM1+IS)*P(IP1)*S2P(IS13)	+BSM(IM1,IS)#P(IP11)#S2P(IS12)+ASHST(
7	7IMI+IS)*P(IP11)*S2P(IS13)	+ASM(IMI,IS)*P(IP1)*S2P(IS12))
305		
202	1NJ=INJ+N146 Continue	
303	CONTINUE	
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•						· • • • • • • • • • • • • • • • • • • •
	,				1	
		1	- + 		+	-
		IN2=IN2+NZ42			· · ·	1
•	305			مت الوين بالمهايا	•	
				•		
-	301				· · · .	-1
	201		· · ·			
· ······. ·	300	CONTINUE				99 Mar 1997 - 77 and 1 an an an an all a gly a set of the second bir for an an an and a second flore
		DO 322 I=1.NMODES		· · ·		
		PUNCH' 30 + (ZJUNK (I,J), J=1	NMODES)	•	· · ·	
- -	322	WRITE(6.34) (ZJUNK(I.J).	J=1 + NMODES)	-	···	
	321	WRITE(6,37)	· .	\$		
	·	NN=0				
		DO 200 IB=1•NOFZ		•	· .	• .
• <u>-</u> . •	•••••••••••••••••••••••••••••••••••••••		·			
•		TH=TTH( 18)				
		$DO 507 NM=1 \cdot NMODES$	*)************************************	· · · · · · · · · · · · · · · · · · ·		
		NN=NN+1				
	· · · · · · · · · · · · · · · · · · ·	PSI=CUN(NM)		- <u></u>		
		NCOE=NCOEE (NM)		e na na ar ingga serena ang an ang ang ang ang ang ang ang an		
•		DO 506 LL=1+NCOE				
		L = (MCO(LL, NM) - 1) / NKZ(NM) +	• <b>)</b>		· · · · · · · · · ·	an a sa s
		M=(L-1)/NTH(NM)+1		•	Ÿ	
		$\frac{1}{1} = MOU(L-1) \times NH(NH)$	M V V			
	•		•••••		. •	
	мр ш	D2=L2			·	· · · · · · · · · · · · · · · · · · ·
C	,	WRITE(6,31) NM,L1,L2,L3,L	49L9M9LL		,	· · ·
		GO TO (2,3,4,5),M				
	. 2	PSI=PSI+COS(D1+TH)+COE(LL	, NM) #COS (D	2#22)		
	-	GO TO 506			· ·	-
• -	٤	PS1=PS1+C05(D1*1H)*C0E(LL		<b>C*</b> [[]		
	. 4	00 10 500 DST=DST+STN(D)&TH)&COF(L)	NN) +COSID	24771		
•••		60 TO 506	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,			
	5	PSI=PSI+SIN(D1+TH)+COE(LL	,NM) #SIN (D.	2*ZZ)		
	506	CONTINUE				
С	2	WRITE(6,35) IB, JB, ZZ, TH, P	SI			
•	507	PHI(NN)=PSI				
-	210	CONTINUE	· •·- · ·			· · · · · · · · · · · · · · · · · · ·
	200	CUNTINUE WRITE(6,36)				
		DO 220 1 B=1.NEREO				
		SM=(00.)				
		PHAT=HCAP		• •		· · · · · · · · ·
•		IF (NSS.LT.1) GO TO 224				
		D0 221 IS=1.NSS				
	221	PHAT=PHAT+ZKKS(IS)*CEXP(-	OW (LB) +CM+	TS(IS))	·	
•	224	IF (NETA1.LT.1) GO TO 825			•	•
•		UU CCC I=I+NEIAI			•	· ·· ·· ·
•		CH2=CH)		•		· · · ·
	- `	SM=ZNCAP (1 • T) #CR1		· · · · · · · · · · · · · · · · · · ·	· • • ···· · ·	an a
		IF (NSIG1.LT.2) GO TO 222				
<b></b>		DO 223 J=2,NSIG1		· · · · · · · · · · · · · · · · · · ·		

			I	- 1				1.		•
	·	· · ·				· ·	· · · · · · · · · · · · · · · · · · ·			
	<u> </u>	CB2=CH2*CB1				· · · ·				
	223	SM=SM+ZNCAP(J,I)+CB2				· · ·				
)ï	222	CONTINUE		<u> </u>						
	825	IF (NETA2.LT.1) GO TO 826		1						•
		DO 822 I=1.NETA2			-		· ·	1		
		CB1=1./(OM(LB)-ZMUCAP(I))								
		C82=C81								
		SM=SM+ZMCAP(1,I)+CB1				•			•	
	:	IF (NSIG2.LT.2) GO TO 822								
		D0 823 J=2+NSIG2						- ,		
		CB2=CB2#CB1							′, <del>-</del>	
	823	SM=SM+ZMCAP(J,I)#CB2			· ·				• .	
	822	CONTINUE								,
· ·····	826	PHAT=(PHAT+SM)+RR2			·····			•	· ·	
	225	NMDX=NMODES*NOFZ*NTHA								
·		IP=0				·			· · · ·	
·	• •	DO 913 IB=1,NMDX,NMODES							.'	
		IP=IP+1				· · · · · · · · · · · · · · · · · · ·				
		IP2=(IP-1)/NTHA+1								
	بالماريمات فرزا الدار	IP4=MOD(IP-1,NTHA)+1							•	· · ·
								•	•	
		DU 914 JB=1,NMDX,NMODES							•	
÷	:						· .	· .	<u>,</u> ,	•
		$\frac{1P3=(1P1-1)/N1HA+1}{1P5=M0P(1P1-1)/N1HA+1}$						······································	·	
		1P5=MUD(1P1+1,NIMA)+1								
		$SM = \{U \bullet \phi U \bullet f \}$				· · ·		<b></b>		******
			•						•	
		1P (NCRUS+EQ+1) 00 10 910								
		UU = ID								
							· .			
	134	FOPNAT (415,8F12,6)					·····			
	124	SMI=SMI+DHI/H )#GHATS// Bal	V147		7.1.7)					
<u>^</u>		WPITE (6.134) 1841 Vol 7. 11			- 2 YL 1 /	SI Pal VI	-7 HINK			
						STEDICIT				
	916	CONTINUE	· · · · · · · · · · · · · · · · · · ·			· · · · · · · · · · · · · · · · · · ·				
		SM=SM+SM1+PHI(IL)+GHAT(LB	•1 Z)							
<u> </u>		WRITE(6+134) L8+L8+IL+LZ+	SHISH	1.PHIC	IL).6	HAT (LB.L	<b>Z</b> )			
		IL=IL+1								
	915	CONTINUE			يون يونيو دو آوه - وي		24 1 Amilia State	· · · · · · · · · · · · · · · · · · ·	· · · · · · · ·	
		GO TO 919								
	918	DO 920 LZ=I,NMODES	·····						· · ·	
		JL=JB+LZ-1	٠.					· · ·	· ·	
_	• •	SM=SM+PHI(JL)+GHATS(LB+LZ	+ZJU	NK (LZ,	ĽZ) ¥₽	HI(IL)#G	HAT (LB.	LZ)		• •
		IL=IL+1								
	920	CONTINUE								
	919	RESPS=SM#PHAT	•						•	•
C		WRITE(6,34) SM,PHAT,RESP	5 .	· · · · · · · · · · · · · · · · · · ·						
	•	X=REAL (RESPS)	-		•				• •	
••••••••••••••••••••••••••••••••••••••	و معددها هورادی	Y=AIMAG(RESPS)								
		IF (ABS(X).GT.1.E-16) GO TO	243						. <sup>.</sup> .	
•••	· •· •	PHASE=1.5707963			····· · .	······································				
		IF (Y.LT.0.) PHASE=PHASE+P	I				•		· -	•
		GO TO 242								

