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PROPELLANT SLOSH COUPLING WITH BENDING

FINAL REPORT

December 1969

Lockheed

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A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION

SUNNYVALE, CALIFORNIA

HREC-1485-2
LMSC/HREC D149410

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Contract NAS8-21485

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FOREWORD

This document presents a final report of a research program (Contract NAS8-21485) performed by Lockheed's Huntsville Research & Engineering Center (Lockheed/Huntsville), for NASA-Marshall Space Flight Center (NASA/MSFC).

Technical supervisor and coordinator of the contract were R. S. Ryan and H. J. Buchanan, respectively, both of the Aero-Astrodynamics Laboratory, NASA/MSFC.

SUMMARY

A new approach which employs the combined system modes instead of the bending and slosh modes separately in formulating the mathematical model of a liquid propellant vehicle is used to simulate the atmospheric flights of the Saturn V vehicle. The model includes two rigid-body motions, four system bending modes and a control system with high-order control dynamics. The aerodynamic forces, thrust, gravitational field and vehicle vibrational characteristics which are functions of flight time are represented by 21 time-varying coefficients. Propellant slosh forces and slosh amplitudes may be calculated after the responses of the vehicle are obtained.

An associated hybrid computer program was developed. The program uses the analog computer to perform the numerical integration of the system and the digital computer to compute and store the response parameters of the system when subjected to a large ensemble of wind samples. At the end of the first passage of the program, the mean values of the response parameters are calculated. The statistics of the wind and vehicle response are computed in the second passage of the program.

For an ensemble of 970 tape winds, the program takes less than five minutes of EAI 8900 hybrid computer time to provide the above data for Saturn V during its first 90 seconds of flight. The excellent computational speed suggests that the Monte Carlo hybrid simulation method is an effective and economic technique for conducting preliminary vehicle design studies.

CONTENTS

NOMENCLATURE

Symbols

a_o	attitude feedback control coefficient, rad/rad
a_1	attitude rate feedback control coefficient, rad/rad/sec
C_1	attitude coefficient associated with angle of attack, $1/sec^2$
C_2	attitude coefficient associated with engine deflection angle, $1/sec^2$
c_{4i}	attitude coefficient associated with the i^{th} system bending mode, $1/sec^2$
c_{5i}	i^{th} system bending coefficient associated with engine deflection angle, m/sec^2
$\overline{D}_i$	i^{th} system bending coefficient associated with angle of attack, m/sec^2
K_1	lateral motion coefficient associated with attitude, m/sec^2
K_2	lateral motion coefficient associated with angle of attack, m/sec^2
K_3	lateral motion coefficient associated with engine deflection angle, m/sec^2
$M'_\alpha(25, t)$	bending moment coefficient due to aerodynamic force at station 25, N-m/rad
$M'_\alpha(90, t)$	bending moment coefficient due to aerodynamic force at station 90, N-m/rad
$M_B(25, t)$	bending moment at station 25, N-m
$M_B(90, t)$	bending moment at station 90, N-m
$M'_\beta(25, t)$	bending moment coefficient due to engine deflection at station 25, N-m/rad

NOMENCLATURE (Continued)

Symbols

$M'_{\beta}(90, t)$	bending moment coefficient due to engine deflection at station 90, N-m/rad
$\left\| M'_{\ddot{\eta}}(25, t) \right\|_i$	i^{th} system bending moment coefficient at station 25, N-m/m/sec^2
$\left\| M'_{\ddot{\eta}}(90, t) \right\|_i$	i^{th} system bending moment coefficient at station 90, N-m/m/sec^2
p_{ni}	rotational acceleration coefficient associated with n^{th} beam and i^{th} system bending mode, dimensionless
s_{ki}	slosh coefficient associated with k^{th} tank and i^{th} system bending mode, dimensionless
t_{ni}	lateral acceleration coefficient associated with n^{th} beam and i^{th} system bending mode, dimensionless
V_m	vehicle velocity, m/sec
V_w	wind velocity, m/sec
$(Y'_G)_i$	slope at gyro point due to the i^{th} system bending mode, 1/m
$(Y'_R)_i$	slope at rate gyro due to the i^{th} system bending mode, 1/m
y	vehicle lateral displacement, m

Greek

α	angle of attack, rad
$(\alpha_2)_n$	n^{th} beam lateral acceleration, m/sec^2
β_E	engine deflection angle, rad

NOMENCLATURE (Continued)

Greek

δ_k	slosh amplitude at k^{th} tank wall, m
ζ_i	damping ratio of the i^{th} system bending mode, dimensionless
η_i	i^{th} system bending mode coordinate, m
$\ddot{\theta}_n$	n^{th} beam rotational acceleration, rad/sec^2
ξ_{k1}	first slosh mode coordinate associated with k^{th} tank, m
ω_i	i^{th} system bending mode frequency, rad/sec

Section 1
INTRODUCTION

To simulate the atmospheric flights of a liquid propellant space vehicle, the dynamics of the propellant are traditionally represented by a mass-spring-dashpot system (Refs. 1, 2 and 3). In the case of Saturn V, the mathematical model of the vehicle is limited to a dynamic system which consists of about 10 second-order ordinary differential equations. The improsed restriction is due to the capacity of a hybrid computer or the excessive computer time which may be required for a digital simulation. Consequently, only the dynamics of the propellant in three of the six tanks of the vehicle can be taken into account. The rest of the propellant is assumed to be solid masses attached to the vehicle. The model represents the vehicle adequately during liftoff; however, in the second half of the first-stage flight, propellant levels will decrease in height, and a proper description of the dynamic behavior of the propellant may require that higher slosh modes be considered. Furthermore, the propellant which was taken as solid masses may have a larger share in the contribution to the dynamics of the vehicle than the sloshing propellant.

Lockheed/Huntsville has introduced a system mode approach in formulating the mathematical model of a large complex liquid propellant space vehicle. The method uses the Lagrange equation for solving a coupled elastic and fluid system which characterizes a liquid propellant vehicle (Ref. 4). The modeling of a vehicle now considers the system bending modes instead of the bending modes and slosh modes of a vehicle. As a consequence, the dynamics of the liquid propellant will always be taken into account and the size of the mathematical model will be smaller than that obtained from the conventional approach.

After the mathematical model of a vehicle is adopted, the statistical response of the vehicle can be obtained analytically as well as numerically (Refs. 2, 3 and 5). Also, depending on the required accuracy, computation time, capability of the computer and the complexity of the model, the atmospheric flights of a vehicle can be simulated on an analog, digital or hybrid computer. Presently, the following four methods may be used for flight simulations (Ref. 6):

1. Monte Carlo hybrid simulation,
2. Monte Carlo digital simulation,
3. State Space method and
4. Sampling Model method.

Although a judicious choice among the methods is controversial, the speed of the analog computation in performing the repetitive numerical integrations of a dynamic system suggests that hybrid simulation is definitely a good and economical method for conducting the preliminary design studies of a vehicle. The objective of this research effort is to show the feasibility of using the system mode approach in formulating mathematical models and of using hybrid flight simulations for Saturn V or future non-beamlike space vehicles.

Section 2
MONTE CARLO SIMULATION METHOD

To ensure a successful launch of a space vehicle, the vehicle must be designed for all possible wind disturbances encountered during its atmospheric flight. Since the wind field is of a random nature and is difficult to define, a statistical approach should be used to determine the dynamic response of a vehicle to wind disturbances. One of the statistical approaches which is currently used in flight simulations is called the Monte Carlo simulation method (Ref. 6). The method employs the fast computational speed and unlimited storage spaces of modern computers to simulate the passage of a vehicle through a large number of recorded wind profiles. The statistics of the vehicle response are computed from the ensemble of the calculated responses. Depending on the required accuracy, computational time and the complexity of a mathematical model, the method can be executed on a digital computer or a hybrid computer.

In general, the digital simulation provides good accuracy and, virtually no limitation on the size of a mathematical model. However, its application to dynamic statistical response studies is often prohibited by the excessive computer time which is needed in performing the repetitive numerical integrations of a system. In case an additional system mode or a nonlinear mathematical model needs to be considered, computational time will increase drastically. Fortunately, in preliminary design or parametric studies, the accuracy of the vehicle response becomes less critical if the simulation can show the basic characteristics of the system properly. In addition, the computational speed of an analog computer will not be affected if nonlinear mathematical models are considered. Hence, hybrid simulation may be used to obtain the statistical response of a dynamic system. Since the size of a hybrid simulation program often needs to be reduced to suit the capacity of a hybrid computer, engineering judgment will play a major role in the modeling of a complex vehicle. The conclusion of this study is that digital simulation may be employed for spot checks of a dynamics analysis. Hybrid simulation should be used to conduct preliminary vehicle design studies.

Section 3
MATHEMATICAL MODEL

The system mode approach is used to model the Saturn V vehicle. An associated hybrid computer program was developed to compute the statistical response of the vehicle to 970 tape wind disturbances. In order to provide a good quantitative study and, at the same time, to accommodate the hybrid computer program in the Lockheed/Huntsville computer, engineering judgment and compromises among accuracy, computational speed and other considerations were made in formulating the following mathematical model of Saturn V. The model includes two rigid-body motions, four system bending modes and a control system with high-order control dynamics. Data used in the simulation were obtained from different sources. Approximations and extrapolations were also employed to define some of the vehicle parameters. Data related to the aerodynamic forces, thrust, nominal trajectory, gravitational field and the wind tape were obtained from Ref. 3 and R. S. Ryan of the Dynamics & Control Division, Aero-Astrodynamics Laboratory, MSFC. Vehicle bending and sloshing data were generated from the Tandem Beam-Slosh Computer Program developed under this contract (Ref. 4).

The equations of motion of the model are given below. Further discussions of these equations can be found in Refs. 2 and 7.

$$\alpha = \phi - \frac{\dot{y}}{V_m} + \frac{V_w}{V_m} \tag{1}$$

$$\ddot{y} = K_1 \phi + K_2 \alpha + K_3 \beta_E \tag{2}$$

$$\ddot{\phi} = C_1 \alpha + C_2 \beta_E + \sum_{i=1}^{4} c_{4i} \eta_i \qquad (3)$$

$$\ddot{\eta}_i = -2 \zeta_i \omega_i \dot{\eta}_i - \omega_i^2 \eta_i + \bar{D}_i \alpha + c_{5i} \beta_E \qquad (4)$$

$$(i = 1, 2, 3, 4)$$

Notations used in Eqs. (1) through (4) are defined below. Numerical data of the coefficients are given in Figs. A-1 through A-9 and Table A-1 of Appendix A. Wind samples which have been converted as functions of flight time are provided for the simulation through an analog wind tape.

α = angle of attack

β_E = engine deflection angle

ζ_i = damping ratio of the i^{th} system bending mode

η_i = i^{th} system bending mode coordinate

ω_i = i^{th} system bending mode frequency

ϕ = attitude angle

C_1 = attitude coefficient associated with angle of attack

C_2 = attitude coefficient associated with engine deflection angle

c_{4i} = attitude coefficient associated with the i^{th} system bending mode

c_{5i} = i^{th} system bending coefficient associated with engine deflection angle

$\bar{D}_i$ = i^{th} system bending coefficient associated with angle of attack

K_1 = lateral motion coefficient associated with attitude

K_2 = lateral motion coefficient associated with angle of attack

K_3 = lateral motion coefficient associated with engine deflection angle

V_m = vehicle velocity

V_w = wind velocity

y = vehicle lateral displacement

The control system of the model is

$$\beta_E = T(\beta_c)\left\{a_o F(\Phi)\left[\phi + \sum_{i=1}^{4}(Y'_G)_i\,\eta_i\right] + a_1 F(\dot{\Phi})\left[\dot{\phi} + \sum_{i=1}^{4}(Y'_R)_i\,\dot{\eta}_i\right]\right\} \tag{5}$$

where

$$T(\beta_c) = \frac{1}{\left[\frac{s^2}{(34.48)^2} + \frac{2(0.434)s}{34.48} + 1\right]\left[\frac{s^2}{(84.09)^2} + \frac{2(0.594)s}{84.09} + 1\right]}$$

$$F(\Phi) = \frac{\sum_{i=0}^{2} p_i s^i}{\sum_{i=0}^{3} q_i s^i}$$

$$F(\dot{\Phi}) = \frac{\sum_{i=0}^{4} p_i^* s^i}{\sum_{i=0}^{5} q_i^* s^i}$$

where s denotes the Laplace operator and

$$p_o = 0.60051 \qquad q_o = 1.0$$

$$p_1 = 0.055535 \qquad q_1 = 0.24335$$

$$p_2 = 3.7209 \times 10^{-3} \qquad q_2 = 8.2079 \times 10^{-3}$$

$$q_3 = 0.090539 \times 10^{-3}$$

$$p_o^* = 0.99253 \qquad q_o^* = 1.0$$

$$p_i^* = 0.014998 \qquad q_i^* = 0.62648$$

$$p_2^* = 0.011931 \qquad q_2^* = 0.12300$$

$$p_3^* = 0.099515 \times 10^{-3} \qquad q_3^* = 8.7553 \times 10^{-3}$$

$$p_4^* = 0.021996 \times 10^{-3} \qquad q_4^* = 0.20157 \times 10^{-3}$$

$$q_5^* = 1.9072 \times 10^{-6}$$

Functions $T(\beta_c)$, $F(\Phi)$ and $F(\dot{\Phi})$ are the engine command, attitude and attitude rate transfer functions of the system, respectively. The coefficients a_o, a_1, $(Y'_G)_i$ and $(Y'_R)_i$ are the attitude gain, attitude rate gain, slope at gyro point associated with i^{th} system bending mode and slope at rate gyro associated with i^{th} system bending mode, respectively. Their numerical values are given in Table A-1 of Appendix A. The above control system was modified by Ryan. Detailed discussion and additional references on the control system can be found in Ref. 8.

The bending moments at stations 25 and 90 of Saturn V are calculated from Eqs. (6) and (7), respectively (Ref. 2).

$$M_B(25,t) = M'_\alpha(25,t)\,\alpha + M'_\beta(25,t)\,\beta_E + \sum_{i=1}^{4} \left[M'_{\ddot{\eta}}(25,t)\right]_i \ddot{\eta}_i \tag{6}$$

$$M_B(90,t) = M'_\alpha(90,t)\,\alpha + M'_\beta(90,t)\,\beta_E + \sum_{i=1}^{4} \left[M'_{\ddot{\eta}}(90,t)\right]_i \ddot{\eta}_i \tag{7}$$

where

$M'_\alpha(25,t)$, $M'_\alpha(90,t)$ = bending moment coefficients due to aerodynamic force at stations 25 and 90, respectively.

$M'_\beta(25,t)$, $M'_\beta(90,t)$ = bending moment coefficients due to engine deflection at stations 25 and 90, respectively.

$\left[M'_{\ddot{\eta}}(25,t)\right]_i$, $\left[M'_{\ddot{\eta}}(90,t)\right]_i$ = i^{th} system bending moment coefficients at stations 25 and 90, respectively.

Their values are presented in Figs. A-10, A-11 and Table A-1 of Appendix A.

The free vibrational characteristics of Saturn V are found by modeling the vehicle as a series of four beams (Fig. 1). The deflection of each beam is described by four fundamental deflection functions. The dynamics of the liquid propellant contained in each tank is represented by its first slosh mode. Bending properties of the vehicle are obtained from the NASA/MSFC Stodola tape. Slosh modes and frequencies of the liquid propellant contained in the

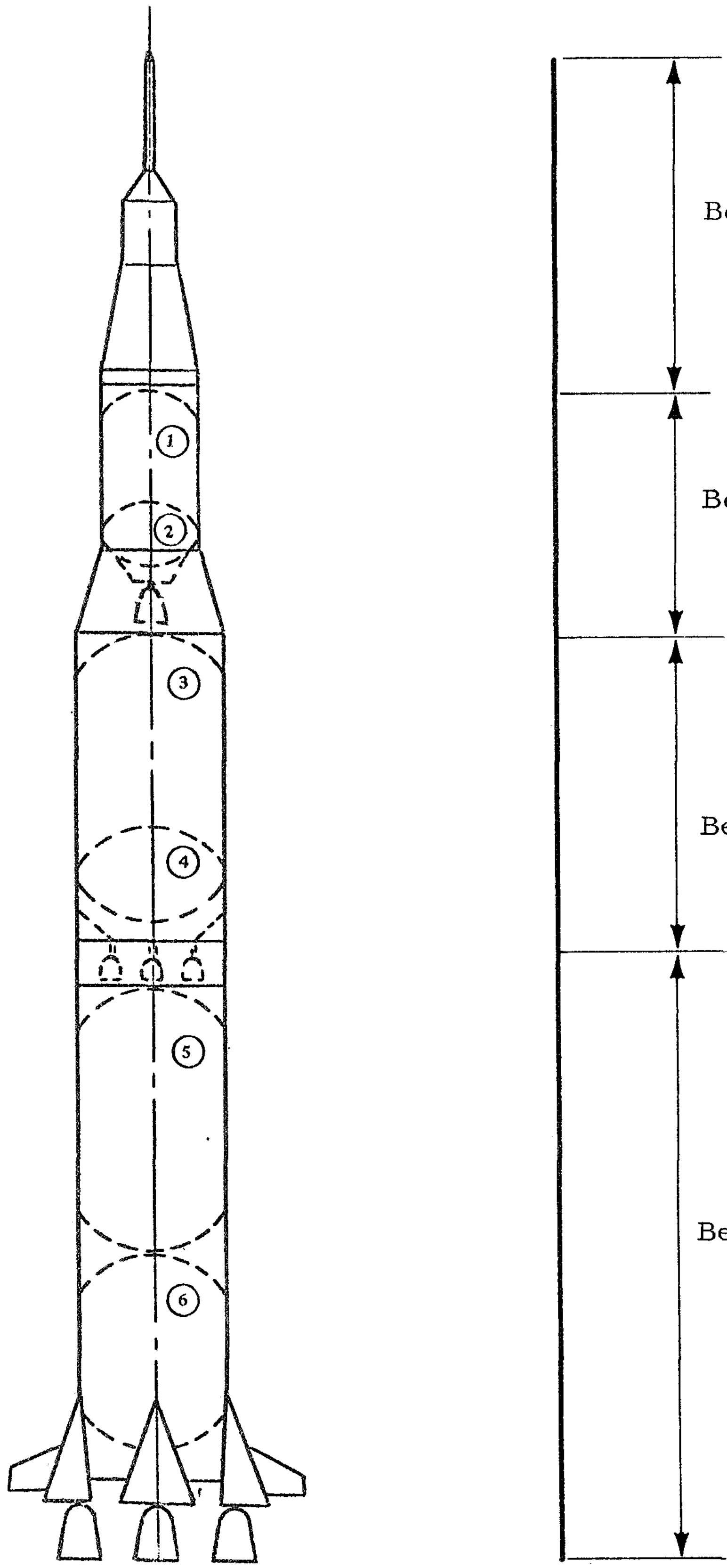


Fig. 1 - Saturn V Vehicle Configuration

Saturn V tanks are calculated from the Lomen program (Ref. 9). Consequently, the generalized coordinates of this system are five beam end displacements, 16 fundamental beam deflection coefficients and six slosh coefficients.

The system modes, frequencies and other quantities of the above Saturn V model are computed from a Lockheed/Huntsville tandem beam slosh program, developed under the same contract.

The first four system bending modes of Saturn V during its first 90 seconds of flight are selected as those shown in Figs. A-15 through A-20 of Appendix A.

Slosh amplitudes and local accelerations are calculated from Eqs. (8) through (11) after the dynamic response of the vehicle is found.

$$\delta_k = b_k \sum_{i=1}^{4} s_{ki} \eta_i \tag{8}$$

$$(\alpha_2)_n = - \ddot{y} + \sum_{i=1}^{4} t_{ni} \ddot{\eta}_i \tag{9}$$

$$\ddot{\theta}_n = - \ddot{\phi} + \sum_{i=1}^{4} p_{ni} \ddot{\eta}_i \tag{10}$$

$$\xi_{k1} = \sum_{i=1}^{4} s_{ki} \eta_i \tag{11}$$

where

$b_1 = 0.5229$, $b_2 = 0.5390$, $b_3 = 0.5431$,

$b_4 = 0.6042$, $b_5 = 0.6020$, $b_6 = 0.6630$

Notations used in Eqs. (8) through (11) are defined below. Numerical values of the coefficients are given in Figs. A-12 to A-14 of Appendix A.

δ_k = slosh amplitude at k^{th} tank wall

$(\alpha_2)_n$ = n^{th} beam lateral acceleration

$\ddot{\theta}_n$ = n^{th} beam rotational acceleration

ξ_{k1} = first slosh mode coordinate associated with k^{th} tank

s_{ki} = slosh coefficient associated with k^{th} tank and i^{th} system bending mode

t_{ni} = lateral acceleration coefficients associated with n^{th} beam and i^{th} system bending mode

p_{ni} = rotational acceleration coefficient associated with n^{th} beam and i^{th} system bending mode

With the above information, the lateral slosh force distribution along the vehicle longitudinal axis can be calculated. Detailed discussions and derivations of the system mode approach are given in Ref. 4.

Section 4
HYBRID COMPUTER PROGRAM

Lockheed/Huntsville has an inhouse EAI 8900 hybrid computer which provides digital, analog and hybrid capabilities for solving complex engineering and scientific problems. The digital computer is general purpose with a high-speed 16K memory and a complete complement of software. The analog computer performs parallel integration to obtain rapid solutions to systems of differential equations in real time or faster. Special software is used to program the hybrid interface, set up and check out simulation, and debug programs.

A hybrid program based on the mathematical model defined in Section 3 was developed to simulate the atmospheric flights of Saturn V. The program uses the analog computer to perform the repetitive numerical integration of the system and the digital computer to control program logic while calculating and storing the response parameters of the system. In order to accommodate the model with the currently available equipment of the computer, curve fitting was employed to approximate some of the time-varying coefficients. The program is designed to simulate the first 90 seconds of the flight and to record the response parameters of the vehicle at every five seconds of flight time without slowing down the analog computation. At the end of the first passage of the program, the mean values of the vehicle responses are computed. Standard deviations of the response parameters are computed in the second passage of the program. The number of exceedance counts, envelopes and plots of certain response parameters are obtained during the run. Consequently, the program will provide the following features in a single run:

1. Response of an individual flight
2. Envelope of a response parameter

3. Mean values and variances of response parameters
4. Number of exceedance counts for a response parameter
5. Statistics of the wind.

For an ensemble of 970 tape winds, the program takes less than five minutes of EAI 8900 hybrid time to compute the above data for Saturn V during its first 90 seconds of flight. The excellent execution speed obtained in this study justifies the conclusion that the Monte Carlo hybrid simulation technique is indeed an effective method for determining the statistical response of a launch vehicle.

The wiring diagrams of the analog program are given in Appendix B. A listing of the digital program is presented in Appendix C. Detailed discussions and additional references on hybrid computation can be found in Refs. 10 and 11.

Section 5
EXAMPLE – STATISTICAL RESPONSE OF SATURN V

The mathematical model defined in Section 3 was used to obtain the response of the Saturn V vehicle to wind disturbances. Effort was made to show that the system mode approach and hybrid simulation are good methods for determining the statistical response of a liquid propellant space vehicle. Additional parametric studies and improvement of the model are needed in order to provide a good quantitative response study of Saturn V.

The developed hybrid program provides the following information:

1. Traces of β_E, β_C, α, $\ddot{y}$, $M_B(90,t)$, $M_B(25,t)$, V_w, η_1, η_2, η_3, η_4, ϕ, $F(\Phi)$, $\dot{\phi}$, $F(\dot{\Phi})$ and timing pulses;

2. Number of exceedance counts of β_E, $M_B(90,t)$ and $M_B(25, t)$ through comparators;

3. Number of exceedance counts of δ_4, δ_5 and δ_6 through digital computation;

4. The mean values, σ^2 and 3σ of β_E, $M_B(90,t)$, $M_B(25,t)$ and V_w, where σ denotes the standard deviation of a variable;

5. The mean values of α, ϕ, δ_k, $(\alpha_2)_n$, $\ddot{\theta}_n$ and ξ_{kl}, where $k = 1,2,\ldots,6$ and $n = 1,2,3$.

As an example, a model which includes the first three system bending modes was used to compute the statistics of Saturn V to 970 tape winds. Output of the hybrid program for the first 90 sec of flight was studied. Some of the results are presented below. The envelope of the 970 tape winds is shown in Fig. 2. The NASA/MSFC synthetic wind profile (Ref. 3) was used to check out the program. Traces of the variables during this slow run are given in Fig. 3. Fig. 4 provides "stretched-out" traces of the variables during fast runs to tape wind disturbances. The scales of these traces are defined in Table A-2 of Appendix A. The mean values and 3σ values of V_w, β_E, M_B (90, t) and M_B (25,t) are given in Fig. 5. Percentage of the number of exceedance counts of M_B (90,t), M_B (25,5), δ_k (k = 4, 5, 6) are given in Fig. 6.

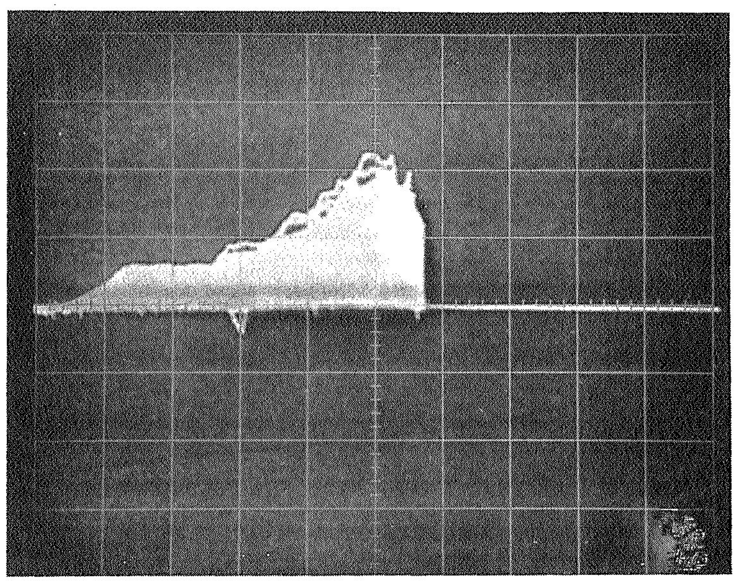


Fig. 2 - Envelope of Tape Winds

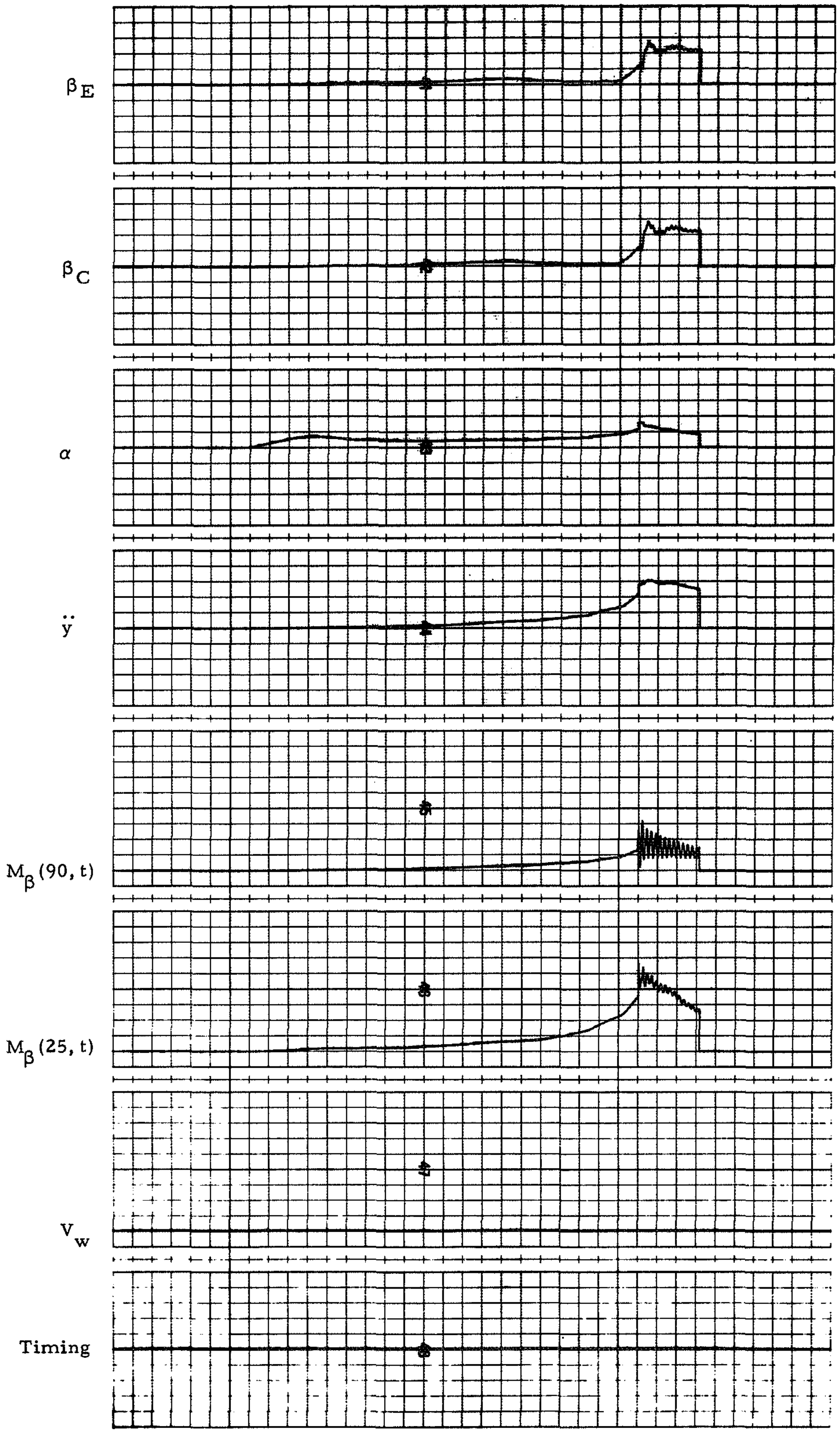


Fig. 3 - Traces of Variables of the Checkout Run

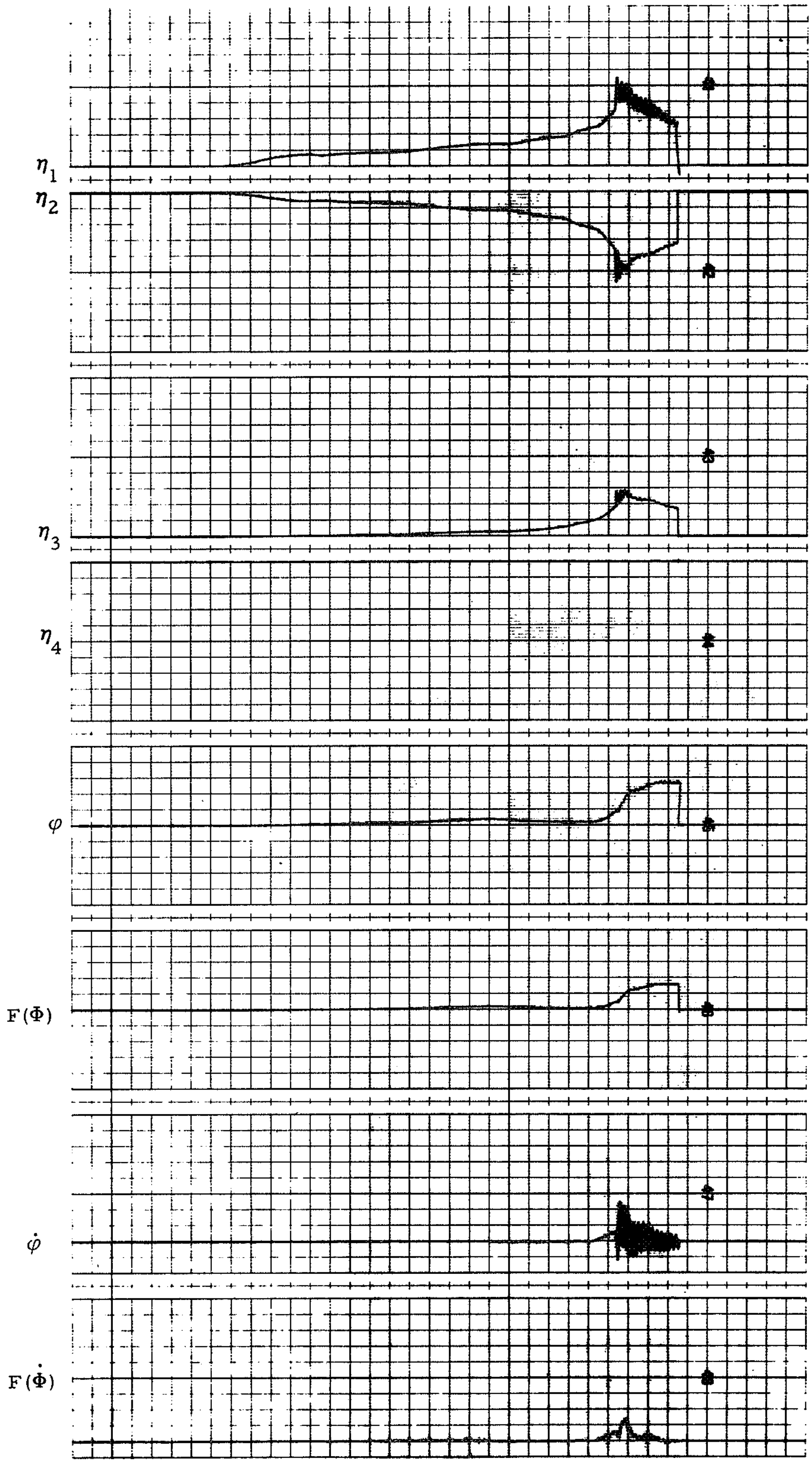


Fig. 3 - (Continued)

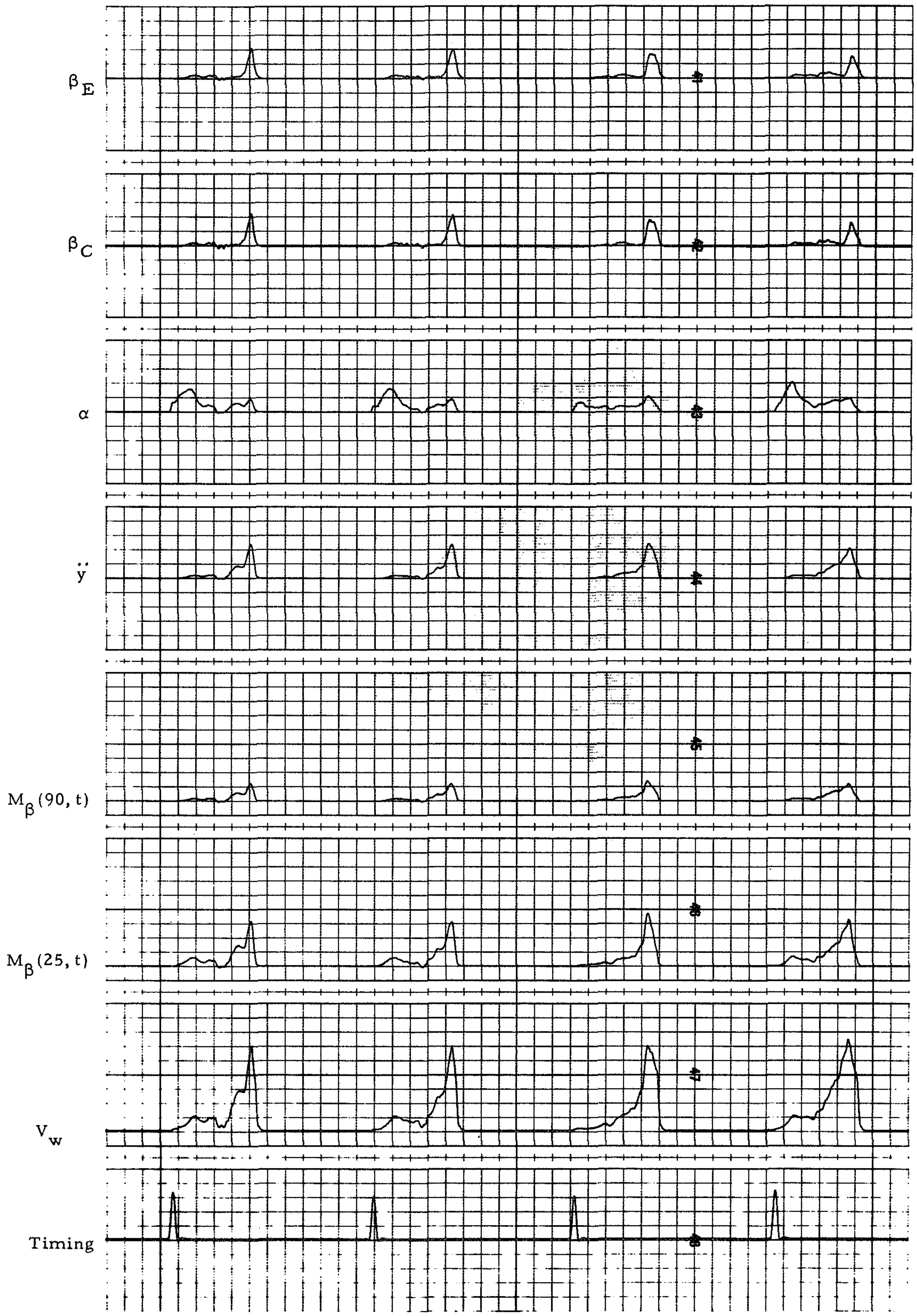


Fig. 4 - Stretched Traces of the Variables During Fast Runs

Fig. 4 - (Continued)

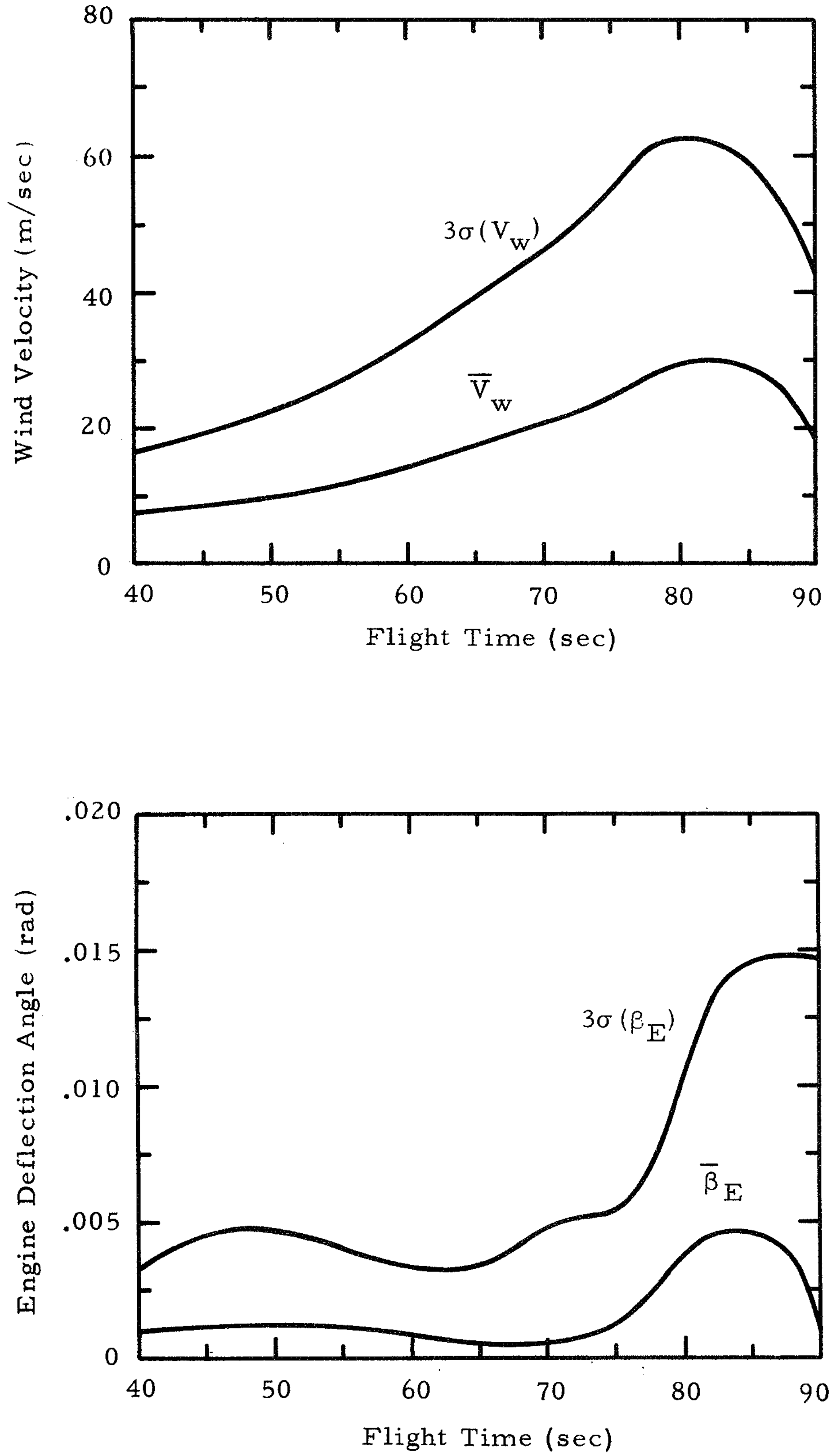
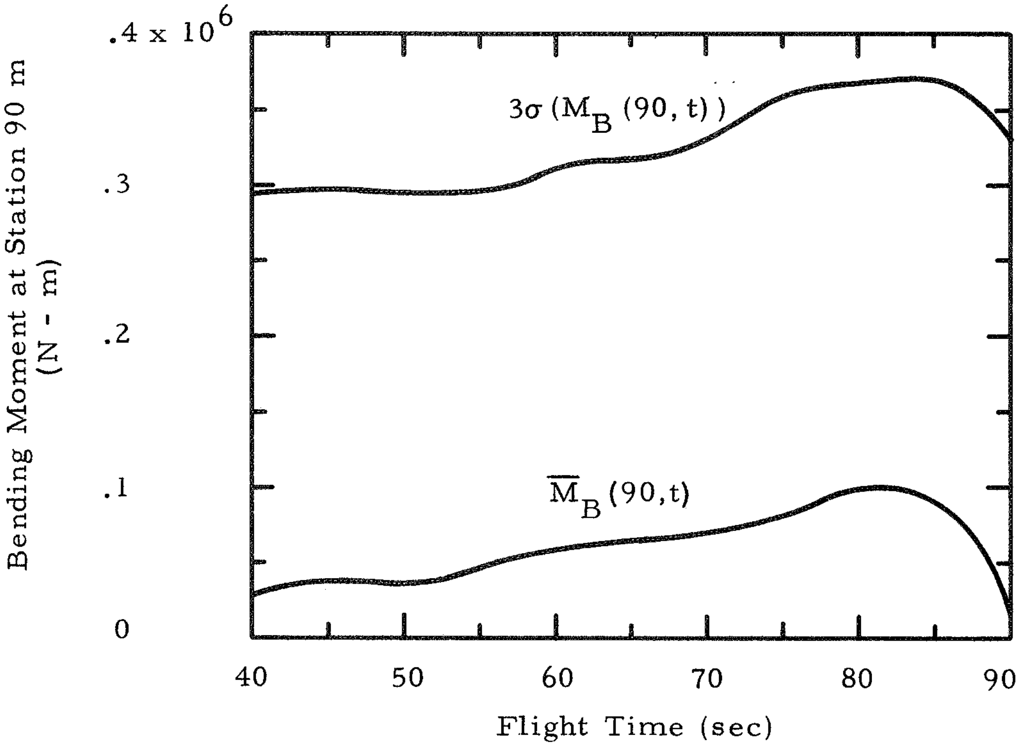


