FRA/ORD-81-54

USER'S MANUAL FOR FRATX1 AND FRATF1 FREIGHT CAR DYNAMIC ANALYSIS COMPUTER PROGRAMS

JULY 1981

PREPARED FOR
U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION
Office of Research and Development
Washington, D.C. 20590

Technical Report Documentation Page

1. Report No.
FRA/ORD-81-54

2. Government Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle
User's Manual for FRATX1 and FRATF1 Freight Car Dynamic Analysis Computer Programs

5. Report Date
July 1981

6. Performing Organization Code

7. Author(s)
George Kachadourian

8. Performing Organization Report No.
MTR-81W188

9. Performing Organization Name and Address

The MITRE Corporation
1820 Dolley Madison Boulevard
McLean, Virginia 22102

10. Work Unit No. (TRAIS)
Project 274L

11. Contract or Grant No.
~~DOT-FR-54090~~
DTFR53-82-C-00087
TO2.4.2

12. Sponsoring Agency Name and Address

U.S. Department of Transportation
Federal Railroad Administration
400 Seventh Street, S.W.
Washington, D. C. 20590

13. Type of Report and Period Covered
Technical Report

14. Sponsoring Agency Code
FRA-RRD-11

15. Supplementary Notes

16. Abstract

This is a user's manual for two versions of a computer program to calculate the dynamic response of freight cars to track inputs. The basic program is nonlinear, written in FORTRAN for Control Data Corporation (CDC) computers with solution in the time domain by numerical integration methods. The two versions are FRATX1, which is set up specifically for the analysis of boxcars, and FRATF1 which is for trailer on flatcar (TOFC) analysis. The program permits the user to perform time history analyses where various track profile variations can be simulated and the resulting freight car responses are calculated. The user can select from a large set of input and response functions for time history plotting by high speed printer.

17. Key Words

Freight Car Dynamic Response
Freight Car Model
Hunting Simulation
Dynamic Loads

18. Distribution Statement

19. Security Classif. (of this report)
Unclassified

20. Security Classif. (of this page)
Unclassified

21. No. of Pages

22. Price

Form DOT F 1700.7 (8-72)

Reproduction of completed page authorized

METRIC CONVERSION FACTORS

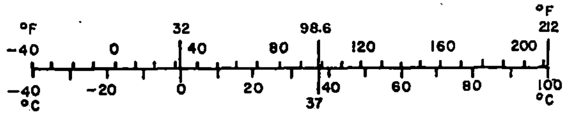
Approximate Conversions to Metric Measures

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

*1 in = 2.54 (exactly). 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.

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



ACKNOWLEDGEMENT

The basic "model" used in FRATE is an adaptation by M.J. Healy, Reference 1*, of work by D.R. Ahlbeck, Reference 2. Healy in his work compiled the basic computational program contained in FRATE.

The MITRE work has made significant changes to the truck model and to the trailer tandem model, and has added certain nonlinear features including Coulomb damping and incorporated printer plot sub-routine for results output.

---

*References are listed in Appendix A

TABLE OF CONTENTS

TABLE OF CONTENTS (Concluded)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Continued)

LIST OF ILLUSTRATIONS (Concluded)

LIST OF TABLES

LIST OF TABLES (Concluded)

1. INTRODUCTION

The computer program FRATE has been developed under the sponsorship of the Federal Railroad Administration (FRA) for the purpose of studying the response characteristics of freight cars. The general objective of its use is to define the response displacements, accelerations and loads of the freight car resulting from over-the-road input motions. This manual is an update of Reference 3 and it includes a simulation of boxcars as well as TOFC.

The need for the analysis capabilities provided by FRATE has grown out of the movement in the United States to heavy haul and high speed freight operations and the resulting detrimental effects on safety margins. FRATE can be used to study the dynamics of various freight car configurations and track geometry conditions. Loads on both track and freight can be determined and safety margins can be evaluated thus providing a means for defining and controlling operational safety margins. FRATE can also be used to evaluate innovations which are continually being tried and incorporated into freight cars as part of the regular program of maintenance and replacement. Analytical studies which aid in the development of these innovations can be done quicker and at less cost than development testing, thus saving time and money and resulting in a better final product.

The name FRATE is the acronym for Freight Car Response Analysis and Test Evaluation. Changes made to previous versions of FRATE include the addition of the option to have up to four, spring mounted lading masses and the elimination of other optional features (SNAPSHOT and ENVELOP) which were found to be of little use. There are two versions of FRATE covered in this manual: FRATF1 contains a trailer on flatcar (TOFC) simulation, and FRATX1 contains a boxcar simulation.

The computer program FRATE is a synthesis of models and analyses by Healy(1), Ahlbeck(2) and Abbott(4). However, the truck model is unique in this MITRE version of FRATE although it bears some similarity to an earlier Ahlbeck model. The MITRE truck model is discussed in Section 3.3. Wyle(5) has also continued to develop Healy's freight car model and currently has three versions. One they have named FRATE 11, which incorporates the basic eleven degree-of-freedom freight car model. The other two are named FRATE 17, and have the truck model expanded from one mass to two masses with a resulting 17 degree-of-freedom model. FRATE 11 and FRATE 17, Version 1, are inherently incapable of adequately simulating the nonlinear roll characteristics of the standard freight car. FRATE 17 Version 2 has this potential, but documentation is not available and an assessment cannot be made at this writing. It should also be noted that FRATE 17, with its two mass truck models, will require a shorter integration time step than FRATE 11 and the MITRE version of FRATE.

The MITRE versions of FRATX1 and FRATF1 of this manual are update of the version resulting from the validation effort of Reference 6, and contained in the Users' Manual, Reference 3. Changes which include the addition of some features and the elimination of others, are as follows:

a. The truck suspension in roll has been changed from bi-linear to tri-linear wherein center plate lift is simulated.

b. Friction snubbers have been added.

c. Hydraulic snubbers have been added.

d. The wheel and rail lateral stiffness has been made bi-linear to simulate conditions with and without flange contact.

e. Several options for input motion functions have been added; refer to Section 5.

f. Output options and formatting have been improved.

g. A lading model has been added.

h. The ENVELOP option has been eliminated. Envelope plots were condensed time histories in that only positive peak values were plotted instead of the continuous wave form. Plotted against frequency, this appeared as a transfer function. The option was dropped to reduce size, complexity, and cost.

i. The SNAPSHOT option has been eliminated also, because of its high cost and limited utility. SNAPSHOT provided oblique view deflection shapes of the TOFC configuration.

2. ANALYSIS PROCEDURE

Analyses using the computer program FRATE will consist of input motions at the wheel/rail interfaces and calculating responses of the freight car. By simulating various track geometry variations and varying the freight car configuration, extensive and informative studies of the freight car dynamic performance can be realized.

The FRATE programs of this manual have been set up for and are being used on the Control Data Corporation (CDC) 7600 computer. A basic assumption of this writing is that CDC will be used. However, the program is written in FORTRAN IV and conversion to other compatible computer systems can be done.

The programs are stored by the FRA, currently in the CDC system, both in FORTRAN and compiled and can be accessed by the user for running problems. If he chooses, the user may copy the program for use on his or any other computer system. Tape copies are also available through the National Technical Information Service, NTIS, Springfield, Virginia 22161.

The running of FRATF1 and FRATX1 requires the use of three files as shown in Figure 2.1. The executive file is short and simple. It calls the needed files and directs problem submission and output delivery.

The data file, FRADF1 or FRADX1, contains all the run and model information required by the four Namelists in FRATF1 or FRATX1. It is recommended that the user acquire the example data files contained in this manual, make modifications to model parameters of mass, dimensions, springs or dampers as needed to simulate the new vehicle and provide run information. Listing of the data files can be found in the example runs at the end of Section 4 and Section 5.

The main programs FRATF1 and FRATX1 should not need to be changed. Changes to the FRA copies on file (at CDC) are not permitted. If a user does have need to modify the main programs he must acquire his own copy and modify it.

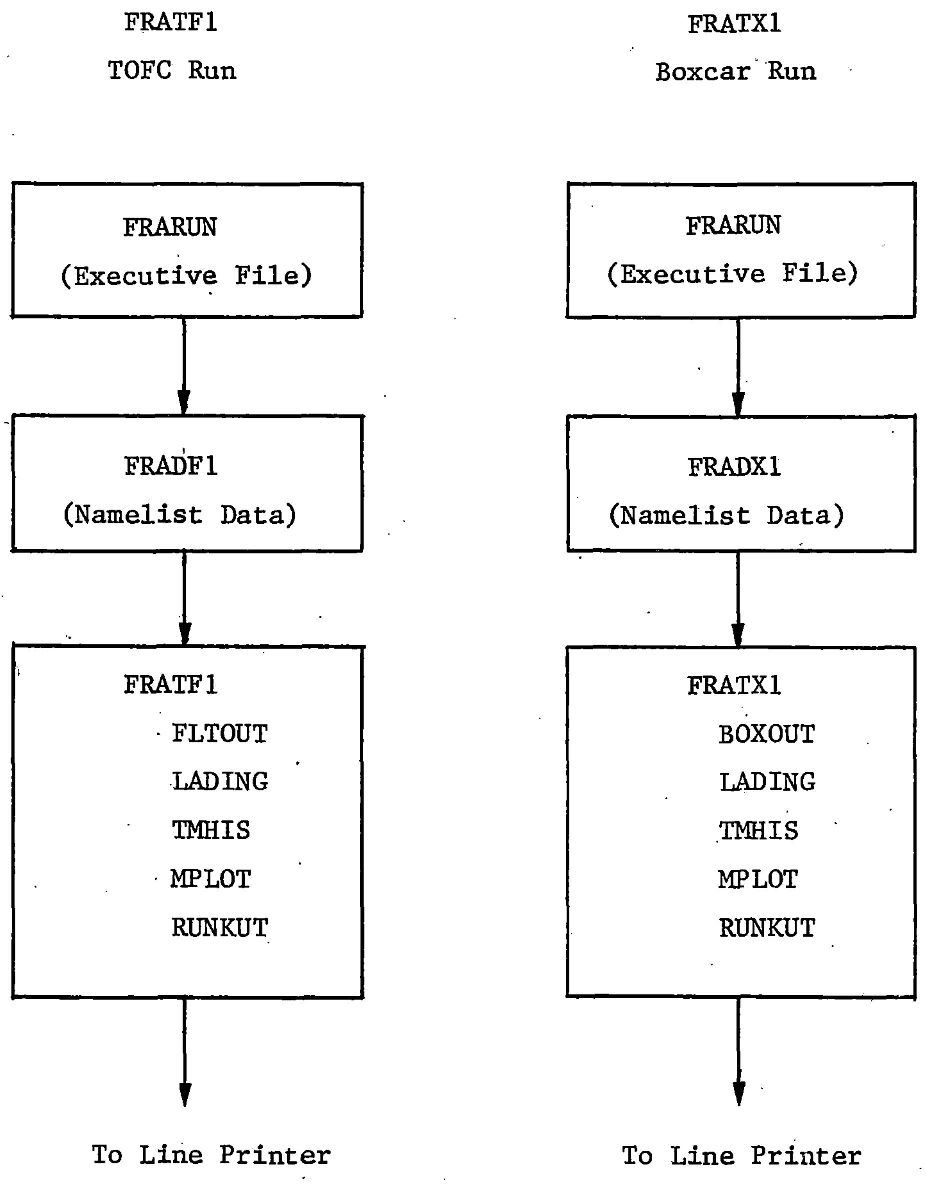


FIGURE 2.1. PROGRAM RUN PROCEDURE

The following procedure is recommended:

1. Access and copy the data file FRADF1 (or FRADX1). The files are available at CDC NOS (Rockville, Maryland) in the KB family and can be accessed and copied by the following commands:

   - GET, FRADF1/UN = ORTH1DC
   - SAVE, FRADF1

2. Modify data file to fit your analysis requirements.

3. Generate executive file as shown in Figure 2.2 with appropriate changes.

4. Submit run.

```
/JOB
XXXXXX,STTCZ,T200,P2.
ACCOUNT,XXXXXXXXXX.
ATTACH,HEADING,HEADING,MR=1.
HEADING.
ATTACH,LGO,FRATCF1,ID=JFC.MR=1.
LDSET,PRESET=ZERO.
LGO.
EXIT,U.
DISPOSE,OUTPUT,PR,ST=TCAI80.
/EOR
/NOSEQ
1DELIVER TO
  (NAME
    AND
     ADDRESS)
/EOR
/READ,FRADF1
/EOF
 -END OF FILE-
```

Insert Your Banner Name

Cyber 76

Cut Off Time = 200 Sec. Octal

Priority

Insert Your Account Number

Attaches Compiled Version
of FRATF1 Program

Rockville, Md. - Change As Needed

Reads Your Copy of the FRADF1 Data File

FIGURE 2.2. EXAMPLE EXECUTIVE FILE

3. DESCRIPTION OF FRATE

This section contains a general description of the computer program FRATE. Its objective is to give the user detailed information of the program. Much of the description is repeated in Section 4 which is for the FRATX1 version and Section 5 for the FRATF1 version.

3.1 Lumped Mass/Spring Connected Configuration

The intended usage of the computer program FRATE has, from its inception, been to include the nonlinear dynamic properties of freight cars. For this reason lumped mass modeling and numerical integration (time domain) method of solution were used. This manual contains two basic configurations: a three mass, 12 degrees of freedom boxcar model (which includes a body torsion mode and a seven mass, 31 degree of freedom TOFC model (which includes four flexible body modes). Each of these models has the option of including up to four spring mounted masses to simulate lading dynamics. This expands the boxcar model to seven masses and 24 degrees of freedom, and the TOFC to 11 masses and 43 degrees of freedom. With the TOFC model there are the additional options of eliminating one or both trailers.

All physical parameter values, i.e. mass, inertia, stiffness, damping and dimensions, are changeable with input data. Thus, FRATX1 can be used to simulate any freight car except when it is necessary to include body bending. IT is also possible to simulate a Container on Flatcar (COFC). Figures 3.1 and 3.2 are pictorial representations of the range of lumped mass variations available to the user with FRATX1 and FRATF1.