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		1	·····			
	· · · · ·				~	
		1				
243 P	HASE=ATAN (Y/X)	· 				
I 241 T	F(X+Y) 240,241,241 F(X.LT.Q.)PHASE=PHA	SE +P I	· · · · · · · · · · · · · · · · · · ·	بېتىنى د مەرى	يستنفر بالمحمد عيارات	, .
G	0 TO 242					
240 P	HASE=PHASE+PI			an a	بر این از این از این از این	
I	F(X.GT.0.) PHASE=PH	ASE+PI		······································	·	<del></del>
42 W	MAG=SQRI(X##2+Y##2) MASE=DHASE#THCON	•			7	
0	MM=ON(LB)/PI2					
<u> </u>	T1=TTH(IP4) *THCON			·		
Т	T2=TTH(IP5)+THCON				•	
W	RITE(6,34) OMM,Z(IP	2),TT1,Z(IP3),TT2	• WMAG • PHASE		·	
$14 \ 0$	ONTINUE	• • • •	•	5 m	· .	
20 C	ONTINUE					
G	O TO 1					
30 F	ORMAT (5E15.8)		· · ·		· · · · ·	
31 F	ORMAT(1615)		· · · · · · · · · · · · · · · · · · ·			
32 F	URMAI(0210+3) OPMAT(1X+10E)2-5)		•			.•
35 F	ORMAT(215+9E12+5/(1	X,10E12.5))				<del></del>
36 F	INSE=ATAN(Y/X)       Image: Second Seco					
15						
37 F	ORMAT(24H0+++END OF		·	<u></u>		
JO F	ND					• •
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- 9F	OR IS INTT		71 6 11		÷	
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	COMMON_ZAZZZI T	20.20)			e e	
-	3 PMASE=ATAN(Y/X) IF (X=Y) 240;241;241 IF (X_LT0.)PMASE=PMASE+PI G0 TO 242 PMASE=PMASE=PHASE=PHASE+PI IF (X_GT.0.)PMASE=PMASE+PI Z MAG=SGPT(IX=24*P82) PMASE=PMASE=THCON MHTOH(LB/PI2 TT1=TTH(IP4)=THCON WRITE(0.34) OMH2(IP2).TT1:2(IP3).TT2.WMAG.PMASE 4 CONTINUE 3 CONTINUE 3 CONTINUE 3 CONTINUE 3 CONTINUE 3 CONTINUE 3 CONTINUE 3 CONTINUE 4 FORMAT(1615) 4 FORMAT(1615) 5 FORMAT(15:5+9E12.5) 5 FORMAT(15:5+9E12.5) 5 FORMAT(15:5+9E12.5) 5 FORMAT(15:5+9E12.5) 5 FORMAT(15:5+9E12.5) 5 FORMAT(15:5+9E12.5) 6 FORMAT(15:5+9E12.5) 5 FORMAT(15:5+9E12.5) 5 FORMAT(15:5+9E12.5) 5 FORMAT(15:5+9E12.5) 6 FORMAT(15:5+9E12.5) 5 FORMAT(15:5+9E12.5) 5 FORMAT(15:5+9E12.5) 5 FORMAT(15:5+9E12.5) 5 FORMAT(15:5+9E12.5) 6 FORMAT(17:1:5+9E12.5) 5 FORMAT(17:1:0:5+0E12.5) 5 FORMAT(17:1:0:5+0E12.5) 6 FORMAT(17:1:0:5+0E12.5) 7 ORMON/A1/YE:TA.WETA.WETA.WETA.WSITC COMMON/A1/YE:TA.WETA.WETA.WSITC COMMON/A1/YE:TA.WETA.WETA.WSITC 10 DIMEN.XA2/ZL110-ZL011.21.21.1 7 L1J=1. 7 L1J=1. 7 L1J=1. 7 L1J=1. 7 L1(1)=7.1 7 L1J=2. 7 L1J=2. 7 L1J=2. 7 L1J=2. 7 L1J=2. 7 L1J=2. 7 L1J=2. 7 L1J=2. 1 T3:T5*1 7 L1J=2. 1 T3:T5*1					
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	7LLJ(*)=7L1J					
ndi Dayaran sasimak	<u>ZLL(I)=ZL1</u>	۲. ۵۰۹ مه ۱۹۹۹ کارو دور اور در ۱۹۹۰ میلید (۱۹۹۰ کارور ۱۹۹۰ کارور ۱۹۹۰ میلید در ۱۹۹۰ میلید در ۱۹۹۰ میلید در ۱۹۹ ۱۹۹۹ کارور در ۱۹۹۹ میلید در ۱۹۹۹ میلید در ۱۹۹۹ کارور در		ar a siya dadiga sanahin kanan dara dir a 1975 mendahin 1475 mendadi bir angu Sanah d		
	7LCJ(T)=7L1J+7N		•	1		
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	<u><u><u></u></u><u></u><u></u><u></u><u></u><u></u><u></u><u></u><u></u><u></u><u></u><u></u><u></u><u></u><u></u><u></u><u></u><u></u></u>					
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	ոստուման, <u>են աններկան</u> ուներում։ 711.1±71	ر ۱۹ روه بر دیست استاد بر اوم دهند بین محمود از بر اوه بر <sub>م</sub> ین <sub>ا</sub> الی ا		يرينيو رو من مه چو مورد مود پرون . در در در مراجع چو مورد مود پرون د		••
		undernanger for ister of englight			an it was and a factor of the second statistic strategy at some of the second states of t	
243 PHASE=ATAN(Y/X) IF (X*Y) 240,241,241 24 IF (X.U.T.0.PHASE=PHASE+PI 36 0 TO 242 26 PHASE=PHASE+PI IF (X.G.1.0.) PHASE=PHASE+PI 22 WHASESPHASE+PI 27 WHASESPHASE+PICON 0HH=0H(EB)/PIC TI2=TIH(IPs)*THCON TT2=TIH(IPs)*THCON WITE(63.34) OMH+2(IP2),TI1.2(IP3),TT2,WHAG,PHASE 914 CONTINUE 30 FORMAT(5215.8) 31 FORMAT(5215.8) 32 FORMAT(5215.8) 33 FORMAT(1215.9) 34 FORMAT(1215.9) 35 FORMAT(1215.9) 35 FORMAT(1215.9) 35 FORMAT(1215.9) 36 FORMAT(1215.9) 37 FORMAT(1215.9) 38 FORMAT(1215.9) 38 FORMAT(1215.9) 39 FORMAT(1215.9) 30 FORMAT(1215.9) 30 FORMAT(1215.9) 30 FORMAT(1215.9) 30 FORMAT(1215.9) 30 FORMAT(1215.9) 31 FORMAT(1215.9) 32 FORMAT(1215.9) 32 FORMAT(1215.9) 33 FORMAT(1215.9) 34 FORMAT(1215.9) 35 FORMAT(1215.9) 37 FORMAT(121.9) 38 FORMAT(121.9) 39 FORMAT(121.9) 30 FORMAT(121.9) 30 FORMAT(121.9) 30 FORMAT(121.9) 31 FORMAT(121.9) 31 FORMAT(121.9) 32 FORMAT(121.9) 32 FORMAT(121.9) 33 FORMAT(121.9) 34 FORMAT(121.9) 35 FORMAT(121.9) 35 FORMAT(121.9) 36 FORMAT(121.9) 37 FORMAT(121.9) 37 FORMAT(121.9) 38 FORMAT(121.9) 39 FORMAT(121.9) 30 FORMAT(121.9) 30 FORMAT(121.9) 30 FORMAT(121.9) 30 FORMAT(121.9) 31 FORMAT(121.9) 31 FORMAT(121.9) 32 FORMAT(121.9) 33 FORMAT(121.9) 34 FORMAT(121.9) 35 FORMAT(121.9) 35 FORMAT(121.9) 36 FORMAT(121.9) 37 FORMAT(121.9) 38 FORMAT(121.9) 30 FORMAT(121.9) 30 FORMAT(121.9) 30 FORMAT(121.9) 30 FORMAT(121.9) 30 FORMAT(121.9) 31 FORMAT(121.9) 31 FORMAT(121.9) 32 FORMAT(121.9) 33 FORMAT(121.9) 34 FORMAT(121.9) 35 FORMAT(121.9) 35 FORMAT(121.9) 35 FORMAT(121.9) 35 FORMAT(121.9) 35 FORMAT(121.9) 35 FORMAT(121.9) 36 FORMAT(121.9) 37 FORMAT(121.9) 30 FORMAT(121.9						
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	7 <u>N=7N-1</u>	ling" gan gan bha na minardainteil na a a antarais	ة " 	يد بارده بحضات المانية عداله محاود	an a		، ۲۰۰۰ و ۲۰۰ مور در	
10	CONTINUE			· · · · ·		÷*.		
****	RETURN							
<u>OFOR91</u>	<u>S. FINDIJ</u> .		71/ D . AC AD .	A10AP - 901	P-CCAP-7	KA - NAL D		
1	SUBRUUIIN. 7KCAMANGAMAI	92.NUIV2NEV2 NCPS.71.schn	2.	C - 71 1 . t - 71	C.1)	NATHAL	VINDECHV	
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1	SMAL +CON1+1		-CON3-SM	• SM1 • SM2 •	SH3+ZZ3+			•
2	SMGM. SN	.CONG.CONT	ZTL CON4	. CD. ZKGAN	1 . SM4	1		
	CON5	- ,					nation and the second	