Fig. 5 - Statistics of the Tape Winds and Certain Response Parameters of Saturn V



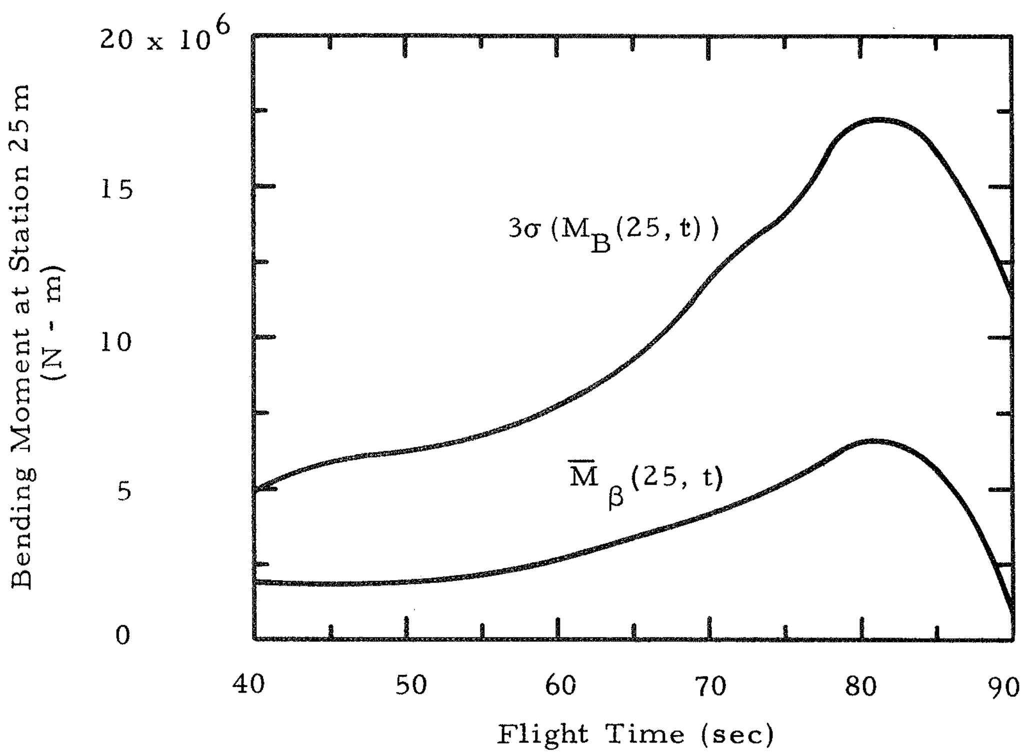


Fig. 5 (Continued)

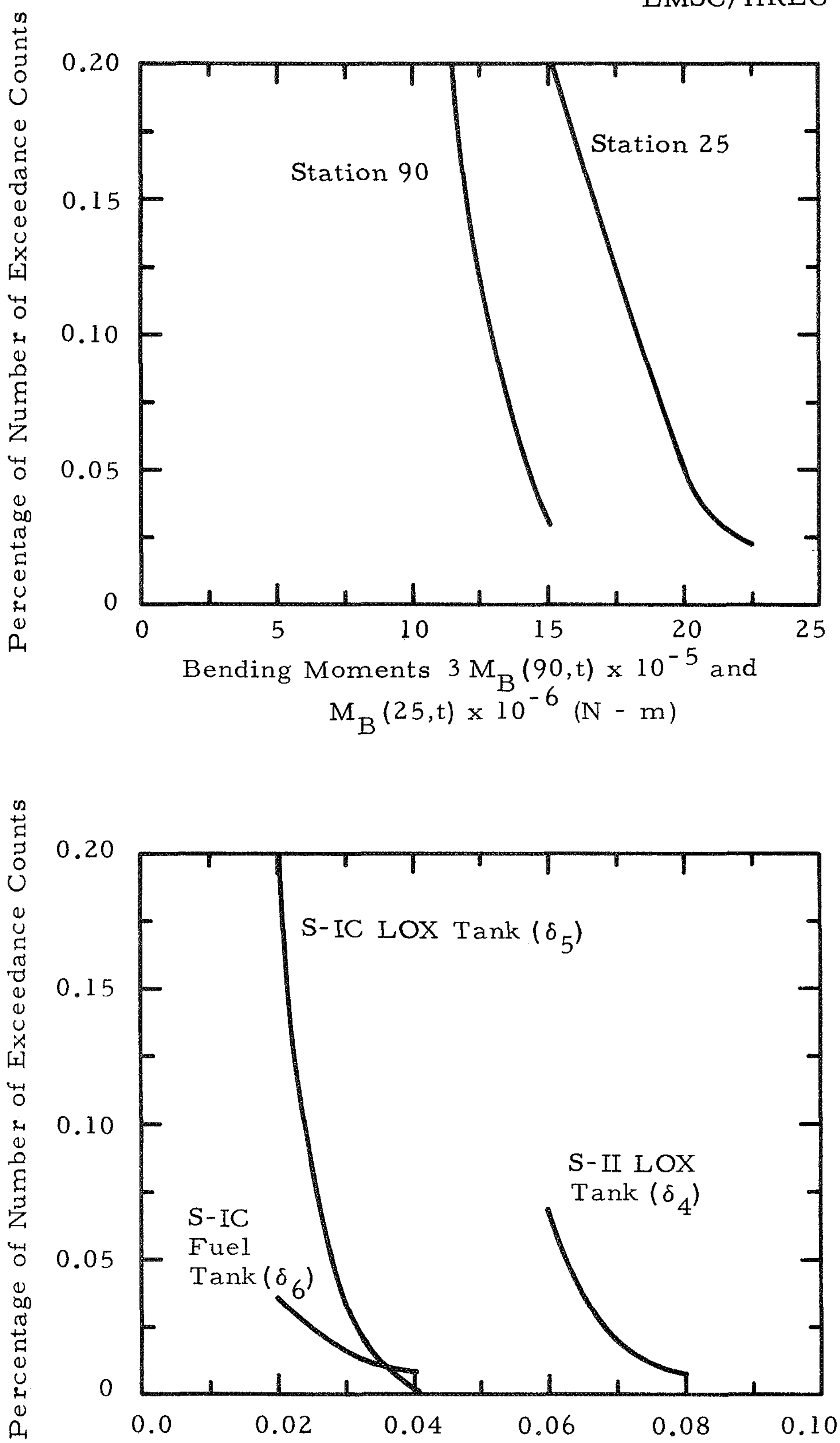


Fig. 6 - Percentage of the Number of Exceedance Counts for the First 90 Seconds of Saturn V Atmospheric Flight

Section 6
CONCLUSIONS AND RECOMMENDATIONS

The advantage of using the system mode approach in formulating a mathematical model of Saturn V for its atmospheric flight simulations was demonstrated. Future space vehicles, such as space shuttles, will have non-beamlike configurations. Based on the present preliminary designs, the vehicle will carry a large amount of liquid propellant during its atmospheric flight. In addition, a large number of structural modes must be included to model the vehicle properly. The system mode approach is possibly the only method which could provide a good mathematical model for flight simulations on a computer. Also, this research effort has shown that the Monte Carlo hybrid simulation technique is an excellent method in obtaining the statistical response of a vehicle. It is an especially powerful method for conducting preliminary design or parametric studies of a vehicle.

With the experience which has been obtained from various flight simulation studies of Saturn V (Ref. 6), one could carry the present state of art one step further. For instance, additional research effort may be made in the following areas.

1. <u>The Sampling Rate of Hybrid Simulations</u>: The wind tapes which Lockheed/Huntsville and Computer Sciences Corporation (Ref. 3) used in the hybrid and analog simulations, respectively, are functions of flight time. This means that the atmospheric flights of a vehicle are simulated on a predetermined trajectory. It would be preferable for the wind tape to be a function of altitude. Then, flight simulations could be perturbed on any arbitrary nominal trajectory with the necessity of making only one wind tape. Furthermore, if a nonlinear or an advanced mathematical model should be used, the trajectory of a flight may be defined as a parameter which depends

on both time and vehicle response. However, two problem areas need to be resolved before the new wind tape can be used in a hybrid simulation:

- The wind data may have to be stored in the digital computer and fed into the analog computer at discrete points during a computer run. Delays due to the repetitive ADC and DAC operations need to be studied.

- The sampling rate of a hybrid simulation must be defined such that the high frequency components of the wind can be properly presented.

2. Hybrid Simulation of Nonlinear Mathematical Models: Techniques and programs developed for flight simulations have all been based on linear mathematical models. The modeling of a vehicle often leads to nonlinear dynamic systems. Since the hybrid simulation is so fast, and nonlinear systems present no difficulty in analog computation, accurate solutions may be obtained if nonlinear mathematical models can be also used in flight simulations.

3. Sampling Model Method for Flight Simulations: The sampling model method is a compromise between the methods of State Space and Monte Carlo simulation (Ref. 5). In this method, a sampling model picks winds from the wind sample population in accordance with its appropriate probability distribution. The same statistics of the vehicle response may be obtained by simulating the passage of a vehicle through only part of the wind samples. Since each wind sample has its own time history, to define a sampling model may be more complicated than solving the problems which can be treated directly by applying the standard techniques of statistics (Refs. 12 and 13). However, this approach may eliminate the limitations which are often encountered in other simulation techniques, such as accuracy, capacity and execution time.

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Appendix A

VEHICLE PARAMETERS AND COEFFICIENTS OF SATURN V

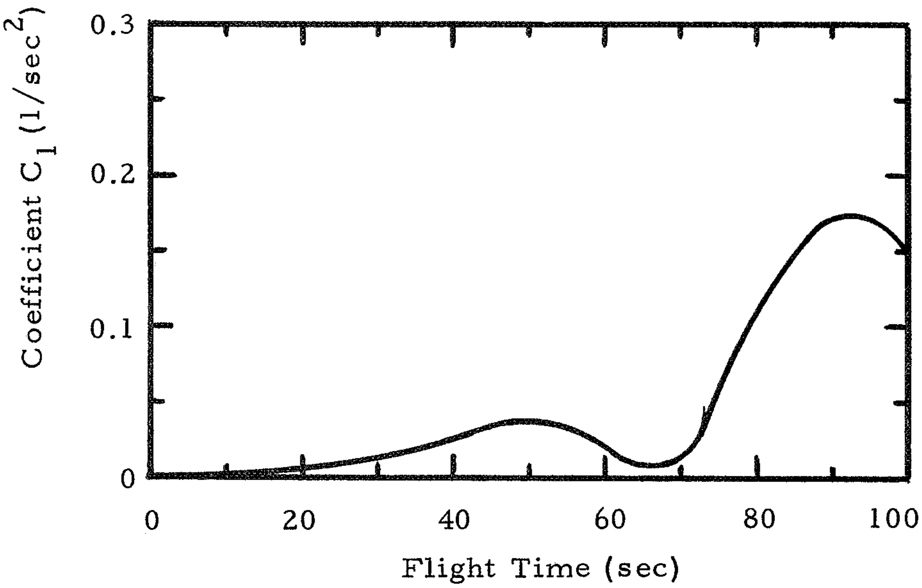


Fig. A-1 - Attitude Coefficient Associated with Angle of Attack

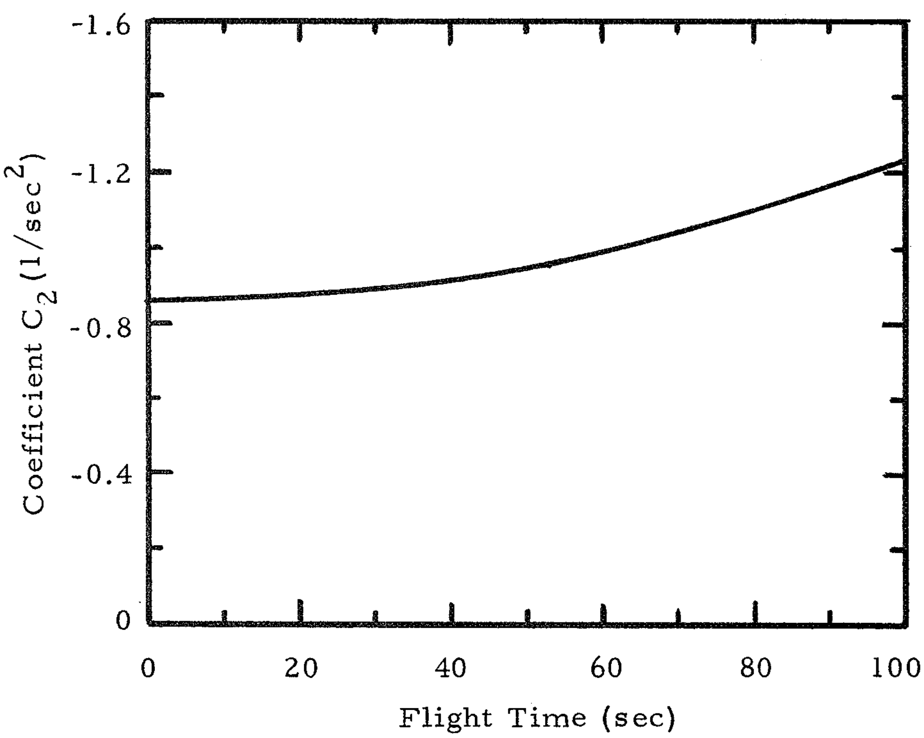


Fig. A-2 - Attitude Coefficient Associated with Engine Deflection Angle

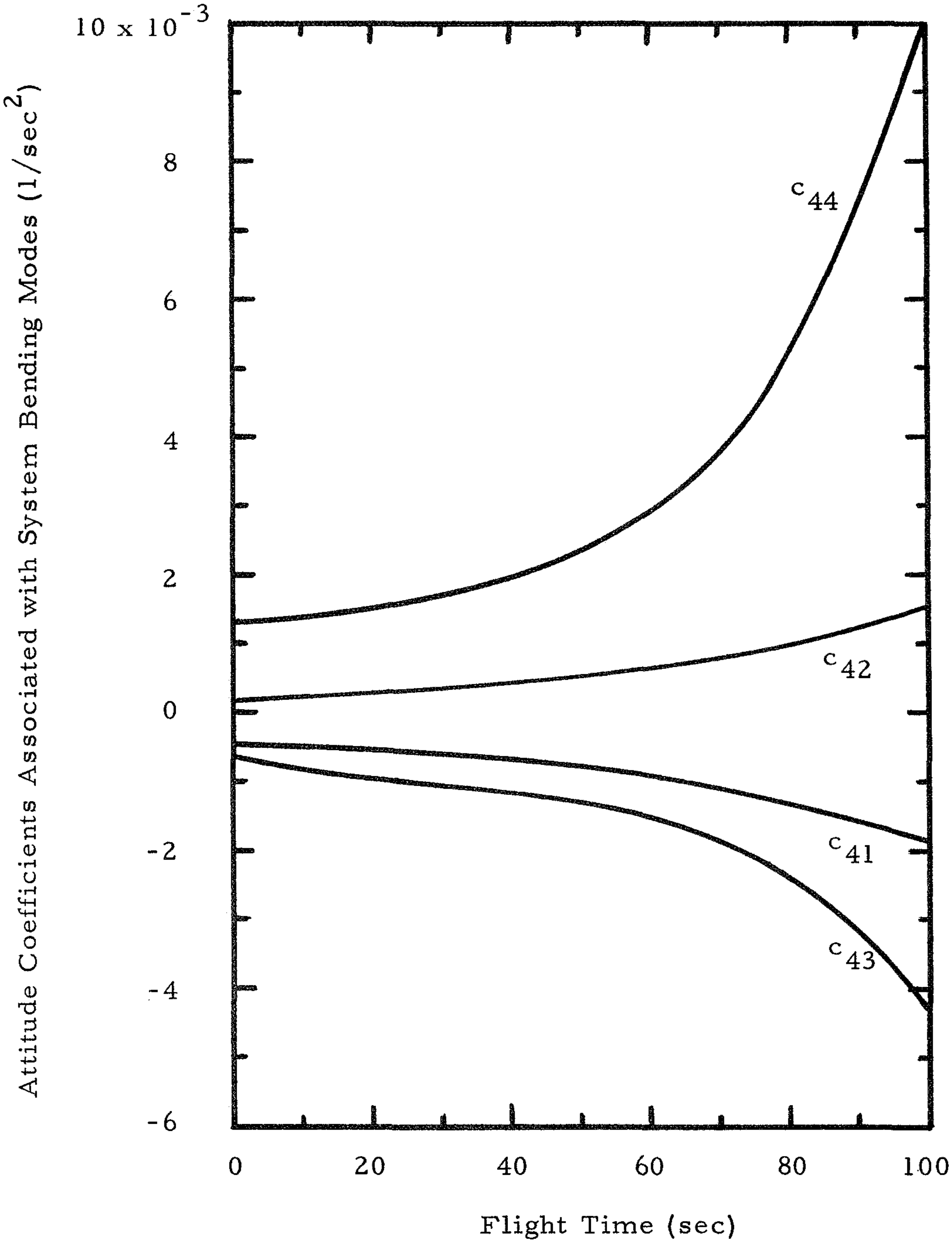


Fig. A-3 - Attitude Coefficient Associated with System Bending Modes

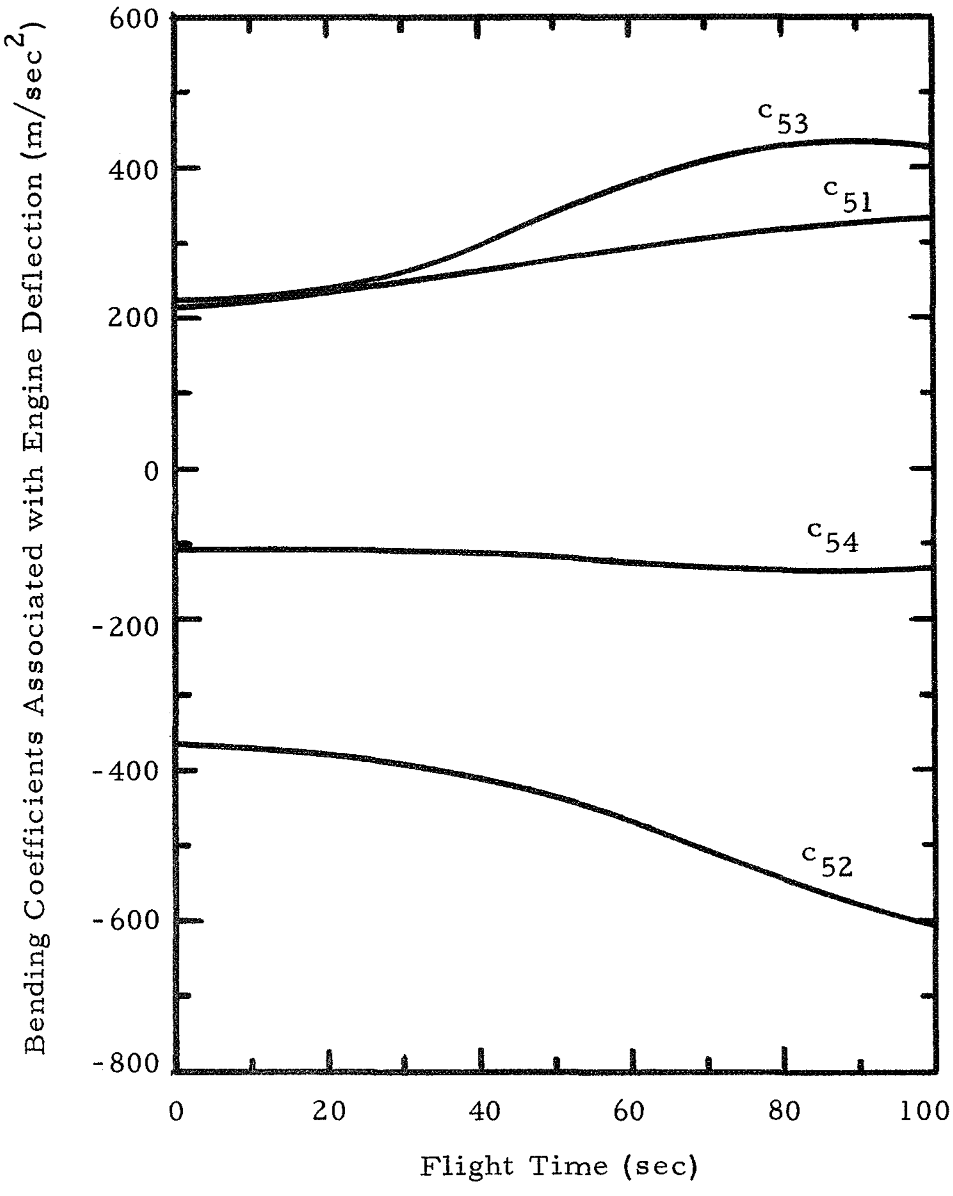
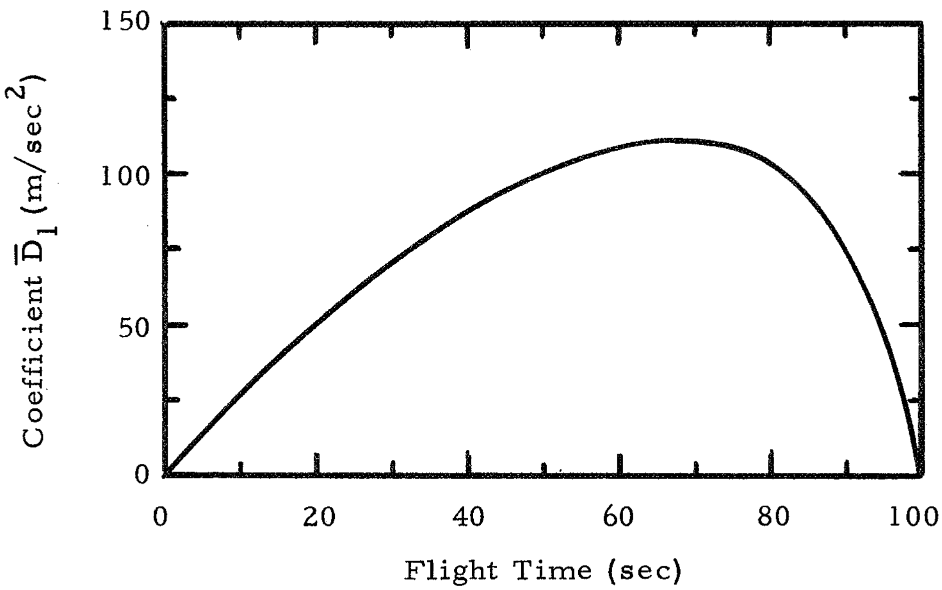


Fig. A-4 - Bending Coefficient Associated with Engine Deflection Angle



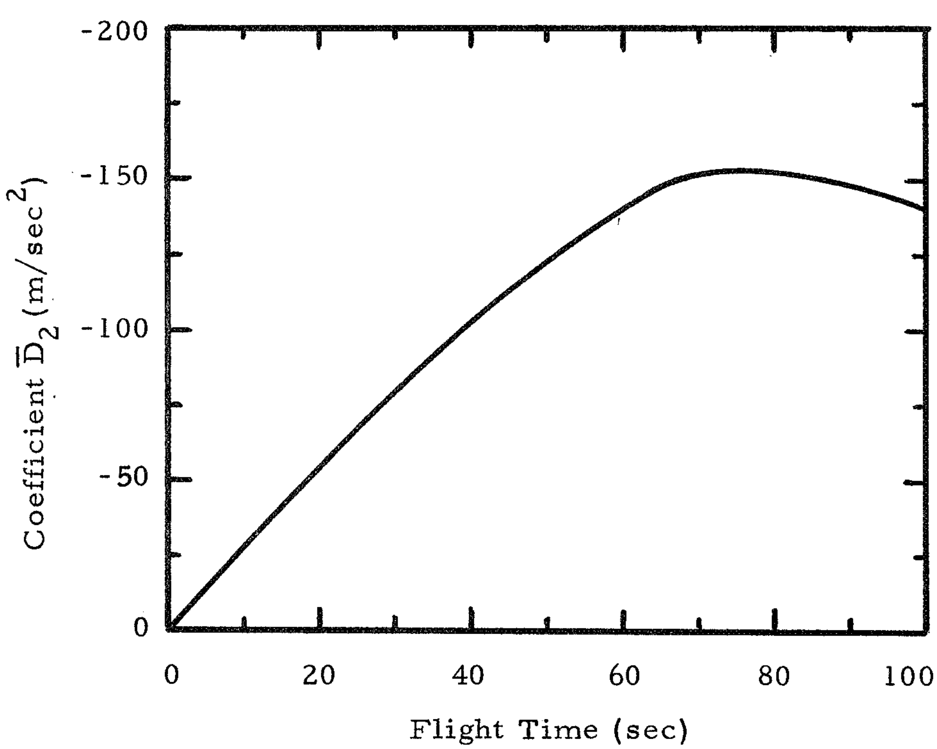
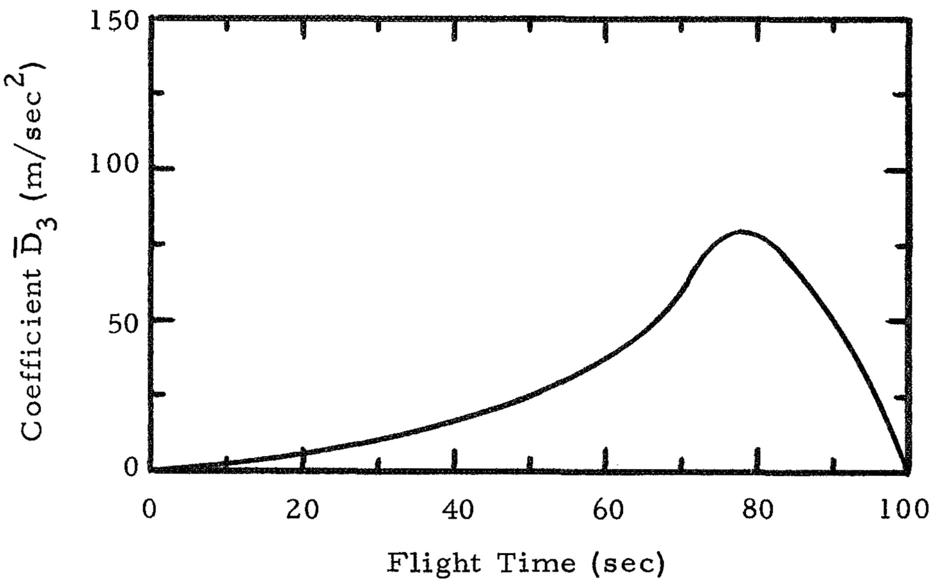
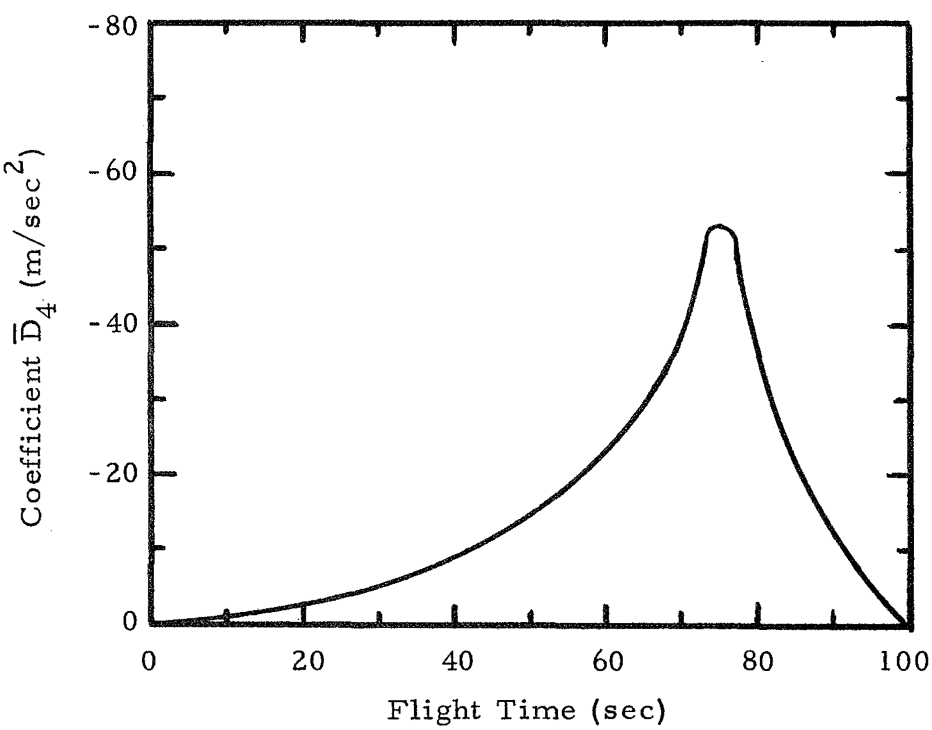


Fig. A-5 - System Bending Coefficients Associated with Angle of Attack





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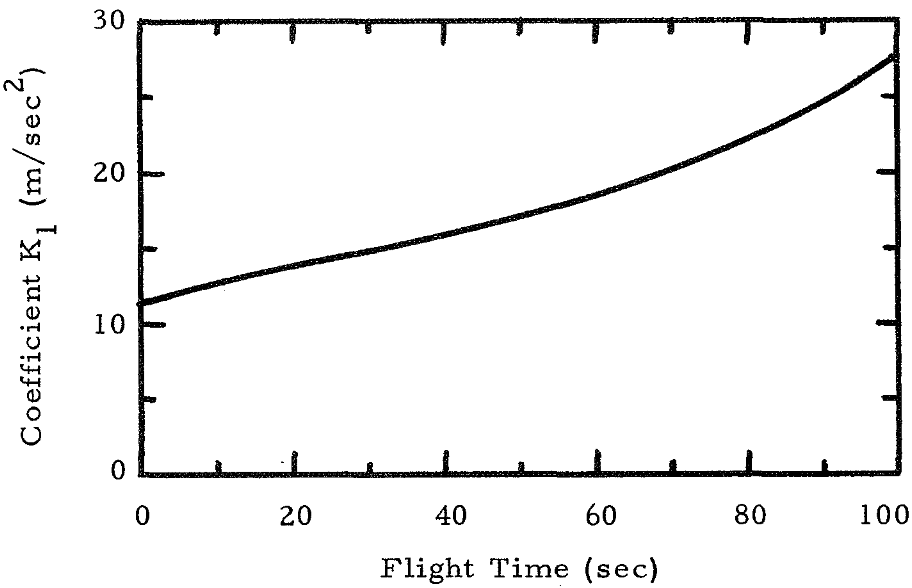


Fig. A-6 - Lateral Motion Coefficient Associated with Attitude

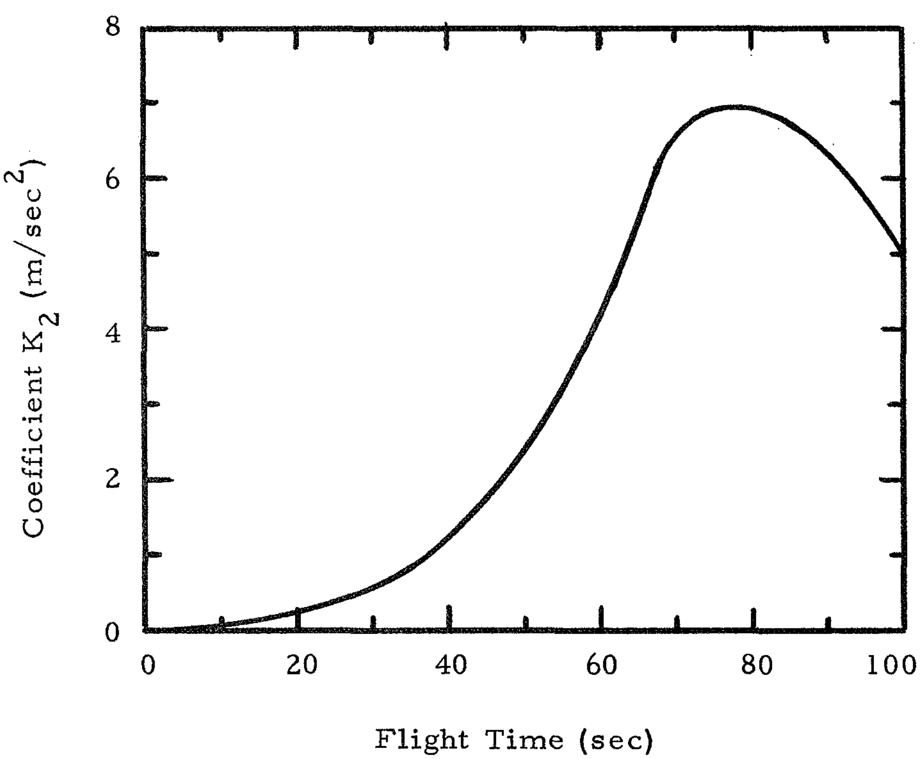


Fig. A-7 - Lateral Motion Coefficient Associated with Angle of Attack

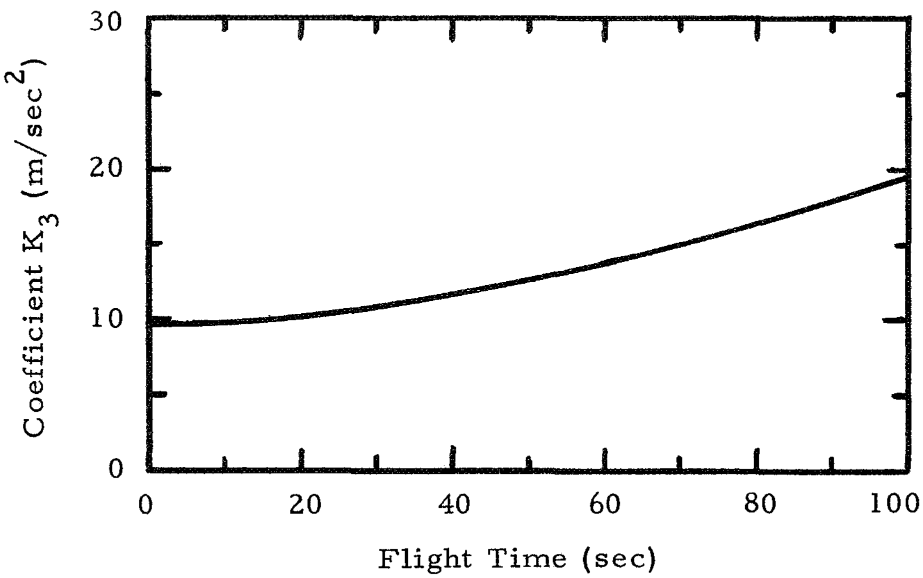


Fig. A-8 - Lateral Motion Coefficient Associated with Engine Deflection Angle

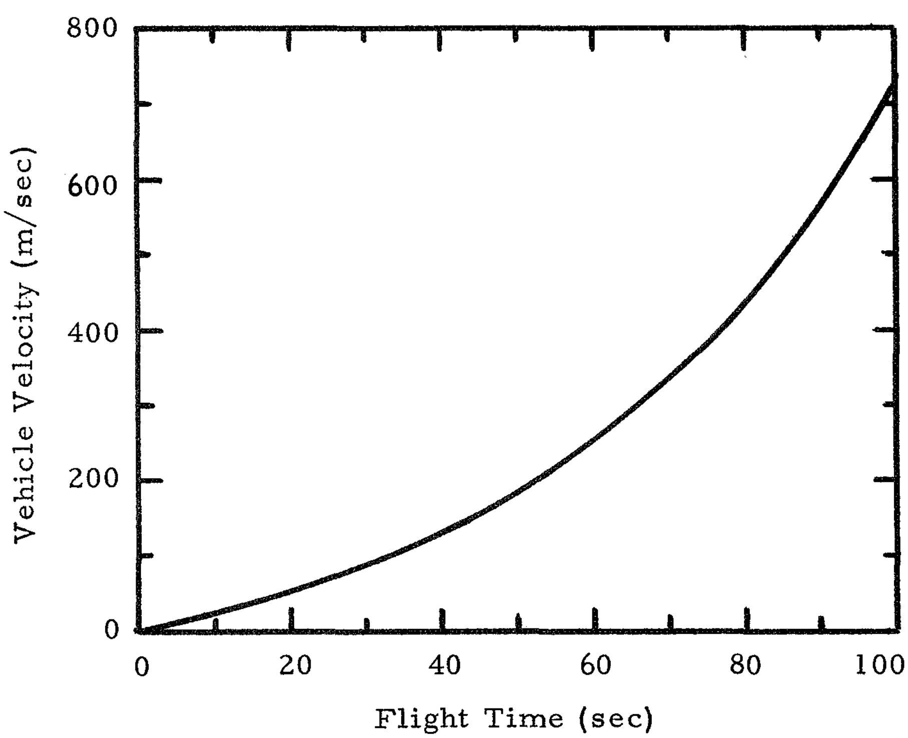
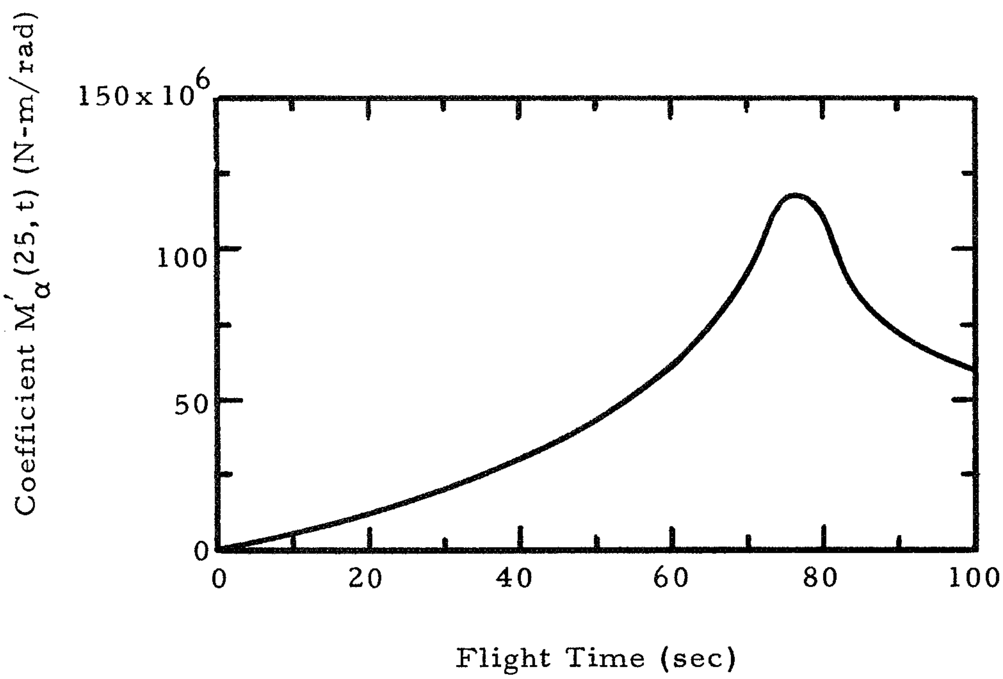


