

FRATE

Volume I: User's Manual

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TECHNICAL REPORT

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16. Abstract FRATE (Freight Car Response Analysis and Test Evaluation) is the name of a digital computer program which numerically solves the structural dynamic equations of motion of a single railroad freight car excited by wheel/rail interface motions. The Federal Railroad Administration (FRA) has sponsored its development for the purpose of applying it to freight car analysis and test problems. This manual has been written with the objective of providing the user with all of the detailed information needed as concisely and accessibly as possible. To this end the manual has been divided into two volumes: Volume I is a User's Manual containing basic user related information, Volume II is a Technical Manual containing more detailed technical information. FRATE is written to allow the simulation of a broad range of freight cars by only simple input data changes. A Trailer-on-Flatcar (TOFC) configuration is simulated in this manual. FRATE solves the equations of motion in the time domain and includes the following features; (1) nonlinearities which presently include separations, bilinear springs and no small angle assumptions, (2) five degree-of-freedom coordinate coupling (longitudinal motions have been omitted), (3) normal mode structural flexibility and (4) frequency response from simulated sweep testing. Although it has not been included in this report coulomb damping has been included and used in a trial version of FRATE.					
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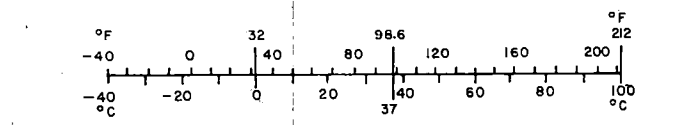
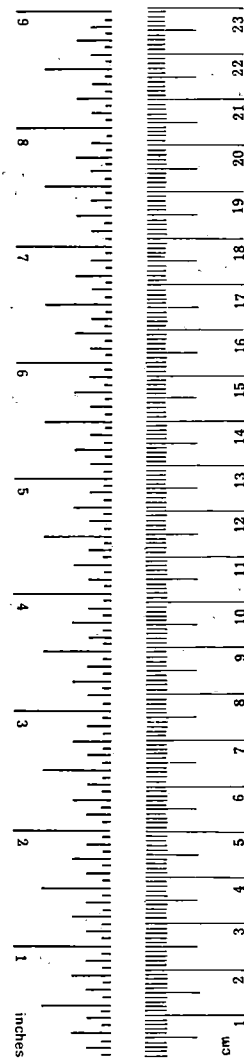
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
LENGTH				
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
AREA				
in ²	square inches	6.5	square centimeters	cm ²
ft ²	square feet	0.09	square meters	m ²
yd ²	square yards	0.8	square meters	m ²
mi ²	square miles	2.6	square kilometers	km ²
	acres	0.4	hectares	ha
MASS (weight)				
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
VOLUME				
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft ³	cubic feet	0.03	cubic meters	m ³
yd ³	cubic yards	0.76	cubic meters	m ³
TEMPERATURE (exact)				
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
LENGTH				
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
AREA				
cm ²	square centimeters	0.16	square inches	in ²
m ²	square meters	1.2	square yards	yd ²
km ²	square kilometers	0.4	square miles	mi ²
ha	hectares (10,000 m ²)	2.5	acres	
MASS (weight)				
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
VOLUME				
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m ³	cubic meters	35	cubic feet	ft ³
m ³	cubic meters	1.3	cubic yards	yd ³
TEMPERATURE (exact)				
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



* 1 in. = 2.54 (exact). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price \$2.25, SD Catalog No. C13.10:286.

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The basic "model" used in FRATE is an adaptation by M.J. Healy⁽¹⁾ of work by D.R. Ahlbeck.⁽²⁾ Healy in his work compiled the basic computational program contained in FRATE. Acknowledgement is also given to Healy and D.W. Gibson of the Wyle Laboratories for their assistance to us in the adaptation of the Wyle work.

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Finally, the contributions of John Caskey and Alan Robbins of MITRE were of great importance to this work. John generated all of the programming for output data plotting. His knowledge of the CDC operational system was essential. Alan supplied additional valuable programming assistance.

¹Healy, M.J., "A Computer Method for Calculating Dynamic Responses of Nonlinear Flexible Rail Vehicles," ASME Paper No. T6-RT-5, 1976.

²Ahlbeck, D.R., "Comparative Analysis of Dynamics of Freight and Passenger Rail Vehicles," Battelle, Columbus, FRA-ORD&D, 74-39, March 1974.

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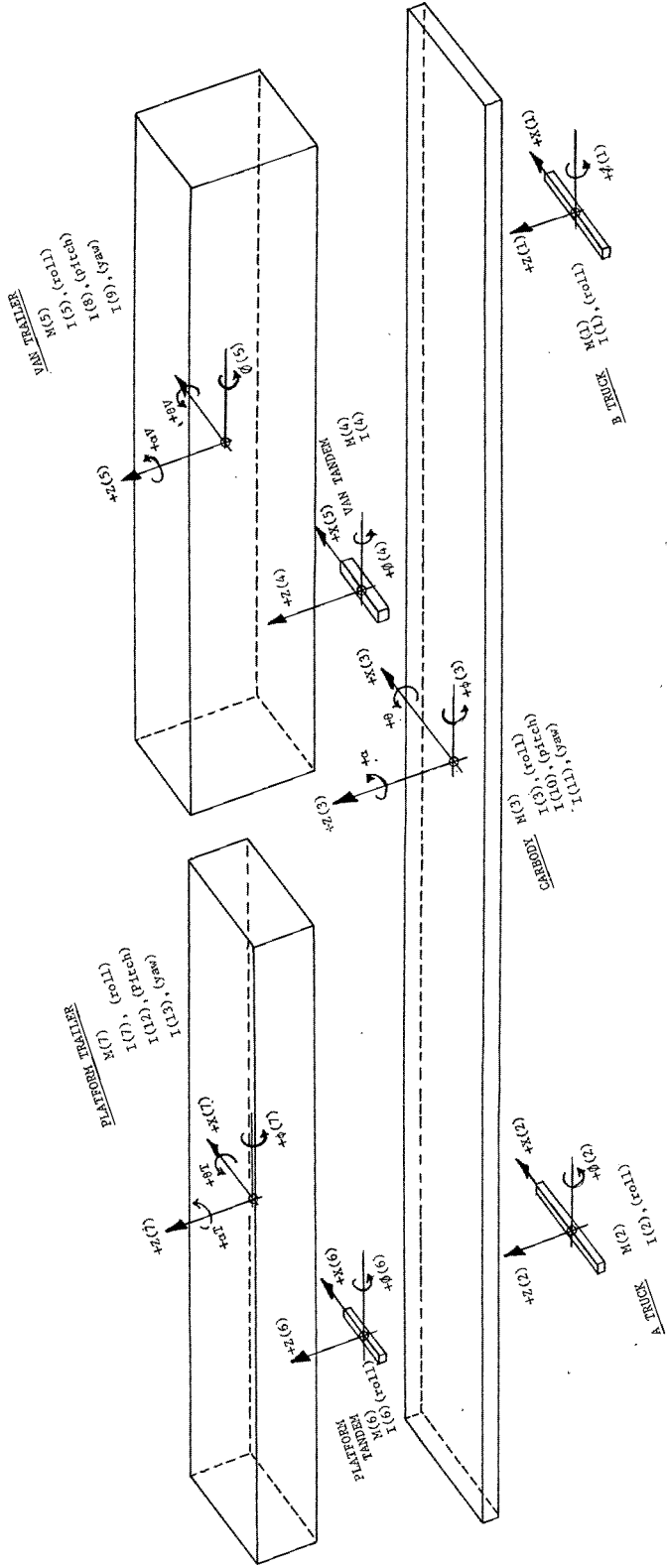
1.0 INTRODUCTION

FRATE is a digital computer program for the analysis of railcar dynamic response developed under the sponsorship of the Federal Railroad Administration (FRA). The name FRATE is an acronym for Freight Car Response Analysis and Test Evaluation. This manual describes FRATE as of April 1978. The computer program is written in Fortran for Control Data Corporation (CDC) computers with solution in the time domain by numerical integration methods. A modified version of FRATE has been converted to and run on an IBM computer by the Trailer Train Company. Work is continuing to enhance its capabilities and make it more attractive to potential users.

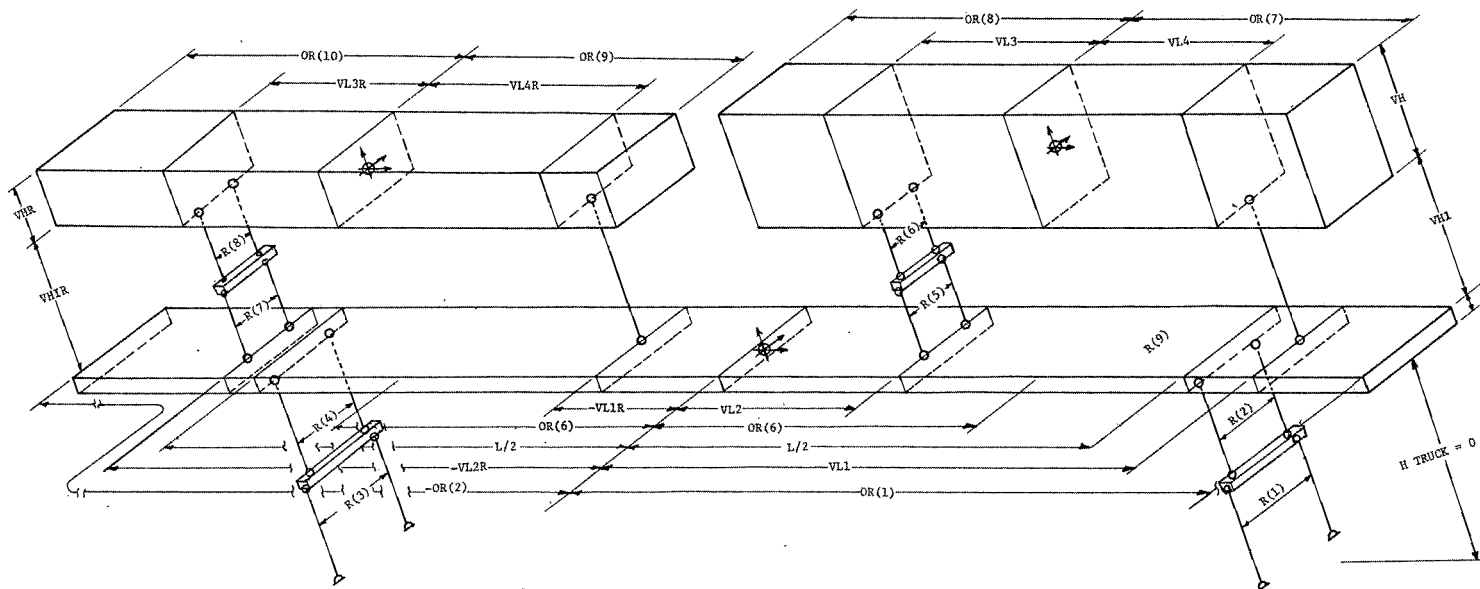
This Users Manual has been prepared in two volumes. Volume I is written for the user who is interested only in how to use the program with enough knowledge of the program to properly interpret analysis output. Volume II is a technical manual written for the analyst/programmer who needs to modify the program or the computer usage. Volume II also presents discussions on the background history of the FRATE program as well as the development of the TOFC model.

Volume I has been written with the assumption that all output will be on line printer.

The FRATE program has been written around the lumped mass, spring-damper configuration shown schematically in Figures 1, 2 and 3. Figure 1 defines the notation used for masses, inertias and degrees of freedom; Figure 2 defines geometry notation; and Figure 3 defines spring-damper and model nodal point notation. Notation for output data can be found in Section 2.0. There are seven lumped masses and 31 degrees of freedom in the basic FRATE model which includes four flexible carbody normal modes. A selection of model size of either three, five or seven lumped masses can be made with a single control command.

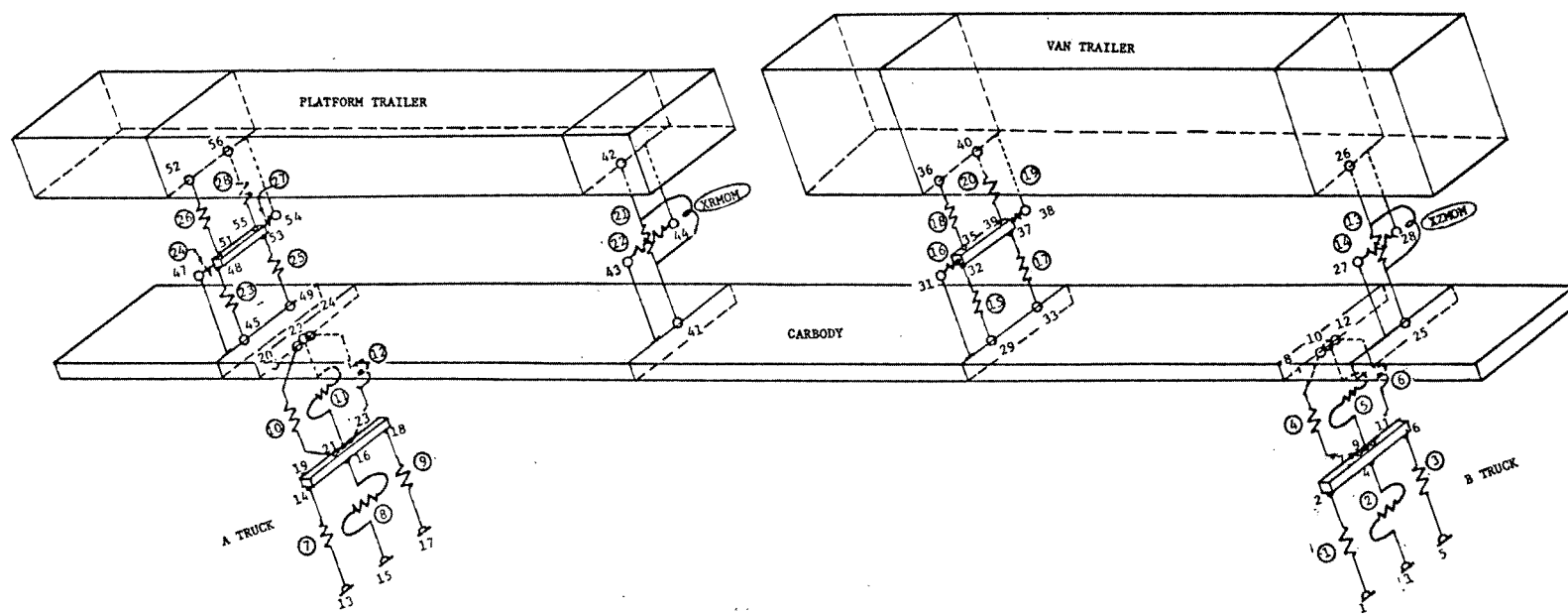


FRATELORE MASEI, INERTIA SI CENTRUL DE MASA AL BELEI RECTANGULARE. FIGURA 1. NOTIUNEA DE LIBERTATE DE MILOC



3

FIGURE 2
FRATE/TOFC GEOMETRY NOTATION



A

SPRING AND DAMPER NOTATION
 — LINEAL SPRING AND DAMPER
 — ANGULAR SPRING AND DAMPER
 ○ CIRCLED NUMBERS - SPRING AND DAMPER ATTACHMENT POINTS
 ○ UNCIRCLED NUMBERS - SPRING AND DAMPER ATTACHMENT POINTS

FIGURE 3
 FRATE/TOFC SPRING-DAMPER NOTATION

2.0 PROGRAM DESCRIPTION

The FRATE program is divided into three separate files:

(1) the program file which contains the actual FRATE program, (2) the data file containing input data which consists of all parameters defining the model being analyzed and all parameters defining what analysis is to be performed and what output is to be obtained; and (3) the run or executive file which is used to execute a FRATE run. The program file and the data file are discussed in this section. The executive file is discussed in Section 4.0.

2.1 Description of FRATE

FRATE is a digital computer program which solves a set of coupled nonlinear differential equations in the time domain. The solutions are obtained using a numerical approximation technique called the Runge-Kutta Method. The equations, as presently written, simulate the vibratory dynamics of a trailer on flatcar (TOFC) configuration. The solutions of these equations of motion are transformed into vibratory responses of specified locations, in specified directions, on and in the freight car and are formatted in the output to enhance their interpretation by the user.

The program is based on an engineering analysis of the vibratory response of a freight car which is excited by externally applied motions at the wheel/rail interfaces. These motions, in the vertical and lateral directions, are harmonic functions of time. The analysis was formulated with the following implicit characteristics:

- a. The freight car is simulated by a set of interconnected lumped masses, springs and dampers in a fixed topology.
- b. The vibratory motions of the lumped masses are described by a set of coupled nonlinear differential equations derived by applying Newton's second law of motion ($F=MA$).
- c. The internal forces in the springs and dampers are functions only of relative displacements and relative velocities.

- d. Normal free-free modes are used to simulate the carbody structural flexibility and are superposed on its rigid body motions.
- e. Small-angle assumptions ($\cos \theta=1$ and $\sin \theta = \tan \theta = \theta$) are not made in the program. Also, second order terms for linear displacement due to angular motions are included. Consequently the analysis is valid for the range of angular deflections up to about 10 degrees.
- f. The nonlinear phenomena of wheel lift-off are included both for the rail car wheels and the tandem wheels.
- g. Bilinear springs are included to represent the centerplate and trucking spring roll spring rates with and without side bearing contact.

The second-order nonlinear differential equations of motion are solved using the fourth order Runge-Kutta Method. This method requires that two first-order differential equations be substituted for each of the second-order equations. The equations are solved in the time domain and therefore require a user-specified numerical integration time step. This step size is fixed by the user at the start of the program and is held constant throughout the computation. The fourth order solution method requires that the equations be solved four times for each time step. The choice of the time step value is important since the numerical stability and the cost of running the program are strongly dependent on it.

The core storage required for FRATE is presently about 219,000 10-byte words, 39,000 in small core (SCM) and 180,000 in large core (LCM). Of this about 9,000 words of SCM are needed for the FORTRAN programs and input data. The remainder 30,000 words SCM and 180,000 words LCM are used for output data.

The total program file consists of the basic FRATE plus five subroutines. The subroutines revise and reformat output data for the various output options. The program is in on-line disc storage at the CDC 7600 front end under the name FRATE01. Table I contains a brief description of each subroutine.

TABLE I

FRATE PROGRAMS

NAME	PURPOSE
FRATE	Calculates the responses of the DOF's and the response points.
PRNPLT	A subroutine of FRATE which uses subroutine MPLOT to produce line-printer ENVELOPE plots.
TMHIS	A subroutine of FRATE which uses subroutine MPLOT to produce line-printer TIME HISTORY plots.
RUNKUT	A subroutine of FRATE which performs the numerical integration of the equations of motion.
MPLOT	A subroutine of PRNPLT and TMHIS which contains the details of line-printer plotting.
ENVCALP	A subroutine of FRATE which partially prepares TOFC envelope output for CalComp plotter.

The programs listed are contained in a file named FRATE01 which is kept in on-line disc storage at the CDC 7600 front end in Minneapolis.

2.2 Input Data File

The input to FRATE utilizes the NAMELIST option of FORTRAN. NAMELIST frees the user from formatted input. It also allows the extensive use of default values for input parameters, so that the program can use preset values for constants and parameters not specified in a given run.

Several points should be emphasized. First, all input parameters are in the English system of units, namely, pounds; seconds and inches. Second, all four namelists must be included in the input file, and they must be listed in the order given in Table II. Third, default values have been incorporated for all input parameters. The user should become familiar with these default values since some are nominal values which will permit the run to continue while others are fatal values which will cause the run to abort.

Table II lists the four NAMELISTS's in the input data file in their proper order with a brief description of each. This is followed by example listings of each namelist and a table describing each parameter, including type definition and default values. The description is somewhat brief for some parameters. Referring to Figures 1, 2 and 3 will greatly enhance the user's understanding of the coordinate system, the mass and inertia inputs, the required input geometries, and the springs and damper locations.

TABLE II
FRATE INPUT NAMELISTS

NAMELIST	DESCRIPTION
CONTRL	Parameters which control the processing of the simulation (type and amount of output integration stepsize, etc.)
EXCIT	Parameters defining type of excitation to be applied to railcar (displacement, acceleration, phase angles, sweeps, dwells, etc.)
VEHIC	Parameters describing vehicle(s) mechanical properties (masses, moments of inertia, geometries spring and damping constants).
MODAL	Parameters defining railcar flexibility.

2.2.1 Namelist CONTRL

CONTRL contains information as to run identification, run times, type of run and type of output. An example listing is given below. Table III contains a description of each term in CONTRL.

Example Listing

```
OLD,FRAD108
/LNH

$CONTRL

RUNO=206.42,

STARTM=2.0, DELTAT=.005, STOPTM=8.,
ENVEL=.F., ENVPLT=.F., ENVCAL=.F., ENPRMX=.F.,
TIMHIS=.T., THSPLT=.T., SNAPSHT=.F.,
STARSNP=5.20, DELTSNP=0.05, STOPSNP=5.60,
IPRINT=1,
IGROUP=4,
OTHER=0,
DEBUG=.F., STARDB=4.15, STOPDB=4.17,$
```

TABLE III

DESCRIPTION OF NAMELIST CONTRL PARAMETERS

Parameter Name	Type ¹	Default Value	Description and Comment
RUNO	R	0.	User chosen number to help, for example, in cataloging production runs
STARTM	R	2.0	Time at which plot data storage is initiated (sec.). Used to bypass response transient phase at simulation start. Generally set equal to 1.0 or 2.0 seconds.
DELTAT	R	.005	Integration stepsize (sec.). DELTAT = .005 has been found to be close to the upper limit. A smaller value may be needed with nonlinear effects such as wheel lift off.
STOPTM	R	3.0	Simulation stop time (sec.)
ENVEL	L	.FALSE.	If set . TRUE., acceleration responses are searched for local maximums and stored for "envelope" plots. See Section 2.4.2 for description of Envelope.)
ENVPLT	L	.FALSE.	If set . TRUE., envelope plots are created on the line printer.
ENVCAL	L	.FALSE.	If set . TRUE., desired "enveloped" responses will be saved on a file for CalComp plotting.
ENPRMX	L	.FALSE.	If set . TRUE., "envelope". values will be printed if at least one hits a maximum value
TIMHIS	L	.FALSE.	If set . TRUE., time history plot data is stored.
THSPLT	L	.FALSE.	If set . TRUE., time history data is plotted on the line "printer".

TABLE III (continued)

Parameter Name	Type ¹	Default Value	Description and Comment
SNAPSHT	L	.FALSE.	If set . TRUE., program saves deflection responses on file for 3-D CalComp plotting program
STRSNP	R	100.	Start time for saving "snapshot" data (sec.)
DELTSNP	R	.05	Time interval at which "snapshot" plots are desired on seconds (> deltata)
STOPSNP	R	100.	Stop time for saving "snapshot" data (sec.)
IPRINT	I	1	Used to define output interval of time for history and envelope plots. Every IPRINT'th envelope max found will be stored for plotting. Time history print interval in number of integration steps is: $NPRINT = IPRINT * IPRNT$ where: $NPRINT$ is the number of time steps between printing's $IPRNT$ is print schedule dependent on f_e , the excitation frequency $0 < f_e < 2., IPRNT = 10$ $2. < f_e < 4., IPRNT = 5$ $4 < f_e < 8., IPRNT = 3$ $f_e > 8., IPRNT = 2$
IGROUP	I	0	Determines specific desired groups of responses to be calculated for either envelope or time history plots (See Table VII for definitions of IGROUP)

TABLE III (concluded)

Parameter Name	Type	Default Value	Description and Comment
OTHER	I	0	Output option yet to be incorporated
DEBUG	L	.FALSE.	If set . TRUE., printed calculations for debugging are output during the time interval STARDB to STOPDB
STARDB	R	100.	Start time for debug output (sec.)
STOPDB	R	100.	Stop time for debug output (sec.)

¹Variable type definitions

R = real
R()= real, array
I = integer
L = logical

2.2.2 Namelist EXCIT

EXCIT contains values defining the sinusoidal input motion as to location, phasing, frequency and amplitude. An example listing is given below followed by a description in Table IV of each term in EXCIT.

