NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Washington, D.C. 20034

TRANSIENT RESPONSE CALCULATION IN THE FREQUENCY DOMAIN WITH GENERAL BENDING RESPONSE PROGRAM (GBRP)

Francis Henderson

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COMPUTATION AND MATHEMATICS DEPARTMENT

RESEARCH AND DEVELOPMENT REPORT

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Report 3513

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Naval Ship Research and Development Center
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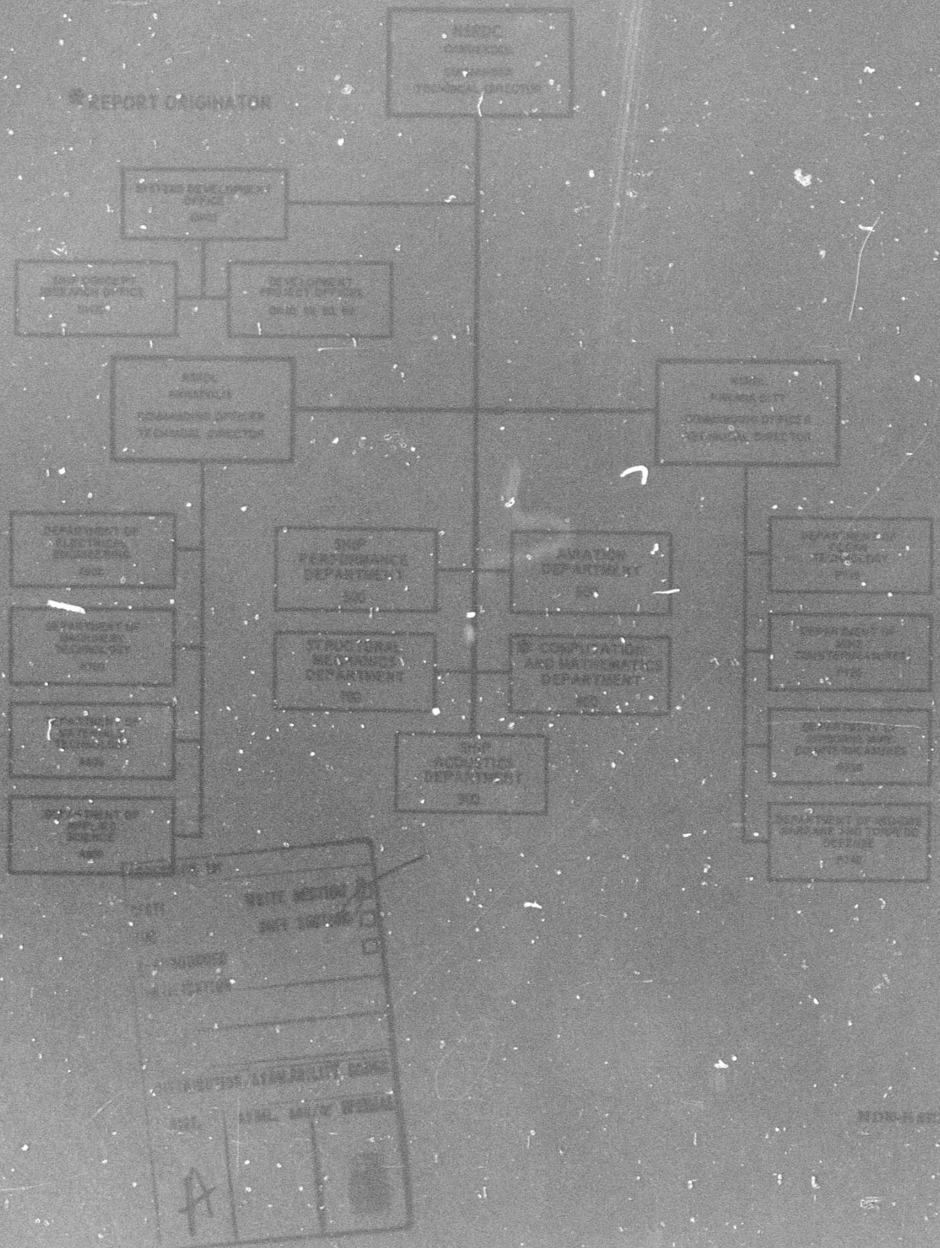

DEPARTMENT OF THE NAVY
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by

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13. ABSTRACT

The General Bending Response Program (GBRP), a digital computer program package for ship vibration analysis, has been augmented to handle calculations of the time response of beam systems under certain types of transient excitation. These excitations are characterized by the fact that their Fourier transforms from the time to the frequency domain can be represented analytically. The method is used to calculate the response of a mass-spring-damper system to a rectangular impulse and of a nonuniform beam to an exponential impulse. A description of the additional data and options required for running problems is included.

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Whirling Response (Propellers)						
Finite Differences						
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ABSTRACT

The General Bending Response Program (GBRP), a digital computer program package for ship vibration analysis, has been augmented to handle calculations of the time response of beam systems under certain types of transient excitation. These excitations are characterized by the fact that their Fourier transforms from the time to the frequency domain can be represented analytically. The method is used to calculate the response of a mass-spring-damper system to a rectangular impulse and of a nonuniform beam to an exponential impulse. A description of the additional data and options required for running problems is included.

ADMINISTRATIVE INFORMATION

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I. PREFACE

The mathematical approach to transient analysis presented here is primarily an extension of a general method[1] utilized to treat a variety of steady-state vibrations: bending, longitudinal, torsional, bending coupled with torsion, and whirling of propeller shafts.

For simplicity, the mathematical development for transient analysis will be carried out only for bending motions of beam-spring systems. To draw attention to correspondences and similarities between the mathematical expressions in reference 1 and those developed in this report, the labels [ ](1, [ ]) will be used when necessary. The first bracket will contain equation numbers applying to the current report; the second bracket will give the corresponding expression in reference 1.

The notation used in reference 1 applies to the current report and will not be repeated except as necessary for clarity.

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[1] Reference is listed on page 35.

II. METHOD OF ANALYSIS

The equations for bending motion of a nonuniform beam are

$$\frac{\partial V(x,t)}{\partial x} = -\mu(x)\frac{\partial^2 y(x,t)}{\partial t^2} - c(x)\frac{\partial y}{\partial t} + P(x,t) \qquad [2.1](1,[2.1])$$

$$\frac{\partial M(x,t)}{\partial x} = V(x,t) + I_{\mu z}(x)\frac{\partial^2 \gamma(x,t)}{\partial t^2} + Q(x,t) \qquad [2.2](1,[2.2])$$

$$\frac{\partial y(x,t)}{\partial x} = \gamma(x,t) - \frac{V(x,t)}{KAG(x)} \qquad [2.3](1,[2.3])$$

$$\frac{\partial \gamma(x,t)}{\partial x} = \frac{M(x,t)}{EI(x)} \qquad [2.4](1,[2.4])$$

where x is the space variable and t is the time variable.

The following conditions are assumed for each time-varying function:

a. The function is real and equal to

$$0 \quad \text{for} \quad t \le 0 \quad .$$

b. The function is absolutely integrable on the interval

$$0 \le t \le \infty \quad .$$

c. The function is of bounded variation in the interval of interest.

Conditions b. and c. insure existence of Fourier transforms for the functions.

Multiplying equations [2.1] through [2.4] by $e^{-i\omega t}$ (where ω is the angular frequency) and then integrating them over the range $0 \le t \le \infty$, one obtains

$$\frac{d\overline{V}(x,\omega)}{dx} = \mu(x)\omega^2\,\overline{Y}(x,\omega) - ic(x)\omega\,\overline{Y}(x,\omega) + \overline{P}(x,\omega) \qquad [2.5](1,[2.5])$$

$$\frac{d\overline{M}(x,\omega)}{dx} = \overline{V}(x,\omega) - I_{\mu z}(x)\omega^2\,\overline{\gamma}(x,\omega) + \overline{Q}(x,\omega) \qquad [2.6](1,[2.6])$$

$$\frac{d\overline{Y}(x,\omega)}{dx} = \overline{\gamma}(x,\omega) - \frac{\overline{V}(x,\omega)}{KAG(x)} \qquad [2.7](1,[2.7])$$

$$\frac{d\bar{\gamma}(x,\omega)}{dx} = \frac{\overline{M}(x,\omega)}{EI(x)}$$ [2.8](1, [2.8])

where $\overline{V}(x,\omega) = \int_0^\infty V(x,t)e^{-i\omega t}\,dt$

$$\overline{M}(x,\omega) = \int_0^\infty M(x,t)e^{-i\omega t}\,dt$$

$$\bar{\gamma}(x,\omega) = \int_0^\infty \gamma(x,t)e^{-i\omega t}\,dt$$

$$\overline{Y}(x,\omega) = \int_0^\infty Y(x,t)e^{-i\omega t}\,dt$$

$$\overline{P}(x,\omega) = \int_0^\infty P(x,t)e^{-i\omega t}\,dt \quad \text{, and}$$

$$\overline{Q}(x,\omega) = \int_0^\infty Q(x,t)e^{-i\omega t}\,dt \quad .$$

It is assumed in writing Equations [2.5] through [2.8] that

$$\int \frac{\partial}{\partial x}[\text{Function }(x,t)]e^{-i\omega t}\,dt$$

$$= \frac{\partial}{\partial x}\int [\text{ Function }(x,t)]\,e^{-i\omega t}\,dt$$

and that all functions and their first derivatives are 0 at $t = 0$. The derivation of approximating finite-difference equations for [2.5] through [2.8] proceeds exactly as described on pages 4-9 of reference 1. The matrix form is

$$[\,A(\omega)\,]\,\vec{\bar{z}} = \vec{\overline{P}}(\omega)$$ [2.9](1, [2.20])

with

$$\vec{z} = \begin{vmatrix} \bar{Y}_1 \\ \bar{M}_1 \\ \bar{Y}_2 \\ \bar{M}_2 \\ \vdots \\ \bar{Y}_N \\ \bar{M}_N \end{vmatrix} , \quad \vec{\bar{P}}(\omega) = \begin{vmatrix} \tilde{\bar{P}}_1(\omega) \\ \tilde{\bar{P}}_1'(\omega) \\ \tilde{\bar{P}}_2(\omega) \\ \tilde{\bar{P}}_2'(\omega) \\ \vdots \\ \tilde{\bar{P}}_N(\omega) \\ \tilde{\bar{P}}_N'(\omega) \end{vmatrix} . \qquad [2.10](1, [2.23])$$

Since the problem under consideration involves a discretizing not only of the space variable x, but also of the frequency (ω) spectrum of the function transforms, it is appropriate to rewrite Equation [2.9],

$$[A(\omega_i)] \vec{\bar{z}} = \vec{\bar{P}}(\omega_i) \qquad [2.11]$$

with

$$\vec{\bar{P}}(\omega_i) = \begin{vmatrix} \tilde{\bar{P}}_1(\omega_i) \\ \tilde{\bar{P}}_1'(\omega_i) \\ \tilde{\bar{P}}_2(\omega_i) \\ \tilde{\bar{P}}_2'(\omega_i) \\ \vdots \\ \tilde{\bar{P}}_N(\omega_i) \\ \tilde{\bar{P}}_N'(\omega_i) \end{vmatrix} .$$

The solution of Equation [2.11] over a suitable number of points, ω_i, yields a discrete sample of the Fourier transform of the structural response,

$$\vec{\bar{z}}(\omega_i) = [A(\omega_i)]^{-1} \vec{\bar{P}}(\omega_i) \qquad [2.12]$$

where

$$\vec{\bar{z}}(\omega_i) = \begin{vmatrix} \bar{Y}_1(\omega_i) \\ \bar{M}_1(\omega_i) \\ \bar{Y}_2(\omega_i) \\ \bar{M}_2(\omega_i) \\ \vdots \\ \bar{Y}_N(\omega_i) \\ \bar{M}_N(\omega_i) \end{vmatrix} . \qquad [2.13]$$

Recall that the forcing functions P(x, t) and Q(x, t), page 3 , are assumed to have analytic transforms. These expressions are used to obtain the values for $\vec{\bar{P}}(\omega_i)$ over any finite range, $0 \leq \omega_i \leq \omega_{FINAL}$ of the frequency transform. Although the range of ω actually extends $+\infty$, a practical upper limit, ω_{FINAL} , must be set in order to carry out the numerical solution. In practice, ω_{FINAL} should satisfy two conditions: it should lie beyond the highest natural frequency of significance for the finite-difference model of the structure, and it should be at a point in the spectrum beyond which the magnitude of the response, $\vec{\bar{z}}(\omega_i)$, remains zero for practical purposes. The transient response is then obtained by numerically calculating the inverse Fourier transform of the complex frequency response,

$$Z(t_i) = 2 \times \frac{1}{2\pi} \int_0^{\sim \omega_{FINAL}} \mathcal{R}\{[\vec{\bar{z}}(\omega_i)]e^{i\omega_i t_i}\}\, d\omega, \qquad [2.14]$$

where $\mathcal{R}$ denotes the real part. It is assumed that the integrand satisfies conditions in the frequency domain analogous to conditions b. and c. (page 3) specified for the time domain.

The form of the integrand and factor of 2 multiplying the integral result from the fact that the response $Z(t_i)$ is known to be real and equal to zero for $t < 0$. The symbol $\tilde{\int}$, denotes numerical integration and t_i denotes particular values of time for which the response is desired.

Damping in the structural system insures that the response spectrum will be bounded at the system natural frequencies.

Trapezoidal and Simpson integration have been utilized in obtaining satisfactory solutions for $Z(t_i)$. The results shown in this report are from trapezoidal integration.