Fig. A-9 - Vehicle Velocity



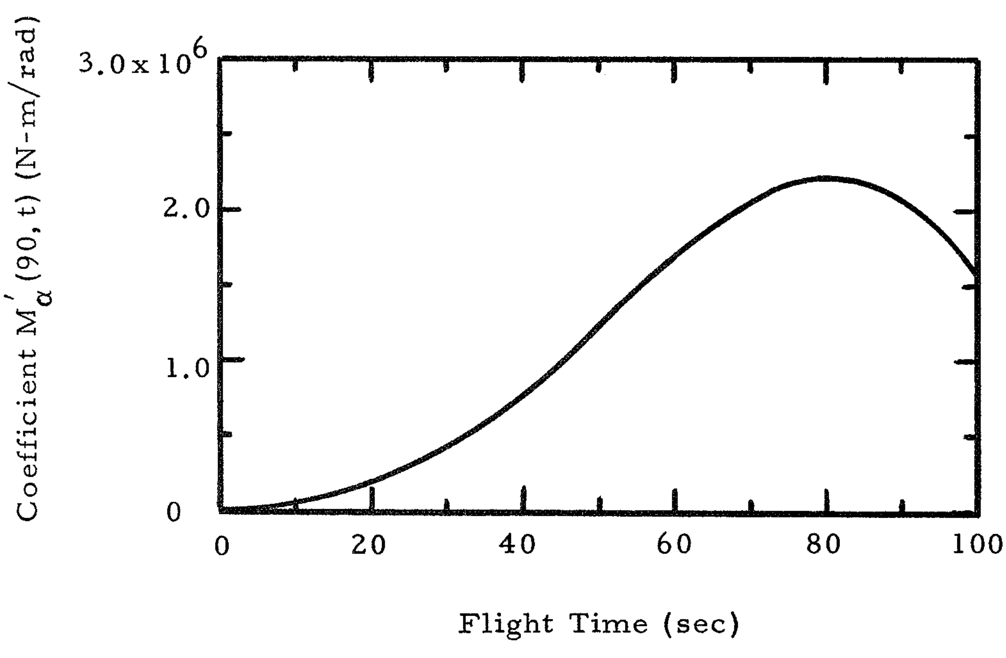


Fig. A-10 - Bending Moment Coefficients Due to Aerodynamic Force

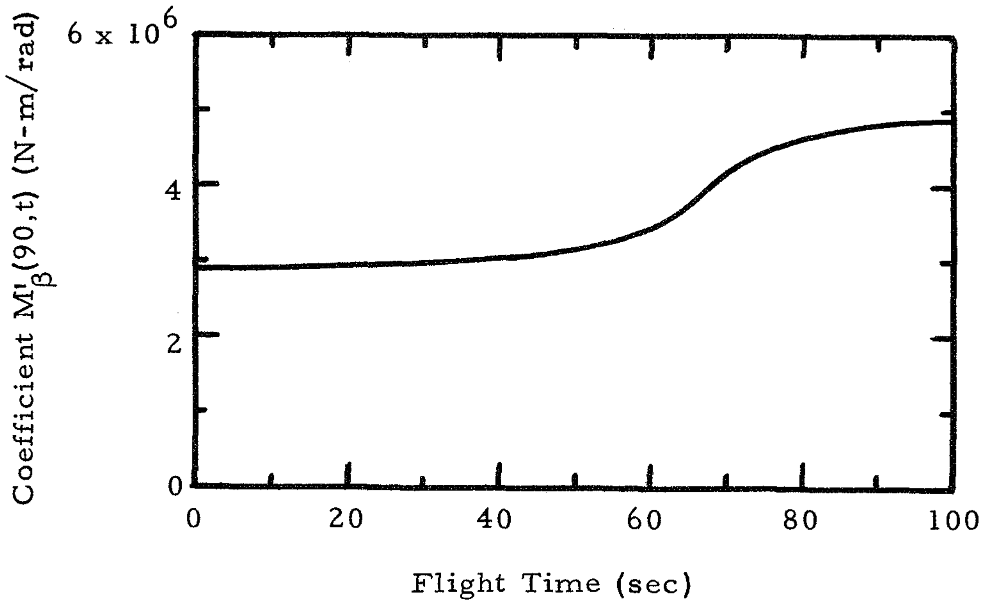


Fig. A-11 - Bending Moment Coefficients Due to Engine Deflection at Station 90

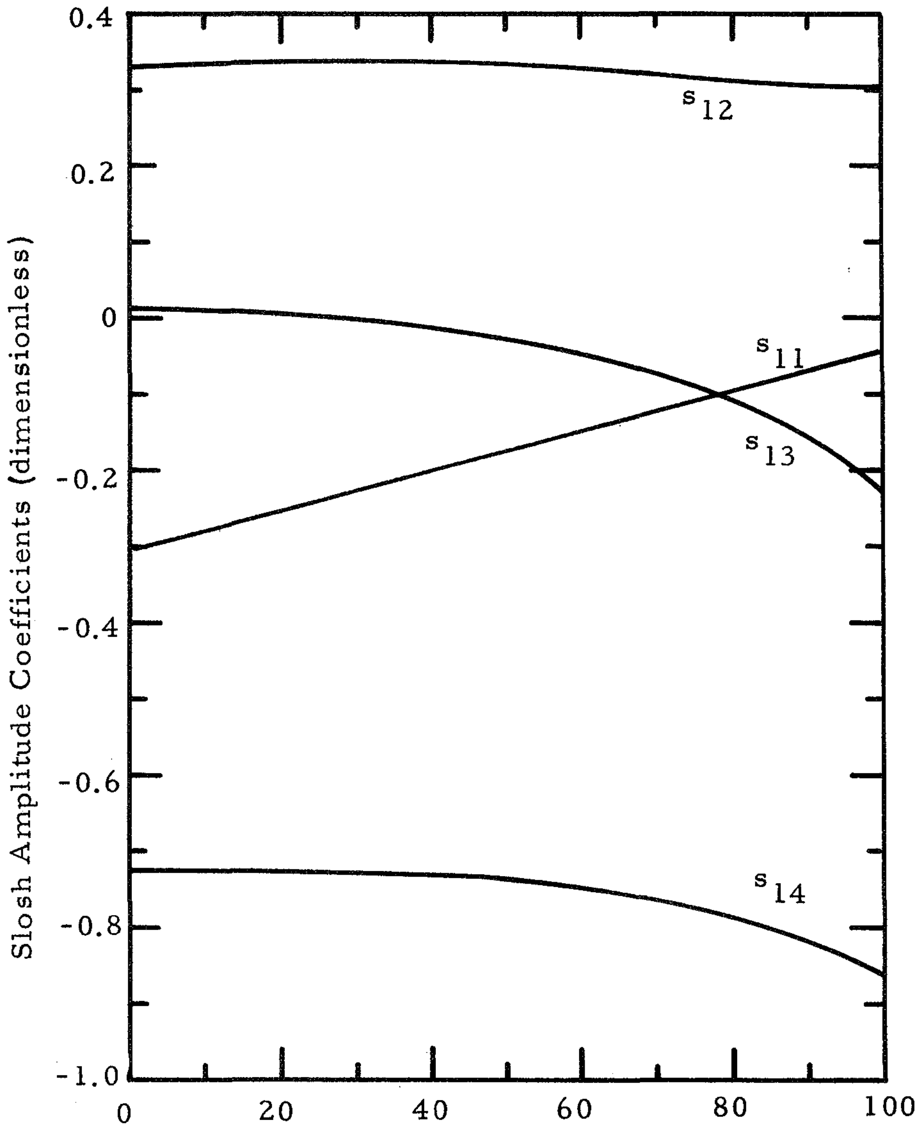
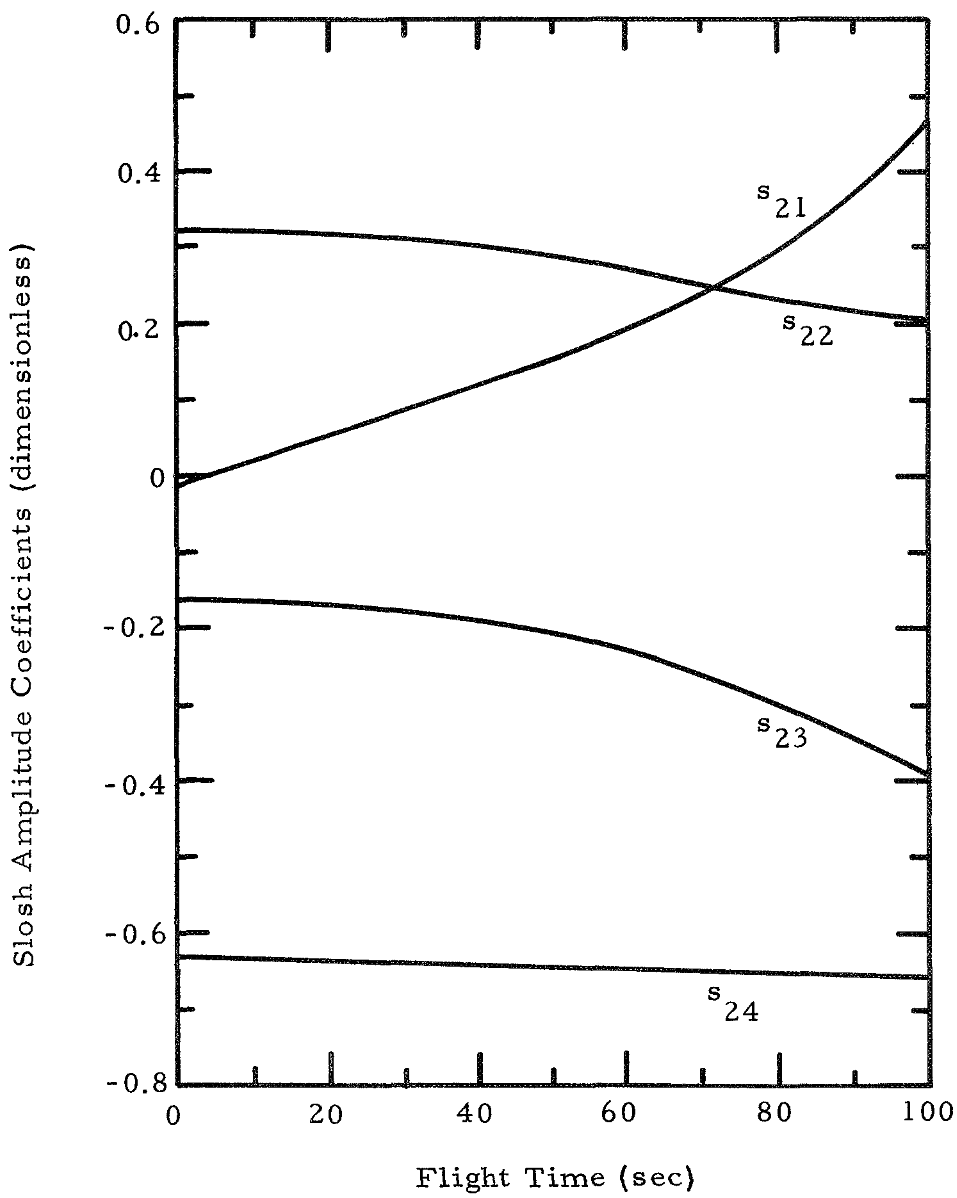


Fig. A-12 - Slosh Amplitude Coefficient



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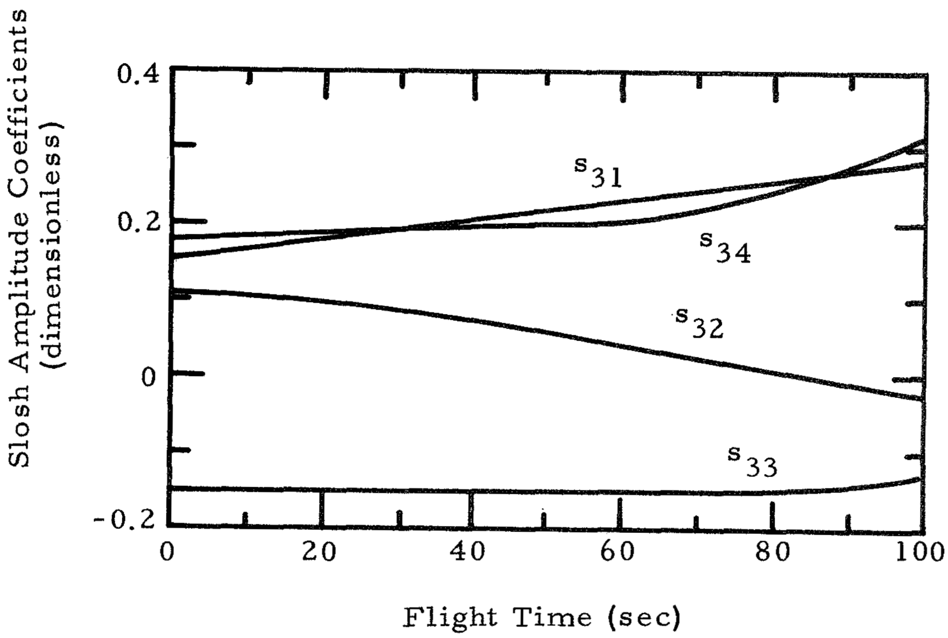

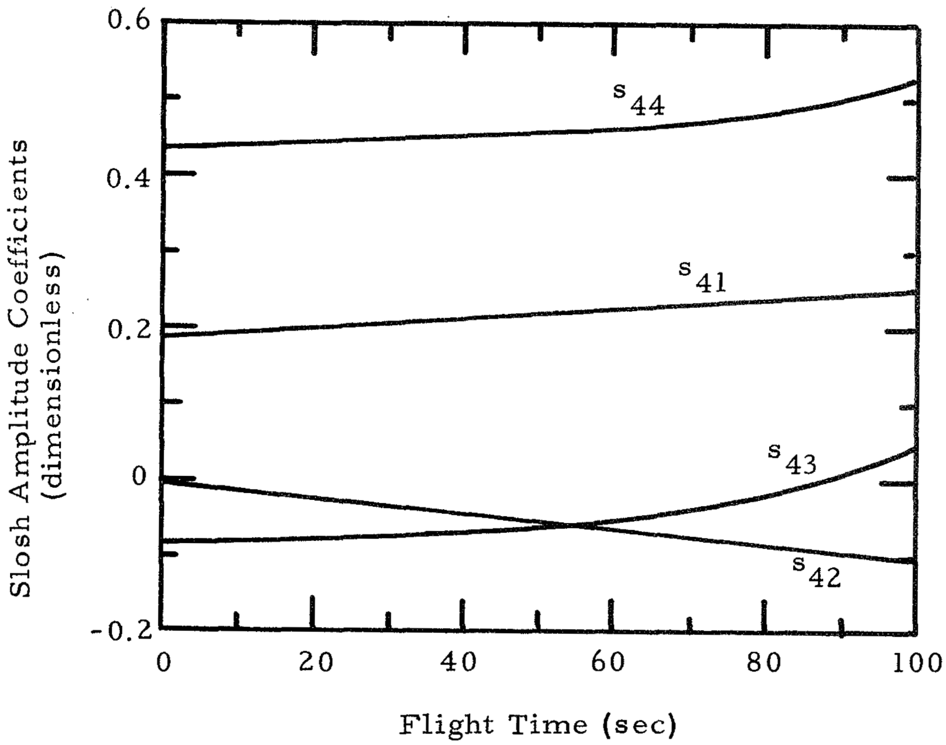

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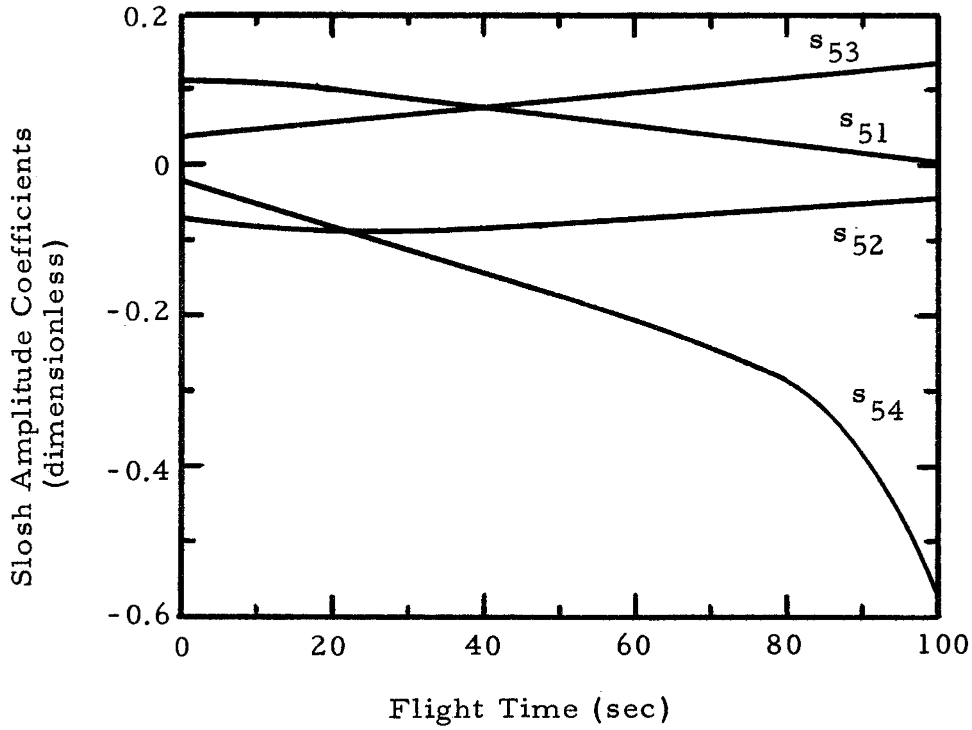

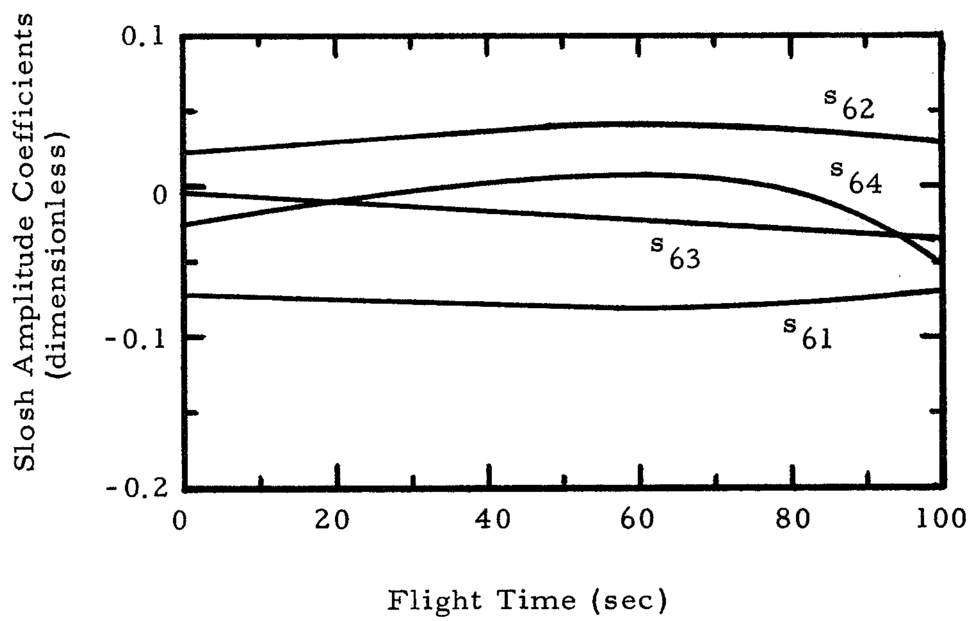

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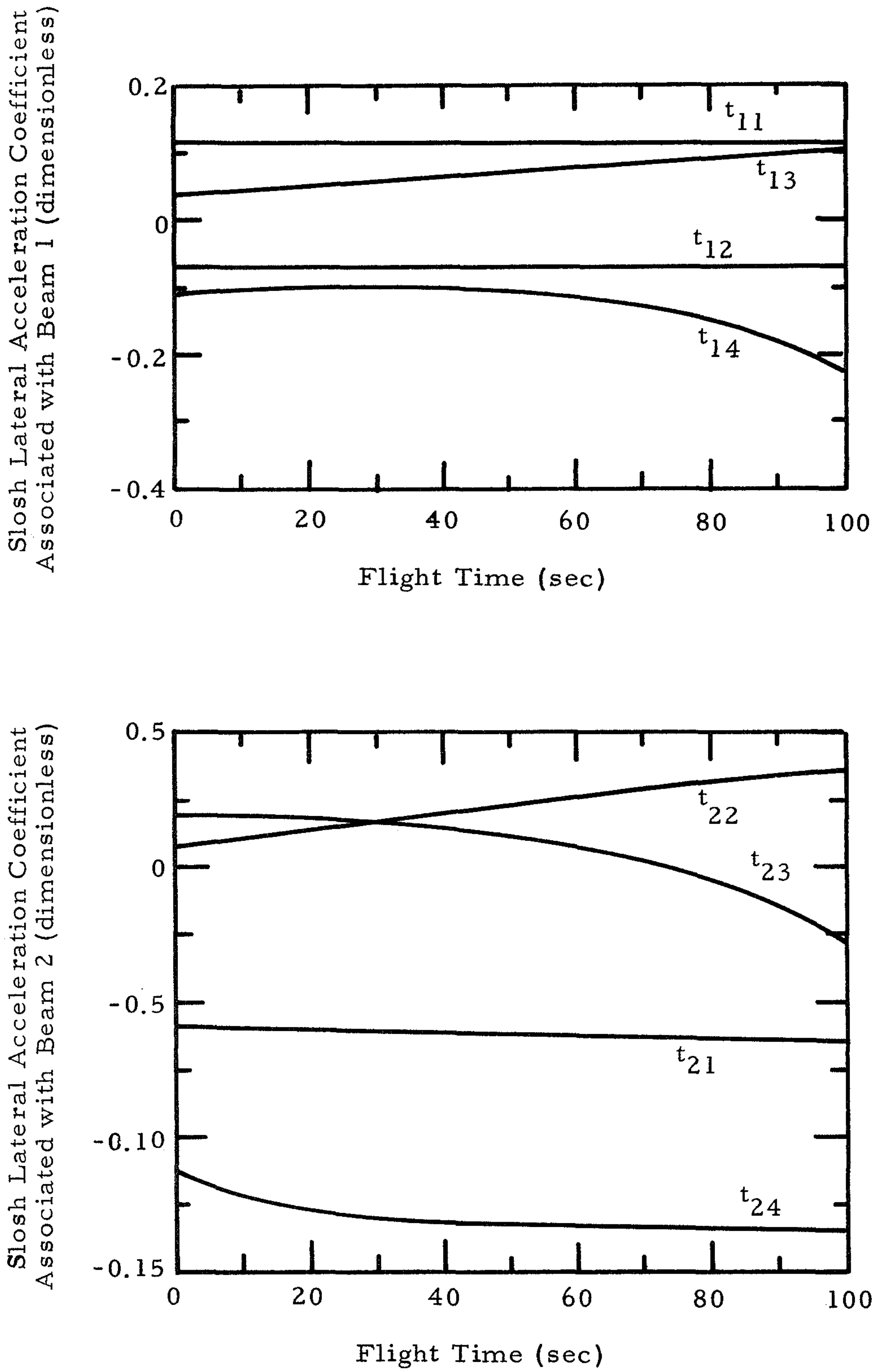
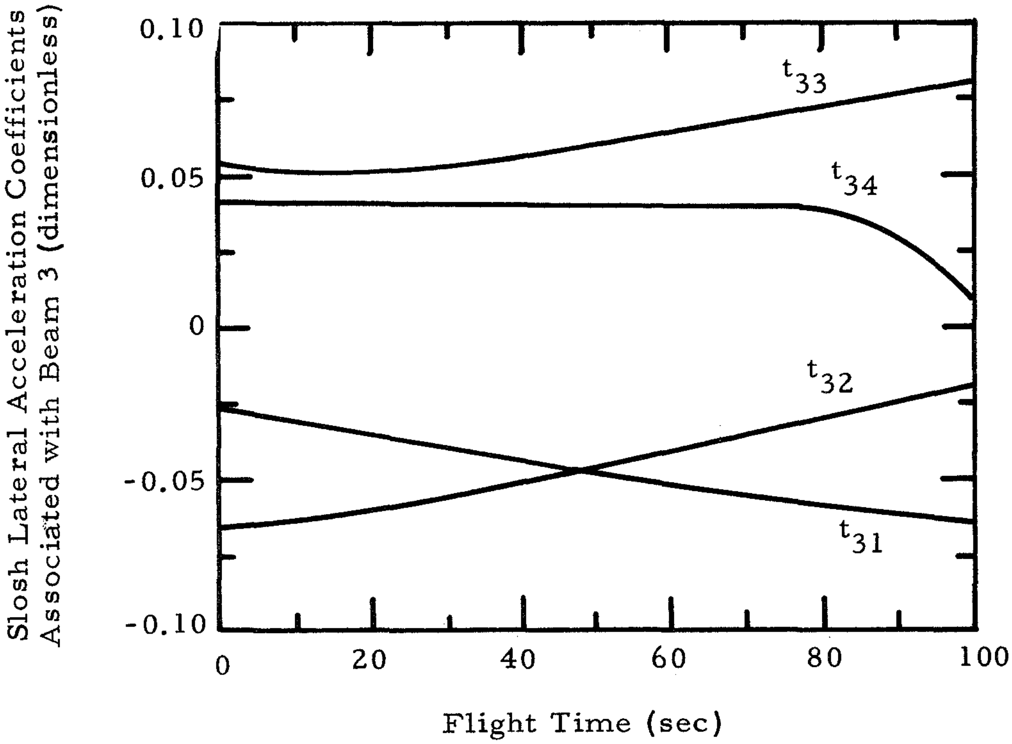


Fig. A-13 - Lateral Acceleration



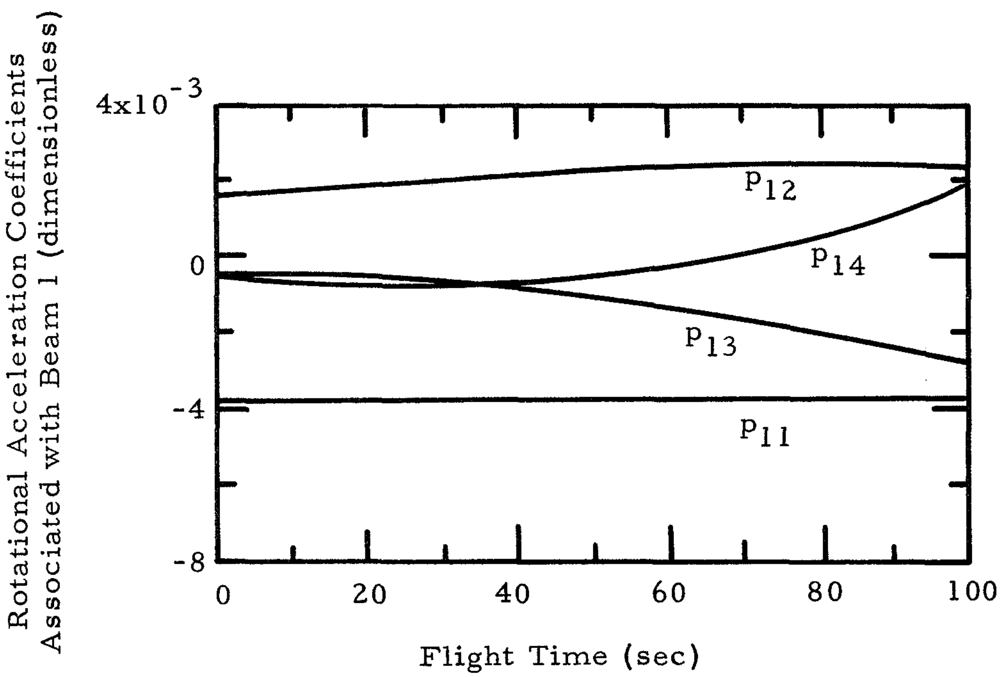
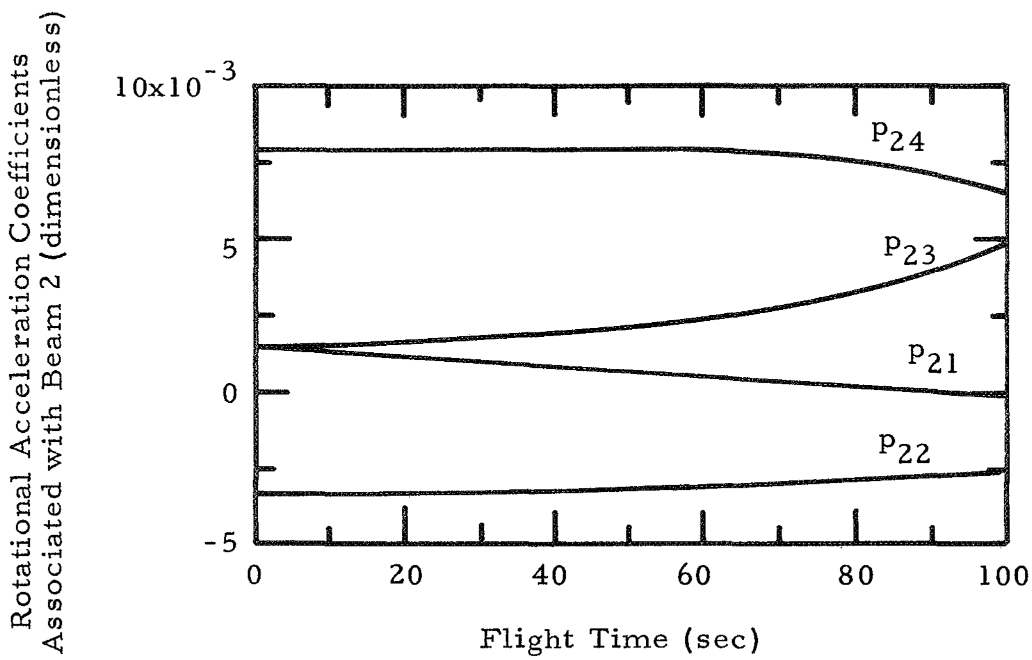
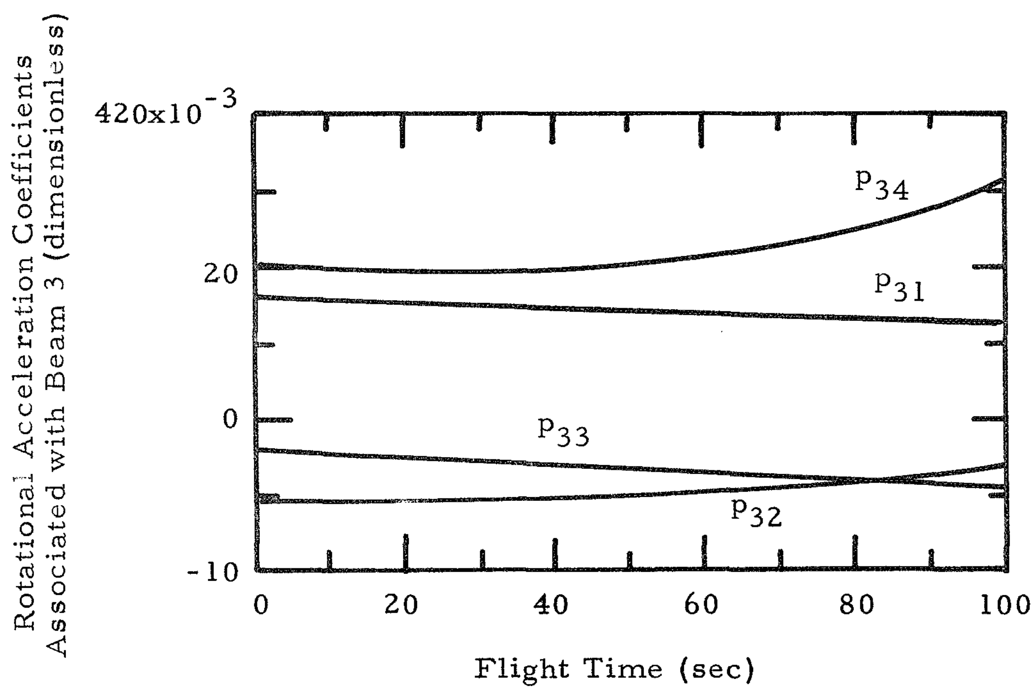


Fig. A-14 - Rotational Acceleration Coefficients





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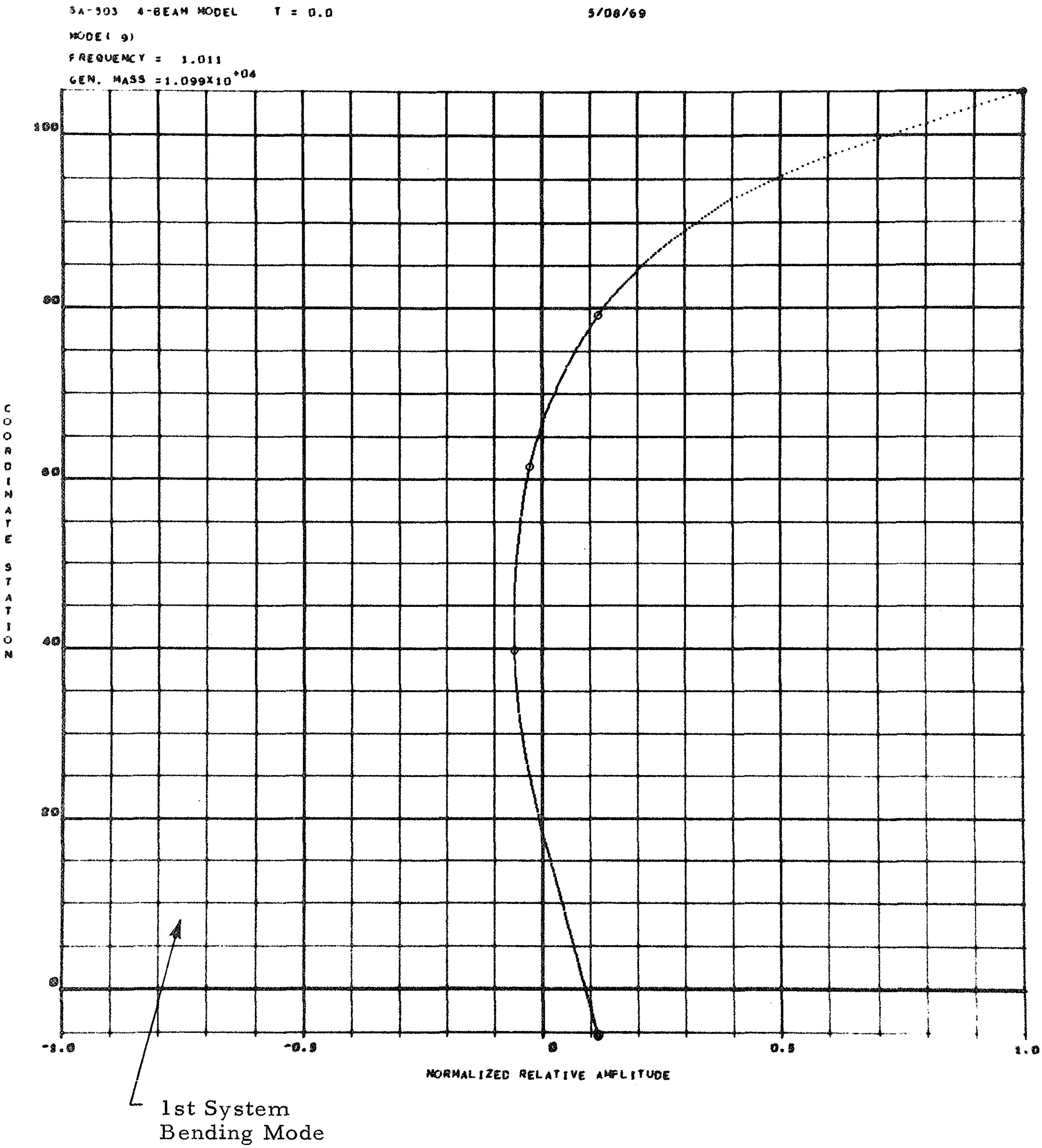
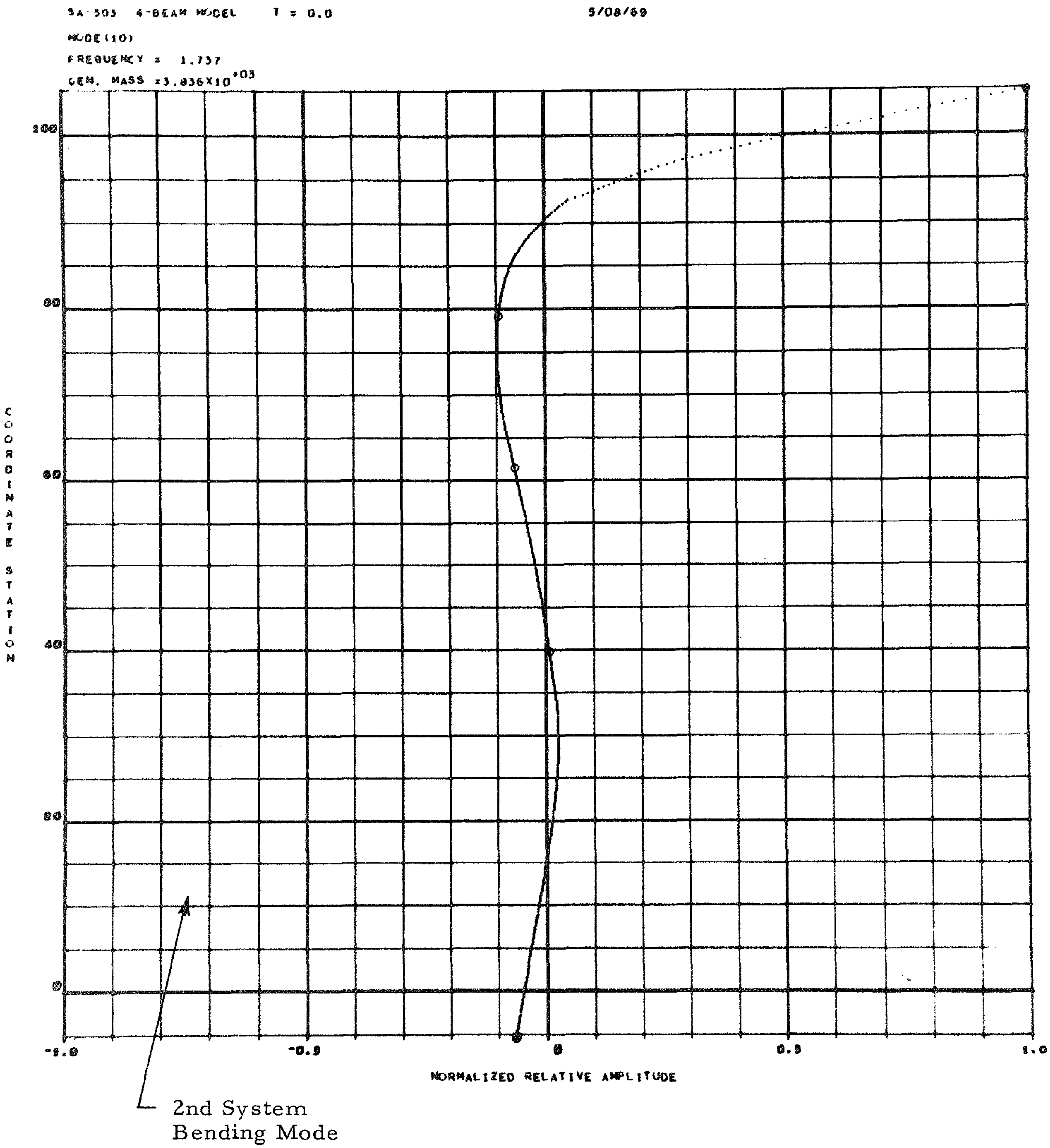