Example Listing

```
$EXCIT
```

```
SINEIN=.T.,
```

```
AMP = 1.00, 0.50, 1.00, 1.00, 0.50, 1.00,
```

```
PHAS= 0.00, 0.00, 180., 0.00, 0.00, 180.,
```

```
FQ=1.1, FQDOT=.0, BETA=0., NDECAY=3.
```

```
DIN=0.0, VIN=0.00, GIN=.01,$
```

TABLE IV
DESCRIPTION OF NAMELIST EXCIT PARAMETERS

Parameter Name	Type	Default Value	Description and Comment
SINEIN	L	.TRUE.	If set . FALSE. will by-pass sinusoidal forcing function calculations
AMP	R(6)	6*0.	Input amplitude multiplier for each of the excitation functions at wheel/rail interfaces of railcar trucks at node points 1, 3, 4, 13, 15 and 17 respectively, (nondimensional factor) (see Figure 3)
PHAS	R(6)	6*0.	Phase angles for each of the excitation functions at node points 1, 3, 5, 13, 15 and 17 (degrees)
FQ	R	1.0	Initial value of sinusoidal excitation frequency, (Hz).
FQDOT	R	0.	Linear frequency sweep rate for the excitation function, (Hz/sec, + for increasing, - for decreasing frequency)
BETA	R	0.	Logarithmic sweep rate (octaves/minute, + for increasing, - for decreasing values of frequency)
NDECAY	I	5000	Number of input vibration cycles at which point input forcing function is set to zero and system responses are allowed to decay to STOPM (cycles)
DIN	R	0.	Displacement amplitude of the sinusoidal vibration excitation function, (inches, 0-peak). Takes precedence over VIN and GIN
VIN	R	0.	Velocity amplitude of sinusoidal vibration excitation function (in/sec, 0-peak). Takes precedence over GIN
GIN	R	0.	Acceleration amplitude of vibration excitation function (g's, 0-peak)

2.2.3 Namelist VEHIC

VEHIC contains values for all parameters defining the model except for modal data. It consists of mass, inertia, dimensional, stiffness and damping data. A listing of VEHIC is given below followed by a description of each parameter. Parameter values are listed in Section 3.0.

Example Listing

```
$VEHIC
NMAS=3,
M=2*22.33,125.0,8.179,152.65,7.013,148.9,3*0.,
INERT=22080.,22080.,108500.,20000.,255000.,17150.,102000.,
.294E7,.319E7,.15E8,.15E8,.131E7,.131E7,2*0.,
R=58.,79.,58.,79.,62.25,43.5,62.25,43.5,108.,0.,
H=16.,VH=60.4,VH1=47.,VHR=37.8,VH1R=47.,
L=792.,VL1=469.,VL2=148.,VL3=131.4,VL4=189.7,
VL1R=-89.,VL2R=-413.,VL3R=115.4,VL4R=208.6,
OR=536.,-536.,-39.,39.,40.,224.,226.,254.,245.,235.,
GAPB=.01, GAPA=.01,
K=.91E5,.95E5,.91E5,.48E5,.36E4,.0,.91E5,.95E5,.91E5,.48E5,.36E4.,
.0,.225E6,.15E5,.225E5,.18E5,.225E5,.5276E5,.18E5,.5276E5,
.225E6,.15E5,.225E5,.18E5,.225E5,.5276E5,.18E5,.5276E5,2*0.,
XZKMOM=.30E8, XRKMOM=.30E8,
KA6=.20E8,KA12=.20E8,KB6=.6185E8,KB12=.6185E8,
C=300.,333.,300.,140.,225.,0.,300.,333.,300.,140.,225.,0.,
1000.,200.,330.,200.,330.,775.,200.,775.,
1000.,200.,330.,200.,330.,775.,200.,775.,2*0.,
XZCMOM=.10E6, XRCMOM=.10E6,
CA6=.35E5,CA12=.35E5,CB6=.78E6,CB12=.78E6,s
```

TABLE V
DESCRIPTION OF NAMELIST VEHIC PARAMETERS

Parameter Name	Type	Default Value	Description
NMAS	I	0	Number of lumped masses required to define vehicle(s) - 3 (railcar alone), 5 (flatcar plus B-end trailer), or 7 (flatcar plus two trailers) are the only presently acceptable values
M	R(10)	10*0.	Mass of lumped mass elements (lbs.) M(1) - B-end truck M(2) - A-end truck M(3) - railcar carbody M(4) - B-end trailer tandem M(5) - B-end trailer M(6) - A-end trailer tandem M(7) - A-end trailer
INERT	R(15)	15*0.	Moment of inertia of lumped mass elements (lb. in. sec. ²) I(1) - B-end truck (roll) I(2) - A-end truck (roll) I(3) - railcar carbody (roll) I(4) - B-end trailer tandem (roll) I(5) - B-end trailer (roll) I(6) - A-end trailer tandem (roll) I(7) - A-end trailer (roll) I(8) - B-end trailer (pitch) I(9) - B-end trailer (yaw) I(10) - railcar carbody (pitch) I(11) - railcar carbody (yaw) I(12) - A-end trailer (pitch) I(13) - A-end trailer (yaw)
R(I)	R(10)	10*0.	Distances between adjacent suspension points (in.) R(1) - B-end truck wheels R(2) - B-end truck/railcar attachment points R(3) - A-end truck wheels R(4) - A-end truck/carbody attachment points R(5) - B-end trailer tandem wheels R(6) - B-end tandem/trailer attachment points R(7) - A-end trailer tandem wheels R(8) - A-end tandem/trailer attachment points R(9) - Width of railcar carbody

TABLE V (continued)

Parameter Name	Type	Default Value	Description
H	R	0.	Carbody height (in.)
L	R	0.	Distance between railcar truck centerlines (in.)
VH	R	0.	B-end trailer height (in.)
VH1	R	0.	Distance from railcar top surface to B-end trailer bottom (in.)
VL1	R	0.	Distance from railcar center of gravity to B-end trailer hitch point (in.)
VL2	R	0.	Distance from railcar center of gravity to B-end trailer tandem (in.)
VL3	R	0.	Distance from B-end trailer suspension point to trailer center of gravity (in.)
VL4	R	0.	Distance from B-end trailer hitch point to trailer center of gravity (in.)
VHR	R	0.	A-end trailer height (in.)
VHLR	R	0.	Distance from railcar top surface to A-end trailer bottom (in.)
VL1R	R	0.	Distance from A-end trailer hitch point to railcar center of gravity (in.)
VL2R	R	0.	Distance from A-end trailer tandem to railcar center of gravity (in.)
VL3R	R	0.	Distance from A-end trailer suspension point to trailer center of gravity (in.)
VL4R	R	0.	Distance from A-end trailer hitch point to trailer center of gravity (in.)
OR(1)	R(10)	10*0.	Longitudinal distances used in response output calculations OR(1) - from carbody cg to B-end of carbody OR(2) - from carbody cg to A-end of carbody OR(6) - 226 inches from carbody c.g., fore and aft OR(7) - from B-end trailer c.g. to hitch end of trailer OR(8) - from B-end trailer c.g. to tandem end of trailer

TABLE V (concluded)

Parameter Name	Type	Default Value	Description
OR(I) continued	R(10)	10*0	OR(9) - from A-end trailer c.g. to hitch end of trailer OR(10) - from A-end trailer c.g. to tandem end of trailer
GAPB, GAPA	R	0.	Gap at B and A truck side bearings. Switch point for bilinear truck roll spring, radians (1" gap = .04 radians)
K	R(30)	30*0.	Spring values (lb./in.) (See Figure 3 for locations)
XZKMOM	R	0.	B-end trailer hitch roll stiffness (in. lb./radian)
XRKMOM	R	0.	A-end trailer hitch roll stiffness (in. lb./radian)
KA6, KB6	R	0.	Bilinear spring values for K(6), B Truck, Carbody roll, (in. lb./radian)
KA12, KB12	R	0.	Bilinear spring values for K(12), A Truck, carbody roll, (in. lb./radian)
C	R(30)	30*0.	Damping values (lb./in./sec.) (See Figure 3 for locations)
XZCMOM	R	0.	B-end trailer hitch roll damping (in. lb. sec./radian)
XRCMOM	R	0	A-end trailer hitch roll damping (in. lb. sec./radian)
CA6, CB6	R	0.	Bilinear damping values for B truck carbody roll, (in. lb./rad./sec.)
CA12, CB12	R	0.	Bilinear damping values for A truck carbody roll, (in. lb./rad./sec.)

NOTE: The c.g. of each body is assumed to be at half its height.

2.2.4 Namelist MODAL

MODAL contains the normal mode information for the carbody. These normal modes are for the empty carbody, not including truck masses, with free-free boundary conditions. The deflection coefficients have been normalized for unit modal masses. Modal information for seven modes are listed. A number of modes, from 0 to 10, can be chosen through the parameter NMODES and the inclusion of deflection coefficients.

Table VI contains a description of the parameters in MODAL. Location of node points for deflection coefficients is shown in Figure 4a. The location and numbering system of problem output data is shown in Figure 4b.

Example Listing of Namelist MODAL

```
$MODAL
NMODES=4,
RF=4.253,8.873,9.417,9.629,15.519,15.599,18.029,3*0.,
ZETA=7*0.02,3*0.0,
NLOC=46,
COEF(1,1)=.139133,.683776E-1,.512E-6,-.12532E-10,.592E-6,-.626276E-1,
.824155E-1,-.529E-6,.23266E-9,.227E-6,-.626276E-1,0,-.768766E-1,
.152E-6,0,.92463E-1,-.529E-6,.92463E-1,.194727,.194727,.683776E-1,
.683776E-1,-.368829E-1,-.368829E-1,-.903879E-1,-.903879E-1,
-.277131E-1,-.277131E-1,.824155E-1,.824155E-1,.209599,.209599,14*0.,
COEF(1,2)=.1077E-5,.331958E-8,.566905E-1,-.863471E-3,.100231,.129931E-1,
-.184794E-6,.704258E-1,.855676E-3,-.507293E-1,-.129940E-1,-.930663E-3,
.325E-6,.598384E-1,.3125E-3,-.305907E-1,.704258E-1,.305901E-1,.531035E-1,
-.531047E-1,.466274E-1,-.466274E-1,.304666E-1,-.304678E-1,-.447888E-2,
.4479E-2,-.37982E-1,.37983E-1,-.46207E-1,.46206E-1,-.4960E-1,.49596E-1,
.198176,.198176,.566905E-1,.566905E-1,-.379632E-1,-.379632E-1,-.791440E-1,
-.791440E-1,-.269666E-1,-.269666E-1,.704258E-1,.704258E-1,.205472,.205472,
COEF(1,3)=.5459E-5,-.491144E-6,.229099E-1,.255278E-2,.383516E-1,-.486152E-1,
-.311685E-6,.273623E-1,-.242100E-2,-.16349E-1,.486091E-1,.267991E-2,
.2003E-5,.226116E-1,-.728602E-3,.865497E-1,.273623E-1,-.86552E-1,
-.150099,.150119,-.137850,.137850,-.106807,.106799,.798774E-3,
-.798404E-3,.105002,-.104994,.130734,-.130734,.141432,-.141454,
.683818E-1,.683818E-1,.229099E-1,.229099E-1,-.106589E-1,-.106589E-1,
-.290141E-1,-.290141E-1,-.117100E-1,-.117100E-1,.273623E-1,.273623E-1,
.859564E-1,.859564E-1,
COEF(1,4)=.12234,-.15435E-1,.3545E-5,-.1187E-6,.175E-5,-.7554E-1,-.1235E-2,
-.6518E-5,.111274E-6,.5687E-5,-.755421E-1,-.125E-6,.485419E-1,.1115E-5,
.32E-7,-.203465E-1,-.6518E-5,-.203386E-1,.230599,.230585,-.154290E-1,
-.154518E-1,-.946543E-1,-.946639E-1,.239724E-2,.239729E-2,.880306E-1,
.890400E-1,-.124088E-2,-.122886E-2,-.243111,-.243097,-.915E-5,-.915E-5,
.354E-5,.354E-5,.745E-5,.745E-5,.177E-5,.177E-5,-.602E-5,-.602E-5,
-.652E-5,-.652E-5,-.349E-6,-.349E-6.
```

Example Listing of Namelist MODAL (continued)

```

COEF(1,5)=.30975E-3,-.263863E-3,.258867E-1,.194368E-3,-.168226E-2,
.87251E-2,-.256151E-3,-.909975E-2,.464493E-3,.586144E-1,-.860299E-2,
.30035E-3,.15626E-3,.309005E-1,-.7291E-4,-.167711E-1,-.909975E-2,.164401E-1,
-.199548E-1,.214758E-1,-.107598E-1,.102320E-1,.132692E-1,-.135408E-1,
.126753E-1,-.120841E-1,-.106510E-1,.102260E-1,-.253388E-1,.248264E-1,
-.304096E-1,.322754E-1,-.231421,-.231421,.258867E-1,.258867E-1,
.858191E-1,.858191E-1,-.193811E-2,-.193811E-2,-.802148E-1,-.802148E-1,
-.909975E-1,-.909975E-1,.253888,.253888,
COEF(1,6)=.895037E-1,-.775666E-1,-.9023E-4,-.766825E-6,.6786E-5,
.124429E-1,-.725247E-1,.3019E-4,-.168293E-5,-.2056E-3,.12505E-1,
-.1161E-5,.480042E-1,-.10844E-3,.278E-6,-.465734E-1,.3019E-4,-.466937E-1,
.220852,.220694,-.775252E-1,-.776080E-1,-.440986E-1,-.440038E-1,
.838907E-1,.839823E-1,-.550254E-1,-.551002E-1,-.724338E-1,-.726156E-1,
.255325,.255097,.81881E-3,.81881E-3,-.9023E-4,-.9023E-4,-.3011E-3,
-.3011E-3,.702E-5,.702E-5,.2811E-3,.2811E-3,.302E-4,.302E-4,
-.8989E-3,-.8989E-3,
COEF(1,7)=.177E-5,-.219171E-5,.132706E-1,.389116E-2,.212431E-1,.224044E-1,
-.21001E-5,.48991E-2,.34039E-2,-.41308E-2,-.22410E-1,.47633E-2,.3266E-5,
-.134728E-2,-.134790E-2,-.121691,.489912E-2,.121688,-.29422,.29423,-.210125,
.210121,-.146192E-1,.146116E-1,.141607,-.141608,-.443903E-1,.443947E-1,
-.183813,.183809,-.244498,.244514,.46009E-1,.46009E-1,.132706E-1,
.132706E-1,-.406076E-2,-.406076E-2,-.42866E-2,-.42866E-2,.109401E-1,
.109401E-1,.489912E-2,.489912E-2,-.36793E-1,-.36793E-1,$
SEND
-END OF FILE-

```

TABLE VI
DESCRIPTION OF NAMLIST MODAL PARAMETERS

Parameter Name	Type	Default Value	Description
NMODES	I	0	Number of desired free-free normal modes to describe flexibility of principal vehicle ($0 \leq \text{NMODES} \leq 10$)
ZETA	R(10)	10*.005	Modal damping factors, one per defined normal mode (ratio to critical)
RF	R(10)	10*.0.	Modal frequencies (Hz)
NLOC	I	0	Number of deflection shape modal displacements desired ($0 < \text{NLOC} < 46$)
COEF	R(46,10)	460*0.	Normal mode deflection shapes, each column representing one mode

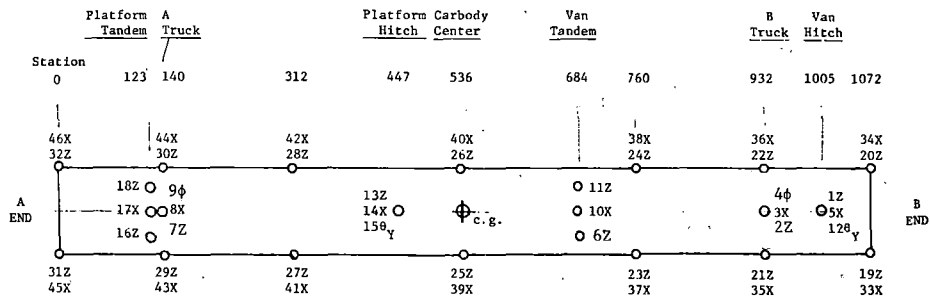


FIGURE 4a
NODE NUMBERING SYSTEM FOR CARBODY FLEXIBLE MODE COEFFICIENTS

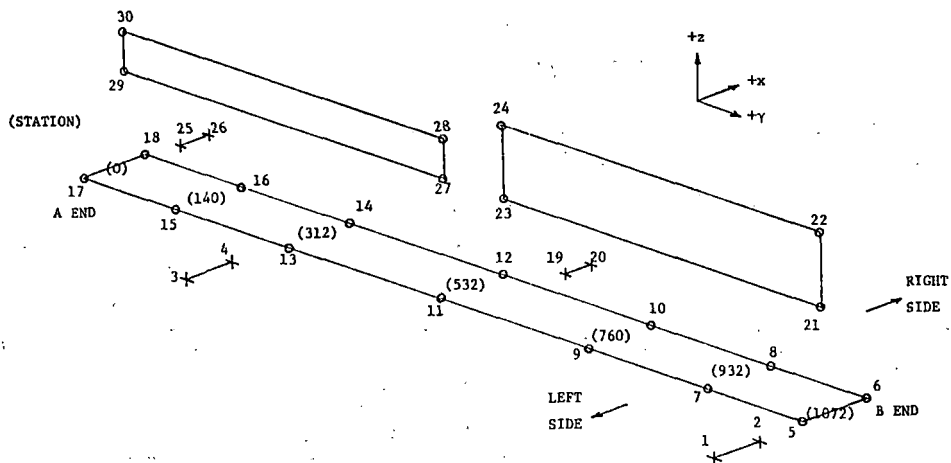


FIGURE 4b
FRATE/TOFC OUTPUT DATA NUMBERING SYSTEM

2.3 Forcing Functions Options

Sinusoidal motions can be imposed on any combination of the six track-wheel interface locations 1, 3, 5, 13, 15 and 17. Nodes 3 and 15 are lateral motions while all others are vertical motions. The frequency of the motion must be the same at all input points. The amplitudes and phase angle relationships between input points can be assigned any values for a run but must remain constant for that run.

The input forcing function is defined in namelist EXCIT. The amplitude of the six input options are defined by the product of the input amplitude (DIN, VIN or GIN) and the amplitude factor AMP(I). DIN, VIN and GIN provide the user the option of constant displacement, velocity or acceleration input amplitudes with a varying frequency input. The AMP(I) factors enable the user to regulate the relative amplitude at the six input nodes. Similarly PHAS(I) enables the user to fix the phase relationships between the six input nodes.

Thus in the example listing in Section 2.2.2 there is a 1.1 Hertz frequency imposed with amplitudes corresponding to 0.01g vertically at each side of each truck and 0.005 g laterally at each truck. The phasing is; when the left side of each truck is going up, the right side is going down and the lateral motion is to the right. This results in a rocking motion with the center of rotation at some point below the rail car.

The frequency of the excitation motions is controlled by the parameters FQ, FQDOT, BETA and NDELAY. FQ is the frequency at time zero. If FQDOT and BETA are zero, as in the example, the excitation frequency will remain constant. The value of NDELAY = 3 will result in the excitation being set equal to zero after three cycles have been completed.

The excitation function has been designed with two objectives in mind. The first was to be able to duplicate the sine-sweep testing performed on a TOFC configuration at the Rail Dynamics Laboratory. The second objective was to simulate the track profile of jointed track. With jointed track, frequency of excitation is related to rail section length and train velocity by the relationship:

$$f = \frac{v}{\lambda}$$

where f = frequency in Hertz

v = velocity in ft./sec.

λ = wave length or rail section length

Also the phase relationship between motions at the A and B truck are determined by the ratio of rail section length to truck center distance.

2.4 Output Options

Since FRATE is a time domain analysis all output results are actually time histories of response motions. However within the time history category output data is available in the three forms known in FRATE as (1) time history, (2) envelope and (3) debug. A description and suggested application of each follows. Examples of each are shown. The location and numbering system of problem output data is shown in Figure 4b.

2.4.1 Time History Output

Time history printer plots are obtained by setting TIMHIS = .T. and THSPLT = .T. in the input data file CONTRL namelist. If the imposed motion is vertical IGROUP = 3 output option is used. If imposed motion is roll, IGROUP = 4 output option is used. See Table VII and Figure 4b for definition of IGROUP. The output results will be time history plots of the response motions of selected locations on the truck, carbody and trailers (lading). The plots will be in

superimposed groups of 3 or 4 on the line printer output as indicated in Table VII.

The usefulness of time history plots is to show the detailed motion response throughout the railcar for a given motion at the rail. Amplitude and wave form (frequency content) of response is available for study.

In order to reduce computer costs and shorten the paper length of the time history plots the print schedules given below are followed.

Time History Print Schedule

Frequency	Print Schedule
less than 2 cps	every 10 th time step
between 2 and 4	every 5 th time step
between 4 and 8	every 3 rd time step
greater than 8	every 2 nd time step

The forcing function can be applied with either constant frequency or varying frequency. It can also be applied for a selected number of cycles and stopped to permit the observation of system decay characteristics. The example time listing shown in Figure 5 is a "decay" run where one cycle of a 0.6 Hertz was applied in a rolling excitation.

2.4.2 Envelope Output

Envelope printer plots are obtained by setting ENVEL = .T. and ENVPLT = .T. in the CONTRL namelist. IGROUP = 1 or 2 output options should be requested for vertical or roll motion respectively.

TABLE VII
FRATE OUTPUT DATA - GROUP OPTIONS

GROUP 1 ENVELOPE VERTICAL	GROUP 2 ENVELOPE ROLL	GROUP 3 TIME HISTORY VERTICAL	GROUP 4 TIME HISTORY ROLL
ZA(1)	ZA(1)	1 Z(1)	1 Z(1)
ZA(3)	ZA(3)	Z(5)	Z(5) 8 X(1)
ZA(5)	ZA(5)	Z(7)	Z(7) X(7)
ZA(7)	ZA(7) XA(7)	ZI(1)	ZI(1) X(11)
ZA(11)	ZA(8)		X(15)
ZA(15)	ZA(11)	2 Z(9)	2 Z(9)
ZA(19)	ZA(12)	Z(11)	Z(11)
ZA(21)	ZA(15) XA(15)	Z(13)	Z(13)
ZA(23)	ZA(16)		
ZA(25)	ZA(19) XA(19)	3 Z(3)	3 Z(3)
ZA(27)	ZA(21) XA(21)	Z(15)	Z(15)
ZA(29)	XA(22)	Z(17)	Z(17)
	ZA(23) XA(23)		
	ZA(25) XA(25)	4 Z(19)	4 Z(19) 9 X(19)
	ZA(27) XA(27)	Z(21)	Z(20) X(21)
	XA(28)	Z(23)	Z(21) X(22)
	ZA(29) XA(29)		Z(23) X(23)
		5 Z(25)	
		Z(27)	5 Z(25) 10 X(25)
		Z(29)	Z(26) X(27)
			Z(27) X(28)
			Z(29) X(29)
			6 Z(2)
			Z(6)
			Z(8)
			ZI(3)
			7 Z(10)
			Z(12)
			Z(16)
			Z(18)

Envelope Note: CalComp plots will be ZA() and/or XA() as shown. Printer plots will have both ZA() and XA() for all points shown.

MULTIPLE PLOT TIME HISTORY

FRATE RUN 206.00

SWEEP RATE = 0.

INPUT MOTION: DIN = .100

1=I(1)
2=I(5)
3=I(7)
4=I(11)

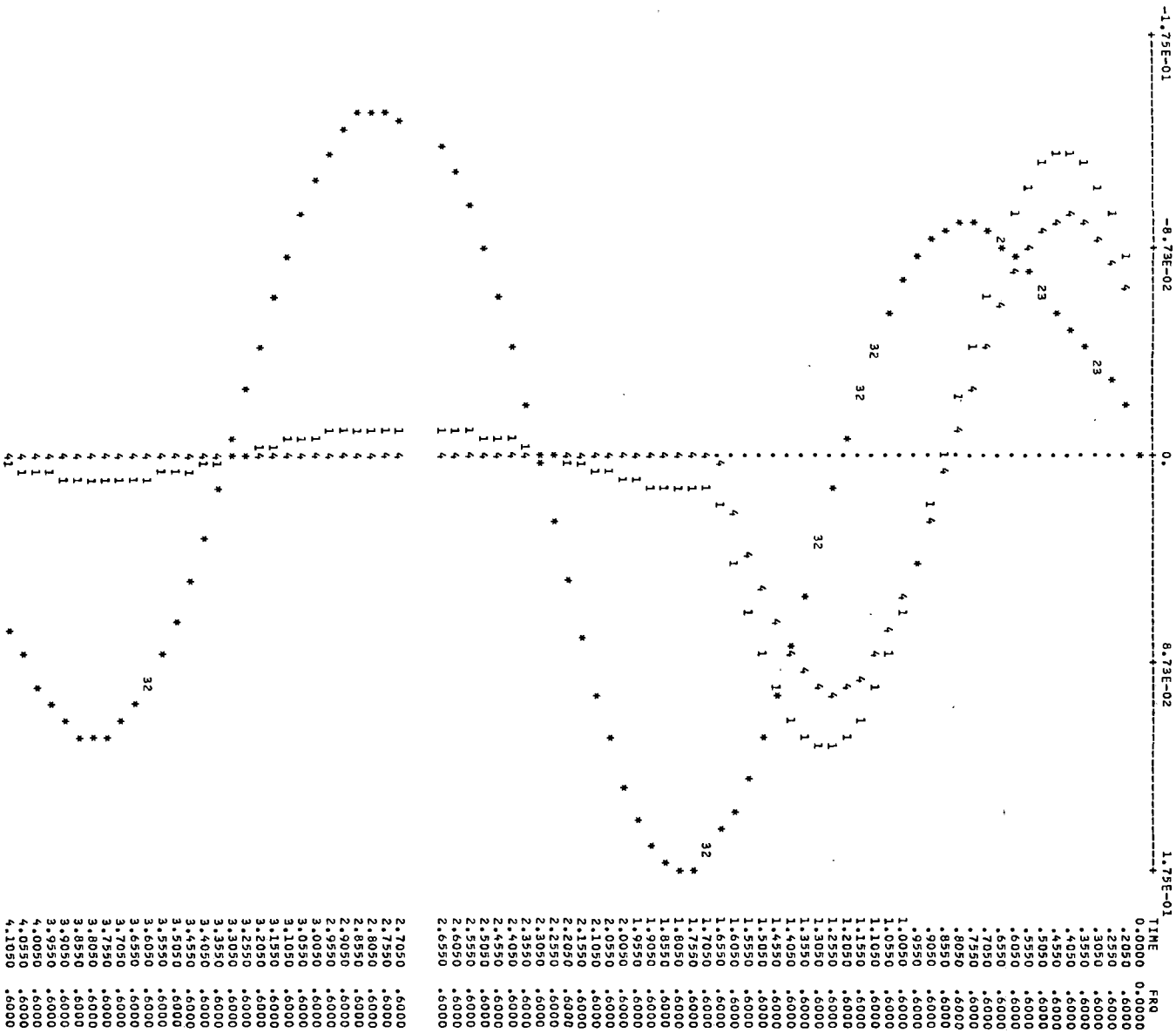


FIGURE 5
EXAMPLE TIME HISTORY/DECAY PLOT

Envelope plots are abbreviated time histories in that only positive peak values are plotted instead of continuous wave form. The envelope plot appears as a frequency transfer function when plotted against frequency. The usefulness of envelope plots is for the identification of resonant frequencies and assessment of amplitude of response at resonance. An example envelope plot is shown in Figure 6.