The analysis discussed here can be extended to the equations of motion for coupled bending-torsion and whirling, yielding the respective response transform vectors,

$$\underset{\text{Bending-Torsion}}{\vec{\bar{z}}(\omega_i)} = \begin{vmatrix} \bar{Y}_1(\omega_i) \\ \bar{M}_1(\omega_i) \\ \bar{\theta}_1(\omega_i) \\ \bar{Y}_2(\omega_i) \\ \bar{M}_2(\omega_i) \\ \bar{\theta}_2(\omega_i) \\ \vdots \\ \bar{Y}_N(\omega_i) \\ \bar{M}_N(\omega_i) \\ \bar{\theta}_N(\omega_i) \end{vmatrix}, \text{ and } \underset{\text{Whirling}}{\vec{\bar{z}}(\omega_i)} = \begin{vmatrix} \bar{Y}_1(\omega_i) \\ \bar{M}_{z_1}(\omega_i) \\ \bar{Z}_1(\omega_i) \\ \bar{M}_{y_1}(\omega_i) \\ \vdots \\ \bar{Y}_N(\omega_i) \\ \bar{M}_{z_N}(\omega_i) \\ \bar{Z}_N(\omega_i) \\ \bar{M}_{y_N}(\omega_i) \end{vmatrix} .$$

III. GBRP - MODIFICATION FOR TRANSIENT RESPONSE

The modification of GBRP required to apply the analysis of the preceding section is striking in its simplicity. All that is needed is a subroutine to evaluate and store the values of $\vec{\overline{P}}(\omega_i)$ from the analytic transform(s) of the transient forcing function(s), P(x, t) and Q(x, t), and a second subroutine to perform the inversion of the discrete response transform $\vec{\overline{Z}}(\omega_i)$ which is computed by GBRP. Additional options have been established for selecting the transient response facility of GBRP, and for selecting particular types of excitation functions. Currently, two excitation functions are available: the rectangular impulse defined by

$$P(t) = \begin{cases} A, & 0 < t \leq \tau \\ 0, & \tau < t \end{cases}$$

and an exponential impulse defined by

$$P(t) = Ae^{-\alpha t} \quad .$$

IV. DATA FOR TRANSIENT RESPONSE

This section supplements Section IV (Input Preparation) of reference 1 by describing the data and options introduced for the time-dependent GPRP solutions.

- Options to select transient calculation and type of impulse

  Option Control Card - "20" card

Columns	Contents	
21 to 24	0003	Selects transient calculation.
25 to 28	0002	Prints frequency transform of excitation.
	0003	Prints frequency transform of excitation along with $[A(\omega_i)]$ and $\vec{P}(\omega_i)$.
41 to 44	0004	Response to rectangular impulse is to be calculated.
	0005	Response to exponential impulse is to be calculated.

- Frequency Range and Increment for Generating $\vec{P}(\omega_i)$, $\vec{\vec{Z}}(\omega_i)$, and for Carrying Out the Inversion of $\vec{\vec{Z}}(\omega_i)$.

- General Data Card - "30" card

Columns	Contents
9-16	Starting frequency in CPS for computing $\vec{P}(\omega_i)$ and $\vec{\vec{Z}}(\omega_i)$. Special Note: A zero starting frequency cannot be directly specified as such because this may result in a zero being computed on the main diagonal of A-matrix. This condition stops the program execution. When a zero starting frequency is desired, it must be approximated by a small number $\epsilon > 0$, for example $\epsilon = 10^{-4}$, 10^{-5}, etc.

Columns	Contents
17-24	Cutoff frequency ω_{FINAL} in CPS, which terminates the calculation of $\vec{\bar{P}}(\omega_i)$ and $\vec{\bar{Z}}(\omega_i)$.
25-32	Frequency increment in cps for generating $\vec{\bar{P}}(\omega_i)$ and hence $\vec{\bar{Z}}(\omega_i)$. Also, the numerical integration stepsize used in carrying out the inversion of $\vec{\bar{Z}}(\omega_i)$.

- Time and Forcing Function Data

  Time Data Card - "32" card (New type)

This card contains the initial time (in seconds), final time, and time increment desired for the transient response output. It also carries the system number[1] of the beam section at which the excitation is applied.

Columns	Contents
3-4	32
7-14	Initial time (seconds)
15-22	Final time (seconds)
23-30	Time increment (seconds)
31-33	System number (reference 1, page 15) of the beam section at which the force is acting (an integer).

- Data for Rectangular Impulse

  Rectangular Impulse Data Card - "33" card (New type)

Columns	Contents
3-4	33
7-14	Amplitude, A, of the impulse.
15-22	Duration of impulse, τ (see page 8).

- **Data for Exponential Impulse**

Exponential Impulse Data Card - "34" card (New type)

Columns	Contents	
3-4	34	
7-14	Amplitude A	see page 8
15-22	Alpha	see page 8
23-30	Time, τ, after which impulse is effectively ≈ 0.	see page 8

The forcing function data on the "32" card must be supplemented by additional data which go on the standard GBRP data cards in use. On the scaling factor cards (types "41", and "42") for the system indicated on the "32" card, one specifies a zero scaling for forces, moments, or torques (columns 65-72). On the section parameter card (type "43") for the section at which the force acts, one specifies a unit, 1.0, in columns 65-72. The rationale behind the specification of forcing function data for the transient calculation may shed light on the seemingly complicated procedure.

Recall that GBRP utilizes its scaling factor data cards to introduce parameters which are complex numbers. Since the transform values for exciting forces, $\bar{P}(\omega_1)$, are of complex form, these values must be introduced into the program as successive scalings of a unit force acting at the appropriate section. The system number specified on the "32" card insures that the scaling factors will multiply the unit force at the section at which it is given.

Some of the data editing facilities of GBRP can be conveniently utilized with the transient response capability. For example, letting option 8 of the Option Control Card (type "20") equal anything other than 0003 will give printed output of the response transform, $\vec{\bar{Z}}(\omega_1)$ for the entire range of ω_i computed. Letting this option equal 0003 suppresses the transform. The magnitude of $\bar{Z}(\omega_i)$ for up to five particular sections of interest can also be easily obtained by giving the section numbers on the Edit Control Card (reference 1, page 17).

It is worth noting that all additional data required for the transient analysis have been specified within the current GBRP format and are completely consistent with previous data and options of the program.

V. GBRP - USAGE FOR TRANSIENT RESPONSE AND SAMPLE PROBLEMS

Some general features of the transient capability are demonstrated in two typical applications. For each case, the data are shown on GBRP input forms and the computer output follows.

The computer clock time (Central Processor Unit (CPU) time) is printed out at various stages of the calculation. The time is given in seconds and appears next to the title, TIME = ______. The first two times given bracket the interval for computing the points of the Fourier transform of the excitation, the 2nd and 3rd times cover the interval required for GBRP calculation of the points of $\vec{\bar{Z}}(\omega_i)$, and the 3rd and 4th times give the interval for the inverse transformation of $\vec{\bar{Z}}(\omega_i)$.

The present version of GBRP is operational on the IBM 360/91 computing system at the Johns Hopkins Applied Physics Laboratory, and is presently being converted to the CDC 6700 computer at the Naval Ship Research and Development Center.

Sample Problem 1.

Mass-Spring-Damper System, Response to Rectangular Impulse

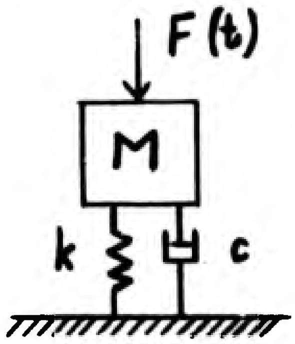

Figure 1. Linear Mass-Spring-Damper System

Data for the structural model

Mass, M, = 1.0 $\frac{\text{lb-ft}}{\text{sec}^2}$

Spring constant, k, = 8.4 lbs/ft

Damping constant, c = 0.6 $\frac{\text{lb-sec}}{\text{ft}}$ (approximately 10% of critical)

Data for the forcing function, F(t)

Amplitude of impulse = 0.5 lbs

Duration of impulse, τ = 2 secs

Data for specifying the response output

This example examines the response from an initial time of 0 (secs) to a final time of 4.1 (secs) in increments of 0.1 second. Although the selection of time range and interval is completely arbitrary, it is important to select the interval such that the transient solution appears in sufficient detail to be practical.

The natural frequency of this system is

$$\sqrt{\frac{k}{m}} = \sqrt{8.4} = 2.8982753 \text{ rad/sec} = 0.4613 \text{ CPS} .$$

The cutoff frequency, ω_{FINAL}, for the transform of the forcing function was chosen as 30 CPS, well beyond the system's natural frequency. The frequency interval for this particular computer run was chosen as 0.02 CPS, giving a considerably detailed sampling of the transform.

The analytic solution for this problem can be obtained in the form

$$Z(t) = \frac{F_0}{m\omega_0^2} [\psi(t) - \psi(t-\tau)\, U(t-\tau)] \qquad [5.1]$$

where F_0 is the magnitude of the impulse,

m is the mass,

$\omega_0^2 = k/m$,

$\psi(t) = 1 - e^{-bt}[\cos \omega t + \frac{b}{\omega} \sin \omega t]$

with $b = \frac{1}{2} \frac{c}{m}$, and

$$U(t-\tau) = \begin{cases} 0, & t < \tau \\ 1, & t > \tau \end{cases}$$

where τ is the impulse duration.

Values of [5.1] are given in Table 1 for comparison with computed results for the system of Figure 1.

TITLE GBRP, Transient Response PROGRAMMER ____ DATE ____

PROBLEM NO 1 PHASE ____ LABEL GBRP SHEET 1 of 6

RUN TITLE CARD

000000(62HΔΔ RESPONSE TO RECTANGULAR IMPULSE

DATA CONTROL CARD

	NO	TYPE	NO	TYPE	etc.											
0090	01	10	01	20	01	30	01	32	01	33	01	41	01	43	01	51	01	53

CASE TITLE CARD

001000(62HΔΔ MASS SPRING SYSTEM, 0.10 CRITICAL DAMPING

OPTION CONTROL CARD

	OP1	OP2	OP3	OP4	OP5	OP6	OP7	OP8	OP9	OP10
00200000				0003	0002			0003	0004	

EDIT CONTROL CARD

00210000

GENERAL DATA CARD

	NO SECTIONS	ω_1 (CPS)	ω_2 (CPS)	$\Delta\omega$ (CPS)
0030	0001	0.00001	30.0	0.02
	5	9	17	25

SYSTEMS DATA CARDS

	SYSTEMS	RADIUS	INITIAL J
0031			
0031			

TITLE ______ PROGRAMMER ______ DATE ______

PROBLEM NO ______ PHASE ______ LABEL GBRP ______ SHEET 2 OF 5

TIME AND EXCITATION DATA

003200	0.0	4.1	0.1	001

RECTANGULAR IMPULSE DATA

003300	0.5	2.0

EXPONENTIAL IMPULSE DATA

003400

TITLE ______ PROGRAMMER ______ DATE ______

PROBLEM NO. ______ PHASE ______ LABEL GBRP ______ SHEET 3 OF 5

SECTION DATA CARDS

5 Section No.	9 End Condn.	13 System	17 Mass	25 Water Inertia	33 $(\Delta x/EI)_n$	41 $(\Delta x)_{n,n+1}$	49 $(\Delta x/\kappa AG)_{n,n+1}$	57 $(I_{MZ}\Delta x)_{n,n+1}$	65 P_n	73
REAL PART OF SCALING FACTORS										
00410000		0001	1.0							
00410000										
00410000										
IMAGINARY PART OF SCALING FACTORS										
00420000										
00420000										
00420000										
PARAMETER VALUES - UNSCALED										
0043 0001		0001	1.0						1.0	
0043										
0043										
0043										
0043										
0043										
0043										
0043										
0043										
0043										
0043										
0043										
0043										
0043										
0043										

TITLE ______ PROGRAMMER ______ DATE ______

PROBLEM NO. ______ PHASE ______ LABEL GBRP ______ SHEET 4 OF 5

5 9 13 17 25 33 41 49 57 65 73

SPECIAL CONNECTION CARDS

	n	m	SYSTEM	$K_{n,m}$	$C_{n,m}$	$C_{n,m}/\omega$	$\Delta X_{n,m}$	$(\Delta X/KAG)_{n,m}$	$(I_{pz}\Delta x)_{n,m}$	$Q_{n,m}$
REAL PART OF SCALING FACTORS										
0051			0001	1.0	1.0					
0051										
0051										
IMAGINARY PART OF SCALING FACTORS										
0052										
0052										
0052										
PARAMETER VALUES - UNSCALED										
0053	0001	0000	0001	8.4	0.6					
0053										
0053										
0053										
0053										
0053										
0053										
0053										
0053										
0053										

TITLE ______ PROGRAMMER ______ DATE ______

PROBLEM NO. ______ PHASE ______ LABEL GBRP ______ SHEET 5 OF 5

CHARACTRON PLOTTING CHARACTERS

006000ΔΔΔΔΔΔ						
34 7	13	19	25	31	37	43

NATURAL FREQUENCY SELECTION CARD

00700000		
34	9	11

START NEW DATA SET CARD

0098
34

END OF DATA CARD

→ 0099
34

Δ indicates blank space

```
GBRP  OCT 7, 1966
    RESPONSE TO RECTANGULAR IMPULSE

DATA CONTROL CARD

NO  TYPE

 1   10
 1   20
 1   30
 1   32
 1   33
 1   41
 1   43
 1   51
 1   53

CASE TITLE-    MASS SPRING SYSTEM, 0.10 CRITICAL DAMPING

OPTION DATA
 20       0   0   0   3   2   0   0   3   4   0

GENERAL DATA -  NUMBER OF SECTIONS     1
                FREQUENCY RANGE FROM     0.000 CPS   TO     30.000 CPS
                FREQUENCY INTERVAL   0.020 CPS

TIMES(SECS) AT WHICH IMPULSE RESPONSE IS DESIRED
     INITIAL TIME =    0.0          FINAL TIME =    4.10000     TIME DIFFERENCE =    0.10000
     IMPULSE AT SECTION    1

PARAMETERS FOR TRANSFORM OF RECTANGULAR PULSE
     AMPLITUDE =    0.500 DURATION OF IMPULSE =    2.000SECS

REAL PARTS OF SCALING FACTORS

SECTION-END CONDN-SYSTEM    MASS      WATER INERTIA    DE/EI(N)     DE(N,N+1)  DE/MAG(N,N+1)  IMZ*DE(N,N+1)    P(N)/T

                      1   1.0000D 00    0.0            0.0          0.0         0.0           0.0            0.0

PARAMETER VALUES FOR EACH SECTION - UNSCALED

SECTION-END CONDN-SYSTEM    MASS      WATER INERTIA    DE/EI(N)     DE(N,N+1)  DE/MAG(N,N+1)  IMZ*DE(N,N+1)    P(N)/T

   1       C          1   1.0000D 00    0.0            0.0          0.0         0.0           0.0            1.0000D 00

REAL PARTS OF SCALING FACTORS

   N       M       SYSTEM   K(N,M)       C(N,M)       C(N,M)/W       DE(N,M)      DE/MAG(N,M)    IMZ*DE(N,M)    Q(N,M)/T

                      1   1.0000D 00   1.0000D 00    0.C            0.0          0.0           0.0            0.0

PARAMETER VALUES FOR SPECIAL CONNECTIONS

   N       M       SYSTEM   K(N,M)       C(N,M)       C(N,M)/W       DE(N,M)      DE/MAG(N,M)    IMZ*DE(N,M)    Q(N,M)/T

   1       C          1   8.4000D 00   6.0000D-01    0.0            0.0          0.0           0.0            0.0
```