Fig. A-15 - System Bending Modes at t=0



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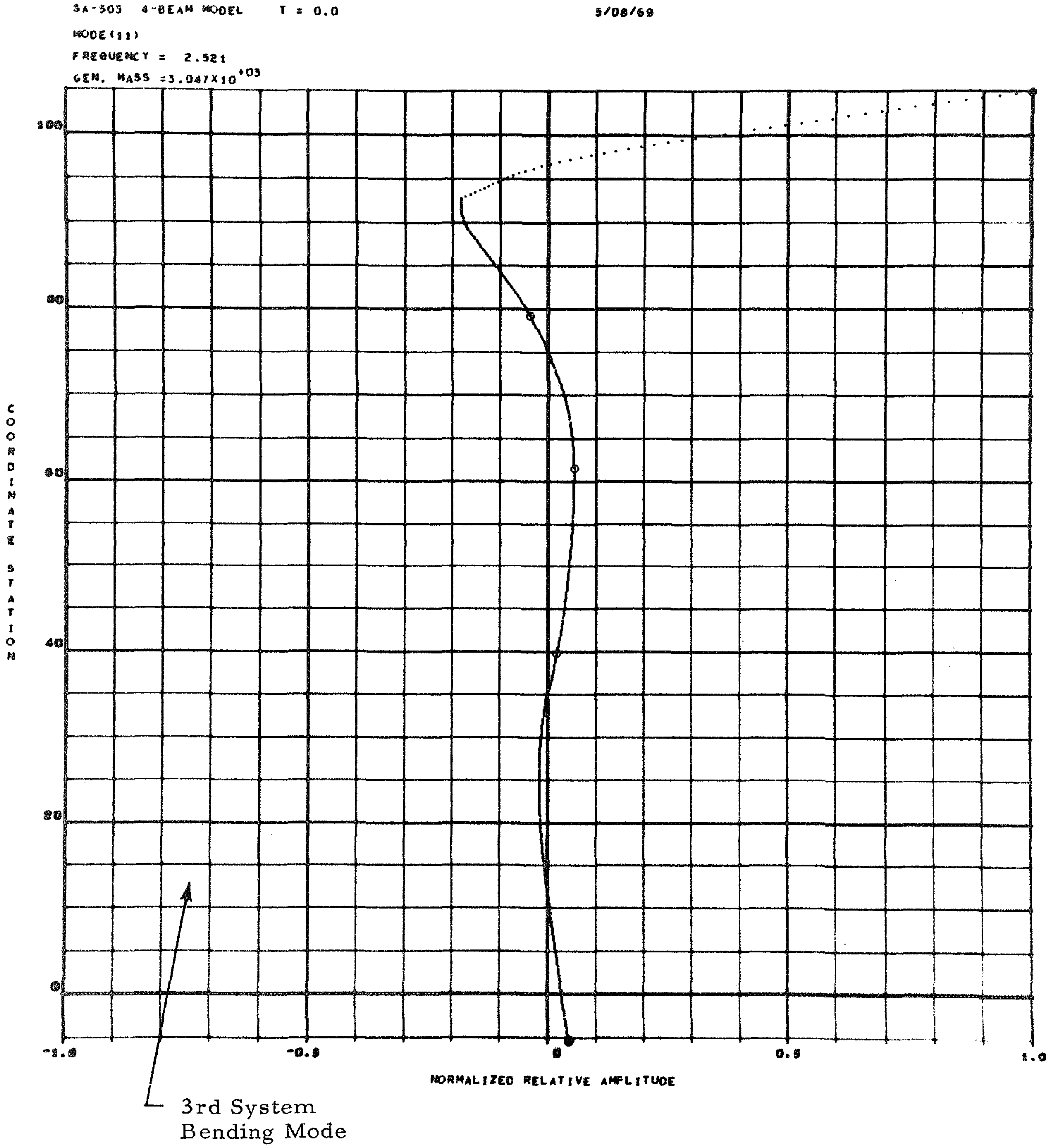

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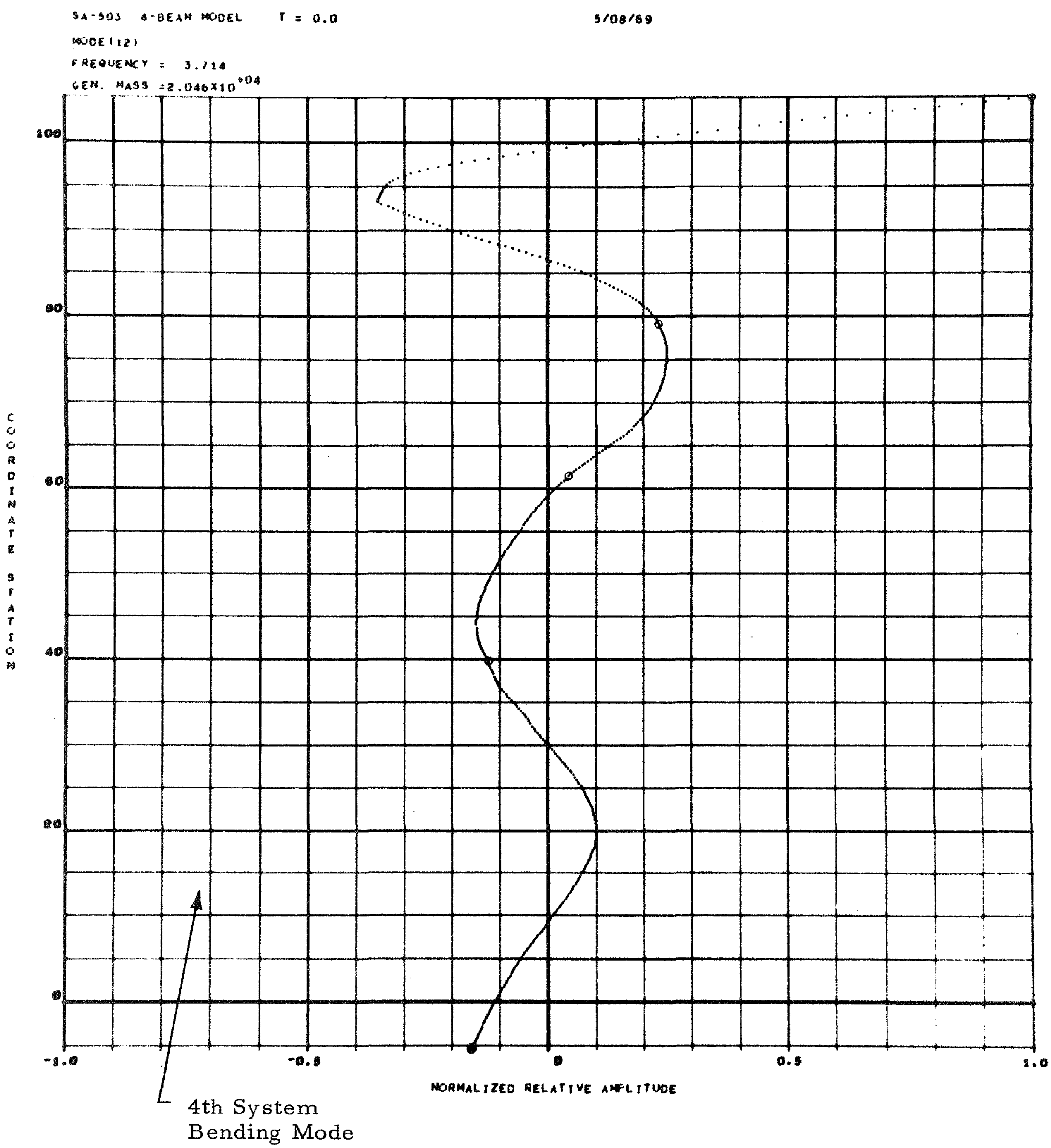


Fig. A-15 - (Continued)

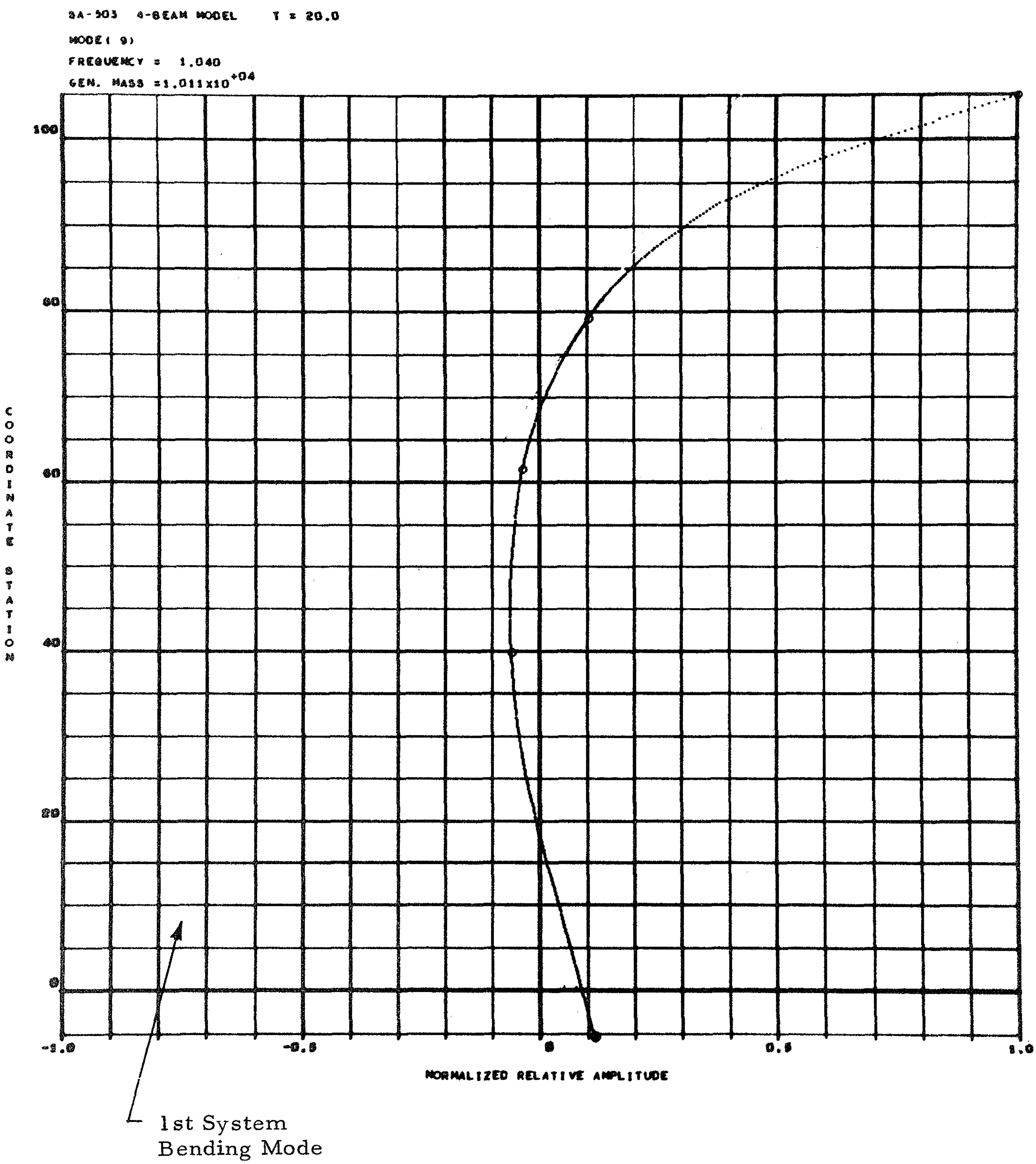
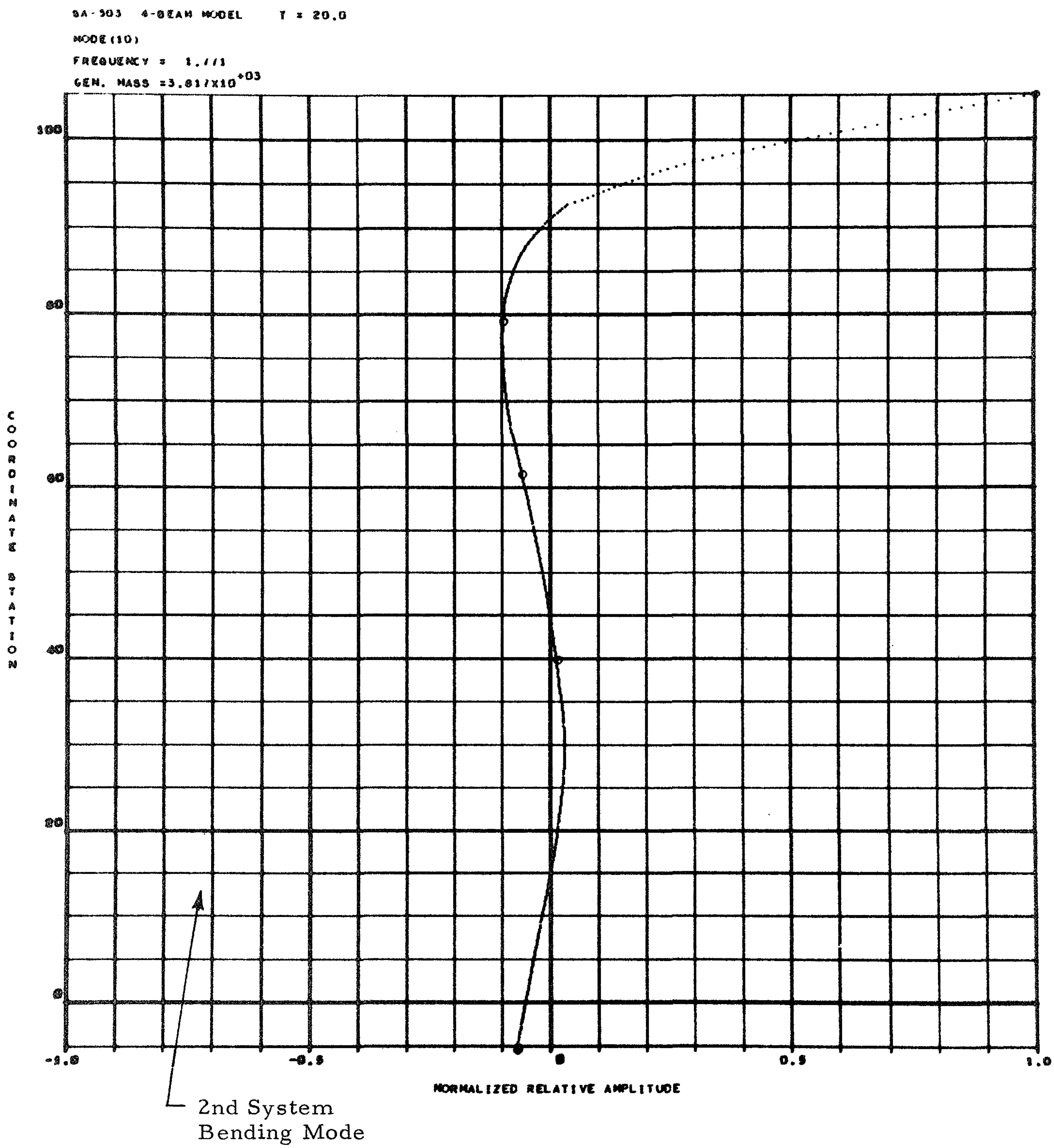


Fig. A-16 - System Bending Modes at t=20 sec



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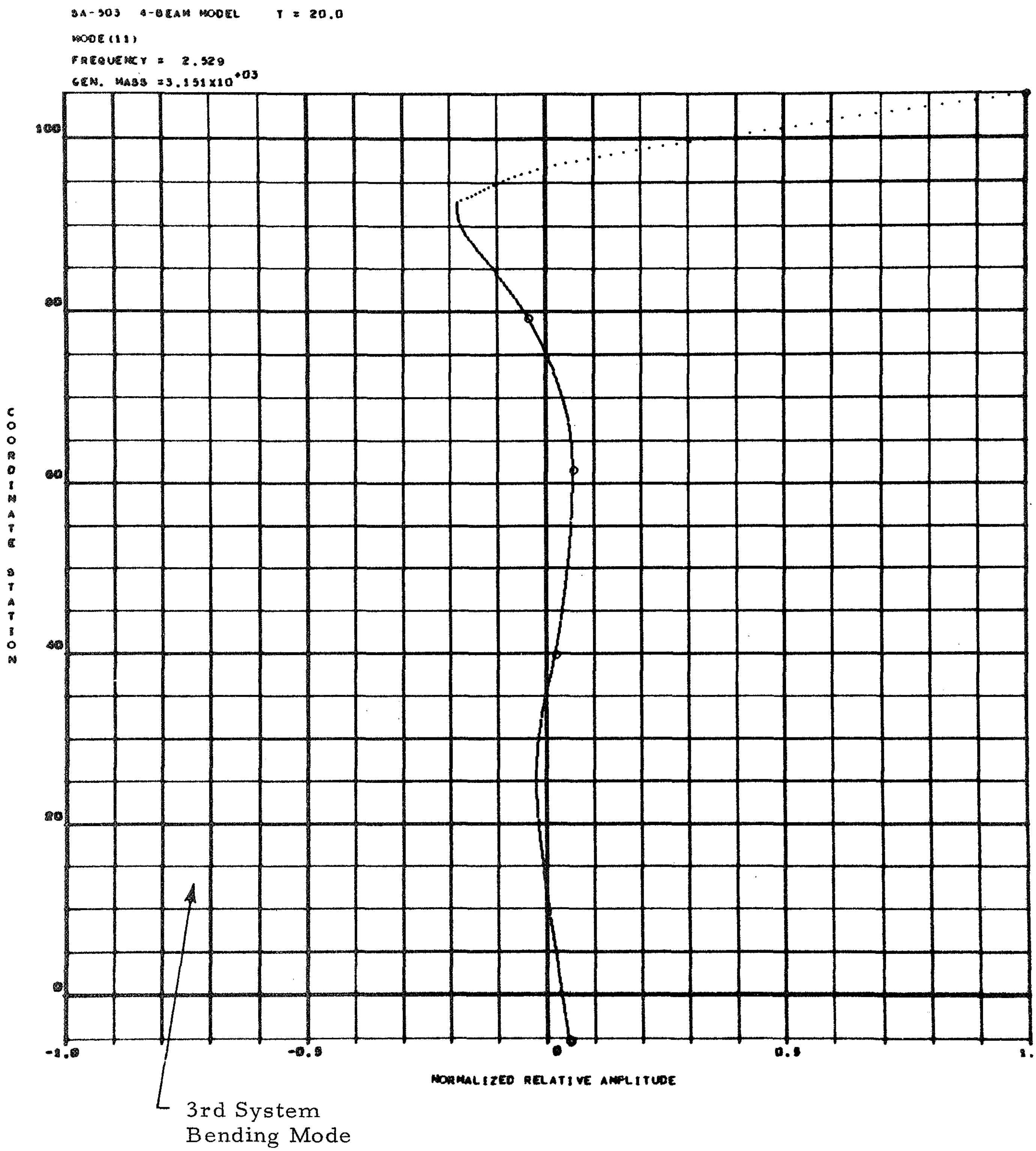

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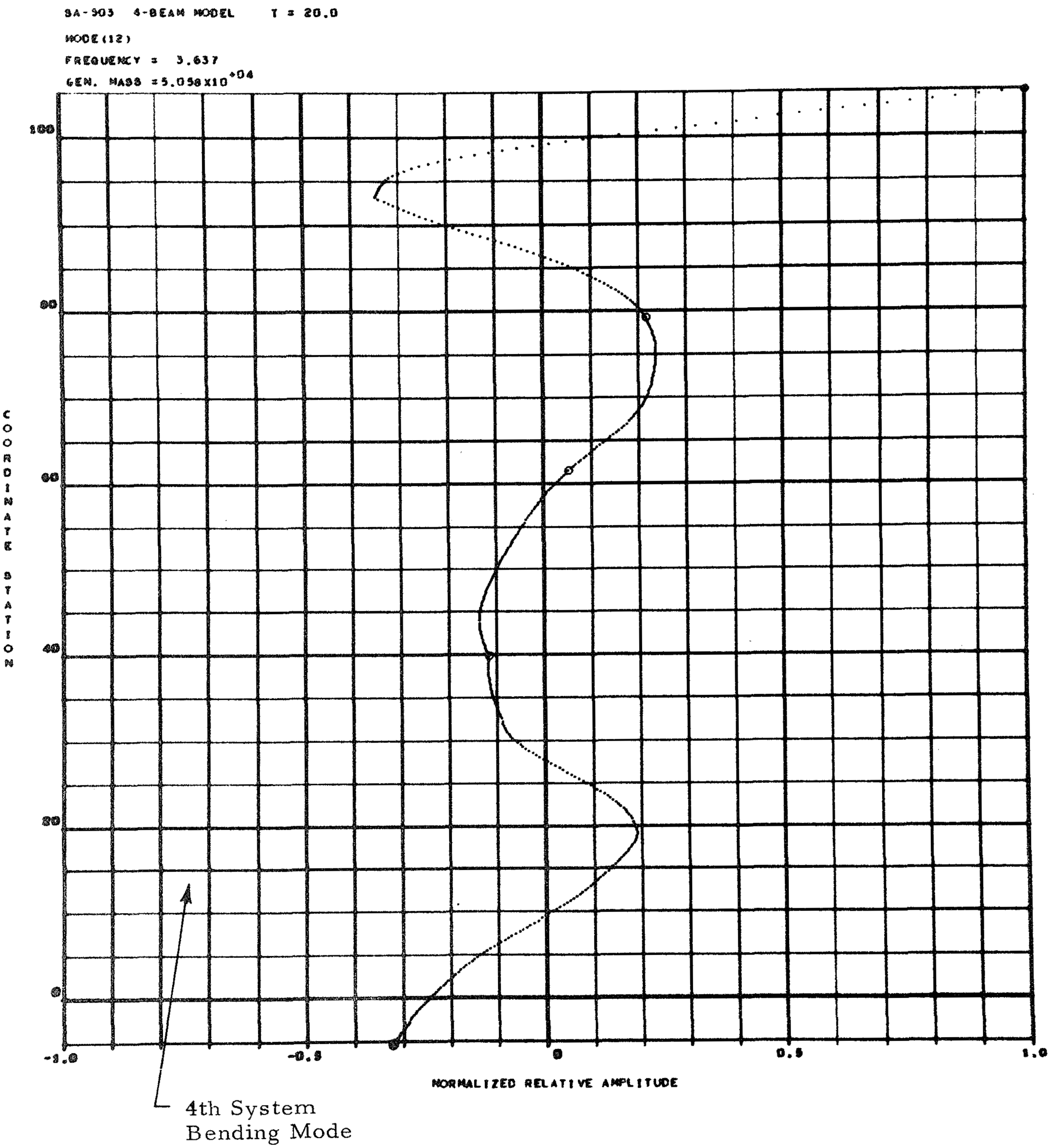

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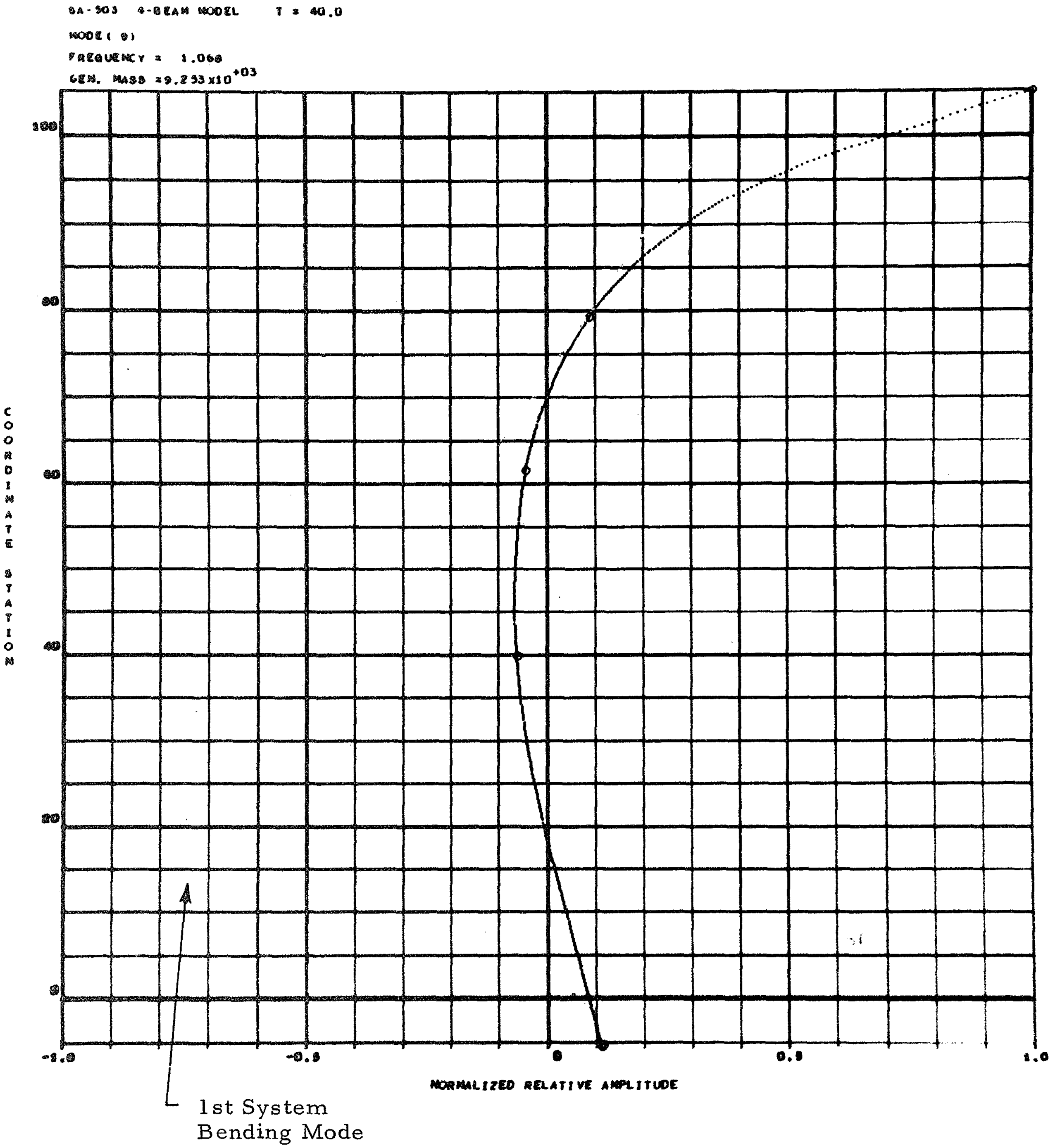
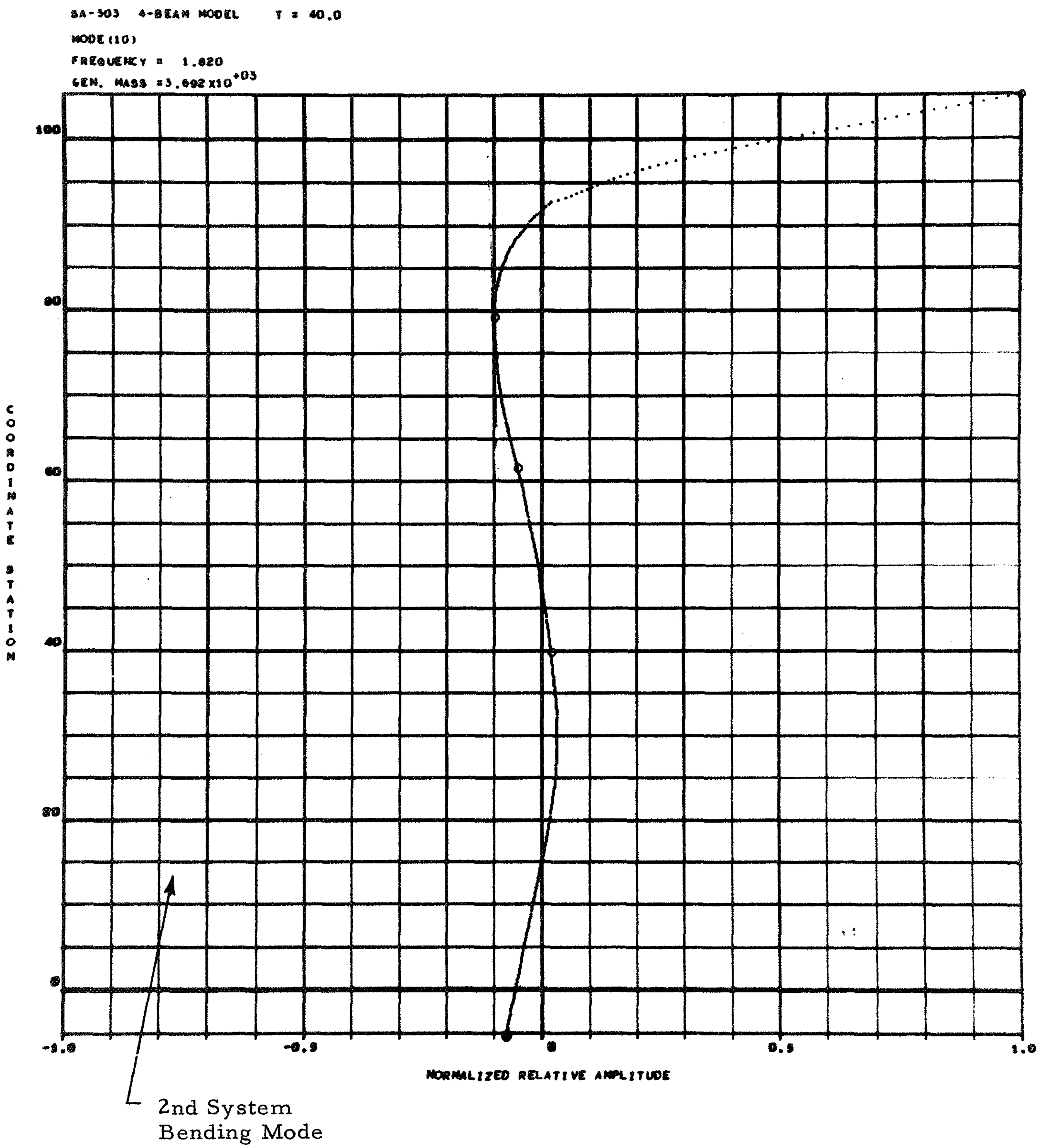


Fig. A-17 - System Bending Modes at t=40 sec



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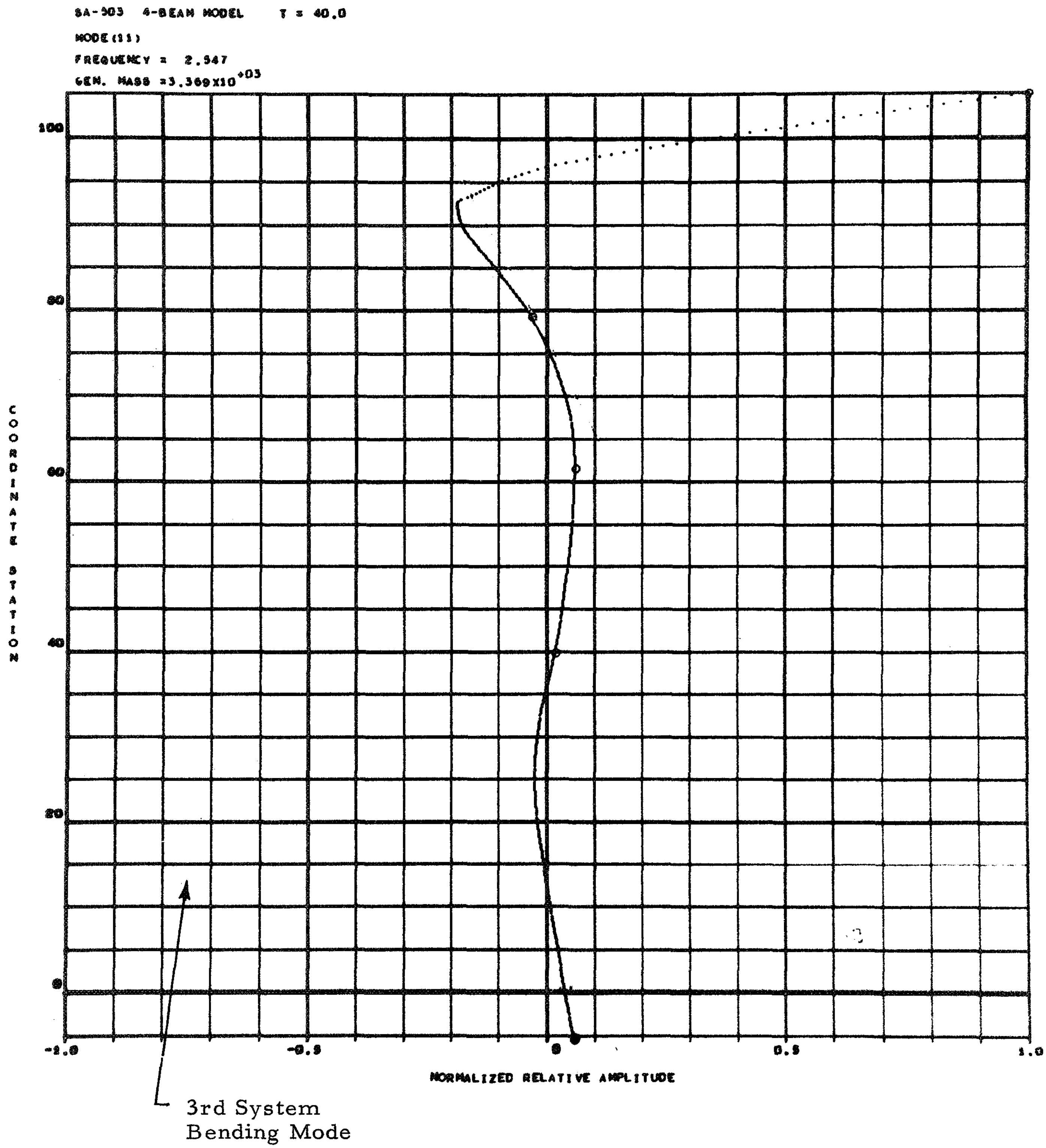

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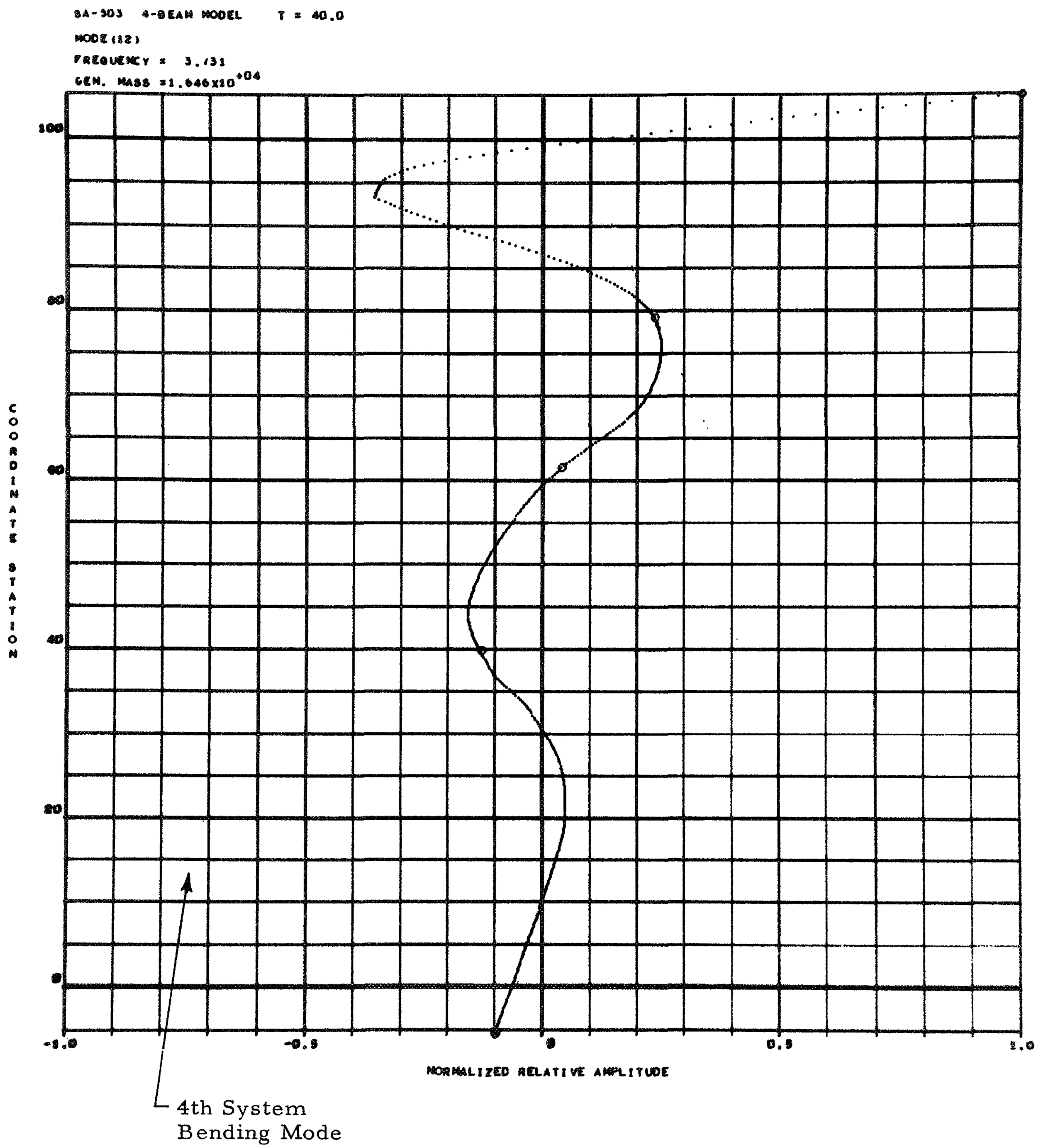