•	<pre>ZM=ZN=1. 10 CONTINUE RETUPN END 0R.JS.FINDIT SUBROUTINT FINDI(7KP,ZKR,ACAP,A1CAP,BC 1ZKGAM,NGAM,NEPS,ZL.FUNI,ZLL,ZLC,ZLJJKI COMPLY A ACAP,A1CAP,BCAP.CCAP.ZKAFUNI, 1.SMAL.CON1.CON2.CB.ZLG.CON3.SM.SM1.SM1.SM2 2SMGM, SN:CON6.CON7.ZTL.CON4.CD.ZKGA 3.CON5 COMMON /A2/ZLT(20,20) DIMENSION ZL3(2CL.ZLH(20).SM4(20).FACT 1CCAP(10,10).ZKA(20).SM2(20).ZKGAM(20) .ZLL(1).ZLL(1).ZLLJ(1).ZLCJ(1) 0ATA FACT/1.1.2.46.20.SM2(20).ZKGAM(20) .ZLL(1).ZLL(1).ZLLJ(1).ZLCJ(1) 0ATA FACT/1.1.2.46.20.SM2(20).ZKGAM(20) .ZLL(1).ZLL(1).ZLLJ(1).ZLCJ(1) 0ATA FACT/1.1.2.46.20.SM2(20).SM2(20).FXGAM(20) .ZLL(1).ZLL(1).ZLLJ(1).ZLCJ(1) 0ATA FACT/1.1.2.46.20.SM4(20).SM2(20).ZKGAM(20) .ZLL(1).C.1. CCar(0.1.1) CCar(0.1.1) CCar(0.2.1.2) CG DC11 10 CON3=(CON2-CD)/ZZ3 11.SMAL=(C0.2.0.) D0 100 TAL=1.NALP ZZ1:ZKR-ZKA(1AL))*(01.) CON1=CEXP(ZZ2*ZL) Z3:1./ZT1 Z4=1./ZZ2 Z71=73 ZZ2=74 D0 11 T1.NBETA ZLG(1)=Z3 ZLH(1)=Z4 Z3=Z3+ZZ1 Z4=Z2? 12 CONTINUS CB=CC SM1=(0C.1) D0 106 IT=1.NBETA ZLG(1)=Z3 ZLH(1)=C.1 D0 107 IT=1.NBETA ID6 SM2(II)=C.1 D0 107 IT=1.NBETA ID6 SM2(II)=C.1 D0 107 IT=1.NBETA ID6 SM2(II)=C.1 D0 107 IT=1.NBETA ID6 SM2(II)=C.1 D0 107 IT=1.NBETA ID6 SM2(II)=C.1 CM1=SM1*Z7*ZLH(1)*ZC(I-1)*ZLH(2) Z1=ZI=-1. TF(I1.LE.1) G0 T0 107 I01</pre>		<b>.</b>					
angan at surveying at surv	DIMENSION ZI	L3(20)+ZLH.(	201, SM4 (.)	20.) .EACT (	11.) + B.CAP	(10, 10)		ę
· 1	CCAP(10+10)	+ ZKA(20) + SM	12(20)+ZK	3AM(20)				
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	DATA FACT/1	• • 1• • 2• • 6 • •	24.120.	• 720 • 504	10. • 40320	• • 36288	1. • 30 28800	1
	ししこてり。キューフ アフマーメフレロュフレリ	01+10 -1 ·	· · ·			۰.		
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		10+6+10						
6	CON3=71		and the state of t					7
·····	GO TO 11					مربع برمیدین در وی رکن و کارانه در از	14.5 ·	•••••
10	CONSETCONZ-	CD1/723						
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	00 100 TAL=	1.NALP	•		•			
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	722=12KP+7K	A(TAL))+(0.	1.)	•	. •	· · ·	÷.	
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	25=1•/221						· · · ·	
eringe versinge versinge – te	~9.二 <u>1.</u> ●./、 <u>人</u> .人.と 」 7 <b>71-</b> 77	دينة (1975) يو <del>انترمين</del> ين (1976) مير (1985) ا	en e	A CARE TO LET TAXA	يە يەر بىر بەتتى <mark>يەمە</mark> مەتت		nanneren et dan maran kunkenen n 2	**
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	BO 12 T=1+N	BETA	· · · · · · · ·		· · · · · · · · · · · · · · · · · · ·	· · · · · · ·	and a constant of the second	
	ZLG(T)=Z3							
	<pre>ZM=ZN-1. CONTINUE RETUPN END S.FINDIT SUBROUTINT FINDITZKP.ZKR.ACAP.A1CAP.BCAP.CCAP.ZKA.NAL ZKGAM.NGAM.NEPS.ZL.FUNI.ZLL.ZLC.ZLLJZLCJJ COMPLEX ACAP.A1CAP.BCAP.CCAP.ZKA.FUNI.ZZI.ZZZZ.Z3.ZLH SMGM. SCAP.A1CAP.BCAP.CCAP.ZKA.FUNI.ZZI.ZZZZZ.Z3.ZLH SMGM. SN.CONG.CONT.ZTL.CON4.CD.ZKGAM.SM4 SCONS COMMON ZAZZIT(20.20) DIMENSION ZL3(2CL)ZLH(20).SM4(20).FACT(11).BCA2(10.10) CCAP(10.10).ZXA(20).SM2(20).ZKAAM(20) .ZL(11.ZLC(1).ZLLJLJJZZCJJ] DIMENSION ZL3(2CLJJLJLJZZCJJ] DATA FACT/1.*1.*2.*6.*24.*120.*720.*5040.*40320.*3628 CD2:1.*0.J CCCT0.1.J ZZI_C(ZKPZKR)*(0.*1.) CON3CCCN2.CD/ZZ3 SMALICC.0.J. DO 10T TAL=1.NALP CON3CCCN2.CD/ZZ3 SMALICC.0.J. DO 10T TAL=1.NALP ZZI_(ZKP-ZKA(TALJ)*(0.*1.) CON1CEXP(ZZZZLJ) ZZI_ZZZZZ ZZI_ZZZZZZZZZZZZZZZZZZZZZZZZ</pre>							
	Z3=Z3+ZZ1	and the second	د ومعدد دو ورود ا	بر بیند آستیوریز پیدود ز	· · · · · · · · · · · · · · · · · · ·		andant, anno 1990 an anntaise sa	
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	ZI=ZI-1.	and the second s			·	1111 31.05 March		
	M1=SM1+ZT+	7LH(1)+7LC(	1-1)+7LH	(2)	, the transferrer	· · · · · · · · · · · · · · · · · · ·	un un en	
	IL=ZI+ZLG(1			·		- · · · · ·	tions as the constraint of	
•	[1=1-?				. •			
··	J=I-1			. قيدية المتوارية م م				
	F[[1.LE.1]	GO TO 107			-			
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	DO 105 II-1.II	ا - مىچەردىيەت سىرىمە جەرزىر برىچە مىغا سىرى دىلەچىرى .	an antin an an and the second second second second second		
	SM2(J)=SM2(J-1)	) + ZIL		N	
1.0.5.	J=J-1	······································			
107	SM2(1)=ZLT(I-1)	+1)+ZLG(2)			· · · · ·
	JE ( 1.4.1.3) 60-	T0	na i fan amerik i gestelenen waarste kompanyaam	-	
	SM3=SM3+(ZI+1.)	<pre>#ZLH(1)+ZLC(I)</pre>	-2) +7LH(2)	· ·	• • •
	5M4(JI)=SM3	- # Purps	a i urguna i rigi tagaya tanti yan damakayar	دو و بوای داده دو اور وار وارد و برو و و وارد و وارد و وارد و وارد	
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	TF(11.LT.1) 30	TO 109		•* ·	
	L <u>1=1+1</u> ,	بالمعيد بالبال والبام ومسيد منار	الماليو فعملته فأرابو مدرا والمتعادين مراجع الربو وهموار	are to the constraints in an annual arc comparison of a second statement way of a	a a na na managana na managana ang kanang k a na
	L2=I	•			•
	.00103J=1+I.1	م سند که معنه د	التيرية محيد مقمانية والاردار والارد		ى يەرىپىلەر بىرىنىيەتلەر يېزىكىيەر <u>بىرىنىيەر بەرىپىرىمۇرىيەر ئ</u> ىمەر تەرىپىلەر بىرىنىيەتلەردىن يەرىپ يەرىپ يەرىپ ت
	L1=L1-1				· · · ·
ويعاده الماهي ويعتره فطاطات واريده	CNN=-CNN	ana	n		
	L2=L2-1		·		
	<u>SN=SN+</u> SM2{J.}.*.[.]	CON1.#1 ZLE (L 2.).*.	ZLH(1)+SM4(L1))	=CNN# ZLHILZ	LEACILIZI
108	CONTINUE				- <b></b>
	.SM=ZLG.(1)*.(CON)	1+LZLLCIL+ZLHA	11+SM11=CN#ZLHL	IJ . AC. LLIJJ.	ESN.
·. ]	(-CN+ZEG(!)+CUN:	5 # F A C I V I J 6 = 11 - 5 1 + 6 M + 6 D 6	- 1 AT / 7 1		
	SMAL SMAL+BCAP	LTAL L.J SM + CB.Z.	H.A.C. I. L. J. J.		
	03=03+00	· .	· · ·		· .
102.	-CONTINUE	م مانوب بالم مانونين مان الم المانين مان المانياني مان مانونيو والم مانونيو والم مانونيو والم مانونيو الم مان 	n an		ng annany un e n' - coursen billiocht commo co, th ocorres samapalitärisair shaa '
100	CONTINUE				
rung, sy the function apply spin as the	DO DOD TOM-1-NO	·		العاملة المحمد المحمد علي المراجعة عن المحمد ال الم	