FOURIER TRANSFORM OF IMPULSE LOAD

TIME = 5.843D-02

REAL PART	IMAG PART
9.99999997D-01	-6.28318528D-05
9.89495157D-01	-1.25065473D-01
9.58397952D-01	-2.46138958D-01
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1	-2.3437D-06	2.4316D-03	9.3455D-03	1.9919D-02	3.3083D-02	4.7621D-02	6.2276D-02	7.5854D-02

TIME(SECS) =	8.000D-01	9.000D-01	1.000D 00	1.10D 00	1.20D 00	1.30D 00	1.40D 00	1.50D 00
SECTION	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL
1	8.7320D-02	9.5867D-02	1.0097D-01	1.0243D-01	1.0032D-01	9.5037D-02	8.7183D-02	7.7548D-02

TIME(SECS) =	1.60D 00	1.70D 00	1.80D 00	1.90D 00	2.000D 00	2.10D 00	2.20D 00	2.30D 00
SECTION	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL
1	6.7015D-02	5.6488D-02	4.6820D-02	3.8743D-02	3.2819D-02	2.6967D-02	1.9274D-02	1.0467D-02

TIME(SECS) =	2.40D 00	2.50D 00	2.60D 00	2.70D 00	2.80D 00	2.90D 00	3.00D 00	3.10D 00
SECTION	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL
1	1.3263D-03	-7.3901D-03	-1.5001D-02	-2.0954D-02	-2.4864D-02	-2.6534D-02	-2.5958D-02	-2.3315D-02

TIME(SECS) =	3.20D 00	3.30D 00	3.40D 00	3.50D 00	3.60D 00	3.70D 00	3.80D 00	3.90D 00
SECTION	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL
1	-1.8938D-02	-1.3283D-02	-6.8821D-03	-2.9694D-04	5.9286D-03	1.1311D-02	1.5465D-02	1.8124D-02

TIME(SECS) =	4.00D 00	4.10D 00						
SECTION	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL
1	1.9161D-02	1.8586D-02						

TIME = 1.441D 01

```
 GBRP  OCT 7, 1966
      RESPONSE TO RECTANGULAR IMPULSE

DATA CONTROL CARD

NO  TYPE




          END GBRP  RUN
         TIME =       1.444D 01
```

Sample Problem 2.

Longitudinal Response of Nonuniform Beam to an Exponential Impulse

Mathematical Model

The model of the nonuniform beam for longitudinal motion is a ten-mass system with spring and damper connections. The rigid body motion of the beam is constrained by attaching one end of the beam to "ground" with a heavily damped spring.

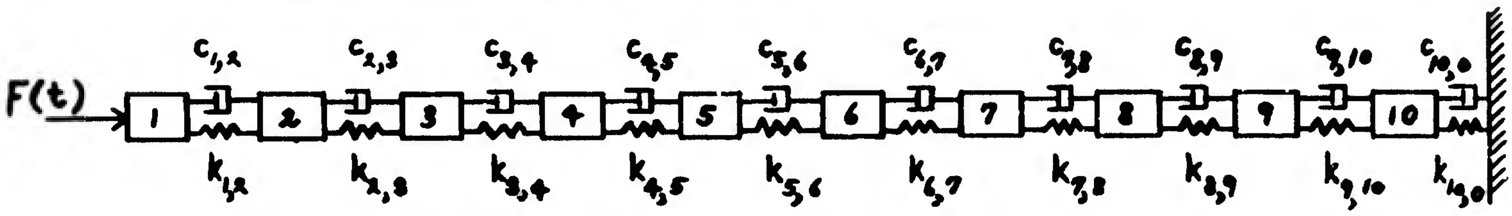

Figure 2. Linear Mass-Spring-Damper Model for a Nonuniform Beam

Data for the structural model

Section	Mass (lb-sec^2/ft)
1	0.032
2	0.083
3	0.164
4	0.180
5	0.245
6	0.291
7	0.137
8	0.205
9	0.131
10	0.047

Spring constants for connections (lb/ft)

$k_{1,2} = 0.319 \times 10^5$

$k_{2,3} = 1.56 \times 10^5$

$k_{3,4} = 2.16 \times 10^5$

$k_{4,5} = 1.92 \times 10^5$

$k_{5,6} = 2.38 \times 10^5$

$k_{6,7} = 2.4 \times 10^5$

$k_{7,8} = 2.4 \times 10^5$

$k_{8,9} = 1.85 \times 10^5$

$k_{9,10} = 0.308 \times 10^5$

$k_{10,0} = 53.3 \times 10^4$

Damping constants (viscous) for connections ($\frac{\text{lb-sec}}{\text{ft}}$)

$c_{1,2} = 1.0$

$c_{2,3} = 2.25$

$c_{3,4} = 3.1$

$c_{4,5} = 3.8$

$c_{5,6} = 4.8$

$c_{6,7} = 3.8$

$c_{7,8} = 3.1$

$c_{8,9} = 3.0$

$c_{9,10} = 1.6$

$c_{10,0} = 4.48 \times 10^3$

Data for the forcing function, F(t)

Amplitude, A = 1500 lbs

Alpha = 3π = 9.4248

τ = 2.0 secs (time after which impulse was considered to be effectively zero)

Data for specifying the response output

The transient response at each beam section is printed out for the range,

Initial time = 0.0 seconds

to

Final time = 3.0 seconds

at

Time increment = 0.1 seconds

Natural Frequencies of the System

GBRC1, a module of GBRP, was used to obtain the free, undamped vibration frequencies of the nonuniform beam model. This information serves as a guide in estimating the frequency range for computing the impulse and response transforms.

The cutoff frequency, ω_{FINAL}, actually selected for the sample problem was 500 CPS which, it can be seen, excludes the contribution of the 10^{th} natural frequency, 551.58 CPS, to the transient response.

The computer output for the natural frequency calculation precedes the transient calculation. It is important to note that these frequencies are undamped.

GBRC1 JULY 25, 1/64
CAMEL - LONGITUDINAL VIBRATION IN AIR

DATA CONTROL CARD

NO	TYPE
1	10
1	20
1	21
1	30
1	41
10	43
2	51
10	53
1	70

CASE TITLE-10 NATURAL FREQUENCIES

OPTION DATA
20 -0 -0 -0 -0 -0 -0 -0 -0 -0 1

OPTION DATA
21 1 5 10 -0 -0 -0 -0 -0 -0 -0

GENERAL DATA - NUMBER OF SECTIONS 10
FREQUENCY RANGE FROM 1.000 CPS TO 600.000 CPS
FREQUENCY INTERVAL 1.000 CPS

REAL PARTS OF SCALING FACTORS

SECTION-END	CONON-SYSTEM	MASS	WATER INERTIA	DX/EI(N)	DX(N,N+1)	DX/KAG(N,N+1)	INZ*DX(N,N+1)	P(N)
	1	1.0000E-02	-0.	-0.	-0.	-0.	-0.	-0.

PARAMETER VALUES FOR EACH SECTION - UNSCALED

SECTION-END	CONON-SYSTEM		MASS	WATER INERTIA	DX/EI(N)	DX(N,N+1)	DX/KAG(N,N+1)	INZ*DX(N,N+1)	P(N)
1	-0	1	3.2000E 00	-0.	-0.	-0.	-0.	-0.	-0.
2	-0	1	8.3000E 00	-0.	-0.	-0.	-0.	-0.	-0.
3	-0	1	1.6400E 01	-0.	-0.	-0.	-0.	-0.	-0.
4	-0	1	1.8000E 01	-0.	-0.	-0.	-0.	-0.	-0.
5	-0	1	2.4500E 01	-0.	-0.	-0.	-0.	-0.	-0.
6	-0	1	2.9100E 01	-0.	-0.	-0.	-0.	-0.	-0.
7	-0	1	1.3700E 01	-0.	-0.	-0.	-0.	-0.	-0.
8	-0	1	2.0500E 01	-0.	-0.	-0.	-0.	-0.	-0.
9	-0	1	1.3100E 01	-0.	-0.	-0.	-0.	-0.	-0.
10	-0	1	4.7000E 00	-0.	-0.	-0.	-0.	-0.	-0.

REAL PARTS OF SCALING FACTORS

N	M	SYSTEM	K(N,M)	C(N,M)	C(N,M)/W	DX(N,M)	DX/KAG(N,M)	INZ*DX(N,M)	Q(N,M)
		1	1.0000E 05	-0.	-0.	-0.	-0.	-0.	-0.
		2	1.0000E 04	-0.	-0.	-0.	-0.	-0.	-0.

PARAMETER VALUES FOR SPECIAL CONNECTIONS

N	M	SYSTEM	K(N,M)	C(N,M)	C(N,M)/W	DX(N,M)	DX/KAG(N,M)	INZ*DX(N,M)	Q(N,M)

88

1	2	1	3.1900E-01	1.0000E 00	-0.	-0.	-0.	-0.	-0.
2	3	1	1.5600E 00	2.2500E 00	-0.	-0.	-0.	-0.	-0.
3	4	1	2.1600E 00	3.1000E 00	-0.	-0.	-0.	-0.	-0.
4	5	1	1.9200E 00	3.8000E 00	-0.	-0.	-0.	-0.	-0.
5	6	1	2.3800E 00	4.8000E 00	-0.	-0.	-0.	-0.	-0.
6	7	1	2.4000E 00	3.8000E 00	-0.	-0.	-0.	-0.	-0.
7	8	1	2.4000E 00	3.1000E 00	-0.	-0.	-0.	-0.	-0.
8	9	1	1.8500E 00	3.0000E 00	-0.	-0.	-0.	-0.	-0.
9	10	1	3.0800E-01	1.6000E 00	-0.	-0.	-0.	-0.	-0.
10	0	2	5.3300E 01	4.4800E 00	-0.	-0.	-0.	-0.	-0.

NFREQ=10

GBRC2

CAMEL - TRANSIENT RESPONSE

LONGITUDINAL VIBRATION IN AIR

FREQUENCY CPS	DEFLECTION SECTION 1	MOMENT 1	DEFLECTION SECTION 5	MOMENT 5	DEFLECTION SECTION 10	MOMENT 10	DEFLECTION SECTION	MOMENT	DEFLECTION	MOMENT
19.48	1.000E 00	0.	9.203E-01	0.	3.603E-02	0.				
79.97	1.000E 00	0.	3.127E-02	0.	3.373E-02	0.				
129.13	1.000E 00	0.	3.084E-01	0.	2.312E-02	0.				
162.97	1.000E 00	0.	5.880E-02	0.	1.155E-02	0.				
215.10	1.000E 00	0.	6.409E-01	0.	4.357E-02	0.				
253.16	1.000E 00	0.	2.889E-01	0.	1.326E-01	0.				
275.09	1.000E 00	0.	1.402E 00	0.	6.575E-02	0.				
327.18	1.000E 00	0.	8.041E-01	0.	1.345E-02	0.				
350.78	1.000E 00	0.	7.356E 00	0.	1.378E 00	0.				
551.58	1.000E 00	0.	3.818E-05	0.	2.156E-04	0.				

GBRC1

CAMEL - TRANSIENT RESPONSE

LONGITUDINAL VIBRATION IN AIR

FREQUENCY 19.48 CPS

STATION	DEFLECTIONS				MOMENTS			
	REAL PART	IMAG PART	ABS VALUE	PHASE ANGLE	REAL PART	IMAG PART	ABS VALUE	PHASE ANGLE
1	1.0000E 00	0.	1.0000E 00	0.	-0.	-0.	0.	0.
2	9.8494E-01	0.	9.8494E-01	0.	-0.	-0.	0.	0.
3	9.7401E-01	0.	9.7401E-01	0.	-0.	-0.	0.	0.
4	9.5503E-01	0.	9.5503E-01	0.	-0.	-0.	0.	0.
5	9.2027E-01	0.	9.2027E-01	0.	-0.	-0.	0.	0.
6	8.7803E-01	0.	8.7803E-01	0.	-0.	-0.	0.	0.
7	8.2019E-01	0.	8.2019E-01	0.	-0.	-0.	0.	0.
8	7.5534E-01	0.	7.5534E-01	0.	-0.	-0.	0.	0.
9	6.5867E-01	0.	6.5867E-01	0.	-0.	-0.	0.	0.
10	3.6028E-02	0.	3.6028E-02	0.	-0.	-0.	0.	0.