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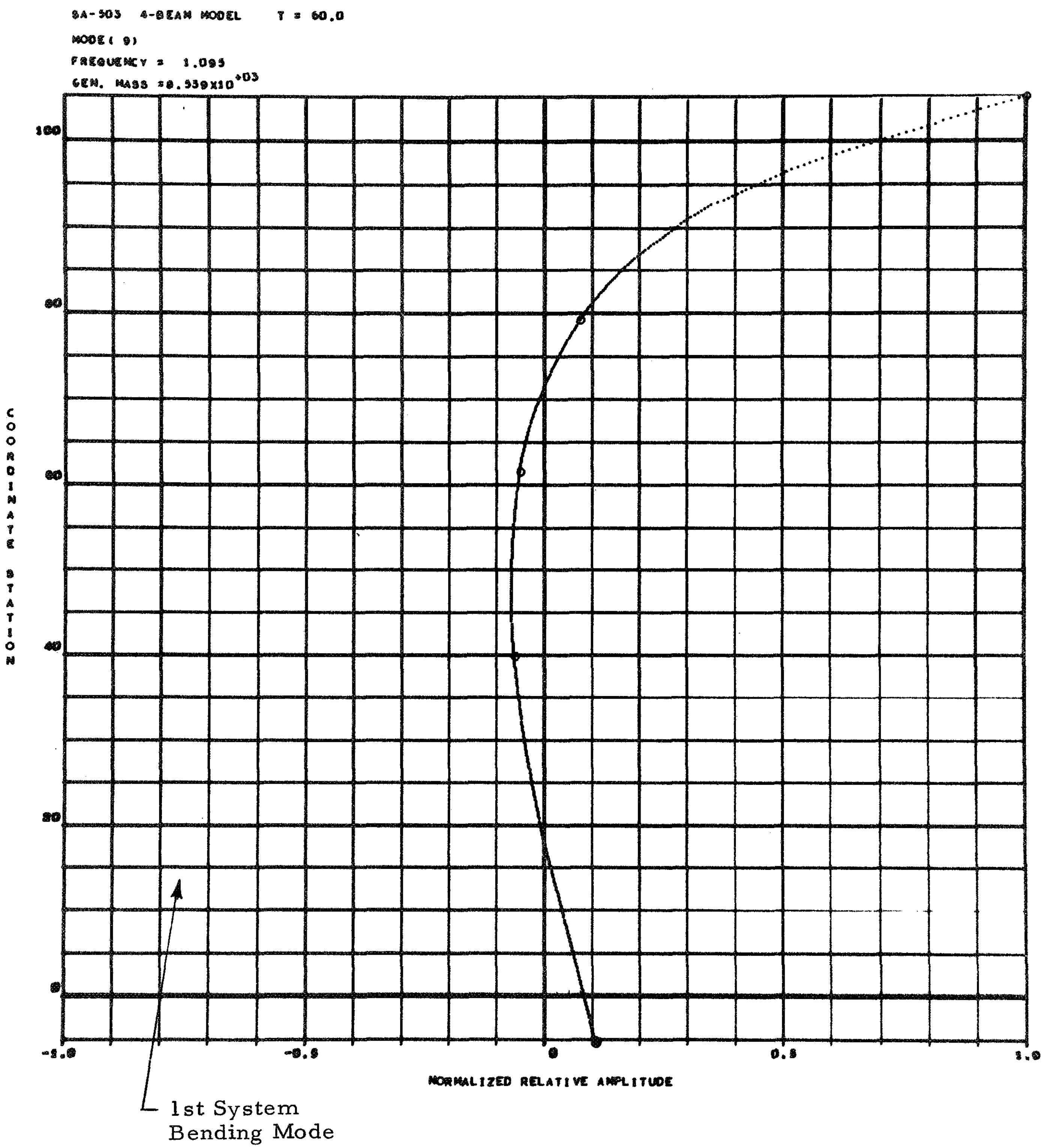
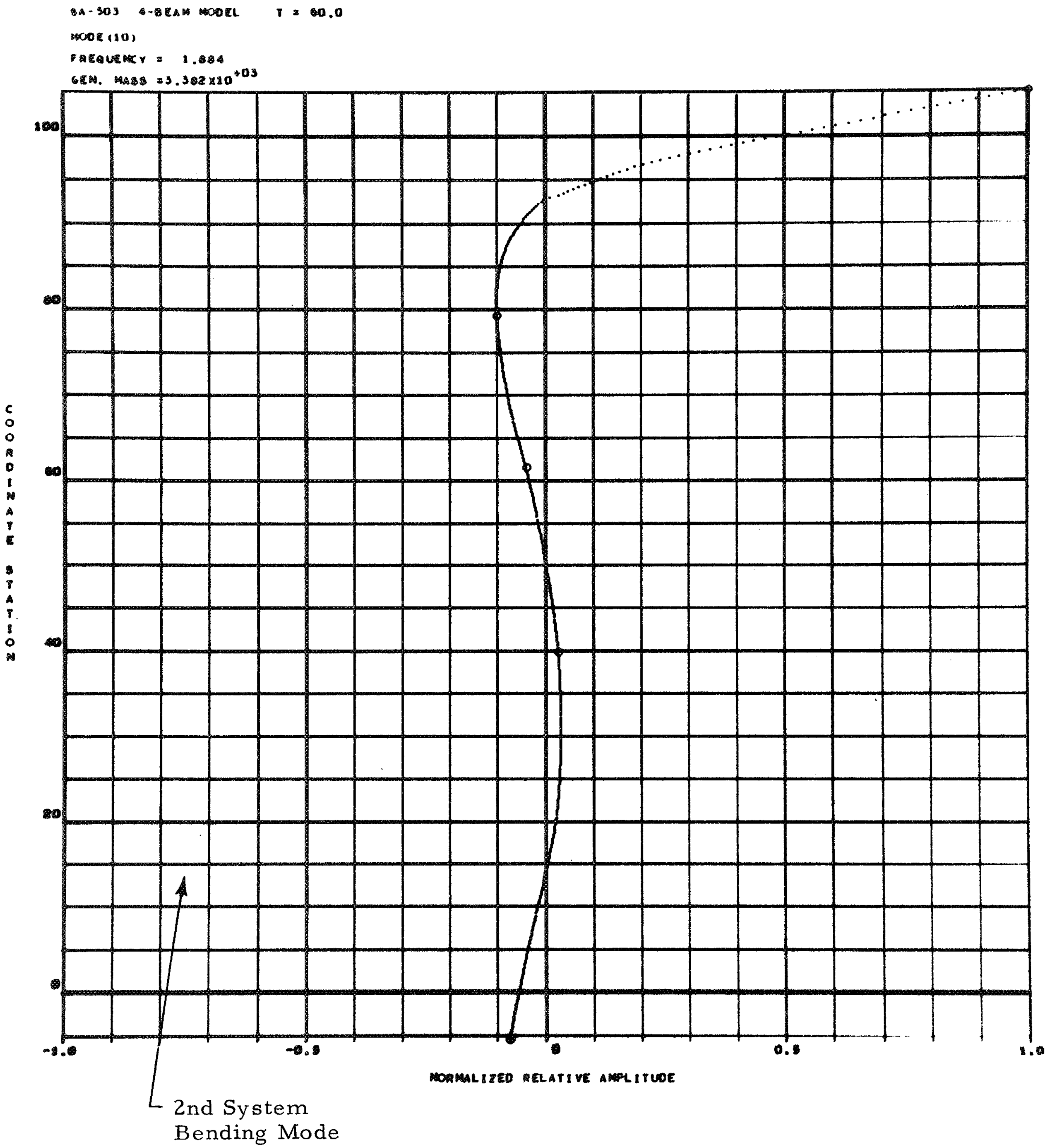


Fig. A-18 - System Bending Modes at t=60 sec



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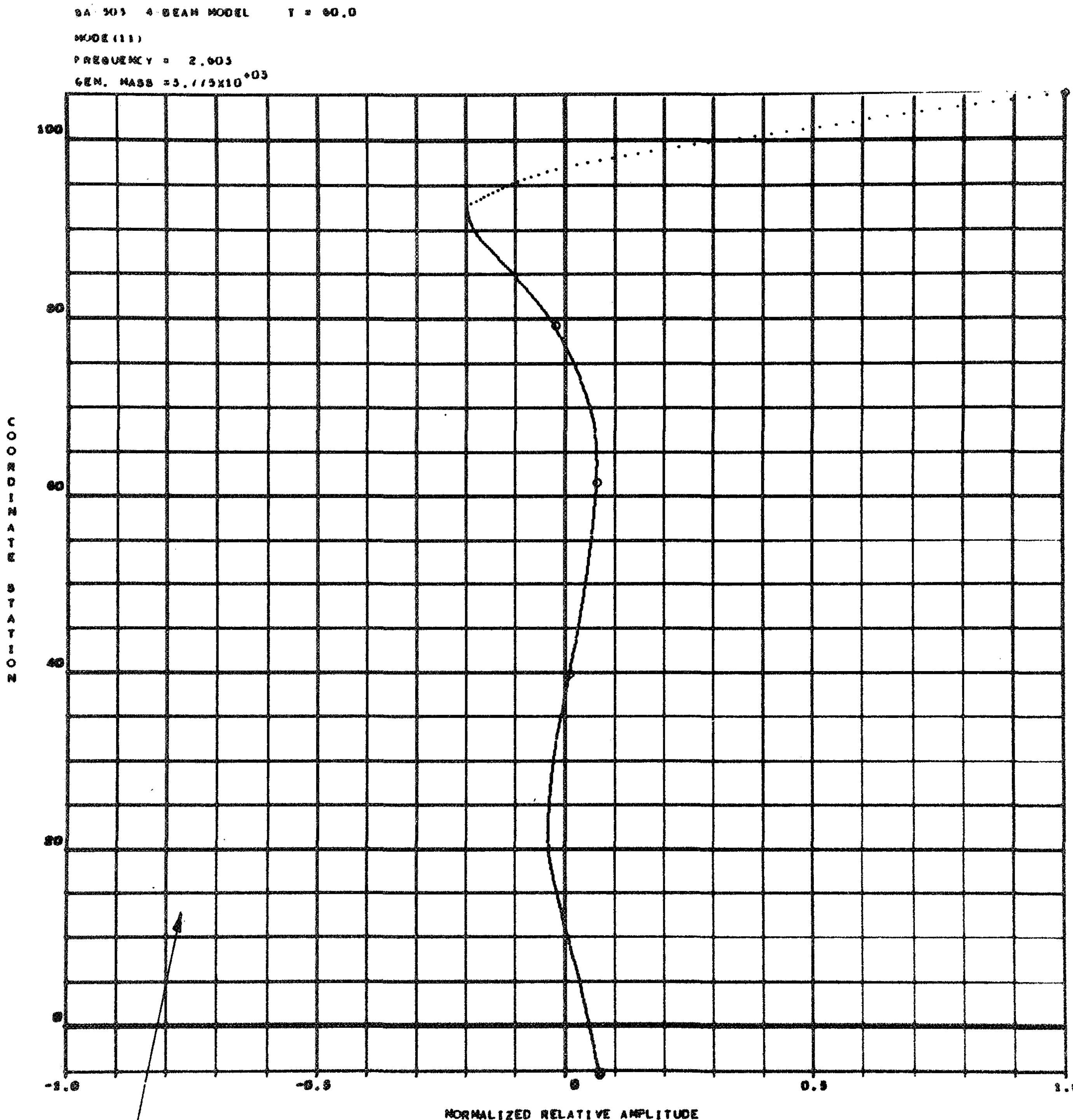


3rd System
Bending Mode

Fig. A-18 - (Continued)

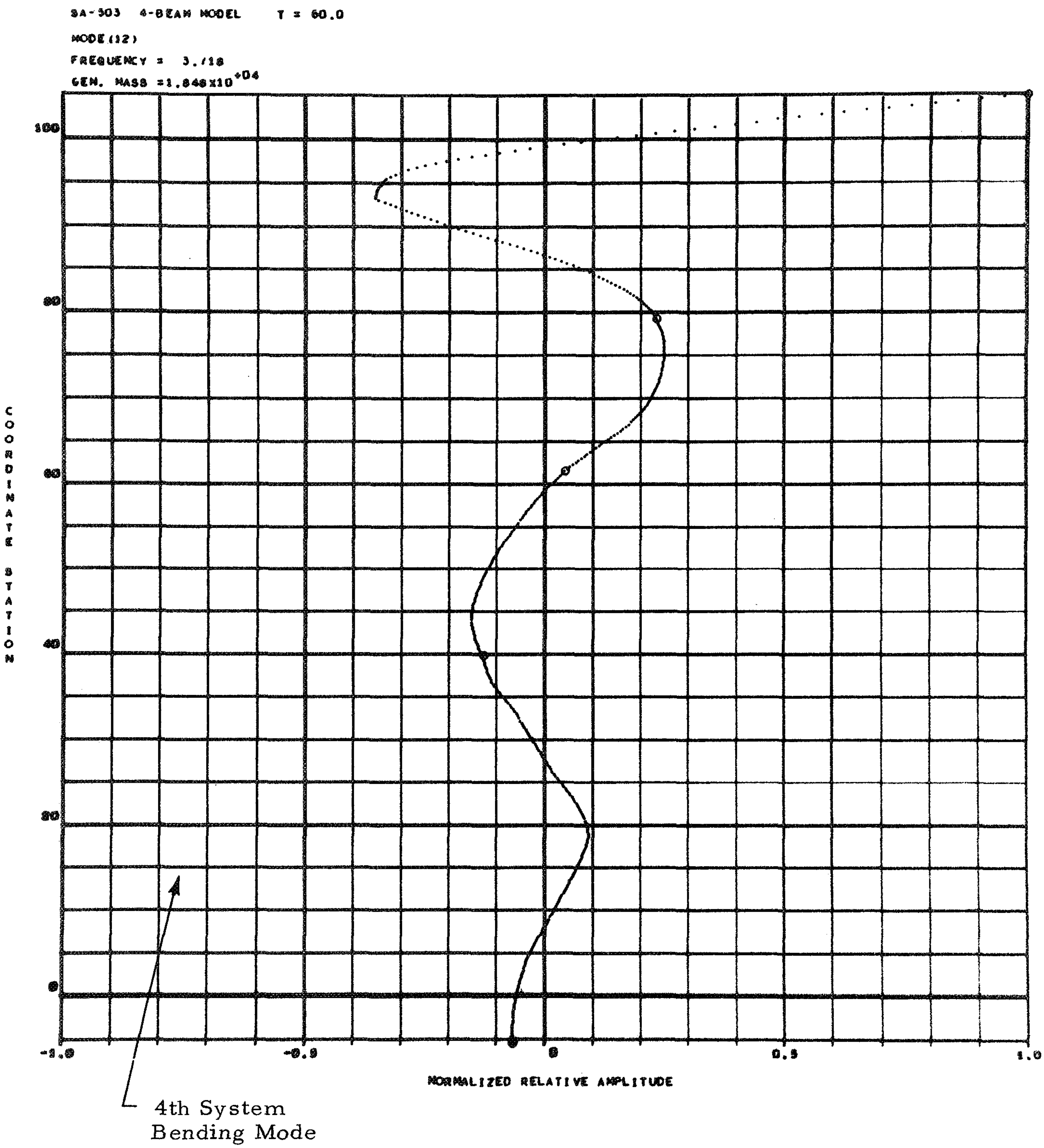


Fig. A-18 - (Continued)

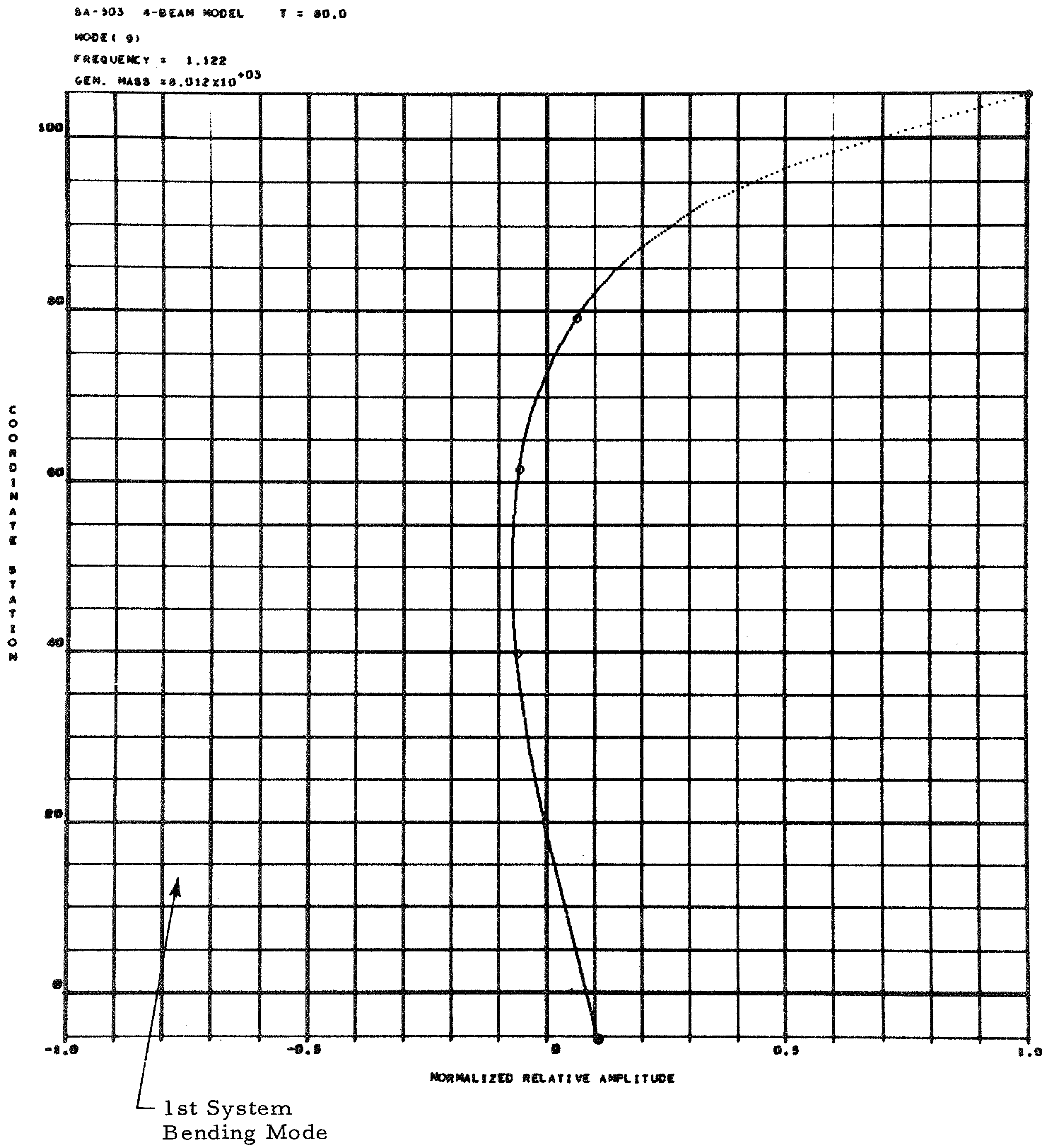
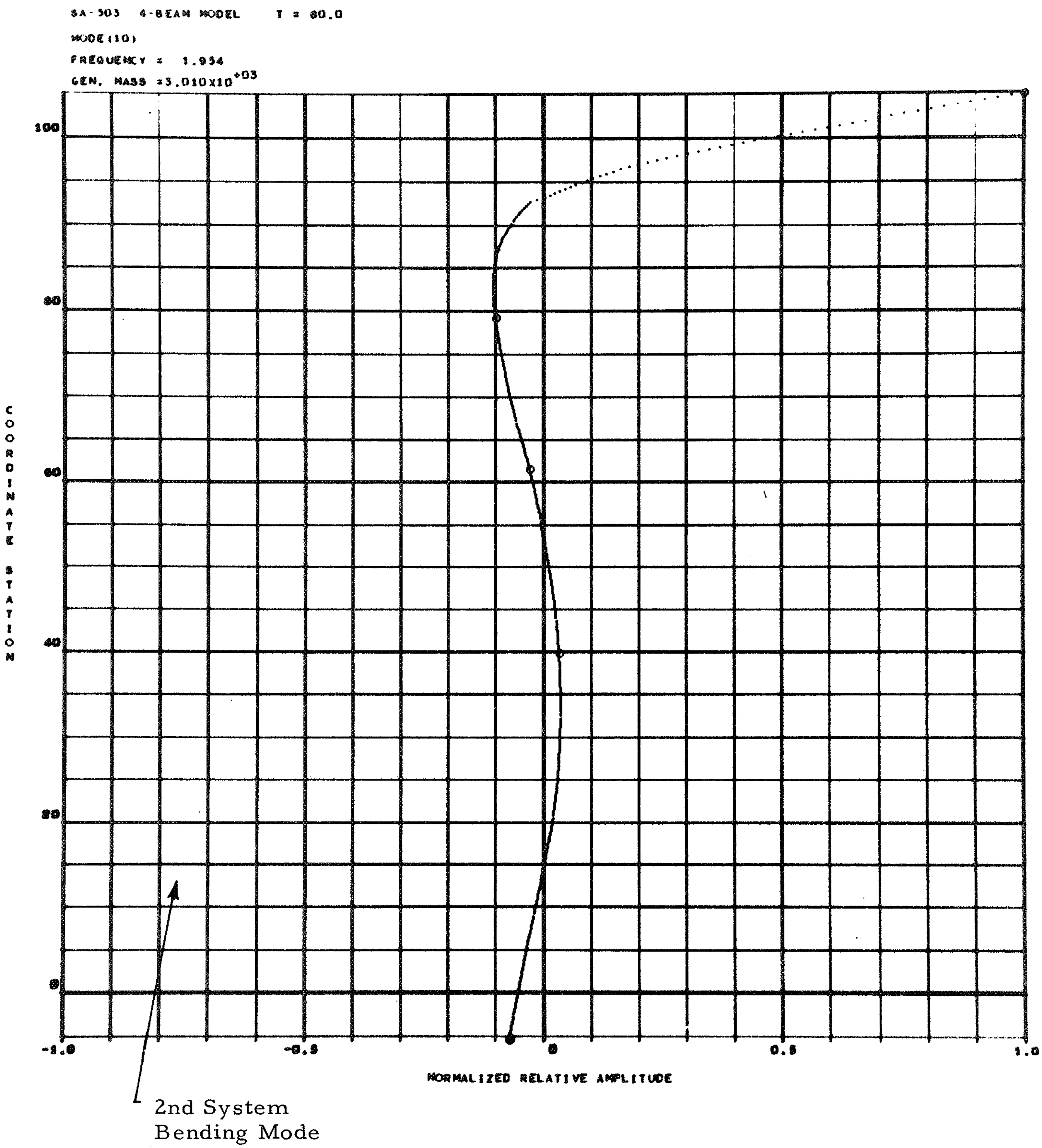


Fig. A-19 - System Bending Modes at t = 80 sec



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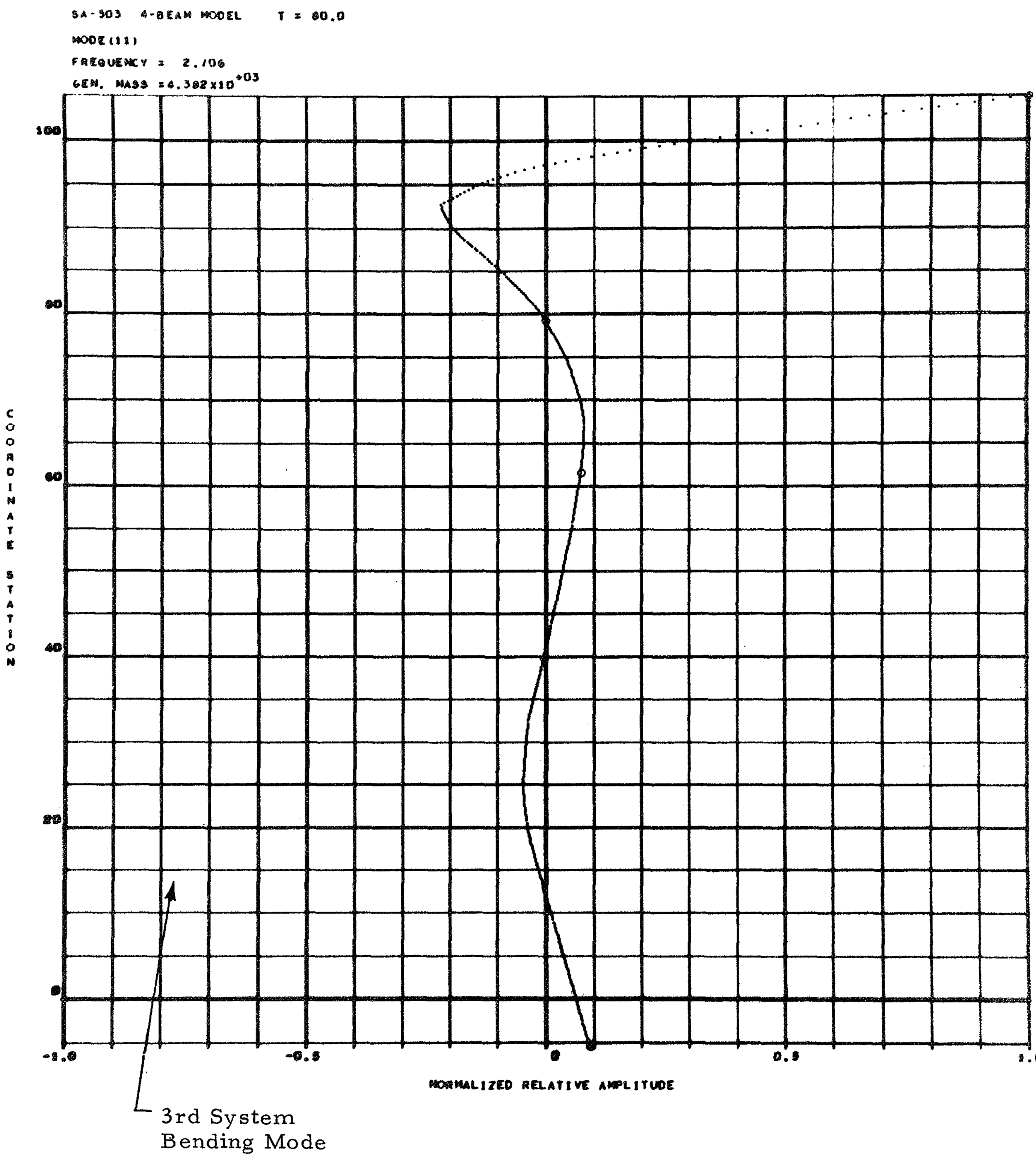
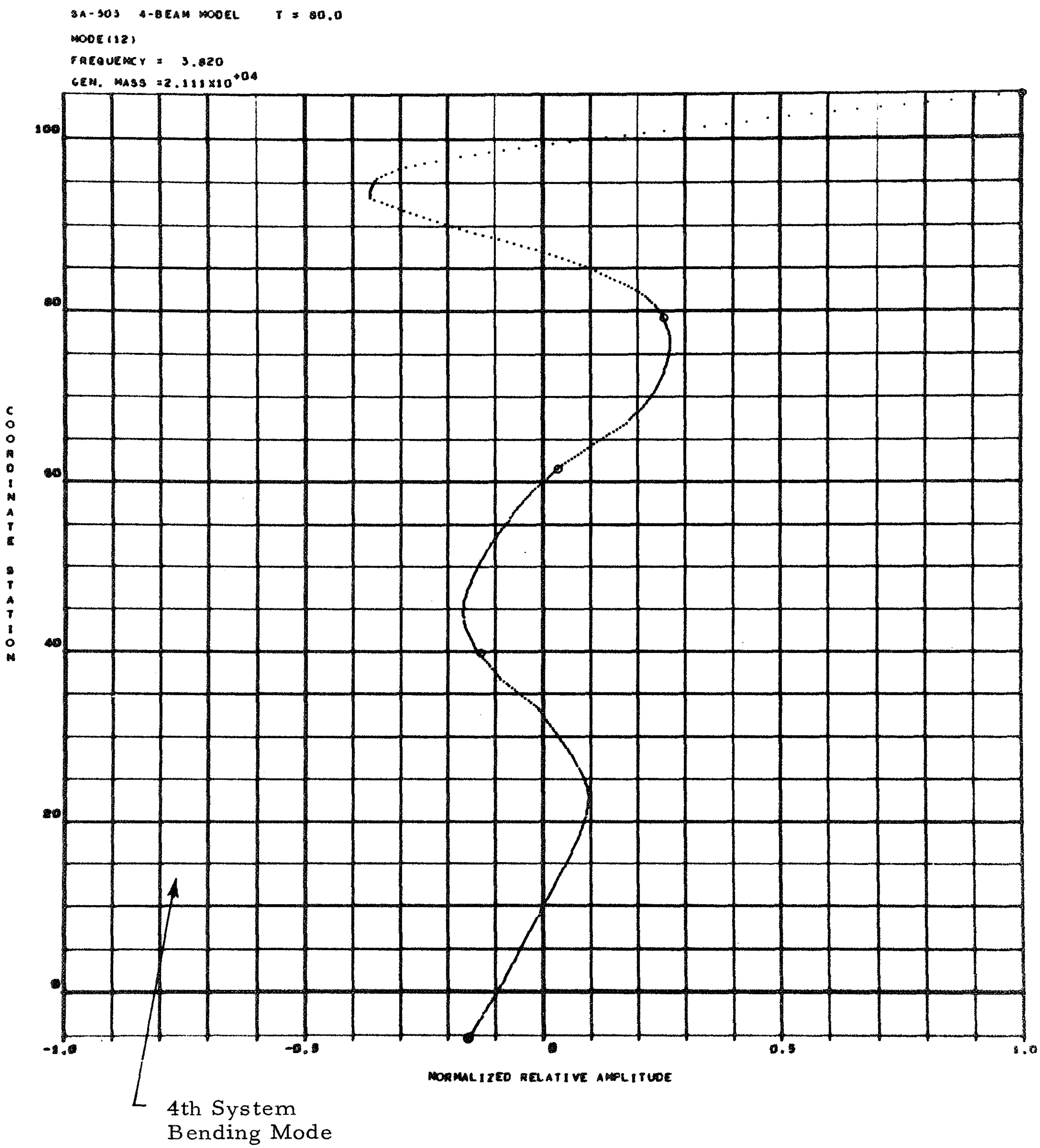


Fig. A-19 - (Continued)



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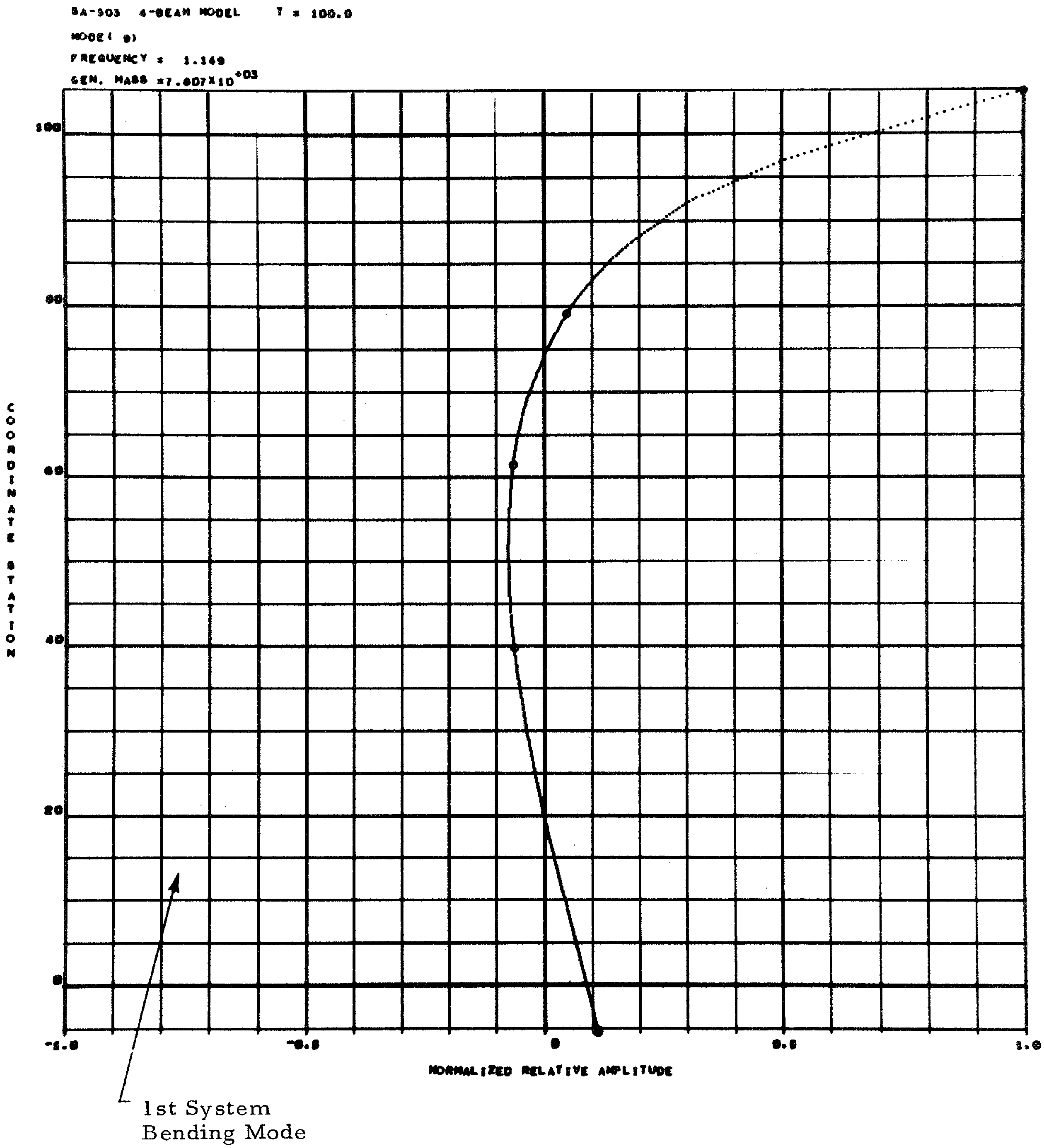
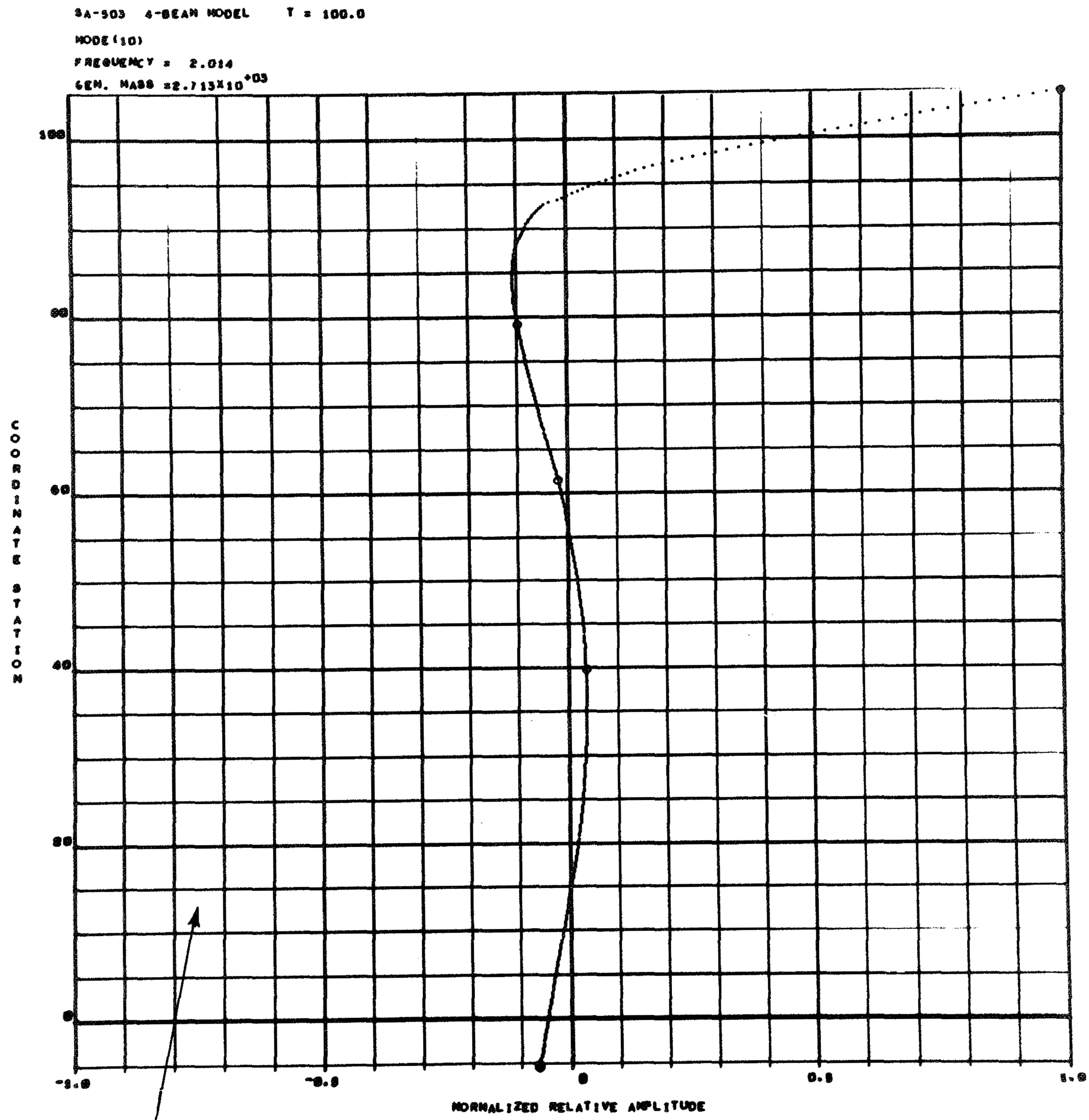
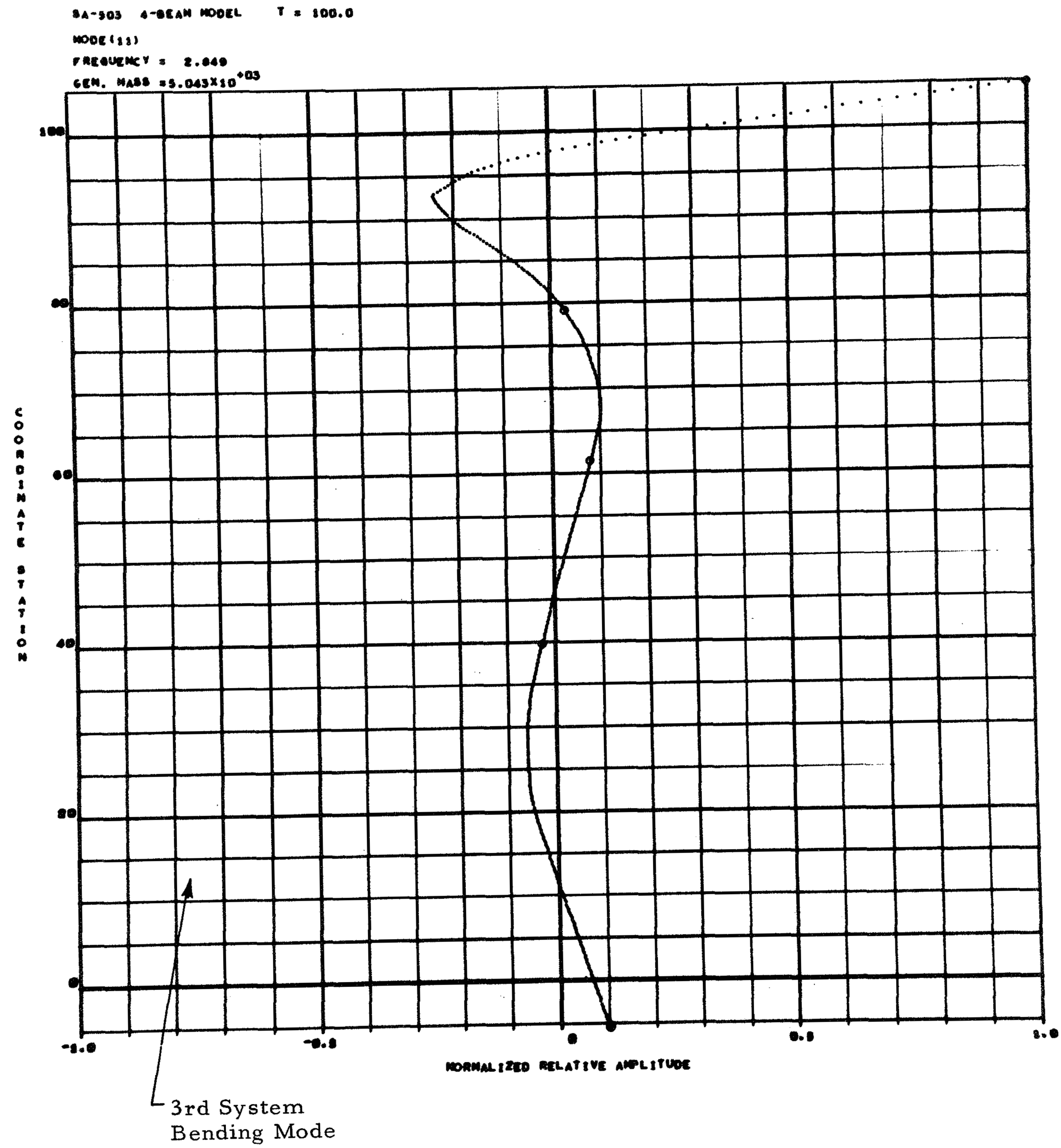


Fig. A-20 - System Bending Modes at t = 100 sec



2nd System
Bending Mode

Fig. A-20 - (Continued)



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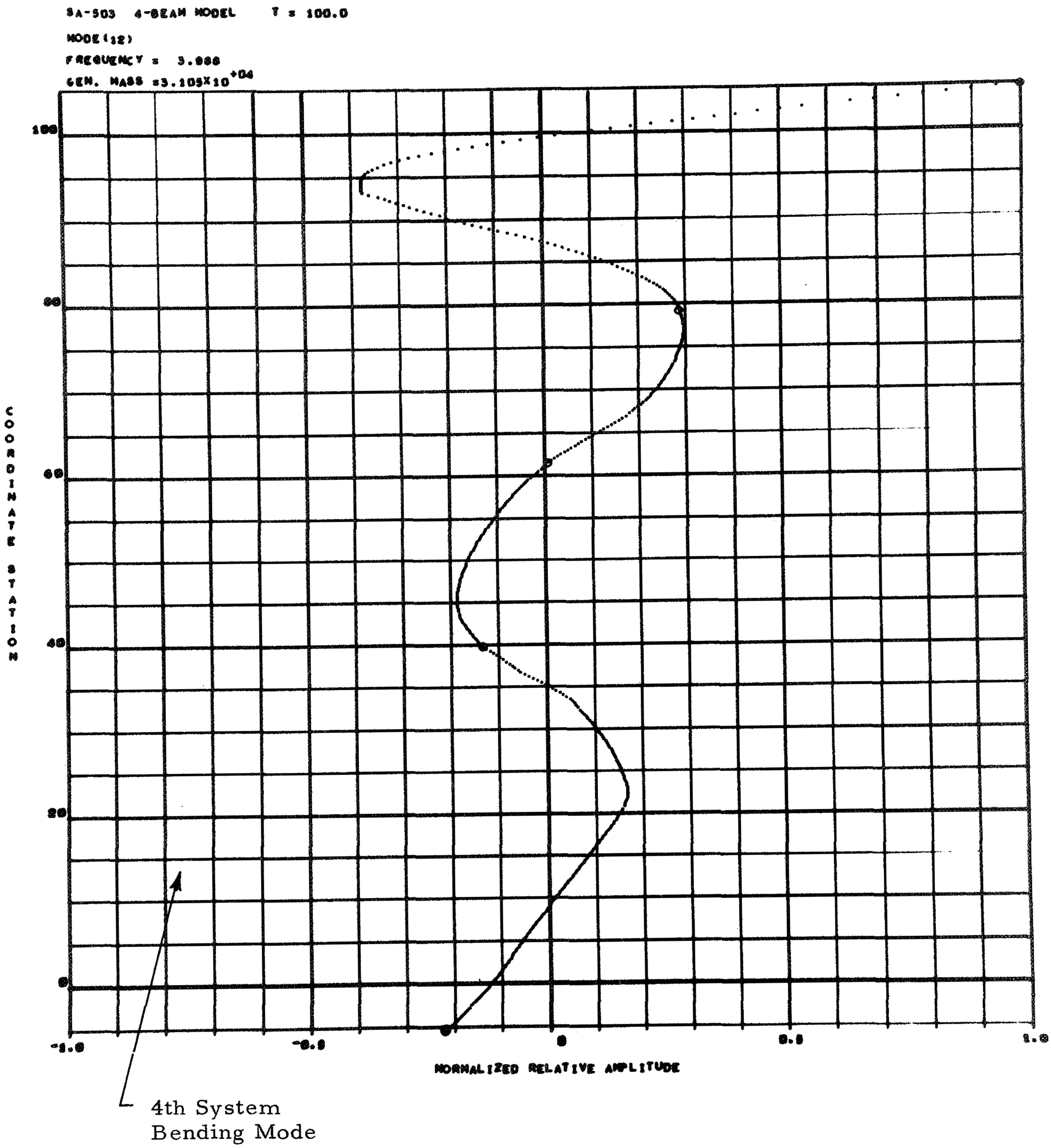