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	7LH(T)=74		•		
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	74=24+222		•		• • •
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	D0 205 71=1+NFF	<b>'S</b>			1
		<b>b</b>	where we assume a set of the	میرونی در معمولاتین و به در ایرون	
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•	I1=I-2 <sup>1</sup>		ал салан. С
	<u>J=I-1</u>	······································	an an a sa s
	IF(I1.LE.1) GO TO 207		•
	<u>D0_ZC5_II=1,11</u>	nan anna a sa	······································
	SMZ(J)=SM2(J-1)+ZIL	4	
Z.0.5		n e - un unaren territeren er regengenennekender	
207	SM2(1)=2L1(3-1)=2L6(2)		
		e in the second se	
204	2H0171-CH2 CH0171-CH2 CH0171-CH2 CH0171-CH2 CH0171-CH2 CH0171-CH2 CH0171-CH2 CH0171-CH2		
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		klabilari — kliątartentarijiti, Oka is klankte belatilationen	n 1843 tan menangi ng C. Kan sanan ng minanangingkangkan
· · · ·	SN= (0.,0.)	· · · · · · · · · · · · · · · · · · ·	-
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	<u>11=T+1</u>		
	L2=I		
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	L1=L1-1		
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	L2=L2-1		
	SN=SN+SM2(J)+(CON5+(ZLLJ(L2)+ZLH(1)+SN4()	1))-CNN+ZLH(L2)	+FACT(L2)
2	1 *CON2)		
208	CONTINUE	and a constant of a constant of the second	
209	SM=ZLG(1)*(CON5*(ZLLJ(1)*ZLH(1)+SM1)-CN*)	ZLH(I) + FACT(I))	+SN+CN+ZLGI
	1T1+CON3+FACTET		اد میں الدور وروپی اور وروپی
	SMGM=SMGM+CCAP(IGM+I)+SM+CB/FACT(I)		· .
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202	CONTINUE		
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241	CONSECCONS-COL/7KP	· · · ·	
		n na si an	an 8 pro 2007 (2015) ), filler of set of the films of free spectra of the set
247	CON5=CC+71+CON5		
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-244	CONG=(CON7-CD)+CONE/ZKR		
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245 	END IS FINDT SUBROUTINE FINDT(ZKP+ZKR+ACAP+A1CAP+BCAP+ IZLL+ZLC+ZLLJ+7LCJ). COMPLEX ACAP+A1CAP+BCAP+ZKA+FUNI+ZZ1+ZZ2+ L SMAL+CON1+CON2+ZLG+CON3+SM+SM1+SM2+SM3+Z Z SM6+SN+CON6+CON7+ZTL+CD+SM4	7KA•NALP•NBETA 73•ZLH•CC•74• 23•	ZL.FUNI.
245	FND IS. FINDT SUBROUTINE FINDT(ZKP+ZKR+ACAP+A1CAP+BCAP+ IZLL+ZLC+ZLLJ+7LCJ). COMPLEX ACAP+A1CAP+BCAP+ZKA+FUNI+ZZ1+ZZ2+ L SMAL+CON1+CON2+ZLG+CON3+SM+SM1+SM2+SM3+Z Z SMG+SN+CONG+CON7+ZTL+CD+SM4 L+YL+SM5+CONB+SM8+SM9+SM7+YZ1+YZ2+Y3+Y4+YO	7KA•NALP•NBETA 73•ZLH•CC•74• 23•	ZL.FUNI.
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245 	<pre>FND IS.FINDT SUBROUTINE FINDT(ZKP+ZKR+ACAP+A1CAP+BCAP+ IZLL+ZLC+ZLLJ+ZLCJ). COMPLTX ACAP+A1CAP+BCAP+ZKA+FUNI+ZZ1+ZZ2+ L SMAL+CON1+CON2+ZLG+CON3+SM+SM1+SM2+SY3+Z Z SMG+SN+CONG+CON7+ZTL+CD+SM4 L+YL+SM5+CONB+SM8+SM9+SM7+YZ1+YZ2+Y3+Y4+Y0 Z SM1C+YON3+YN+YBON+YBON1+YM+CON11 COMMON /A2/ZLT(20+20)</pre>	• 7KA • NALP • NBETA • 73 • 71H • CC • 74 • • 73 •	ZL.FUNI.
245 	FND IS. FINDT SUBROUTINE FINDT(ZKP+ZKR+ACAP+A1CAP+BCAP+ IZLL+ZLC;ZLLJ+ZLCJ). COMPLTX ACAP+A1CAP+BCAP+ZKA+FUNI+ZZ1+ZZ2+ L SMAL+CON1+CON2+ZLG+CON3+SM+SM1+SM2+S43+Z Z SMG+SN+CONG+CON7+ZTL+CD+SM4 L+YL+SM5+CONB+SM8+SM9+SM7+YZ1+YZ2+Y3+Y4+YO Z SM1C+YON3+YN+YBON+YBON1+YM+CON11 COMMON /A2/ZLT(20+20) DIMENSION ZLG(2C)+ZLH(20)+SM4(20)+FACT(11)	• 7KA • NALP • NBETA • 73 • 71H • CC • 74 • • 73 • • 73 • • 73 • 71H • CC • 74 • • 73 • • 74 • 74 • • 74 • • 74 • • 74 • • 75 • • 74 • • 74 • • 74 • • 74 • • 73 • • 74 • • 73 • • 74 • • 73 • • 74 • • 74 • • 73 • • 74 • • 73 • • 74 • • 73 • • 74 • • 74 • • 73 • • 74 •	ZL.FUNI.
245 	FND IS. FINDT SUBROUTINE FINDT(ZKP+ZKR+ACAP+A1CAP+BCAP+ IZLL+ZLC,ZLLJ+TLCJ). COMPLEX ACAP+A1CAP+BCAP+ZKA+FUNI+ZZ1+ZZ2+ I SMAL+CON1+CON2+ZLG+CON3+SM+SM1+SM2+SM3+Z Z SMG+SN+CONG+CON7+ZTL+CD+SM4 L+YL+SM5+CONB+SM8+SM9+SM7+YZ1+YZ2+Y3+Y4+Y0 Z SM1C+YON3+YN+YBON+YBON1+YM+CON11 COMMON /A2/ZLT(20+20) DIMENSION ZLG(2C)+ZLH(20)+SM4(20)+FACT(11)	• 7KA • NALP • NBETA • 73 • 72LH • CC • 74 • • 73 • • 73 • 72LH • CC • 74 • • 73 • • 73 • 72LH • CC • 74 • • 73 • • 73 • 72LH • CC • 74 • • 74 • • 73 • 72LH • CC • 74 • • 73 • • 73 • 72LH • CC • 74 • • 73 • • 73 • 72LH • CC • 74 • • 73 • • 74	ZL.FUNI.
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245	<pre>FND IS_FINDT SUBROUTINE_FINDT(ZKP+ZKR+ACAP+A1CAP+BCAP+ IZLL+ZLC,ZLLJ+ZLCJ). COMPLTX_ACAP+A1CAP+BCAP+ZKA+FUNI+ZZ1+ZZ2+ I_SHAL+CON1+CON2+ZLG+CON3+SM+SM1+SM2+SY3+Z Z_SM6+SN+CON6+CON7+ZTL+CD+SM4 L+YL+SM5+CON8+SM8+SM9+SM7+YZ1+YZ2+Y3+Y4+Y0 Z_SM10+YON3+YN+YBON+YBON1+YM+CON11 COMMON_ZA2/ZLT(20+20) DIMENSION_ZLG(20)+ZLH(20)+SM4(20)+FACT(11) 103</pre>	• 7KA • NALP • NBETA • 73 • 72 H • CC • 74 • • 73 • • 1 • YLG • YL H • Y IL • • 10 • BCAPt 10 • 10 •	• Z L • FUNI •
245 	<pre>FND IS_FINDT SUBROUTINE_FINDT(ZKP+ZKR+ACAP+A1CAP+BCAP+ IZLL+ZLC,ZLLJ+ZLCJ), COMPLTX_ACAP+A1CAP+BCAP+ZKA+FUNI+ZZ1+ZZ2+ I_SMAL+CON1+CON2+ZLG+CON3+SM+SM1+SM2+SY3+Z Z_SMG+SN+CONG+CON7+ZTL+CD+SM4 L+YL+SM5+CONB+SM8+SM9+SM7+YZ1+YZ2+Y3+Y4+Y0 Z_SM1C+YON3+YN+YBON+YBON1+YM+CON11 COMMON_ZAZZLT(Z0+20) DIMENSION_ZLG(2C)+ZLH(20)+SM4(20)+FACT(11) 103</pre>	• 7KA • NALP • NBETA • 73 • 71H • CC • 74 • • 73 • • 73 • 71H • CC • 74 • • 73 • • 73 • 71H • CC • 74 • • 73 • • 73 • 71H • CC • 74 • • 73 • • 73 • 71H • CC • 74 • • 73 • • 73 • 71H • CC • 74 • • 73 • • 73 • 71H • CC • 74 • • 73 • • 73 • 71H • CC • 74 • • 73 • • 73 • 71H • CC • 74 • • 73 • • 71 • 71H • CC • 74 • • 73 • • 71 • 71H • CC • 74 • • 73 • • 71 • 71H • CC • 74 • • 73 • • 71 • 71H • CC • 74 • • 73 • • 71 • 71H • 71H • 71H • • 71 • 71H • 71H • • 71 • 71H • 71H • • 71 • 71H • • 71H	ZL.FUNI.