3.2 Flow Chart

FRATE is a digital computer program which solves a set of coupled nonlinear differential equations in the time domain. Solution is obtained using a Runge-Kutta numerical integration procedure. A flow chart of the computer program is shown in Figure 3.3. The program is seen to have three basic stages: the first stage consists of reading in the input data and defining necessary initial conditions and constants. The time integration is performed in stage 2; and the output data is prepared for plotting and plotted in the third stage. The integration is accomplished with two loops: the inner loop (through RUNKUT) is circuited four times for each time step and each time dependent function; after the fourth circuit, the inner loop is exited and the second loop is followed wherin the output data is calculated

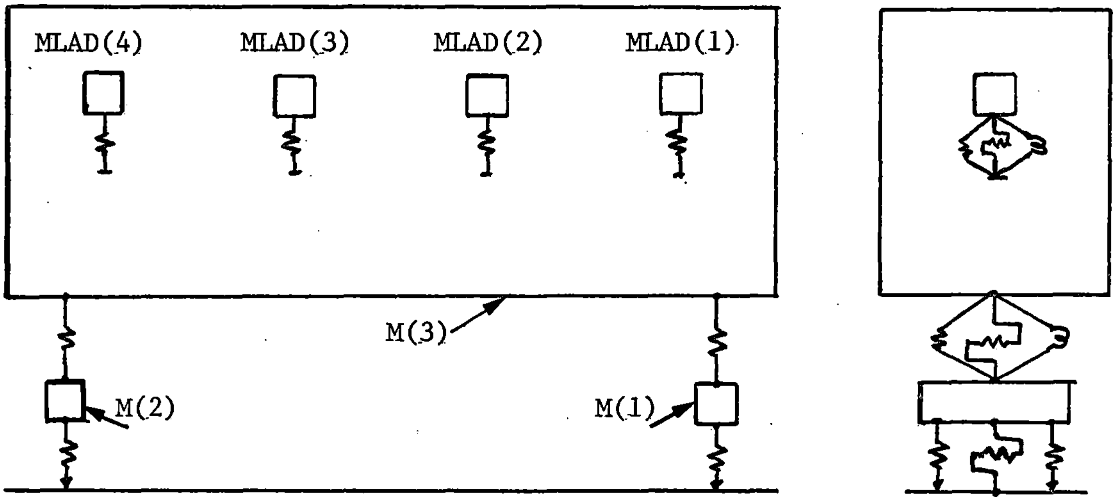
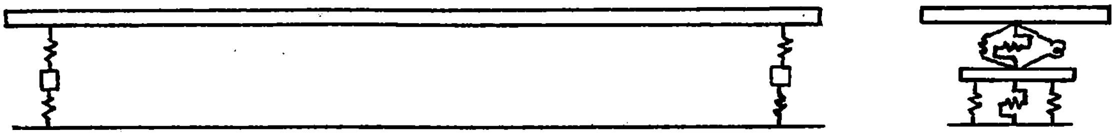
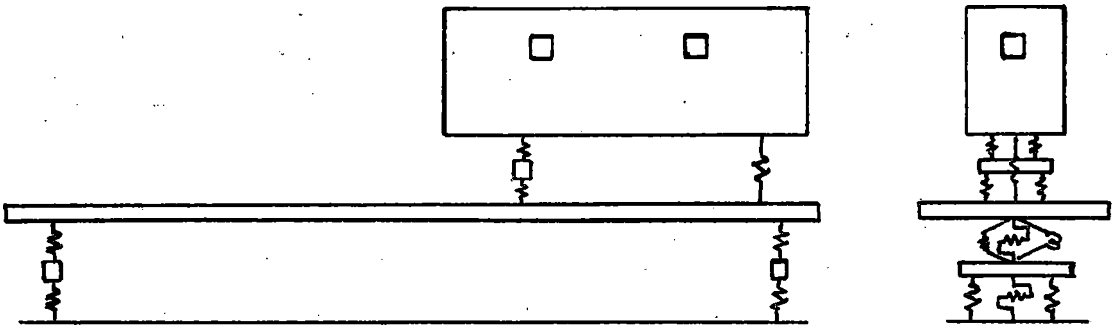


FIGURE 3.1. FRATX1 LUMPED MASS CONFIGURATION

a. Empty, Flexible Flatcar - NMAS = 3



b. Flatcar and One Trailer - NMAS = 5



c. Flatcar and Two Trailers - NMAS = 7

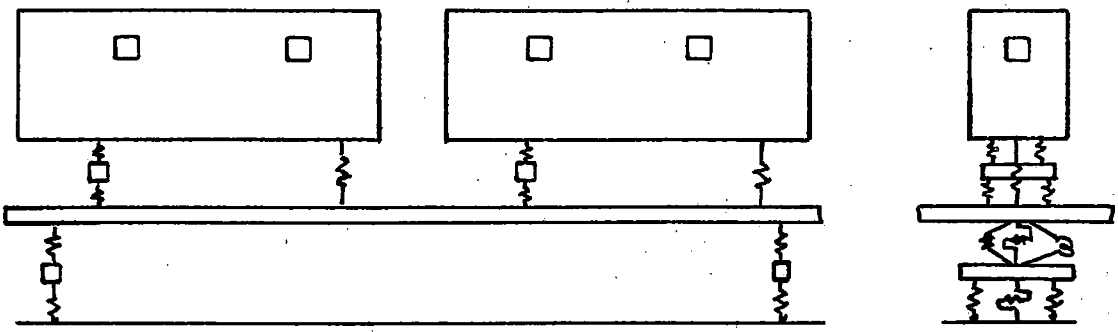


FIGURE 3.2. FRATF1, TRAILER ON FLATCAR LUMPED MASS CONFIGURATIONS

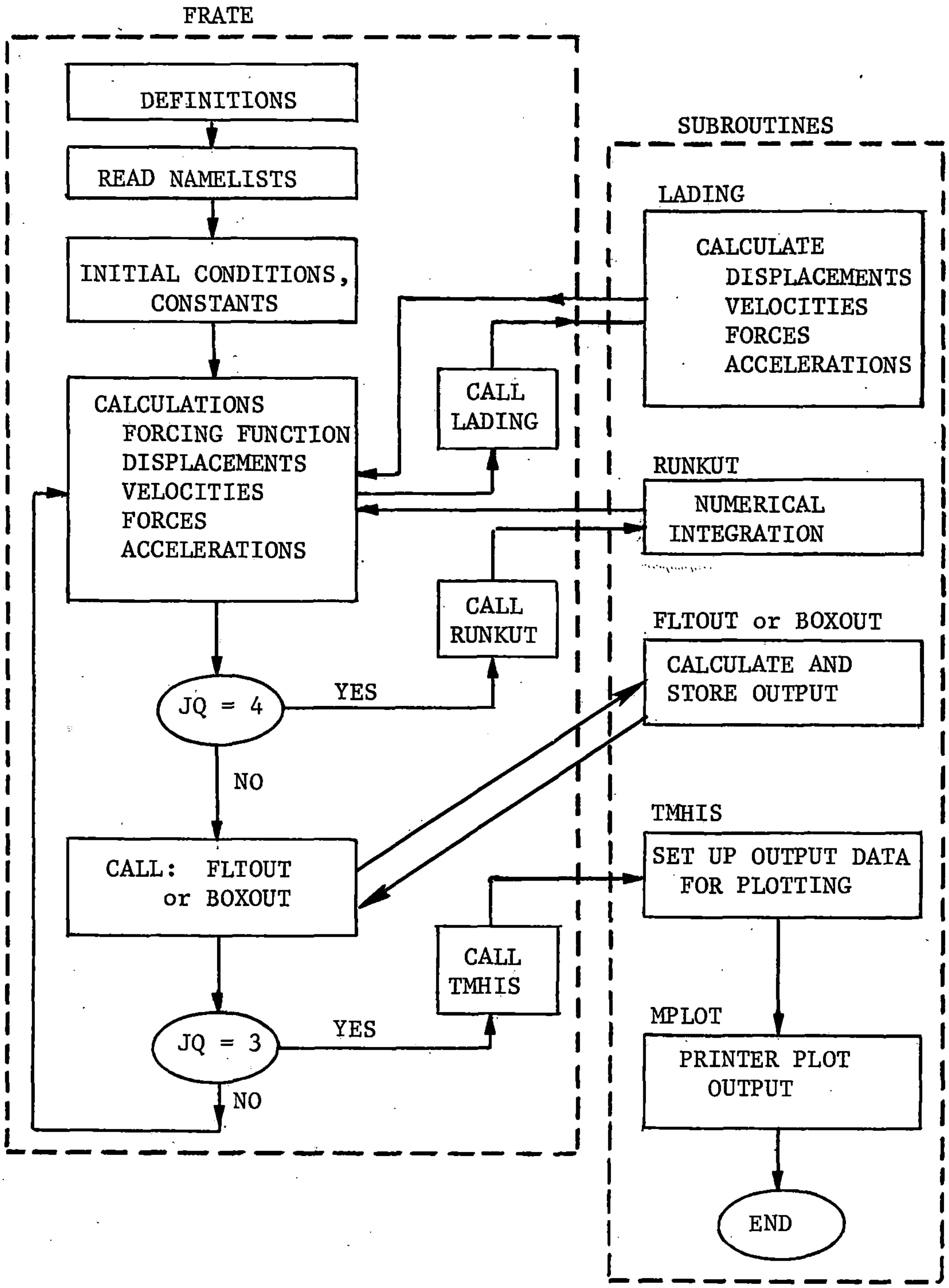


FIGURE 3.3. PROGRAM FLOW CHART

and stored in a data array. After stop time has been reached the stored data is processed through subroutine TMHIS and MPLOT and output on a line printer.

The flow chart applies to both FRATE versions of this manual. The version FRATF1, for trailer on flatcar (TOFC), can have a maximum of 43 degrees of freedom. FRATX1, which is for boxcars, will have 24 degrees of freedom at most. The two versions differ only in that unneccesary equations of motions have been eliminated in FRATX1 and in that the output subroutines are different.

3.3 Special Features

This section discusses in detail some of the special features of FRATE. The information will be useful in understanding the capabilities and limitations of the program.

3.3.1 Nonlinear Truck Roll

Roll motion of a freight car is very nonlinear. For small roll angles, the motion is primarily one of rocking on the center plate with relatively small motions of the truck bolsters (Figure 3.4a). For larger roll angles, the side bearings will make contact, on alternate sides, and the carbody and truck bolster will be moving together with all the relative motion taken up in the truck springs (Figure 3.4b). As the amplitude of the roll motion continues to increase, there will occur either wheel lift at the rail (Figure 3.4c) or separation at the center plate (Figure 3.4).

Although wheel lift and center plate lift can occur simultaneously, it is not probable. Center plate lift will occur with empty or lightly loaded freight cars with relatively high center of gravities. When center plate lift occurs, the resulting loading conditions tend to preclude wheel lift. Conversely, if wheel lift occurs first, the center plate lift condition is usually avoided.

The spring/dampers 4, 5 and 6 in the B truck and 10, 11 and 12 in the A truck (see Figure 3.5a) simulate the truck suspension system and include the above-mentioned nonlinear aspects due to the center plate and side bearing. This portion of the model is critical to the roll, yaw and lateral simulation and is a basic deviation from the modeling of Healy(1) and Ahlbeck(2). Spring/dampers 4 and 10 are vertical, 5 and 11 are lateral and 6 and 12 are roll. The objective of separating the spring functions in this manner is to be able to assign nonlinear properties that are peculiar to the roll motions of the car.