Fig. A-20 - (Continued)

Table A-1
VEHICLE PARAMETERS

Description	i =				Unit
	1	2	3	4	
$(Y'_G)_i = (Y'_R)_i$	-0.0115	0.001	0.01	0.008	1/m
ζ_i	0.05	0.05	0.05	0.05	Dimensionless
ω_i	7.0	12.125	16.7	23.75	rad/sec
$\left[M'_{\ddot{\eta}}(25,t)\right]_i = \left[M'_{\ddot{\eta}}(25)\right]_i$	406,300.0	-240,900.0	148,000.0	-93,000.0	N-m/m/sec^2
$\left[M'_{\ddot{\eta}}(90,t)\right]_i = \left[M'_{\ddot{\eta}}(90)\right]_i$	48,840.0	28,865.0	-4,000.0	-23,000.0	N-m/m/sec^2
a_o	0.86				rad/sec
a_1	1.15				rad/sec/sec
$M'_\beta(25,t) = M'_\beta(25)$	302.0×10^6				N-m/rad

Table A-2
VARIABLE SCALES

Variable (s)	Unit/Division
β_E, β_C	0.00125
α	0.025
$\ddot{y}$	0.12
$M_B(90, t)$	4×10^4
$M_B(25, t)$	10^6
V_w	2
η_1	0.02
η_2	0.01
η_3	0.005
η_4	0.003
ϕ , $F(\Phi)$	0.002
$\dot{\phi}$, $F(\dot{\Phi})$	0.001

Appendix B

ANALOG WIRING DIAGRAMS

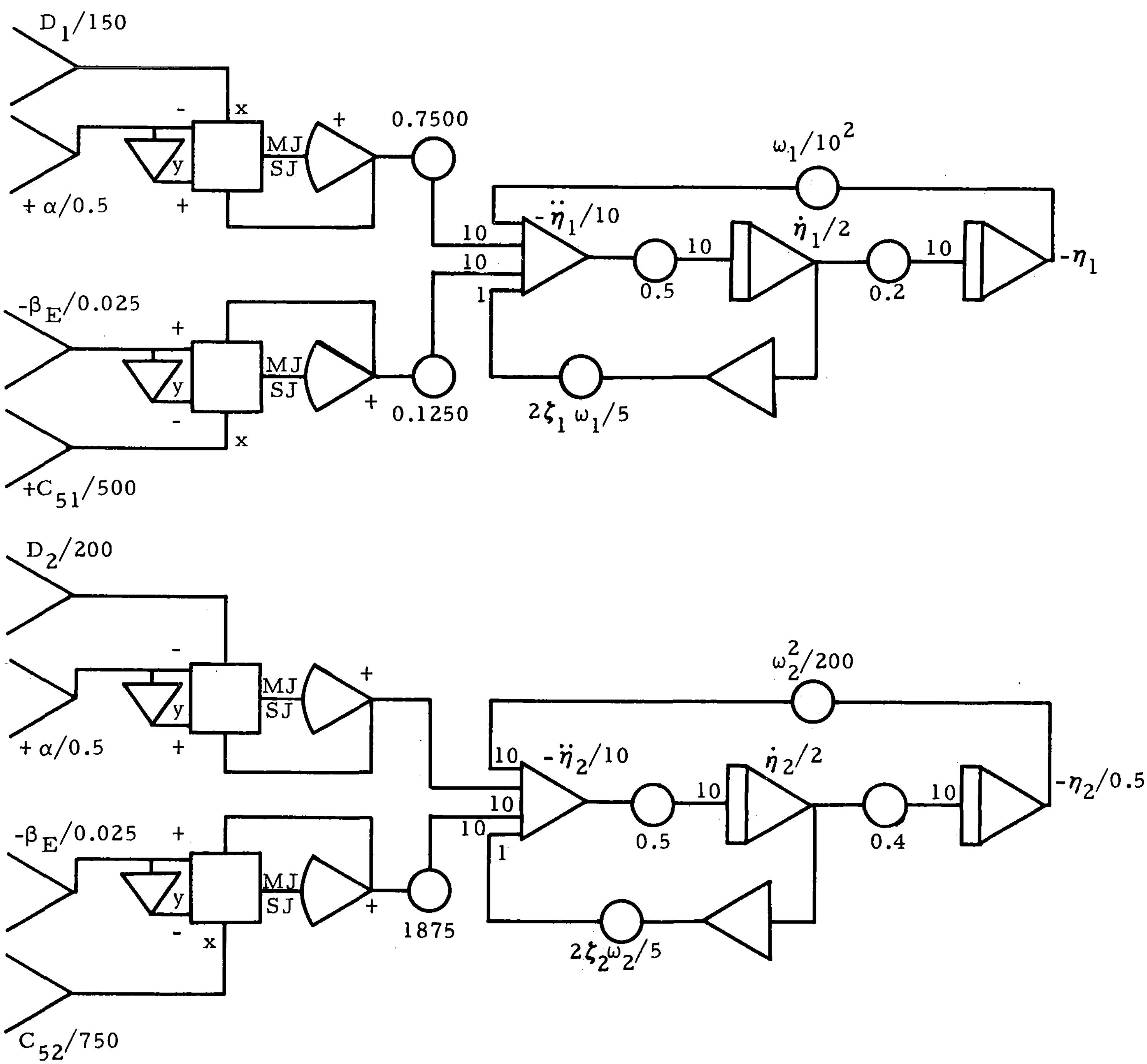


Fig. B-1 - Analog Wiring Diagram (Bending Modes)

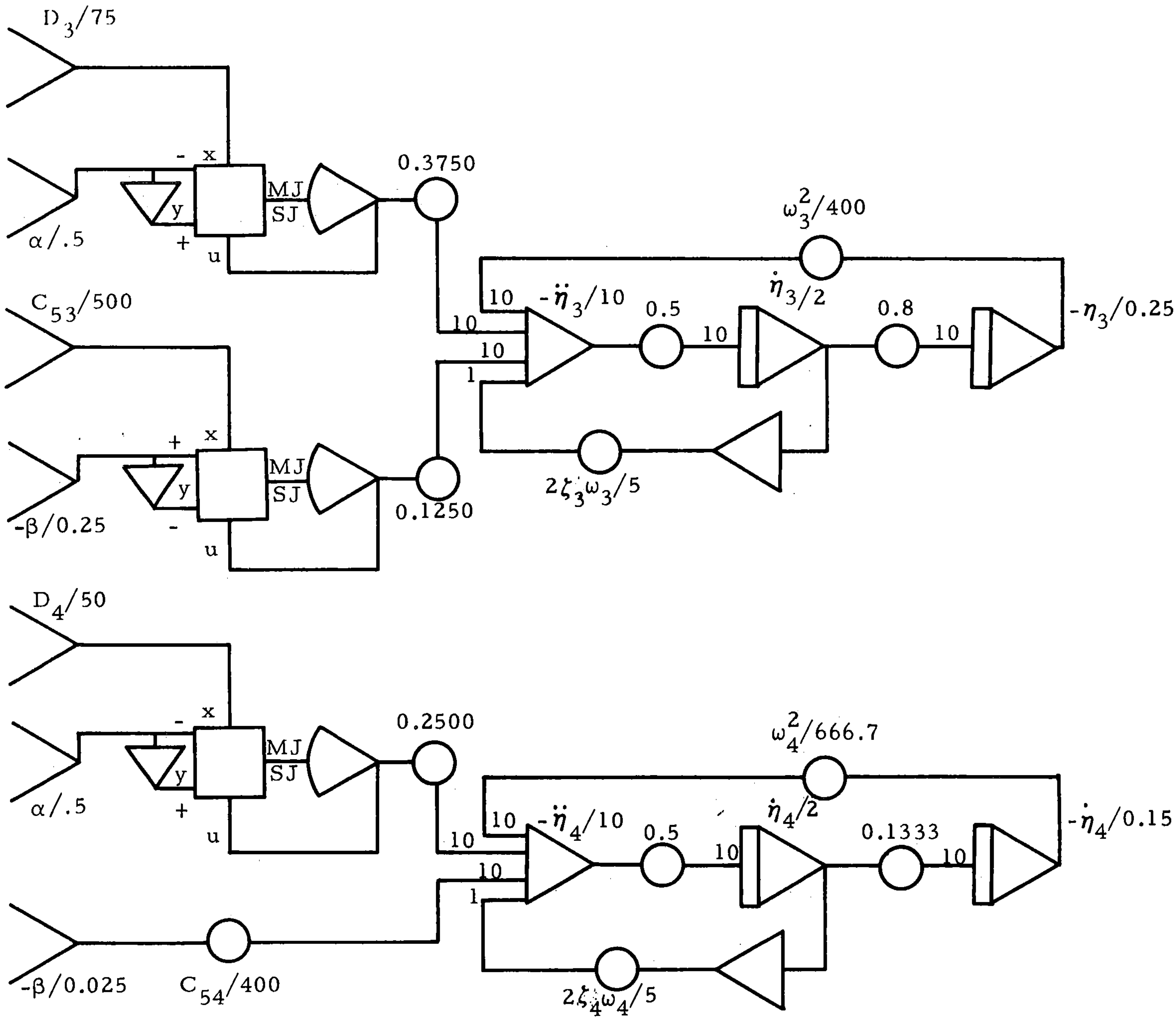


Fig. B-1 - (Continued)

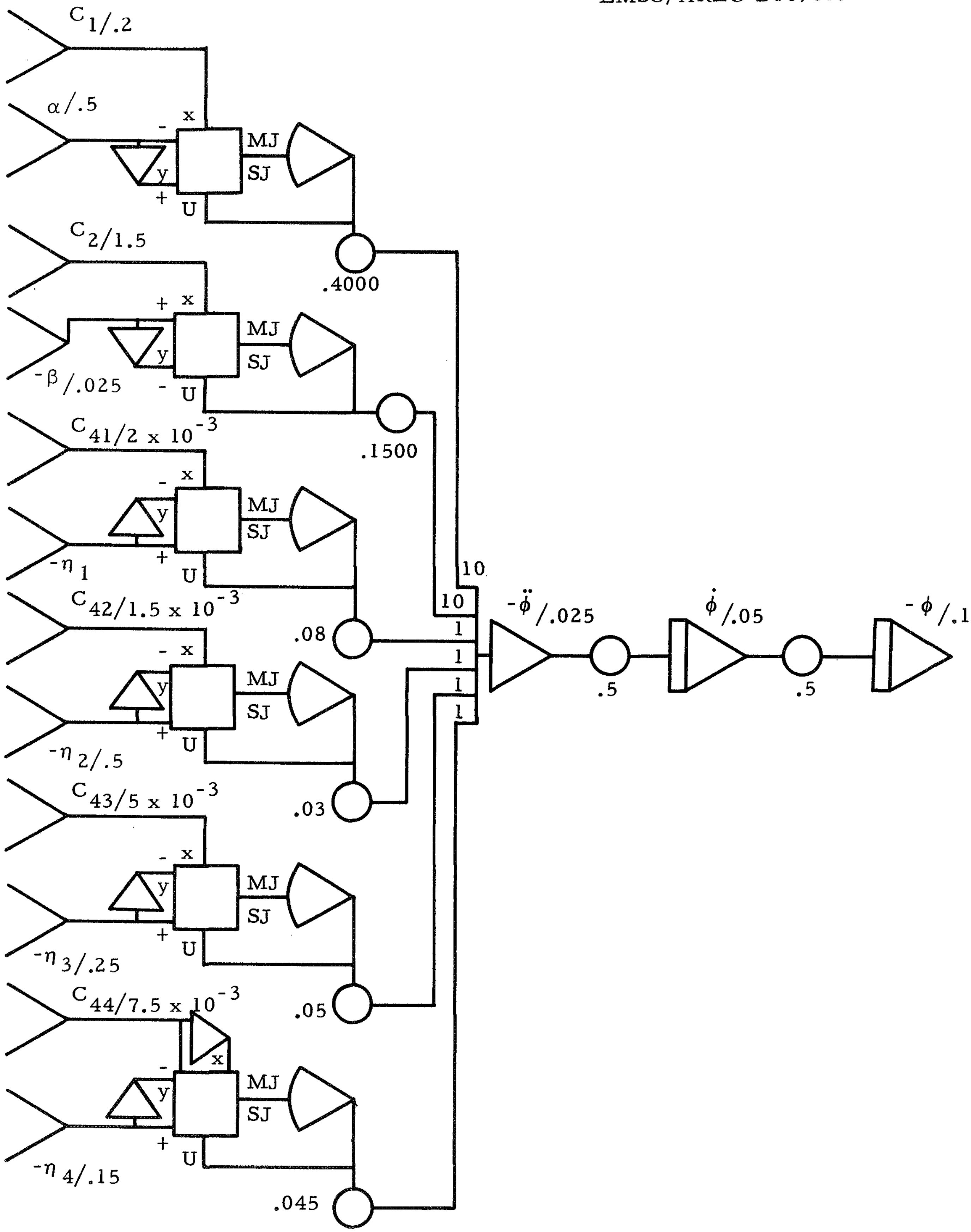
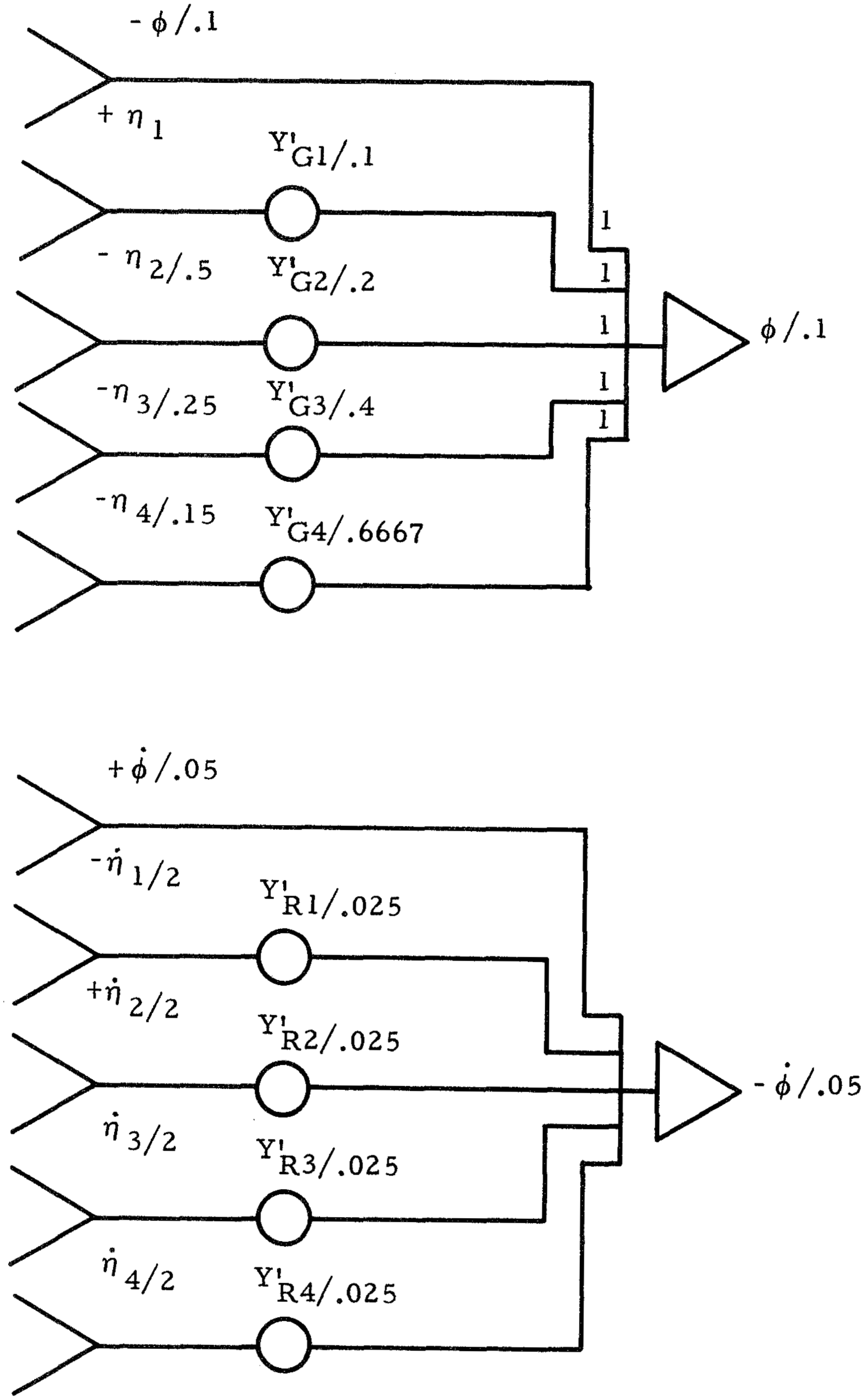


Fig. B-2 - Analog Wiring Diagram (Attitude Angle)



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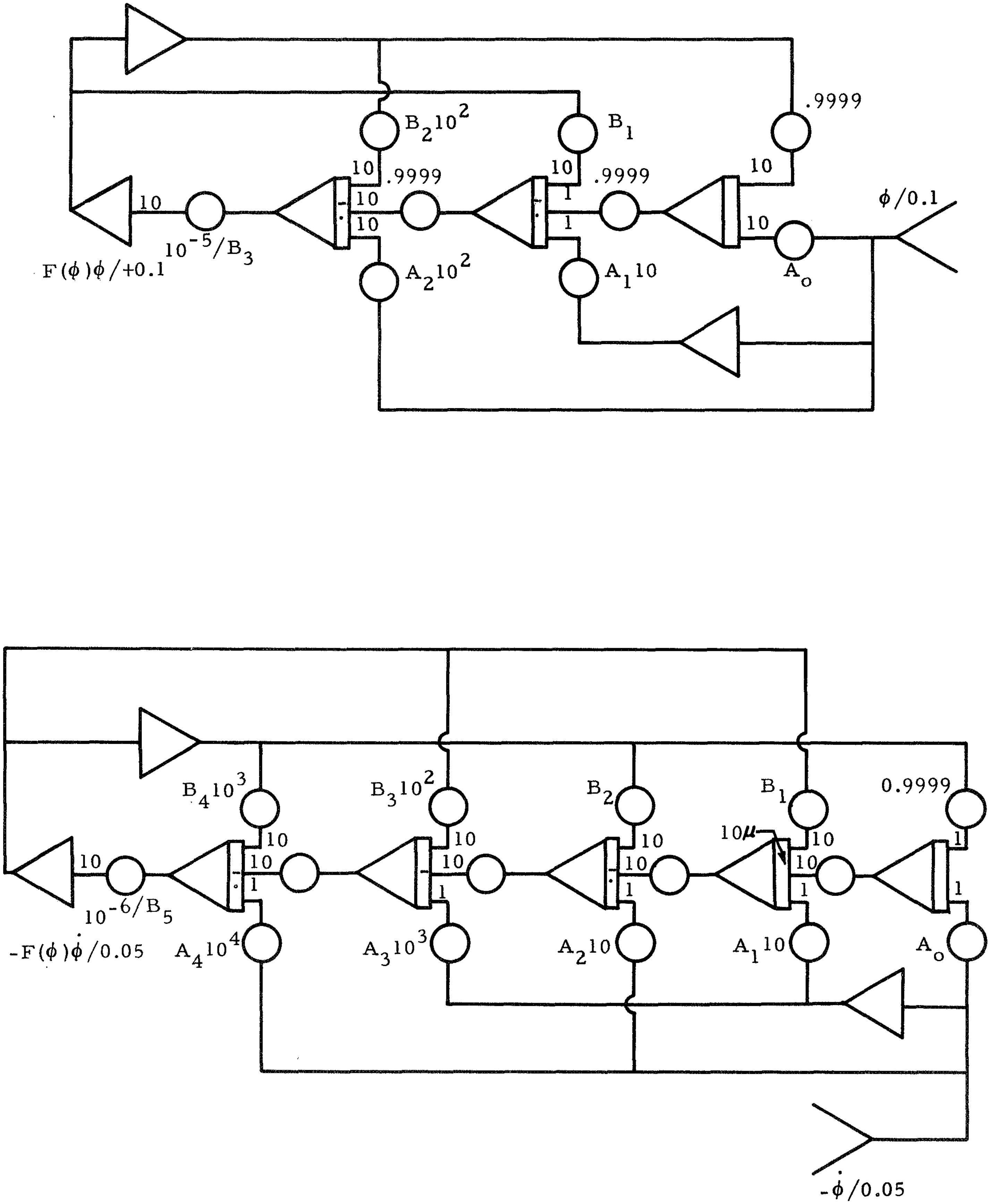

Fig. B-3 - Analog Wiring Diagram (Attitude Filters)

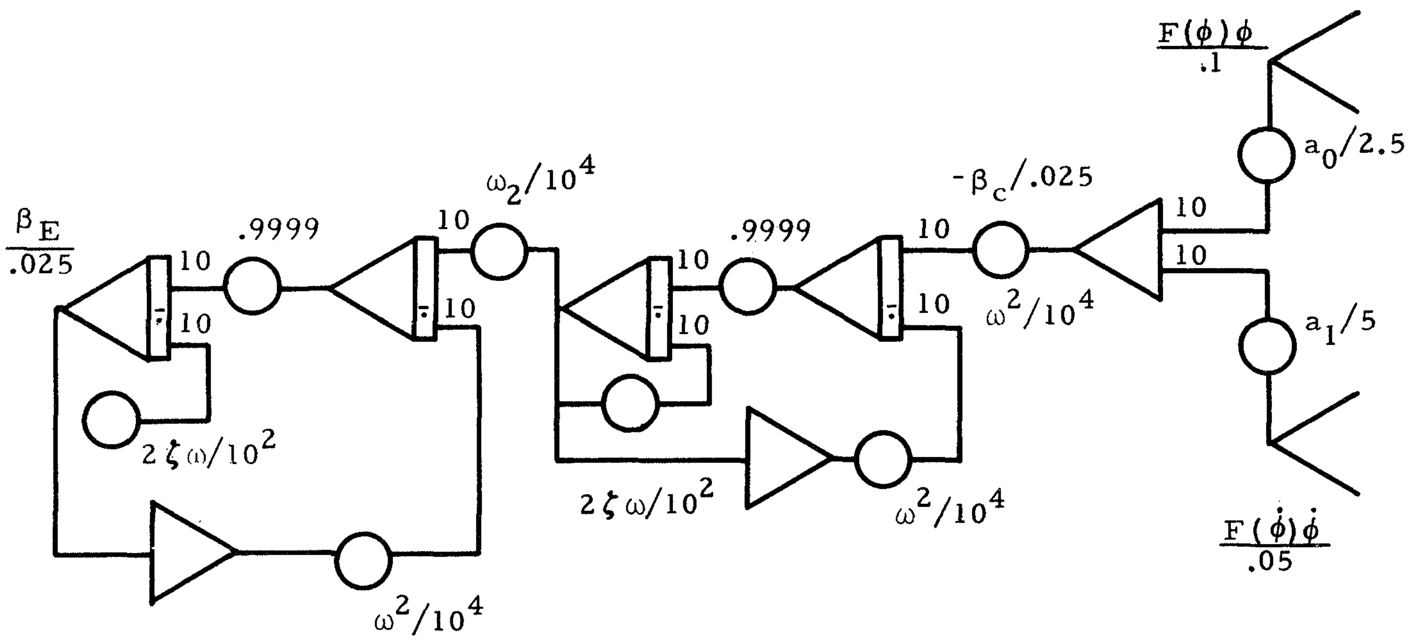

Fig. B-4 - Analog Wiring Diagram (Engine Deflection Angle)

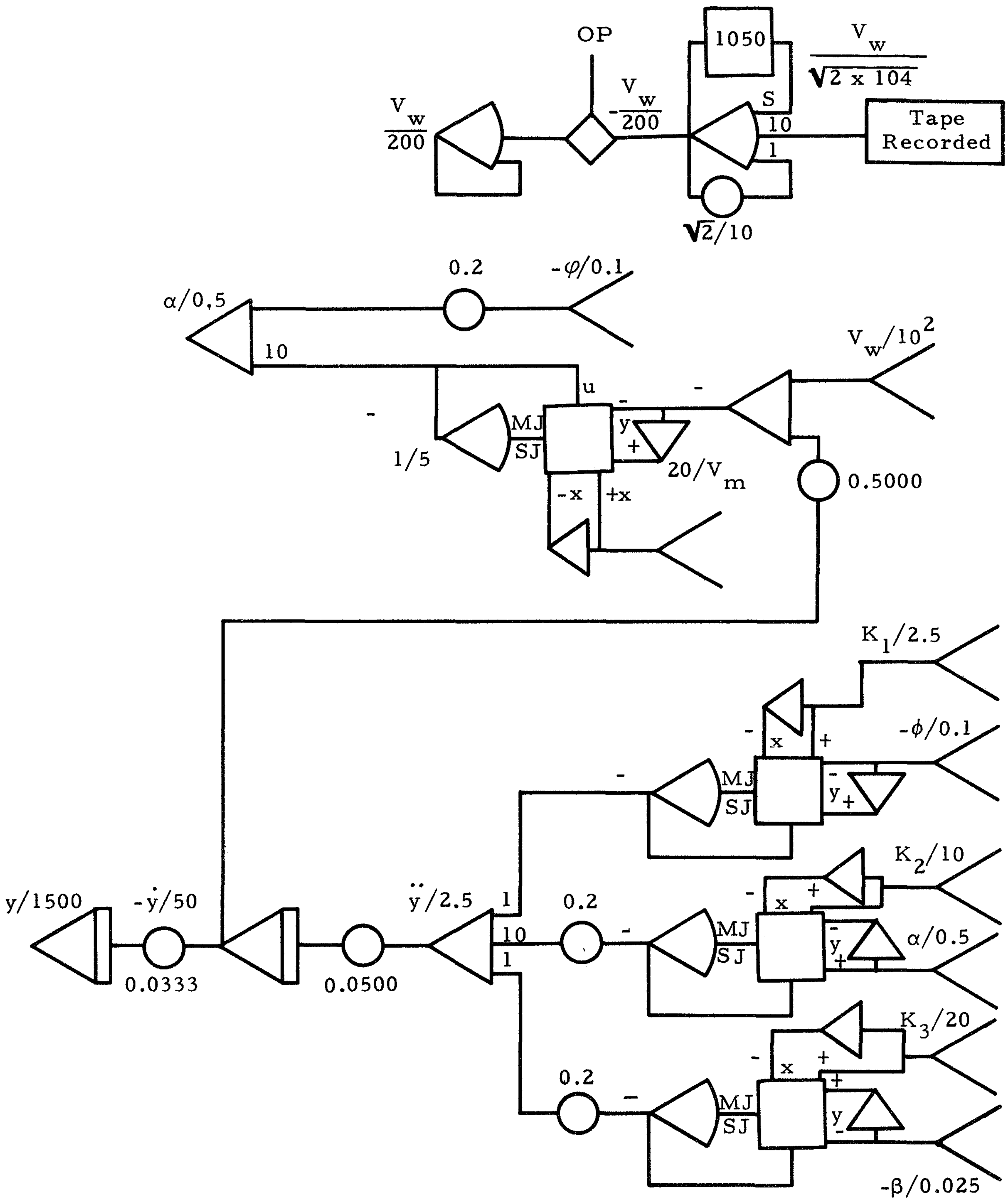

Fig. B-5 - Analog Wiring Diagram (Wind, Angle of Attack and Altitude)

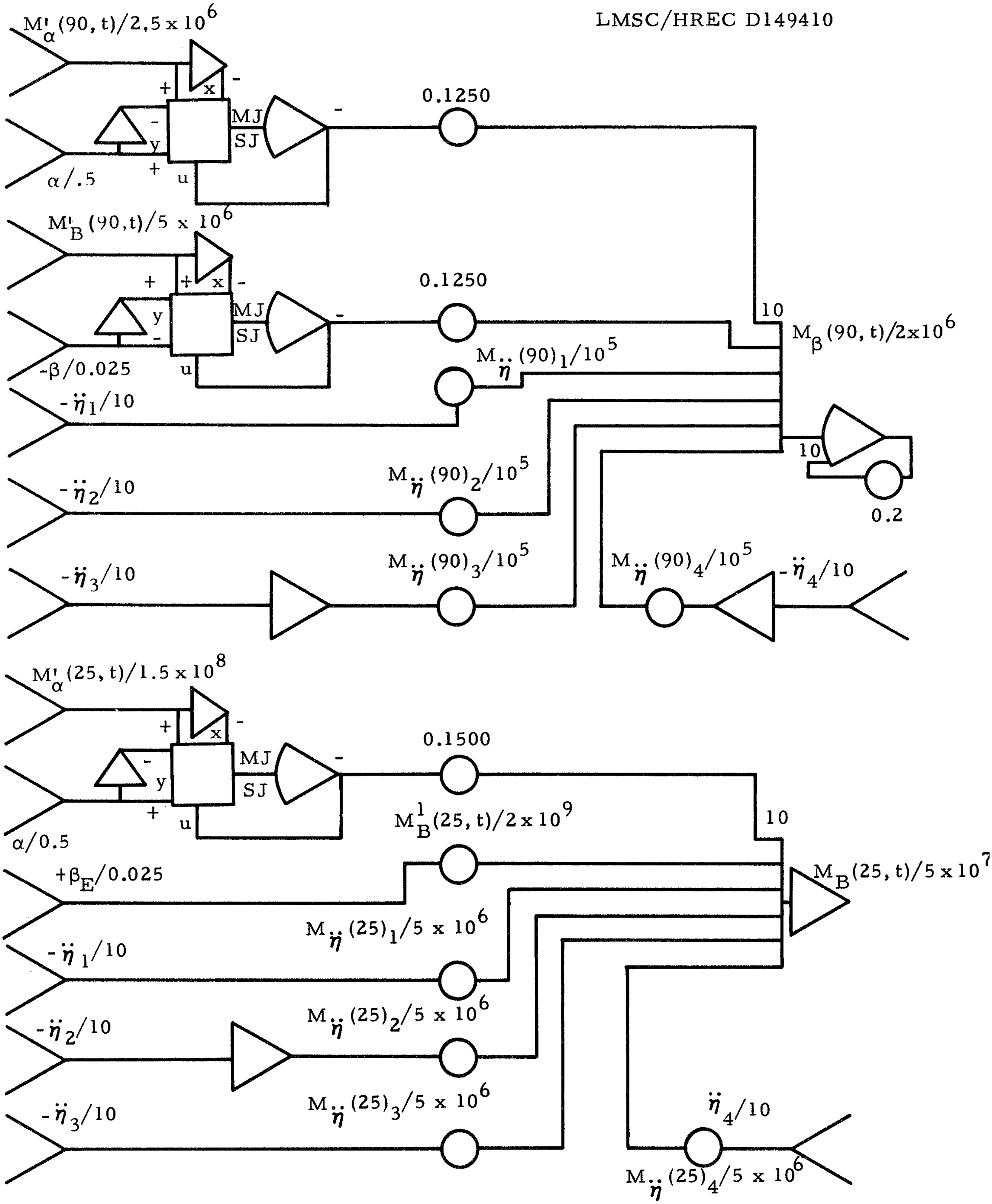

Fig. B-6 - Analog Wiring Diagram (Bending Moments)

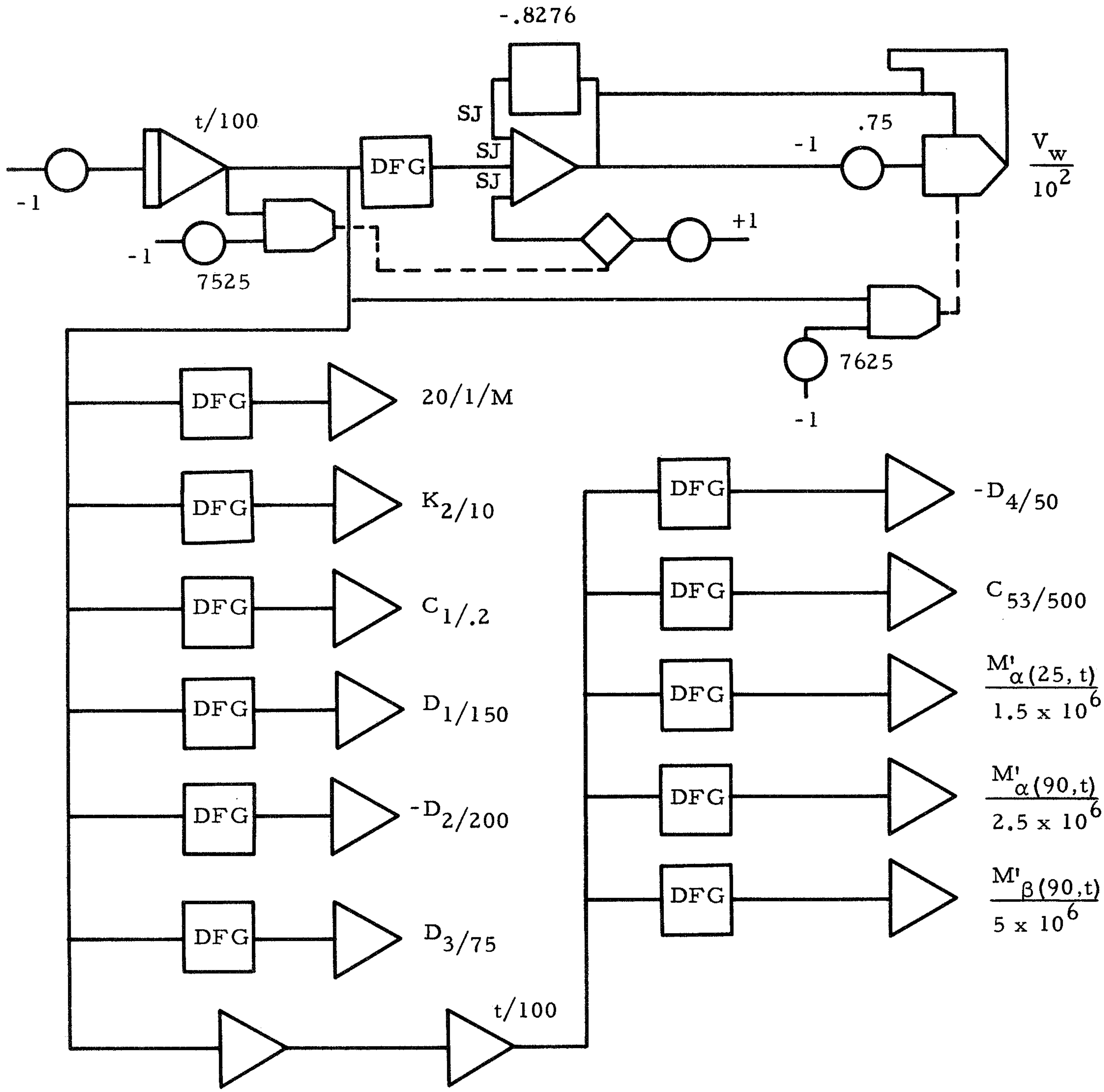

Fig. B-7 - Analog Wiring Diagram (Coefficients)

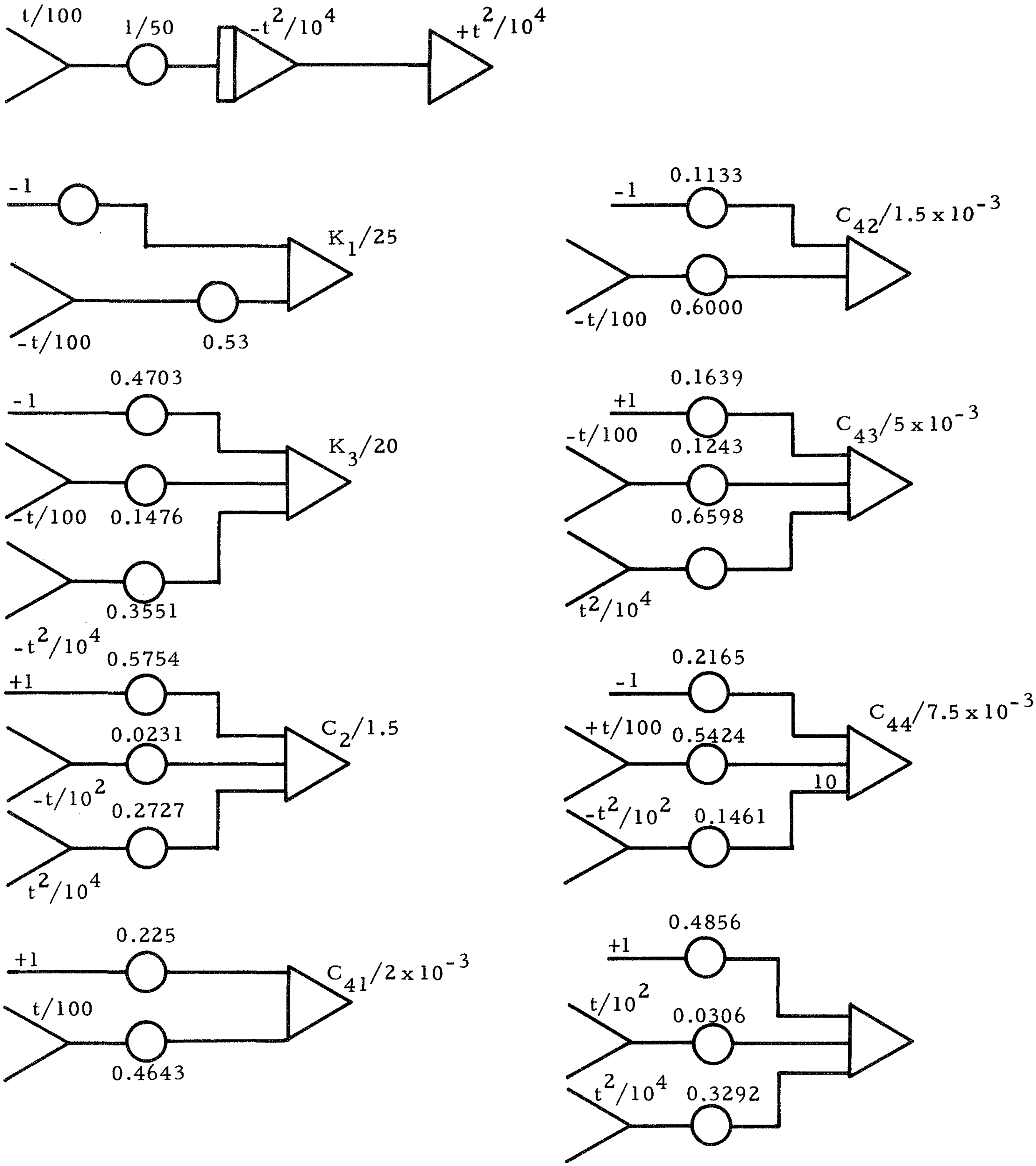

Fig. B-7 - (Continued)