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	¥72=¥4								
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12	CONTINUE			•					
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## SAMPLE PROBLEM - COMPARISON WITH NASTRAN CODE

. 4. 0

In this section, we apply the results of this study to a specific engineering problem in order to test the usefulness, accuracy and efficiency of the developed approach as compared to strictly numerical methods. The NASTRAN code is selected as representative of such methods. The problem consists of a ring-stiffened cylindrical shell excited by a random pressure field whose correlation properties resemble those of pressure fluctuations beneath a turbulent boundary layer, Figure 2.

Two discrete models of the shell were constructed: Model 1, having 360 degrees of freedom, is shown in Figures 3, 4; Model 2 is a more detailed one (720 degrees of freedom) and is shown in Figure 5. The NASTRAN eigenvalue routine was used to obtain the corresponding normal frequencies, modal masses and values of the associated mode shapes for the first few modes. Table 1 lists the computed natural frequencies for both shell models, while Figures 6 and 7 show typical NASTRAN plots of the deformed shell in its natural modes. The solution to the eigenvalue problem is common to both the present approach and the NASTRAN calculation. At this point, the present method departs from numerical procedures. The NASTRAN-generated mode-shape data was first curve-fitted using the FITMSC code (Section 3.1) which produced values for the coefficients in Equation (19) (see Figure 1). Typical FITMSC plots are shown in Figures 8 and 9. The points in these figures are the NASTRAN values. Each curve represents a cross-section of the shell. For clarity in presentation, the curves have been displaced relative to each other. The undeformed ends of the shell are shown by the inner and outer circles in each plot.

<sup>\*</sup>The modeling was performed by Mr. G. Jones, Goddard Space Flight Center, who is also responsible for the NASTRAN calculation of the eigenvalue and response problems.



(44" apart) 10 Axial Stiffeners (36" inch)



		۰.	
m	n	Model 1	Model 2
4	1	154.4, 154.4 Hz	130.7, 130.7 Hz
3	1	149.8, 149.8 Hz	131.4, 131.4 Hz
5	1	170.2 - Hz	160.7, 167.4 Hz
2	1	187.5, 187.5 Hz	175.8, 175.8 Hz
4	2	258.4. 258.4 Hz	214.5. 214.5 Hz
6	1		217.3.217.3 Hz
5	2	259.2 - Hz	219.0. 228.5 Hz
3	2	-	243.7, 243.7 Hz
6	2		259.9, 259.9 Hz
1	1	280.4, 280.4 Hz	276.8, 276.8 Hz

TABLE 1. Modal Frequencies of shell model 1 and 2 (m = number of circumferential waves, n = number of axial half waves).



Figure 3.













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Figure 6.

Shell Model 1 in Natural Vibration (f = 149.8 Hz)

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Figure 6. - continued (f = 259.2 Hz)



Figure 7.





Figure 7. - continued (f = 167.4 Hz)





Figure 7. - continued (f = 214.5 Hz)











Figure 7. - continued (f = 259.9 Hz)







Figure 8. - continued (f = 170.2 Hz)







Figure 8. - continued (f = 258.4 Hz)





Figure 8. - continued (f = 280.4 Hz)



Figure 9.

Trigonometric Interpolation of Mode Shape Data. Shell Model 2 (f = 130.7 Hz)



Figure 9. - continued (f = 160.7 Hz)



Figure 9. - continued (f = 214.5 Hz)



Figure 9. - continued (f = 217.3 Hz)





Figure 9. - continued (f = 228.5 Hz)







Figure 9. - continued (f = 259.9 Hz)



## Figure 9. - continued (f = 259.9 Hz)

The output of the FITMSC code, along with the other structural parameters (e.g. modal frequencies and masses, length, radius, damping<sup>\*</sup>, et cetera) constitute part of the input to the RANCYL code (Section 3.3). The remaining parameters depend on the input function.

The following form for the pressure cross-spectral density was chosen:

$$\hat{Q}(Z,\Theta,\omega) = 0.016 \exp[-0.05\Theta - 0.025 |Z|] \cos 0.1Z; (psi)^2 / Hz 0 < \Theta < \pi$$
 (59)

With reference to Equation (25),

$$Q_1(Z) = e^{-0.025 |Z|} \cos 0.1 Z$$

$$= \frac{1}{2} \left[ e^{i(0.1 + 0.025i)Z} + e^{i(-0.1 + 0.025i)Z} \right] U(Z)$$
$$+ \frac{1}{2} \left[ e^{i(0.1 - 0.025i)Z} + e^{i(-0.1 - 0.025i)Z} \right] U(-Z)$$
(60)

$$Q_2(\Theta) = e^{-0.05\Theta}; \quad 0 < \Theta < \pi$$
 (61)

$$\hat{Q}_{3}(\omega) = 0.016$$
 (62)

Expanding Equations (34) and (36),

$$Q_{1}(Z) = A_{0} + A_{1} \delta(Z) + U(Z) \sum_{\alpha=1}^{\infty} e^{i\kappa \alpha Z} \left\{ iB_{\alpha,1} + iB_{\alpha,2}(iZ) + \dots \right\}$$
  
+  $U(-Z) \sum_{\gamma=1}^{\infty} e^{i\kappa \gamma Z} \left\{ -iC_{\gamma,1} - iC_{\gamma,2}(iZ) \dots \right\}$  (63)

\*For this example, the ratio of damping to critical damping was chosen to be 0.01. In terms of this ratio, the modal damping  $a_n$  is given by  $a_n = 0.01 \omega_n$ .

$$Q_{2}(\Theta) = D_{0} + D_{1} \delta(\Theta) + \sum_{\eta=1} e^{i\kappa} \eta^{\Theta} \left\{ E_{\eta,0} + E_{\eta,1} \Theta + \dots \right\}$$
(64)

Comparing Equations (60) and (63),

$$A_{0} = A_{1} = 0$$

$$\alpha = 1, 2; \beta = 1$$

$$P_{1,1} = P_{2,1} = \frac{1}{2i}$$

$$\kappa_{\alpha = 1} = 0.1 + 0.025i$$

$$\kappa_{\alpha = 2} = -0.1 + 0.025i$$

$$R_{\alpha, \beta} = \kappa_{\alpha} = 0, \text{ all } \alpha > 2, \beta > 1$$

$$C_{1,1} = C_{2,1} = -\frac{1}{2i}$$

$$\kappa_{\gamma = 1} = 0.1 - 0.025i$$

$$\kappa_{\gamma = 2} = -0.1 - 0.025i$$

$$\kappa_{\gamma = 2} = -0.1 - 0.025i$$

$$\kappa_{\gamma = 2} = -0.1 - 0.025i$$

Similarly, comparison of Equation (61) with (64) yields

$$D_{o} = D_{1} = 0$$
$$\eta = 1, \sigma = 0$$

E<sub>1,0</sub> = 1; E<sub>η,σ</sub> = 0, all η>1, σ>0  

$$\kappa_{n=1} = 0.05i; \kappa_n = 0, all η>1$$

From Equations (62) and (33), we further deduce

$$H_{o} = N_{\eta,\sigma} = M_{\xi,\rho} = 0, \text{ all } \eta, \sigma, \xi,$$

 $H_1 = 0.016$ 

The above values for the pressure field parameters constituted the remaining portion of the input to the RANCYL code, which was run to obtain values for the response cross-spectral and power spectral densities at selected grid points of shell models 1 and 2. For this purpose, grid points 2, 3 and 4 were selected (see Figures 3 - 5). The power spectral density at the same grid points was also computed using the NASTRAN computer program (rigid format 11). The pressure was input in the form of discrete values at the grid points. Rigid format 11, modal random response, makes use of modal data to derive a dynamic transfer function for a set of input frequencies and then using the input random loads to calculate the structural response at those frequencies.

The results of these computations are shown in Figures 10 -19. Power spectral density plots at grid points 2, 3, and 4 of shell model 1 are shown in Figures 10 - 12 along with the NASTRAN values. The power spectral density at the same grid points of shell model 2 is plotted in Figures 13 - 15. Due to difficulties encountered in the NASTRAN analysis of shell model 2, a limited number of values were obtained, as shown in these figures. Typical cross-spectral density results obtained using the RANCYL code are shown in Figures 16 - 19. A NASTRAN calculation of response cross-spectral density was not performed.