GBRC1

CAMEL - TRANSIENT RESPONSE

LONGITUDINAL VIBRATION IN AIR

FREQUENCY 79.97 CPS

STATION	DEFLECTIONS				MOMENTS			
	REAL PART	IMAG PART	ABS VALUE	PHASE ANGLE	REAL PART	IMAG PART	ABS VALUE	PHASE ANGLE
1	1.0000E 00	0.	1.0000E 00	0.	-0.	-0.	0.	0.
2	7.4678E-01	0.	7.4678E-01	0.	-0.	-0.	0.	0.
3	5.9470E-01	0.	5.9470E-01	0.	-0.	-0.	0.	0.
4	3.7086E-01	0.	3.7086E-01	0.	-0.	-0.	0.	0.
5	3.1274E-02	0.	3.1274E-02	0.	-0.	-0.	0.	0.
6	-2.5081E-01	-0.	2.5081E-01	0.	-0.	-0.	0.	0.
7	-4.5376E-01	-0.	4.5376E-01	0.	-0.	-0.	0.	0.
8	-5.9133E-01	-0.	5.9133E-01	0.	-0.	-0.	0.	0.
9	-6.0437E-01	-0.	6.0437E-01	0.	-0.	-0.	0.	0.
10	-3.3726E-02	-0.	3.3726E-02	0.	-0.	-0.	0.	0.

GBRC1

CAMEL - TRANSIENT RESPONSE

LONGITUDINAL VIBRATION IN AIR

FREQUENCY 129.13 CPS

STATION	DEFLECTIONS				MOMENTS			
	REAL PART	IMAG PART	ABS VALUE	PHASE ANGLE	REAL PART	IMAG PART	ABS VALUE	PHASE ANGLE
1	1.0000E 00	0.	1.0000E 00	0.	-0.	-0.	0.	0.
2	3.3968E-01	0.	3.3968E-01	0.	-0.	-0.	0.	0.
3	8.5685E-02	0.	8.5685E-02	0.	-0.	-0.	0.	0.
4	-1.4058E-01	-0.	1.4058E-01	0.	-0.	-0.	0.	0.
5	-3.0837E-01	-0.	3.0837E-01	0.	-0.	-0.	0.	0.
6	-2.3477E-01	-0.	2.3477E-01	0.	-0.	-0.	0.	0.
7	2.5594E-02	-0.	2.5594E-02	-0.	-0.	-0.	0.	0.
8	2.7634E-01	0.	2.7634E-01	0.	-0.	-0.	0.	0.
9	4.0007E-01	0.	4.0007E-01	0.	-0.	-0.	0.	0.
10	2.3124E-02	0.	2.3124E-02	0.	-0.	-0.	0.	0.

GBRC1

CAMEL - TRANSIENT RESPONSE

LONGITUDINAL VIBRATION IN AIR

FREQUENCY 162.97 CPS

STATION	DEFLECTIONS				MOMENTS			
	REAL PART	IMAG PART	ABS VALUE	PHASE ANGLE	REAL PART	IMAG PART	ABS VALUE	PHASE ANGLE
1	1.0000E 00	0.	1.0000E 00	0.	-0.	-0.	0.	0.
2	-5.1842E-02	-0.	5.1842E-02	0.	-0.	-0.	0.	0.
3	-2.3801E-01	-0.	2.3801E-01	0.	-0.	-0.	0.	0.
4	-1.8298E-01	-0.	1.8298E-01	0.	-0.	-0.	0.	0.
5	5.8796E-02	0.	5.8796E-02	0.	-0.	-0.	0.	0.
6	1.9038E-01	-0.	1.9038E-01	-0.	-0.	-0.	0.	0.
7	7.8828E-02	0.	7.8828E-02	0.	-0.	-0.	0.	0.
8	-7.9906E-02	-0.	7.9906E-02	0.	-0.	-0.	0.	0.
9	-1.9299E-01	-0.	1.9299E-01	0.	-0.	-0.	0.	0.
10	-1.1553E-02	-0.	1.1553E-02	0.	-0.	-0.	0.	0.

GBRC1

CAMEL - TRANSIENT RESPONSE

LONGITUDINAL VIBRATION IN AIR

FREQUENCY 215.10 CPS

STATION	DEFLECTIONS				MOMENTS			
	REAL PART	IMAG PART	ABS VALUE	PHASE ANGLE	REAL PART	IMAG PART	ABS VALUE	PHASE ANGLE
1	1.0000E 00	0.	1.0000E 00	0.	-0.	-0.	0.	0.
2	-8.3252E-01	-0.	8.3252E-01	0.	-0.	-0.	0.	0.
3	-3.9814E-01	-0.	3.9814E-01	0.	-0.	-0.	0.	0.
4	4.6776E-01	0.	4.6776E-01	0.	-0.	-0.	0.	0.
5	6.4086E-01	-0.	6.4086E-01	-0.	-0.	-0.	0.	0.
6	-4.2456E-01	-0.	4.2456E-01	0.	-0.	-0.	0.	0.
7	-5.4078E-01	-0.	5.4078E-01	0.	-0.	-0.	0.	0.
8	-9.3111E-02	-0.	9.3111E-02	0.	-0.	-0.	0.	0.
9	6.7611E-01	-0.	6.7611E-01	-0.	-0.	0.	0.	0.
10	4.3570E-02	0.	4.3570E-02	0.	-0.	-0.	0.	0.

GBRC1

CAMEL - TRANSIENT RESPONSE

LONGITUDINAL VIBRATION IN AIR

FREQUENCY 253.16 CPS

STATION	DEFLECTIONS REAL PART	DEFLECTIONS IMAG PART	DEFLECTIONS ABS VALUE	DEFLECTIONS PHASE ANGLE	MOMENTS REAL PART	MOMENTS IMAG PART	MOMENTS ABS VALUE	MOMENTS PHASE ANGLE
1	1.0000E 00	0.	1.0000E 00	0.	-0.	-0.	0.	0.
2	-1.5382E 00	0.	1.5382E 00	0.	-0.	-0.	0.	0.
3	1.3444E-02	0.	1.3444E-02	0.	-0.	-0.	0.	0.
4	1.1082E 00	-0.	1.1082E 00	-0.	-0.	-0.	0.	0.
5	-2.8887E-01	-0.	2.8887E-01	0.	-0.	-0.	0.	0.
6	-6.6356E-01	-0.	6.6356E-01	0.	-0.	-0.	0.	0.
7	1.0005E 00	0.	1.0005E 00	0.	-0.	-0.	0.	0.
8	1.2196E 00	-0.	1.2196E 00	-0.	-0.	-0.	0.	0.
9	-1.9156E 00	-0.	1.9156E 00	0.	-0.	-0.	0.	0.
10	-1.3262E-01	-0.	1.3262E-01	0.	-0.	-0.	0.	0.

GBRC1

CAMEL - TRANSIENT RESPONSE

LONGITUDINAL VIBRATION IN AIR

FREQUENCY 275.09 CPS

STATION	DEFLECTIONS REAL PART	DEFLECTIONS IMAG PART	DEFLECTIONS ABS VALUE	DEFLECTIONS PHASE ANGLE	MOMENTS REAL PART	MOMENTS IMAG PART	MOMENTS ABS VALUE	MOMENTS PHASE ANGLE
1	1.0000E 00	0.	1.0000E 00	0.	-0.	-0.	0.	0.
2	-1.9971E 00	0.	1.9971E 00	0.	-0.	-0.	0.	0.
3	5.6453E-01	0.	5.6453E-01	0.	-0.	-0.	0.	0.
4	1.1340E 00	-0.	1.1340E 00	-0.	-0.	-0.	0.	0.
5	-1.4016E 00	-0.	1.4016E 00	0.	-0.	-0.	0.	0.
6	8.6339E-01	-0.	8.6339E-01	-0.	-0.	-0.	0.	0.
7	-1.8149E-02	-0.	1.8149E-02	0.	-0.	-0.	0.	0.
8	-8.6874E-01	-0.	8.6874E-01	0.	-0.	-0.	0.	0.
9	9.0383E-01	-0.	9.0383E-01	-0.	-0.	-0.	0.	0.
10	6.5751E-02	0.	6.5751E-02	0.	-0.	-0.	0.	0.

GBRC1

CAMEL - TRANSIENT RESPONSE

LONGITUDINAL VIBRATION IN AIR

FREQUENCY 327.18 CPS

STATION	DEFLECTIONS				MOMENTS			
	REAL PART	IMAG PART	ABS VALUE	PHASE ANGLE	REAL PART	IMAG PART	ABS VALUE	PHASE ANGLE
1	1.0000E 00	0.	1.0000E 00	0.	-0.	-0.	0.	0.
2	-3.2407E 00	0.	3.2407E 00	0.	-0.	-0.	0.	0.
3	3.1787E 00	-0.	3.1787E 00	-0.	-0.	-0.	0.	0.
4	-2.3845E 00	-0.	2.3845E 00	0.	-0.	-0.	0.	0.
5	8.0405E-01	-0.	8.0405E-01	-0.	-0.	-0.	0.	0.
6	-1.2157E-01	-0.	1.2157E-01	0.	-0.	-0.	0.	0.
7	-4.1654E-01	-0.	4.1654E-01	0.	-0.	-0.	0.	0.
8	2.9334E-01	-0.	2.9334E-01	-0.	-0.	-0.	0.	0.
9	-1.5942E-01	-0.	1.5942E-01	0.	-0.	-0.	0.	0.
10	-1.3446E-02	-0.	1.3446E-02	0.	-0.	-0.	0.	0.

GBRC1

CAMEL - TRANSIENT RESPONSE

LONGITUDINAL VIBRATION IN AIR

FREQUENCY 350.78 CPS

STATION	DEFLECTIONS				MOMENTS			
	REAL PART	IMAG PART	ABS VALUE	PHASE ANGLE	REAL PART	IMAG PART	ABS VALUE	PHASE ANGLE
1	1.0000E 00	0.	1.0000E 00	0.	-0.	-0.	0.	0.
2	-2.4670E 00	0.	2.4670E 00	0.	-0.	-0.	0.	0.
3	3.2002E 00	-0.	3.2002E 00	-0.	-0.	-0.	0.	0.
4	-4.5102E 00	-0.	4.5102E 00	0.	-0.	-0.	0.	0.
5	7.3559E 00	-0.	7.3559E 00	-0.	-0.	-0.	0.	0.
6	-1.9856E 01	-0.	1.9856E 01	0.	-0.	-0.	0.	0.
7	7.0112E 01	-0.	7.0112E 01	-0.	-0.	-0.	0.	0.
8	-3.4339E 01	-0.	3.4339E 01	0.	-0.	-0.	0.	0.
9	1.5004E 01	0.	1.5004E 01	0.	-0.	-0.	0.	0.
10	1.3775E 00	-0.	1.3775E 00	-0.	-0.	-0.	0.	0.

GBRC1

CAMEL - TRANSIENT RESPONSE

LONGITUDINAL VIBRATION IN AIR

FREQUENCY 551.58 CPS

STATION	DEFLECTIONS				MOMENTS			
	REAL PART	IMAG PART	ABS VALUE	PHASE ANGLE	REAL PART	IMAG PART	ABS VALUE	PHASE ANGLE
1	1.0000E 00	0.	1.0000E 00	0.	-0.	-0.	0.	0.
2	-4.0202E-02	0.	4.0202E-02	0.	-0.	-0.	0.	0.
3	3.9922E-03	-0.	3.9922E-03	-0.	-0.	-0.	0.	0.
4	-4.9582E-04	-0.	4.9582E-04	0.	-0.	-0.	0.	0.
5	3.8177E-05	-0.	3.8177E-05	-0.	-0.	-0.	0.	0.
6	-3.0552E-06	-0.	3.0552E-06	0.	-0.	-0.	0.	0.
7	5.5006E-07	-0.	5.5006E-07	-0.	-0.	-0.	0.	0.
8	3.8409E-07	-0.	3.8409E-07	-0.	-0.	-0.	0.	0.
9	-4.9431E-06	-0.	4.9431E-06	0.	-0.	-0.	0.	0.
10	2.1558E-04	0.	2.1558E-04	0.	-0.	-0.	0.	0.

GBRC1 JULY 25, 1964
CAMEL - TRANSIENT RESPONSE

DATA CONTROL CARD

NO TYPE

END GBRC1 RUN

TITLE GBRP Transient Response PROGRAMMER DATE

PROBLEM NO 2. PHASE LABEL GBRP SHEET 1 OF 5

RUN TITLE CARD

000000(62HΔΔ CAMEL - TRANSIENT RESPONSE

DATA CONTROL CARD

NO TYPE NO TYPE etc.