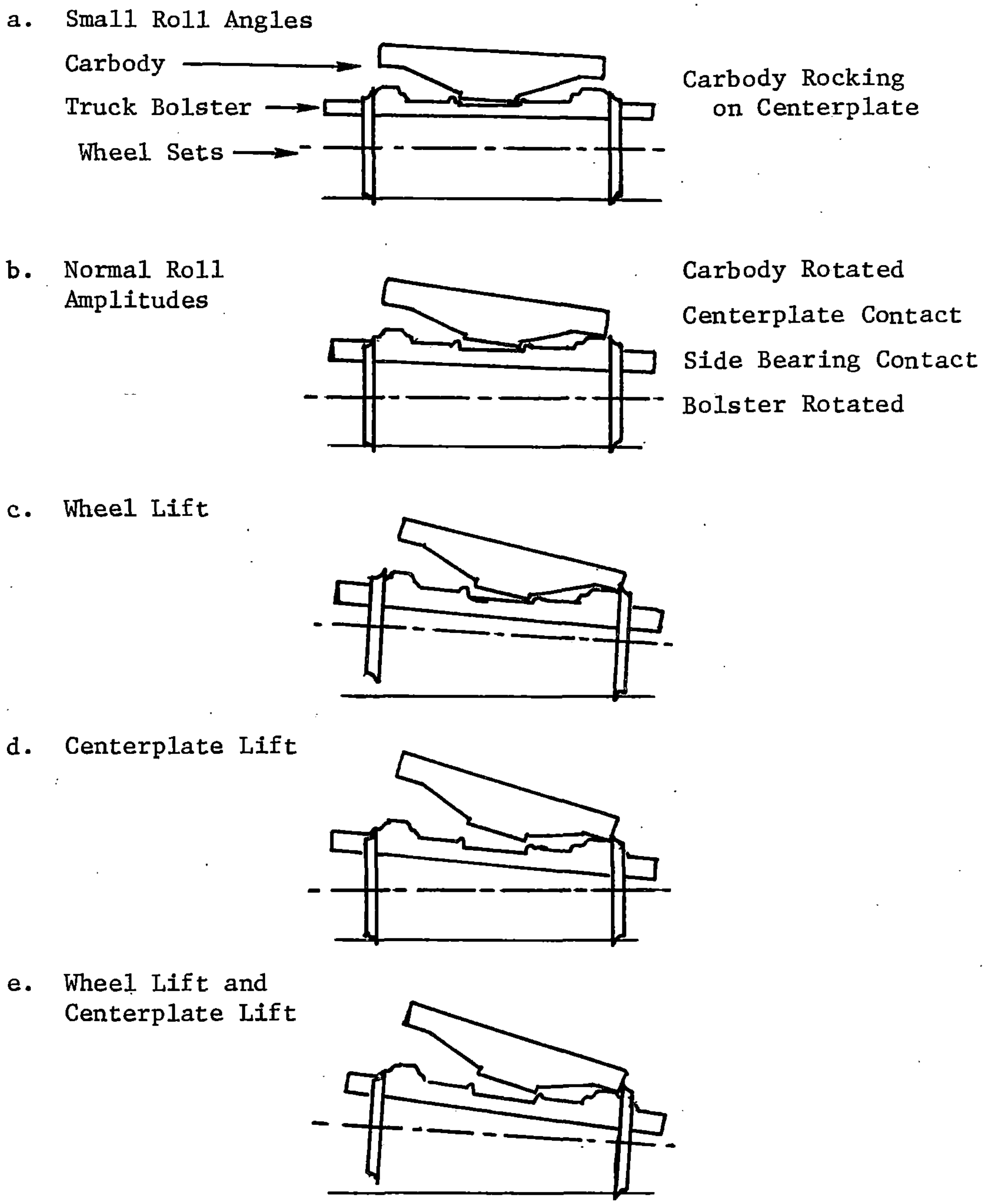
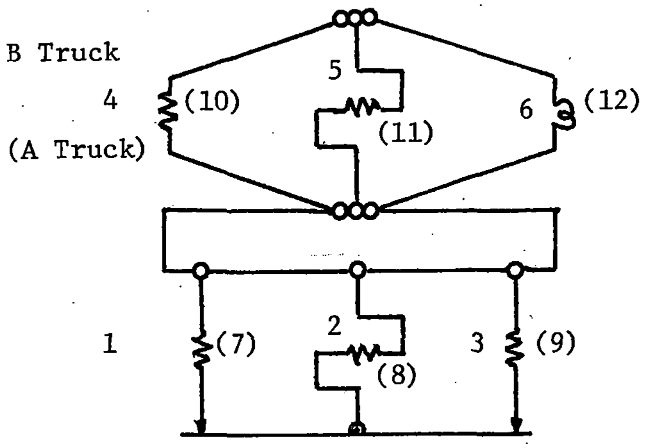
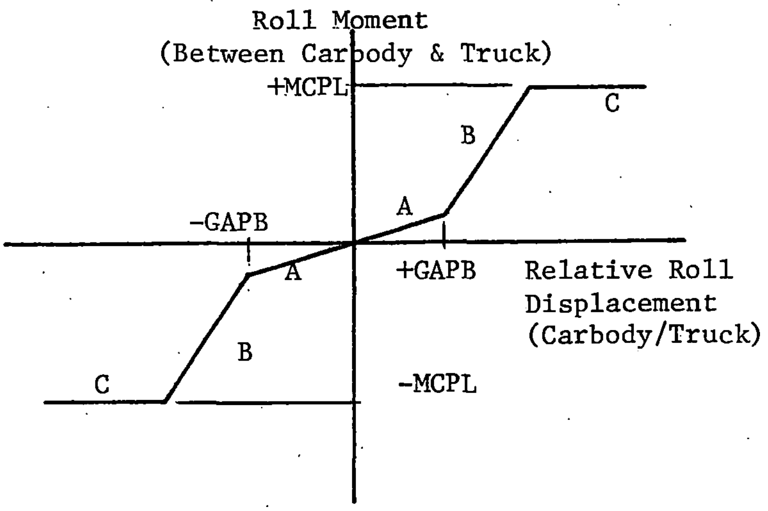


FIGURE 3.4. FREIGHT CAR ROCKING MOTIONS

a. Spring Damper Notation



b. Load Deflection Diagram



A-A Center plate Rocking Before Side Bearing Contact
B-B Side Bearing Contact Has Been Made
C-C Center plate Has Lifted

FIGURE 3.5. TRUCK ROLL LOAD DEFLECTION DIAGRAM, WITHOUT SNUBBERS

The roll spring rate is divided into three regions: before side bearing contact, after side bearing contact and after center plate lift. The angle at which side bearing contact is made is a function of side bearing gap. The roll moment resulting in center plate lift, MCPL, is a function of the gravity force and the lateral distance from carbody centerline to the side bearing. Figure 3.5 is a load deflection diagram, not drawn to scale, which pictorially describes the nonlinear roll spring rate. The equations for the B truck, F(6), for each region are shown below for roll conditions A, B and C (refer to Figure 3.5).

Path A-A

F(6) = (DISP(11) - DISP(12)) * KCP6 + (VEL(11) - VEL(12)) * CCP6

Path B-B

F(6) = GAPBS * KCP6 + (DISP(11) - DISP(12) - GAPBS) * K(6) + (VEL(11) - VEL(12)) * C(6)

Beyond C

F(6) = MCPL

where:

DISP(11), DISP(12), VEL(11) and VEL(12) are the displacements and velocities of the attachment points of spring/damper number (6), radians and radians/second.

KCP6 = roll spring constant with center plate rocking motion, in.lb./rad.

CCP6 = roll viscous damping with center plate rocking motion, in.lb./rad./sec.

GAPBS = side bearing gap (with proper sign) each side with equal gap B truck, radians.

K(6) = roll spring constant of truck suspension, in.lb./rad.

C(6) = roll viscous damping of truck suspension (does not include snubbers), in.lb./rad./sec.

MCPL = C1 * (R(10)/2.) = the moment required lift carbody off center plate , in.lb.

C1 = dead weight of carbody at B truck, lbs.

R(10) = transverse distance between side bearings, inches.

3.3.2 Snubbers, Friction and Hydraulic

Coulomb damping has been incorporated into FRATE using the sliding spring concept used by Abbott(4) and Heller(7). The FRATE adaptation has four spring damper elements in parallel as shown in Figure 3.6: a stiffness, K, representing the stiffness of the truck suspension system, a viscous damper, C, representing damping within the system other than snubbers, a local structure spring, KS, and a hydraulic snubber, CHS. The spring and damper K&C, are active full time. The spring KS will load up to the value MFS (force friction snubber) and hold constant at MFS to the end of the stroke. When the motion reverses, the spring KS will unload and load up in the opposite direction until MFS (opposite sign) is reached. The hydraulic snubber is programmed to be in effect on down stroke and zero on up stroke.

In the case of the vertical truck spring/dampers K(4), B truck and K(10), A truck, the load deflection diagram of Figure 3.7 applies. In a typical vertical oscillatory motion the approximate load deflection path will be A-B-C-D. The equations for F(4) for each leg are shown below. If the force F(4) becomes negative, it is reset equal to zero, where positive is compression.

Path A-B

```
     F(4) = (DISP(7) - DISP(8)) * (K(4) + KS4)
            + (VEL(7) - VEL(8)) * (C(4) + 2*CHS4)
```

Path B-C

```
     F(4) = (DISP(7) - DISP(8)) * K(4) + MFS4
            + (VEL(7) - VEL(8)) * (C(4) + 2*CHS4)
```

Path C-D

```
     F(4) = (DISP(7) - DISP(8)) * (K(4) + KS4)
            + (VEL(7) - VEL(8)) * C(4)
```

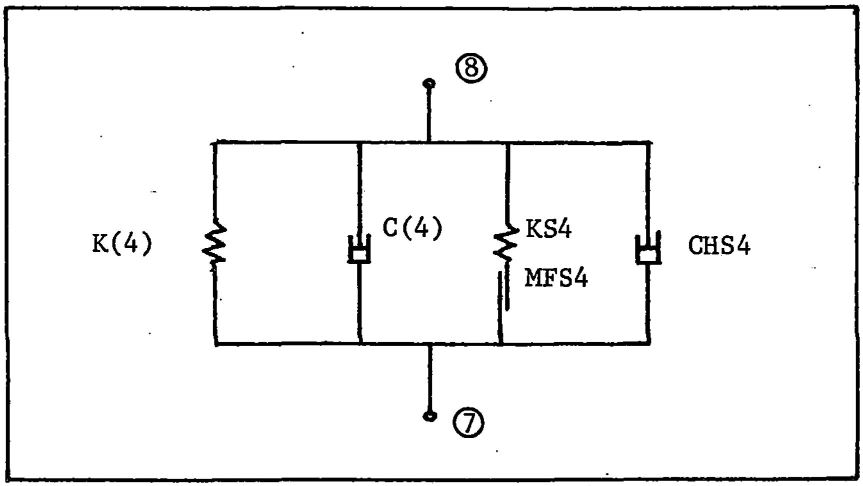


FIGURE 3.6. SPRING DAMPER SCHEMATIC, B TRUCK VERTICAL SUSPENSION

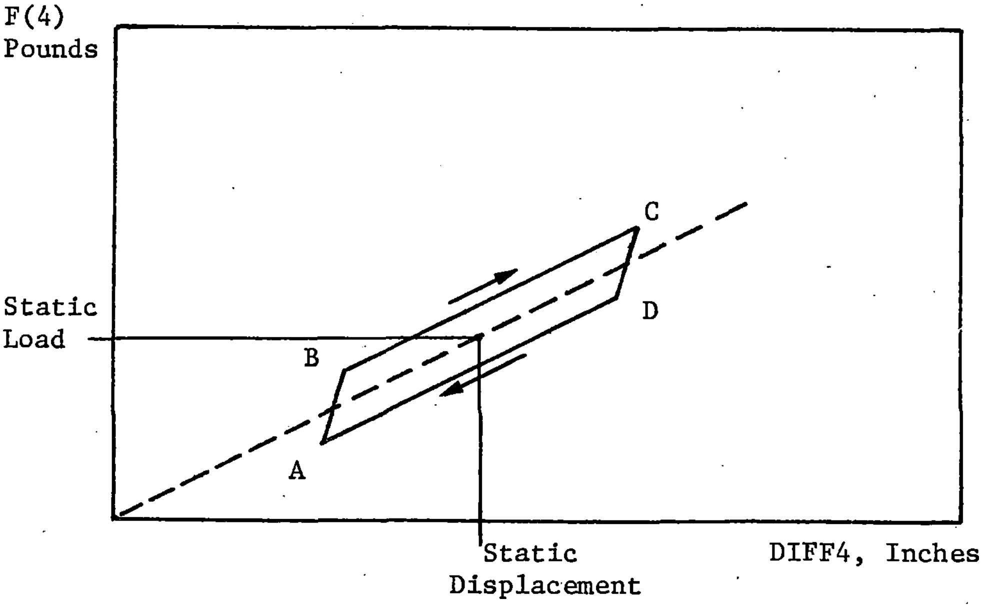


FIGURE 3.7. LOAD DISPLACEMENT DIAGRAM FOR B TRUCK VERTICAL SUSPENSION SYSTEM

Path D-A
F(4) = (DISP(7) - DISP(8) * K(4) - MFS4
+ (VEL(7) - VEL(8)) *C(4)

where:

DISP(7), DISP(8), VEL(7), VEL(8) = displacement and velocity of the connection points of spring/damper number (4), in., and in./sec. See Figure 3.6.

K(4) = spring constant, vertical, B truck suspension, lb./in.

KS4 = Spring constant, vertical, structure local to friction snubber, lb./in.

C(4) = viscous damper, vertical, B truck suspension (does not include snubbers), lb./in./sec.

CHS4 = 2*CHSB = vertical component of hydraulic snubber, lb./in./sec.

MFS4 = 2*FFSB = vertical component of friction snubber force, lb.

The truck roll snubbers are programmed as shown schematically in Figure 3.8. Neither of the snubbers (friction and hydraulic) are active between points A, -A and beyond points C, -C. For these regions, the force equations are the same as shown for Figure 3.5. The snubbers are activated in the regions ABCD and A-B-C-D. The corresponding force equations for F(6) are shown below.

Path A-B
F(6) = GAPBS * KCP6
+ (DISP(11) - DISP(12) - GAPBS) *(K(6) + KS6)
+ (VEL(11) - VEL(12) * (C(6) + CHS6))

Path B-C
F(6) = (DISP(11) - DISP(12)) * KCP6 + MFS6
+ (DISP(11) - DISP(12) - GAPBS) * K(6)
+ (VEL(11) - VEL(12)) * (C(6) + CHS6))

Beyond C
F(6) = MCPL

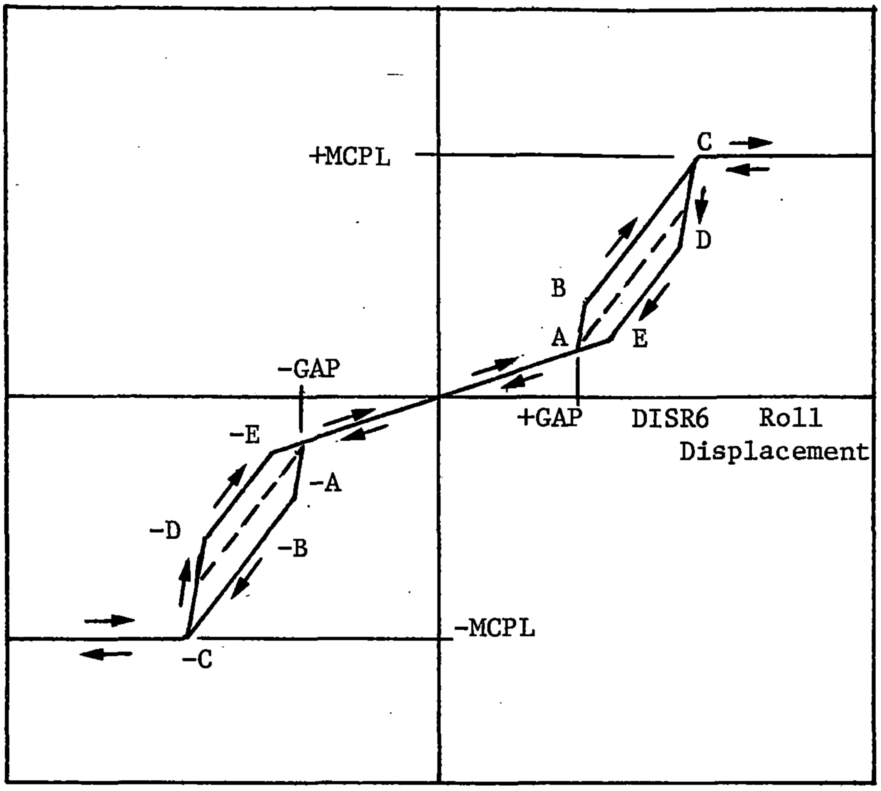


FIGURE 3.8. TRUCK ROLL LOAD-DISPLACEMENT DIAGRAM, WITH SNUBBERS

Path C-D

```
F(6) = GAPBS * KCP6
     +(DISP(11) - DISP(12) - GAPBS) * K(6)
     +(DISP(11) - DISP(12) -DISR6) * KS6
     +(VEL(11) - VEL(12)) * C(6)
```

Path D-E

(Same as B-B, Section 3.3.1)

```
F(6) = GAPBS * KCP6 + (DISP(11) - DISP(12) - GAPBS) * K(6)
       + (VEL(11) - VEL(12)) * C(6)
```

Path E-A-A-E

(Same as A-A Section 3.3.1)

```
F(6) = (DISP(11) - DISP(12)) * KCP6
       + (VEL(11) - VEL(12)) * CCP6
```

where:

CHS6 = CHSB * $(R(11)/2.)^2$ = viscous damping rate of hydraulic snubber for B truck in roll, in.lb./rad./sec.