2.4.3 DEBUG Output

DEBUG is a tabular printout of all primary parameters in a time step consisting of the following:

- a. time in seconds
- b. the values of the six excitation functions
- c. spring/damper forces
- d. acceleration, velocity and displacement of each of the 27 rigid body degrees of freedom
- e. the carbody normal mode responses, ETA, and their first and second derivatives

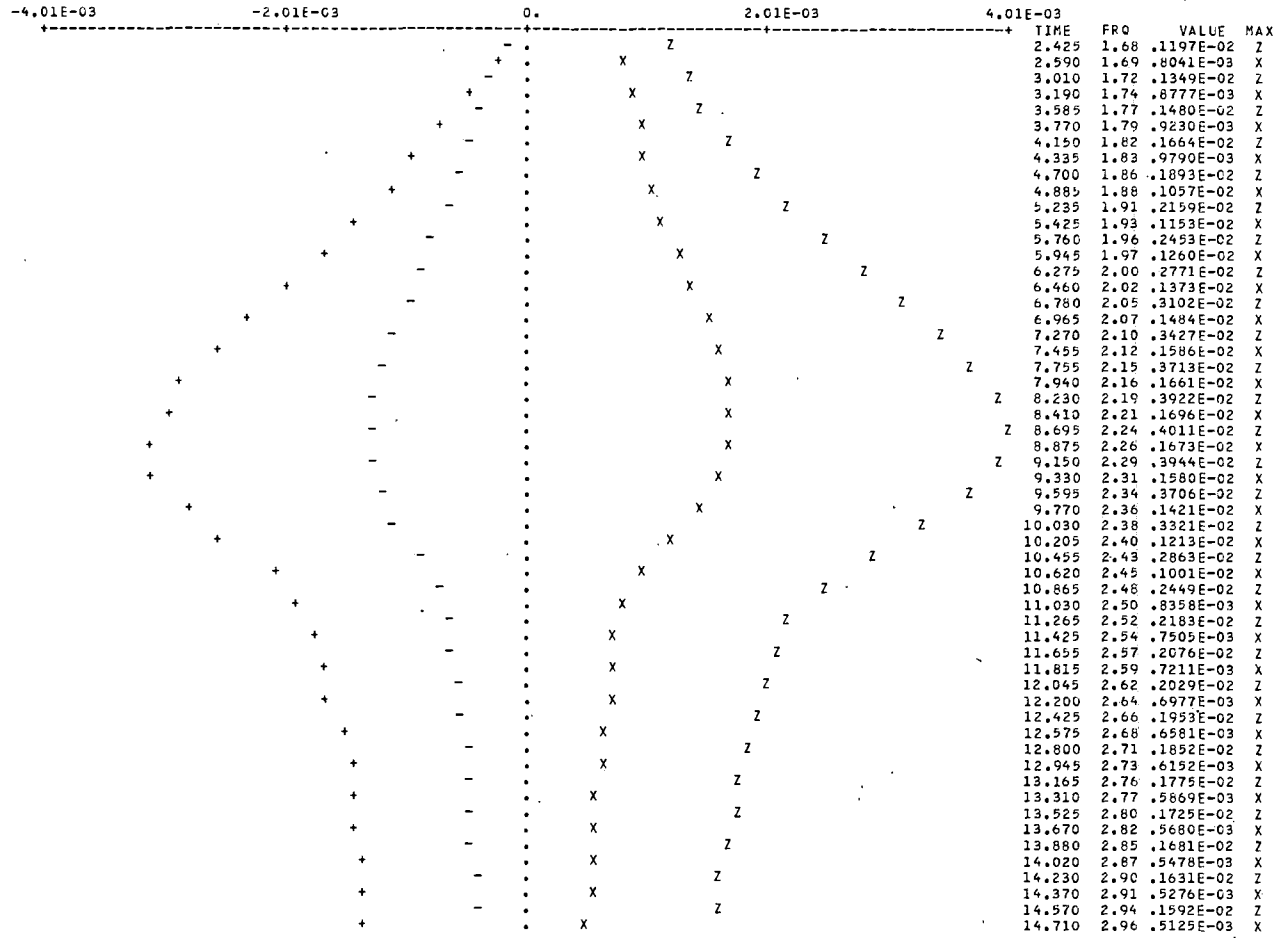
An example debug printout is shown in Figure 7. This is from an analysis with NMAS = 5, i.e. one trailer and NMODES = 0, i.e. rigid carbody. Hence the zeros for the forces and degrees of freedom corresponding to the second trailer and for the carbody modes. Also, in this run NDECAY = 1, hence the zero excitation functions.

The order of listing of the degrees of freedom are shown in Table VIII.

Debug is intended to be used as a diagnostic aid rather than for production. The detailed numerical information can be helpful in searching for the cause of unexpected behavior but is too voluminous and cumbersome for anything else.

ENVELOPE PRINT PLOTS FOR TFC2 POINT 3

Z IS SYMBOL FOR ZA AND - IS SYMBOL FOR CORRESPONDING XA
 X IS SYMBOL FOR XA AND + IS SYMBOL FOR CORRESPONDING ZA



29

FIGURE 6
 SAMPLE ENVELOPE PLOT

TIME = 4.1550

ZI(I) = 0.

0.

30

I	F(I) (LBS)	ACCELERATION (GS OR RAD/SEC.SQ)
1	2.1867E+04	-4.2046E-05
2	-3.0416E+01	-4.8185E-05
3	2.1935E+04	-9.0021E-04
4	2.0077E+04	-9.5311E-04
5	-3.0265E+01	-1.5683E-03
6	2.0127E+04	-6.3452E-03
7	2.2725E+04	-1.3340E-06
8	-3.2831E+01	4.4305E-06
9	2.2825E+04	-3.6885E-06
10	2.0941E+04	1.2111E-05
11	-3.2657E+01	-4.5604E-07
12	2.1013E+04	-9.6445E-04
13	2.9765E+04	-7.0767E-04
14	-2.0631E+01	-1.1199E-02
15	1.7337E+04	-7.9719E-03
16	-2.6269E+01	-4.3865E-06
17	1.7370E+04	-5.2200E-06
18	1.5598E+04	1.8375E-05
19	-2.2892E+01	1.6511E-07
20	1.5648E+04	0.
21	0.	0.
22	0.	0.
23	0.	0.
24	0.	0.
25	0.	0.
26	0.	0.
27	0.	0.
28	0.	0.

MODE
1

ETADD
0.

ETAD
0.

FIGURE 7
SAMPLE DEBUG OUTPUT, NM

0.

0.

0.

0.

VELOCITY
(IN/SEC OR RAD/SEC)

DISPLACEMENT
(IN OR RAD)

-1.1201E-03

3.0730E-04

-6.1881E-04

3.3004E-04

1.1900E-02

9.7437E-03

9.2354E-03

-4.7612E-01

-1.7978E-04

-4.9511E-01

6.4742E-02

-5.3748E+00

3.2044E-05

-2.5425E-05

4.7152E-04

-3.7934E-05

1.3115E-04

-8.5451E-05

1.1765E-04

2.3941E-04

-2.0402E-05

4.2223E-07

4.6121E-03

1.4144E-02

-4.4756E-02

2.4017E-02

5.2279E-02

-6.0190E+00

7.5798E-02

-5.8439E+00

3.6499E-04

-1.0711E-04

5.6169E-04

-1.2652E-04

8.3045E-05

1.8155E-03

8.3173E-06

-6.4836E-06

0.

0.

0.

0.

0.

0.

0.

0.

0.

0.

0.

0.

0.

0.

0.

0.

0.

0.

ETA

0.

AS=5, NMODES=0

TABLE VIII
DEGREE OF FREEDOM LISTING ORDER IN FRATE/TOFC

1. X(1) 2. X(2) 3. X(3) 4. z(1) 5. z(2) 6. z(3) 7. \emptyset (1) 8. \emptyset (2) 9. \emptyset (3) 10. θ 11. α	Rail Car (1) = B truck (2) = A truck (3) = Carbody c.g.
12. X(4) 13. X(5) 14. z(4) 15. z(5) 16. \emptyset (4) 17. \emptyset (5) 18. θV 19. αV	Van Trailer (4) = tandem (5) = trailer c.g. V = trailer c.g.
20. X(6) 21. X(7) 22. z(6) 23. z(7) 24. \emptyset (6) 25. \emptyset (7) 26. θT 27. αT	Platform Trailer (6) = tandem (7) = trailer c.g. T = trailer c.g.

This listing order is followed in the DER's and VAR's used in the FRATE equations of motion and in the degree of freedom response listings in DEBUG output.

2.5 Analysis Procedure

There are two basic objectives envisioned in performing analyses with FRATE: (1) to obtain a definition of the dynamic characteristics of the vehicle under study and (2) to obtain a definition of response (accelerations, deflections and loads) to specific input loadings.

The analysis procedure which is to be followed in any time domain analysis is to apply an input (forcing) function and observe the resulting responses. With astute selection of forcing functions and evaluation of resulting responses a description of the dynamic characteristics of the model can be obtained. This description includes resonant frequencies, amplitudes of responses both on and off resonance and the general shape of the response at resonance. For example, it may be apparent that there is one particular resonance which is easily excited to large amplitudes. Repeated analyses can be made with variations on parameters (springs, dampers, masses, mass distribution, etc.) to see which parameters are most effective in reducing responses and to arrive at some acceptable configuration.

A second analysis requirement may be to predict the loads on critical members in a railcar configuration with a given input loading condition. The analysis may be simply to provide design load values or it may be used to see what changes to the model will result in reduced loads on the members under study.

With these types of analysis in mind FRATE has been set up with the capability to impose motions at the wheel-rail interface and to read out responses at selected points throughout the vehicle. The following six categories of analyses were anticipated:

Analysis Input Motion Options

- (1) Vertical input motions with frequency varied over a relatively wide band.
- (2) Roll input motions with frequency varied over a relatively wide band.
- (3) Vertical input motions with frequency held constant or varied over a narrow band.
- (4) Roll input motions with frequency held constant or varied over a narrow band.
- (5) Vertical input motions with a limited number of fixed frequency cycles in order to observe decay characteristics.
- (6) Roll input motions with a limited number of cycles at a fixed frequency to observe decay characteristics.

Table IX relates type of analysis, analysis objective and the various options available in FRATE to perform the analysis.

TABLE IX
FRATE ANALYSIS OBJECTIVES AND OPTIONS

Descriptive Item	Analysis Input Motion Options					
	1	2	3	4	5	6
Analysis Objective	Resonance Search		Resonance Description		Resonance Search, Decay Rate	
Input Direction	Vertical	Roll	Vertical	Roll	Vertical	Roll
Input Frequency	Wide Band Sweep		Constant or Narrow Band Sweep		Constant and Stop	
Type of Response	Forced				Decay	
Type of Output	Enveloped (accelerations)		Time History (displacements)			
Output IGROUP (See Table VII)	1	2	3	4	3	4

3.0 MODEL DESCRIPTION

The freight car model of this report is a TOFC (Trailer on Flatcar) configuration. The TOFC model in its present state has evolved from modeling by Ahlbeck, et al., Reference 1, by Healy, Reference 2, and by Mitre. It consists of the lumped mass simulation shown schematically in Figure 1, 2 and 3. Figure 1 defines the notation used for masses, inertias and degrees of freedom, Figure 2 defines geometric notation and Figure 3 defines spring damper notation. The railcar is represented by three rigid body masses: two trucks and the carbody. Carbody flexibility is included through application of a component normal mode technique using the first four free-free normal modes. Each of the two highway trailers are represented by two rigid masses: one for the trailer body and one for the wheel/axle assembly. The mass, stiffness, damping and dimensional values used are shown in Tables X, XI, and XII.

The springs and dampers are all in pairs. That is for each spring there is a corresponding damper each attached to the same model node points. The force acting between the attachment node points is the combined effect of spring and damper. All damping is included as viscous.

The truck spring/dampers, K(4), K(6), K(10), K(12) and C(4), C(6), C(10) and C(12) are modeled in a way which differs from the ordinary and is felt to need some description to aid the user's understanding. Spring/dampers K(4), C(4) and K(10), C(10) represent the total vertical stiffness and damping of trucks B and A respectively acting at the carbody centerline. Spring dampers K(6), C(6) and K(12), C(12) represent the total roll stiffness at trucks B and A respectively acting at the carbody centerline. Figure 8a shows these springs schematically.

TABLE X
TOFC MASS PROPERTIES

SYMBOL	DESCRIPTION	VALUE
M(1)	B Truck Mass	22.33
M(2)	A Truck Mass	22.33
M(3)	Carbody Mass	125.00
M(4)	Tandem Mass, Van Trailer	8.179
M(5)	Van Trailer Mass	152.70
M(6)	Tandem Mass, Platform Trailer	7.013
M(7)	Platform Trailer	148.9
I(1)	B Truck Roll Inertia	.2208E5
I(2)	A Truck Roll Inertia	.2208E5
I(3)	Carbody Roll Inertia	.1085E6
I(4)	Van Tandem Roll Inertia	.2000E5
I(5)	Van Trailer Roll Inertia	.2550E6
I(6)	Platform Tandem Roll Inertia	.1715E5
I(7)	Platform Trailer Roll Inertia	.1020E6
I(8)	Van Trailer Pitch Inertia	.2940E7
I(9)	Van Trailer Van Inertia	.3190E7
I(10)	Carbody Pitch Inertia	.1500E8
I(11)	Carbody Van Inertia	.1500E8
I(12)	Platform Trailer Pitch Inertia	.1310E7
I(13)	Platform Trailer Van Inertia	.1310E7

Units: M(I) = lb. sec.²/in.

I(I) = lb. in. sec.²

TABLE XI
TOFC SPRING AND DAMPER VALUES

NUMBER	SPRING CONSTANT K lb./in.	VISCOUS DAMPING CONSTANT C lb.sec./in.	DAMPING RATIO C/C _c (3)	REPRESENTING
1,3,7,9	.91E5	300.	.020	Side frame, wheels and track, vertical, 2 per truck
2,8	.95E5	333.	.022	Side frame, wheels and track, lateral, 1 per truck
4,10	.48E5	1400. (1) 140. (2)	.183 .018	Truck spring vertical, 1 per truck
5,11	.16E5 (4) .36E4 (5) .10E6 (6)	200. 45. 1250.	.079	Truck lateral, 1 per truck (with gib contact)
A6, A12*	.21E8 (4) .114E8 (5)	.20E6 .10E6	.060 .055	Centerplate and truck spring in truck roll
B6, B12*	.6185E8	.20E7 (1) .78E6 (2)	.203 .079	Truck springs in truck roll
13,21	.225E6	1000.	.028	Trailer hitch vertical
14,22	.150E5	200.	.084	Trailer hitch lateral
15,17,23,25	.225E5	330.	.092	Tandem tires, vertical, 2 per tandem
16,24	.180E5	200.	.070	Tandem tires, lateral, 1 per tandem
18,20,26,28	.5276E5	775.	.092	Tandem springs vertical, 2 per tandem
19,27	.180E5	200.	.070	Tandem springs lateral, 1 per tandem
XZMOM* XRMOM	.30E8	.10E6	.021	Trailer hitch, roll moment

* Angular spring and dampers, units are inch pounds per radian and inch pound seconds per radian.

(1) 100% snubbers in truck springs.

(2) 0% snubbers in truck springs.

(3) C/C_c is obtained by using $C_c = k/\Pi f$ and, assuming $f = 2.0$ Hertz.

(4) Fully loaded TOFC

(5) Empty flatcar

(6) Gib contact

TABLE XII

TOFC DIMENSION VALUES

(units are inches except as noted)

$$R(1) = R(3) = 58.00$$

$$R(2) = R(4) = 79.00$$

$$R(5) = R(7) = 62.25$$

$$R(6) = R(8) = 43.50$$

$$L = 792.0$$

$$VL1 = 469.0$$

$$VL1R = -89.0$$

$$VL2 = 148.0$$

$$VL2R = -413.0$$

$$VL3 = 131.4$$

$$VL3R = 115.4$$

$$VL4 = 189.7$$

$$VL4R = 208.6$$

$$H = 16.0$$

$$VH = 60.4$$

$$VHR = 37.8$$

$$VH1 = 47.0$$

$$VH1R = 47.0$$

$$OR(1) = 536.0$$

$$OR(2) = -536.0$$

$$OR(6) = 224.0$$

$$OR(7) = 226.0$$

$$OR(8) = 254.0$$

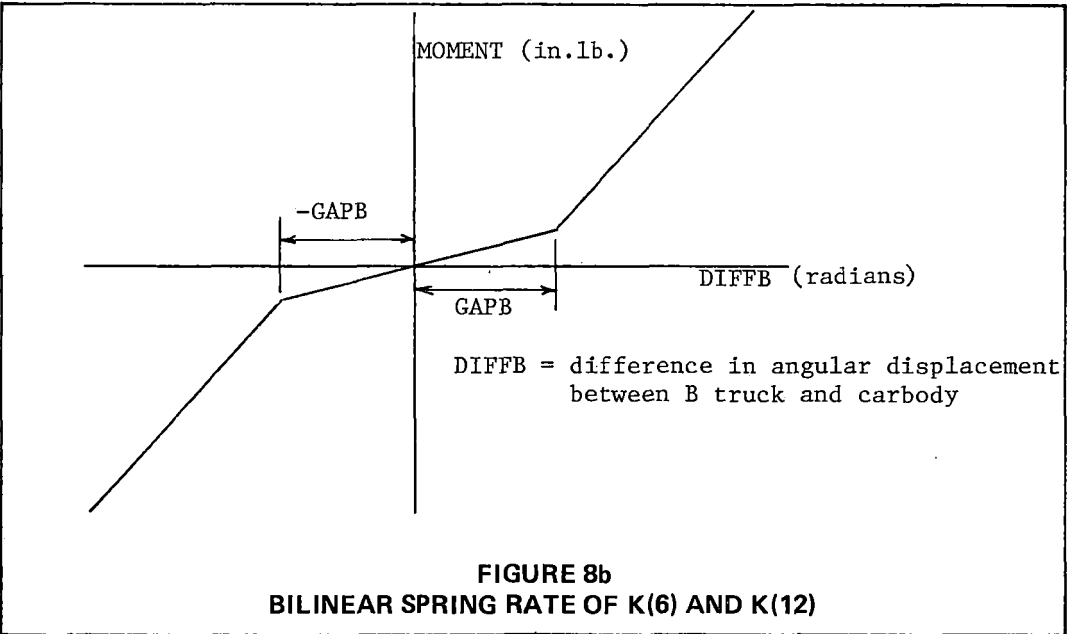
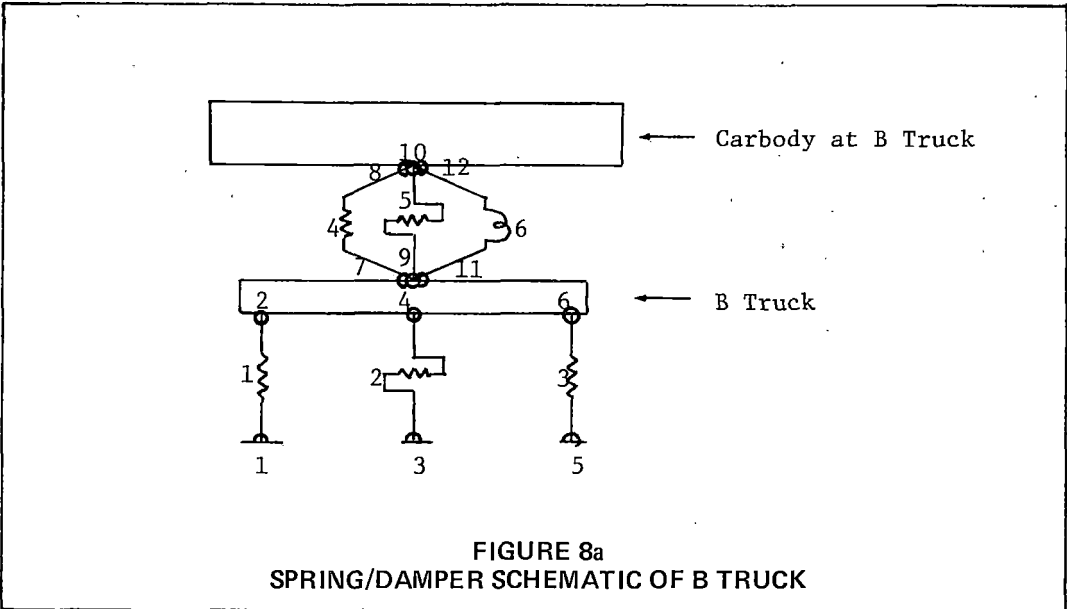
$$OR(9) = 245.0$$

$$OR(10) = 235.0$$

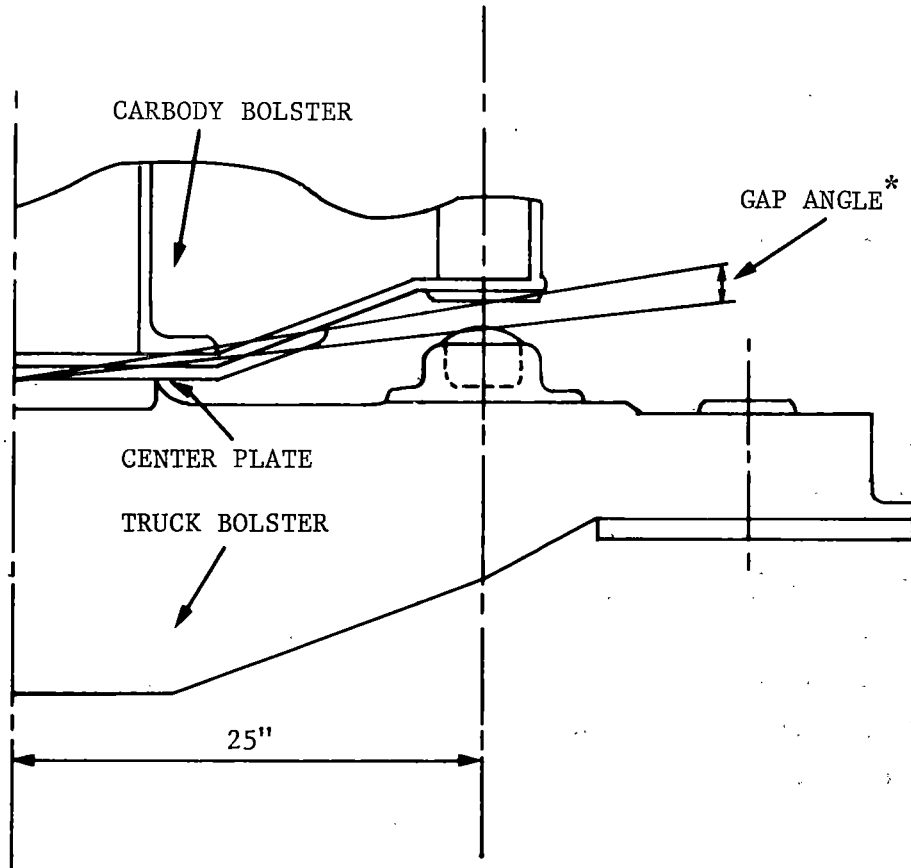
$$GAPB = .01, \text{ radians}$$

$$GAPA = .01, \text{ radians}$$

NOTE: GAP angle is based on side bearing clearance at 25 inches from carbony centerline and assumes equal gap on each side. (.01 radians = .25 inch gap.) See Figure 9.