0090	01	10	01	20	01	30	01	32	01	34	01	41	10	43	02	51	10	53
	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39

CASE TITLE CARD

001000(62HΔΔ LONGITUDINAL VIBRATION IN AIR

OPTION CONTROL CARD

	OP1	OP2	OP3	OP4	OP5	OP6	OP7	OP8	OP9	OP10
00200000				0003	0002			0003	0005	
	9	13	17	21	25	29	33	37	41	45

EDIT CONTROL CARD

00210000					
	9	13	17	21	25

29

GENERAL DATA CARD

	NO SECTIONS	ω_1(CPS)	ω_2(CPS)	$\Delta\omega$ (CPS)
0030	0010	0.00001	500.0	0.5
	5	9	17	25

SYSTEMS DATA CARDS

	SYSTEMS	RADIUS	INITIAL J
0031			
0031			

TITLE ______ PROGRAMMER ______ DATE ______

PROBLEM NO ______ PHASE ______ LABEL GBRP ______ SHEET 2 OF 5

TIME AND EXCITATION DATA

003200	0.0	3.0	0.1	001

RECTANGULAR IMPULSE DATA

003300		

EXPONENTIAL IMPULSE DATA

003400	1500.0	9.424778	2.0

TITLE ______ PROGRAMMER ______ DATE ______

PROBLEM NO. ______ PHASE ______ LABEL. GBRP ______ SHEET 3 OF 5

SECTION DATA CARDS

5	9	13	17	25	33	41	49	57	65	73
SECTION NO	END CONDN.	SYSTEM	MASS	WATER INERTIA	$(\Delta x/EI)_n$	$(\Delta x)_{n,n+1}$	$(\Delta x/kAG)_{n,n+1}$	$(J_{nz}\Delta x)_{n,n+1}$	P_n	
REAL PART OF SCALING FACTORS										
00410000		0001	ΔΔ1.0E-2							
00410000										
00410000										
IMAGINARY PART OF SCALING FACTORS										
00420000										
00420000										
00420000										
PARAMETER VALUES - UNSCALED										
00430001		0001	3.2						1.0	
00430002		0001	8.3							
00430003		0001	16.4							
00430004		0001	18.0							
00430005		0001	24.5							
00430006		0001	29.1							
00430007		0001	13.7							
00430008		0001	20.5							
00430009		0001	13.1							
00430010		0001	4.7							
0043										
0043										
0043										
0043										
0043										

TITLE ______ PROGRAMMER ______ DATE ______

PROBLEM NO. ______ PHASE ______ LABEL GBRP ______ SHEET 4 OF 5

5 0 13 17 25 33 41 49 57 65 73

SPECIAL CONN. TION CARDS

	n	m	SYSTEM	$K_{n,m}$	$C_{n,m}$	$C_{n,m}/\omega$	$\Delta X_{n,m}$	$(\Delta X/KAG)_{n,m}$	$(I_{pz}\Delta x)_{n,m}$	$Q_{n,m}$
REAL PART OF SCALING FACTORS										
0051			0001	ΔΔΔ1.0E5	1.0					
0051			0002	ΔΔΔ1.0E4	ΔΔΔ1.0E3					
0051										
IMAGINARY PART OF SCALING FACTORS										
0052										
0052										
0052										
PARAMETER VALUES - UNSCALED										
0053	0001	0002	0001	0.3190	1.000					
0053	0002	0003	0001	1.560	2.250					
0053	0003	0004	0001	2.160	3.100					
0053	0004	0005	0001	1.920	3.800					
0053	0005	0006	0001	2.380	4.800					
0053	0006	0007	0001	2.400	3.800					
0053	0007	0008	0001	2.400	3.100					
0053	0008	0009	0001	1.850	3.000					
0053	0009	0010	0001	0.3080	1.600					
0053	0010	0000	0002	53.3	4.48					

TITLE ______ PROGRAMMER ______ DATE ______

PROBLEM NO. ______ PHASE ______ LABEL GBRP ______ SHEET 5 OF 5

CHARACTRON PLOTTING CHARACTERS

00600	ΔΔΔΔΔΔ						
34	7	13	19	25	31	37	43

NATURAL FREQUENCY SELECTION CARD

00700000		
34	5	11

START NEW DATA SET CARD

0098
34

END OF DATA CARD

→ 0099
34

Δ indicates blank space

```
GRRP  OCT 7, 1966
     CAMEL  -  TRANSIENT RESPONSE

DATA CONTROL CARD

NO  TYPE

 1   10
 1   20
 1   30
 1   32
 1   34
 1   41
10   43
 2   51
10   53

CASE TITLE-    LONGITUDINAL VIBRATION IN AIR

OPTION DATA
 20        0   0   0   1   2   0   0   1   5   0

GENERAL DATA -  NUMBER OF SECTIONS   10
                 FREQUENCY RANGE FROM     0.000 CPS  TO   500.000 CPS
                 FREQUENCY INTERVAL    0.500 CPS

TIMES(SECS) AT WHICH IMPULSE RESPONSE IS DESIRED
     INITIAL TIME =   0.0         FINAL TIME =   3.00000    TIME DIFFERENCE =   0.10000
     IMPULSE AT SECTION   1

PARAMETERS FOR TRANSFORM OF EXPONENTIAL IMPULSE
     A = 1.50000 03        ALPHA = 7.4248D 00       TAU =  2.00000 00
```

REAL PARTS OF SCALING FACTORS

SECTION-END	CONDN-SYSTEM		MASS	WATER INERTIA	DX/EI(N)	DX(N,N+1)	DX/KAG(N,N+1)	IMZ*DX(N,N+1)	P(N)/Y
		1	1.00000-02	0.0	0.0	0.0	0.0	0.0	0.0

PARAMETER VALUES FOR EACH SECTION - UNSCALED

SECTION-END	CONDN-SYSTEM		MASS	WATER INERTIA	DX/EI(N)	DX(N,N+1)	DX/KAG(N,N+1)	IMZ*DX(N,N+1)	P(N)/Y
1	0	1	3.20000 00	0.0	0.0	0.0	0.0	0.0	1.00000 00
2	0	1	8.30000 00	0.0	0.0	0.0	0.0	0.0	0.0
3	0	1	1.64000 01	0.0	0.0	0.0	0.0	0.0	0.0
4	0	1	1.80000 01	0.0	0.0	0.0	0.0	0.0	0.0
5	0	1	2.45000 01	0.0	0.0	0.0	0.0	0.0	0.0
6	0	1	2.91000 01	0.0	0.0	0.0	0.0	0.0	0.0
7	0	1	1.37000 01	0.0	0.0	0.0	0.0	0.0	0.0
8	0	1	2.05000 01	0.0	0.0	0.0	0.0	0.0	0.0
9	0	1	1.31000 01	0.0	0.0	0.0	0.0	0.0	0.0
10	0	1	4.70000 00	0.0	0.0	0.0	0.0	0.0	0.0

REAL PARTS OF SCALING FACTORS

N	M	SYSTEM	K(N,M)	C(N,M)	C(N,M)/W	DX(N,M)	DX/KAG(N,M)	IMZ*DX(N,M)	Q(N,M)/Y

1	1.00000 05	1.00000 00	0.0	0.0	0.0	0.0	0.0
2	1.00000 04	1.00000 03	0.0	0.0	0.0	0.0	0.0

PARAMETER VALUES FOR SPECIAL CONNECTIONS

N	M	SYSTEM	K(N,M)	C(N,M)	C(N,M)/W	DX(N,M)	DX/KAG(N,M)	IMZ*DX(N,M)	Q(N,M)/Y
1	2	1	3.19000-01	1.00000 00	0.0	0.0	0.0	0.0	0.0
2	3	1	1.56000 00	2.25000 00	0.0	0.0	0.0	0.0	0.0
3	4	1	2.16000 00	3.10000 00	0.0	0.0	0.0	0.0	0.0
4	5	1	1.92000 00	3.80000 00	0.0	0.0	0.0	0.0	0.0
5	6	1	2.39000 00	4.80000 00	0.0	0.0	0.0	0.0	0.0
6	7	1	2.40000 00	3.80000 00	0.0	0.0	0.0	0.0	0.0
7	8	1	2.40000 00	3.10000 00	0.0	0.0	0.0	0.0	0.0
8	9	1	1.85000 00	3.00000 00	0.0	0.0	0.0	0.0	0.0
9	10	1	3.08000-01	1.60000 00	0.0	0.0	0.0	0.0	0.0
10	0	2	5.33000 01	4.48000 00	0.0	0.0	0.0	0.0	0.0

FOURIER TRANSFORM OF IMPULSE LOAD

TIME = 9.850D-02

REAL PART	IMAG PART
1.591549410 02	-1.061032810-03
1.432388740 02	-4.774724620 01
1.101835120 02	-7.345640920 01
7.957694060 01	-7.957747070 01
5.729541260 01	-7.639426500 01
4.212900170 01	-7.021528330 01
3.183081380 01	-6.366184940 01
2.469633740 01	-5.762495170 01
1.962175630 01	-5.232481390 01
1.591543060 01	-4.774639770 01
1.314118560 01	-4.380403940 01
1.101838180 01	-4.040080660 01
9.362026100 00	-3.744816660 01
8.047136530 00	-3.487097840 01
6.987271090 00	-3.260731150 01
6.121328270 00	-3.060668200 01
5.405249160 00	-2.882803140 01
4.806681940 00	-2.723789620 01
4.301475650 00	-2.580888240 01
3.871328500 00	-2.451843950 01
3.502180160 00	-2.334789100 01
3.183092920 00	-2.228167150 01
2.905460310 00	-2.130672820 01
2.662438730 00	-2.041204790 01
2.448533570 00	-1.958828480 01
2.259293740 00	-1.882746280 01
2.091083670 00	-1.812273900 01
1.940911100 00	-1.746821270 01
1.806295670 00	-1.685877150 01
1.685167690 00	-1.628996540 01
1.575789440 00	-1.575790480 01
1.476693460 00	-1.525917550 01
1.386633800 00	-1.479076970 01
1.304547150 00	-1.435002720 01
1.229521730 00	-1.393458770 01
1.160772170 00	-1.354234970 01
1.097619090 00	-1.317143630 01
1.039472390 00	-1.282016630 01
9.858176110-01	-1.248702960 01
9.362045930-01	-1.217066590 01
8.902380750-01	-1.186984690 01
8.475698800-01	-1.158346060 01

8.07892347D-01	-1.13104982D 01
7.70932810D-01	-1.10500420D 01
7.36448942D-01	-1.08012560D 01
7.04224789D-01	-1.05633765D 01
6.74067411D-01	-1.03357047D 01
6.45804001D-01	-1.01176003D 01
6.19279420D-01	-9.90847480D 00
5.94354076D-01	-9.70778715D 00
5.70902091D-01	-9.51503860D 00
5.48809720D-01	-9.32976884D 00
5.27973973D-01	-9.15155234D 00
5.08301423D-01	-8.97999515D 00
4.89707156D-01	-8.81473202D 00
4.72113859D-01	-8.65542385D 00
4.55451023D-01	-8.50175542D 00
4.39654231D-01	-8.35343328D 00
4.24664543D-01	-8.21018395D 00
4.10427942D-01	-8.07175223D 00
3.96894856D-01	-7.93789972D 00
3.84019719D-01	-7.80840347D 00
3.71760593D-01	-7.68305470D 00
3.60078829D-01	-7.56165776D 00
3.48938756D-01	-7.44402909D 00
3.38307418D-01	-7.32999627D 00
3.28154323D-01	-7.21939726D 00
3.18451230D-01	-7.11207956D 00
3.09171951D-01	-7.00789957D 00
3.00292172D-01	-6.90672191D 00
2.91789299D-01	-6.80841889D 00
2.83642313D-01	-6.71286994D 00
2.75831637D-01	-6.61996110D 00
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2.47604794D-01	-6.27265641D 00
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2.35088422D-01	-6.11230050D 00
2.29183002D-01	-6.03515389D 00
2.23497234D-01	-5.95992770D 00
2.18020362D-01	-5.88655121D 00
2.12742283D-01	-5.81495712D 00
2.07653494D-01	-5.74508134D 00
2.02745054D-01	-5.67686283D 00
1.98008545D-01	-5.61024340D 00
1.93436033D-01	-5.54516753D 00
1.89020036D-01	-5.48159226D 00
1.84753494D-01	-5.41943702D 00
1.80629741D-01	-5.35868349D 00
1.76642478D-01	-5.29927548D 00
1.72785749D-01	-5.24116884D 00
1.69053920D-01	-5.18432132D 00
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1.58555887D-01	-5.02093746D 00
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1.37558237D-01	-4.67698097D 00
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1.27380520D-01	-4.50077920D 00
1.25012564D-01	-4.45878224D 00
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8.60296723D-02	-3.69927646D 00
8.47119314D-02	-3.67085090D 00
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7.00163304D-02	-3.33744553D 00
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6.62593255D-02	-3.24670737D 00
6.53673208D-02	-3.22478824D 00
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4.84031411D-02	-2.77511373D 00

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4.62286320D-02	-2.71208004D 00
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2.90587757D-02	-2.15034958D 00
2.87987903D-02	-2.14071026D 00
2.85422782D-02	-2.13115695D 00
2.82891779D-02	-2.12168852D 00
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2.77929729D-02	-2.10300179D 00
2.75497516D-02	-2.09378130D 00
2.73097090D-02	-2.08464129D 00
2.70727899D-02	-2.07558073D 00
2.68389402D-02	-2.06659857D 00
2.66081073D-02	-2.05769380D 00
2.63802395D-02	-2.04886543D 00
2.61552861D-02	-2.04011248D 00
2.59331977D-02	-2.03143399D 00
2.57139260D-02	-2.02282900D 00
2.54974233D-02	-2.01429660D 00
2.52836434D-02	-2.00583586D 00
2.50725407D-02	-1.99744590D 00
2.48640707D-02	-1.98912581D 00
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2.44548555D-02	-1.97269183D 00
2.42540257D-02	-1.96457624D 00
2.40556596D-02	-1.95652713D 00
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2.36661587D-02	-1.94062516D 00
2.34749460D-02	-1.93277070D 00
2.32860413D-02	-1.92497956D 00
2.30994075D-02	-1.91725096D 00
2.29150084D-02	-1.90958417D 00
2.27328084D-02	-1.90197845D 00
2.25527728D-02	-1.89443306D 00
2.23748674D-02	-1.88694729D 00
2.21990587D-02	-1.87952044D 00
2.20253139D-02	-1.87215182D 00
2.18536008D-02	-1.86484074D 00
2.16838879D-02	-1.85758653D 00
2.15161442D-02	-1.85038853D 00
2.13503393D-02	-1.84324610D 00
2.11864436D-02	-1.83615858D 00
2.10244278D-02	-1.82912535D 00
2.08642633D-02	-1.82214579D 00
2.07059220D-02	-1.81521929D 00
2.05493762D-02	-1.80834524D 00
2.03945991D-02	-1.80152304D 00
2.02415639D-02	-1.79475213D 00
2.00902448D-02	-1.78803191D 00
1.99406161D-02	-1.78136183D 00
1.97926527D-02	-1.77474131D 00
1.96463300D-02	-1.76816982D 00
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1.93585106D-02	-1.75517175D 00
1.92169669D-02	-1.74874411D 00
1.90769698D-02	-1.74236336D 00
1.89384970D-02	-1.73602901D 00
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3.08858789D-03	-7.01109467D-01
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1.66685801D-03	-5.15059133D-01
1.66326761D-03	-5.14504124D-01
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1.65612154D-03	-5.13397686D-01
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1.56399183D-03	-4.98913401D-01
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1.47633914D-03	-4.84731358D-01
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1.46738721D-03	-4.83259529D-01
1.46442132D-03	-4.82770904D-01
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1.45851646D-03	-4.81796611D-01
1.45557741D-03	-4.81310938D-01
1.45264724D-03	-4.80826243D-01
1.44972590D-03	-4.80342523D-01
1.44681337D-03	-4.79859776D-01
1.44390961D-03	-4.79377997D-01
1.44101458D-03	-4.78897186D-01
1.43812825D-03	-4.78417337D-01
1.43525058D-03	-4.77938450D-01
1.43238154D-03	-4.77460520D-01