MFS6 = FFSB * R(12)/2. = roll moment in B truck due to friction snubber, lb.in.

R(11) = transverse distance between hydraulic snubbers, in.

R(12) = transverse distance between friction snubbers, in.

All other terms as defined in section 3.3.1.

3.3.3 Nonlinear Hunting Motion Simulation

FRATE does not predict the occurrence of hunting. It assumes a hunting condition exists and predicts the force and motion responses of the freight car configuration being analyzed. The analysis consists of sinusoidal forces, applied laterally to each truck mass, that are representative of creep forces. The forces at the A and B truck would normally be phased to simulate a hunting condition coupled with body yaw motion. The wheel-rail lateral stiffness is made bilinear, representative of before and after flange contact. The input creep forces are, arbitrarily, made large enough to force the desired amplitudes of motion of the truck. The output results of interest are the amplitudes of carbody and lading motions, forces at the wheel-rail interface, and acceleration loading on the lading.

3.3.4 Forcing Function Options

The forcing functions presently available in FRATE are lateral forces acting on the truck masses to simulate a hunting condition, and vertical and lateral displacements at the wheel-rail interface to simulate track geometry variations. There are four options available:

1. SINEIN - for sinusoidal input.
2. RECSIN - for rectified sine input.
3. PULSE - for a (1-cos) shaped track anomaly input.
4. HUNT - for lateral creep force input.

The vector amplitudes of SINEIN, RECSIN and HUNT can also be varied by a (1-cos) or an exponential function. With the (1-cos) function one can, for example, apply a sine function that varies in amplitude from zero to a maximum and back to zero. With the exponential shape, the forcing function can be brought up to full amplitude gradually.

A detailed description of the forcing function options and how they are used is given in Section 6.

3.3.5 Body Flexibility

Carbody flexibility is included by a superposition of normal modes of the free-free carbody, i.e. separated from the trucks with no external restraints. Input data required are the normal mode frequencies and deflection coefficients normalized for unit modal mass. Deflection coefficients are required for the points where each spring attaches to the carbody. The normal modes, which are determined separately from FRATE, are for the carbody and cargo assumed rigidly attached in a free-free boundary condition, i.e. less trucks.

For FRATF1, in which a flatcar is simulated, the first four body modes have been included. The predominant motions in each mode are: mode 1, vertical bending; mode 2, lateral bending with torsion; mode 3, torsion with lateral bending; and mode 4, second vertical bending. Since boxcars are relatively stiff, only the first body torsion mode has been included in FRATX1. Development of the torsion mode is in Section 4.4.

3.3.6 Program Output

Program output listing contains five types of data. First, all input data is listed by Namelist group but with lading model parameters listed separately. Second, the initial deflections of the vertical and pitch degrees of freedom are listed. Third, if there are any spring forces reset to zero in the run solution (i.e. separations), the first 100 separations are listed by spring number and time of occurrence. Fourth, if DEBUG output has been requested it will be listed at this point. Finally, time history plots of selected data are plotted.

DEBUG is a listing of the value of every degree of freedom for each DELTAT time step within the DEBUG time interval requested. Its intended use is as an aid in trouble shooting. DEBUG output can be voluminous; a start-stop DEBUG interval of 0.10 seconds with a DELTAT of .005 will result in 20 pages of computer printout It is consequently recommended that DEBUG be used sparingly. Example DEBUG printouts are given in the example runs at the end of Sections 4 and 5. The time history plots are provided in superimposed sets of four. The FRATF1 program contains a 20 group selection. The FRATX1 has 15 option groups. Specific detailed information on the output time history plots is given in Sections 4.3 and 5.3.

3.4 Namelist/Input Data

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 parameter 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 3-1. 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 3-1 - 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 Mechanical Properties (Masses, Moments of Inertia, Geometries and Spring and Damping Constants)
MODAL	Parameters Defining Railcar Flexibility

Table 3-1 lists the four Namelists in the input data file in their proper order with a brief description of each. This is followed by four tables describing each parameter in each Namelist; Table 3-2 for Namelist CONTRL, Table 3-3 for Namelist EXCIT, Table 3-4 for Namelist VEHIC and Table 3-5 for Namelist MODAL. Examples of Namelist input data for FRATX1 and FRATF1 are given in Section 4.2 and 5.2.

TABLE 3-2 - DESCRIPTION OF NAMELIST CONTRL PARAMETERS

Parameter Name	Type*	Default Value	Description and Comment
RUNO	R	0.0	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 Generally Set Equal to 1.0 or 2.0 sec.
DELTAT	R	0.005	Integration Stepsize, sec.--DELTAT = 0.005 Has Been Found to be Close to the Upper Limit--A Smaller Value May Be Needed with Nonlinear Effects Such as Wheel Lift
STOPTM	R	3.0	Simulation Stop Time, sec.
IPRINT	I	1	Used to Define Output Time Interval for Time History Plots--Time History Print Interval in Number of Integration Steps is: NPRINT = IPRINT * IPRINT where: NPRINT Is the Number of Time Steps Between Printings IPRNT Is Print Schedule Dependent on FREQ, the Excitation Frequency IPRNT = 16./FREQ = 10 (Whichever is Smaller)
IPLOT			Identifies Groups of Output Functions to be Calculated for Time History Plots, with Four Functions Per Plot--See Sections 4.3 and 5.3 for Definitions of Output Functions
FRATX1	I(15)	15x0	
FRATF1	I(20)	20x0	
DEBUG	L	FALSE	If Set--TRUE--Printed Calculations for Debugging Are Output During the Time Interval STARDB to STOPDB
STARDB	R	100.0	Start Time for Debug Output, sec.
STOPDB	R	100.0	Stop Time for Debug Output, sec.

---

*Variable Type Definitions

R = Real
R( ) = Real, Array
I = Integer
L = Logical

TABLE 3-3 - DESCRIPTION OF NAMELIST EXCIT PARAMETERS

Parameter Name	Type*	Default Value	Description and Comment
SINEIN	L	.TRUE.	If Set .FALSE. Will Bypass Sinusoidal Forcing Function Calculations
RECSIN	L	.FALSE.	Rectified Sine Forcing Function--Gives Precedence to SINEIN
AMP	R(6)	1.0, 0.0, 1.0, 1.0, 0.0, 1.0	Input Amplitude Multiplier for Each of the Excitation Functions at Wheel-Rail Interfaces of Railcar Trucks at Node Points 1, 3, 5, 13, 15 and 17 Respectively--Nondimensional Factor
PHAS	R(6)	0.0, 0.0, 180.0, 0.0, 0.0, 180.0	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	0.0	Linear Frequency Sweep Rate for the Excitation Function, Hz/sec., + for Increasing/- for Decreasing Frequency
BETA	R	0.0	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 STOPTM, Cycles
DIN	R	0.25	Displacement Amplitude of Input Forcing in., 0 peak--Takes Precedence Over VIN and GIN
VIN	R	0.0	Velocity Amplitude of Input Forcing Function, in./sec, 0 peak--Takes Precedence Over GIN
GIN	R	0.0	Acceleration Amplitude of Input Forcing Function, g's, 0 peak
PULSE	L	.FALSE.	For Transient Input Due to Track Anomaly

TABLE 3-3 - DESCRIPTION OF NAMELIST EXCIT PARAMETERS (CONCLUDED)

Parameter Name	Type	Default Value	Description and Comment
BFRONT	L	.FALSE.	Direction of Car Motion With PULSE
PL	R	20.0	Pulse Length in Feet, Shape is 1-cosine
SPEED	R	44.0	Track Speed at PULSE Encounter, feet/second
S1	R	1.0	Shape is Constant
S2	R	0.0	Shape is (1-cos(TH/S2))/2
S3	R	0.0	Shape is (1-EXP(-3.0*FQ*/S3))
HUNT	L	.FALSE.	For Hunting Motion Simulations
FCRB	R	200.00	Lateral Creep Force Vector Applied to B Truck, lbs.
FCRA	R	200.00	Lateral Creep Force Vector Applied to A Truck, lbs.
PHASB	R	0.0	Phase Angle of FCRB, Degrees
PHASA	R	0.0	Phase Angle of FCRA, Degrees

TABLE 3-4 - DESCRIPTION OF NAMELIST VEHIC PARAMETERS

Parameter Name	Type	Default Value	Description
NMAS	I	3.0	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			Mass of Lumped Mass Elements, lbs. lbs. sec.^{2}/in.
FRATX1	R(3)	3x0.0	M(1) - B End Truck
FRATF1	R(7)	7x0.0	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			Moment of Inertia of Lumped Mass Elements, in. lbs. sec.^{2}
FRATX1	R(5)	5x0.0	I(1) - B End Truck, Roll
FRATF1	R(13)	13x0.0	I(2) - A End Truck, Roll
			I(3) - Railcar Carbody, Roll
			I(4) - Railcar Carbody, Pitch
			I(5) - Railcar Carbody, Yaw
			I(6) - B End Trailer Tandem, Roll*
			I(7) - B End Trailer, Roll*
			I(8) - B End Trailer, Pitch*
			I(9) - B End Trailer, Yaw*
			I(10) - A End Trailer Tandem, Roll*
			I(11) - A End Trailer, Roll*
			I(12) - A End Trailer, Pitch*
			I(13) - A End Trailer, Yaw*
R(I)	R(14)	14x0.0	Transverse Distances, in.
			R(1) - Between Truck Wheels, B End
			R(2) - Between Truck Spring Nest Centers, B End
			R(3) - Between Truck Wheels, A End
			R(4) - Between Truck Spring Nest Centers, A End
			R(5) - Between Trailer Tandem Wheels B Trailer*
			R(6) - Between Tandem/Trailer Attachment Points, B Trailer*
			R(7) - Between Trailer Tandem Wheels, A Trailer*
			R(8) - Between Tandem/Trailer Attachment Points, A Trailer*
			R(9) - Width of Railcar Carbody
			R(10)- Transverse Distance Between Side Bearings
			R(11)- Transverse Distance Between Hydraulic Snubbers
			R(12)- Transverse Distance Between Friction Snubbers
			R(13-14) - Not in Use
H/2	R	8.0	Vertical Distance from Centerplate to Carbody, C.G., in.

TABLE 3-4 - DESCRIPTION OF NAMELIST VEHIC PARAMETERS (CONTINUED)

Parameter Name	Type	Default Value	Description
HTRK	R	9.0	Vertical Distance From Axle to Centerplate, in.
HAXL	R	16.5	Axle Height, From Top of Rail, in.
VH	R	49.5	B End Trailer Height, in.*
VH1	R	54.4	Distance From Railcar Top Surface of B End Trailer Bottom, in.*
VL1	R	469.0	Distance From Railcar Center of Gravity to B End Trailer Hitch Point, in.*
VL2	R	109.0	Distance From Railcar Center of Gravity to B End Trailer Tandem, in.*
VL3	R	156.0	Distance From B End Trailer Suspension Point to Trailer Center of Gravity, in.*
VL4	R	204.0	Distance From B End Trailer Hitch Point to Trailer Center of Gravity, in.*
VHR	R	49.5	A End Trailer Height, in.*
VHIR	R	54.4	Distance From Railcar Top Surface to A End Trailer Bottom, in.*
VL1R	R	-85.0	Distance From A End Trailer Hitch Point to Railcar Center of Gravity, in.*
VL2R	R	-445.0	Distance From A End Trailer Tandem to Railcar Center of Gravity, in.*
VL3R	R	156.0	Distance From A End Trailer Suspension Point to Trailer Center of Gravity, in.*
VL4R	R	204.0	Distance From A End Trailer Hitch Point to Trailer Center of Gravity, in.*
L	R	792.0	Longitudinal Distance Between Railcar Truck Centerlines, in.
OR(I)	R(10)	10x0.0	Longitudinal Distances Used in Response Output Calculations, in. OR(1) - From Carbody C.G. to B End of Carbody OR(2) - From Carbody C.G. to A End of Carbody OR(6) - 226 Inches From Carbody C.G., Fore & Aft OR(7) - From B End Trailer C.G. to Hitch End of Trailer*

TABLE 3-4 - DESCRIPTION OF NAMELIST VEHIC PARAMETERS (CONCLUDED)

Parameter Name	Type	Default Value	Description
			OR(8) - From B End Trailer C.G. to Tandem End of Trailer* 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	0.01	Gap at B and A Truck Side Bearings--Switch Point for Bilinear Truck Roll Spring, Radians (1" gap = .04 radians)
GAGEB GAGEA	R	0.5	1/2 Gage Clearance of B and A Truck Wheels; Transition Point of Bilinear Spring, in.
K	R(30)	30x0.0	Spring Values, lbs./in.--See Section 4 and Section 5 for Location
KCP6 KCP12	R		Truck Roll Spring Constants Before Side Bearing Contact, in. lbs./radian
KLSB KLSA	R	0.0	Spring Constant for Local Structure in Series With Friction Snubber, lbs./in.
KFCB KFCA	R	0.0	Lateral Spring Constant Between Wheel and Rail With Flange Contact, in./lbs.
XZKMOM	R	0.0	B End Trailer Hitch Roll Stiffness, in. lbs./radian*
XRKMOM	R	0.0	A End Trailer Hitch Roll Stiffness, in. lbs./radian*
C	R(30)	30x0.0	Damping Values, lbs./in./sec. --See Sections 4 and 5 for Locations
CCP6 CCP12	R	0.0	Truck Roll Damping Before Side Bearing Contact, in. lbs./radian/sec.
XZCMOM	R	0.0	B End Trailer Hitch Roll Damping, in. lbs. sec./radian*
XRCMOM	R	0.0	A End Trailer Hitch Roll Damping, in. lbs. sec./radian*
FFSB FFSA	R	0.0	Friction Snubber Force for One Side of One Truck, lbs.
CHSB CHSA	R	0.0	Hydraulic Snubber Damping Rate, One Side of One Truck, lbs./in./sec.