The objective of this truck spring/damper arrangement is to be able to represent the bilinear roll spring/damper characteristics of the truck as related to side bearing contact conditions. As shown in Figure 8b there is a relatively soft spring rate representative of the centerplate and truck springs in series for the condition without side bearing contact. After the bearing gap has been reached the centerplate is in effect bottomed out and rolling motions of the carbody is reacted directly by the truck springs. The bearing gap angle is illustrated in Figure 9.



* Roll motion is assumed to be about a longitudinal axis at the center of the carbody.

FIGURE 9
SIDE BEARING GAP ANGLE

4.0 OPERATING INSTRUCTIONS

There are three files involved in performing a FRATE analysis; (1) the program file, (2) the data file and (3) the submit (executive) file. The run procedure requires modification of the data and executive files, according to the analysis to be performed, and submittal of the executive file. In this section we will briefly review the executive file to provide a general understanding of its function. The data file has been described in detail in Section 2.2. The model parameters presently in the FRATE/TOFC version are listed in Section 2.2 and again in Section 3.0.

It is assumed that the user has access to the CDC computer system and has sufficient knowledge of the system to perform the required editing.

4.1 Executive File (FRARUN)

Figure 10 is a flow chart for the executive file FRARUN. The user will connect to the CDC Cyber 173 in Rockville, Md. on the KB NOS systems. He will call and modify the submit and data file to the extent required by the analysis to be performed, and return them to on-line disc storage. The executive file will then be called and submitted into the system. The executive file contains the necessary command messages to accomplish the following operational steps:

- a. The data file is called from on-line disc storage in Rockville.
- b. The data file along with run information is cyberlinked to the cyber 76 front end in Minneapolis.
- c. The FRATE program is called from on-line disc storage in Minneapolis.
- d. The problem is run on the 7600.

- e. Output results are cyberlinked back to the Cyber 173 in Rockville and disposed to the high speed line printer. The line printer output headings will contain delivery instructions.

As the CDC system is modified and improved this problem submittal procedure will be revised. In particular it will be possible to connect directly to the 7600 rather than cyberlink through the Cyber 173 and receive output directly to a line printer closer to the point of origin of the problem. This will provide some cost savings and considerable time savings.

A copy of the executive file with explanatory notes is presented in Figure 11. The user will need to make the following changes.

- a. A user number must be supplied.
- b. Dispose systems may need to be changed. TCA is the Minneapolis front end, I98 is the Rockville KB NOS system.
- c. Delivery instructions must be changed.
- d. Data file number may be different.
- e. Priority preference may be different.

Procedure:

- 1 - User connects to Cyber 173, calls and edits FRARUN and FRADxxx and submits FRARUN to Cyber 76.
- 2 - FRARUN directs performance of analysis.
- 3 - Output is delivered to user.

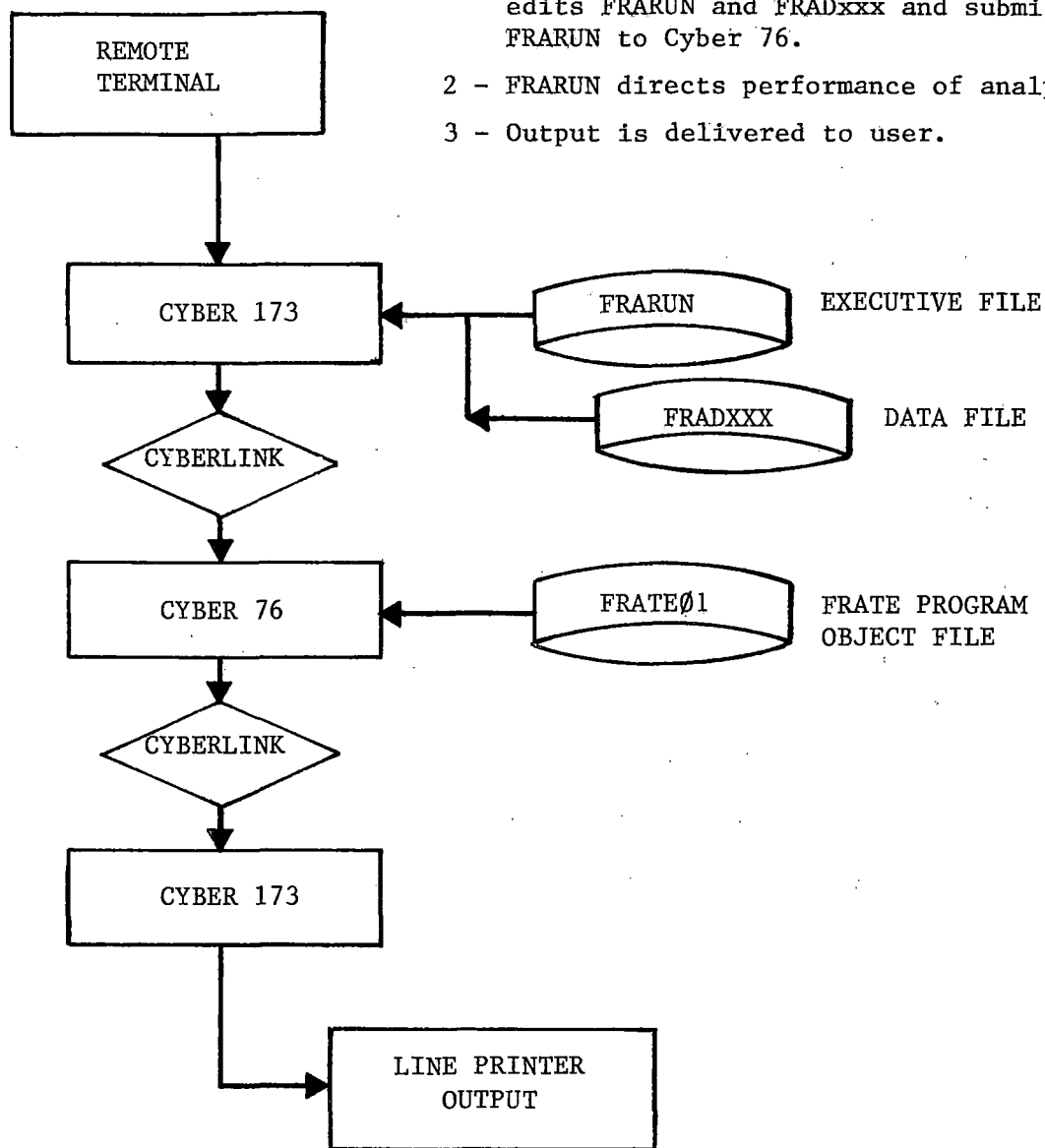


FIGURE 10

EXECUTIVE FILE FRARUN FLOW CHART


```

OLD,FRARUN
READY.
LNH
/JOB
CASKET,STTCZ,T200,P4.
ACCOUNT. . . . .
ATTACH,HEADING,HEADING,MR=1.
HEADING.
ATTACH,LGO,FRATE01.ID=JFC,MR=1.
LDSET,PRESET=ZERO.
LGO.
EXIT,U.
DISPOSE,OUTPUT,PR,ST=TCAI98.
/EOB
/NOSEQ
IDELIVER TO
KACHADOUR
MITRE CORP
7915 WEST
PARK DR.
MCLEAN,VA.
/EOB
/READ,FRAD108
/EOF
READY.

```

BANNER NAME
 SYSTEM ID (CYBER 76)
 CUT OFF TIME (200 SEC., OCTAL)
 PRIORITY
 ACCOUNT NUMBER
 OUTPUT HEADING COMMANDS
 RUN COMMANDS
 FRATE01 IS OBJECT FILE AT TCA
 MR=1 ALLOWS MULTIPLE USER ACCESS
 OUTPUT DATA COMMANDS
 I98 = KB SYSTEM, NOS ROCKVILLE
 TCA = CYBER 76 FRONT END
 PR = HIGH SPEED LINE PRINTER
 HEADING INFORMATION
 DATA FILE CONTAINING RUN INFORMATION

FIGURE 11
EXECUTIVE FILE FRARUN LISTING
 (for use with FRATE object file
 at Cyber 76, no CalComp Plots)

5.0 EXAMPLE FRATE RUNS

Four examples of typical FRATE analyses are given below. These are: (1) a Time History decay to show the empty flatcar first roll resonance, (2) a Time History decay to show the loaded TOFC first roll resonance, (3) an Envelope frequency sweep with TOFC to obtain an indication of resonances in the 1.0 to 16 Hertz range, and (4) a Time History narrow band sweep to study one resonance.

The examples contain a step-by-step description of reviewing and preparing the data and executive files, listings of these files including some of the editing procedures and some representative results from each run.

5.1 Example No. 1 - Empty Flatcar Decay

Input Procedure

It is desired to obtain the fundamental roll resonance frequency of the empty flatcar. One quick and easy way to do this is to input a single cycle of a sine wave with its frequency equated to the best estimate of the roll resonance. The decaying response can then be analyzed for frequency content and decay rate.

The pages which follow contain copies of computer listings with notes on the steps followed to set up and run FRATE.

- Step 1: Call data file FRAD108 from storage, enter edit and list the first 17 lines. (The VEHIC and MODAL name-lists are not needed since no model changes are to be made).
- Step 2: Review the data file and note what changes are to be made:
- Line 2. Change run number
 - Line 3. Start, delta and stop times are about right
 - Lines 4, 5 and 6. We want time history output.
 - Line 7. With IPRINT = 1 and FQ = 2.0 the program will output every 5th DELTAT, or every $5 * .005 = .025$ seconds. This will provide 20 points for each cycle. IPRINT = 2 would cut this down to 10 points per cycle. 10 points per cycle is adequate but 20 is better and the cost will not be prohibitive for a short run.
 - Line 8. IGROUP = 4 is correct for roll input time history. See Table VII.
 - Lines 9 and 10. No OTHER or DEBUG printout is desired.
 - Lines 11-14. We do want to input a sine roll motion. We therefore want input at input locations 1, 3, 4 and 6 with phasing 0, 180, 0, and 180. (See Table IV and Figure 3).

Line 15. The first roll resonance of the empty flat-car should be near 2.0 Hertz - change FQ to 2.0.
 NDECAY = 1 will set the input to zero after one cycle.

- Step 3: Make changes and replace file.
- Step 4: The data file is called again and listed for two purposes: one, so that a final check can be made on the file contents; and two, to have a record of what was input for the run.
- Step 5: The executive file FRARUN is called, listed and reviewed. This also serves as a record of what was input.
- Step 6: The run is submitted to the 7600 (TCA).
- Step 7: After the run has had time to be performed and the day file is available for access it is called for and listed on the remote terminal.
- Step 8: Determine Costs.

1. Input Costs

\$9.00/hour connect:	~6 min.	= \$ 0.90
\$0.25/1000 TIO*	: ~4000 TIO	= 1.00
\$0.35/SBU*	: .272 SBU	= .09

2. Run Costs (from day file)

\$.02/IODB* input and day file (cyberlink cost)	: 9 IODB	= .18
\$.05/IODB output (cyberlink and printer)	: 230 IODB	= 11.50
\$1.15/SBU, P4 priority	: 6 SBU	= 6.90

Total run cost		\$20.57
----------------	--	---------

*CDC Terminology

- TIO - Terminal Input/Output Charges
 SBU - System Billing Unit
 IODB - Input/Output Data Blocks

Discussion of Results

The input motion imposed at the wheel/rail interface was one cycle of a sine wave of roll motion with frequency equal to 2.0 Hertz. The roll motion is generated by imposing vertical motion on each side of each truck with π phasing between opposite sides of each truck. The time history of the varying oscillations is studied and the following information reduced:

1. Frequency content of the varying oscillations: in this case only one frequency was apparent.

$$f_{\text{decay}} = 2.08 \text{ Hertz}$$

2. The decay rate of the oscillations is obtained using the approximation

$$\zeta = \frac{1}{2\pi n} \ln \frac{A_0}{A_n}$$

where ζ = ratio to critical (viscous) damping
ln = natural log
 A_0 = amplitude of reference cycle
 A_n = amplitude of nth cycle following the reference cycle

$$\zeta = .088$$

3. By noting the amplitudes and phasings of the response motions it is possible to construct a picture showing the relative motions of the carbody. This was done and it was found that the carbody was in a rolling motion: that is a combination of roll and lateral translational motion phased such that the effective center of rotation of carbody motions is somewhere near the center of gravity of the carbody.

This kind of motion is normally found in the second roll resonance rather than the first. Another run was made to include translational input at the wheel track interface for one cycle of a 1.5 Hertz sine wave. The decaying oscillations of this run were measured to be 1.8 Hertz.

It was therefore concluded that the first and second roll resonances were at 1.8 and 2.08 Hertz, respectively.

Representative time history plots are shown below.

REMOTE TERMINAL LISTINGS

Step 1: Call and list data file

Step 2: Note change to be made: - RUNO

OLD,FRAD108 - FQ

/EDIT

BEGIN TEXT EDITING.

?

L;17

\$CONTRL 300.02

RUNO=300.01,

STARTM=0.5, DELTAT=.005, STOPTM=8.,

ENVEL=.F., ENVPLT=.F., ENVCAL=.F., ENPRMX=.F.,

TIMHIS=.T., THSPLT=.T., SNAPSHT=.F.,

STARSNP=5.20, DELTSNP=0.05, STOPSNP=5.60,

IPRINT=1,

IGROUP=4,

OTHER=0,

DEBUG=.F., STARDB=4.15, STOPDB=4.17,\$

\$EXCIT

SINEIN=.T.,

AMP = 1.00, 0.00, 1.00, 1.00, 0.00, 1.00,

PHAS= 0.00, 0.00, 180., 0.00, 0.00, 180.,

FQ=0.5, FQDOT=.0, BETA=0., NDECAY=1,

DIN=0.40, VIN=0.00, GIN=.0,\$

\$VEHIC 2.0

?

F:/RUNO/

RUNO=300.01,

?

RS:/300.01/,/300.02/

? L

RUNO=300.02,

?

F:/FQ=/

FQ=0.5, FQDOT=.0, BETA=0., NDECAY=1,

?

RS:/0.5/,/2.0/

? L

FQ=2.0, FQDOT=.0, BETA=0., NDECAY=1,

?

END

END TEXT EDITING.

\$EDIT,FRAD108.

/

REPLACE

/

Step 3: Make Changes and Replace File

REMOTE TERMINAL LISTINGS (continued)

Step 4: Call and list data file for check and record.

```

OLD,FRAD108
/LNH
$CONTRL
RUNO=300.02,
STARTM=0.5, DELTAT=.005, STOPTM=8.,
ENVEL=.F., ENVPLT=.F., ENVCAL=.F., ENPRMX=.F.,
TIMHIS=.T., THSPLT=.T., SNAPSHT=.F.,
STARSNP=5.20, DELTSNP=0.05, STOPSNP=5.60,
IPRINT=1,
IGROUP=4,
OTHER=0,
DEBUG=.F., STARDB=4.15, STOPDB=4.17,$
$EXCIT
SINEIN=.T.,
AMP = 1.00, 0.0, 1.00, 1.00, 0.0, 1.00,
PHAS= 0.00, 0.00, 180., 0.00, 0.00, 180.,
FQ=2.0, FQDOT=.0, BETA=0.0, NDECAY=1,
DIN=0.4, VIN=0.00, GIN=.0,$
$VEHIC
NMAS=3,
M=2*22.33,125.0,8.179,152.65,7.013,148.9,3*0.,
INERT=22080.,22080.,108500.,20000.,255000.,17150.,102000.,
.294E7,.319E7,.15E8,.15E8,.131E7,.131E7,2*0.,
R=58.,79.,58.,79.,62.25,43.5,62.25,43.5,108.,0.,
H=16.,VH=60.4,VH1=47.,VHR=37.8,VH1R=47.,
L=792.,VL1=469.,VL2=148.,VL3=131.4,VL4=189.7,
VL1R=-89.,VL2R=-413.,VL3R=115.4,VL4R=208.6,
OR=536.,-536.,-39.,39.,40.,224.,226.,254.,245.,235.,
GAPB=.01,GAPA=.01,
K=.91E5,.95E5,.91E5,.48E5,.6E4,.0,.91E5,.95E5,.91E5,.48E5,.6E4,
.0,.225E6,.15E5,.225E5,.18E5,.225E5,.5276E5,.18E5,.5276E5,
.225E6,.15E5,.225E5,.18E5,.225E5,.5276E5,.18E5,.5276E5,2*0.,
XZKMOM=.30E8, XRCMOM=.30E8,
KA6=.92E7,KA12=.92E7,KB6=.6185E8,KB12=.6185E8,
C=150.,20.,150.,140.,225.,0.,150.,20.,150.,140.,225.,0.,
1000.,500.,330.,200.,330.,775.,200.,775.,
1000.,500.,330.,200.,330.,775.,200.,775.,2*0.,
XZCMOM=.10E6, XRCMOM=.10E6,
CA6=.10E6,CA12=.10E6,CB6=.78E6,CB12=.78E6,$
$MODAL
NMODES=4,
RF=4.253,8.873,9.417,9.629,15.519,15.599,18.029,3*0.,
ZETA=7*0.02,3*0.0,
NLOC=46,
COEF(1,1)=.139133,.683776E-1,.512E-6,-.12532E-10,.592E-6,-.626276E-1,
.824155E-1,-.529E-6,.2 *INTERRUPTED*
STOP
*TERMINATED*

```

REMOTE TERMINAL LISTINGS (continued)

Step 5: Call and list executive file. Review for changes.

OLD,FRARUN
READY.
LNH
/JOB
CASKET,STTCZ,T200,P4.
ACCOUNT,
ATTACH,HEADING,HEADING,MR=1.
HEADING.
ATTACH,FRATE,FRATE01,ID=JFC,MR=1.
FRATE.
EXIT,U.
DISPOSE,OUTPUT,PR,ST=TCAI98.
/EOR
/NOSEQ
1DELIVER TO
KACHADOUR
MITRE CORP
7915 WEST
PARK DR.
MCLEAN,VA.
/EOR
/READ,FRAD108
/EOF
READY.

Step 6: Submit Executive File

SUBMIT,FRARUN,H=TCA,T
09.59.26.ADLCBAO

SBU 0.272 UNTS.
READY.

Step 7: Obtain Day File (after available for access)

REMOTE TERMINAL LISTINGS (CONTINUED) - DAY FILE

QFETCH.,DAY

ADLCBAO RELEASED TO USER AS - FILE

**** TWIN CITIES CYBERNET CENTER V2.1.4 **** 05/09/78 78129
 OHH.MM.SS CPU SECOND ORIGIN

```

    11.09.43.TCA. 99 TCA SCOPE 3.4.3 406E.344 12/09/77
    11.09.48 00000.004 TCZ. -CBAQA,STTCZ,T200,P4.
    11.09.48 00000.004 TCZ. CYR02 - JOB NAME- CBAQAIX
    11.09.48 00000.005 JOB. -ACCOUNT,
    11.09.49 00000.031 JOB. -ATTACH,HEADING,HEADING,MR=1.
    11.09.49 00000.035 TCZ. PF254 - CYCLE 3 ATTACHED FROM SN=SYSTEM
    11.09.49 00000.035 LOD. -HEADING.
    11.09.49 00000.040 USR. FORTRAN LIBRARY 410W 04/05/76
    11.09.49 00000.041 TCZ. PF646 - PFMACRO - ATTACH - ZZZOQZ - HEAD22
    11.09.49 00000.044 TCZ. PF254 - CYCLE 2 ATTACHED FROM SN=SYSTEM
    11.09.50 00000.068 USR. STOP
    11.09.50 00000.068 USR. .027 CP SECONDS EXECUTION TIME
    11.09.50 00000.070 JOB. -ATTACH,FRATE,FRATE01.ID=JFC,MR=1.
    11.09.50 00000.073 TCZ. PF254 - CYCLE 1 ATTACHED FROM SN=SYSTEM
    11.09.50 00000.074 LOD. -FRATE.
    11.09.53 00000.208 USR. FORTRAN LIBRARY 433 05/11/77
    11.09.57 00004.405 USR. STOP
    11.09.57 00004.405 USR. 4.196 CP SECONDS EXECUTION TIME
    11.09.57 00004.406 JOB. -EXIT,U.
    11.09.57 00004.406 JOB. -DISPOSE,OUTPUT,PR,ST=TCAI98.
    11.09.57 00004.406 TCZ. CYB01 - FILE OUTPUT DC=40 ST=TCAI98 SIZE=0000000230 IODB } x$.05
    11.09.58 00004.408 TCZ. CYB01 - FILE CBAQAIX DC=04 ST=TCAI99 SIZE=0000000006 IODB }
    11.09.58 00004.410 TCZ. CYB01 - FILE OUTPUT DC=40 ST=TCAI99 SIZE=0000000003 IODB } x .02
    11.09.58 00004.410 TCZ. RM770 - MAXIMUM ACTIVE FILES 1
    11.09.58 00004.410 TCZ. RM771 - OPEN/CLOSE CALLS 13
    11.09.58 00004.411 TCZ. RM772 - DATA TRANSFER CALLS 2,259
    11.09.58 00004.411 TCZ. RM773 - CONTROL/POSITIONING CALLS 12
    11.09.58 00004.411 TCZ. RM774 - BM DATA TRANSFER CALLS 700
    11.09.58 00004.411 TCZ. RM775 - BM CONTROL/POSITIONING CALLS 55
    11.09.58 00004.411 TCZ. RM776 - QUEUE MANAGER CALLS 110
    11.09.58 00004.411 TCZ. RM777 - RECALL CALLS 99
    11.09.58 00004.412 TCZ. SCM 176.647 KWS
    11.09.58 00004.412 TCZ. LCM 852.371 KWS
    11.09.58 00004.412 TCZ. I/O 0.029 MW
    11.09.58 00004.412 TCZ. RMS 0.044 MWS
    11.09.58 00004.412 TCZ. USER 4.053 SEC
    11.09.58 00004.413 TCZ. JOB 4.415 SEC
    11.09.58 00004.413 TCZ. DIO 300.872 KW
    11.09.58 00004.413 TCZ. SBU 6 x$1.15
    11.09.58 00004.413 TCZ. SC053 - JOB PRIORITY - P4
    
```

EMPTY FLATCAR DECAY PRINTER OUTPUT page 1

INPUT PARAMETERS FOR FRATE RUN NO. 300.02

TIME HISTORY RUN PARAMETERS

TIME HISTORY PRINT PLCT = T
 START TIME = .500
 DELTA T = .005
 STOP TIME = 8.000
 IGROUP = 4
 IPRINT = 1
 OTHER = C

 DEEUG = F
 STARDP = 4.150
 STCPDB = 4.170

EXCITATION PARAMETERS

SINEIN = T
 AMP(I) = 1.000 0.000 1.000 1.000 0.000 1.000
 PHAS(I) = 0.000 0.000180.000 0.000 0.000180.000
 FQ = 2.000
 FQDOT = 0.000
 BETA = 0.000
 DIN = .400
 VIN = 0.000
 GIN = 0.000
 NDECAY = 1

MODEL PARAMETERS

NMAS = 2

 M = .2233E+02 .2233E+02 .1250E+03 .6179E+01 .1527E+03 .7013E+01 .1489E+03 0. 0. 0.
 INERT = .2208E+05 .2208E+05 .1085E+06 .2000E+05 .2550E+06 .1715E+05 .1020E+06 .2940E+07 .3190E+07 .1500E+08
 .1500E+08 .1310E+07 .1310E+07 0.
 P = 58.000 79.000 58.000 79.000 62.250 43.500 62.250 43.500 108.000 0.000
 H = 16.000
 L = 792.000
 GR = 536.000 -536.000 -39.000 39.000 40.000 224.000 226.000 254.000 245.000 235.000

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PRINTER OUTPUT page 2

INPUT PARAMETERS FOR FRATE - CONTINUED -

K =
 .9100E+05 .9500E+05 .9100E+05 .4800E+05
 .6000E+04 0. .2250E+06 .1500E+05
 .2250E+06 .1500E+05 .2250E+05 .1800E+05

XZKMDM = .3000E+06 XFKMDM = .3000E+06
 KA6 = .9200E+07 KA12 = .9200E+07
 KB6 = .6185E+06 KE12 = .6185E+06

C =
 .1500E+03 .2000E+02 .1500E+03 .1400E+03
 .2250E+03 0. .1000E+04 .5000E+03
 .1000E+04 .5000E+03 .3300E+03 .2000E+03

XZCMDM = .1000E+06 XRCMDM = .1000E+06
 CA6 = .1000E+06 CA12 = .1000E+06
 CB6 = .7600E+06 CB12 = .7600E+06

VH = 60.400
 VH1 = 47.000
 VH1P = 47.000
 VHR = 37.800
 VL1 = 469.000
 VL2 = 148.000
 VL3 = 131.400
 VL4 = 189.700
 VL1P = -89.000
 VL2R = -413.000
 VL3P = 115.400
 VL4R = 208.600

GAPB = .0100 GAPA = .0100

NONFAL MODE PARAMETERS

NMODES = 4
 FREQ = 4.253 8.873 9.417 9.629 15.519
 ZETA = .020 .020 .020 .020 .020
 NLDC = 46

55

.6000E+04	0.	.9100E+05	.9500E+05	.9100E+05	.4800E+05
.2250E+05	.1800E+05	.2250E+05	.5276E+05	.1800E+05	.5276E+05
.2250E+05	.5276E+05	.1800E+05	.5276E+05	0.	0.