TIME = 1.098D 00
TIME = 3.015D 01

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SECTION	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL
1	2.5663D-03	-3.3070D-02	-4.7098D-02	-4.4256D-02	-3.4520D-02	-2.4467D-02	-1.5509D-02	-8.0312D-03
2	2.5100D-03	-4.4099D-02	-5.0187D-02	-4.3953D-02	-3.4127D-02	-2.4119D-02	-1.5219D-02	-7.8587D-03
3	2.4807D-03	-4.3063D-02	-4.9061D-02	-4.2823D-02	-3.3389D-02	-2.3640D-02	-1.4918D-02	-7.6951D-03
4	2.4249D-03	-3.9144D-02	-4.6225D-02	-4.0831D-02	-3.2027D-02	-2.2746D-02	-1.4371D-02	-7.3989D-03
5	2.3250D-03	-3.3378D-02	-4.1469D-02	-3.7570D-02	-2.9673D-02	-2.1163D-02	-1.3395D-02	-6.8693D-03
6	2.2070D-03	-2.9781D-02	-3.7402D-02	-3.4369D-02	-2.7219D-02	-1.9457D-02	-1.2322D-02	-6.2865D-03
7	2.0498D-03	-2.7826D-02	-3.4033D-02	-3.0957D-02	-2.4501D-02	-1.7515D-02	-1.1076D-02	-5.6110D-03
8	1.8758D-03	-2.6053D-02	-3.0875D-02	-2.7574D-02	-2.1792D-02	-1.5565D-02	-9.8183D-03	-4.9318D-03
9	1.6214D-03	-2.2966D-02	-2.6733D-02	-2.3446D-02	-1.8497D-02	-1.3183D-02	-8.2807D-03	-4.1126D-03
10	6.1508D-06	8.3948D-05	-2.1207D-04	-1.4541D-04	1.2679D-05	1.6657D-04	2.8516D-04	3.6198D-04

SECTION	TIME(SECS) = 8.00D-01	9.00D-01	1.00D 00	1.10D 00	1.20D 00	1.30D 00	1.40D 00	1.50D 00
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1	-2.1617D-03	2.1892D-03	5.1976D-03	7.0702D-03	8.0216D-03	8.2583D-03	7.9685D-03	7.3163D-03
2	-2.0974D-03	2.1682D-03	5.1142D-03	6.9468D-03	7.8774D-03	8.1083D-03	7.8237D-03	7.1839D-03
3	-2.0345D-03	2.1595D-03	5.0572D-03	6.8601D-03	7.7758D-03	8.0027D-03	7.7216D-03	7.0904D-03
4	-1.9194D-03	2.1478D-03	4.9613D-03	6.7134D-03	7.6035D-03	7.8235D-03	7.5484D-03	6.9316D-03
5	-1.7140D-03	2.1259D-03	4.7892D-03	6.4507D-03	7.2953D-03	7.5027D-03	7.2381D-03	6.6470D-03
6	-1.4937D-03	2.0900D-03	4.5832D-03	6.1417D-03	6.9343D-03	7.1271D-03	6.8744D-03	6.3128D-03
7	-1.2523D-03	2.0197D-03	4.3028D-03	5.7324D-03	6.4591D-03	6.6330D-03	6.3953D-03	5.8715D-03
8	-1.0203D-03	1.9265D-03	3.9879D-03	5.2801D-03	5.9357D-03	6.0891D-03	5.8674D-03	5.3848D-03
9	-7.7091D-04	1.7501D-03	3.5142D-03	4.6185D-03	5.1753D-03	5.2995D-03	5.1005D-03	4.6766D-03
10	4.0047D-04	4.0754D-04	3.9094D-04	3.5757D-04	3.1402D-04	2.6536D-04	2.1564D-04	1.6786D-04

TIME(SECS) =	1.600 00	1.700 00	1.800 00	1.900 00	2.000 00	2.100 00	2.200 00	2.300 00
SECTION	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL
1	6.4397D-03	5.4503D-03	4.4344D-03	3.4544D-03	2.5869D-03	-3.3075D-02	-4.7094D-02	-4.4262D-02
2	6.3241D-03	5.3534D-03	4.3569D-03	3.3973D-03	2.5219D-03	-4.4102D-02	-5.0192D-02	-4.3958D-02
3	6.2421D-03	5.2942D-03	4.3005D-03	3.3531D-03	2.4911D-03	-4.3066D-02	-4.9066D-02	-4.2828D-02
4	6.1027D-03	5.1665D-03	4.2049D-03	3.2783D-03	2.4342D-03	-3.9147D-02	-4.6229D-02	-4.0836D-02
5	5.8526D-03	4.9551D-03	4.0329D-03	3.1439D-03	2.3334D-03	-3.3381D-02	-4.1473D-02	-3.7574D-02
6	5.5583D-03	4.7060D-03	3.8298D-03	2.9851D-03	2.2145D-03	-2.9784D-02	-3.7406D-02	-3.4374D-02
7	5.1689D-03	4.3755D-03	3.5601D-03	2.7740D-03	2.0566D-03	-2.7829D-02	-3.4036D-02	-3.0961D-02
8	4.7390D-03	4.0103D-03	3.2617D-03	2.5402D-03	1.8819D-03	-2.6055D-02	-3.0879D-02	-2.7578D-02
9	4.1125D-03	3.4774D-03	2.8259D-03	2.1986D-03	1.6267D-03	-2.2969D-02	-2.6737D-02	-2.3450D-02
10	1.2411D-04	8.5668D-05	5.3178D-05	2.6788D-05	6.3832D-06	8.3599D-05	-2.1232D-04	-1.4562D-04

TIME(SECS) =	2.400 00	2.500 00	2.600 00	2.700 00	2.800 00	2.900 00	3.000 00	
SECTION	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL
1	-3.4525D-02	-2.4472D-02	-1.5513D-02	-8.0351D-03	-2.1650D-03	2.1865D-03	5.1955D-03	
2	-3.4132D-02	-2.4124D-02	-1.5223D-02	-7.8624D-03	-2.1005D-03	2.1656D-03	5.1122D-03	
3	-3.3394D-02	-2.3645D-02	-1.4922D-02	-7.6987D-03	-2.0376D-03	2.1570D-03	5.0552D-03	
4	-3.2032D-02	-2.2751D-02	-1.4375D-02	-7.4025D-03	-1.9224D-03	2.1453D-03	4.9593D-03	
5	-2.9677D-02	-2.1167D-02	-1.3399D-02	-6.8728D-03	-1.7169D-03	2.1235D-03	4.7873D-03	
6	-2.7222D-02	-1.9461D-02	-1.2326D-02	-6.2899D-03	-1.4966D-03	2.0877D-03	4.5813D-03	
7	-2.4505D-02	-1.7519D-02	-1.1080D-02	-5.6142D-03	-1.2550D-03	2.0175D-03	4.3010D-03	
8	-2.1796D-02	-1.5568D-02	-9.8216D-03	-4.9348D-03	-1.0228D-03	1.9245D-03	3.9862D-03	
9	-1.8500D-02	-1.3186D-02	-8.2836D-03	-4.1152D-03	-7.7310D-04	1.7483D-03	3.5127D-03	
10	1.2497D-05	1.6642D-04	2.8505D-04	3.6189D-04	4.0040D-04	4.0749D-04	3.9081D-04	

TIME = 4.024D 01

```
 GBRP  OCT 7, 1966
      CAMEL  -  TRANSIENT RESPONSE

DATA CONTROL CARD

NO  TYPE

END GBRP  RUN
TIME =       4.026D 01
```

VI. COMPUTING SYSTEM TIMES ASSOCIATED WITH GBRP TRANSIENT CALCULATIONS

Consideration will be given to the significance of computing system times required by the various steps of the transient calculation. As indicated in Section III., the total calculation process involves three major steps:

1) transformation of the excitation,

2) GBRP solution of Equation [2.11] pg. 5 for the range of frequencies in the impulse spectrum, and

3) inverse transformation of the response spectrum.

These three steps require, respectively, the following movements of data between computer memory and auxiliary storage devices (disks):

1) writing of the points of $\vec{P}(\omega_i)$ on disk,

2) reading of $\vec{P}(\omega_i)$ for use by GBRP in the solving of equations [2.11],

3) writing of $\vec{Z}(\omega_i)$ on disk, and

4) reading of $\vec{Z}(\omega_i)$ for the inverse transformation process.

It is useful in assessing the practicability of this approach to estimate both the central processing unit (CPU) and input/output (I/O) times associated with each of these three steps. The CPU times can be obtained directly from the computer output of Section V. The total CPU time subtracted from the total GBRP execution time gives the total I/O time. Dividing this latter time by the total number of reads and writes gives an average time per I/O operation. Since the number of I/O operations for each step is known, the corresponding I/O times per step can be estimated. These I/O times are known to vary slightly among runs because they are dependent upon the computing system environment existing when the runs are made.

The time distribution among steps for the two sample problems of Section V. is summarized in Tables 1 and 2. Tables 1 and 2 illustrate that I/O operations accounted for the preponderance of the total execution time. This use resulted from a decision to minimize the computer core region size (< 200 K bytes) devoted to the parameters and instructions of GBRP and the intermediate results, $\vec{\vec{P}}(\omega_i)$ and $\vec{\vec{Z}}(\omega_i)$. Actually, in-core solutions for both these problems are easily obtained by specifying a larger region for the execution of the program. This change would reduce I/O to the writing of $\vec{\vec{Z}}(\omega_i)$ on disk and one pass (N=1) to read the $\vec{\vec{Z}}(\omega_i)$ back for the inverse transformation. The result would be a reduction of 7x(1501) = 10,507 I/O operations for problem 1 and of 7x(1001) = 7,007 I/O operations for problem 2. In turn, this would mean a saving of about 0.016 x 10,507 = 168.11 seconds for problem 1 or a reduced running time of <u>60.93 seconds</u> and a saving of about 0.016 x 7007 = 112.11 seconds for problem 2 for a reduced running time of <u>26.53 seconds.</u>

It is highly desirable to keep N=1 for the inversion of $\vec{\vec{Z}}(\omega_i)$, especially when many points, ω_i , are involved. The value of N (not a data input number) is determined by the size of a two-dimensional array utilized in the inversion process and the <u>number</u> of time points at which the response is to be calculated. The number of rows in the array equals the total number of beam sections. The number of columns equals the <u>number</u> of time points which will be computed, simultaneously, <u>per pass of the $\vec{\vec{Z}}(\omega_i)$ file.</u> The dimensions of this array are variable and are assigned at program execution time. For example, the array was given the dimensions (1, 8) for problem 1 and (10, 8) for problem 2. Since the response was to be output at 42 time points for problem 1, and since only eight time points could be handled at once in the array, six passes through the $\vec{Z}(\omega_i)$ points were required. To make this an

N=1 situation, the dimensions of the array would have to be changed to (1, 42). Similarly, for problem 2, response was to be calculated for 31 time points so that four passes through $\vec{\bar{Z}}(\omega_1)$ were required.

The variably dimensioned array for the core working space thus allows core-orientation or I/O-orientation of the transient calculation as dictated by the number of beam sections and time points at which results are desired and/or the particular capabilities of the computing system. The two test problems illustrate the use of this array to provide I/O-orientation of the inversion process in order to minimize core storage.

TABLE 1

Computing System Times Associated with Sample Problem 1

1501 points of $\vec{Z}(\omega_i)$

Step	I/O	No. of I/O	I/O time (secs)	CPU time (secs)
1 Compute and Store $\vec{P}(\omega_i)$	Write $\vec{P}(\omega_i)$ on disk	1501	23.854	1.51
2 GBRP Computes and Stores $\vec{Z}(\omega_i)$	Read $\vec{P}(\omega_i)$ from disk	1501	23.854	4.57
	Write $\vec{Z}(\omega_i)$ on disk	1501	23.854	
3 Inverse Transform $\vec{Z}(\omega_i)$	Read $\vec{Z}(\omega_i)$ from disk	N=6 Nx(1501)	143.126	8.27
	Total	= 13,509	Total	= 14.35

Total I/O time = (total execution time) - (total CPU time) = 229.04-14.35 = 214.69 seconds.

Average time per I/O = (total I/O time) ÷ (total I/O) = 0.015892 seconds.

CPU time per solution of $\vec{Z}(\omega_i)$ = (Step 2 CPU time) ÷ 1501 = 0.0030 seconds.

For this problem, $[A(\omega_i)]$ is of order 4x4 with bandwidth of 3.

TABLE 2

Computing System Times Associated with Sample Problem 2
1001 points of $\vec{\bar{Z}}(\omega_i)$

Step	I/O	No. of I/O	I/O time (secs)	CPU time (secs)
1 Compute and Store $\vec{P}(\omega_i)$	Write $\vec{P}(\omega_i)$ on disk	1001	12.990	1.00
2 GBRP Computes and Stores $\vec{\bar{Z}}(\omega_i)$	Read $\vec{P}(\omega_i)$ from disk	1001	12.990	29.05
	Write $\vec{\bar{Z}}(\omega_i)$ on disk	1001	12.990	
3 Inverse Transform $\vec{\bar{Z}}(\omega_i)$	Read $\vec{\bar{Z}}(\omega_i)$ from disk	N=4 N x (1001)	51.960	10.09
	Total =	7,007	Total =	41.14

Total I/O time = (total execution time) - (total CPU time) = 132.07-41.14 = 90.93 seconds.