Inspection of the results show very good agreement, in general. The mode-shape fits, as exemplified in Figures 8 and 9, are indeed excellent. It should be noted that, at most, eight terms of Eq. (19) were necessary to produce any one mode shape. The power spectral density results based on shell model 1 show reasonable agreement in general trend

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Response Cross-Spectral Density (Modulus) 142



Response Cross-Spectral Density (Modulus)

8 3 200 280 260 260 ł 1 1 240 П 1 11 1.1 . 1. Response Cross-Spectral Density at Grid Points 2 and 4 (z=66 in., z'=110 in.,  $\theta=\theta=0$ ) 1.111 +-1: 160 2 Shell Model 1 140 į ÷ 1 11 ŀ 11 i -Figure 19 i, ..... ÷ 120 10-5-----.17. 1 ;; ' ; ] . [ . **1**8 10-6 10-4-1,0<sup>-3</sup> 0

Response Cross-Spectral Density (Modulus)

and shape of the curves, though magnitude differences exist. These differences are reduced considerably when a more detailed model is used (Shell Model 2) resulting in the very good agreement shown in Figures 13 - 15. That is, the NASTRAN and RANCYL results converge to a particular value when more detailed discrete models are used, as expected. Differences in the high frequency range still persist, however, as one would also expect in going from a discrete to a continuous representation of the structure. The importance of modeling becomes clear by comparing the RANCYL calculation based on Models 1 and 2. Typical of the existing differences is Figure 20 where the power spectral density at grid point 3 of Shell Models 1 and 2 is plotted.

A comparison of computer time required by the two methods was also performed in order to assess the efficiency of the present approach as compared to strictly numerical techniques. With reference to Eq. (48), it is noted that the terms within the brackets (i. e., the terms summed over p, q, r, and s) are independent of frequency and position. For a set of input values, the evaluation of these terms is carried out, once and for all, regardless of the number of spatial points and frequencies at which the response is calculated. The machine time required for the evaluation of these terms was found to be 5.04 sec. and 70 sec. for Shell Model 1 and 2, respectively. In addition to this fixed time, 0.009 sec. per point (i. e., per set of values for z,  $\theta$ , z',  $\theta'$  and  $\omega$ ) was required in the case of Model 1 and 0.0107 sec. per point in the case of Model 2. Thus, the machine time, t<sub>m</sub>, required by the RANCYL code is related linearly to the number of points at which the response is calculated through the formula

$$t_{m} = a + bn \quad sec. \tag{65}$$

where n is the number of points and where a = 5.04, b = 0.009 in the case of Model 1 and a = 70, b = 0.0107 in the case of Model 2. The above



time requirement is the same in both power spectral and cross-spectral density calculations. Typically, each curve in Figures 10-19 represents part of a single computer run involving approximately 75 points (i.e., 75 frequency values at the coordinates of the chosen grid point), resulting in a total machine time of 5 72 sec. and 70.8 sec. for Model 1 and 2, respectively. In this particular application of the NASTRAN code, up to nine frequencies per run were input at each grid point in the Model 1 power spectral density analysis and two frequencies per run were input in the case of Model 2. The corresponding machine times are shown in Table 2. The RANCYL time requirements for the same number of points, are also shown. These values are based on Eq. (65).

MODEL	NO. of POINTS	MACHINE	TIME
		NASTRAN	RANCYL (sec)
1	7	636	5.1
1	9	750	5.12
2	2	444	70.02

Table 2

2 Machine Time Requirements in the Response Evaluation of the Sample Problem

It should be noted that the NASTRAN code was run on IBM 360-95 computer, while RANCYL was run on a Univac 1108 computer. The latter machine is slower by at least a factor of three. On the other hand, some fraction of the time required by the FITMSC code for the trigonometric interpolation of the mode-shape data should be added on to the RANCYL entries in Table 2. In this particular sample problem, the curve-fitting routine required a total of 77 sec. for twelve modes of Model 1 and 115 sec. for eighteen modes of Model 2. The time requirement of this routine depends strictly on the number of modes and on the number of points per mode. It is an initial time investment, independent of the evaluation of Eq. (48) and the number of points at which the response is evaluated.

## CONCLUDING REMARKS

1. A methodology for the calculation of structural response has been presented and applied to nonuniform beams and cylindrical shells. The method rests on the use of parametric representations for the impulse response and input functions. Use of these representations makes possible the derivation of analytic response solutions applicable to a host of structures of the above geometries and pressure fields. The arbitrary parameters in the response solutions can be fixed once results of the numerical solution to the eigenvalue problem and a particular input function are available.

2. Use of the developed computer codes, based on the analytical results, is simple and efficient. For instance, for an initial run of the RANCYL code, it is necessary to manually keypunch about a dozen cards only (the remaining cards are direct output of the FITMSC code). For a restart run,only a few cards need to be punched manually. In general, only those cards containing the grid point coordinates or frequency values are changed. In its present form, given two or more spatial points, the code computed the response power spectral and crossspectral densities at these points simultaneously for up to seventy-five frequencies per run. The dimensions of the pertinent code variables may still be increased significantly without exceeding core storage to allow for more frequencies, mode shapes, grid points, et cetera.

3. The spatial-temporal distribution of pressure (or, the corresponding spectrum) must be given in one of two forms for the analyst to determine values for the relevant input parameters to the code: if an analytic function is given, values for these parameters can easily be specified by direct comparison of the given input function to the class of functions considered in this study. Such has been the case in the sample problem (Section 4.0). If pressure field data is given, then the analyst must either empirically

5.0

fit a function to the data, or employ some interpolation technique. In the first instance, the procedure for identifying input values for the pressure field parameters is the same as before, namely, by simple comparison. In the latter instance, readily available interpolation routines involve either polynomials or trigonometric functions, both of which belong to the class of input functions considered. Such a routine can easily be coupled to the response codes so that its output (i. e. , values for the coefficients) can be directly input to the RANCYL or DEXCYL codes.

4. The FITMSC code has been most successful in its application to the sample problem, both from the standpoint of the goodness of the fits to the given mode-shape data and the minimal computer time necessary. This, however, may not always be the case. Difficulties may arise in the application of the code to shells of unusual construction, especially for high frequency modes. It is anticipated, however, that in the case of most common engineering applications, this will not be the case.

5. The sample problem has demonstrated some of the advantages of the tools developed in this study. Although general conclusions valid for all applications should not be drawn on this basis, some features of the comparison with the NASTRAN computation are indicative of the usefulness of the developed codes. Perhaps the most striking features are the efficiency, and hence low cost of operation (Table 2), the ease with which the analyst can use RANCYL and the number of spatialfrequency points per run at which the response can be evaluated (e.g., in the case of shell model 1, a RANCYL run accommodated seventy-five frequency values. NASTRAN accommodated nine). Comparison of the results of the two calculations (Figures 10-15) points out the importance of modeling in response calculations and the usefulness of the developed

codes as guides in the application of the discrete element approach. The differences in the results stem from both modeling of the discrete structure and modeling of the driving pressure field. In the discrete element approach (e.g., NASTRAN), the pressure field is specified by <u>discrete</u> values only at the structural grid points; the present method requires a <u>continuous</u> representation of the pressure, i. e., a function. As the number of structural grid points considered increases, the model better approximates the continuous structure. Moreover, pressure field values at a larger number of points are specified, so that the discrete pressure field representation better approximates a continuous function. Indeed, the disagreement in the results, exemplified particularly in the vicinity of 165 Hz, is considerably reduced when a more detailed discrete model is used. In fact, the agreement in results based on model 2 is surprisingly good.

6. The results of this study indicate that the developed codes can provide a valuable supplement to numerical analyses of complex structures, especially in the early stages of design of a vehicle where ease and speed of computation is crucial. The application of the developed methodology to other structural shapes (coordinate systems) should further increase its usefulness and versatility. Such an extension follows the same procedure, (Figure 1). However, the mathematical manipulation can be greatly complicated depending upon the coordinate system used. This is particularly true if the structure and driving pressure field can not be represented most conveniently in the same coordinate system.

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## APPENDIX

Evaluation of 
$$P_{pr}(L)$$
,  $S_{qs}(2\pi)$ 

Consider Equation (51). Using Equation (34) and letting

$$f(z, z') = \varphi_{p}(z) \varphi_{r}(z') = \exp \left[i(k_{p}z + k_{r}z')\right]$$

$$P_{pr}(L) = A_{o} \int_{0}^{L} dz_{o} \int_{0}^{L} dz'_{o} f(z_{o}, z'_{o}) + A_{1} \int_{0}^{L} dz_{o} \int_{0}^{L} dz'_{o} f(z_{o}, z'_{o}) \delta(z_{o} - z'_{o})$$

$$+ \sum_{\alpha, \beta} \frac{B_{\alpha, \beta}}{(\beta - 1)!} i^{\beta} \int_{0}^{L} dz_{o} \int_{0}^{L} dz'_{o} f(z_{o}, z'_{o}) e^{i\kappa \alpha^{Z} o} Z_{o}^{\beta - 1} U(Z_{o})$$

$$- \sum_{\gamma, \epsilon} \frac{C_{\gamma, \epsilon}}{(\epsilon - 1)!} i^{\epsilon} \int_{0}^{L} dz_{o} \int_{0}^{L} dz'_{o} f(z_{o}, z'_{o}) e^{i\kappa \gamma^{Z} o} Z_{o}^{\epsilon - 1} U(-Z_{o}) \quad (A1)$$

where Z = z - z'. The first two terms are evaluated trivially giving rise to the first two terms in Equation (53). To evaluate the third integral in Equation (A1), let  $z'_{0} = z_{0} - Z_{0}$  to obtain

$$\int_{0}^{L} dz_{o} \int_{z_{o}-L}^{z_{o}} dZ_{o} f(z_{o}, z_{o}-Z_{o}) e^{i\kappa \alpha Z_{o}} Z_{o}^{\beta-1} U(Z_{o})$$