.2250E+03	0.	.1500E+03	.2000E+02	.1500E+03	.1400E+03
.3300E+03	.2000E+03	.3300E+03	.7750E+03	.2000E+03	.7750E+03
.3300E+03	.7750E+03	.2000E+03	.7750E+03	0.	0.

15.599	18.029	0.000	0.000	0.000
.020	.020	0.000	0.000	0.000

TIME HISTORY PLOT RESULTS

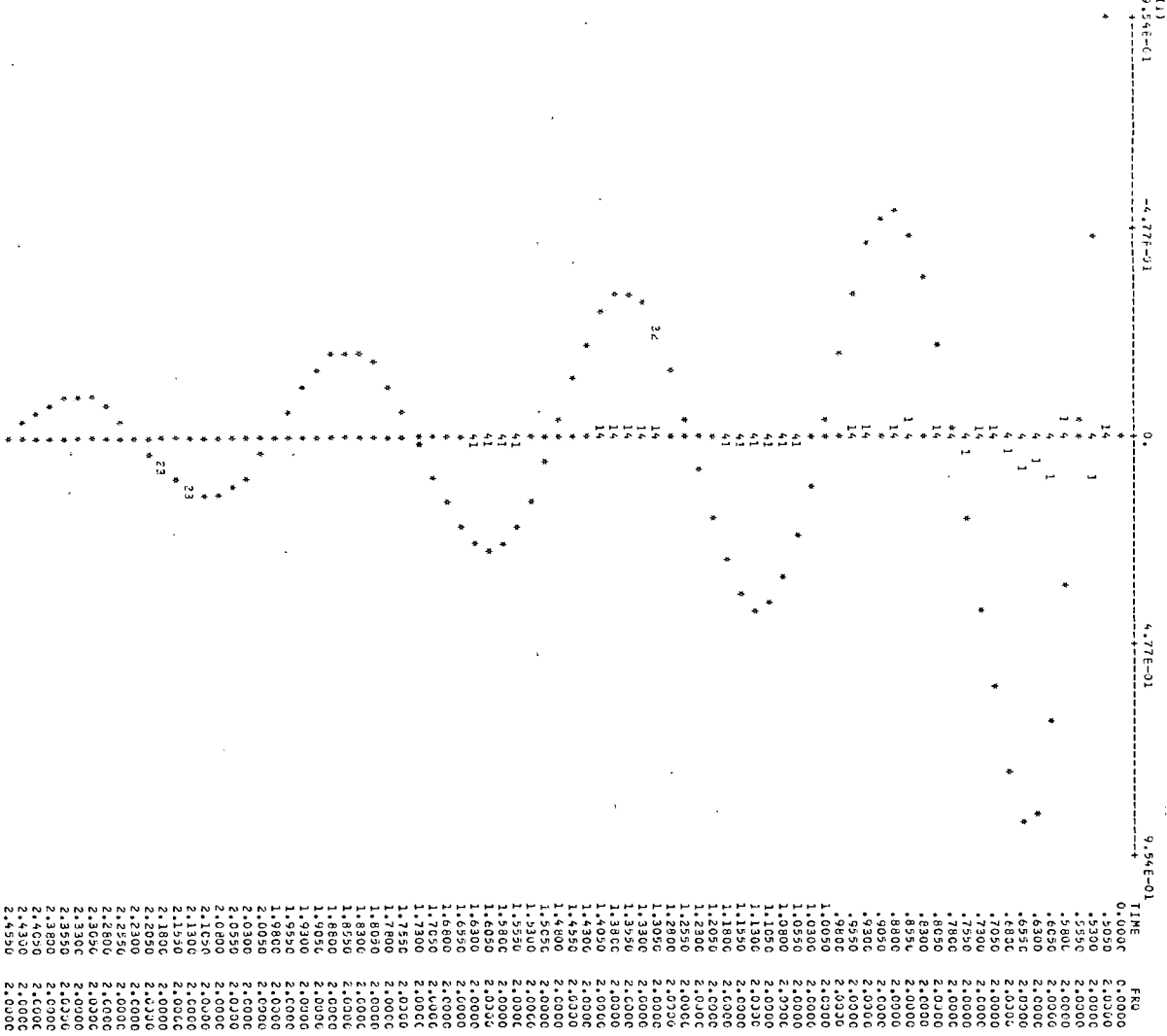
MULTIPLE PLOT TIME HISTORY

FRATE RUN 300.002

SHEEP WATE = 0.

INPUT POSITION DIM = 440

1=2(1)
2=2(5)
3=2(7)
4=2(11)
5=2(14)



5.2 Example No. 2 - Loaded TOFC Decay

It is desired to obtain the fundamental roll resonance frequency of the fully loaded TOFC configuration. The basic difference between this example and Example No. 1, which had the same objective for the empty flatcar, is that NMAS is changed from 3 to 7. That is a change from a 3 mass to a 7 mass configuration.

Step 1: Call data file and enter EDIT mode.
(see Example No. 1 for listing)

Step 2: Review data file and note changes to be made.

Line 2. Change run number.

Line 3. Since the expected frequency is 0.5 Hz
increase start and stop times.

Lines 4-6. No change.

Line 7. Change IPRINT from 1 to 2 (below 2.0 Hertz
the standard schedule is to print every 10th
time step. At 0.5 Hz this is 40 points per
cycle. With IPRINT = 2 we are reduced to
20 points per cycle which is more than
adequate and will cut the length of the plot
in half.

Lines 8-14. No change.

Line 15. Change FQ from 2.0 to 0.5 Hertz.

Lines 16-17. No change.

Line 18. Change NMAS from 3 to 7.
No other changes needed.

Step 3: Incorporate changes and replace file.

Step 4: Call and list data file - check for corrections.

Step 5: Call and list executive file - check and modify if
necessary (no change required).

Step 6: Submit run to 7600.

Step 7: Obtain day file.

Step 8: Determine costs.

(1) Input Costs

\$9.00/hr connect	: 0.03:24	=	\$.50
.25/1000 TIO	: 4116 TIO	=	1.30
.35/SBU	: .545 SBU	=	.19

(2) Run Costs (day file)

\$.02/IODB Input and day file	: 9 IODB	=	\$.18
.05/IODB Output	: 139 IODB	=	7.95
1.15/SBU	+ 9 SBU	=	<u>10.35</u>

Total run costs = \$19.20

Discussion of Results

From analysis of the time history plots of decaying oscillations we are able to define the following characteristics of the fully loaded TOFC configuration being analyzed.

- (1) The fundamental roll resonance:

$$f = 0.38 \text{ Hertz}$$

- (2) The effective damping related to the 0.38 Hertz resonance:

$$\zeta = .019$$

- (3) The motion associated with this 0.38 Hertz resonance is the roll motion characteristic of the fundamental; that is, the effective center of rotation is below the car body and near the top of rail plane.

The first three pages of the results output and two representative time history plots are given at the end of Section 5.2.

REMOTE TERMINAL LISTINGS

Steps 1, 2 and 3; Call FRAD108, enter EDIT, review, make changes and replace file.

```
OLD,FRAD108
/EDIT
BEGIN TEXT EDITING.
?

F:/RUNO/
RUNO=300.02,
? RS:/.02/./0.03/
? L
RUNO=300.03,
?

S
? L
STARTM=.5, DELTAT=.005, STOPTM=8.,
? RS:/.5/./2.0/
? RS:/8././12./
? L
STARTM=2.0, DELTAT=.005, STOPTM=12..
?

F:/IPRINT/
IPRINT=1.
? RS:/1/./2/
? L
IPRINT=2,
?

F:/FQ/
FQ=2.0, FQDOT=.0, BETA=0.0, NDECAY=1.
? RS:/2.0/./0.5/
? L
FQ=0.5, FQDOT=.0, BETA=0.0, NDECAY=1.
?

F:/NMAS/
NMAS=3.
? RS:/3/./7/
? L
NMAS=7,
?

END
END TEXT EDITING.
$EDIT,FRAD108.
/

REPLACE
/
```

REMOTE TERMINAL LISTINGS (continued)

Step 4: Call, list and check data file

```

OLD,FRAD108
/LNH
$CONTRL
RUNO=300.03,
STARTM=2.0, DELTAT=.005, STOPTM=12.,
ENVEL=.F., ENVPLT=.F., ENVCAL=.F., ENPRMX=.F.,
TIMHIS=.T., THSPLT=.T., SNAPSHT=.F.,
STARSNP=5.20, DELTSNP=0.05, STOPSNP=5.60,
IPRINT=2,
IGROUP=4,
OTHER=0,
DEBUG=.F., STARDDB=4.15, STOPDB=4.17,$
$EXCIT
SINEIN=.T.,
AMP = 1.00, 0.00, 1.00, 1.00, 0.00, 1.00,
PHAS= 0.00, 0.00, 180., 0.00, 0.00, 180.,
FQ=0.5, FQDOT=.0, BETA=0.0, NDECAY=1,
DIN=0.4, VIN=0.00, GIN=.0,$
$VEHIC
NMA=7,
M=2*22.33,125.0,8.179,152.65,7.013,148.9,3*0.,
INERT=22080.,22080.,108500.,20000.,255000.,17150.,102000.,
.294E7.,.319E7.,.15E8.,.15E8.,.131E7.,.131E7,2*0.,
R=58.,79.,58.,79.,62.25,43.5,62.25,43.5,108.,0.,
H=16.,VH=60.4,VH1=47.,VHR=37.8,VH1R=47.,
L=792.,VL1=469.,VL2=148.,VL3=131.4,VL4=189.7,
VL1R=-89.,VL2R=-413.,VL3R=115.4,VL4R=208.6,
OR=536.,-536.,-39.,39.,40.,224.,226.,254.,245.,235.,
GAPB=.01,GAPA=.01,
K=.91E5.,.95E5.,.91E5.,.480E5.,.60E4,0.0.,.91E5.,.95E5.,.91E5.,.480E5.,.60E4,
0.0.,.225E6.,.15E5.,.225E5.,.18E5.,.225E5.,.5276E5.,.18E5.,.5276E5,
.225E6.,.15E5.,.225E5.,.18E5.,.225E5.,.5276E5.,.18E5.,.5276E5,2*0.,
XZKMOM=.30E8, XRKMOM=.30E8,
KA6=.92E7,KA12=.92E7,KB6=.6185E8,KB12=.6185E8,
C=150.,20.,150.,140.,225.,0.,150.,20.,150.,140.,225.,0.,
1000.,500.,330.,200.,330.,775.,200.,775.,
1000.,500.,330.,200.,330.,775.,200.,775.,2*0.,
XZCMOM=.10E6, XRCMOM=.10E6,
CA6=.10E6,CA12=.10E6,CB6=.78E6,CB12=.78E6,$
$MODAL
NMODES=4,
RF=4.253,8.873,9.417,9.629,15.519,15.599,18.029,3*0.,
ZETA=7*0.02,3*0.0,
NLOC=46,
COEF(1,1)=.139133,.683776E-1.,.512E-6,- *INTERRUPTED*
STOP
*TERMINATED*

```

REMOTE TERMINAL LISTINGS (continued)

Steps 5 and 6: Call and list executive file. Check and modify
if needed. (No changes needed) Submit to 7600.

OLD,FRARUN
READY.

LNH
/JOB
CASKET,STTCZ.T200,P4.
ACCOUNT,
ATTACH,HEADING,HEADING,MR=1.
HEADING.
ATTACH,FRATE,FRATE01,ID=JFC,MR=1.
FRATE.
EXIT,U.
DISPOSE,OUTPUT,PR.ST=TCAI98.
/EOR
/NOSEQ
1DELIVER TO
KACHADOUR
MITRE CORP
7915 WEST
PARK DR.
MCLEAN,VA.
/EOR
/READ,FRAD108
/EOF
READY.

SUBMIT,FRARUN,H=TCA,T
12.07.49.ADLCKBY

SBU 0.260 UNTS.
READY.

BYE

DOTMITR LOG OFF 12.07.59.
SBU 1.313
TIO = 8821

Step 7: Obtain Day File, when ready for access.

REMOTE TERMINAL LISTINGS (continued) - DAY FILE

QFETCH.,DAY

ADLCBKY RELEASED TO USER AS - FILE

**** TWIN CITIES CYBERNET CENTER V2.1.4 **** 05/16/78 78136

OHH.MM.SS CPU SECOND ORIGIN

```

11.21.40.TCA. 99 TCA SCOPE 3.4.3 406F.102 05/01/78
11.21.54 00000.004 TCZ. -CBKYA,STTCZ,T200,P4.
11.21.54 00000.004 TCZ. CYB02 - JOB NAME- CBKYANV
11.21.54 00000.005 JOB. -ACCOUNT;
11.21.56 00000.033 JOB. -ATTACH,HEADING,HEADING.MR=1.
11.21.56 00000.036 TCZ. PF254 - CYCLE 3 ATTACHED FROM SN=SYSTEM
11.21.56 00000.037 LOD. -HEADING.
11.21.57 00000.042 USR. FORTRAN LIBRARY 410W 04/05/76
11.21.57 00000.042 TCZ. PF646 - PFMACRO - ATTACH - ZZZQOZ - HEAD22
11.21.57 00000.046 TCZ. PF254 - CYCLE 2 ATTACHED FROM SN=SYSTEM
11.21.57 00000.069 USR. STOP
11.21.57 00000.069 USR. .027 CP SECONDS EXECUTION TIME
11.21.57 00000.071 JOB. -ATTACH,FRATE,FRATE01,ID=JFC,MR=1.
11.21.57 00000.075 TCZ. PF254 - CYCLE 1 ATTACHED FROM SN=SYSTEM
11.21.57 00000.076 LOD. -FRATE.
11.22.01 00000.210 USR. FORTRAN LIBRARY 433 05/11/77
11.23.05 00007.175 USR. STOP
11.23.05 00007.176 USR. 6.964 CP SECONDS EXECUTION TIME
11.23.05 00007.176 JOB. -EXIT,U.
11.23.05 00007.176 JOB. -DISPOSE,OUTPUT.PR,ST=TCAI98.
11.23.05 00007.177 TCZ. CYB01 - FILE OUTPUT DC=40 ST=TCAI98 SIZE=0000000139 IODB x $.05
11.23.07 00007.179 TCZ. CYB01 - FILE CBKYANV DC=04 ST=TCAI99 SIZE=0000000006 IODB} x .02
11.23.07 00007.180 TCZ. CYB01 - FILE OUTPUT DC=40 ST=TCAI99 SIZE=0000000003 IODB}
11.23.07 00007.181 TCZ. RM770 - MAXIMUM ACTIVE FILES 1
11.23.07 00007.181 TCZ. RM771 - OPEN/CLOSE CALLS 13
11.23.07 00007.181 TCZ. RM772 - DATA TRANSFER CALLS 1,527
11.23.07 00007.181 TCZ. RM773 - CONTROL/POSITIONING CALLS 12
11.23.07 00007.181 TCZ. RM774 - BM DATA TRANSFER CALLS 677
11.23.07 00007.181 TCZ. RM775 - BM CONTROL/POSITIONING CALLS 55
11.23.07 00007.182 TCZ. RM776 - QUEUE MANAGER CALLS 105
11.23.07 00007.182 TCZ. RM777 - RECALL CALLS 99
11.23.07 00007.182 TCZ. SCM 289.521 KWS
11.23.07 00007.182 TCZ. LCM 1 396.580 KWS
11.23.07 00007.182 TCZ. I/O 0.019 MW
11.23.07 00007.183 TCZ. RMS 0.062 MWS
11.23.07 00007.183 TCZ. USER 6.874 SEC
11.23.07 00007.183 TCZ. JOB 7.185 SEC
11.23.07 00007.183 TCZ. DIO 289.096 KW
11.23.07 00007.183 TCZ. SBU 9 x $1.15
11.23.07 00007.184 TCZ. SC053 - JOB PRIORITY - P4

```

READY.

INPUT PARAMETERS FOR FRATE RUN NO. 300.03

TIME HISTORY RUN PARAMETERS

TIME HISTORY PRINT PLCT = T
 START TIME = 2.000
 DELTA T = .005
 STEP TIME = 12.000
 IGROUP = 4
 IPRINT = 2
 OTHER = 0

 DEBUG = F
 STARDB = 4.150
 STGPLB = 4.170

EXCITATION PARAMETERS

SINEIN = T
 AMP(I) = 1.000 0.000 1.000 1.000 0.000 1.000
 PHAS(I) = 0.000 0.000180.000 0.000 0.000180.000
 FC = .500
 FQDGT = 0.000
 BETA = 0.000
 DIN = .400
 VIN = 0.000
 GIN = 0.000
 NDECAY = 1

MODEL PARAMETERS

NMAS = 7

 M = .2233E+02 .2233E+02 .1250E+03 .8179E+01 .1527E+03 .7013E+01 .1489E+03 0. 0. 0.
 INERT = .2208E+05 .2208E+05 .1085E+06 .2000E+05 .2550E+06 .1715E+05 .1020E+06 .2940E+07 .3190E+07 .1500E+08
 .1500E+08 .1310E+07 .1310E+07 0. 0.
 R = 58.000 79.000 58.000 79.000 62.250 43.500 62.250 43.500 108.000 0.000
 H = 16.000
 L = 792.000
 OR = 536.000 -536.000 -39.000 39.000 40.000 224.000 226.000 254.000 245.000 235.000

PRINTER OUTPUT page 2

INPUT PARAMETERS FOR FRATE - CONTINUED -

K =
 .9100E+05 .9500E+05 .9100E+05 .4800E+05
 .6000E+04 0. .2250E+06 .1500E+05
 .2250E+06 .1500E+05 .2250E+05 .1800E+05

XZKMDM = .3000E+08 XRKMDM = .3000E+06
 KA6 = .9200E+07 KA12 = .9200E+07
 KB6 = .6185E+06 KB12 = .6185E+08

C =
 .1500E+03 .2000E+02 .1500E+03 .1400E+03
 .2250E+03 0. .1000E+04 .5000E+03
 .1000E+04 .5000E+03 .3300E+03 .2000E+03

XZCMDM = .1000E+06 XRCMDM = .1000E+06
 CA6 = .1000E+06 CA12 = .1000E+06
 CB6 = .7800E+06 CB12 = .7800E+06

VH = 60.400
 VH1 = 47.000
 VH1R = 47.000
 VHR = 37.800
 VL1 = 469.000
 VL2 = 148.000
 VL3 = 131.400
 VL4 = 189.700
 VL1R = -89.000
 VL2R = -413.000
 VL3R = 115.400
 VL4R = 208.600

GAPB = .0100 GAPA = .0100

NORMAL MODE PARAMETERS

NMDES = 4
 FREQ = 4.253 8.873 9.417 9.629 15.519
 ZETA = .020 .020 .020 .020 .020
 NLCC = 46

.6000E+04	0.	.9100E+05	.9500E+05	.9100E+05	.4800E+05
.2250E+05	.1800E+05	.2250E+05	.5276E+05	.1800E+05	.5276E+05
.2250E+05	.5276E+05	.1800E+05	.5276E+05	0.	0.

.2250E+03	0.	.1500E+03	.2000E+02	.1500E+03	.1400E+03
.3300E+03	.2000E+03	.3300E+03	.7750E+03	.2000E+03	.7750E+03
.3300E+03	.7750E+03	.2000E+03	.7750E+03	0.	0.

15.599	18.029	0.000	0.000	0.000
.020	.020	0.000	0.000	0.000

MODE SHAPES FOLLOW

69

.15913E+00	.10770E-05	.54590E-05	-
.66378E-01	.33196E-08	-.49114E-06	-
.51200E-06	.56691E-01	.22910E-01	-
-.12532E-10	-.66347E-03	.25526E-02	-
.59200E-06	.10023E+00	.38352E-01	-
-.62628E-01	.12593E-01	-.48615E-01	-
.82416E-01	-.18479E-06	-.31169E-06	-
-.52900E-06	.70426E-01	.27362E-01	-
.23266E-09	.65568E-03	-.24210E-02	-
.22700E-06	-.50729E-01	-.16349E-01	-
-.62628E-01	-.12994E-01	.48609E-01	-
0.	-.92066E-03	.26799E-02	-
-.76877E-01	.32500E-06	.20030E-05	-
.15200E-06	.59838E-01	.22612E-01	-
0.	.31250E-03	-.72860E-03	-
.92463E-01	-.30591E-01	.86550E-01	-
-.52900E-06	.70426E-01	.27362E-01	-
.92463E-01	.30550E-01	-.86552E-01	-
.19473E+00	.53109E-01	-.15010E+00	-
.19473E+00	-.52105E-01	.15012E+00	-
.68378E-01	.46627E-01	-.13785E+00	-
.68378E-01	-.46627E-01	.13785E+00	-
-.36883E-01	.30467E-01	-.10681E+00	-
-.36883E-01	-.30468E-01	.10680E+00	-
-.90386E-01	-.44789E-02	.79877E-03	-
-.90386E-01	.44790E-02	-.79840E-03	-
-.27713E-01	-.37982E-01	.10500E+00	-
-.27713E-01	.37983E-01	-.10499E+00	-
.82416E-01	-.46207E-01	.13073E+00	-
.82416E-01	.46206E-01	-.13073E+00	-
.20980E+00	-.49500E-01	.14143E+00	-
.20980E+00	.49596E-01	-.14145E+00	-
0.	.19818E+00	.68382E-01	-
0.	.19818E+00	.68382E-01	-
0.	.56691E-01	.22910E-01	-
0.	.56691E-01	.22910E-01	-
0.	-.37963E-01	-.10659E-01	-
0.	-.37963E-01	-.10659E-01	-
0.	-.79144E-01	-.29014E-01	-
0.	-.79144E-01	-.29014E-01	-
0.	-.26967E-01	-.11710E-01	-
0.	-.26967E-01	-.11710E-01	-
0.	.70426E-01	.27362E-01	-
0.	.70426E-01	.27362E-01	-
0.	.20547E+00	.85956E-01	-
0.	.20547E+00	.85956E-01	-
0.	.20547E+00	.85956E-01	-

THE INITIAL DEFLECTIONS ARE

-.5068	-.5248	-3.331	.3437E-03
-4.949	-3.703	.1201E-01	
-3.077	-3.820	-.3403E-02	

12234E+00	.30975E-03	.89504E-01	.17700E-05
15435E-01	-.26386E-03	-.77567E-01	-.21917E-05
35450E-05	.25887E-01	-.90230E-04	.13271E-01
11870E-06	.19437E-03	-.76683E-06	.38912E-02
17500E-05	-.16823E-02	.67860E-05	.21243E-01
75540E-01	.87251E-02	.12443E-01	.22404E-01
12350E-02	-.25615E-03	-.72525E-01	-.21001E-05
65180E-05	-.90998E-02	.30190E-04	.48991E-02
11127E-06	.46449E-03	-.16829E-05	.34039E-02
56870E-05	.58614E-01	-.20560E-03	-.41308E-02
75542E-01	-.86030E-02	.12505E-01	-.22410E-01
12500E-06	.30035E-03	-.11610E-05	.47633E-02
48542E-01	.15626E-03	.48004E-01	.32660E-05
11150E-05	.30901E-01	-.10844E-03	-.13473E-02
32000E-07	-.72910E-04	.27800E-06	-.13479E-02
20347E-01	-.16771E-01	-.46573E-01	-.12169E-02
65180E-05	-.90998E-02	.30190E-04	.48991E+00
20339E-01	.16440E-01	-.46694E-01	.12169E+00
23060E+00	-.19955E-01	.22085E+00	-.29422E+00
23059E+00	.21476E-01	.22069E+00	.29423E+00
15429E-01	-.10760E-01	-.77525E-01	-.21013E+00
15452E-01	.10232E-01	-.77608E-01	.21012E+00
94654E-01	.13269E-01	-.44099E-01	-.14619E-01
94664E-01	-.13541E-01	-.44004E-01	.14612E-01
23972E-02	.12675E-01	.83891E-01	.14161E+00
23973E-02	-.12084E-01	.83982E-01	-.14161E+00
88031E-01	-.10651E-01	-.55025E-01	-.44390E-01
88040E-01	.10226E-01	-.55100E-01	.44395E-01
12409E-02	-.25339E-01	-.72434E-01	-.18381E+00
12289E-02	.24826E-01	-.72616E-01	.18381E+00
24311E+00	-.30410E-01	.25533E+00	-.24450E+00
24310E+00	.32275E-01	.25510E+00	.24451E+00
91500E-05	-.23142E+00	.81881E-03	.46009E-01
91500E-05	-.23142E+00	.81881E-03	.46009E-01
35400E-05	.25887E-01	-.90230E-04	.13271E-01
35400E-05	.25887E-01	-.90230E-04	.13271E-01
74500E-05	.85819E-01	-.30110E-03	-.40608E-02
74500E-05	.85819E-01	-.30110E-03	-.40608E-02
17700E-05	-.19381E-02	.70200E-05	-.42866E-02
17700E-05	-.19381E-02	.70200E-05	-.42866E-02
60200E-05	-.80215E-01	.28110E-03	.10940E-01
60200E-05	-.80215E-01	.28110E-03	.10940E-01
65200E-05	-.90998E-01	.30200E-04	.48991E-02
65200E-05	-.90998E-01	.30200E-04	.48991E-02
34900E-06	.25389E+00	-.89890E-03	-.36793E-01
34900E-06	.25389E+00	-.89890E-03	-.36793E-01