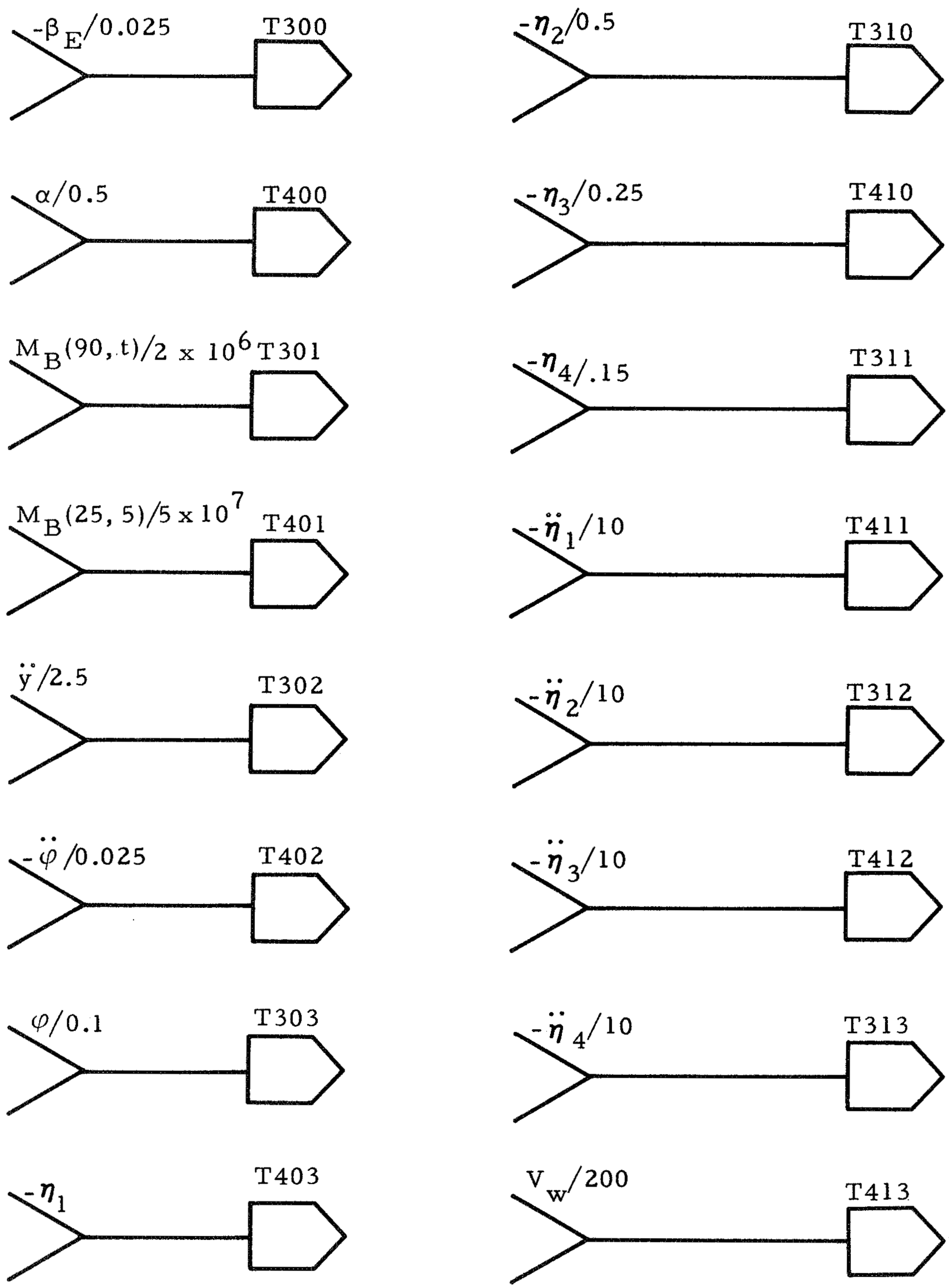

Fig. B-8 - Analog Wiring Diagram (Analog-to-Digital Transfers)

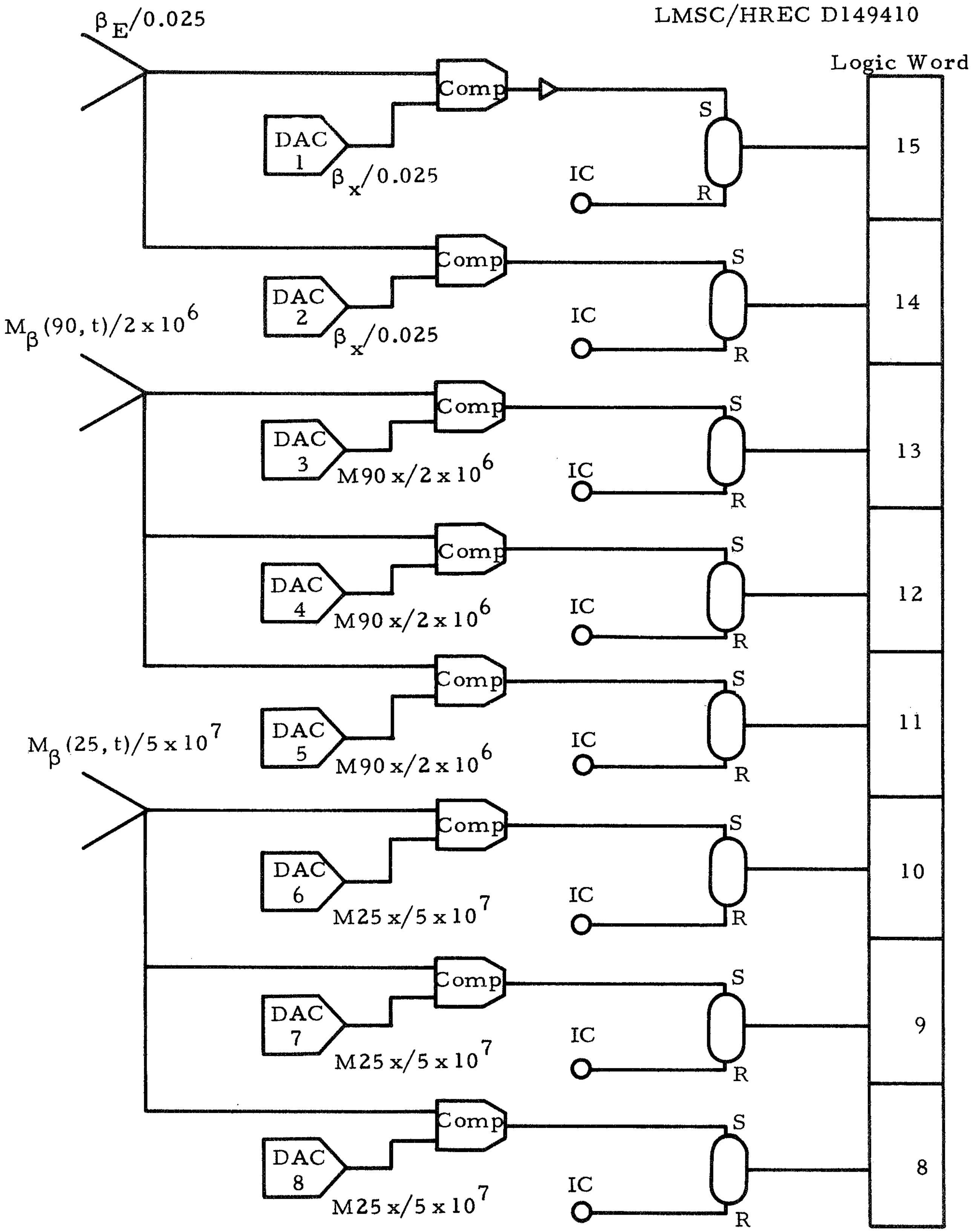

Fig. B-9 - Analog Wiring Diagram (Exceedance Counts)

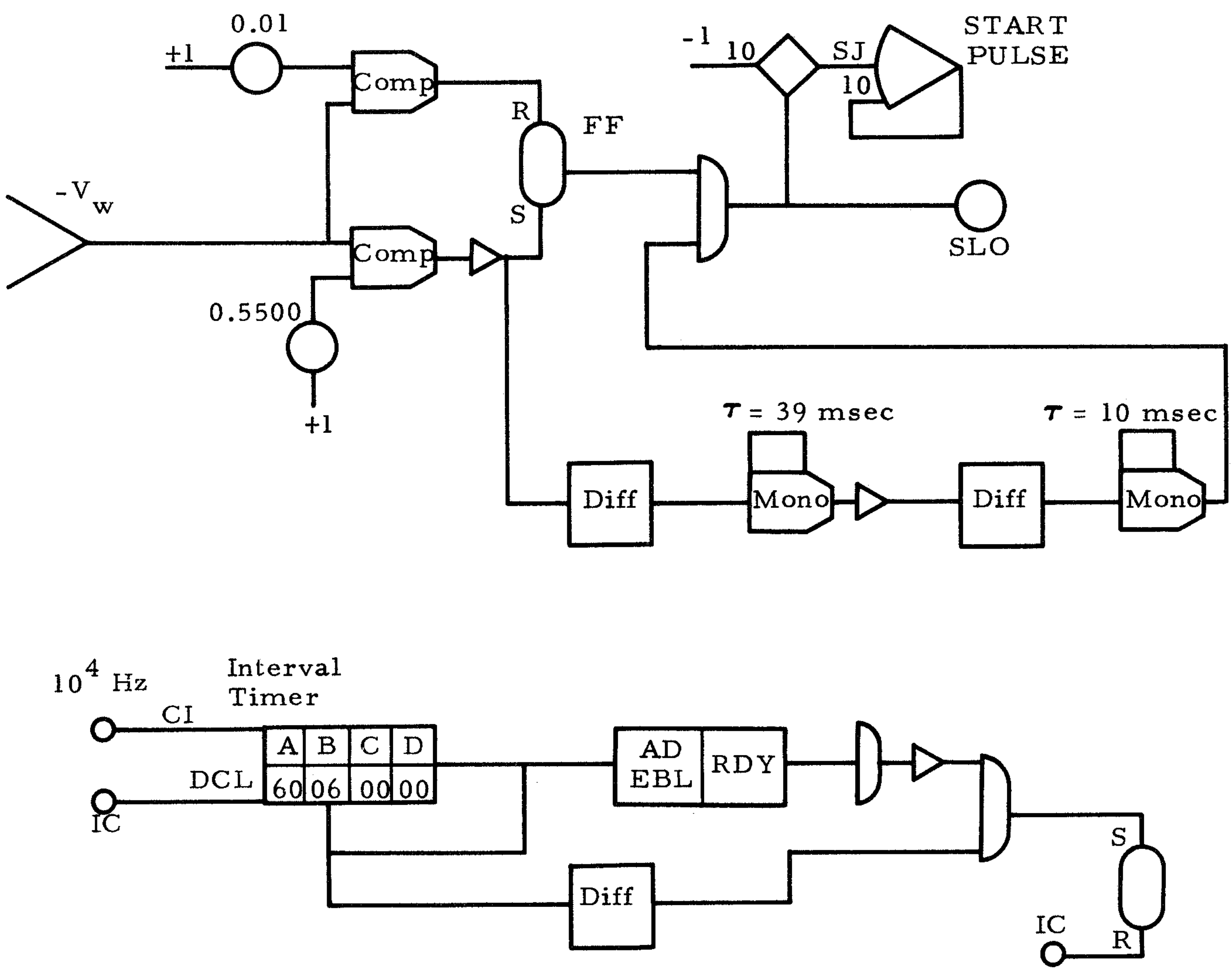

Fig. B-10 - Analog Wiring Diagram (Logic for Wind Tape and A/D)