Since the range of  $z_{o}$  is always less than L, the lower limit of the  $Z_{o}$  integration is always negative. In view of the step function  $U(Z_{o})$ , it follows that the integral to be evaluated is

Al

$$\int_{0}^{L} dz_{o} \int_{0}^{z_{o}} dZ_{o}^{f(z_{o}, z_{o} - Z_{o})} e^{i\kappa \alpha^{Z} \sigma} Z_{o}^{\beta - 1}$$

$$= \int_{0}^{L} dz_{o}^{f(z_{o}, z_{o} - Z_{o})} e^{i\kappa \alpha^{Z} \sigma} Z_{o}^{\beta - 1}$$

$$= \int_{0}^{L} dz_{o}^{f(z_{o}, z_{o} - Z_{o})} e^{i(\kappa \alpha^{Z} \sigma)} Z_{o}^{\beta - 1}$$

$$= \int_{0}^{L} dz_{o}^{f(z_{o}, z_{o} - Z_{o})} e^{i(\kappa \alpha^{Z} \sigma)} Z_{o}^{\beta - 1}$$

Repeated application of the formula

$$\int dx \ e^{ax} x^{n} = e^{ax} \left\{ \frac{x^{n}}{a} + \sum_{k=1}^{n} \frac{(-1)^{k} n(n-1) (n-2) \dots (n-k+1)}{a^{k+1}} x^{n-k} \right\}$$
(A2)

gives rise to the term within the  $\alpha$ ,  $\beta$ -sum in Equation (53). Similarly, to evaluate the fourth integral in Equation (A1), let  $z'_{0} = z_{0} - Z_{0}$  to obtain

$$\int_{0}^{L} dz_{o} \int_{z_{o}-L}^{z_{o}} dZ_{o} f(z_{o}, z_{o}-Z_{o}) e^{i\kappa \gamma^{Z} o} Z_{o}^{\epsilon-1} U(-Z_{o})$$

Since the integrand vanishes for  $Z_0 > 0$  and the upper limit of the  $Z_0$ -integration is always positive, the integral to be evaluated is

$$\int_{0}^{L} dz_{o} \int_{z_{o}-L}^{0} dZ_{o} f(z_{o}, z_{o}-Z_{o}) e^{i\kappa \gamma z_{o}} Z_{o}^{\epsilon-1}$$

$$= \int_{0}^{L} dz_{o} \varphi_{p}(z_{o}) \int_{z_{o}-L}^{0} dZ_{o} \varphi_{r}(z_{o}-Z_{o}) e^{i\kappa \gamma z_{o}} Z_{o}^{\epsilon-1}$$

$$= \int_{0}^{L} dz_{o} e^{i(k_{p}+k_{r})z_{o}} \int_{z_{o}-L}^{0} dZ_{o} e^{-i(k_{r}-\kappa_{\gamma})Z_{o}} Z_{o}^{\epsilon-1}$$

A2 .

Repeated use of Equation (A2) yields the term within the  $\gamma, \epsilon$ -sum in Equation (53).

In the evaluation of  $S_{qs}(2\pi)$ , we note that the first two terms of Equation (36) in (52) give rise to the first two terms of Equation (54) in a straightforward manner. The evaluation for the third term of Equation (36) is somewhat more complex because of the conditions on  $Q_2(\theta - \theta')$  given in Equation (31). These conditions can be combined in a single equation by introducing appropriate step functions:

$$Q_{2}(\Theta) = Q_{2}(|\Theta|) U(\pi - |\Theta|) + Q_{2}(2\pi - |\Theta|) U(|\Theta| - \pi)$$
(A3)

where  $\Theta = \theta - \theta'$ . Using Equation (A3) in Equation (52) and letting

$$f(\theta, \theta') = \boldsymbol{\varphi}_{q}(\theta) \boldsymbol{\varphi}_{s}(\theta') = \exp \left[i(k_{q}\theta + k_{s}\theta')\right], \quad (A4)$$

we obtain

$$S_{qs}(2\pi) = \int_{0}^{2\pi} d\theta_{o} \int_{0}^{2\pi} d\theta'_{o} f(\theta_{o}, \theta'_{o}) Q_{2}(|\Theta_{o}|) U(\pi - |\Theta_{o}|) + \int_{0}^{2\pi} d\theta_{o} \int_{0}^{2\pi} d\theta'_{o} f(\theta_{o}, \theta'_{o}) Q_{2}(2\pi - |\Theta_{o}|) U(|\Theta_{o}| - \pi)$$
(A5)

Under the change of variable  $\theta'_{o} = \theta_{o} - \Theta_{o}$ , Equation (A5) becomes

A 3

$$\begin{split} \mathbf{S}_{qs}(2\pi) &= \int_{0}^{2\pi} \mathrm{d}\boldsymbol{\theta}_{o} \int_{\boldsymbol{\theta}_{o}-2\pi}^{\boldsymbol{\theta}_{o}} \mathrm{d}\boldsymbol{\Theta}_{o} f(\boldsymbol{\theta}_{o},\boldsymbol{\theta}_{o}-\boldsymbol{\Theta}_{o}) \, \boldsymbol{\Omega}_{2}(|\boldsymbol{\Theta}_{o}|) \, \mathrm{U}(\pi - |\boldsymbol{\Theta}_{o}|) \\ &+ \int_{0}^{2\pi} \mathrm{d}\boldsymbol{\theta}_{o} \int_{\boldsymbol{\theta}_{o}-2\pi}^{\boldsymbol{\theta}_{o}} \mathrm{d}\boldsymbol{\Theta}_{o} f(\boldsymbol{\theta}_{o},\boldsymbol{\theta}_{o}-\boldsymbol{\Theta}_{o}) \, \boldsymbol{\Omega}_{2}(2\pi - |\boldsymbol{\Theta}_{o}|) \, \mathrm{U}(|\boldsymbol{\Theta}_{o}| - \pi) \\ &= \int_{0}^{2\pi} \mathrm{d}\boldsymbol{\theta}_{o} \int_{\boldsymbol{\Theta}}^{\boldsymbol{\Theta}} \mathrm{d}\boldsymbol{\Theta}_{o} f(\boldsymbol{\theta}_{o},\boldsymbol{\theta}_{o}-\boldsymbol{\Theta}_{o}) \, \boldsymbol{\Omega}_{2}(\boldsymbol{\Theta}_{o}) \, \mathrm{U}(\pi - \boldsymbol{\Theta}_{o}) \\ &+ \int_{0}^{2\pi} \mathrm{d}\boldsymbol{\theta}_{o} \int_{\boldsymbol{\Theta}_{o}-2\pi}^{\boldsymbol{\Theta}} \mathrm{d}\boldsymbol{\Theta}_{o} f(\boldsymbol{\theta}_{o},\boldsymbol{\theta}_{o}-\boldsymbol{\Theta}_{o}) \, \boldsymbol{\Omega}_{2}(-\boldsymbol{\Theta}_{o}) \, \mathrm{U}(\pi + \boldsymbol{\Theta}_{o}) \\ &+ \int_{0}^{2\pi} \mathrm{d}\boldsymbol{\theta}_{o} \int_{\boldsymbol{\Theta}_{o}-2\pi}^{\boldsymbol{\Theta}} \mathrm{d}\boldsymbol{\Theta}_{o} f(\boldsymbol{\theta}_{o},\boldsymbol{\theta}_{o}-\boldsymbol{\Theta}_{o}) \, \boldsymbol{\Omega}_{2}(2\pi - \boldsymbol{\Theta}_{o}) \, \mathrm{U}(\pi + \boldsymbol{\Theta}_{o}) \\ &+ \int_{0}^{2\pi} \mathrm{d}\boldsymbol{\theta}_{o} \int_{\boldsymbol{\Theta}_{o}}^{\boldsymbol{\Theta}} \mathrm{d}\boldsymbol{\Theta}_{o} f(\boldsymbol{\theta}_{o},\boldsymbol{\theta}_{o}-\boldsymbol{\Theta}_{o}) \, \boldsymbol{\Omega}_{2}(2\pi - \boldsymbol{\Theta}_{o}) \, \mathrm{U}(\boldsymbol{\Theta}_{o}-\pi) \\ &+ \int_{0}^{2\pi} \mathrm{d}\boldsymbol{\theta}_{o} \int_{\boldsymbol{\Theta}_{o}}^{\boldsymbol{\Theta}} \mathrm{d}\boldsymbol{\Theta}_{o} f(\boldsymbol{\theta}_{o},\boldsymbol{\theta}_{o}-\boldsymbol{\Theta}_{o}) \, \boldsymbol{\Omega}_{2}(2\pi - \boldsymbol{\Theta}_{o}) \, \mathrm{U}(\boldsymbol{\Theta}_{o}-\pi) \end{split}$$