NOTE: The C.G. of each body is assumed to be at half its height.

---

* These terms are in FRATF1 only.

TABLE 3-5 - DESCRIPTION OF NAMELIST MODAL PARAMETERS

Parameter Name	Type	Default Value	Description
NMODES	I	0	Number of Desired Free-Free Normal Modes to Describe Flexibility of Principal Vehicle (Less than 5)
ZETA	R(4)	4x0.005	Modal Damping Factors, One Per Defined Normal Mode (Ratio to Critical)
RF	R(4)	4x0.0	Modal Frequencies (Hz.)
NLOC	I	0	Number of Deflection Shape Modal Displacements in FRATF1 (NLOC = 46)
COEF			
FRATF1	R(46,4)	184x0.0	Normal Mode Deflection Shapes, Each Column Representing One Mode (Non-Dimensional)--Required as Input for FRATF1 Only

4. FRATX1

FRATX1 is a version of FRATE configured specifically for boxcar or other type freight cars similar to boxcars with respect to body flexibility. FRATX1 and FRATF1 are the same basic program, their differences being in size and in output. The elimination of the trailers and three out of four carbody flexibility modes from the FRATF1 version eliminates 17 degrees of freedom. Configurations other than boxcars can also be simulated with FRATX1 by appropriate choice of mass, inertia, dimension, stiffness and damping values.

4.1 Lumped Mass/Spring Model

FRATE uses a lumped mass model configured, for the FRATX1 boxcar as shown in Figure 4.1. The basic model has three masses, two trucks and carbody, and twelve degrees of freedom. The truck degrees of freedom are lateral translation, vertical translation and roll (X, Z and ϕ respectively.) The carbody has the five degrees of freedom of X, Z, ϕ, θ and α where θ is pitch and α is yaw. Carbody torsion is the twelfth degree of freedom.

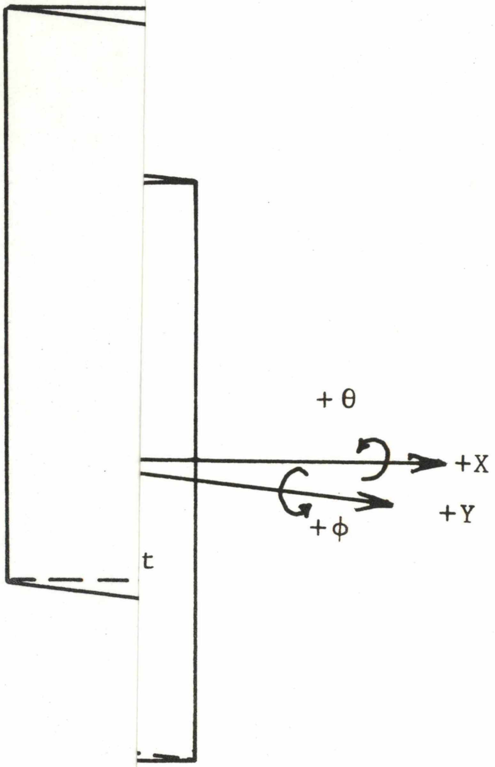
Lading masses are optional up to four. Lading degrees of freedom are Z, X and ϕ. The lading masses can be located anywhere within the carbody and are referenced by their X, Y and Z c.g. location relative to the carbody c.g. A summary of degrees of freedom assignments is given below.

Model Degrees of Freedom

B Truck: X Z ϕ
A Truck: X Z ϕ
Carbody: X Z ϕ θ α
Lading(4): X Z ϕ

Figure 4-1 has two symbols to represent spring dampers: the sawtooth symbol is for lineal spring/dampers (lb./in. and lb./in./sec.) and the loop symbol is for rotational spring/dampers (in. lb./rad. and in. lb./rad./sec.). In either case, there is a spring and a viscous damper in a parallel arrangement.

There are six spring/dampers which are programmed to have only positive (compression) values; that is if the force in the spring damper calculates to be negative, it is reset equal to zero. These six spring/dampers are numbers 1, 3, 7 and 9 which represent the wheel-rail interface and 4 and 10 which represent the vertical truck suspension system.



Suspension)

Mass)

-Rail Stiffness)

f Rail)

FIGURE 4.1. SCHEMATIC OF LUMPED MASS MODEL OF BOXCAR IN FRATX1

The spring/dampers 2 and 8 represent the lateral stiffness of the wheels and rails. These springs have been programmed as bilinear in representation of stiffness change with and without flange contact with the break point dependent on gage clearance.

The spring/dampers 4 and 10 represent the vertical stiffness and damping characteristics of the suspension systems of trucks B and A respectively. The representation includes the friction and hydraulic snubbers as discussed in Section 3.3.2. The hydralic snubbers are in effect for the down stroke only. No negative (tension) loads are allowed; i.e., the load in spring/dampers 4 and 10 are either compressive or zero.

Spring/dampers 6 and 12 (Figure 4.1) are the most complex in the model. They represent the suspension systems roll characteristics for trucks B and A respectively. The spring rates have three linear ranges: for small angles, i.e., before side bearing contact, the spring rate represents rocking on the center plate; after side bearing contact the spring rate is representative of the truck suspension system and finally after center plate lift, zero spring rate is assumed. Superimposed on this are the friction and hydraulic snubbers, with the hydraulic snubber active only on the down stroke, after side bearing contact and before center plate lift. Refer back to Sections 3.3.1 and 3.3.2 for further descriptions of the truck model.

Dimensional notations used in FRATX1 is shown in Figure 4.2 and Figure 4.3.

4.2 Example Model Parameter Values For A 70 Ton Boxcar

Model parameter values, dimension, stiffness, damping, mass and inertia are presented in this section as an example for FRATX1. Table 4-1 contains all dimensional values. Spring/damper values are presented in Table 4-2. Mass properties and weight break down are presented in Table 4-3 and 4-4.

This example model is representative of a 50 foot boxcar with 40 foot 6 inch truck center distance, a light (empty) weight of 62,000 pounds and total lading weight of 100,000 pounds. The top 30 percent of the lading is represented as four spring mounted lumps with X, Z and degrees of freedom. The lading model configuration is shown in Section 7.

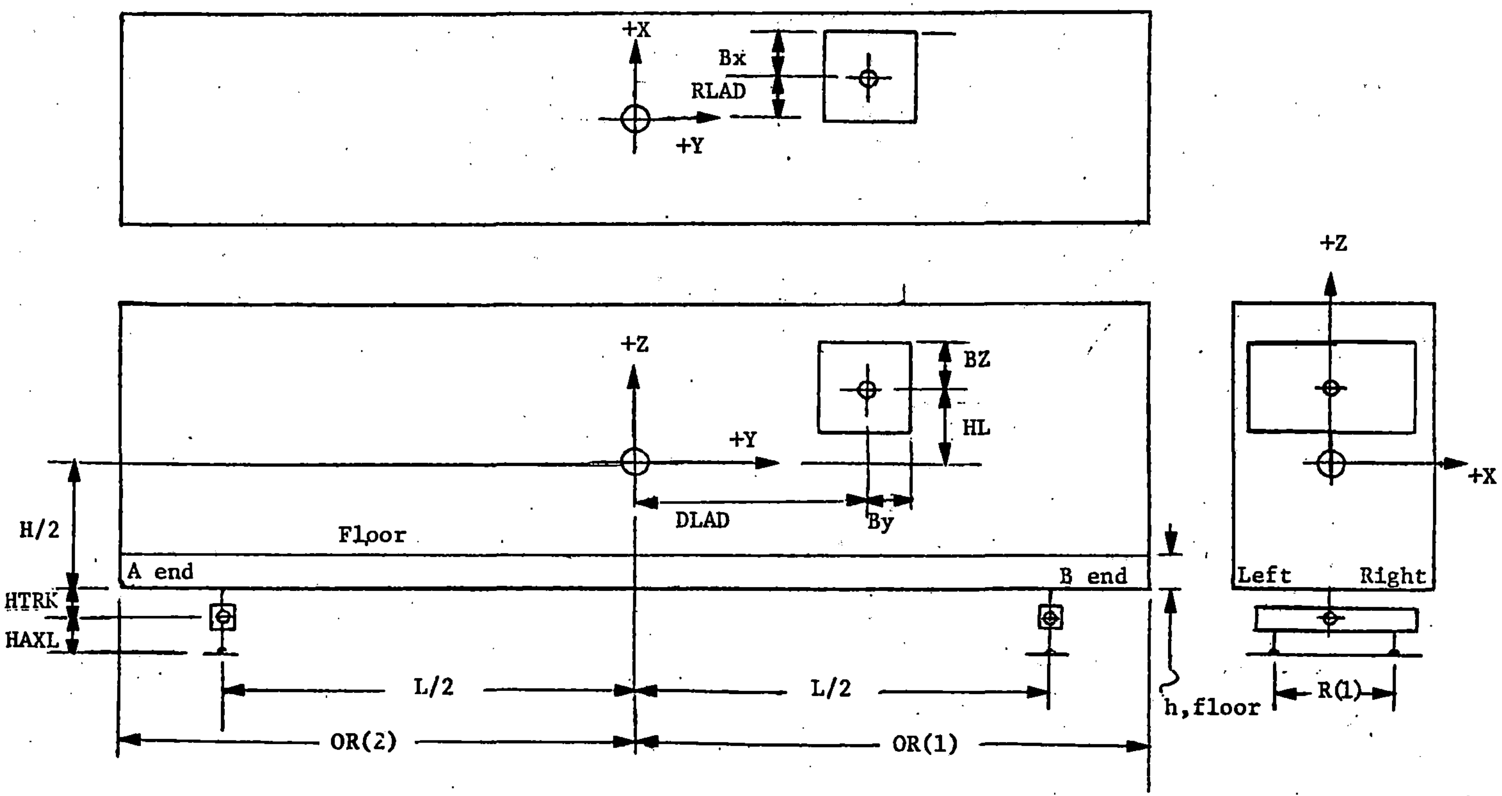
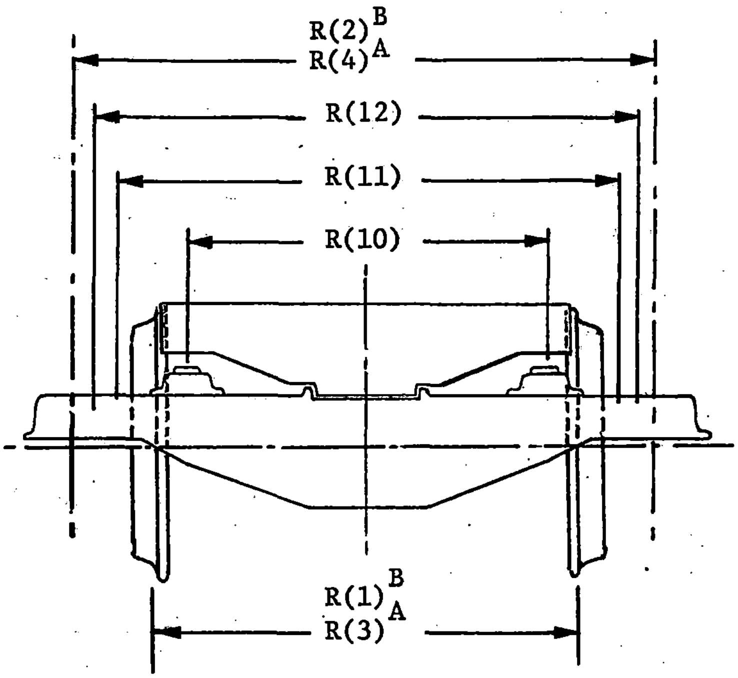


FIGURE 4.2. FRATX1 DIMENSIONAL NOTATION



R(1) & R(3) = Distance Between Wheels
R(2) & R(4) = Distance Between Spring Nest Centers

R(10) = Distance Between Side Bearings
R(11) = Distance Between Hydraulic Snubbers
R(12) = Distance Between Friction Snubbers
B = B Truck
A = A Truck

FIGURE 4.3. TRUCK LATERAL DIMENSION NOTATION

TABLE 4-1 - DIMENSIONAL VALUES, EXAMPLE BOXCAR

Item	Value*	Description
L	486.0	Distance Between Truck Centers
R(1), R(3)	58.0	Wheel Gage Distance
R(2), R(4)	79.0	Distance Between Spring Nest Centers
R(10)	50.0	Distance Between Side Bearings
R(11)	89.0	Distance Between Hydraulic Snubbers
R(12)	79.0	Distance Between Friction Snubbers
H/2.**	47.87	C.G. Height Above Centerplate of Carbody and Fixed Lading
HTRK	9.0	Height of Centerplate From Axle
HAXL	16.5	Height of Axle From Top of Rail
GAPA, GAPB	0.01 radians	Side Bearing Gap, Each Side
GAGEA, GAGEB	0.5	Gage Clearance, Each Rail
RLAD(I)***	0.0, 0.0 0.0, 0.0	X Distance of Sprung Lading C.G.
DLAD(I)***	225.0 ,75.0, -75.0, -225.0	Y Distance of Sprung Lading C.G.
HL(I)***	38.63	Z Distance of Sprung Lading C.G.
BX, BY, BZ	50.0, 75.0, 12.0	Location of Sprung Lading Corner Relative to Its Own C.G.