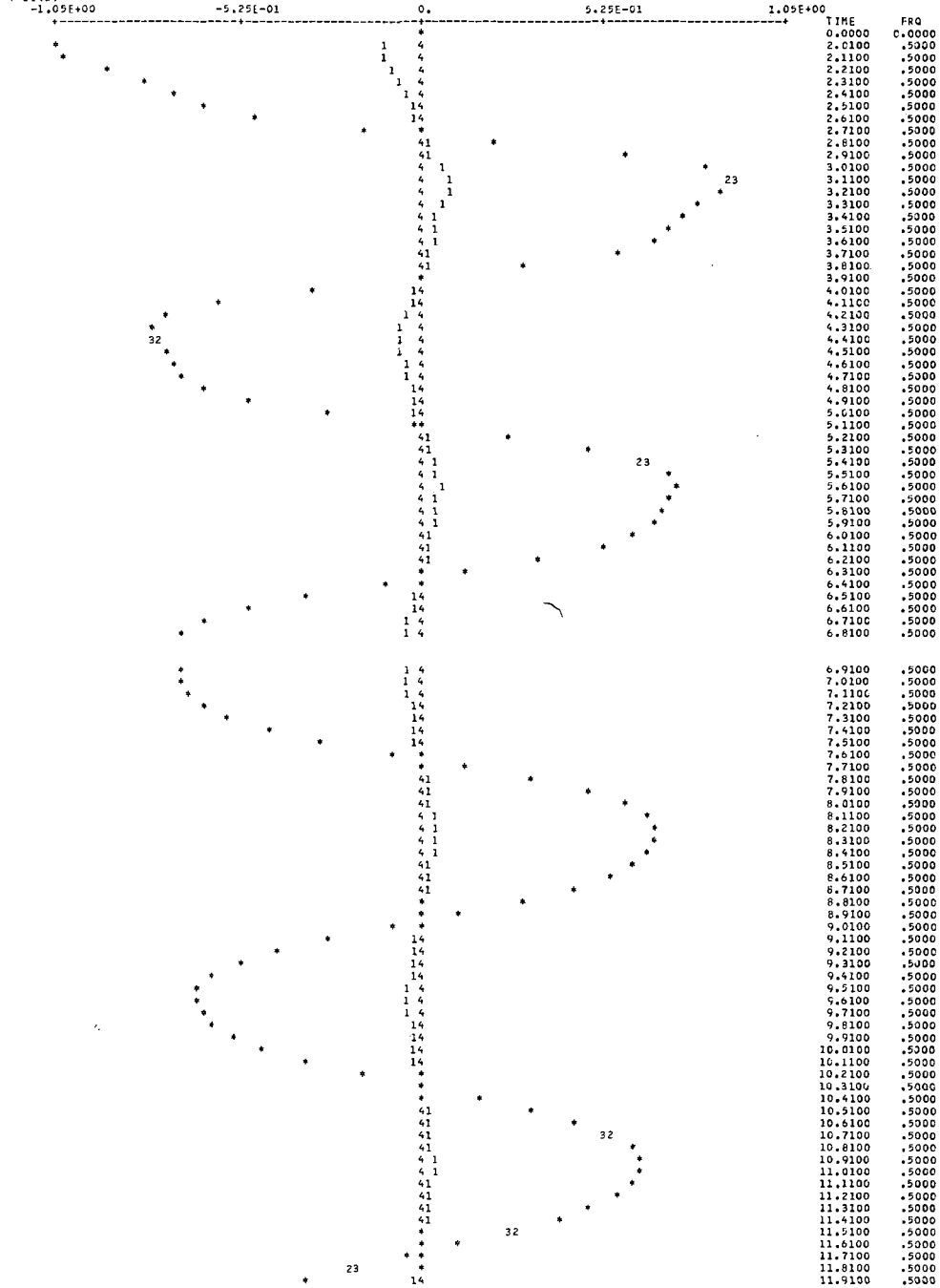
TIME HISTORY PLOT RESULTS
 Response displacements Z(1), Z(5) and Z(7). Input motions ZI(1).
 Refer to Figure 4 for locations.

#RATE RUN 20C.C3

SWEEP RATE = 0.

INPUT MOTION: CIN= .400

1=Z(1)
 2=Z(5)
 3=Z(7)
 4=ZI(1)



TIME HISTORY PLOT RESULTS (CONTINUED)
 Trailer response locations Z(19), Z(20), Z(21) and Z(23).
 See Figure 4 for locations.

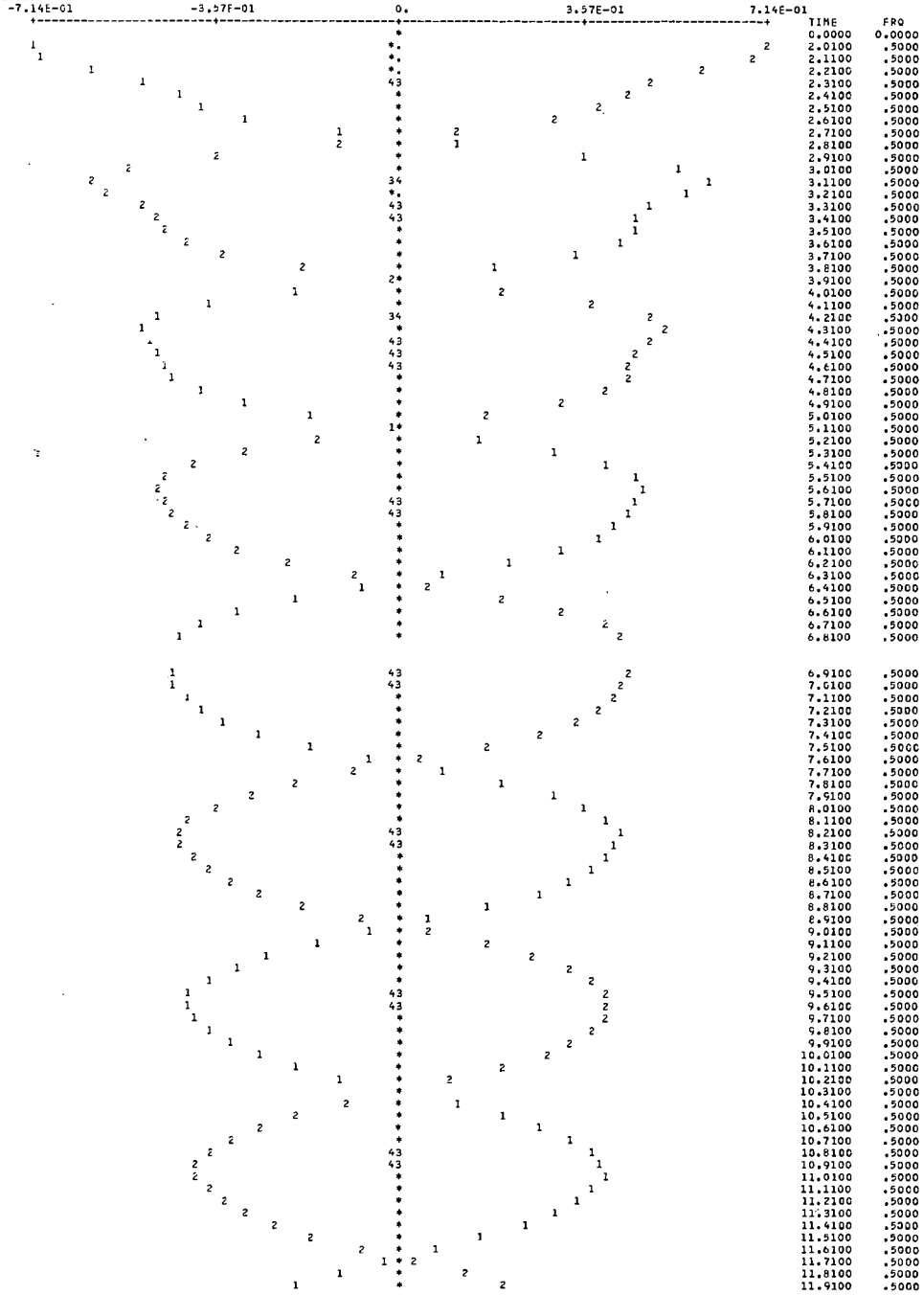
MULTIPLE PLOT TIME HISTORY

PRATE RUN 300.C3

SWEEP RATE = C.

INPUT FUNCTION: G1N = .4CC

- 1=Z(19)
- 2=Z(20)
- 3=Z(21)
- 4=Z(23)



5.3 Example No. 3 - TOFC Envelope

Example No. 3 is a sixty second envelope run with the objective of locating roll resonances other than the fundamental. The run is a frequency sweep with frequency changing at the rate of 4 octaves per minute (i.e. increasing logarithmically and doubling every 15 seconds) starting at 1.0 Hertz. The steps followed and the remote terminal listings are detailed below. Because of the length of the printer plots only representative output plots are shown.

Step 1. Call data file, enter edit mode and list 17 lines.

Step 2. Review data file and note changes to be made.

Line 2. Change run number.

Line 3. Change start and stop times. We want to start at 1.0 Hertz and sweep to 16 Hertz, 4 octaves, which at BETA = 4 is 60 seconds.

Lines 4 and 5. Switch from time history to envelope.

Lines 6 and 7. No change.

Line 8. Change to group 2 (see Table VII)

Lines 9-14. No change.

Line 15. Start frequency, FQ, is 1.0 Hertz sweep rate, BETA, is 4.0 NDECAY is put out of range at 5000.

Line 16. Change excitation from constant displacement to constant acceleration. Level, .01 g's, is purposely low to avoid nonlinear effects.

Step 3. Make changes to data file and replace file.

Step 4. Call and list data file. Check for correctness.

Step 5. Call and list executive file. Check and modify as needed. (No changes necessary in this case.)

Step 6. Submit run to 7600.

Step 7. Obtain Day File, when ready for access.

Step 8. Determine costs.

1. Input costs

\$9.00/hr connect	: 10 min.	= \$.90
.25/100 TIO	: 5581 TIO	= 1.39
.35/SBU	: .963 SBU	= .34

2. Run and Output Costs (Day File)

\$.02/IODB input and day file	: 9 IODB	= .18
\$.05/IODB Output	: 618 IODB	=30.90
\$1.15/SBU	: 50 SBU	= <u>57.50</u>

Total Run Cost =91.21

Discussion of Results

Because of the length of the printer plots only representative output plots are shown. The output filled 96 pages; 3 pages contained a listing of the input data and the remainders contained the envelope plots. The three pages of input data and six pages excerpted from the envelope plots can be found at the end of Section 5.3.

A review of the envelope plots show three resonances between 1.0 and 16.0 Hertz; 1.4, 6.1 and 13.6 Hertz. The 1.4 Hertz resonance is evidenced by amplified motions of the carbody and trailers. The 6.1 Hertz resonance is apparently a carbody resonance. The 13.6 Hertz resonance is apparently a truck resonance.

The next step in analysis would be to look at the detailed motion of each resonance. This is done for the 1.4 Hertz resonance in Example No. 4.

REMOTE TERMINAL LISTINGS

Step 1: Call data file, enter edit mode and list CONTRL and EXCIT namelists.

Step 2: Review and note changes to be made.

```

OLD.FRADI08
/EDIT
BEGIN TEXT EDITING.
?
  L:17
  $CONTRL
  RUNO=300.03. 300.04
  STARTM=2.0. 1.0 DELTAT=.005, STOPTM=12. 60.
  ENVEL=.F. ENVPLT=.F. ENVCAL=.F., ENPRMX=.F.. ← F to T
  TIMHIS=.T. THSPLT=.T. SNAPSHT=.F.. ← T to F
  STARSNP=5.20, DELTSNP=0.05, STOPSNP=5.60,
  IPRINT=2.
  IGROUP=4. 2
  OTHER=0.
  DEBUG=.F.. STARDB=4.15, STOPDB=4.17,$
  $EXCIT
  SINEIN=.T.,
  AMP = 1.00, 0.00, 1.00, 1.00, 0.00, 1.00,
  PHAS= 0.00, 0.00, 180., 0.00, 0.00, 180.,
  FQ=0.5 FQDOT=.0, BETA=0.0 NDECAY=1.
  DIN=0.4 VIN=0.00, GIN=0. $ 5000
  $VEHIC
  ?
  1.0
  4.0
  .01
  0.
  
```

REMOTE TERMINAL LISTINGS (continued)

Step 3. Make changes to data file.

```
F:/RUNO/
RUNO=300.03,
? RS:/.03/,/.04/
? RS:/2.0/,/1.0/
? RS:/12/,/60/
? L;2
RUNO=300.04,
STARTM=1.0, DELTAT=.005, STOPTM=60.,
?
S;2
? RS:/.T./,/.F./;2
? RS:/.F./;/.T./;2
? L;2
ENVEL=.T., ENVPLT=.T., ENVCAL=.F., ENPRMX=.F.,
TIMHIS=.F., THSPLT=.F., SNAPSHT=.F..
?
F:/IGROUP/
IGROUP=4,
? RS:/4/,/2/
? L
IGROUP=2,
?
F:/FQ/
FQ=0.5, FQDOT=.0, BETA=0.0, NDECAY=1,
? RS:/0.5/,/1.0/
? RS:/0.0/,/4.0/
? RS:/=1/,/=/5000,/
? L
FQ=1.0, FQDOT=.0, BETA=4.0, NDECAY=5000,
?
S
? RS:/.0./,/.01./
? RS:/0.4/,/0./
? L
DIN=0., VIN=0.00, GIN=.01,$
?
END
END TEXT EDITING.
$EDIT.FRAD108.
/
REPLACE
/
```

REMOTE TERMINAL LISTINGS (continued)

Step 4. Call and list data file.

```

OLD,FRAD108
/LNH
$CONTRL
RUNO=300.04.
STARTM=1.0, DELTAT=.005, STOPTM=60.,
ENVEL=.T., ENVPLT=.T., ENVCAL=.F., ENPRMX=.F.,
TIMHIS=.F., THSPLT=.F., SNAPSHT=.F.,
STARSNP=5.20, DELTSNP=0.05, STOPSNP=5.60.
IPRINT=2.
IGROUP=2.
OTHER=0.
DEBUG=.F., STARDDB=4.15, STOPDB=4.17,$
$XCIT
SINEIN=.T.,
AMP = 1.00, 0.00, 1.00, 1.00, 0.00, 1.00,
PHAS= 0.00, 0.00, 180., 0.00, 0.00, 180.,
FQ=1.0, FQDOT=.0, BETA=4.0, NDECAY=5000.
DIN=0., VIN=0.00, GIN=.01.$
$VEHIC
NMAS=7.
M=2*22.33,125.0,8.179,152.65,7.013,148.9,3*0..
INERT=22080.,22080.,108500.,20000.,255000.,17150.,102000.,
.294E7.,.319E7.,.15E8.,.15E8.,.131E7.,.131E7,2*0.,
R=58.,79.,58.,79.,62.25,43.5,62.25,43.5,108.,0.,
H=16.,VH=60.4,VH1=47.,VHR=37.8,VH1R=47..
L=792.,VL1=469.,VL2=148.,VL3=131.4,VL4=189.7.
VL1R=-89.,VL2R=-413.,VL3R=115.4,VL4R=208.6.
OR=536.,-536.,-39.,39.,40.,224.,226.,254.,245.,235..
GAPB=.01,GAPA=.01.
K=.91E5.,.95E5.,.91E5.,.480E5.,.60E4,0.0.,.91E5.,.95E5.,.91E5.,.480E5.,.60E4.
0.0.,.225E6.,.15E5.,.225E5.,.18E5.,.225E5.,.5276E5.,.18E5.,.5276E5.,
.225E6.,.15E5.,.225E5.,.18E5.,.225E5.,.5276E5.,.18E5.,.5276E5,2*0..
XZKMOM=.30E8. XRCMOM=.30E8.
KA6=.92E7,KA12=.92E7,KB6=.6185E8,KB12=.6185E8.
C=150.,20.,150.,140.,225.,0.,150.,20.,150.,140.,225.,0..
1000.,500.,330.,200.,330.,775.,200.,775.,
1000.,500.,330.,200.,330.,775.,200.,775.,2*0..
XZCMOM=.10E6. XRCMOM=.10E6.
CA6=.10E6,CA12=.10E6,CB6=.78E6,CB12=.78E6.$
$MODAL
NMODES=4.
RF=4.253,8.873,9.417,9.629,15.519,15.599,18.029,3*0..
ZETA=7*0.02,3*0.0.
NLOC=46.
COEF(1,1)=.1 *INTERRUPTED*
STOP
*TERMINATED*

```

REMOTE TERMINAL LISTINGS (continued)

Step 5. Call and list executive file. Check and modify as needed.

Step 6. Submit Run to 7600.

```
OLD.FRARUN
READY.
LNH
/JOB
CASKET,STTCZ,T200,P4.
ACCOUNT,
ATTACH,HEADING,HEADING,MR=1.
HEADING.
ATTACH,FRATE,FRATE01,ID=JFC,MR=1.
FRATE.
EXIT,U.
DISPOSE,OUTPUT,PR,SI=TCAI98.
/EOR
/NOSEQ
1DELIVER TO
KACHADOUR
MITRE CORP
7915 WEST
PARK DR.
MCLEAN,VA.
/EOR
/READ,FRAD108
/EOF
READY.
```

```
SUBMIT.FRARUN,H=TCA,T
09.37.50.ADLCAQH
```

```
SBU      0.255 UNTS.
READY.
```

BYE

```
DOTMITR LOG OFF 09.37.56.
SBU      0.963
TIO =    5581
```

Step 7: Obtain Day File, when ready for access.

REMOTE TERMINAL LISTINGS (continued) - DAY FILE

QFETCH.,DAY

ADLCAQH RELEASED TO USER AS - FILE

**** TWIN CITIES CYBERNET CENTER V2.1.4 **** 05/16/78 78136

OHH.MM.SS CPU SECOND ORIGIN

08.53.33	00000.004	TCZ.	TCA SCOPE 3.4.3	406F.102	05/01/78	
08.53.33	00000.004	TCZ.	-CAQHA,STTCZ,T200,P4.			
08.53.33	00000.005	JOB.	CYB02 - JOB NAME-	CAQHA7Y		
08.53.33	00000.032	JOB.	-ACCOUNT,			
08.53.33	00000.036	TCZ.	-ATTACH.HEADING,HEADING,MR=1.			
08.53.33	00000.036	LOD.	PF254 - CYCLE	3 ATTACHED FROM SN=SYSTEM		
08.53.34	00000.041	USR.	-HEADING.			
08.53.34	00000.042	TCZ.	FORTRAN LIBRARY 410W	04/05/76		
08.53.34	00000.045	TCZ.	PF646 - PFMACRO - ATTACH - ZZZQQZ - HEAD22			
08.53.34	00000.068	USR.	PF254 - CYCLE	2 ATTACHED FROM SN=SYSTEM		
08.53.34	00000.069	USR.	STOP			
08.53.34	00000.071	JOB.	.027 CP SECONDS EXECUTION TIME			
08.53.34	00000.074	TCZ.	-ATTACH.FRATE,FRATE01,ID=JFC,MR=1.			
08.53.34	00000.075	LOD.	PF254 - CYCLE	1 ATTACHED FROM SN=SYSTEM		
08.53.37	00000.209	USR.	-FRATE.			
08.54.31	00040.573	USR.	FORTRAN LIBRARY 433	05/11/77		
08.54.31	00040.573	USR.	STOP			
08.54.31	00040.573	JOB.	40.363 CP SECONDS EXECUTION TIME			
08.54.31	00040.574	JOB.	-EXIT,U.			
08.54.31	00040.574	TCZ.	-DISPOSE,OUTPUT.PR,ST=TCAI98.			
08.54.32	00040.576	TCZ.	CYB01 - FILE OUTPUT DC=40 ST=TCAI98 SIZE=0000000618 IODB			
08.54.32	00040.578	TCZ.	CYB01 - FILE CAQHA7Y DC=04 ST=TCAI99 SIZE=0000000006 IODB			
08.54.32	00040.578	TCZ.	CYB01 - FILE OUTPUT DC=40 ST=TCAI99 SIZE=0000000003 IODB			
08.54.32	00040.578	TCZ.	RM770 - MAXIMUM ACTIVE FILES	1		
08.54.32	00040.578	TCZ.	RM771 - OPEN/CLOSE CALLS	13		
08.54.32	00040.578	TCZ.	RM772 - DATA TRANSFER CALLS	5,596		
08.54.32	00040.578	TCZ.	RM773 - CONTROL/POSITIONING CALLS	12		
08.54.32	00040.579	TCZ.	RM774 - BM DATA TRANSFER CALLS	797		
08.54.32	00040.579	TCZ.	RM775 - BM CONTROL/POSITIONING CALLS	55		
08.54.32	00040.579	TCZ.	RM776 - QUEUE MANAGER CALLS	129		
08.54.32	00040.579	TCZ.	RM777 - RECALL CALLS	99		
08.54.32	00040.580	TCZ.	SCM	1 651.093	KWS	
08.54.32	00040.580	TCZ.	LCM	7 963.272	KWS	
08.54.32	00040.580	TCZ.	I/O	0.076	MW	
08.54.32	00040.580	TCZ.	RMS	0.402	MWS	
08.54.32	00040.580	TCZ.	USER	39.979	SEC	
08.54.32	00040.580	TCZ.	JOB	40.582	.SEC	
08.54.32	00040.580	TCZ.	DIO	350.536	KW	
08.54.32	00040.581	TCZ.	SBU	50		
08.54.32	00040.581	TCZ.	SC053 -	JOB PRIORITY - P4		

READY.

INPUT PARAMETERS FOR FRATE RUN NO. 300.04

ENVELOPE RUN PARAMETERS

ENVELOPE PRINT PLCTS = T
 ENVELOPE CALCOMP PLCTS = F
 PRINT ALL POINTS FOR EACH MAX = F
 START TIME = 1.000
 DELTA T = .000
 STCP TIME = 60.000
 IGFQUP = 2
 IPRINT = 2
 OTHER = 0

 DEBUG = F
 STAKDB = 4.150
 STCPDB = 4.170

EXCITATION PARAMETERS

SINEIN = T
 AMP(I) = 1.000 0.000 1.000 1.000 0.000 1.000
 PHAS(I) = 0.000 0.000 180.000 0.000 0.000 180.000
 FG = 1.000
 FGDUT = 0.000
 BETA = 4.000
 DIN = 0.000
 VIN = 0.000
 GIN = .010
 NDECAY = 5000

MODEL PARAMETERS

NMAS = 7

 M = .2233E+02 .2233E+02 .1250E+03 .8179E+01 .1527E+03 .7013E+01 .1489E+03 0. 0. 0.
 INERT = .2208E+05 .2208E+05 .1085E+06 .2000E+05 .2550E+06 .1715E+05 .1020E+06 .2940E+07 .3190E+07 .1500E+08
 .1500E+08 .1310E+07 .1310E+07 0. 0.
 R = 58.000 79.000 58.000 79.000 62.250 43.500 62.250 43.500 108.000 0.000
 H = 16.000
 L = 792.000
 DR = 536.000 -536.000 -39.000 39.000 40.000 224.000 226.000 254.000 245.000 235.000

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INPUT PARAMETERS FOR FFATE - CONTINUED -

K	=				
		.9100E+05	.9500E+05	.9100E+05	.4800E+05
		.6000E+04	0.	.2250E+06	.1500E+05
		.2250E+06	.1500E+05	.2250E+05	.1800E+05
XZKMDM	=	.3000E+08		XFKMDM	= .3000E+08
KA6	=	.9200E+07		KA12	= .9200E+07
KB6	=	.6185E+08		KB12	= .6185E+08
C	=				
		.1500E+03	.2000E+02	.1500E+03	.1400E+03
		.2250E+03	0.	.1000E+04	.5000E+03
		.1000E+04	.5000E+03	.3300E+03	.2000E+03
XZCMDM	=	.1000E+06		XRCMDM	= .1000E+06
CA6	=	.1000E+06		CA12	= .1000E+06
CB6	=	.7800E+06		CB12	= .7800E+06
VF	=	60.400			
VH1	=	47.000			
VH1R	=	47.000			
VHR	=	37.800			
VL1	=	469.000			
VL2	=	148.000			
VL3	=	131.400			
VL4	=	189.700			
VL1R	=	-89.000			
VL2R	=	-413.000			
VL3R	=	115.400			
VL4R	=	208.600			
GAPB	=	.0100		GAPA	= .0100

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NORMAL MODE PARAMETERS

NMODES	=	4			
FREQ	=	4.253	8.873	9.417	9.629 15.519
ZETA	=	.020	.020	.020	.020 .020
NLCC	=	46			

.6000E+04	0.	.9100E+05	.9500E+05	.9100E+05	.4800E+05
.2250E+05	.1800E+05	.2250E+05	.5276E+05	.1800E+05	.5276E+05
.2250E+05	.5276E+05	.1800E+05	.5276E+05	0.	0.