Let

$$S_{1} = \int_{0}^{2\pi} d\theta_{o} \int_{0}^{\theta} d\Theta_{o} f(\theta_{o}, \theta_{o} - \Theta_{o}) Q_{2}(\Theta_{o}) U(\pi - \Theta_{o})$$
(A)

$$S_{2} = \int_{0}^{2\pi} d\theta_{o} \int_{\theta_{o}-2\pi}^{0} d\Theta_{o} f(\theta_{o}, \theta_{o}-\Theta_{o}) Q_{2}(-\Theta_{o}) U(\pi+\Theta_{o})$$
(A8)

$$S_{3} = \int_{0}^{2\pi} d\theta_{o} \int_{0}^{\theta} d\Theta_{o} f(\theta_{o}, \theta_{o} - \Theta_{o}) Q_{2}(2\pi - \Theta_{o}) U(\Theta_{o} - \pi)$$

(A9)

7)

$$= \int_{0}^{2\pi} d\theta_{0} \int_{\theta_{0}^{-2\pi}}^{0} d\Theta_{0} f(\theta_{0}, \theta_{0}^{-}\Theta_{0}) Q_{2}(2\pi + \Theta_{0}) U(-\Theta_{0}^{-\pi})$$
(A10)

To establish the regions of integration in Equations (A7) - (A10), one need only plot the limits of the  $\theta_0, \Theta_0$  integrations and the domain in which the integrands do not vanish, that is, where the step functions are unity. This is done in Figure 21. From this figure, it follows that

$$S_{1} = \int_{0}^{\pi} d\theta_{o} \int_{0}^{\theta_{o}} d\Theta_{o} F(\theta_{o}, \Theta_{o}) + \frac{r^{2}\pi}{J_{\pi}} d\theta_{o} \int_{0}^{\pi} d\Theta_{o} F(\theta_{o}, \Theta_{o})$$
(A11)

$$S_{2} = \int_{0}^{\pi} d\theta_{o} \int_{-\pi}^{0} d\Theta_{o} G(\theta_{o}, \Theta_{o}) + \int_{\pi}^{2\pi} d\theta_{o} \int_{\theta_{o}^{-2\pi}}^{0} d\Theta_{o} G(\theta_{o}, \Theta_{o})$$
(A)

2)

(A13)

(A14)

(A15)

(A16)

(A17)

(A18)

$$S_3 = \int_{\pi}^{2\pi} d\theta_0 \int_{\pi}^{\theta_0} d\Theta_0 H(\theta_0, \Theta_0)$$

$$S_{4} = \int_{0}^{\pi} d\theta_{0} \int_{\theta_{0}-2\pi}^{-\pi} d\Theta_{0} J(\theta_{0}, \Theta_{0})$$

where

 $S_4$ 

$$F(\theta_{o}, \Theta_{o}) = f(\theta_{o}, \theta_{o} - \Theta_{o}) Q_{2}(\Theta_{o})$$

$$G(\theta_{o}, \Theta_{o}) = f(\theta_{o}, \theta_{o} - \Theta_{o}) Q_{2}(-\Theta_{o})$$

$$H(\theta_{o}, \Theta_{o}) = f(\theta_{o}, \theta_{o} - \Theta_{o}) Q_{2}(2\pi - \Theta_{o})$$

$$J(\theta_{o}, \Theta_{o}) = f(\theta_{o}, \theta_{o} - \Theta_{o}) Q_{2}(2\pi + \Theta_{o})$$

Α5





 $\mathbf{A}$ 6

## Consider Equation (All). Using Equations (Al5), (A4)

and the third term of Equation (36),

$$\begin{split} \mathbf{S}_{1} &= \int_{0}^{\pi} \mathrm{d}_{\Theta} \int_{0}^{\Theta} \mathrm{d}_{\Theta} \varphi_{q}(\Theta) \varphi_{s}(\Theta - \Theta) Q_{2}(\Theta) \\ &+ \int_{\pi}^{2\pi} \mathrm{d}_{\Theta} \int_{0}^{\pi} \mathrm{d}_{\Theta} \varphi_{q}(\Theta) \varphi_{s}(\Theta - \Theta) Q_{2}(\Theta) \\ &= \sum_{\eta,\sigma} \mathbf{E}_{\eta,\sigma} \left[ \int_{0}^{\pi} \mathrm{d}_{\Theta} e^{i(\mathbf{k}_{q} + \mathbf{k}_{s})\Theta} \int_{0}^{\Theta} \mathrm{d}_{\Theta} e^{-i(\mathbf{k}_{s} - \kappa_{\eta})\Theta} \Theta_{0}^{\sigma} \\ &+ \int_{\pi}^{2\pi} \mathrm{d}_{\Theta} e^{i(\mathbf{k}_{q} + \mathbf{k}_{s})\Theta} \int_{0}^{\Theta} \mathrm{d}_{\Theta} e^{-i(\mathbf{k}_{s} - \kappa_{\eta})\Theta} \Theta_{0}^{\sigma} \right] \end{split}$$

Repeated application of Equation (A2) yields Equation (55). Similarly, with Equations (A16) and (A4) in (A12)

$$S_{2} = \int_{0}^{\pi} d\theta_{o} \int_{-\pi}^{0} d\Theta_{o} \varphi_{q}(\theta_{o}) \varphi_{s}(\theta_{o} - \Theta_{o}) Q_{2}(-\Theta_{o})$$
$$+ \int_{\pi}^{2\pi} d\theta_{o} \int_{\theta_{o}}^{0} d\Theta_{o} \varphi_{q}(\theta_{o}) \varphi_{s}(\theta_{o} - \Theta_{o}) Q_{2}(-\Theta_{o})$$

Letting  $y = -\Theta_{o}$  and using Equation (36), we have  $S_{2} = \int_{0}^{\pi} d\theta_{o} \ \varphi_{q}(\theta_{o}) \int_{0}^{\pi} dy \ \varphi_{s}(\theta+y) \ Q_{2}(y)$   $+ \int_{\pi}^{2\pi} d\theta_{o} \ \varphi_{q}(\theta_{o}) \int_{0}^{2\pi-\theta_{o}} dy \ \varphi_{s}(\theta_{o}+y) \ Q_{2}(y)$ 

Α7

$$\sum_{\eta,\sigma} E_{\eta,\sigma} \left[ \int_{0}^{\pi} d\theta_{o} e^{i(k_{q}+k_{s})\theta} \int_{0}^{\pi} dy e^{i(k_{s}+\kappa_{\eta})y} y^{\sigma} + \int_{\pi}^{2\pi} d\theta_{o} e^{i(k_{q}+k_{s})\theta} \int_{0}^{2\pi-\theta} \int_{0}^{2\pi-\theta} dy e^{i(k_{s}+\kappa_{\eta})y} y^{\sigma} \right]$$

which can be evaluated by application of Equation (A2) to yield Equation (56). To evaluate S<sub>3</sub>, let  $y = 2\pi - \Theta_0$  in Equation (A13) to obtain

$$S_{3} = \int_{\pi}^{2\pi} d\theta_{o} \int_{2\pi - \theta_{o}}^{\pi} dy H(\theta_{o}, 2\pi - y)$$

$$= \int_{\pi}^{2\pi} d\theta_{o} \int_{2\pi - \theta_{o}}^{\pi} dy f(\theta_{o}, \theta_{o} + y - 2\pi) \Omega_{2}(y)$$

$$= \int_{\pi}^{2\pi} d\theta_{o} \varphi_{q}(\theta_{o}) \int_{2\pi - \theta_{o}}^{\pi} dy \varphi_{s}(\theta + y - 2\pi) \Omega_{2}(y)$$

$$= \sum_{\eta, \sigma} E_{\eta, \sigma} e^{-2\pi i k_{s}} \int_{\pi}^{2\pi} d\theta_{o} e^{i(k_{q} + k_{s}) \theta_{o}} \int_{2\pi - \theta_{o}}^{\pi} dy e^{i(k_{s} + \kappa_{q})y} y^{\sigma} (A19)$$

where use has been made of Equations (A17), (A4) and (36). Similarly, let  $y = 2\pi + \Theta_0$  in Equation (A14) to obtain

$$S_{4} = \int_{0}^{\pi} d\theta_{o} \int_{\theta_{o}}^{\pi} dy J(\theta_{o}, y-2\pi) = \int_{0}^{\pi} d\theta_{o} \int_{\theta_{o}}^{\pi} dy f(\theta_{o}, \theta_{o}-y+2\pi) Q_{2}(y)$$
$$= \int_{0}^{\pi} d\theta_{o} \phi_{q}(\theta_{o}) \int_{\theta_{o}}^{\pi} dy \phi_{s}(\theta_{o}-y+2\pi) Q_{2}(y)$$
$$= \sum_{\eta, \sigma} E_{\eta, \sigma} e^{2\pi i k_{s}} \int_{0}^{\pi} d\theta_{o} e^{i(k_{q}+k_{s})\theta_{o}} \int_{\theta_{o}}^{\pi} dy e^{-i(k_{s}-\kappa_{\eta})y} y^{\sigma}$$
(A20)

A8

where Equations (A18), (A4) and (36) have been used. Equations (A19) and (A20) can now be evaluated using Equation (A2) to yield Equations (57) and (58), respectively.

Α9