---

*All dimensions are in inches except where noted otherwise.

**The boxcar height, H, is a synthetic number equal to two times the distance from the centerplate plane to the combined c.g. of carbody and fixed lading.

***Lading c.g. distances are measured from c.g. of carbody and fixed lading.

TABLE 4-2 - SPRING AND DAMPER VALUES AND DESCRIPTIONS OF FRATX1 WITH EXAMPLE 70 TON BOXCAR

Name	Value/Units	Location	Descriptions
K(1), K(3) K(7), K(9)	0.91 E5 lbs./in.	Wheel-Rail, Vertical	Compressive Only (i.e. Wheel Lift)
C(1), C(3) C(7), C(9)	300. lbs./in./sec.		Viscous Damping But Zero With Wheel Lift
K(2), K(8) KFCB, KFCA	0.10 E5 lbs./in.[1] 0.95 E5 lbs./in.[2]	Wheel-Rail, Lateral	Bilinear: [1]No Flange Contact. [2]Flange Contact
C(2), C(8)	1,100. lbs./in./sec.		
K(4), K(10)	0.48 E5 lbs./in.	Truck Suspension Vertical	Spring Force and Damping is Zero with Centerplate Lift
C(4), C(10)	450. lbs./in./sec.		
K(5), K(11)	0.138 E5 lbs./in.[1] 0.10 E6 lbs./in.[2]	Truck Suspension Lateral	[1]Without Gib Contact Varies with G.W.--See Figure 3-4 [2]With Gib Contact (Not Programmed Bilinear)
C(5), C(11)	480. lbs./in./sec.		
KCP6, KCP12	0.20 E8 in. lbs./rad	Centerplate, Roll	In Effect Before Side Bearing Contact
CCP6, CCP12	0.20 E6 in. lbs./rad./sec.		
K(6), K(12)	0.75 E8 in. lbs./rad.	Truck Suspension Roll	In Effect After Side Bearing Contact and Before Centerplate Lift--Roll Spring/Damping Rates are Zero with Centerplate Lifted --Returning Moment is Due to Inertial Forces
C(6), C(12)	0.60 E6 in. lbs./rad./sec.		

TABLE 4-2 - SPRING AND DAMPER VALUES AND DESCRIPTIONS OF FRATX1 WITH EXAMPLE 70 TON BOXCAR (CONCLUDED)

Name	Value/Units	Location	Descriptions
KLSB, KLSA	0.10 E6 lbs./in.	Structure Local to Friction Snubbers	Compression Only-- Force Limited by FFSB and FFSA KS4 = 2 * KLSB KS10 = 2 * KLSA KS6 = KLSB * (R(12)/2)^2 KS12 = KLSA * (R(12)/2)^2
FFSB, FFSA	2,000. lbs.	Friction Snubber Force	Compression Only MFS4 = 2 * FFSB MFS10 = 2 * FFSA MFS6 = FFSB * R(12)/2 MFS12 = FFSA * R(12)/2
CHSB, CHSA	0.0 lbs./in./sec.	Hydraulic Snubber Rate	Compression Only CHS4 = 2 * CHSB CHS10 = 2 * CHSA CHS6 = CHSB * (R(11)/2)^2 CHS12 = CHSA * (R(11)/2)^2
KLAD (1)(4) (7)(10)	0.621 E5 lbs./in.	Lading Support, Vertical	Based on: fn = 9.0 Hz. Q = 16
CLAD (1)(4) (7)(10)	70. lbs./in./sec.		
KLAD (2)(5) (8)(11)	0.690 ± 4 lbs./in.	Lading Support, Lateral	Based on: fn = 3.0 Hz. Q = 7.0
CLAD (2)(5) (8)(11)	52. lbs./in./sec.		
KLAD (3)(6) (9)(12)	0.114 E9 in. lbs./rad.	Lading Support, Roll	Based on: fn = 13.0 Hz. Q = 10.0
CLAD (3)(6) (9)(12)	0.14 E6 in. lbs./rad./sec.		

TABLE 4-3 - MASS PROPERTIES OF 70 TON BOXCAR WITH 50 TON LOAD

Item	Weight Units (lbs. Or lbs. in. ^{2})	Mass Units (lb. sec.^{2}/in. Or in. lbs. sec.^{2})	Description*
M(1), M(2)	8,600	22.28	Truck Mass
M(3)	114,800	297.41	Carbody Mass
MLAD (1-4)	7,500	19.43	Sprung Lading Mass
I(1), I(2)	0.849 E7	0.22 E5	Truck Roll Inertia
I(3)	0.20102 E9	0.5208 E6	Carbody Roll Inertia
I(4)	0.34202 E10	0.8861 E7	Carbody Pitch Inertia
I(5)	0.3286 E10	0.8513 E7	Carbody Yaw Inertia
ILAD (1-4)	0.6610 E7	0.171 E5	Sprung Lading Roll Inertia

---

*Carbody mass and inertias include that portion of the lading which is assumed fixed to the carbody. The carbody torsion mode is for carbody and fixed lading.

TABLE 4-4 - WEIGHT AND C.G. BREAKDOWN OF 70 TON BOXCAR

Item	Weight (lbs.)	C.G. Height From Top of Rail (in.)	W x H (in. lbs)
Trucks (ea.)	8,600	16.5	0.1419 E6
Carbody	44,800	75.5	3.3824 E6
Fixed Lading	70,000	72.0	5.040 E6
Sprung Lading	7,500	112.0	0.840 E6
Carbody and Trucks	62,000	59.13	3.666 E6
Carbody and Fixed Lading	114,800	73.37	8.4224 E6
Total Lading	100,000	84.00	8.400 E6
Total	162,000	74.48	12.0662 E6

Spring and damper values are based primarily on the TOFC model resulting from the validation effort of Reference 6. The lateral stiffness of the truck suspension system was found to be dependent on the gross weight of the car in the work of Reference 6 and Reference 8. For the example model it was assumed that the gib was not in contact and the value for K(5) and K(11) of .138E5 lb./in was taken from Figure 4.4 for a gross weight of 162,000 pounds.

4.3 Output Options With FRATX1

The output provided by the FRATE programs consists of five parts (1) a listing of the input data as contained in the four Namelist; (2) the initial deflections of the vertical and pitch degrees of freedom; (3) a listing of separating spring and time of separation for the first 100 separations; (4) the DEBUG option listing; and (5) time histories of selected input and response functions. Each of these is discussed in Section 3.3.6. This section contains details of the specific functions available for time history plotting and how selections are made.

Time histories are plotted in groups of four. Each of the four functions plotted is identified by numbers, 1-4, and its number is used as the plotting symbol. Where two or more functions have the same value, an asterisk is used for the plot symbol. In the example time histories of Section 4.5, the plot points have been connected by hand to help in studying the results. The plotting is started at STARTM which, for the example, is 9.5 seconds after the problem start.

There are 15 groups of output functions to choose from, with four functions in each group. These 60 functions are listed by their IPLOT groups, in Table 4-5. The choice is made through the input parameter IPLOT (I): any integer for (I) will cause that group to be plotted and 0 (zero) will cause it to be omitted.

4.4 Carbody Torsional Flexibility

As a general rule, the body of a freight car is stiff relative to the truck suspension systems and the dynamics of the freight car consists of rigid body motions of the car body on the truck suspension system. Two exceptions to this rule must be addressed. Flatcar bodies are flexible and this flexibility must be included in dynamic response analyses. This is addressed in Section 5.

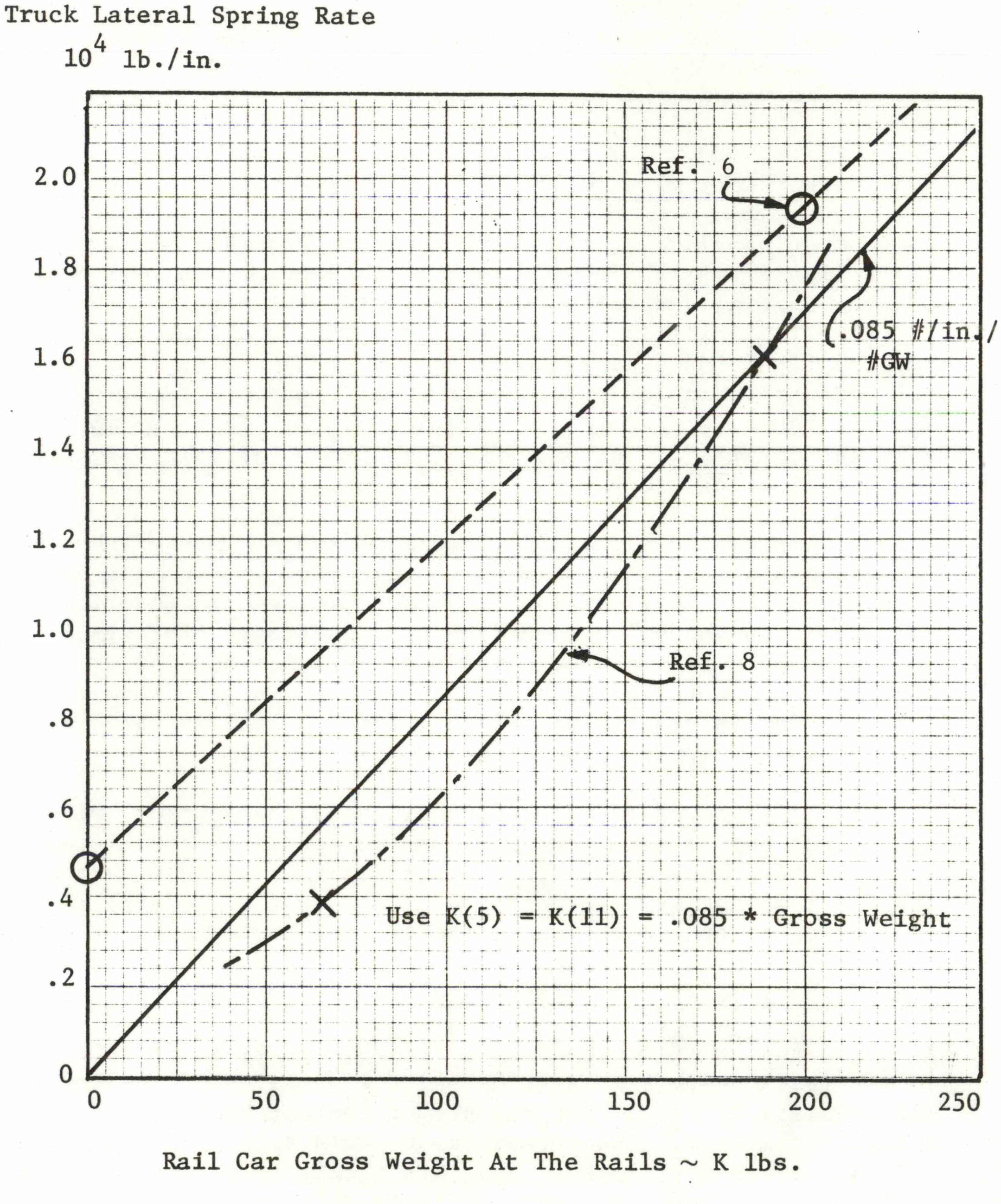


FIGURE 4.4. TRUCK LATERAL STIFFNESS, K(5) & K(11), VARIATION WITH VEHICLE GROSS WEIGHT

TABLE 4-5 - FRATX1 OUTPUT DATA

IPLOT Number	Curve Number	Description of Output Data
1		Vertical (Z) Input Motion
	1	Vertical Input, B Truck, Left Side, in.
	2	Crosslevel Input, B Truck, in.
	3	Vertical Input, A Truck, Left Side, in.
	4	Crosslevel Input, A Truck, in.
2		Lateral (X) Input Motion
	1	Lateral Input, B Truck, in.
	2	Lateral Response, B Truck, in.
	3	Lateral Input, A Truck, in.
	4	Lateral Response, A Truck, in.
3		Roll Motions
	1	Input Crosslevel, B Truck, Degrees
	2	Roll Response, B Truck, Degrees
	3	Roll Response, A Truck, Degrees
	4	Roll Response, Carbody C.G., Degrees
4		Wheel-Rail Forces, B Truck
	1	Vertical Force, Left Side, lbs.
	2	Lateral Force, lbs.
	3	Vertical Force, Right Side, lbs.
	4	Roll Moment at Centerplate /25., in. lbs.
5		Wheel-Rail Forces, A Truck
	1	Vertical Force, Left Side, lbs.
	2	Lateral Force, lbs.
	3	Vertical Force, Right Side, lbs.
	4	Carbody Inertial Roll Momemt /50., in. lbs.
6		Vertical (Z) Acceleration Responses
	1	Vertical Acceleration, B Truck C.G., g's
	2	Vertical Acceleration, A Truck C.G., g's
	3	Vertical Acceleration, Carbody at B Truck, g's
	4	Vertical Acceleration, Carbody at A Truck, g's
7		Lateral (X) Acceleration Responses
	1	X Acceleration, B Truck C.G., g's
	2	X Acceleration, Carbody Bottom at B Truck, g's
	3	X Acceleration, Carbody Top at B Truck, g's
	4	X Acceleration, Carbody C.G., g's
8		Z Acceleration at Corner of Lading
	1	Z Acceleration, Corner Lading 1, g's
	2	Z Acceleration, Corner Lading 2, g's
	3	Z Acceleration, Corner Lading 3, g's
	4	Z Acceleration, Corner Lading 4, g's
9		X Acceleration at Corner of Lading
	1	X Acceleration at Corner Lading 1, g's
	2	X Acceleration at Corner Lading 2, g's
	3	X Acceleration at Corner Lading 3, g's
	4	X Acceleration at Corner Lading 4, g's

TABLE 4-5 - FRATXI OUTPUT DATA (CONCLUDED)

IPLOT Number	Curve Number	Description of Output Data
10		Vertical (Z) Responses of Trucks and Carbody
	1	Z Motion, B Truck C.G., in.
	2	Z Motion, Carbody at B Truck, in.
	3	Z Motion, A Truck C.G., in.
	4	Z Motion, Carbody at A Truck, in.
11		Lateral (X) Motions of Carbody
	1	Carbody Bottom at B Truck, in.
	2	Carbody Top at B Truck, in.
	3	Carbody Bottom at A Truck, in.
	4	Carbody Top at A Truck, in.
12		C.G. Motions of Lading Number 1
	1	Z Input, in.
	2	Z Response, in.
	3	X Input, in.
	4	X Response, in.
13		C.G. Motions of Lading Number 2
	1	Z Input, in.
	2	Z Response, in.
	3	X Input, in.
	4	X Response, in.
14		C.G. Motions of Lading Number 3
	1	Z Input, in.
	2	Z Response, in.
	3	X Input, in.
	4	X Response, in.
15		C.G. Motions of Lading Number 4
	1	Z Input, in.
	2	Z Response, in.
	3	X Input, in.
	4	X Response, in.