Average time per I/O = (total I/O time) ÷ (total I/O) = 0.01298 seconds.

CPU time per solution of $\vec{\bar{Z}}(\omega_i)$ = (Step 2 CPU time) ÷ 1001 = 0.0290 seconds.

For this problem, $[A(\omega_i)]$ is of order 20x20 with bandwidth of 6.

VII. RESULTS OBTAINED FOR TWO SAMPLE PROBLEMS USING SEVERAL VALUES FOR THE FREQUENCY INCREMENT

The accuracy of the GBRP transient solution is dependent upon the selection of ω_{FINAL}, the cutoff frequency for $\vec{\bar{P}}(\omega_i)$ and $\vec{\bar{Z}}(\omega_i)$, and the value selected for $\Delta\omega$.

Tables 3 and 4 illustrate the results obtained for the two structures of Section V when several values of $\Delta\omega$ were used. The tabulated numbers are those for the deflection response. Note that the response obtained for problem 1 with $\Delta\omega = 0.5$ CPS (Table 3) is completely meaningless. The result is predictable, however, from a consideration of the coarseness ($\Delta\omega = 0.5$ CPS) with which the Fourier transform of the rectangular pulse was sampled (pg. 110).

Note: The symbol, D, accompanying numbers in these tables signifies powers of 10 associated with double-precision values. The symbol, E, is similarly associated with single-precision values.

TABLE 3

Time Response of Mass-Spring-Damper System Using Several Values of Δω

Response (ft)

Time (Secs)	Δω (CPS) 0.5	Δω (CPS) 0.029	Δω (CPS) 0.02	Analytic
0.0	5.9518 D-02	-2.2965 D-05	-2.3437 D-06	4.3309 E-13
0.1	5.9521 D-02	2.4105 D-03	2.4316 D-03	2.4337 E-3
0.2	5.9524 D-02	9.3239 D-03	9.3455 D-03	9.3477 E-3
0.3	5.9526 D-02	1.9897 D-02	1.9919 D-02	1.9921 E-2
0.4	5.9529 D-02	3.3061 D-02	3.3083 D-02	3.3086 E-2
0.5	5.9531 D-02	4.7598 D-02	4.7621 D-02	4.7624 E-2
0.6	5.9532 D-02	6.2253 D-02	6.2276 D-02	6.2278 E-2
0.7	5.9532 D-02	7.5831 D-02	7.5[illegible]54 D-02	7.5857 E-2
0.8	5.9532 D-02	8.7297 D-02	8.7320 D-02	8.7322 E-2
0.9	5.9531 D-02	9.5844 D-02	9.5867 D-02	9.5869 E-2
1.0	5.9529 D-02	1.0095 D-01	1.0097 D-01	1.0098 E-1
1.1	5.9526 D-02	1.0240 D-01	1.0243 D-01	1.0243 E-1
1.2	5.9524 D-02	1.0030 D-01	1.0032 D-01	1.0032 E-1
1.3	5.9522 D-02	9.5015 D-02	9.5037 D-02	9.5039 E-2
1.4	5.9519 D-02	8.7163 D-02	8.7183 D-02	8.7186 E-2
1.5	5.9518 D-02	7.7528 D-02	7.7548 D-02	7.7551 E-2
1.6	5.9516 D-02	6.6994 D-02	6.7015 D-02	6.7017 E-2
1.7	5.9516 D-02	5.6467 D-02	5.6488 D-02	5.6490 E-2
1.8	5.9516 D-02	4.6799 D-02	4.6820 D-02	4.6822 E-2
1.9	5.9517 D-02	3.8723 D-02	3.8743 D-02	3.8745 E-2
2.0	5.9518 D-02	3.2798 D-02	3.2819 D-02	3.2821 E-2
2.1	5.9521 D-02	2.6947 D-02	2.6967 D-02	2.6970 E-2
2.2	5.9524 D-02	1.9253 D-02	1.9274 D-02	1.9276 E-2
2.3	5.9526 D-02	1.0446 D-02	1.0467 D-02	1.0470 E-2
2.4	5.9529 D-02	1.3048 D-03	1.3263 D-03	1.3287 E-3
2.5	5.9531 D-02	-7.4118 D-03	-7.3901 D-03	-7.3877 E-3
2.6	5.9532 D-02	-1.5023 D-02	-1.5001 D-02	-1.4998 E-2
2.7	5.9532 D-02	-2.0976 D-02	-2.0954 D-02	-2.0952 E-2
2.8	5.9532 D-02	-2.4886 D-02	-2.4864 D-02	-2.4862 E-2
2.9	5.9531 D-02	-2.6556 D-02	-2.6534 D-02	-2.6531 E-2
3.0	5.9529 D-02	-2.5980 D-02	-2.5958 D-02	-2.5956 E-2
3.1	5.9526 D-02	-2.3337 D-02	-2.3315 D-02	-2.3313 E-2
3.2	5.9524 D-02	-1.8960 D-02	-1.8938 D-02	-1.8936 E-2
3.3	5.9522 D-02	-1.3304 D-02	-1.3283 D-02	-1.3281 E-2
3.4	5.9519 D-02	-6.9032 D-03	-6.8821 D-03	-6.8797 E-3
3.5	5.9518 D-02	-3.1785 D-04	-2.9694 D-04	-2.9456 E-4
3.6	5.9516 D-02	5.9078 D-03	5.9286 D-03	5.9309 E-3
3.7	5.9516 D-02	1.1291 D-02	1.1311 D-02	1.1314 E-2
3.8	5.9516 D-02	1.5444 D-02	1.5465 D-02	1.5467 E-2
3.9	5.9517 D-02	1.8104 D-02	1.8124 D-02	1.8126 E-2
4.0	5.9518 D-02	1.9140 D-02	1.9161 D-02	1.9163 E-2
4.1	5.9521 D-02	1.8565 D-02	1.8586 D-02	1.8588 E-2

TABLE 4

Time Response of Nonuniform Beam Model Using Several Values of $\Delta \omega$

Response (ft)

	time = 0 (secs)		
Section	$\Delta\omega$ (CPS) 0.5	$\Delta\omega$ (CPS) 0.25	$\Delta\omega$ (CPS) 0.10
1	2.5663 D-03	2.0692 D-06	7.3735 D-06
2	2.5100 D-03	-8.3452 D-06	-3.1642 D-06
3	2.4807 D-03	-4.9506 D-06	1.2634 D-07
4	2.4248 D-03	-5.1443 D-06	-2.3798 D-07
5	2.3250 D-03	-4.7652 D-06	-1.6656 D-07
6	2.2070 D-03	-4.3906 D-06	-1.5843 D-07
7	2.0498 D-03	-3.8810 D-06	-1.4418 D-07
8	1.8758 D-03	-3.3152 D-06	-1.3070 D-07
9	1.6214 D-03	-2.41[illegible]3 D-06	-1.1291 D-07
10	6.1508 D-06	2.3[illegible]2 D-06	-5.9694 D-09

	time = 0.1 (secs)		
Section	$\Delta\omega$ (CPS) 0.5	$\Delta\omega$ (CPS) 0.25	$\Delta\omega$ (CPS) 0.10
1	-3.3070 D-02	-3.4822 D-02	-3.4840 D-02
2	-4.4099 D-02	-4.5819 D-02	-4.5836 D-02
3	-4.3063 D-02	-4.4760 D-02	-4.4778 D-02
4	-3.9144 D-02	-4.0803 D-02	-4.0820 D-02
5	-3.3378 D-02	-3.4968 D-02	-3.4984 D-02
6	-2.9781 D-02	-3.1289 D-02	-3.1305 D-02
7	-2.7826 D-02	-2.9225 D-02	-2.9240 D-02
8	-2.6053 D-02	-2.7331 D-02	-2.7345 D-02
9	-2.2966 D-02	-2.4061 D-02	-2.4082 D-02
10	8.3848 D-05	9.5252 D-05	9.2890 D-05

	time = 0.2 (secs)		
Section	$\Delta\omega$ (CPS) 0.5	$\Delta\omega$ (CPS) 0.25	$\Delta\omega$ (CPS) 0.10
1	-4.7088 D-02	-4.8156 D-02	-4.8189 D-02
2	-5.0187 D-02	-5.1236 D-02	-5.1269 D-02
3	-4.9061 D-02	-5.0096 D-02	-5.0129 D-02
4	-4.6225 D-02	-4.7235 D-02	-4.7267 D-02
5	-4.1469 D-02	-4.2436 D-02	-4.2467 D-02
6	-3.1402 D-02	-3.8318 D-02	-3.8348 D-02
7	-3.4033 D-02	-3.4881 D-02	-3.4908 D-02
8	-3.0875 D-02	-3.1649 D-02	-3.1674 D-02
9	-2.6733 D-02	-2.7378 D-02	-2.7420 D-02
10	-2.1207 D-04	-1.9029 D-04	-1.9254 D-04

	time = 0.3 (secs)		
Section	$\Delta\omega$ (CPS) 0.5	$\Delta\omega$ (CPS) 0.25	$\Delta\omega$ (CPS) 0.10
1	-4.4256 D-02	-4.4772 D-02	-4.4815 D-02
2	-4.3953 D-02	-4.4459 D-02	-4.4501 D-02
3	-4.2823 D-02	-4.3322 D-02	-4.3364 D-02
4	-4.0831 D-02	-4.1317 D-02	-4.1358 D-02
5	-3.7570 D-02	-3.8033 D-02	-3.8073 D-02
6	-3.4369 D-02	-3.4806 D-02	-3.4844 D-02
7	-3.0957 D-02	-3.1359 D-02	-3.1395 D-02
8	-2.7574 D-02	-2.7939 D-02	-2.7971 D-02
9	-2.3446 D-02	-2.3757 D-02	-2.3786 D-02
10	-1.4541 D-0[illegible]	-1.1733 D-04	-1.1938 D-04

TABLE 4 (Continued)

Section	time = 0.4 (secs) Δω (CPS) 0.5	Δω (CPS) 0.25	Δω (CPS) 0.10	time = 0.5 (secs) Δω (CPS) 0.5	Δω (CPS) 0.25	Δω (CPS) 0.10
1	-2.4467 D-02	-3.4608 D-02	-3.4655 D-02	-2.4467 D-02	-2.4241 D-02	-2.4289 D-02
2	-2.4119 D-02	-3.4213 D-02	-3.4260 D-02	-2.4119 D-02	-2.3897 D-02	-2.3944 D-02
3	-2.3640 D-02	-3.3472 D-02	-3.3519 D-02	-2.3640 D-02	-2.3419 D-02	-2.3466 D-02
4	-2.2746 D-02	-3.2107 D-02	-3.2152 D-02	-2.2746 D-02	-2.2528 D-02	-2.2574 D-02
5	-2.1163 D-02	-2.9746 D-02	-2.9790 D-02	-2.1163 D-02	-2.0950 D-02	-2.0994 C-02
6	-1.9457 D-02	-2.7285 D-02	-2.7326 D-02	-1.9457 D-02	-1.9252 D-02	-1.9294 D-02
7	-1.7515 D-02	-2.4559 D-02	-2.4598 D-02	-1.7515 D-02	-1.7321 D-02	-1.7361 D-02
8	-1.5565 D-02	-2.1841 D-02	-2.1877 D-02	-1.5565 D-02	-1.5383 D-02	-1.5419 D-02
9	-1.3183 D-02	-1.8534 D-02	-1.8566 D-02	-1.3183 D-02	-1.3020 D-02	-1.3052 D-02
10	1.6557 D-04	4.3754 D-05	4.1965 D-05	1.6657 D-04	1.9809 D-04	1.9659 D-04

Section	time = 0.6 (secs) Δω (CPS) 0.5	Δω (CPS) 0.25	Δω (CPS) 0.10	time = 0.7 (secs) Δω (CPS) 0.5	Δω (CPS) 0.25	Δω (CPS) 0.10
1	-1.5508 D-02	-1.5069 D-02	-1.5114 D-02	-8.0312 D-03	-7.4615 D-03	-7.5030 D-03
2	-1.5219 D-02	-1.4831 D-02	-1.4831 D-02	-7.8587 D-03	-7.2778 D-03	-7.3390 D-03
3	-1.4918 D-02	-1.4489 D-02	-1.4534 D-02	-7.6951 D-03	-7.1400 D-03	-7.1808 D-03
4	-1.4371 D-02	-1.3950 D-02	-1.3993 D-02	-7.3989 D-03	-6.8542 D-03	-6.8942 D-03
5	-1.3395 D-02	-1.2987 D-02	-1.3030 D-02	-6.8693 D-03	-6.3437 D-03	-6.3822 D-03
6	-1.2322 D-02	-1.1932 D-02	-1.1973 D-02	-6.2865 D-03	-5.7842 D-03	-5.8209 D-03
7	-1.1076 D-02	-1.0710 F-02	-1.0748 D-02	-5.6110 D-03	-5.1408 D-03	-5.1751 D-03
8	-9.8183 D-03	-9.4793 D-03	-9.5139 D-03	-4.9318 D-03	-4.4978 D-03	-4.5292 D-03
9	-8.2807 D-03	-7.9825 D-03	-8.0126 D-03	-4.1126 D-03	-3.7327 D-03	-3.7601 D-03
10	2.8516 D-04	3.1528 D-04	3.1407 D-04	3.6198 D-04	3.8941 D-04	3.8847 D-04