.2250E+03	0.	.1500E+03	.2000E+02	.1500E+03	.1400E+03
.3300E+03	.2000E+03	.3300E+03	.7750E+03	.2000E+03	.7750E+03
.3300E+03	.7750E+03	.2000E+03	.7750E+03	0.	0.

15.599	18.029	0.000	0.000	0.000
.020	.020	0.000	0.000	0.000

MODE SHAPES FCLLCW

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.13913E+00	.10770E-05	.54590E-05	.
.68378E-01	.33196E-08	-.49114E-06	-. .
.51200E-06	.56691E-01	.22910E-01	-. .
-.12532E-10	-.86347E-03	.25528E-02	-. .
.59200E-06	.10023E+00	.38352E-01	-. .
-.62628E-01	.12993E-01	-.48615E-01	-. .
.82416E-01	-.18479E-06	-.31169E-06	-. .
-.52900E-06	.70426E-01	.27362E-01	-. .
.23266E-09	.85568E-03	-.24210E-02	-. .
.22700E-06	-.50729E-01	-.16349E-01	-. .
-.62628E-01	-.12994E-01	.48609E-01	-. .
0.	-.93066E-03	.26799E-02	-. .
-.76877E-01	.32500E-00	.20030E-05	.
.15200E-06	.59836E-01	.22612E-01	.
C.	.31250E-03	-.72860E-03	.
.92463E-01	-.30591E-01	.86550E-01	-. .
-.52900E-06	.70426E-01	.27362E-01	-. .
.92463E-01	.30590E-01	-.86552E-01	-. .
.19472E+00	.53109E-01	-.15010E+00	-. .
.19473E+00	-.53105E-01	.15012E+00	-. .
.68378E-01	.46627E-01	-.13785E+00	-. .
.68378E-01	-.46627E-01	.13785E+00	-. .
-.36883E-01	.30467E-01	-.10681E+00	-. .
-.36883E-01	-.30468E-01	.10680E+00	-. .
-.90388E-01	-.44789E-02	.79877E-03	.
-.90388E-01	.44790E-02	-.79840E-03	.
-.27713E-01	-.37982E-01	.10500E+00	.
-.27713E-01	.37983E-01	-.10499E+00	.
.82416E-01	-.46207E-01	.13073E+00	-. .
.82416E-01	.46206E-01	-.13073E+00	-. .
.20960E+00	-.49600E-01	.14143E+00	-. .
.20960E+00	.49596E-01	-.14143E+00	-. .
C.	.15818E+00	.68382E-01	-. .
C.	.15818E+00	.68382E-01	-. .
C.	.56691E-01	.22910E-01	.
0.	.56691E-01	.22910E-01	.
C.	-.37983E-01	-.10659E-01	.
0.	-.37983E-01	-.10659E-01	.
C.	-.79144E-01	-.29014E-01	.
0.	-.79144E-01	-.29014E-01	.
0.	-.26967E-01	-.11710E-01	-. .
C.	-.26967E-01	-.11710E-01	-. .
C.	.70426E-01	.27362E-01	-. .
C.	.70426E-01	.27362E-01	-. .
C.	.20547E+00	.85956E-01	-. .
0.	.20547E+00	.85956E-01	-. .

THE INITIAL DEFLECTIONS ARE

-.5066	-.5248	-3.331	.3437E-03
-4.949	-3.703	.1201E-01	
-3.077	-3.820	-.2403E-02	

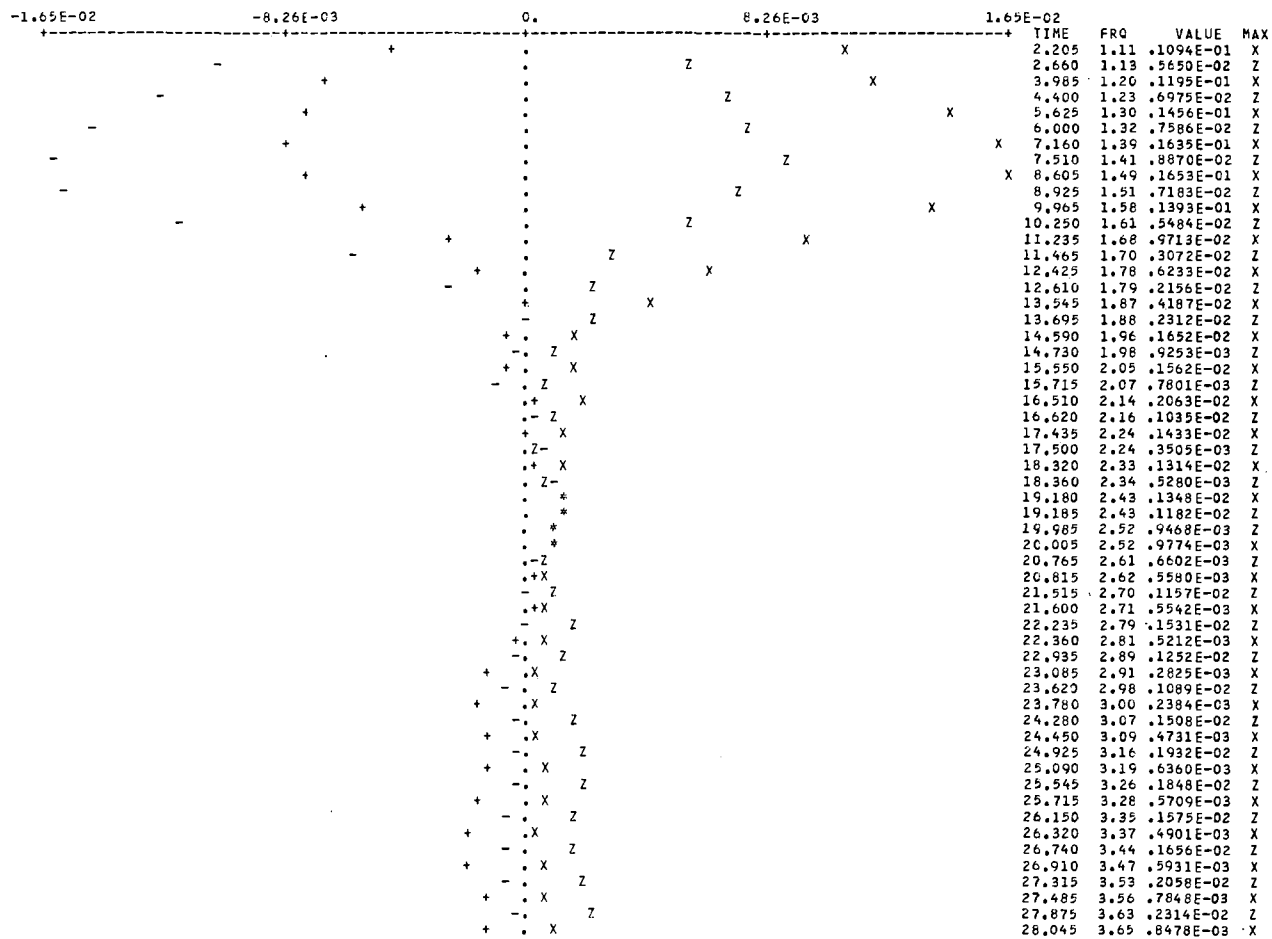
12234E+00	.30975E-03	.89504E-01	.17700E-05
15435E-01	-.26386E-03	-.77567E-01	-.21917E-05
35450E-05	.25887E-01	-.90230E-04	.13271E-01
11870E-06	.19437E-03	-.76683E-06	.38912E-02
17500E-05	-.16823E-02	.67860E-05	.21243E-01
75540F-01	.87251E-02	.12443E-01	.22404E-01
12350E-02	-.25615E-03	-.72525E-01	-.21001E-05
65180E-05	-.90998E-02	.30190E-04	.48991E-02
11127E-06	.46449E-03	-.16829E-05	.34039E-02
56870E-05	.58614E-01	-.20560E-03	-.41308E-02
72542E-01	-.86030E-02	.12505E-01	-.22410E-01
12500E-06	.30035E-03	-.11610E-05	.47633E-02
48542E-01	.15626E-03	.48004E-01	.32660E-05
11150E-05	.30901E-01	-.10844E-03	-.13473E-02
32000E-07	-.72910E-04	.27800E-06	-.13479E-02
20347E-01	-.16771E-01	-.46573E-01	-.12169E+00
65180E-05	-.90998E-02	.30190E-04	.48991E-02
20339E-01	.16440E-01	-.46694E-01	.12169E+00
23060E+00	-.19955E-01	.22085E+00	-.29422E+00
23059E+00	.21476E-01	.22069E+00	.29423E+00
15429E-01	-.10760E-01	-.77525E-01	-.21013E+00
15452E-01	.10232E-01	-.77608E-01	.21012E+00
94654E-01	.13269E-01	-.44099E-01	-.14619E-01
94664E-01	-.13541E-01	-.44004E-01	.14612E-01
23972E-02	.12675E-01	.83891E-01	.14161E+00
23973E-02	-.12084E-01	.83982E-01	-.14161E+00
88031E-01	-.10651E-01	-.55025E-01	-.44390E-01
88040E-01	.10226E-01	-.55100E-01	.44395E-01
12409E-02	-.25339E-01	-.72434E-01	-.18381E+00
12289E-02	.24826E-01	-.72616E-01	.18381E+00
24311E+00	-.30410E-01	.25533E+00	-.24490E+00
24310E+00	.32275E-01	.25510E+00	.24451E+00
91500E-05	-.23142E+00	.81881E-03	.46009E-01
91500E-05	.23142E+00	.81881E-03	.46009E-01
35400E-05	.25887E-01	-.90230E-04	.13271E-01
35400E-05	.25887E-01	-.90230E-04	.13271E-01
74500E-05	.85819E-01	-.30110E-03	-.40608E-02
74500E-05	.85819E-01	-.30110E-03	-.40608E-02
17700E-05	-.19381E-02	.70200E-05	-.42866E-02
17700E-05	-.19381E-02	.70200E-05	-.42866E-02
60200E-05	-.80215E-01	.28110E-03	.10940E-01
60200E-05	-.80215E-01	.28110E-03	.10940E-01
65200F-05	-.90998E-01	.30200E-04	.48991E-02
65200E-05	-.90998E-01	.30200E-04	.48991E-02
34900E-06	.25389E+00	-.89890E-03	-.36793E-01
34900E-06	.25389E+00	-.89890E-03	-.36793E-01

TOFC ENVELOPE (CONTINUED)

Sample printer plot showing 1.4 Hertz resonance.

ENVELOPE PRINT PLOTS FOR TFC2 POINT 5

Z IS SYMBOL FOR ZA AND - IS SYMBOL FOR CORRESPONDING XA
 X IS SYMBOL FOR XA AND + IS SYMBOL FOR CORRESPONDING ZA

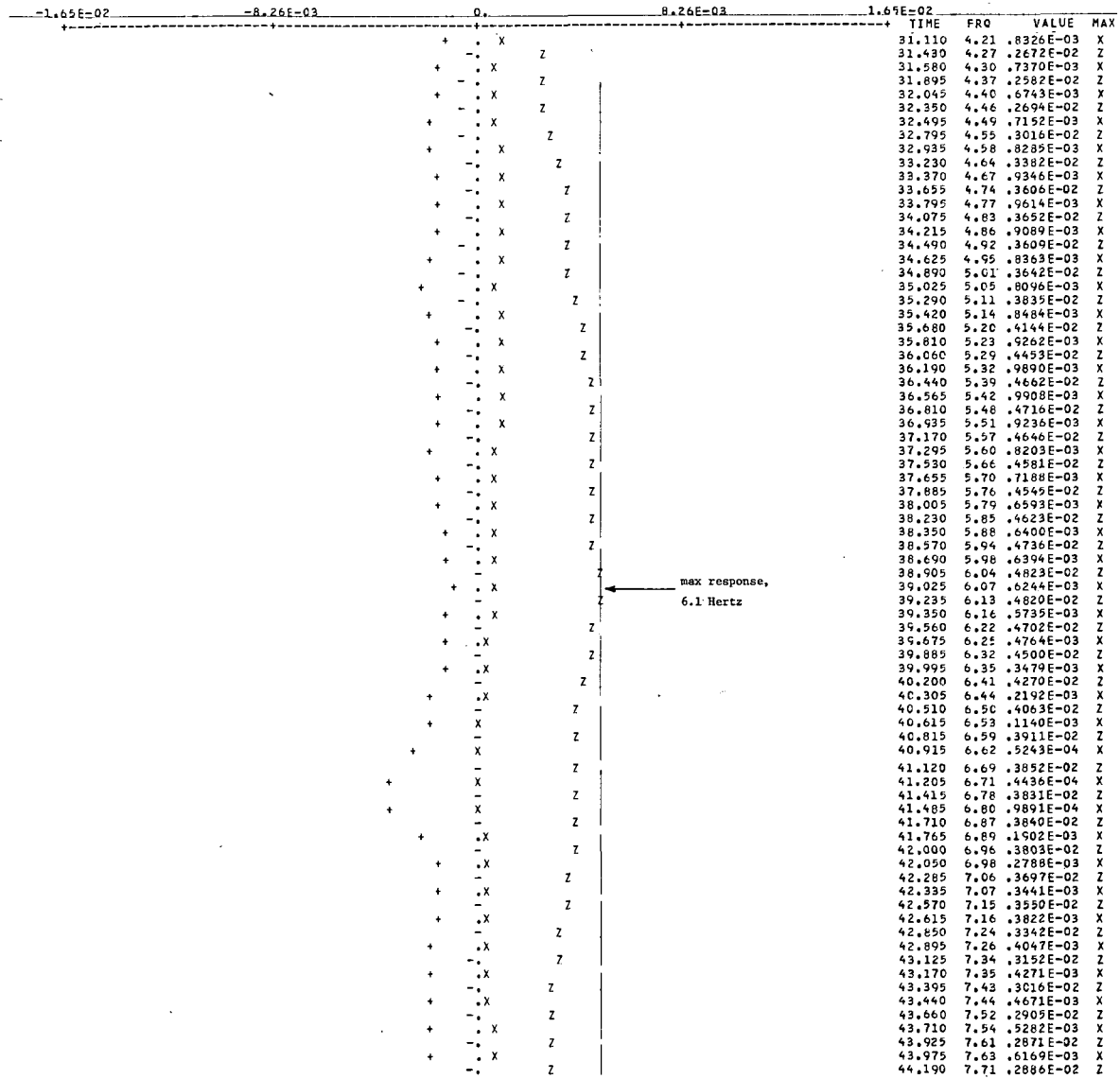


TOFC ENVELOPE (CONTINUED)

Sample printer plot showing 6.1 Hertz resonance.

ENVELOPE PRINT PLOTS FOR TEC2 POINT 5

Z IS SYMBOL FOR ZA AND - IS SYMBOL FOR CORRESPONDING XA
 X IS SYMBOL FOR XA AND + IS SYMBOL FOR CORRESPONDING ZA

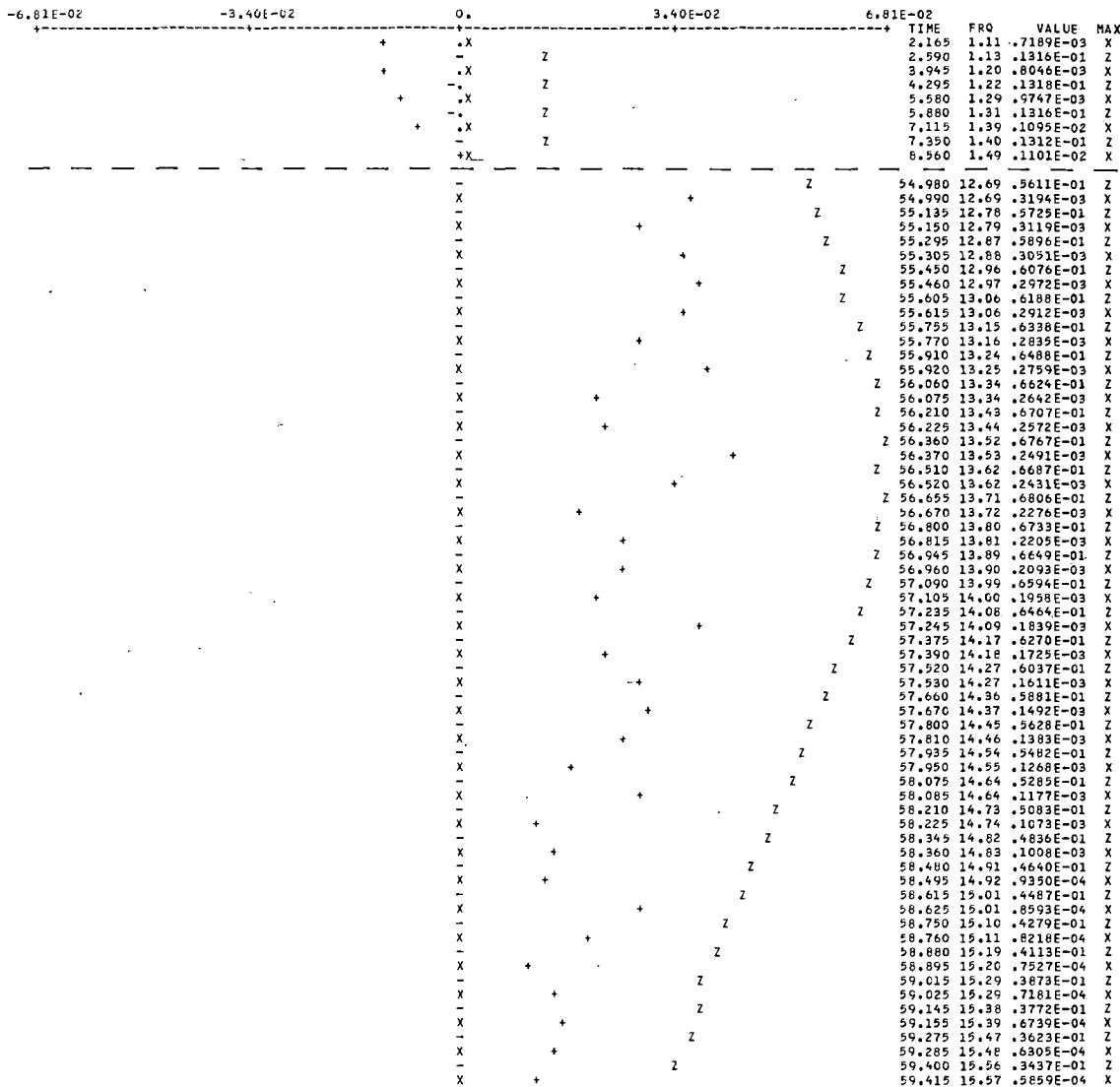


TOFC ENVELOPE (CONTINUED)

Sample printer plot showing 13.6 Hertz resonance.

ENVELOPE PRINT PLOTS FOR TFC2 POINT 1

Z IS SYMBOL FOR ZA AND - IS SYMBOL FOR CORRESPONDING XA
 X IS SYMBOL FOR XA AND + IS SYMBOL FOR CORRESPONDING ZA



5.4 Example No. 4 - TOFC Time History

There were resonances indicated in Example No. 3 at 1.4, 6.1 and 13.6 Hertz. Example No. 4 is run with the objective of obtaining additional information on the 1.4 Hertz resonance. For this a time history run was made between 1.0 and 1.6 Hertz at a slower sweep rate. The steps followed in the run set up and submittal are presented below followed by the associated remote terminal print out and representative run results.

Step 1. Call data file, enter edit mode and list 17 lines.

Step 2. Review data file and note changes to be made.

Line 2. Change run number.

Line 3. Change stop time. Start at 1.0 Hertz and sweep to 1.6 Hertz at sweep rate of 0.02 Hertz per second - thus 30 second run time.

Line 4-14. No changes.

Line 15. Change to FQ = 1.0 and FQDOT = .02 as noted above. Set NDECAY = 5000, i.e. out of range of problem run cycles.

Line 16. Time history plots are in displacement values. Consequently input should be constant amplitude.

Step 3. Make changes to data file and replace file.

Step 4. Call and list data file and check for correctness.

Step 5. Call and list executive file. Change if necessary.

Step 6. Submit run to 7600.

Step 7. Obtain Day File, when ready for access.

Step 8. Determine Costs

1. Input costs

\$9.00/hr. connect -	~10 min.	\$.90
.25/100 TIO	~4000 TIO	1.00
.34/SBU	~.5 SBU	.17

2. Run and Output Costs

\$.02/IODB input and day file	9 IODB	.18
.05/IODB output	350 IODB	17.50
1.15/SBU	23 SBU	<u>26.45</u>

Total run cost \$46.20

Discussion of Results

A review of the time history plots revealed the presence of the fundamental roll resonance, 0.38 Hertz, in addition to the forced response at 1.0 to 1.6 Hertz. The presence of the 0.38 Hz motion is presumed to be the decaying motion triggered by the problem start transient. Because the frequency is very low and because for this TOFC configuration the damping is low it takes a relatively long time for this motion to damp out.

Since our interest was in the 1.4 Hz frequency region it was necessary to visually separate the motion at this frequency from the 0.38 Hz motion. Through this process we concluded that the maximum amplitude of the higher frequency actually occurred at 1.44 Hertz. The amplitude and phase relationship was obtained by analysis of the time history plots. With this data the relative amplitude plot of Figure 12 was made. Figure 12 shows the motion to be typical of the second roll resonance with the effective axis of rotation above the carbody and close to the c.g.'s of the trailers.