Freight cars other than flatcars are all relatively stiff in bending but not all are stiff in torsion. Gondola and open top hopper cars, for example, are torsionally flexible and can have torsion resonances in the two to five Hertz frequency range. All-door boxcars, 90 foot multiple door boxcars, and cattle cars are also torsionally flexible to varying degrees. For the purposes of FRATX1, it was concluded that the carbody could be assumed to be rigid as to bending but that torsional flexibility should be included. It was also concluded that the method by which torsional flexibility is to be modeled must be able to simulate a wide range of freight car configurations. To accomplish these objectives, the following simplifying assumptions were made:

a. It is desired to obtain the fundamental torsional mode, uncoupled from bending of the carbody, considered as a free-free body, including fixed lading and not including truck masses nor flexibly mounted lading masses.

b. Assume uniform stiffness.

c. Assume uniform distribution of mass and inertia.

d. Assume torsion axis is a straight line passing through the c.g. of the carbody plus fixed lading.

With these assumptions, the deflection shape is a sine function that can be determined for any vehicle loading condition using the following expression:

$$\phi(y) = C \sin\left(\frac{\pi y}{2 \times OR(1)}\right)$$

where:

$\phi(y)$ = roll (torsion) relative displacement as a function of the y coordinate (non-dimensional)

y = longitudinal coordinate with origin at the vehicle center (inches)

C = constant

OR(1) = longitudinal distance from center to B end of carbody (inches)

The value of the constant C is obtained from the definition of the generalized mass and the assumed value of unity, as follows:

$$M = \int_{-\ell}^{\ell} \phi^2(y)\, I_o\, dy$$

where:

M = generalized mass (lb.in.sec.^{2})

I_o = running roll inertia of the carbody with fixed lading (lb.in.sec.^{2}/in.)

ℓ = half the overall length of the carbody, inches

Substituting the expression for $\phi(y)$ and performing the integration results in the following expression for the generalized mass:

$$M = C^2 I_o \ell$$

or, using $I_o \ell = I(3)/2$.

$$M = C^2 I(3)/2.$$

then, normalizing to M = 1.0

$$C = \sqrt{2/I(3)}$$

and

$$\phi(y) = \sin\left(\frac{\pi y}{2 \times OR(1)}\right) \times \sqrt{2/I(3)}$$

which is the deflection shape of the first torsion mode of the free-free carbody normalized for unit modal mass.

The natural frequency for the fundamental torsion mode obtained in this manner can be determined using the following expression:

$$F = \frac{1}{2}\sqrt{\frac{GJ}{2\ell\, I(3)}}$$

where:

f = natural frequency, (Hertz)
GJ = torsional stiffness (lb in^2)
2ℓ = total length of the carbody (inches)
I(3) = roll inertia of the carbody with fixed lading (lb. in.$sec.^2$)

The analytical determination of the carbody torsional frequency is at best an estimate because of difficulties encountered in calculating the torsional stiffness GJ, such as load path complexity at the door openings, the tendency of the doors to carry some of the load and nonlinear effects due to the side, top and end panels buckling and racking. The recommended approach is to use experimentally determined natural frequencies whenever possible and to perform analyses with a range of values to be sure that all probable conditions are covered.

The deflection coefficients for the carbody torsion mode as obtained within FRATX1 are contained in Table 4-6. The coefficient represent the relative deflection of ϕ, Z and X at locations within the carbody where the two trucks and four ladings are attached.

4.5 Example FRATX1 Run

The following pages contain the Namelist input data as submitted to the CDC computer system and the resulting printout. The input data file is given in Figure 4.5. Input data as listed with the computer printout is given in Figure 4.6. An example DEBUG printout is given in Figure 4.7. Representative time history printout are given in Figures 4.8 through 4.14.

The example is for a loaded boxcar with four spring mounted lading masses. The input excitation function is a rectified sine simulation of 39 foot staggered joint bolted rail at a track speed of 16.0 miles per hour.

Lading assumptions and development of the lading model can be found in Section 7.1.

TABLE 4-6 - CARBODY TORSION MODE DEFLECTION COEFFICIENTS

Coefficient	Location	Degrees of Freedom	Equation
COEF(1)	B Truck	ϕ	SIN(L/2.*DREF)/SRIN3
COEF(2)	A Truck	ϕ	SIN(-L/2.*DREF)/SRIN3
COEF(3)	Lading 1	ϕ	SIN(DLAD(1)*DREF)/SRIN3
COEF(4)	Lading 2	ϕ	SIN(DLAD(2)*DREF)/SRIN3
COEF(5)	Lading 3	ϕ	SIN(DLAD(3)*DREF)/SRIN3
COEF(6)	Lading 4	ϕ	SIN(DLAD(4)*DREF)/SRIN3
COEF(7)	B Truck	Z	H/2.*(1-COS(COEF(1)))
COEF(8)	A Truck	Z	H/2.*(1-COS(COEF(2)))
COEF(9)	Lading 1	Z	-HL(1)*(1-COS(COEF(3))) +RLAD(1)*SIN(COEF(3))
COEF(10)	Lading 2	Z	-HL(2)*(1-COS(COEF(4))) +RLAD(2)*SIN(COEF(4))
COEF(11)	Lading 3	Z	-HL(3)*(1-COS(COEF(5))) +RLAD(3)*SIN(COEF(5))
COEF(12)	Lading 4	Z	-HL(4)*(1-COS(COEF(6))) +RLAD(4)*SIN(COEF(6))
COEF(13)	B Truck	X	H/2.*SIN(COEF(1))
COEF(14)	A Truck	X	H/2.*SIN(COEF(2))
COEF(15)	Lading 1	X	-HL(1)*SIN(COEF(3)) + RLAD(1)*(1-COS(COEF(3)))
COEF(16)	Lading 2	X	-HL(2)*SIN(COEF(4)) + RLAD(2)*(1-COS(COEF(4)))
COEF(17)	Lading 3	X	-HL(3)*SIN(COEF(5)) + RLAD(3)*(1-COS(COEF(5)))
COEF(18)	Lading 4	X	-HL(4)*SIN(COEF(6)) + RLAD(4)*(1-COS(COEF(6)))

Where:

SRIN3=SQRT(INERT(3)/2.)
DREF=PI/OR(1)/2.

```
OLD.FRADX1
READY.
LNH
 $CONTRL
 RUNO=000.11,
 STARTM=9.5.   DELTAT=.005,   STOPTM=19.0,
 IPRINT=2,
 IPLOT=1,2,3.4,4*0,9,0.11,12,3*0,
 DEBUG=.T..  STARDB=0.00.  STOPDB=0.01,$
 $EXCIT
 SINEIN=.F..
 RECSIN=.T.,
 S1= 1.,    S2= 0.0,    S3=.0.
 AMP =  1.00,    .00.    1.0,  1.00.    .00,   1.0.
 PHAS=  0.0.   .0,    90.,  186.9.  .0.  276.9,
 FQ=0.297,  FQDOT=0.0,  BETA=0.,  NDECAY=500.
 DIN=.500.        VIN=0.00,     GIN=.0.
 PULSE=.F.,    BFRONT=.T.,    PL=  43.65.    SPEED=36.67,
 HUNT=.F.,    FCRB=0.0,      FCRA=0.0,
              PHASB=0.0.     PHASA=0.0,$
 $VEHIC
 NMAS=3,
 M=2*22.28,297.41,
 INERT=.220E5,.220E5,.5208E6,.8861E7,.8513E7,
 R=58.,79.,58.,79.,4*0.,108.,50.,89.,79.,2*0.,
 H=95.74,HAXL=16.5,HTRK=9.0,L=486.,
 OR=290.,-290.,4*0.,226.,254.,245.,235..
 GAGEB=0.50,  GAGEA=0.50,
 GAPB=.01,    GAPA=.01,
 K=.91E5,.10E5,.91E5,.48E5,.138E5,.75E8.
   .91E5,.10E5,.91E5,.48E5,.138E5,.75E8,
 KLSB=.10E6,  KLSA=.10E6,  CLSB=.10E4,  CLSA=.10E4,
 KCP6=.20E8.   KCP12=.20E8.   KFCB=.95E5.   KFCA=.95E5,
 C=300.,1100.,300.,450.,480.,.60E6,
   300.,1100.,300.,450.,480.,.60E6,
 CCP6=.20E6,  CCP12=.20E6,
 FFSB=2000..  FFSA=2000.,  CHSB=0.0.  CHSA=0.0,
 MLAD = 19.43, 19.43. 19.43, 19.43.
 INLAD = .171E5, .171E5, .171E5, .171E5.
 HL  = 31.42,  31.42,  31.42,  31.42,
 DLAD = 225.,  75.,  -75., -225.,
 RLAD =  0.0, 0.0, 0.0. 0.0,
 BX = 50.0, BY = 75.0, BZ = 12.0.
 KLAD = .621E5, .690E4, .114E9. .621E5. .690E4, .114E9.
        .621E5, .690E4, .114E9, .621E5, .690E4, .114E9,
 CLAD = 70., 52., .14E6, 70., 52., .14E6.
        70., 52., .14E6, 70., 52., .14E6,$
 $MODAL
 NMODES=1,
 RF=5.0,
 ZETA=.02,
 $END
READY.
```

FIGURE 4.5. INPUT DATA FILE FOR FRATX1 EXAMPLE RUN

```
  INPUT  PARAMETERS  FOR  FRATX1,  RUN  NO.       .11

TIME HISTORY RUN PARAMETERS            (Namelist CONTRL)

          START TIME   =  9.500
          DELTA T      =   .005
          STOP TIME    = 19.000
          IPRINT    =  2
          IPLOT     =  1  2  3  4  0  0  0  0  9  0 11 12  0  0  0

          DEBUG        =  T
          STARDB       =  0.000
          STOPDB       =   .010

EXCITATION PARAMETERS                  (Namelist EXCIT)

          SINEIN    =  F
          RECSIN    =  T

          AMP(I)    =     1.000    0.000    1.000    1.000    0.000    1.000
          PHAS(I)   =     0.000    0.000   90.000  186.900    0.000  276.900
          FO        =      .297
          FODOT     =     0.000
          BETA      =     0.000
          CIN       =      .500
          VIN       =     0.000
          GIN       =     0.000
          NDECAY    =    500

          SHAPE   =   S1+(1-COS(OMEGA X T/S2))/2.+(1-EXP(-3.FO X T / S3))

            S1 =  1.0000
            S2 =  0.0000  WHERE S2 = LENGTH OF 1-COS IN CYCLES OF FO
            S3 =  0.0000  WHERE S3 = CYCLES OF FQ FOR SHAPE TO REACH .95

          PULSE     = F      BFRONT    = T      PL    = 43.6500FT      SPEED    =  36.670FT/SEC
             (NOTE:DIN EQUALS 1/2 PULSE HEIGHT)

          HUNT      = F      FCRB      =   0.               FCRA     =    0.
                             PHASB     =    0.0000          PHASA    =     0.0000
```

FIGURE 4.6. COMPUTER PRINTOUT OF INPUT DATA, EXAMPLE FRATX1 RUN

```
MODEL PARAMETERS              (Namelist VEHIC)

        NMAS   =   3

        M      =   .2228E+02  .2228E+02  .2974E+03

        INERT  =   .2200E+05  .2200E+05  .5208E+06  .8861E+07  .8513E+07

        K      =   .9100E+05   .1000E+05   .9100E+05   .4800E+05   .1380E+05   .7500E+08
                   .9100E+05   .1000E+05   .9100E+05   .4800E+05   .1380E+05   .7500E+08

        KLSB    =   .1000E+06     KLSA   =    .1000E+06
        CLSB    =   .1000E+04     CLSA   =    .1000E+04
        KCP6   =   .2000E+08     KCP12  =    .2000E+08
        KFCB   =   .9500E+05     KFCA   =    .9500E+05

        C      =   .3000E+03   .1100E+04   .3000E+03   .4500E+03   .4800E+03   .6000E+06
                   .3000E+03   .1100E+04   .3000E+03   .4500E+03   .4800E+03   .6000E+06

        CCP6    =   .2000E+06     CCP12   =    .2000E+06


        CHSB    =  0.             CHSA    =   0.

        GAGEB   =     .500     GAGEA    =     .500


        R    =      58.000      79.000      58.000      79.000      0.000      0.000      0.000
                    0.000     108.000      50.000      89.000     79.000      0.000      0.000

        DR     =    290.000   -290.000      0.000      0.000      0.000
                    0.000     226.000     254.000     245.000     235.000

        H    =  95.740      HAXL    =  16.500      HTRK    =    9.000

        L       = 486.000

        GAPB    =  .0100     GAPA    =  .0100

        FFSB   =     .2000E+04     FFSA    =     .2000E+04
```