Section	time = 0.8 (secs) Δω (CPS) 0.5	Δω (CPS) 0.25	Δω (CPS) 0.10	time = 0.9 (secs) Δω (CPS) 0.5	Δω (CPS) 0.25	Δω (CPS) 0.10
1	-2.1617 D-03	-1.5296 D-03	-1.5658 D-03	2.1892 D-03	2.8313 D-03	2.8010 D-03
2	-2.0974 D-03	-1.4750 D-03	-1.5110 D-03	2.1682 D-03	2.8006 D-03	2.7703 D-03
3	-2.0345 D-03	-1.4189 D-03	-1.4544 D-03	2.1595 D-03	2.7849 D-03	2.7550 D-03
4	-1.9194 D-03	-1.3155 D-03	-1.3504 D-03	2.1478 D-03	2.7610 D-03	2.7317 D-03
5	-1.7140 D-03	-1.1318 D-03	-1.1654 D-03	2.1259 D-03	2.7168 D-03	2.6886 D-03
6	-1.4937 D-03	-9.3794 D-04	-9.6995 D-04	2.0900 D-03	2.6538 D-03	2.6269 D-03
7	-1.2523 D-03	-7.3279 D-04	-7.6265 C-04	2.0197 D-03	2.5463 D-03	2.5212 D-03
8	-1.0203 D-03	-5.4141 D-04	-5.6885 D-04	1.9265 D-03	2.4114 D-03	2.3884 D-03
9	-7.7091 D-04	-3.5286 D-04	-3.7671 D-04	1.7501 D-03	2.1727 D-03	2.1527 D-03
10	4.0047 D-04	4.2444 D-04	4.2375 D-04	4.0754 D-04	4.2769 D-04	4.2722 D-04

TABLE 4 (Continued)

	time = 1.0 (secs)			time = 1.1 (secs)		
Section	Λ_ω (CPS) 0.5	Λ_ω (CPS) 0.25	Λ_ω (CPS) 0.10	Λ_ω (CPS) 0.5	Λ_ω (CPS) 0.25	Λ_ω (CPS) 0.10
1	5.1976 D-03	5.8114 D-03	5.7870 D-03	7.0702 D-03	7.6295 D-03	7.6107 D-03
2	5.1142 D-03	5.7188 D-03	5.6944 D-03	6.9468 D-03	7.4978 D-03	7.4789 D-03
3	5.0572 D-03	5.6550 D-03	5.6309 D-03	6.8601 D-03	7.4049 D-03	7.3863 D-03
4	4.9613 D-03	5.5474 D-03	5.5237 D-03	6.7134 D-03	7.2474 D-03	7.2292 D-03
5	4.7892 D-03	5.3537 D-03	5.3310 D-03	6.4507 D-03	6.9650 D-03	6.9474 D-03
6	4.5832 D-03	5.1216 D-03	5.0999 D-03	6.1417 D-03	6.6320 D-03	6.6153 D-03
7	4.3023 D-03	4.8053 D-03	4.7851 D-03	5.[illegible]24 D-03	6.1899 D-03	6.1743 D-03
8	3.9879 D-03	4.4503 D-03	4.4317 D-03	5.2801 D-03	5.7008 D-03	5.6865 D-03
9	3.5142 D-03	3.9167 D-03	3.9006 D-03	4.6185 D-03	4.9843 D-03	4.9719 D-03
10	3.9084 D-04	4.0711 D-04	4.0683 D-04	3.5757 D-04	3.7014 D-04	3.7001 D-04

	time = 1.2 (secs)			time = 1.3 (secs)		
Section	Λ_ω (CPS) 0.5	Λ_ω (CPS) 0.25	Λ_ω (CPS) 0.10	Λ_ω (CPS) 0.5	Λ_ω (CPS) 0.25	Λ_ω (CPS) 0.10
1	8.0216 D-03	8.5105 D-03	8.4969 D-03	8.2583 D-03	8.6693 D-03	8.6601 D-03
2	7.8774 D-03	8.3592 D-03	8.3454 D-03	8.1083 D-03	8.5135 D-03	8.5041 D-03
3	7.7758 D-03	8.2521 D-03	8.2385 D-03	8.0027 D-03	8.4032 D-03	8.3939 D-03
4	7.6035 D-03	8.0704 D-03	8.0570 D-03	7.8235 D-03	8.2160 D-03	8.2069 D-03
5	7.2953 D-03	7.7448 D-03	7.7320 D-03	7.5027 D-03	7.8875 D-03	7.8718 D-03
6	6.9343 D-03	7.3627 D-03	7.3505 D-03	7.1271 D-03	7.4871 D-03	7.4788 D-03
7	6.4591 D-03	6.8586 D-03	6.8472 D-03	6.6330 D-03	6.9686 D-03	6.9609 D-03
8	5.9357 D-03	6.3029 D-03	6.2925 D-03	6.0891 D-03	6.3974 D-03	6.3903 D-03
9	5.1753 D-03	5.4944 D-03	5.4853 D-03	5.2995 D-03	5.5671 D-03	5.5610 D-03
10	3.1402 D-04	3.2322 D-04	3.2320 D-04	2.6536 D-04	2.7161 D-04	2.7168 D-04

	time = 1.4 (secs)			time = 1.5 (secs)		
Section	Λ_ω (CPS) 0.5	Λ_ω (CPS) 0.25	Λ_ω (CPS) 0.10	Λ_ω (CPS) 0.5	Λ_ω (CPS) 0.25	Λ_ω (CPS) 0.10
1	7.9685 D-03	8.3004 D-03	8.2949 D-03	7.3163 D-03	7.5727 D-03	7.5702 D-03
2	7.8237 D-03	8.1509 D-03	8.1452 D-03	7.1839 D-03	7.4367 D-03	7.4339 D-03
3	7.7216 D-03	8.0451 D-03	8.0395 D-03	7.0904 D-03	7.3403 D-03	7.3376 D-03
4	7.5484 D-03	7.8654 D-03	7.8599 D-03	6.9316 D-03	7.1765 D-03	7.1739 D-03
5	7.2381 D-03	7.5432 D-03	7.5379 D-03	6.6470 D-03	6.8826 D-03	6.8801 D-03
6	6.8744 D-03	7.1651 D-03	7.1600 D-03	6.3128 D-03	6.5371 D-03	6.5348 D-03
7	6.3953 D-03	6.6661 D-03	6.6615 D-03	5.8715 D-03	6.0805 D-03	6.0783 D-03
8	5.8674 D-03	6.1161 D-03	6.1118 D-03	5.3848 D-03	5.5766 D-03	5.5746 D-03
9	5.1005 D-03	5.3162 D-03	5.3125 D-03	4.6766 D-03	4.8428 D-03	4.8411 D-03
10	2.1564 D-04	2.1941 D-04	2.1953 D-04	1.6786 D-04	1.6964 D-04	1.6979 D-04

GERP OCT 7, 1966
RESPONSE TO RECTANGULAR IMPULSE

DATA CONTROL CARD

NO	TYPE
1	10
1	20
1	30
1	32
1	33
1	41
1	43
1	51
1	53

CASE TITLE- MASS SPRING SYSTEM, 0.10 CRITICAL DAMPING

OPTION DATA
20 0 0 0 3 2 0 0 3 4 0

GENERAL DATA - NUMBER OF SECTIONS 1
FREQUENCY RANGE FROM 0.000 CPS TO 30.000 CPS
FREQUENCY INTERVAL 0.500 CPS

TIMES(SECS) AT WHICH IMPULSE RESPONSE IS DESIRED
INITIAL TIME = 0.0 FINAL TIME = 4.10000 TIME DIFFERENCE = 0.10000
IMPULSE AT SECTION 1

PARAMETERS FOR TRANSFORM OF RECTANGULAR PULSE
AMPLITUDE = 0.500 DURATION OF IMPULSE = 2.000SECS

REAL PARTS OF SCALING FACTORS

SECTION-END	CONDN-SYSTEM		MASS	WATER INERTIA	DX/EI(N)	DX(N,N+1)	DX/KAG(N,N+1)	IMZ*DX(N,N+1)	P(N)/Y
		1	1.00000 00	0.0	0.0	0.0	0.0	0.0	0.0

PARAMETER VALUES FOR EACH SECTION - UNSCALED

SECTION-END	CONDN-SYSTEM		MASS	WATER INERTIA	DX/EI(N)	DX(N,N+1)	DX/KAG(N,N+1)	IMZ*DX(N,N+1)	P(N)/Y
1	0	1	1.00000 00	0.0	0.0	0.0	0.0	0.0	1.00000 00

REAL PARTS OF SCALING FACTORS

N	M	SYSTEM	K(N,M)	C(N,M)	C(N,M)/W	DX(N,M)	DX/KAG(N,M)	IMZ*DX(N,M)	Q(N,M)/Y
		1	1.00000 00	1.00000 00	0.0	0.0	0.0	0.0	0.0

PARAMETER VALUES FOR SPECIAL CONNECTIONS

N	M	SYSTEM	K(N,M)	C(N,M)	C(N,M)/W	DX(N,M)	DX/KAG(N,M)	IMZ*DX(N,M)	Q(N,M)/Y
1	0	1	8.4[illegible]	6.00[illegible]D-01	0.0	0.0	0.0	0.0	0.0

FOURIER TRANSFORM OF IMPULSE LOAD

REAL PART	IMAG PART
9.999999970D-01	-6.283185280D-05
1.999845730D-05	-1.256468340D-09
9.998757320D-06	-6.281686630D-10
6.665479550D-06	-4.187326480D-10
4.998832330D-06	-3.140141190D-10
3.998841330D-06	-2.511828350D-10
3.332179550D-06	-2.092952450D-10
2.855992020D-06	-1.793755040D-10
2.498851080D-06	-1.569356810D-10
2.221074610D-06	-1.394824750D-10
1.998853330D-06	-1.255199040D-10
1.817035840D-06	-1.140959780D-10
1.665521220D-06	-1.045760380D-10
1.537316500D-06	-9.652070220D-11
1.427426720D-06	-8.961612750D-11
1.332188890D-06	-8.363216210D-11
1.248855770D-06	-7.839619190D-11
1.175326540D-06	-7.377621810D-11
1.109967210D-06	-6.966957450D-11
1.051487800D-06	-6.599520920D-11
9.938563320D-07	-6.268828040D-11
9.512373770D-07	-5.969629740D-11
9.079474150D-07	-5.697631300D-11
8.694217930D-07	-5.449284900D-11
8.321899710D-07	-5.221634060D-11
7.988566920D-07	-5.012195300D-11
7.680875100D-07	-4.818867240D-11
7.395975240D-07	-4.639859790D-11
7.131425360D-07	-4.473638610D-11
6.885120290D-07	-4.318680970D-11
6.655235540D-07	-4.174440540D-11
6.440182050D-07	-4.039318870D-11
6.238569420D-07	-3.912642310D-11
6.049175710D-07	-3.793643150D-11
5.870922800D-07	-3.681643950D-11
5.702855770D-07	-3.576044730D-11
5.544125790D-07	-3.476312150D-11
5.393975810D-07	-3.381970540D-11
5.251728450D-07	-3.292594300D-11
5.116775820D-07	-3.207801480D-11
4.988570820D-07	-3.127248310D-11
4.866619720D-07	-3.050624590D-11
4.750475820D-07	-2.977649630D-11
4.639733950D-07	-2.908068870D-11
4.534025810D-07	-2.841650890D-11
4.433015790D-07	-2.778184840D-11
4.336397520D-07	-2.717478200D-11
4.243890660D-07	-2.659354840D-11
4.155238260D-07	-2.603653300D-11
4.070204310D-07	-2.550225300D-11
3.988571730D-07	-2.498934450D-11
3.910140420D-07	-2.449655020D-11
3.834725690D-07	-2.402270960D-11
3.762156810D-07	-2.356674990D-11
3.692275660D-07	-2.312767780D-11
3.624935640D-07	-2.270457210D-11
3.560000620D-07	-2.229657750D-11
3.497344020D-07	-2.190289850D-11
3.436848000D-07	-2.152279490D-11
3.378402690D-07	-2.115557630D-11
3.321905550D-07	-2.080059840D-11

TIME = 1.078D-01

TIME(SECS) =	0.0	1.000D-01	2.000D-01	3.000D-01	4.000D-0	5.000D-01	6.000D-01	7.000D-01
SECTION	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL
1	5.9518D-02	5.9521D-02	5.9524D-02	5.9526D-02	5.9529D-02	5.9531D-02	5.9532D-02	5.9532D-02

TIME(SECS) =	8.000D-01	9.000D-01	1.000D 00	1.100D 00	1.200D 00	1.300D 00	1.400D 00	1.500D 00
SECTION	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL
1	5.9532D-02	5.9531D-02	5.9529D-02	5.9526D-02	5.9524D-02	5.9522D-02	5.9519D-02	5.9518D-02

TIME(SECS) =	1.600D 00	1.700D 00	1.800D 00	1.900D 00	2.000D 00	2.100D 00	2.200D 00	2.300D 00
SECTION	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL
1	5.9516D-02	5.9516D-02	5.9516D-02	5.9517D-02	5.9518D-02	5.9521D-02	5.9524D-02	5.9526D-02

TIME(SECS) =	2.400 00	2.500 00	2.600 00	2.700 00	2.800 00	2.900 00	3.000 00	3.100 00
SECTION	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL
1	5.9529D-02	5.9531D-02	5.9532D-02	5.9532D-02	5.9532D-02	5.9531D-02	5.9529D-02	5.9526D-02

TIME(SECS) =	3.200 00	3.300 00	3.400 00	3.500 00	3.600 00	3.700 00	3.800 00	3.900 00
SECTION	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL
1	5.9524D-02	5.9522D-02	5.9519D-02	5.9518D-02	5.9516D-02	5.9516D-02	5.9516D-02	5.9517D-02

TIME(SECS) =	4.000 00	4.100 00						
SECTION	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL	DEFL
1	5.9518D-02	5.9521D-02						

TIME = 6.171D-01

GBRP OCT 7, 1966
RESPONSE TO RECTANGULAR IMPULSE

DATA CONTROL CARD

NO TYPE

END GBRP RUN

REFERENCE

1. Cuthill, E. H. and Henderson, F. M., "Description and Usage of General Bending Response Code 1 (GBRC1)," David Taylor Model Basin Report 1925 (July 1965).

BIBLIOGRAPHY

Weber, Ernst, "Linear Transient Analysis," Vol. II, John Wiley and Sons, Inc., New York, 1956.