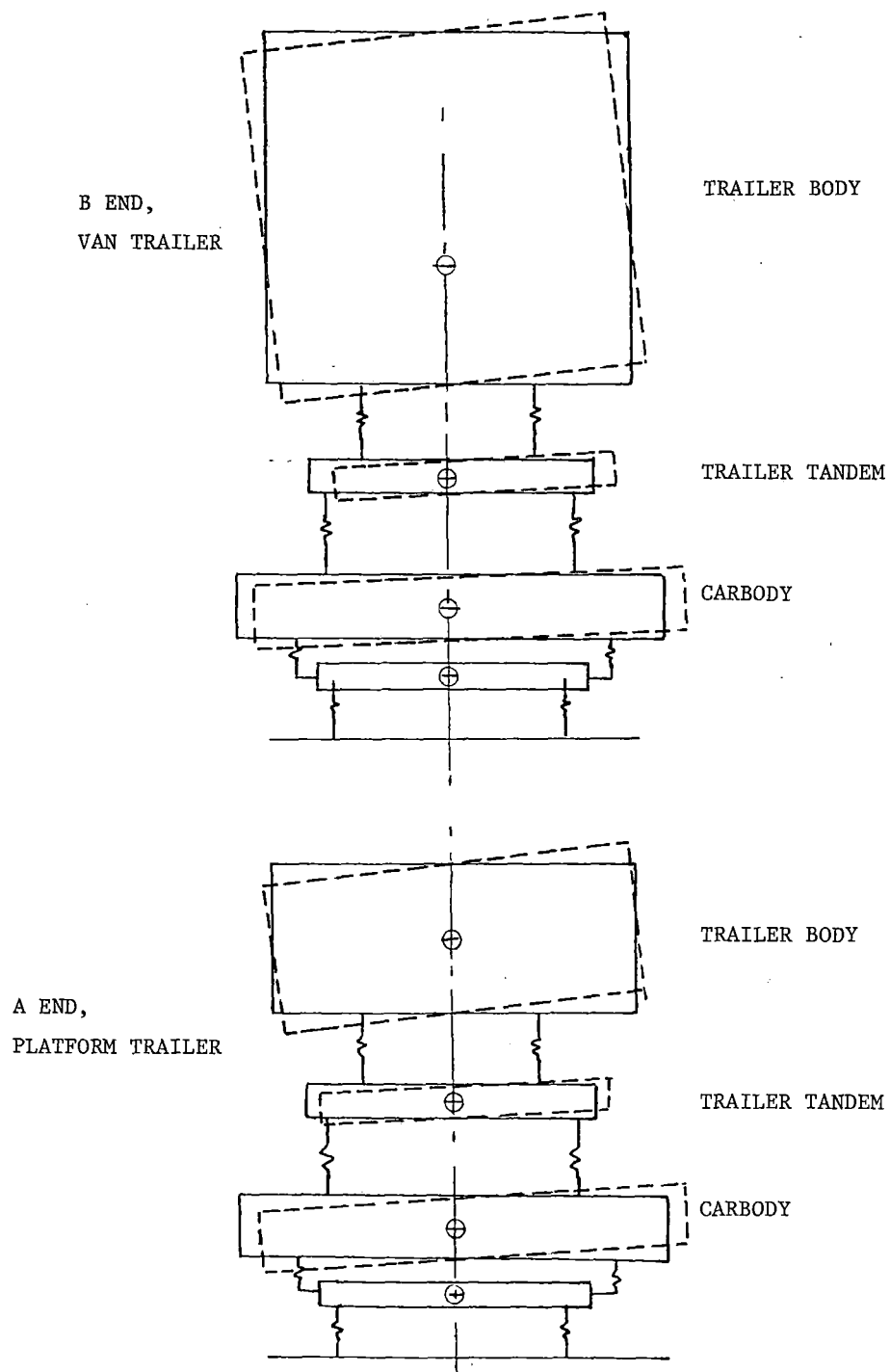


FIGURE 12
RELATIVE DEFLECTION IN ROLL/LATERAL TRANSLATION
OF 1.44 HERTZ RESONANCE

REMOTE TERMINAL LISTINGS

Steps 1, 2 and 3. Call data file, enter EDIT mode, note and make changes and replace file.

```

OLD,FRAD108
/EDIT
BEGIN TEXT EDITING.
?
  L;17
  $CONTRL
  RUNO=300.05. 300.06
  STARTM=2.0, DELTAT=.005, STOPTM=12. 30.
  ENVEL=.F., ENVPLT=.F., ENVCAL=.F., ENPRMX=.F.,
  TIMHIS=.T., THSPLT=.T., SNAPSHT=.F.,
  STARSNP=5.20, DELTSNP=0.05, STOPSNP=5.60,
  IPRINT=2,
  IGROUP=4,
  OTHER=0,
  DEBUG=.F., STARDDB=4.15, STOPDB=4.17.$
  $EXCIT
  SINEIN=.T.,
  AMP = 1.00, 0.00, 1.00, 1.00, 0.00, 1.00,
  PHAS= 0.00, 0.00, 180., 0.00, 0.00, 180.,
  FQ=0.5, FQDOT=.0, BETA=0.0, NDECAY=1
  DIN=0.4, VIN=0.00, GIN=.0,$ 5000
  $VEHIC 0.2 1.0 .02.
?
  F:/RUNO/
  RUNO=300.05.
? RS:/.05/./06/
? RS:/12/./30/
?
  L;2
  RUNO=300.06.
  STARTM=2.0, DELTAT=.005, STOPTM=30.,
?
  F:/FQ/
  FQ=0.5, FQDOT=.0, BETA=0.0, NDECAY=1.
?
  RS:/1/./5000/
? RS:/.0/./02/
? RS:/0.5/./1.0/
?
  L
  FQ=1.0, FQDOT=.02, BETA=0.0, NDECAY=5000.
?
  S
? RS:/0.4/./0.2/
? L
  DIN=0.2, VIN=0.00, GIN=.0,$
?
  END
  END TEXT EDITING.
  $EDIT,FRAD108.
/
  REPLACE
/

```

REMOTE TERMINAL LISTINGS (continued)

Step 4. Call and list data file and check for correctness.

```

OLD,FRAD108
/LNH
$CONTRL
RUNO=300.06,
STARTM=2.0, DELTAT=.005, STOPTM=30.,
ENVEL=.F., ENVPLT=.F., ENVCAL=.F., ENPRMX=.F.,
TIMHIS=.T., THSPLT=.T., SNAPSHT=.F.,
STARSNP=5.20, DELTSNP=0.05, STOPSNP=5.60,
IPRINT=2,
IGROUP=4,
OTHER=0,
DEBUG=.F., STARDDB=4.15, STOPDB=4.17,$
$EXCIT
SINEIN=.T.,
AMP = 1.00, 0.00, 1.00, 1.00, 0.00, 1.00,
PHAS= 0.00, 0.00, 180., 0.00, 0.00, 180.,
FQ=1.0, FQDOT=.02, BETA=0.0, NDECAY=5000,
DIN=0.2, VIN=0.00, GIN=.0.$
$VEHIC
NMA=7,
M=2*22.33,125.0,8.179,152.65,7.013,148.9,3*0.,
INERT=22080.,22080.,108500.,20000.,255000.,17150.,102000.,
.294E7,.319E7,.15E8,.15E8,.131E7,.131E7,2*0.,
R=58.,79.,58.,79.,62.25,43.5,62.25,43.5,108.,0.,
H=16.,VH=60.4,VH1=47.,VHR=37.8,VH1R=47.,
L=792.,VL1=469.,VL2=148.,VL3=131.4,VL4=189.7,
VL1R=-89.,VL2R=-413.,VL3R=115.4,VL4R=208.6,
OR=536.,-536.,-39.,39.,40.,224.,226.,254.,245.,235.,
GAPB=.01,GAPA=.01,
K=.91E5,.95E5,.91E5,.480E5,.60E4,0.0,.91E5,.95E5,.91E5,.480E5,.60E4,
0.0,.225E6,.15E5,.225E5,.18E5,.225E5,.5276E5,.18E5,.5276E5,
.225E6,.15E5,.225E5,.18E5,.225E5,.5276E5,.18E5,.5276E5,2*0.,
XZKMOM=.30E8, XRCMOM=.30E8,
KA6=.92E7,KA12=.92E7,KB6=.6185E8,KB12=.6185E8,
C=150.,20.,150.,140.,225.,0.,150.,20.,150.,140.,225.,0.,
1000.,500.,330.,200.,330.,775.,200.,775.,
1000.,500.,330.,200.,330.,775.,200.,775.,2*0.,
XZCMOM=.10E6, XRCMOM=.10E6,
CA6=.10E6,CA12=.10E6,CB6=.78E6,CB12=.78E6,$
$MODAL
NMODES=4,
RF=4.253,8.873,9.417,9.629,15.519,15.599,18.029,3*0.,
ZETA=7*0.02,3*0.0,
NLOC=46,
COEF(1,1)=.139133,.683776E-1,.512 *INTERRUPTED*
STOP
*TERMINATED*

```

REMOTE TERMINAL LISTINGS (continued)

Steps 5 and 6. Call and list executive file. Check. Submit to 7600.

```
OLD,FRARUN
READY.
LNH
/JOB
CASKET,STTCZ,T200,P4.
ACCOUNT,
ATTACH,HEADING,HEADING,MR=1.
HEADING.
ATTACH,FRATE,FRATE01,ID=JFC,MR=1.
FRATE.
EXIT,U.
DISPOSE,OUTPUT,PR,ST=TCAI98.
/EOR
/NOSEQ
1DELIVER TO
  KACHADOUR
  MITRE CORP
  7915 WEST
  PARK DR.
  MCLEAN,VA.
/EOR
/READ,FRAD108
/EOF
READY.

SUBMIT,FRARUN,H=TCA,T
  15.48.42.ADLCCRK

SBU      0.268 UNTS.
READY.
```

Step 7: Obtain Day File, when ready for access.

REMOTE TERMINAL LISTINGS (continued) - DAY FILE

```

OFETCH.,DAY
ADLCCRK RELEASED TO USER AS - FILE
**** TWIN CITIES CYBERNET CENTER V2.1.4 ****      05/16/78      78136
OHH.MM.SS CPU SECOND ORIGIN
      15.13.49.TCA. 99      TCA SCOPE 3.4.3      406F.102 05/01/78
16.11.05 00000.005 TCZ.      -CCRKA,STTCZ.T200.P4.
16.11.05 00000.006 TCZ.      CYR02 - JOB NAME- CCRKA3M
16.11.05 00000.006 JOB.      -ACCOUNT.
16.11.07 00000.034 JOB.      -ATTACH,HEADING,HEADING.MR=1.
16.11.07 00000.038 TCZ.      PF254 - CYCLE      3 ATTACHED FROM SN=SYSTEM
16.11.07 00000.038 LOD.      -HEADING.
16.11.07 00000.043 USR.      FORTRAN LIBRARY 410W      04/05/76
16.11.07 00000.044 TCZ.      PF646 - PFMACRO - ATTACH - ZZZQZ - HEAD22
16.11.07 00000.047 TCZ.      PF254 - CYCLE      2 ATTACHED FROM SN=SYSTEM
16.11.07 00000.071 USR.      STOP
16.11.07 00000.071 USR.      .028 CP SECONDS EXECUTION TIME
16.11.08 00000.073 JOB.      -ATTACH,FRATE,FRATE01,ID=JFC,MR=1.
16.11.08 00000.077 TCZ.      PF254 - CYCLE      1 ATTACHED FROM SN=SYSTEM
16.11.08 00000.077 LOD.      -FRATE.
16.11.18 00000.212 USR.      FORTRAN LIBRARY 433      05/11/77
16.11.42 00018.319 USR.      STOP
16.11.42 00018.319 USR.      18.106 CP SECONDS EXECUTION TIME
16.11.42 00018.319 JOB.      -EXIT,U.
16.11.42 00018.320 JOB.      -DISPOSE,OUTPUT,PR,ST=TCAI98.
16.11.42 00018.320 TCZ.      CYB01 - FILE OUTPUT DC=40 ST=TCAI98 SIZE=0000000350 IODB
16.11.57 00018.322 TCZ.      CYB01 - FILE CCRKA3M DC=04 ST=TCAI99 SIZE=0000000006 IODB
16.11.57 00018.324 TCZ.      CYB01 - FILE OUTPUT DC=40 ST=TCAI99 SIZE=0000000003 IODB
16.11.57 00018.324 TCZ.      RM770 - MAXIMUM ACTIVE FILES      1
16.11.57 00018.324 TCZ.      RM771 - OPEN/CLOSE CALLS      13
16.11.57 00018.324 TCZ.      RM772 - DATA TRANSFER CALLS      3,327
16.11.57 00018.325 TCZ.      RM773 - CONTROL/POSITIONING CALLS      12
16.11.57 00018.325 TCZ.      RM774 - BM DATA TRANSFER CALLS      735
16.11.57 00018.325 TCZ.      RM775 - BM CONTROL/POSITIONING CALLS      63
16.11.57 00018.325 TCZ.      RM776 - QUEUE MANAGER CALLS      121
16.11.57 00018.325 TCZ.      RM777 - RECALL CALLS      104
16.11.57 00018.326 TCZ.      SCM      743.750 KWS
16.11.57 00018.326 TCZ.      LCM      3 596.885 KWS
16.11.57 00018.326 TCZ.      I/O      0.044 MW
16.11.57 00018.326 TCZ.      RMS      0.169 MWS
16.11.57 00018.326 TCZ.      USER      17.882 SEC
16.11.57 00018.327 TCZ.      JOB      18.328 SEC
16.11.57 00018.327 TCZ.      DIO      320.840 KW
16.11.57 00018.327 TCZ.      SBU      23
16.11.57 00018.327 TCZ.      SC053 -      JOB PRIORITY - P4
READY.

```

TOFC TIME HISTORY PRINTER OUTPUT page 1

INPUT PARAMETERS FOR FRATE RUN NO. 300.06

TIME HISTORY RUN PARAMETERS

TIME HISTORY PRINT PLOT = T
 START TIME = 2.000
 DELTA T = .005
 STEP TIME = 30.000
 IGRGUP = 4
 IPRINT = 2
 OTHER = C

 DEBUG = F
 STARDB = 4.150
 STCPDB = 4.170

EXCITATION PARAMETERS

SINEIN = T
 AMP(I) = 1.000 0.000 1.000 1.000 0.000 1.000
 PHAS(I) = 0.000 0.000180.000 0.000 0.000180.000
 FC = 1.000
 FCDDT = .020
 BETA = 0.000
 DIN = .200
 VIN = 0.000
 GIN = 0.000
 NDECAY = 5000

MODEL PARAMETERS

NPAS = 7

 M = .2233E+C2 .2233E+02 .1250E+03 .8179E+01 .1527E+03 .7013E+01 .1489E+03 0. 0. 0.
 INERT = .2208E+05 .2208E+05 .1085E+06 .2000E+05 .2550E+06 .1715E+05 .1020E+06 .2940E+07 .3190E+07 .1500E+08
 .1500E+C8 .1310E+07 .1310E+07 0. 0.
 R = 58.000 79.000 58.000 79.000 62.250 43.500 62.250 43.500 108.000 0.000
 H = 16.000
 L = 792.000
 OR = 536.000 -536.000 -39.000 39.000 40.000 224.000 226.000 254.000 245.000 235.000

93

INPUT PARAMETERS FOR FRATE - CONTINUED -

K
 .9100E+05 .9500E+05 .9100E+05 .4800E+05
 .6000E+04 3. .2250E+06 .1500E+05
 .2250E+06 .1500E+05 .2250E+05 .1800E+05

XZKMDM = .3000E+08 XFKMDM = .3000E+08

KA6 = .9200E+07 KA12 = .9200E+07

Kb6 = .6185E+08 KB12 = .6185E+08

C
 .1500E+03 .2000E+02 .1500E+03 .1400E+03
 .2250E+03 0. .1000E+04 .5000E+03
 .1000E+04 .5000E+03 .3500E+03 .2000E+03

XZCMDM = .1000E+06 XRCMDM = .1000E+06

CA6 = .1000E+06 CA12 = .1000E+06

Cb6 = .7800E+06 CB12 = .7800E+06

VH = 60.400
 VH1 = 47.000
 VHIR = 47.000
 VHR = 37.800
 VL1 = 469.000
 VL2 = 148.000
 VL3 = 131.400
 VL4 = 189.700
 VL1R = -89.000
 VL2R = -413.000
 VL3R = 115.400
 VL4R = 208.600

GAPB = .0100 GAPA = .0100

NORMAL MODE PARAMETERS

NPCDES = 4
 FREQ = 4.253 8.873 9.417 9.629 15.519
 ZETA = .020 .020 .020 .020 .020
 NLGC = 46

94

.6000E+04	0.	.9100E+05	.9500E+05	.9100E+05	.4800E+05
.2250E+05	.1800E+05	.2250E+05	.5276E+05	.1800E+05	.5276E+05
.2250E+05	.5276E+05	.1800E+05	.5276E+05	0.	0.

.2250E+03	0.	.1500E+03	.2000E+02	.1500E+03	.1400E+03
.3300E+03	.2000E+03	.3300E+03	.7750E+03	.2000E+03	.7750E+03
.3300E+03	.7750E+03	.2000E+03	.7750E+03	0.	0.

15.599	18.029	0.000	0.000	0.000
.020	.020	0.000	0.000	0.000

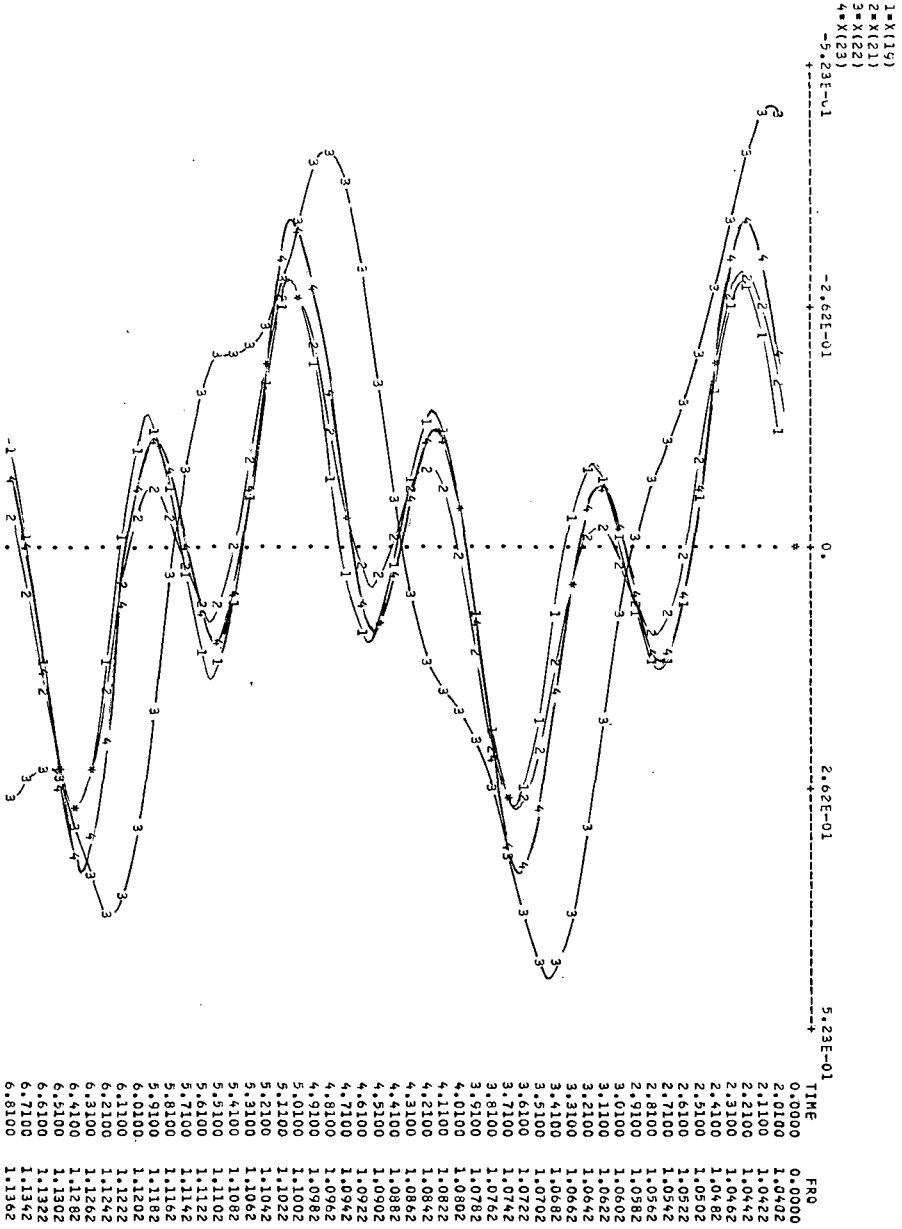
TOFC TIME HISTORY

Sample Printer Plot

FRATE RUN 333.06
 PRATE RUN 300.08

SWEEP RATE: FCDOT= .02C
 INPUT ACTION: GIN= .2CC

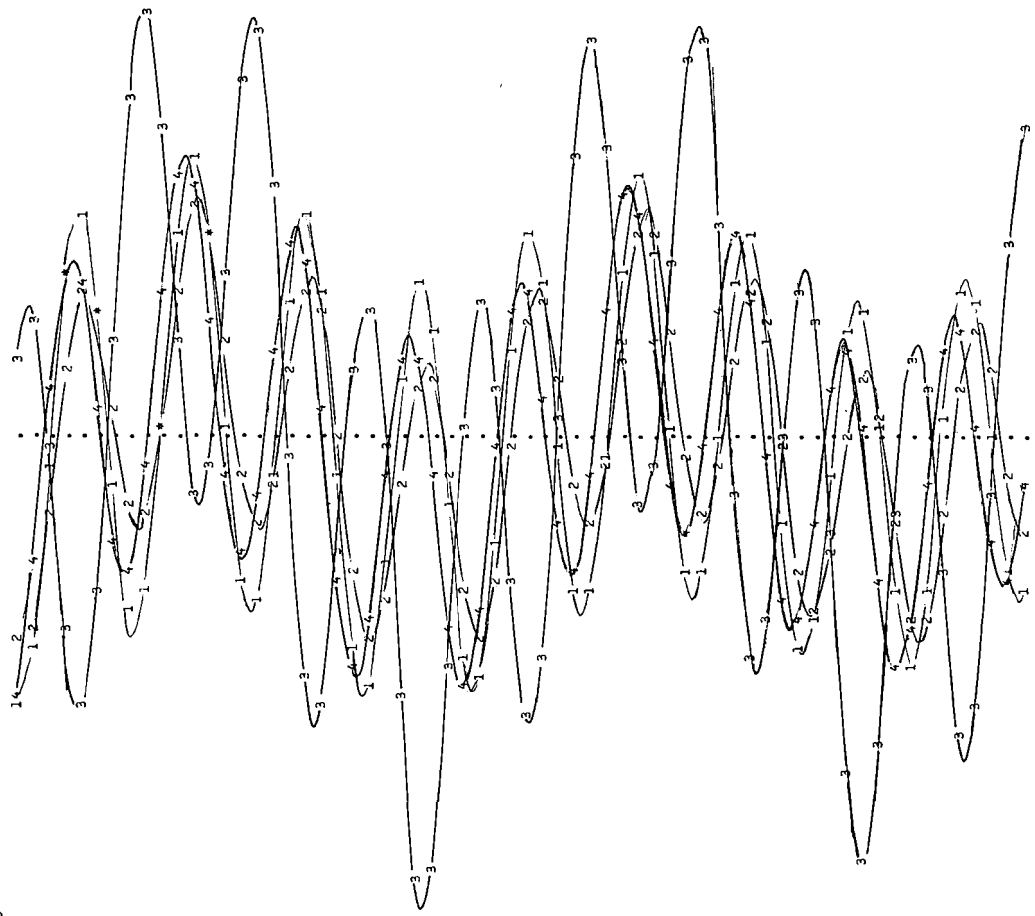
MULTIPLE PLOT TIME HISTORY



TIME	FRQ
0.0000	0.0000
2.0100	1.0402
2.1100	1.0422
2.2100	1.0442
2.3100	1.0462
2.4100	1.0482
2.5100	1.0502
2.6100	1.0522
2.7100	1.0542
2.8100	1.0562
2.9100	1.0582
3.0100	1.0602
3.1100	1.0622
3.2100	1.0642
3.3100	1.0662
3.4100	1.0682
3.5100	1.0702
3.6100	1.0722
3.7100	1.0742
3.8100	1.0762
3.9100	1.0782
4.0100	1.0802
4.1100	1.0822
4.2100	1.0842
4.3100	1.0862
4.4100	1.0882
4.5100	1.0902
4.6100	1.0922
4.7100	1.0942
4.8100	1.0962
4.9100	1.0982
5.0100	1.1002
5.1100	1.1022
5.2100	1.1042
5.3100	1.1062
5.4100	1.1082
5.5100	1.1102
5.6100	1.1122
5.7100	1.1142
5.8100	1.1162
5.9100	1.1182
6.0100	1.1202
6.1100	1.1222
6.2100	1.1242
6.3100	1.1262
6.4100	1.1282
6.5100	1.1302
6.6100	1.1322
6.7100	1.1342
6.8100	1.1362

TOFC TIME HISTORY (CONTINUED)
Sample Printer Plot

-523
+



- 1 = X(19)
- 2 = X(21)
- 3 = X(22)
- 4 = X(23)

19.6100 1.3922
19.7100 1.3942
19.8100 1.3962
19.9100 1.3982
20.0100 1.4002
20.1100 1.4022
20.2100 1.4042
20.3100 1.4062
20.4100 1.4082
20.5100 1.4102
20.6100 1.4122
20.7100 1.4142
20.8100 1.4162
20.9100 1.4182
21.0100 1.4202
21.1100 1.4222
21.2100 1.4242
21.3100 1.4262
21.4100 1.4282
21.5100 1.4302
21.6100 1.4322
21.7100 1.4342
21.8100 1.4362
21.9100 1.4382
22.0100 1.4402
22.1100 1.4422
22.2100 1.4442
22.3100 1.4462
22.4100 1.4482
22.5100 1.4502
22.6100 1.4522
22.7100 1.4542
22.8100 1.4562
22.9100 1.4582
23.0100 1.4602
23.1100 1.4622
23.2100 1.4642
23.3100 1.4662
23.4100 1.4682
23.5100 1.4702
23.6100 1.4722
23.7100 1.4742
23.8100 1.4762
23.9100 1.4782
24.0100 1.4802
24.1100 1.4822
24.2100 1.4842
24.3100 1.4862
24.4100 1.4882
24.5100 1.4902
24.6100 1.4922
24.7100 1.4942
24.8100 1.4962
24.9100 1.4982
25.0100 1.5002
25.1100 1.5022
25.2100 1.5042
25.3100 1.5062
25.4100 1.5082
25.5100 1.5102
25.6100 1.5122
25.7100 1.5142
25.8100 1.5162
25.9100 1.5182

FRA/OR&D SCIENTIFIC AND TECHNICAL REPORTS

1. Report Title: FRATE User's Manual, Vol. I
2. Report Author(s): George Kachadourian et. al.
3. Performing Organization: MITRE Corporation
4. Sponsoring OR&D Office & Program Manager: RRD-11, N. T. Tsai
5. Purpose of Report (Include whether this is a project in itself or is it a part of a larger program): This is the first volume of two volumes on the computer program FRATE for the analysis of railcar dynamic responses.
6. Intended Users: Railroad industry and other research organization.
7. Benefits to Users (Describe benefits to rail transportation from this report): Provide the computer program for the calculation of non-linear vehicle response to track irregularities.
8. Status of this Research (on-going or completed): on-going
9. Validity

Is the report soundly based in its research method and reasoning? Yes No

Are its conclusions properly supported? Yes No
10. Originality

Is the content new, novel or original in substance? Yes No
11. Sensitivity

Describe if the report has any sensitive issues affecting the industry competition, proprietary data, policy, regulation, legislation, etc. None

12. Publication

Is the report publishable in its present form? Yes No

Is there a need for urgency in its publication? Yes No

If yes, explain why _____

Does the abstract convey the report's meaning? Yes No

13. Recommendations for Publication: Should Be Published Should Not Be Published

14. Number of copies to be Published: 128

15. Distribution Recommendations: Limited Unlimited

Standard Mailing Lists: ZTR-15, FRA-18X, FRA-18GG, _____

Internal Report Recipients (Office Symbols): ZTR-15 _____

External Report Recipient Groups: FRA-18X, 18-GG _____

16. Report disposition & Final Action: _____

8/21/78

Date

Meng Tsai
Program Manager/COTR

8/21/78

Date

Chio Almazan
Cognizant Division Chief

Ronald E. Spanter
Office Director

FRATE, Volume I: Users' Manual, 1978
US DOT, FRA

512540 00 2835 2