Appendix C

LISTINGS OF THE DIGITAL PROGRAM

```
$JOB
$FR•.IU1••4003
      LOGICAL INDIC
      EXTENDED TITLE
      REAL M90X•M25X•M90B•M25B•M90V•M25V•M90•M25•MA25•MA90•MB90•M903•
     1M253•I1B•I2B•I3B
      DATAIOCT8/O 00377/
      COMMON / BLOCK / IOCT8•I•IERR•NMAX•NRMAX•NPASS•NRUN•INDIC•ICHAN•
     1 T1•T2•N•ILOC
      COMMON    ADSCAL(16)•DASCAL(16)•BX(4)•DEL4X(3)•DEL5X(3)•DEL6X(3)•
     1IBX(4)•IM90X(6)•IM25X(6)•ID4(3)•ID5(3)•ID6(3)•BB(18)•AB(18)•
     2YDDB(18)•PHI2B(18)•VWB(18)•ATA1B(18)•ATA2B(18)•ATA3B(18)•ATA4B(18)
     3•
     4ATD1B(18)•ATD2B(18)•ATD3B(18)•ATD4B(18)•PHIB(18)•XI1B(18)•XI2B(18)
     5•XI3B(18)•XI4B(18)•XI5B(18)•XI6B(18)•DEL1B(18)•DEL2B(18)•DEL3B(18)
     6•DEL4B(18)•DEL5B(18)•DEL6B(18)•                           BV(18)•
     7AV(18)•VWV(18)•DAC(8)•ADC(16)•B(18)•A(18)•YDD(18)•PHI2(18)•PHI(18)
     8•ATA1(18)•ATA2(18)•ATA3(18)•ATA4(18)•ATD1(18)•ATD2(18)•ATD3(18)•
     9ATD4(18)•VW(18)•DEL4(18)•DEL5(18)•DEL6(18)•IIBX(4)•IIM90X(6)•
     1IIM25X(6)•IID4(3)•IID5(3)•IID6(3)•B3(18)•A3(18)•VW3(18)•TITLE(20)•
     2S11(18)•S12(18)•S13(18)•S14(18)•S21(18)•S22(18)•S23(18)•S24(18)•
     3S31(18)•S32(18)•S33(18)•S34(18)•S41(18)•S42(18)•S43(18)•S44(18)•
     4S51(18)•S52(18)•S53(18)•S54(18)•S61(18)•S62(18)•S63(18)•S64(18)•
     5T11(18)•T12(18)•T13(18)•T14(18)•T21(18)•T22(18)•T23(18)•T24(18)•
     6T31(18)•T32(18)•T33(18)•T34(18)•P11(18)•P12(18)•P13(18)•P14(18)•
     7P21(18)•P22(18)•P23(18)•P24(18)•P31(18)•P32(18)•P33(18)•P34(18)
     1•A21B(18)•A22B(18)•A23B(18)
      COMMON
     1      M90X(6)•M25X(6)•M90B(18)•M25B(18)•M90V(18)•M25V(18)•M90(18)•
     1M25(18)•MA25(18)•MA90(18)•MB90(18)•M903(18)•M253(18)•
     2I1B(18)•I2B(18)•I3B(18)
      DATAIOCT8/O 00377/                                         VRAN0040
 1000 FORMAT(21H•CONSOLE•DISCONNECTED)
 1010 FORMAT(29H•NON-EXISTING COMPONENT REQ'D)
 1030 FORMAT(8I10)
 1040 FORMAT(18H OVERFLOW DAC CH. I2)
 1050 FORMAT(27H NON-EXISTING DAC CH. REQ'D)
 1060 FORMAT(24H MISSED BEGINNING OF RUN)
```

```
 1070 FORMAT(26H ERROR IN BLOCK ADDRESSING)
 1080 FORMAT(18H OVERLOAD ADC CH. I2)
 1090 FORMAT(27H NON-EXISTING ADC CH. REQ'D)
 1100 FORMAT(14H END OF PASS 1)
 1110 FORMAT(20A4)
 1150 FORMAT(1X9E14.7/)
 1160 FORMAT(1X9I14)
 1700 FORMAT(I14,8E14.7)
C INPUT DATA
C INPUT A/D AND D/A SCALE FACTORS
   14 READ 1110,(TITLE(I),I=1,20)
      CALL READ
C INITIALIZE ANALOG MODE AND START OF RUN INDICATOR
  100 CALL QICO(1,IERR)
      IF (IERR.EQ.1) GO TO 5
      IF(IERR.EQ.2)TYPE 1000
      PAUSE
      GO TO 100
    5 CONTINUE
C INPUT NO. OF POINTS/RUN AND NO. OF RUNS
      READ 1020,NMAX,NRMAX
C SET INITIAL CONDITIONS
   21 NPASS=1
      IBX(1)=0
      IBX(3)=0
      DO 8 I=1,5,2
      IM90X(I)=0
      IM25X(I)=0
    8 CONTINUE
      DO 230 I=1,3
      ID4(I)=0
      ID5(I)=0
      ID6(I)=0
  230 CONTINUE
      DO 9 I=1,18
      BB(I)=0.
      AB(I)=0.
      VWB(I)=0.
```

```
      ATA1B(I)=0.
      ATA2B(I)=0.
      ATA3B(I)=0.
      ATA4B(I)=0.
      ATD1B(I)=0.
      ATD2B(I)=0.
      ATD3B=0.
      ATD4B=0.
      YDDB(I)=0.
      PHI2B(I)=0.
      PHIB(I)=0.
    9 CONTINUE
C     INITIAL CONDITION FOR PASS 2
      IBX(2)=0
      IBX(4)=0
   40 DO 16 I=2,6,2
      IM90X(I)=0.
      IM25X(I)=0.
   16 CONTINUE
      DO 17 I=1,18
      BV(I)=0.
      AV(I)=0.
      M90V(I)=0.
      M25V(I)=0.
      VWV(I)=0.
   17 CONTINUE
    4 NRUN=1
      CALL QTEFF0(1,0,INDIC,IERR)
      IF(IERR.EQ.1)GO TO 51
      IF(IERR.EQ.2)TYPE 1000
      IF(IERR.EQ.3)TYPE 1010
      PAUSE
      GO TO 4
C TEST FOR PASS NO..
   51 IF(NPASS.EQ.1)GO TO 10
      IF(NPASS.EQ.2)GO TO 11
C SET FIRST SET OF EXCEEDANCE LEVELS
   10 DAC(1)=-BX(1)*DASCAL(1)
```

```
      DAC(2)=-BX(3)*DASCAL(2)
      DAC(3)=-M90X(1)*DASCAL(3)
      DAC(4)=-M90X(3)*DASCAL(4)
      DAC(5)=-M90X(5)*DASCAL(5)
      DAC(6)=-M25X(1)*DASCAL(6)
      DAC(7)=-M25X(3)*DASCAL(7)
      DAC(8)=-M25X(5)*DASCAL(8)
      GO TO 12
C SET SECOND SET OF EXCEEDANCE LEVELS
   11 DAC(1)=-BX(2)*DASCAL(1)
      DAC(2)=-BX(4)*DASCAL(2)
      DAC(3)=-M90X(2)*DASCAL(3)
      DAC(4)=-M90X(4)*DASCAL(4)
      DAC(5)=-M90X(6)*DASCAL(5)
      DAC(6)=-M25X(2)*DASCAL(6)
      DAC(7)=-M25X(4)*DASCAL(7)
      DAC(8)=-M25X(6)*DASCAL(8)
   12 CALL QDAJMO(0.8.DAC.IERR.ICHAN)
      IF(IERR.EQ.1)GO TO 3
      IF(IERR.EQ.2)TYPE 1040.ICHAN
      IF(IERR.EQ.3)TYPE 1050
      PAUSE
      GO TO 14
C TEST FOR BEGINNING OF RUN
    3 CALL QTEFFO(1.0.INDIC.IERR)
      IF(IERR.EQ.1)GO TO 13
      IF(IERR.EQ.2)TYPE 1000
      IF(IERR.EQ.3) TYPE 1010
      PAUSE
      GO TO 14
   13 IF(INDIC)GO TO 18
C TEST FOR BEGINNING OF RUN
   19 CALL QTEFFO(1.0.INDIC.IERR)
      IF(INDIC)GO TO 20
      GO TO 19
 20   CALL QTEFFO(1.0.INDIC.IERR)
      IF(INDIC)GO TO 20
      GO TO 50
```

```
C MISSED BEGINNING OF RUN
   18 TYPE 1060
      CALL QICO(1,IERR)
      NRUN=NRUN-1
      PRINT 1160,NRUN
      PRINT 1150,T1
      PRINT 1150,T2
      PAUSE
C TEST FOR PASS NO.
      IF(NPASS.EQ.1)GO TO 21
      IF(NPASS.EQ.2)GO TO 40
C SELECT OPERATE TO START ANALOG
 50   CONTINUE
/       LDOB     =*2047,,12
      CALL CLOCKS
      IF(IERR.EQ.1)GO TO 22
      IF(IERR.EQ.2)TYPE 1000
      TYPE 1060
      PAUSE
C READ ADC'S
   22 DO 23 N=1,NMAX
      CALL QSTREO(0,16,     IERR)
      IF(IERR.EQ.1)GO TO 24
      IF(IERR.EQ.2)TYPE 1070
      CALL QICO(1,IERR)
      PAUSE
      GO TO 14
   24 CALL QADCVO(0,16,ADC,IERR,ICHAN)
      IF(IERR.EQ.1)GO TO 41
      IF(IERR.EQ.2)TYPE 1080  ,ICHAN
      IF(IERR.EQ.3)TYPE 1090
      CALL QICO(1,IERR)
      PAUSE
      GO TO 14
   41 B(N)=ADC(1)*ADSCAL(1)
      A(N)=ADC(2)*ADSCAL(2)
      YDD(N)=ADC(3)*ADSCAL(3)
      PHI2(N)=ADC(4)*ADSCAL(4)
```

```
      PHI(N)=ADC(5)*ADSCAL(5)
      ATA1(N)=ADC(6)*ADSCAL(6)
      ATA2(N)=ADC(7)*ADSCAL(7)
      ATA3(N)=ADC(8)*ADSCAL(8)
      ATA4(N)=ADC(9)*ADSCAL(9)
      ATD1(N)=ADC(10)*ADSCAL(10)
      ATD2(N)=ADC(11)*ADSCAL(11)
      ATD3(N)=ADC(12)*ADSCAL(12)
      ATD4(N)=ADC(13)*ADSCAL(13)
      VW(N)=ADC(14)*ADSCAL(14)
      M90(N)=ADC(15)*ADSCAL(15)
      M25(N)=ADC(16)*ADSCAL(16)
   23 CONTINUE
C SELECT HOLD MODE TO STOP ANALOG
/       LDOB    ='2447.,12
C READ EXCEEDANCE COUNT
      CALL QLGINO(1,ILOC,IERR)
      IF(IERR.EQ.1)GO TO 25
      IF(IERR.EQ.2)TYPE 1000
      PAUSE
      GO TO 14
C SELECT THE IC MODE ON THE ANALOG
 25   CONTINUE
/       LDOB    ='3047.,12
      T1=CLOCKR(0)
C TEST PASS NO.
      IF(NPASS.EQ.1)GO TO 26
      IF(NPASS.EQ.2)GO TO 2
C CALCULATE THE FIRST SET OF EXCEEDANCE COUNTS
C**
C*    SUBROUTINE COUNTS
C     DO 27 I=1,5,2
C  26 IIBX(1)=0
C     IIBX(3)=0
C     IIM90X(I)=0
C     IIM25X(I)=0
C  27 CONTINUE
C     IF(ILOC.AND.1)IIBX(1)=1
```

```
C      IF(ILOC.AND.2)IIBX(3)=1
C      IF(ILOC.AND.4)IIM90X(1)=1
C      IF(ILOC.AND.8)IIM90X(3)=1
C      IF(ILOC.AND.16)IIM90X(5)=1
C      IF(ILOC.AND.32)IIM25X(1)=1
C      IF(ILOC.AND.64)IIM25X(3)=1
C      IF(ILOC.AND.128)IIM25X(5)=1
C      IBX(1)=IBX(1)+IIBX(1)
C      IBX(3)=IBX(3)+IIBX(3)
C      DO 28 I=1,5,2
C      IM90X(I)=IM90X(I)+ IIM90X(I)
C      IM25X(I)=IM25X(I)+ IIM25X(I)
C   28 CONTINUE
C      DO 210 I=1,3
C      IID4(I)=0
C      IID5(I)=0
C      IID6(I)=0
C  210 CONTINUE
C      DO 200 I=1,NMAX
C      DEL4(I)=.6042*(S41(I)*ATA1(I)+S42(I)*ATA2(I)+S43(I)*ATA3(I) +
C     1                 S44(I)*ATA4(I))
C      DEL5(I)=.59*(S51(I)*ATA1(I)+S52(I)*ATA2(I)+S53(I)*ATA3(I)
C     1             + S54(I)*ATA4(I))
C      DEL6(I)=.64*(S61(I)*ATA1(I)+S62(I)*ATA2(I)+S63(I)*ATA3(I)+
C     1                S64(I)*ATA4(I))
C      IF(DEL4(I).GT.DEL4X(1))IID4(1)=1
C      IF(DEL4(I).GT.DEL4X(2))IID4(2)=1
C      IF(DEL4(I).GT.DEL4X(3))IID4(3)=1
C      IF(DEL5(I).GT.DEL5X(1))IID5(1)=1
C      IF(DEL5(I).GT.DEL5X(2))IID5(2)=1
C      IF(DEL5(I).GT.DEL5X(3))IID5(3)=1
C      IF(DEL6(I).GT.DEL6X(1))IID6(1)=1
C      IF(DEL6(I).GT.DEL6X(2))IID6(2)=1
C      IF(DEL6(I).GT.DEL6X(3))IID6(3)=1
C  200 CONTINUE
C      DO 220 I=1,3
C      ID4(I)=ID4(I)+IID4(I)
C      ID5(I)=ID5(I)+IID5(I)
```

```
C      ID6(I)=ID6(I)+IID6(I)
C 220  CONTINUE
C CALCULATE THE SUMMATION OF XI
C      DO 29 I=1,NMAX
C      BB(I)=BB(I)+ B(I)
C      AB(I)=AB(I)+ A(I)
C      M90B(I)=M90B(I)+M90(I)
C      M25B(I)=M25B(I)+M25(I)
C      VWB(I)=VWB(I) +VW(I)
C      ATA1B(I)=ATA1B(I) +ATA1(I)
C      ATA2B(I)=ATA2B(I)+ATA2(I)
C      ATA3B(I)=ATA3B(I)+ ATA3(I)
C      ATA4B(I)=ATA4B(I)+ ATD4(I)
C      ATD1B(I)=ATD1B(I)+ATD1(I)
C      ATD2B(I)=ATD2B(I)+ATD2(I)
C      ATD3B(I)=ATD3B(I)+ATD3(I)
C      ATD4B(I)=ATD4B(I)+ATD4(I)
C      PHIB(I)=PHIB(I)+ PHI(I)
C      YDDB(I)=YDDB(I)+YDD(I)
C      PHI2B(I)=PHI2B(I)+PHI2(I)
C  29  CONTINUE
C      RETURN
C      END
C**
   26 CALL COUNTS
      IF(NRUN.EQ.NRMAX)GO TO 30
      T2=CLOCKR(0)
      NRUN=NRUN+1
      GO TO 3
C CALCULATE MEAN VALUES
   30 DO 31 I=1,NMAX
      BB(I)=BB(I)/NRMAX
      AB(I)=AB(I)/NRMAX
      M90B(I)=M90B(I)/NRMAX
      M25B(I)=M25B(I)/NRMAX
      PHIB(I)=PHIB(I)/NRMAX
      VWB(I)=VWB(I)/NRMAX
      ATA1B(I)=ATA1B(I)/NRMAX
```

```
      ATA2B(I)=ATA2B(I)/NRMAX
      ATA3B(I)=ATA3B(I)/NRMAX
      ATA4B(I)=ATA4B(I)/NRMAX
      ATD1B(I)=ATD1B(I)/NRMAX
      ATD2B(I)=ATD2B(I)/NRMAX
      ATD3B(I)=ATD3B(I)/NRMAX
      ATD4B(I)=ATD4B(I)/NRMAX
      YDDB(I)=YDDB(I)/NRMAX
      PHI2B(I)=PHI2B(I)/NRMAX
   31 CONTINUE
C END OF PASS 1
      TYPE 1100
      PAUSE
      NPASS=NPASS+1
      GO TO 4
C CALCULATE THE SECOND SET OF EXCEEDANCE COUNTS
 2    IIBX(2)=0
      IIBX(4)=0
      DO 32 I=2,6,2
      IIM90X(I)=0
      IIM25X(I)=0
   32 CONTINUE
C     IF(ILOC.AND.1)IIBX(2)=1
C     IF(ILOC.AND.2)IIBX(4)=1
C     IF(ILOC.AND.4)IIM90X(2)=1
C     IF(ILOC.AND.8)IIM90X(4)=1
C     IF(ILOC.AND.16)IIM90X(6)=1
C     IF(ILOC.AND.32)IIM25X(2)=1
C     IF(ILOC.AND.64)IIM25X(4)=1
C     IF(ILOC.AND.128)IIM25X(6)=1
ASSEMBL
        CA      /ILOC
        AHM1    /IIBX+1,,15
        ROT     1
        AHM1    /IIBX+3,,15
        ROT     1
        AHM1    /IIM90X+1,,15
        ROT     1
```

```
        AHM1     /IIM90X+3,,15
        ROT      1
        AHM1     /IIM90X+5,,15
        ROT      1
        AHM1     /IIM25X+1,,15
        ROT      1
        AHM1     /IIM25X+3,,15
        ROT      1
        AHM1     /IIM25X+5,,15
FORTRAN
      IBX(2)=IBX(2)+IIBX(2)
      IBX(4)=IBX(4)+IIBX(4)
      DO 33 I=2,6,2
      IM90X(I)=IM90X(I)+IIM90X(I)
      IM25X(I)=IM25X(I)+IIM25X(I)
   33 CONTINUE
C CALCULATE SUMMATION(X-XB)**2
      DO 34 I=1,NMAX
      BV(I)=BV(I)+ (B(I)-BB(I))**2
      M90V(I)=M90V(I)+ (M90(I)-M90B(I))**2
      M25V(I)=M25V(I)+ (M25(I)-M25B(I))**2
      VWV(I)=VWV(I) +(VW(I)-VWB(I))**2
   34 CONTINUE
      IF(NRUN.EQ.NRMAX)GO TO 35
      NRUN=NRUN+1
      GO TO 3
C*
C     SUBROUTINE VARIAN
C  CALCULATE THE VARIANCES
C  35 DO 42 I=1,NMAX
C     BV(I)=BV(I)/(NRMAX-1)
C     AV(I)=AV(I)/(NRMAX-1)
C     M90V(I)=M90V(I)/(NRMAX-1)
C     M25V(I)=M25V(I)/(NRMAX-1)
C     VWV(I)=VWV(I)/(NRMAX-1)
C     B3(I)=3.*SQRT(BV(I))
C     A3(I)=3.*SQRT(AV(I))
C     M903(I)=3.*SQRT(M90V(I))
```

```
C      M253(I)=3.*SQRT(M25V(I))
C      VW3(I)=3.*SQRT(VWV(I))
C      XI1B(I)= S11(I)*ATA1B(I) +S12(I)*ATA2B(I) +S13(I)*ATA3B(I)
C     1         +S14(I)*ATA4B(I)
C      XI2B(I)= S21(I)*ATA1B(I) +S22(I)*ATA2B(I) +S23(I)*ATA3B(I)
C     1         +S24(I)*ATA4B(I)
C      XI3B(I)= S31(I)*ATA1B(I) +S32(I)*ATA2B(I) +S33(I)*ATA3B(I)
C     1         +S34(I)*ATA4B(I)
C      XI4B(I)= S41(I)*ATA1B(I) +S42(I)*ATA2B(I) +S43(I)*ATA3B(I)
C     1        +S44(I)*ATA4B(I)
C      XI5B(I)= S51(I)*ATA1B(I) +S52(I)*ATA2B(I) +S53(I)*ATA3B(I)
C     1         +S54(I)*ATA4B(I)
C      I1B(I) =-PHI2B(I) +P11(I)*ATD1B(I)+P12(I)*ATD2B(I)+P13(I)*ATD3B(I)
C     1                 +P14(I)*ATD4B(I)
C     1                 + T34(I)*ATD4B(I)
C     1                 +P24(I)*ATD4B(I)
C      I2B(I) =-PHI2B(I) +P21(I)*ATD1B(I)+P22(I)*ATD2B(I)+P23(I)*ATD3B(I)
C      XI6B(I)= S61(I)*ATA1B(I) +S62(I)*ATA2B(I) +S63(I)*ATA3B(I)
C     1         +S64(I)*ATA4B(I)
C      DEL1B(I)= XI1B(I)*.5299
C      DEL2B(I)= XI2B(I)*.539
C      DEL3B(I)= XI3B(I)*.5431
C      DEL4B(I)= XI4B(I)*.6042
C      DEL5B(I)= XI5B(I)*.59
C      DEL6B(I)= XI6B(I)*.64
C      A21B(I)=YDDB(I) + T11(I)*ATD1B(I)+T12(I)*ATD2B(I) +T13(I)*ATD3B(I)
C     1                 + T14(I)*ATD4B(I)
C      A22B(I)=YDDB(I) + T21(I)*ATD1B(I)+T22(I)*ATD2B(I) +T23(I)*ATD3B(I)
C     1                 + T14(I)*ATD4B(I)
C      A23B(I)=YDDB(I) + T31(I)*ATD1B(I)+T32(I)*ATD2B(I) +T33(I)*ATD3B(I)
C      I3B(I)= -PHI2B(I) +P31(I)*ATD1B(I)+P32(I)*ATD2B(I)+P33(I)*ATD3B(I)
C     1                +P34(I)*ATD4B(I)
C   42 CONTINUE
C      RETURN
C      END
C*
   35 CALL VARIAN
      CALL WRITE
      PAUSE
      GO TO 14
      END
```

```
      SUBROUTINE WRITE
      REAL M90X,M25X,M90B,M25B,M90V,M25V,M90,M25,MA25,MA90,MB90,M903,
     1M253,I1B,I2B,I3B
      COMMON     ADSCAL(16),DASCAL(16),BX(4),DEL4X(3),DEL5X(3),DEL6X(3),
     1IBX(4),IM90X(6),IM25X(6),ID4(3),ID5(3),ID6(3),BB(18),AB(18),
     2YDDB(18),PHI2B(18),VWB(18),ATA1B(18),ATA2B(18),ATA3B(18),ATA4B(18)
     3,
     4ATD1B(18),ATD2B(18),ATD3B(18),ATD4B(18),PHIB(18),XI1B(18),XI2B(18)
     5,XI3B(18),XI4B(18),XI5B(18),XI6B(18),DEL1B(18),DEL2B(18),DEL3B(18)
     6,DEL4B(18),DEL5B(18),DEL6B(18),                          BV(18),
     7AV(18),VWV(18),DAC(8),ADC(16),B(18),A(18),YDD(18),PHI2(18),PHI(18)
     8,ATA1(18),ATA2(18),ATA3(18),ATA4(18),ATD1(18),ATD2(18),ATD3(18),
     9ATD4(18),VW(18),DEL4(18),DEL5(18),DEL6(18),IIBX(4),IIM90X(6),
     1IIM25X(6),IID4(3),IID5(3),IID6(3),B3(18),A3(18),VW3(18),TITLE(20),
     2S11(18),S12(18),S13(18),S14(18),S21(18),S22(18),S23(18),S24(18),
     3S31(18),S32(18),S33(18),S34(18),S41(18),S42(18),S43(18),S44(18),
     4S51(18),S52(18),S53(18),S54(18),S61(18),S62(18),S63(18),S64(18),
     5T11(18),T12(18),T13(18),T14(18),T21(18),T22(18),T23(18),T24(18),
     6T31(18),T32(18),T33(18),T34(18),P11(18),P12(18),P13(18),P14(18),
     7P21(18),P22(18),P23(18),P24(18),P31(18),P32(18),P33(18),P34(18)
     1,A21B(18),A22B(18),A23B(18)
      COMMON
     1      M90X(6),M25X(6),M90B(18),M25B(18),M90V(18),M25V(18),M90(18),
     1M25(18),MA25(18),MA90(18),MB90(18),M903(18),M253(18),
     2I1B(18),I2B(18),I3B(18)
 1120 FORMAT(1H1,5X,20A4)
 1130 FORMAT(1H0,50H THE EXCEEDANCE LEVELS ARE LISTED ABOVE THE COUNTS)
 1140 FORMAT(1H0,5HBX(1)9X5HBX(2)9X5HBX(3)9X5HBX(4))
 1150 FORMAT(1X9E14.7/)
 1160 FORMAT(1X9I14)
 1170 FORMAT(1H0,8HMB90X(1)6X8HMB90X(2)6X8HMB90X(3)6X8HMB90X(4)6X
     1             8HMB90X(5)6X8HMB90X(6))
 1180 FORMAT(1H0,8HMB25X(1)6X8HMB25X(2)6X8HMB25X(3)6X8HMB25X(4)6X
     1             8HMB25X(5)6X8HMB25X(6))
 1190 FORMAT(1H0,71HTHE VARIABLES ARE LISTED ABOVE THE MEAN SIGMA SQUARE
     1,AND 3 SIGMA VALUES)
 1200 FORMAT(1H0,4HB(1)10X4HB(2)10X4HB(3)10X4HB(4)10X4HB(5)10X4HB(6)10X4
     1HB(7)10X4HB(8),10X4HB(9))
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```
1210 FORMAT(1H0,5HB(10)9X5HB(11)9X5HB(12)9X5HB(13)9X5HB(14)9X5HB(15)9X5
    1HB(16)9X5HB(17)9X5HB(18))
1220 FORMAT(1H0,4HA(1)10X4HA(2)10X4HA(3)10X4HA(4)10X4HA(5)10X4HA(6)10X4
    1HA(7)10X4HA(8)10X4HA(9))
1230 FORMAT(1H0,5HA(10)9X5HA(11)9X5HA(12)9X5HA(13)9X5HA(14)9X5HA(15)9X5
    1HA(16)          9X5HA(17)9X5HA(18))
1240 FORMAT(1H0,7HMB90(1)7X7HMB90(2)7X7HMB90(3)7X7HMB90(4)7X7HMB90(5)7X
    17HMB90(6)7X7HMB90(7)7X7HMB90(8)7X7HMB90(9))
1250 FORMAT(1H0,8HMB90(10)6X8HMB90(11)6X8HMB90(12)6X8HMB90(13)6X8HMB90(
    114)6X8HMB90(15)6X8HMB90(16)6X8HMB90(17)6X8HMB90(18))
1260 FORMAT(1H0,7HMB25(1)7X7HMB25(2)7X7HMB25(3)7X7HMB25(4)7X7HMB25(5)7X
    1             7HMB25(6)7X7HMB25(7)7X7HMB25(8)7X7HMB25(9))
1270 FORMAT(1H0,8HMB25(10)6X8HMB25(11)6X8HMB25(12)6X8HMB25(13)6X8HMB25(
    114)6X8HMB25(15)6X8HMB25(16)6X8HMB25(17)6X8HMB25(18))
1280 FORMAT(1H0,5HVW(1)9X5HVW(2)9X5HVW(3)9X5HVW(4)9X5HVW(5)9X5HVW(6)9X
    1             5HVW(7)9X5HVW(8)9X5HVW(9))
1290 FORMAT(1H0,6HVW(10)8X6HVW(11)8X6HVW(12)8X6HVW(13)8X6HVW(14)8X
    1             6HVW(15)8X6HVW(16)8X6HVW(17)8X6HVW(18))
1300 FORMAT(1H0,46HTHE VARIABLES ARE LISTED ABOVE THE MEAN VALUES)
1310 FORMAT(1H0,6HPHI(1)8X6HPHI(2)8X6HPHI(3)8X6HPHI(4)8X6HPHI(5)8X
    1             6HPHI(6)8X6HPHI(7)8X6HPHI(8)8X6HPHI(9))
1320 FORMAT(1H1)
1330 FORMAT(1H0,7HPHI(10)7X7HPHI(11)7X7HPHI(12)7X7HPHI(13)7X7HPHI(14)7X
    1            7HPHI(15)7X7HPHI(16)7X7HPHI(17)7X7HPHI(18))
1340 FORMAT(1H0,8HDEL4X(1)6X8HDEL4X(2)6X8HDEL4X(3))
1341 FORMAT(1H0,7HDEL1(1)7X7HDEL1(2)7X7HDEL1(3)7X7HDEL1(4)7X7HDEL1(5)7X
    1             7HDEL1(6)7X7HDEL1(7)7X7HDEL1(8)7X7HDEL1(9))
1342 FORMAT(1H0,8HDEL1(10)6X8HDEL1(11)6X8HDEL1(12)6X8HDEL1(13)6X
    1             8HDEL1(14)6X8HDEL1(15)6X8HDEL1(16)6X8HDEL1(17)6X
    1             8HDEL1(18))
1343 FORMAT(1H0,7HDEL2(1)7X7HDEL2(2)7X7HDEL2(3)7X7HDEL2(4)7X7HDEL2(5)7X
    1             7HDEL2(6)7X7HDEL2(7)7X7HDEL2(8)7X7HDEL2(9))
1350 FORMAT(1H0,8HDEL5X(1)6X8HDEL5X(2)6X8HDEL5X(3))
1360 FORMAT(1H0,8HDEL6X(1)6X8HDEL6X(2)6X8HDEL6X(3))
1370 FORMAT(1H0,8HDEL2(10)6X8HDEL2(11)6X8HDEL2(12)6X8HDEL2(13)6X
    1             8HDEL2(14)6X8HDEL2(15)6X8HDEL2(16)6X8HDEL2(17)6X
    1             8HDEL2(18))
1380 FORMAT(1H0,7HDEL3(1)7X7HDEL3(2)7X7HDEL3(3)7X7HDEL3(4)7X7HDEL3(5)7X
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    1            7HDEL3(6)7X7HDEL3(8)7X7HDEL3(9))
1390 FORMAT(1H0,8HDEL3(10)6X8HDEL3(11)6X8HDEL3(12)6X8HDEL3(13)6X
    1            8HDEL3(14)6X8HDEL3(15)6X8HDEL3(16)6X8HDEL3(17)6X
    1            8HDEL3(18))
1400 FORMAT(1H0,7HDEL4(1)7X7HDEL4(2)7X7HDEL4(3)7X7HDEL4(4)7X7HDEL4(5)7X
    1            7HDEL4(6)7X7HDEL4(7)7X7HDEL4(8)7X7HDEL4(9))
1410 FORMAT(1H0,8HDEL4(10)6X8HDELA(11)6X8HDEL4(12)6X8HDEL4(13)6X
    1            8HDEL4(14)6X8HDEL4(15)6X8HDEL4(16)6X8HDEL4(17)6X
    1            8HDEL4(18))
1420 FORMAT(1H0,7HDEL5(1)7X7HDEL5(2)7X7HDEL5(3)7X7HDEL5(4)7X7HDEL5(5)7X
    1            7HDEL5(6)7X7HDEL5(7)7X7HDEL5(8)7X7HDEL5(9))
1430 FORMAT(1H0,8HDEL5(10)6X8HDEL5(11)6X8HDEL5(12)6X8HDEL5(13)6X
    1            8HDEL5(14)6X8HDEL5(15)6X8HDEL5(16)6X8HDEL5(17)6X
    1            8HDEL5(18))
1440 FORMAT(1H0,7HDEL6(1)7X7HDEL6(2)7X7HDEL6(3)7X7HDEL6(4)7X7HDEL6(5)7X
    1            7HDEL6(6)7X7HDEL6(7)7X7HDEL6(8)7X7HDEL6(9))
1450 FORMAT(1H0,8HDEL6(10)6X8HDEL6(11)6X8HDEL6(12)6X8HDEL6(13)6X
    1            8HDEL6(14)6X8HDEL6(15)6X8HDEL6(16)6X8HDEL6(17)6X
    1            8HDEL6(18))
1460 FORMAT(1H0,8HALPH1(1)6X8HALPH1(2)6X8HALPH1(3)6X8HALPH1(4)6X
    1            8HALPH1(5)6X8HALPH1(6)6X8HALPH1(7)6X8HALPH1(8)6X
    1            8HALPH1(9))
1470 FORMAT(1H0,9HALPH1(10)5X9HALPH1(11)5X9HALPH1(12)5X9HALPH1(13)5X
    1            9HALPH1(14)5X9HALPH1(15)5X9HALPH1(16)5X9HALPH1(17)5X
    1            9HALPH1(18))
1480 FORMAT(1H0,8HALPH2(1)6X8HALPH2(2)6X8HALPH2(3)6X8HALPH2(4)6X
    1            8HALPH2(5)6X8HALPH2(6)6X8HALPH2(7)6X8HALPH2(8)6X
    1            8HALPH2(9))
1490 FORMAT(1H0,9HALPH2(10)5X9HALPH2(11)5X9HALPH2(12)5X9HALPH2(13)6X
    1            9HALPH2(14)5X9HALPH2(15)5X9HALPH2(16)5X9HALPH2(17)6X
    1            9HALPH2(18))
1500 FORMAT(1H0,8HALPH3(1)6X8HALPH3(2)6X8HALPH3(3)6X8HALPH3(4)6X
    1            8HALPH3(5)6X8HALPH3(6)6X8HALPH3(7)6X8HALPH3(8)6X
    1            8HALPH3(9))
1510 FORMAT(1H0,9HALPH3(10)5X9HALPH3(11)5X9HALPH3(12)5X9HALPH3(13)5X
    1            9HALPH3(14)5X9HALPH3(15)5X9HALPH3(16)5X9HALPH3(17)5X
    1            9HALPH3(18))
1520 FORMAT(1H0,7HIDD1(1)7X7HIDD1(2)7X7HIDD1(3)7X7HIDD1(4)7X7HIDD1(5)7X
```

```
     1          7HIDD1(6)7X7HIDD1(7)7X7HIDD1(8)7X7HIDD1(9))
 1530 FORMAT(1H0,8HIDD1(10)6X8HIDD1(11)6X8HIDD1(12)6X8HIDD1(13)6X
     1          8HIDD1(14)6X8HIDD1(15)6X8HIDD1(16)6X8HIDD1(17)6X
     1          8HIDD1(18))
 1540 FORMAT(1H0,7HIDD2(1)7X7HIDD2(2)7X7HIDD2(3)7X7HIDD2(4)7X7HIDD2(5)
     1         7X7HIDD2(6)7X7HIDD2(7)7X7HIDD2(8)7X7HIDD2(9))
 1550 FORMAT(1H0,8HIDD2(10)6X8HIDD2(11)6X8HIDD2(12)6X8HIDD2(13)6X
     1          8HIDD2(14)6X8HIDD2(15)6X8HIDD2(16)6X8HIDD2(17)6X
     1          8HIDD2(18))
 1560 FORMAT(1H0,7HIDD3(1)7X7HIDD3(2)7X7HIDD3(3)7X7HIDD3(4)7X7HIDD3(5)7X
     1          7HIDD3(6)7X7HIDD3(7)7X7HIDD3(8)7X7HIDD3(9))
 1570 FORMAT(1H0,8HIDD3(10)6X8HIDD3(11)6X8HIDD3(12)6X8HIDD3(13)6X
     1          8HIDD3(14)6X8HIDD3(15)6X8HIDD3(16)6X8HIDD3(17)6X
     1          8HIDD3(18))
 1580 FORMAT(1H0,6HXI1(1)8X6HXI1(2)8X6HXI1(3)8X6HXI1(4)8X6HXI1(5)8X
     1          6HXI1(6)8X6HXI1(7)8X6HXI1(8)8X6HXI1(9))
 1590 FORMAT(1H0,7HXI1(10)7X7HXI1(11)7X7HXI1(12)7X7HXI1(13)7X7HXI1(14)7X
     1          7HXI1(15)7X7HXI1(16)7X7HXI1(17)7X7HXI1(18))
 1600 FORMAT(1H0,6HXI2(1)8X6HXI2(2)8X6HXI2(3)8X6HXI2(4)8X6HXI2(5)8X
     1          6HXI2(6)8X6HXI2(7)8X6HXI2(8)8X6HXI2(9))
 1610 FORMAT(1H0,7HXI2(10)7X7HXI2(11)7X7HXI2(12)7X7HXI2(13)7X7HXI2(14)7X
     1          7HXI2(15)7X7HXI2(16)7X7HXI2(17)7X7HXI2(18))
 1620 FORMAT(1H0,6HXI3(1)8X6HXI3(2)8X6HXI3(3)8X6HXI3(4)8X6HXI3(5)8X
     1          6HXI3(6)8X6HXI3(7)8X6HXI3(8)8X6HXI3(9))
 1630 FORMAT(1H0,7HXI3(10)7X7HXI3(11)7X7HXI3(12)7X7HXI3(13)7X7HXI3(14)7X
     1          7HXI3(15)7X7HXI3(16)7X7HXI3(17)7X7HXI3(18))
 1640 FORMAT(1H0,6HXI4(1)8X6HXI4(2)8X6HXI4(3)8X6HXI4(4)8X6HXI4(5)8X
     1          6HXI4(6)8X6HXI4(7)8X6HXI4(8)8X6HXI4(9))
 1650 FORMAT(1H0,7HXI4(10)7X7HXI4(11)7X7HXI4(12)7X7HXI4(13)7X7HXI4(14)7X
     1          7HXI4(15)7X7HXI4(16)7X7HXI4(17)7X7HXI4(18))
 1660 FORMAT(1H0,6HXI5(1)8X6HXI5(2)8X6HXI5(3)8X6HXI5(4)8X6HXI5(5)8X
     1          6HXI5(6)8X6HXI5(7)8X6HXI5(8)8X6HXI5(9))
 1670 FORMAT(1H0,7HXI5(10)7X7HXI5(11)7X7HXI5(12)7X7HXI5(13)7X7HXI5(14)7X
     1          7HXI5(15)7X7HXI5(16)7X7HXI5(17)7X7HXI5(18))
 1680 FORMAT(1H0,6HXI6(1)8X6HXI6(2)8X6HXI6(3)8X6HXI6(4)8X6HXI6(5)8X
     1          6HXI6(6)8X6HXI6(7)8X6HXI6(8)8X6HXI6(9))
 1690 FORMAT(1H0,7HXI6(10)7X7HXI6(11)7X7HXI6(12)7X7HXI6(13)7X7HXI6(14)7X
     1          7HXI6(15)7X7HXI6(16)7X7HXI6(17)7X7HXI6(18))
```

```
 1710 FORMAT(1H1)
C PRINT EXCEEDANCE COUNTS
      PRINT 1120,(TITLE(I),I=1,20)
      PRINT 1130
      PRINT 1140
      PRINT 1150,(BX(I),I=1,4)
      PRINT 1160,(IBX(I),I=1,4)
      PRINT 1170
      PRINT 1150,(M90X(I),I=1,6)
      PRINT 1160,(IM90X(I),I=1,6)
      PRINT 1180
      PRINT 1150,(M25X(I),I=1,6)
      PRINT 1160,(IM25X(I),I=1,6)
      PRINT 1340
      PRINT 1150,(DEL4X(I),I=1,3)
      PRINT 1160,(ID4(I),I=1,3)
      PRINT 1350
      PRINT 1150,(DEL5X(I),I=1,3)
      PRINT 1160,(ID5(I),I=1,3)
      PRINT 1360
      PRINT 1150,(DEL6X(I),I=1,3)
      PRINT 1160,(ID6(I),I=1,3)
C PRINT MEAN VALUES AND VARIANCES
      PRINT 1190
      PRINT 1200
      PRINT 1150,(BB(I),I=1,9)
      PRINT 1150,(BV(I),I=1,9)
      PRINT 1150,(B3(I),I=1,9)
      PRINT 1210
      PRINT 1150,(BB(I),I=10,18)
      PRINT 1150,(BV(I),I=10,18)
      PRINT 1150,(B3(I),I=10,18)
      PRINT 1240
      PRINT 1150,(M90B(I),I=1,9)
      PRINT 1150,(M90V(I),I=1,9)
      PRINT 1150,(M903(I),I=1,9)
      PRINT 1710
      PRINT 1250
```

```
PRINT 1150,(M90B(I),I=10,18)
PRINT 1150,(M90V(I),I=10,18)
PRINT 1150,(M903(I),I=10,18)
PRINT 1320
PRINT 1260
PRINT 1150,(M25B(I),I=1,9)
PRINT 1150,(M25V(I),I=1,9)
PRINT 1150,(M253(I),I=1,9)
PRINT 1270
PRINT 1150,(M25B(I),I=10,18)
PRINT 1150,(M25V(I),I=10,18)
PRINT 1150,(M253(I),I=10,18)
PRINT 1280
PRINT 1150,(VWB(I),I=1,9)
PRINT 1150,(VWV(I),I=1,9)
PRINT 1150,(VW3(I),I=1,9)
PRINT 1290
PRINT 1150,(VWB(I),I=10,18)
PRINT 1150,(VWV(I),I=10,18)
PRINT 1150,(VW3(I),I=10,18)
PRINT 1300
PRINT 1220
PRINT 1150,(AB(I),I=1,9)
PRINT 1230
PRINT 1150,(AB(I),I=10,18)
PRINT 1310
PRINT 1150,(PHIB(I),I=1,9)
PRINT 1330
PRINT 1150,(PHIB(I),I=10,18)
PRINT 1710
PRINT 1341
PRINT 1150,(DEL1B(I),I=1,9)
PRINT 1342
PRINT 1150,(DEL1B(I),I=10,18)
PRINT 1343
PRINT 1150,(DEL2B(I),I=1,9)
PRINT 1370
PRINT 1150,(DEL2B(I),I=10,18)
```

```
PRINT 1380
PRINT 1150,(DEL3B(I),I=1,9)
PRINT 1390
PRINT 1150,(DEL3B(I),I=10,18)
PRINT 1400
PRINT 1150,(DEL4B(I),I=1,9)
PRINT 1410
PRINT 1150,(DEL4B(I),I=10,18)
PRINT 1420
PRINT 1150,(DEL5B(I),I=1,9)
PRINT 1430
PRINT 1150,(DEL5B(I),I=10,18)
PRINT 1440
PRINT 1150,(DEL6B(I),I=1,9)
PRINT 1450
PRINT 1150,(DEL6B(I),I=10,18)
PRINT 1710
PRINT 1460
PRINT 1150,(A21B(I),I=1,9)
PRINT 1470
PRINT 1150,(A21B(I),I=10,18)
PRINT 1480
PRINT 1150,(A22B(I),I=1,9)
PRINT 1490
PRINT 1150,(A22B(I) ,I=10,18)
PRINT 1500
PRINT 1150,(A23B(I) ,I=1,9)
PRINT 1510
PRINT 1150,(A23B(I) ,I=10,18)
PRINT 1520
PRINT 1150,(I1B(I),I=1,9)
PRINT 1530
PRINT 1150,(I1B(I),I=10,18)
PRINT 1540
PRINT 1150,(I2B(I),I=1,9)
PRINT 1550
PRINT 1150,(I2B(I),I=10,18)
PRINT 1560
```

```
      PRINT 1150,(I3B(I),I=1,9)
      PRINT 1570
      PRINT 1150,(I3B(I),I=10,18)
      PRINT 1710
      PRINT 1580
      PRINT 1150,(XI1B(I),I=1,9)
      PRINT 1590
      PRINT 1150,(XI1B(I),I=10,18)
      PRINT 1600
      PRINT 1150,(XI2B(I),I=1,9)
      PRINT 1610
      PRINT 1150,(XI2B(I),I=10,18)
      PRINT 1620
      PRINT 1150,(XI3B(I),I=1,9)
      PRINT 1630
      PRINT 1150,(XI3B(I),I=10,18)
      PRINT 1640
      PRINT 1150,(XI4B(I),I=1,9)
      PRINT 1650
      PRINT 1150,(XI4B(I),I=10,18)
      PRINT 1660
      PRINT 1150,(XI5B(I),I=1,9)
      PRINT 1670
      PRINT 1150,(XI5B(I),I=10,18)
      PRINT 1680
      PRINT 1150,(XI6B(I),I=1,9)
      PRINT 1690
      PRINT 1150,(XI6B(I),I=10,18)
      RETURN
      END
.
.
$LO,.GU1,,0
$XQ,.MAIN,0
```

```
      SUBROUTINE COUNTS
      DATA ILOC/0/
      LOGICAL INDIC
      EXTENDED TITLE
      REAL M90X,M25X,M90B,M25B,M90V,M25V,M90,M25,MA25,MA90,MB90,M903,
     1M253,I1B,I2B,I3B
      COMMON / BLOCK / IOCT8,I,IERR,NMAX,NRMAX,NPASS,NRUN,INDIC,ICHAN,
     1 T1,T2,N,ILOC
      COMMON      ADSCAL(16),DASCAL(16),BX(4),DEL4X(3),DEL5X(3),DEL6X(3),
     1IBX(4),IM90X(6),IM25X(6),ID4(3),ID5(3),ID6(3),BB(18),AB(18),
     2YDDB(18),PHI2B(18),VWB(18),ATA1B(18),ATA2B(18),ATA3B(18),ATA4B(18)
     3,
     4ATD1B(18),ATD2B(18),ATD3B(18),ATD4B(18),PHIB(18),XI1B(18),XI2B(18)
     5,XI3B(18),XI4B(18),XI5B(18),XI6B(18),DEL1B(18),DEL2B(18),DEL3B(18)
     6,DEL4B(18),DEL5B(18),DEL6B(18),                          BV(18),
     7AV(18),VWV(18),DAC(8),ADC(16),B(18),A(18),YDD(18),PHI2(18),PHI(18)
     8,ATA1(18),ATA2(18),ATA3(18),ATA4(18),ATD1(18),ATD2(18),ATD3(18),
     9ATD4(18),VW(18),DEL4(18),DEL5(18),DEL6(18),IIBX(4),IIM90X(6),
     1IIM25X(6),IID4(3),IID5(3),IID6(3),B3(18),A3(18),VW3(18),TITLE(20),
     2S11(18),S12(18),S13(18),S14(18),S21(18),S22(18),S23(18),S24(18),
     3S31(18),S32(18),S33(18),S34(18),S41(18),S42(18),S43(18),S44(18),
     4S51(18),S52(18),S53(18),S54(18),S61(18),S62(18),S63(18),S64(18),
     5T11(18),T12(18),T13(18),T14(18),T21(18),T22(18),T23(18),T24(18),
     6T31(18),T32(18),T33(18),T34(18),P11(18),P12(18),P13(18),P14(18),
     7P21(18),P22(18),P23(18),P24(18),P31(18),P32(18),P33(18),P34(18)
     1,A21B(18),A22B(18),A23B(18)
      COMMON
     1      M90X(6),M25X(6),M90B(18),M25B(18),M90V(18),M25V(18),M90(18),
     1M25(18),MA25(18),MA90(18),MB90(18),M903(18),M253(18),
     2I1B(18),I2B(18),I3B(18)
 1700 FORMAT(I14,8E14.7)
C
C
   26 IIBX(1)=0
      IIBX(3)=0
      DO 27 I=1,5,2
      IIM90X(I)=0
      IIM25X(I)=0
```

```
   27 CONTINUE
C       IF(ILOC.AND.1)IIBX(1)=1
C       IF(ILOC.AND.2)IIBX(3)=1
C       IF(ILOC.AND.4)IIM90X(1)=1
C       IF(ILOC.AND.8)IIM90X(3)=1
C       IF(ILOC.AND.16)IIM90X(5)=1
C       IF(ILOC.AND.32)IIM25X(1)=1
C       IF(ILOC.AND.64)IIM25X(3)=1
C       IF(ILOC.AND.128)IIM25X(5)=1
ASSEMBL
         CA        /ILOC
         AHM1      /IIBX+0..15
         ROT       1
         AHM1      /IIBX+2..15
         ROT       1
         AHM1      /IIM90X+0..15
         ROT       1
         AHM1      /IIM90X+2..15
         ROT       1
         AHM1      /IIM90X+4..15
         ROT       1
         AHM1      /IIM25X+0..15
         ROT       1
         AHM1      /IIM25X+2..15
         ROT       1
         AHM1      /IIM25X+4..15
FORTRAN
        IBX(1)=IBX(1)+IIBX(1)
        IBX(3)=IBX(3)+IIBX(3)
        DO 28 I=1,5,2
        IM90X(I)=IM90X(I)+ IIM90X(I)
        IM25X(I)=IM25X(I)+ IIM25X(I)
   28 CONTINUE
        DO 210 I=1,3
        IID4(I)=0
        IID5(I)=0
        IID6(I)=0
  210 CONTINUE
```

```
      DO 200 I=1,NMAX
      DEL4(I)=.6042*(S41(I)*ATA1(I)+S42(I)*ATA2(I)+S43(I)*ATA3(I) +
     1                S44(I)*ATA4(I))
      DEL5(I)=.59*(S51(I)*ATA1(I)+S52(I)*ATA2(I)+S53(I)*ATA3(I)
     1            + S54(I)*ATA4(I))
      DEL6(I)=.64*(S61(I)*ATA1(I)+S62(I)*ATA2(I)+S63(I)*ATA3(I)+
     1              S64(I)*ATA4(I))
      IF(DEL4(I).GT.DEL4X(1))IID4(1)=1
      IF(DEL4(I).GT.DEL4X(2))IID4(2)=1
      IF(DEL4(I).GT.DEL4X(3))IID4(3)=1
      IF(DEL5(I).GT.DEL5X(1))IID5(1)=1
      IF(DEL5(I).GT.DEL5X(2))IID5(2)=1
      IF(DEL5(I).GT.DEL5X(3))IID5(3)=1
      IF(DEL6(I).GT.DEL6X(1))IID6(1)=1
      IF(DEL6(I).GT.DEL6X(2))IID6(2)=1
      IF(DEL6(I).GT.DEL6X(3))IID6(3)=1
  200 CONTINUE
      DO 220 I=1,3
      ID4(I)=ID4(I)+IID4(I)
      ID5(I)=ID5(I)+IID5(I)
      ID6(I)=ID6(I)+IID6(I)
  220 CONTINUE
C CALCULATE THE SUMMATION OF XI
      DO 29 I=1,NMAX
      BB(I)=BB(I)+ B(I)
      AB(I)=AB(I)+ A(I)
      M90B(I)=M90B(I)+M90(I)
      M25B(I)=M25B(I)+M25(I)
      VWB(I)=VWB(I) +VW(I)
      ATA1B(I)=ATA1B(I) +ATA1(I)
      ATA2B(I)=ATA2B(I)+ATA2(I)
      ATA3B(I)=ATA3B(I)+ ATA3(I)
      ATA4B(I)=ATA4B(I)+ ATD4(I)
      ATD1B(I)=ATD1B(I)+ATD1(I)
      ATD2B(I)=ATD2B(I)+ATD2(I)
      ATD3B(I)=ATD3B(I)+ATD3(I)
      ATD4B(I)=ATD4B(I)+ATD4(I)
      PHIB(I)=PHIB(I)+ PHI(I)
```

```
      YDDB(I)=YDDB(I)+YDD(I)
      PHI2B(I)=PHI2B(I)+PHI2(I)
   29 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE VARIAN
      LOGICAL INDIC
      EXTENDED TITLE
      REAL M90X,M25X,M90B,M25B,M90V,M25V,M90,M25,MA25,MA90,MB90,M903,
     1M253,I1B,I2B,I3B
      COMMON / BLOCK / IOCT8,I,IERR,NMAX,NRMAX,NPASS,NRUN,INDIC,ICHAN,
     1 T1,T2,N,ILOC
      COMMON     ADSCAL(16),DASCAL(16),BX(4),DEL4X(3),DEL5X(3),DEL6X(3),
     1IBX(4),IM90X(6),IM25X(6),ID4(3),ID5(3),ID6(3),BB(18),AB(18),
     2YDDB(18),PHI2B(18),VWB(18),ATA1B(18),ATA2B(18),ATA3B(18),ATA4B(18)
     3,
     4ATD1B(18),ATD2B(18),ATD3B(18),ATD4B(18),PHIB(18),XI1B(18),XI2B(18)
     5,XI3B(18),XI4B(18),XI5B(18),XI6B(18),DEL1B(18),DEL2B(18),DEL3B(18)
     6,DEL4B(18),DEL5B(18),DEL6B(18),                             BV(18),
     7AV(18),VWV(18),DAC(8),ADC(16),B(18),A(18),YDD(18),PHI2(18),PHI(18)
     8,ATA1(18),ATA2(18),ATA3(18),ATA4(18),ATD1(18),ATD2(18),ATD3(18),
     9ATD4(18),VW(18),DEL4(18),DEL5(18),DEL6(18),IIBX(4),IIM90X(6),
     1IIM25X(6),IID4(3),IID5(3),IID6(3),B3(18),A3(18),VW3(18),TITLE(20),
     2S11(18),S12(18),S13(18),S14(18),S21(18),S22(18),S23(18),S24(18),
     3S31(18),S32(18),S33(18),S34(18),S41(18),S42(18),S43(18),S44(18),
     4S51(18),S52(18),S53(18),S54(18),S61(18),S62(18),S63(18),S64(18),
     5T11(18),T12(18),T13(18),T14(18),T21(18),T22(18),T23(18),T24(18),
     6T31(18),T32(18),T33(18),T34(18),P11(18),P12(18),P13(18),P14(18),
     7P21(18),P22(18),P23(18),P24(18),P31(18),P32(18),P33(18),P34(18)
     1,A21B(18),A22B(18),A23B(18)
      COMMON
     1      M90X(6),M25X(6),M90B(18),M25B(18),M90V(18),M25V(18),M90(18),
     1M25(18),MA25(18),MA90(18),MB90(18),M903(18),M253(18),
     2I1B(18),I2B(18),I3B(18)
C   CALCULATE THE VARIANCES
   35 DO 42 I=1,NMAX
      BV(I)=BV(I)/(NRMAX-1)
      AV(I)=AV(I)/(NRMAX-1)
      M90V(I)=M90V(I)/(NRMAX-1)
      M25V(I)=M25V(I)/(NRMAX-1)
      VWV(I)=VWV(I)/(NRMAX-1)
      B3(I)=3.*SQRT(BV(I))
      A3(I)=3.*SQRT(AV(I))
```

```
      M903(I)=3.*SQRT(M90V(I))
      M253(I)=3.*SQRT(M25V(I))
      VW3(I)=3.*SQRT(VWV(I))
      XI1B(I)= S11(I)*ATA1B(I) +S12(I)*ATA2B(I) +S13(I)*ATA3B(I)
     1         +S14(I)*ATA4B(I)
      XI2B(I)= S21(I)*ATA1B(I) +S22(I)*ATA2B(I) +S23(I)*ATA3B(I)
     1         +S24(I)*ATA4B(I)
      XI3B(I)= S31(I)*ATA1B(I) +S32(I)*ATA2B(I) +S33(I)*ATA3B(I)
     1         +S34(I)*ATA4B(I)
      XI4B(I)= S41(I)*ATA1B(I) +S42(I)*ATA2B(I) +S43(I)*ATA3B(I)
     1        +S44(I)*ATA4B(I)
      XI5B(I)= S51(I)*ATA1B(I) +S52(I)*ATA2B(I) +S53(I)*ATA3B(I)
     1         +S54(I)*ATA4B(I)
      XI6B(I)= S61(I)*ATA1B(I) +S62(I)*ATA2B(I) +S63(I)*ATA3B(I)
     1         +S64(I)*ATA4B(I)
      DEL1B(I)= XI1B(I)*.5229
      DEL2B(I)= XI2B(I)*.539
      DEL3B(I)= XI3B(I)*.5431
      DEL4B(I)= XI4B(I)*.6042
      DEL5B(I)= XI5B(I)*.59
      DEL6B(I)= XI6B(I)*.64
      A21B(I)=-YDDB(I)+ T11(I)*ATD1B(I)+T12(I)*ATD2B(I) +T13(I)*ATD3B(I)
     1                 + T14(I)*ATD4B(I)
      A22B(I)=-YDDB(I)+ T21(I)*ATD1B(I)+T22(I)*ATD2B(I) +T23(I)*ATD3B(I)
     1                 + T14(I)*ATD4B(I)
      A23B(I)=-YDDB(I)+ T31(I)*ATD1B(I)+T32(I)*ATD2B(I) +T33(I)*ATD3B(I)
     1                 + T34(I)*ATD4B(I)
      I1B(I) =-PHI2B(I) +P11(I)*ATD1B(I)+P12(I)*ATD2B(I)+P13(I)*ATD3B(I)
     1                 +P14(I)*ATD4B(I)
      I2B(I) =-PHI2B(I) +P21(I)*ATD1B(I)+P22(I)*ATD2B(I)+P23(I)*ATD3B(I)
     1                 +P24(I)*ATD4B(I)
      I3B(I)= -PHI2B(I) +P31(I)*ATD1B(I)+P32(I)*ATD2B(I)+P33(I)*ATD3B(I)
     1                 +P34(I)*ATD4B(I)
   42 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE READ
      REAL M90X,M25X,M90B,M25B,M90V,M25V,M90,M25,MA25,MA90,MB90,M903,
     1M253,I1B,I2B,I3B
      COMMON     ADSCAL(16),DASCAL(16),BX(4),DEL4X(3),DEL5X(3),DEL6X(3),
     1IBX(4),IM90X(6),IM25X(6),ID4(3),ID5(3),ID6(3),BB(18),AB(18),
     2YDDB(18),PHI2B(18),VWB(18),ATA1B(18),ATA2B(18),ATA3B(18),ATA4B(18)
     3,
     4ATD1B(18),ATD2B(18),ATD3B(18),ATD4B(18),PHIB(18),XI1B(18),XI2B(18)
     5,XI3B(18),XI4B(18),XI5B(18),XI6B(18),DEL1B(18),DEL2B(18),DEL3B(18)
     6,DEL4B(18),DEL5B(18),DEL6B(18),                           BV(18),
     7AV(18),VWV(18),DAC(8),ADC(16),B(18),A(18),YDD(18),PHI2(18),PHI(18)
     8,ATA1(18),ATA2(18),ATA3(18),ATA4(18),ATD1(18),ATD2(18),ATD3(18),
     9ATD4(18),VW(18),DEL4(18),DEL5(18),DEL6(18),IIBX(4),IIM90X(6),
     1IIM25X(6),IID4(3),IID5(3),IID6(3),B3(18),A3(18),VW3(18),TITLE(20),
     2S11(18),S12(18),S13(18),S14(18),S21(18),S22(18),S23(18),S24(18),
     3S31(18),S32(18),S33(18),S34(18),S41(18),S42(18),S43(18),S44(18),
     4S51(18),S52(18),S53(18),S54(18),S61(18),S62(18),S63(18),S64(18),
     5T11(18),T12(18),T13(18),T14(18),T21(18),T22(18),T23(18),T24(18),
     6T31(18),T32(18),T33(18),T34(18),P11(18),P12(18),P13(18),P14(18),
     7P21(18),P22(18),P23(18),P24(18),P31(18),P32(18),P33(18),P34(18)
     1,A21B(1Γ),A22B(18),A23B(18)
      COMMON
     1      M90X(6),M25X(6),M90B(18),M25B(18),M90V(18),M25V(18),M90(18),
     1M25(18),MA25(18),MA90(18),MB90(18),M903(18),M253(18),
     2I1B(18),I2B(18),I3B(18)
 1020 FORMAT(8E10.4)
C INPUT A/D AND D/A SCALE FACTORS
      READ(5,1020) ADSCAL
      READ(5,1020) DASCAL
C INPUT EXCEEDANDE LEVELS
      READ(5,1020) BX
      READ(5,1020) M90X
      READ(5,1020) M25X
      READ(5,1020) DEL4X
      READ(5,1020) DEL5X
      READ(5,1020) DEL6X
      READ(5,1020) MA25
      READ(5,1020) MA90
```

```
READ(5,1020) MB90
READ(5,1020) S11
READ(5,1020) S12
READ(5,1020) S13
READ(5,1020) S14
READ(5,1020) S21
READ(5,1020) S22
READ(5,1020) S23
READ(5,1020) S24
READ(5,1020) S31
READ(5,1020) S32
READ(5,1020) S33
READ(5,1020) S34
READ(5,1020) S41
READ(5,1020) S42
READ(5,1020) S43
READ(5,1020) S44
READ(5,1020) S51
READ(5,1020) S52
READ(5,1020) S53
READ(5,1020) S54
READ(5,1020) S61
READ(5,1020) S62
READ(5,1020) S63
READ(5,1020) S64
READ(5,1020) T11
READ(5,1020) T12
READ(5,1020) T13
READ(5,1020) T14
READ(5,1020) T21
READ(5,1020) T22
READ(5,1020) T23
READ(5,1020) T24
READ(5,1020) T31
READ(5,1020) T32
READ(5,1020) T33
READ(5,1020) T34
READ(5,1020) P11
```

```
READ(5,1020) P12
READ(5,1020) P13
READ(5,1020) P14
READ(5,1020) P21
READ(5,1020) P22
READ(5,1020) P23
READ(5,1020) P24
READ(5,1020) P31
READ(5,1020) P32
READ(5,1020) P33
READ(5,1020) P34
RETURN
END
```

```
FINAL MODEL-PROPELLANT SLOSH COUPLING WITH BENDING
-.025     .5        2.5       -.025     -.1       -1.0      -.5       -.25
-.15      -10.      -10.      -10.      -10.      200.
  40.0      40.0
                                                            2.E6      5.E7
                        .5E-6     .5E-6     .5E-6     .2E-7     .2E-7     .2E-7
0.        0.        0.        0.        0.        0.        0.        0.
.016      .018      .02       .022
    .325E6    .35E6    .375E6      .4E6    .425E6      .5E6
      1.E7    1.25E7     1.5E7    1.75E7      2.E7    2.25E7
.06       .07       .08
.02       .03       .04
.02       .03       .04
       0.0      .3E7      .6E7    1.25E7     2.0E7     1.5E7     3.0E7    3.65E7
     4.3E7    5.25E7     6.2E7     8.1E7     10.E7   10.75E7    11.5E7    9.25E7
      7.E7
    .025E6     .05E6    .125E6      .2E6    .315E6     .43E6    .605E6     .78E6
  1.015E6    1.25E6   1.475E6     1.7E6   1.885E6    2.07E6    2.16E6    2.25E6
  2.175E6     2.1E6
  2.885E6    2.89E6    2.90E6    2.91E6   2.935E6    2.96E6   2.985E6    3.01E6
  3.065E6    3.12E6    3.27E6    3.42E6    3.80E6    4.18E6     4.4E6    4.62E6
    4.72E6    4.82E6
-.29025   -.2775    -.2648    -.252     -.239     -.226     -.213     -.2
-.187     -.174     -.161     -.148     -.13525   -.1225    -.1098    -.097
-.0835    -.07
.3332     .3345     .3358     .337      .337      .337      .337      .337
.3348     .3325     .3302     .328      .3242     .3205     .3168     .313
.3098     .3065
.00875    .0065     .00425    .002      -.0015    -.005     -.0085    -.012
-.021     -.030     -.039     -.048     -.0635    -.079     -.0945    -.11
-.138     -.166
-.7222    -.7235    -.7248    -.726     -.727     -.728     -.729     -.730
-.7342    -.7385    -.7428    -.747     -.7572    -.7675    -.7778    -.788
-.8075    -.8270
.004      .020      .036      .052      .06875    .0855     .1022     .119
.1375     .1560     .1745     .193      .2182     .2435     .2688     .294
.338      .382
.3232     .3215     .3198     .318      .3135     .3090     .3045     .3
.2925     .2850     .2775     .27       .261      .252      .243      .234
.226      .21C
```

-.163	-.165	-.167	-.169	-.174	-.179	-.184	-.189
-.1988	-.2085	-.2182	-.228	-.2452	-.2625	-.2798	-.297
-.3202	-.3435						
-.6315	-.633	-.6345	-.636	-.6372	-.6385	-.6398	-.641
-.6422	-.6435	-.6448	-.646	-.647	-.648	-.649	-.65
-.6515	-.6530						
.1588	.1655	.1722	.179	.185	.191	.197	.203
.2095	.2160	.2225	.229	.235	.241	.247	.253
.2598	.2665						
.1060	.1020	.098	.094	.088	.082	.076	.07
.0625	.055	.0475	.04	.0325	.0250	.0175	.01
.0025	-.005						
-.15	-.15	-.15	-.15	-.15	-.15	-.15	-.15
-.15	-.15	-.15	-.15	-.15	-.15	-.15	-.15
-.1450	-.1400						
.1828	.1855	.1882	.191	.1918	.1925	.1932	.194
.1955	.1970	.1985	.2	.209	.218	.2270	.236
.2555	.2750						
.1910	.1940	.1970	.2	.2030	.2060	.2090	.212
.2155	.2190	.2225	.226	.2292	.2325	.2358	.239
.2418	.2445						
-.0082	-.0135	-.01875	-.024	-.02875	-.0335	-.03825	-.043
-.0485	-.0540	-.0595	-.065	-.07025	-.0755	-.08075	-.086
-.09075	-.0955						
-.082	-.081	-.080	-.079	-.0772	-.0755	-.0738	-.072
-.067	-.062	-.057	-.052	-.0435	-.035	-.0265	-.018
-.0025	.013						
.4378	.4395	.4412	.443	.4448	.4465	.4482	.45
.4528	.4555	.4582	.461	.4662	.4715	.4768	.482
.492	.502						
.1082	.1055	.1028	.1	.094	.088	.082	.076
.0695	.063	.0565	.05	.0445	.0390	.0335	.028
.0222	.0165						
-.0742	-.0785	-.0828	-.087	-.0852	-.0835	-.0818	-.08
-.0775	-.0750	-.0725	-.07	-.067	-.064	-.061	-.058
-.0542	-.0505						
.045	.050	.055	.06	.064	.068	.072	.076
.0808	.0855	.09025	.095	.10025	.1055	.1108	.116

.1208	.1255						
-.0358	-.0515	-.0672	-.083	-.0985	-.1140	-.1295	-.145
-.1602	-.1755	-.1908	-.206	-.2255	-.2450	-.2645	-.284
-.353	-.422						
-.0728	-.0735	-.0742	-.075	-.0758	-.0765	-.0772	-.078
-.0788	-.0795	-.802	-.081	-.0818	-.0825	-.0832	-.078
-.076	-.074						
.0248	.0265	.0282	.03	.0315	.033	.0345	.036
.037	.038	.039	.04	.0392	.0385	.0378	.037
.0352	.0335						
-.0058	-.0075	-.0092	-.011	-.0122	-.0135	-.0148	-.016
-.0175	-.0190	-.0205	-.022	-.0238	-.0255	-.0272	-.029
-.0305	-.032						
-.0205	-.0170	-.0135	-.01	-.0075	-.0050	-.0025	0.0
.0018	.0035	.0052	.007	.0045	.002	-.0005	-.003
-.0148	-.0265						
.1165	.1160	.1155	.115	.1145	.1140	.1135	.113
.1125	.1120	.1115	.111	.1108	.1105	.1102	.11
.11	.11						
-.07	-.07	-.07	-.07	-.07	-.07	-.07	-.07
-.07	-.07	-.07	-.07	-.07	-.07	-.07	-.07
-.07	-.07						
.0425	.045	.0475	.05	.0532	.0565	.0598	.063
.0665	.0700	.0735	.077	.0802	.0835	.0868	.09
.093	.096						
-.106	-.104	-.102	-.1	-.1	-.1	-.1	-.1
-.104	-.108	-.112	-.116	-.1262	-.1365	-.1468	-.157
-.172	-.187						
-.0592	-.0595	-.0598	-.06	-.0602	-.0605	-.0608	-.061
-.0614	-.0618	-.0621	-.0625	-.0626	-.0628	-.0629	-.063
-.0632	-.0635						
.0096	.0112	.0129	.0145	.0159	.0172	.0186	.02
.0218	.0235	.0252	.027	.0282	.0295	.0308	.032
.0332	.0345						
.0196	.0192	.0189	.0185	.0176	.0168	.0159	.015
.0131	.0112	.0094	.0075	.0044	.0012	-.0019	-.005
-.0105	-.0160						
-.1162	-.1200	-.1238	-.1275	-.1286	-.1298	-.1309	-.132

-.1321	-.1322	-.1324	-.1325	-.1329	-.1332	-.1336	-.134
-.1342	-.1345						
-.029	-.031	-.033	-.035	-.0372	-.0395	-.0418	-.044
-.0461	-.0482	-.0504	-.0525	-.0541	-.0558	-.0574	-.059
-.0608	-.0625						
-.0635	-.0620	-.0605	-.059	-.057	-.055	-.053	-.051
-.0485	-.0460	-.0435	-.041	-.0382	-.0355	-.0328	-.03
-.0272	-.0245						
.0535	.0530	.0525	.052	.0528	.0535	.0542	.055
.0571	.0592	.0614	.0635	.0656	.0678	.0699	.072
.074	.076						
.0418	.0415	.0412	.041	.0408	.0405	.0402	.04
.0398	.0395	.0392	.039	.0388	.0385	.0382	.038
.0305	.0230						
-.00382	-.00382	-.00382	-.00382	-.00382	-.00382	-.00382	-.00382
-.00382	-.00382	-.00382	-.00382	-.00382	-.00382	-.00382	-.00382
-.00382	-.00382						
.00169	.00175	.00181	.00187	.00194	.00200	.00207	.00214
.00218	.00221	.00224	.00228	.00230	.00233	.00235	.00238
.00235	.00232						
-.00051	-.00054	-.00057	-.0006	-.00066	-.00073	-.00080	-.00086
-.00099	-.00112	-.00124	-.00137	-.00154	-.00172	-.00189	-.00206
-.00226	-.00246						
-.00056	-.00064	-.00072	-.0008	-.00078	-.00075	-.00072	-.0007
-.00059	-.00048	-.00037	-.00026	-.000062	.000135	.000332	.00053
.00044	.000358						
.001425	.00135	.001275	.0012	.001118	.001035	.00095	.00087
.00078	.00070	.00061	.00052	.00044	.00036	.00028	.0002
.00012	.00005						
-.00329	-.00328	-.00326	-.00325	-.00325	-.00325	-.00325	-.00325
-.00321	-.00318	-.00314	-.0031	-.00302	-.00295	-.00288	-.0028
-.00272	-.00265						
.00156	.00162	.00169	.00175	.00176	.00177	.00178	.00179
.00194	.00210	.00225	.0024	.00261	.00276	.00292	.00325
.00366	.00408						
.00794	.00794	.00794	.00794	.00794	.00794	.00794	.00794
.00793	.00792	.00791	.0079	.0078	.0077	.0076	.0075
.00726	.00702						

.00802	.00795	.00788	.0078	.00772	.00765	.00758	.0075
.00738	.00725	.00712	.007	.00695	.00690	.00685	.0068
.0067	.0066						
-.00205	-.00220	-.00235	-.0025	-.00262	-.00275	-.00288	-.003
-.00312	-.00325	-.00338	-.0035	-.00362	-.00375	-.00388	-.004
-.00412	-.00425						
-.00536	-.00532	-.00529	-.00525	-.00521	-.00518	-.00514	-.0051
-.00502	-.00495	-.00488	-.0048	-.0046	-.0044	-.0042	-.004
-.00375	-.00350						
.0103	.0101	.0099	.0097	.00978	.00985	.00992	.01
.01022	.01045	.01068	.0109	.01132	.01175	.012175	.0126
.0134	.0142						
18	970						