FIGURE 4.6. COMPUTER PRINTOUT OF INPUT DATA, EXAMPLE FRATX1 RUN (CONTINUED)

```
  LADING PARAMETERS           (Namelist VEHIC, concluded)

        MLAD    =     .1943E+02  .1943E+02  .1943E+02  .1943E+02

        INLAD   =     .1710E+05  .1710E+05  .1710E+05  .1710E+05

        DLAD    =     .2250E+03  .7500E+02 -.7500E+02 -.2250E+03

        RLAD    =   0.         0.         0.         0.

        KLAD    =     .6210E+05  .6900E+04  .1140E+09  .6210E+05  .6900E+04  .1140E+09
                      .6210E+05  .6900E+04  .1140E+09  .6210E+05  .6900E+04  .1140E+09

        CLAD    =     .7000E+02  .5200E+02  .1400E+06  .7000E+02  .5200E+02  .1400E+06
                      .7000E+02  .5200E+02  .1400E+06  .7000E+02  .5200E+02  .1400E+06

        HL      =     .3142E+02  .3142E+02  .3142E+02  .3142E+02

        BX      =     .5000E+02     BY     =    .7500E+02      BZ      =   .1200E+02

NORMAL MODE PARAMETERS        (Namelist MODAL)

        NMODES   =   1

        FREQ     =   5.000    0.000    0.000    0.000    0.000

        ZETA     =    .020    0.000    0.000    0.000    0.000
```

FIGURE 4.6. COMPUTER PRINTOUT OF INPUT DATA, EXAMPLE FRATX1 RUN (CONTINUED)

```
TORSION MODE SHAPE OF CARBODY

          1 - 6 ARE ROLL ANGLES, RADIANS
          7 - 12 ARE Z DEFLECTIONS, INCHES
          13 - 18 ARE X DEFLECTIONS, INCHES
          ORDER: TRUCK B, TRUCK A, LADING 1, LADING 2, LADING 3, LADING 4


  .18965E-02     0.                0.                0.                0.
 -.18965E-02     0.                0.                0.                0.
  .18394E-02     0.                0.                0.                0.
  .77438E-03     0.                0.                0.                0.
 -.77438E-03     0.                0.                0.                0.
 -.18394E-02     0.                0.                0.                0.
  .86087E-04     0.                0.                0.                0.
  .86087E-04     0.                0.                0.                0.
 -.53156E-04     0.                0.                0.                0.
 -.94206E-05     0.                0.                0.                0.
 -.94206E-05     0.                0.                0.                0.
 -.53156E-04     0.                0.                0.                0.
  .90785E-01     0.                0.                0.                0.
 -.90785E-01     0.                0.                0.                0.
 -.57795E-01     0.                0.                0.                0.
 -.24331E-01     0.                0.                0.                0.
  .24331E-01     0.                0.                0.                0.
  .57795E-01     0.                0.                0.                0.



           THE INITIAL DEFLECTIONS ARE

        Z(1) = -.4451        Z(2) = -.4451        Z(3) = -1.953        THETA =  0.

      ZLAD(1) = -2.074    ZLAD(2) = -2.074    ZLAD(3) = -2.074    ZLAD(4) = -2.074
```

FIGURE 4.6. COMPUTER PRINTOUT OF INPUT DATA, EXAMPLE FRATX1 RUN (CONCLUDED)

```
DEBUG AT TIME =  0.0000

ZI(I) =     -2.5000E-01     0.               2.5000E-01  -1.8994E-01    0.               2.4638E-01

  I          F(I)                ACCELERATION               VELOCITY                DISPLACEMENT
            (LBS)            (GS OR RAD/SEC.SQ)       (IN/SEC OR RAD/SEC)        (IN OR RAD)
  1       1.7750E+04            0.                         0.                        0.
  2      -7.1121E+02            0.                         0.                        0.
  3       6.3250E+04            0.                         0.                        0.
  4       7.2400E+04            0.                         0.                       -4.4506E-01
  5       0.                    0.                         0.                       -4.4506E-01
  6       0.                    0.                         0.                       -1.9534E+00
  7       2.3216E+04            0.                         0.                        0.
  8      -6.2062E+02            0.                         0.                        0.
  9       6.2921E+04            0.                         0.                        0.
 10       7.2400E+04            0.                         0.                        0.
 11       0.                    0.                         0.                        0.
 12       0.                    0.                         0.                        1.2630E-02

  1       7.5000E+03            0.                         0.                       -2.0742E+00
  2       0.                    0.                         0.                        0.
  3       0.                    0.                         0.                        0.
  4       7.5000E+03            0.                         0.                       -2.0742E+00
  5       0.                    0.                         0.                        0.
  6       0.                    0.                         0.                        0.
  7       7.5000E+03            0.                         0.                       -2.0742E+00
  8       0.                    0.                         0.                        0.
  9       0.                    0.                         0.                        0.
 10       7.5000E+03            0.                         0.                       -2.0742E+00
 11       0.                    0.                         0.                        0.
 12       0.                    0.                         0.                        0.


MODE        ETADD                      ETAD                       ETA
  1      -9.3865E-01                 0.                          1.2630E-02
```

FIGURE 4.7. DEBUG PRINTOUT EXAMPLE FRATX1 RUN

```
DEBUG AT TIME =    .0050

ZI(I) =     -2.4533E-01     0.              2.4998E-01    -1.8531E-01      0.                2.4580E-01

   I           F(I)                ACCELERATION              VELOCITY                   DISPLACEMENT
              (LBS)             (GS OR RAD/SEC.SQ)      (IN/SEC OR RAD/SEC)           (IN OR RAD)
   1        2.0071E+04              0.                     -1.5601E-01                -3.9183E-04
   2       -7.6008E+02              0.                     -1.4200E-01                -3.5375E-04
   3        6.1340E+04              0.                     -5.1767E-04                -6.5567E-07
   4        7.2530E+04              0.                      3.6448E-02                -4.4499E-01
   5       -6.8382E+01              0.                      8.9991E-01                -4.4260E-01
   6        6.9962E+04              0.                      2.0074E-02                -1.9534E+00
   7        2.5071E+04              0.                      2.8098E-01                 7.2076E-04
   8       -6.6150E+02              0.                      2.4474E-01                 6.2813E-04
   9        6.0987E+04              0.                      5.8669E-04                 9.7104E-07
  10        7.4671E+04              0.                     -1.5127E-04                -2.6492E-07
  11       -2.7059E+01              0.                     -3.1601E-06                -6.1018E-09
  12        6.1886E+04              0.                      6.4075E-02                 1.2744E-02

   1        7.4978E+03              0.                     -1.9336E-04                -2.0742E+00
   2       -6.2748E+00              0.                     -1.1731E-03                -2.2513E-06
   3        2.6596E+03              0.                      6.3977E-04                 1.2865E-06
   4        7.5016E+03              0.                      1.0417E-04                -2.0742E+00
   5       -3.3294E+00              0.                     -5.4888E-04                -1.0018E-06
   6        1.2295E+03              0.                      2.7821E-04                 5.4689E-07
   7        7.5054E+03              0.                      4.0027E-04                -2.0742E+00
   8        9.3960E-01              0.                      3.5761E-04                 8.1376E-07
   9       -8.5016E+02              0.                     -2.4755E-04                -5.2858E-07
  10        7.5092E+03              0.                      6.9761E-04                -2.0742E+00
  11        3.8850E+00              0.                      9.8188E-04                 2.0632E-06
  12       -2.2803E+03              0.                     -6.0911E-04                -1.2682E-06


 MODE         ETADD                  ETAD                    ETA
   1        2.2026E+01             6.4075E-02              1.2744E-02
```

FIGURE 4.7. DEBUG PRINTOUT EXAMPLE FRATX1 RUN (CONTINUED)

```
DEBUG AT TIME =    .0100

ZI(I) =     -2.4067E-01    0.             2.4991E-01   -1.8069E-01    0.              2.4517E-01

     I         F(I)                 ACCELERATION                 VELOCITY                    DISPLACEMENT
              (LBS)               (GS OR RAD/SEC.SQ)        (IN/SEC OR RAD/SEC)            (IN OR RAD)
     1       2.5671E+04               0.                     -3.1139E-01                  -1.5604E-03
     2      -9.0448E+02               0.                     -2.8417E-01                  -1.4195E-03
     3       5.6094E+04               0.                     -3.9597E-03                  -1.0106E-05
     4       7.2871E+04               0.                      1.0466E-01                  -4.4464E-01
     5      -2.1280E+02               0.                      1.2575E+00                  -4.3700E-01
     6       1.5134E+05               0.                      7.7384E-02                  -1.9531E+00
     7       2.9515E+04               0.                      4.9347E-01                   2.6942E-03
     8      -7.8505E+02               0.                      4.2912E-01                   2.3455E-03
     9       5.5888E+04               0.                      2.4433E-03                   8.0228E-06
    10       7.6312E+04               0.                     -5.4048E-04                  -1.9281E-06
    11      -1.5260E+02               0.                     -8.6586E-06                  -3.4608E-08
    12       1.3268E+05               0.                      2.1367E-01                   1.3407E-02

     1       7.4877E+03               0.                     -1.9290E-03                  -2.0742E+00
     2      -1.1261E+01               0.                     -3.3088E-03                  -1.2921E-05
     3       3.1890E+03               0.                      1.4567E-03                   6.4676E-06
     4       7.5101E+03               0.                      1.3949E-03                  -2.0742E+00
     5      -8.1690E+00               0.                     -1.9239E-03                  -6.6549E-06
     6       2.0288E+03               0.                      7.2305E-04                   2.9503E-06
     7       7.5324E+03               0.                      4.6914E-03                  -2.0742E+00
     8      -3.7199E+00               0.                      8.1309E-05                   2.4348E-06
     9       3.4177E+02               0.                     -3.4374E-04                  -2.1642E-06
    10       7.5548E+03               0.                      8.0149E-03                  -2.0741E+00
    11      -6.2838E-01               0.                      1.4662E-03                   8.7012E-06
    12      -8.1841E+02               0.                     -1.0774E-03                  -5.6815E-06


  MODE         ETADD                    ETAD                  ETA
     1       3.7724E+01               2.1367E-01             1.3407E-02
```

FIGURE 4.7. DEBUG PRINTOUT EXAMPLE FRATX1 RUN (CONCLUDED)

```
                                        MULTIPLE PLOT TIME HISTORY

     FRATX1 RUN      .11  SWEEP RATE = 0.            INPUT MOTION: DIN=   .500

                     PLOT 1                      VERTICAL (Z) INPUT MOTION

1=VERTICAL INPUT ,B TRUCK, LEFT SIDE, INCHES
2=CROSS LEVEL INPUT ,B TRUCK, INCHES
3=VERTICAL INPUT, A TRUCK, LEFT SIDE, INCHES
4=CROSS LEVEL INPUT, A TRUCK, INCHES
```

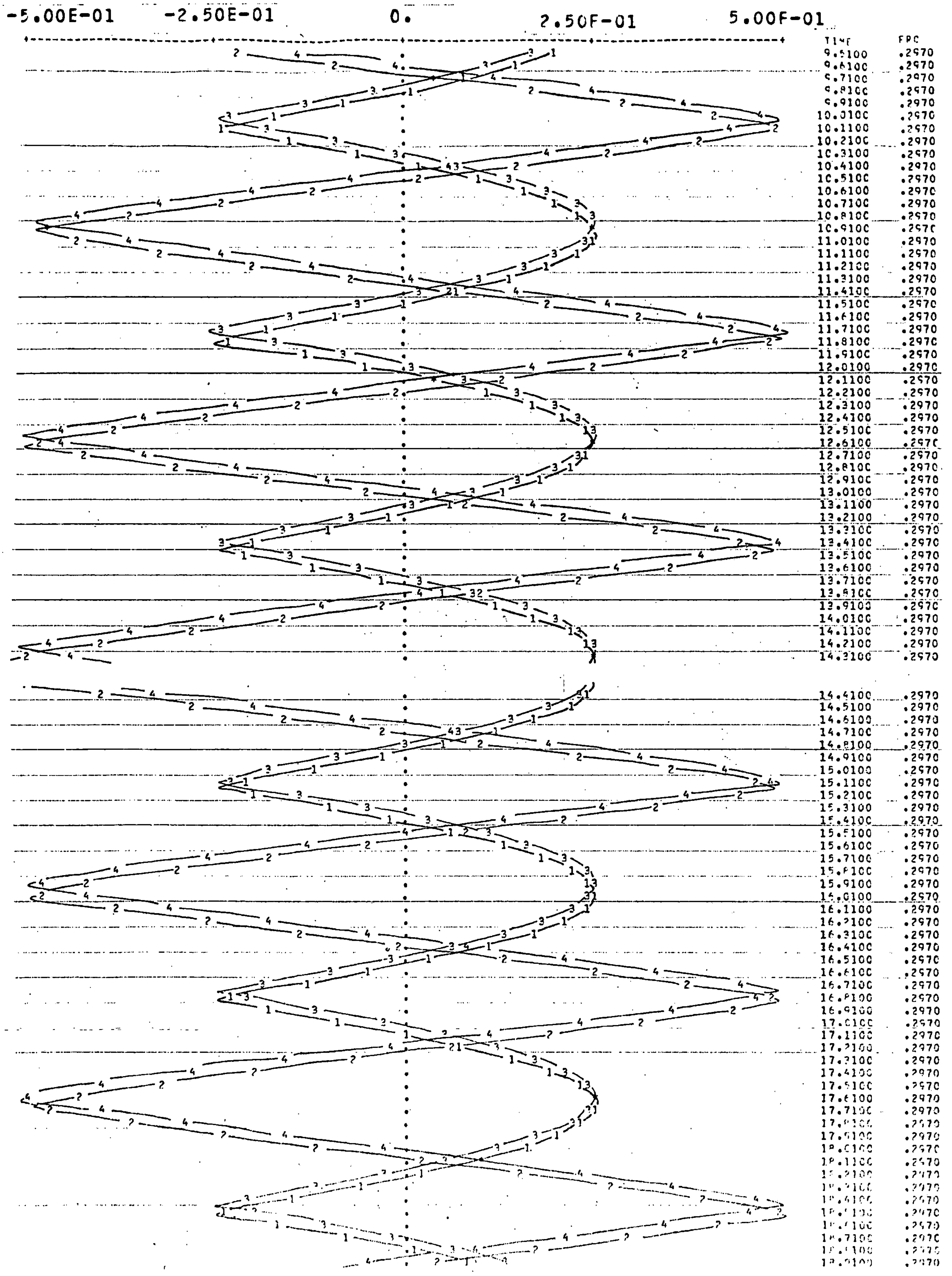


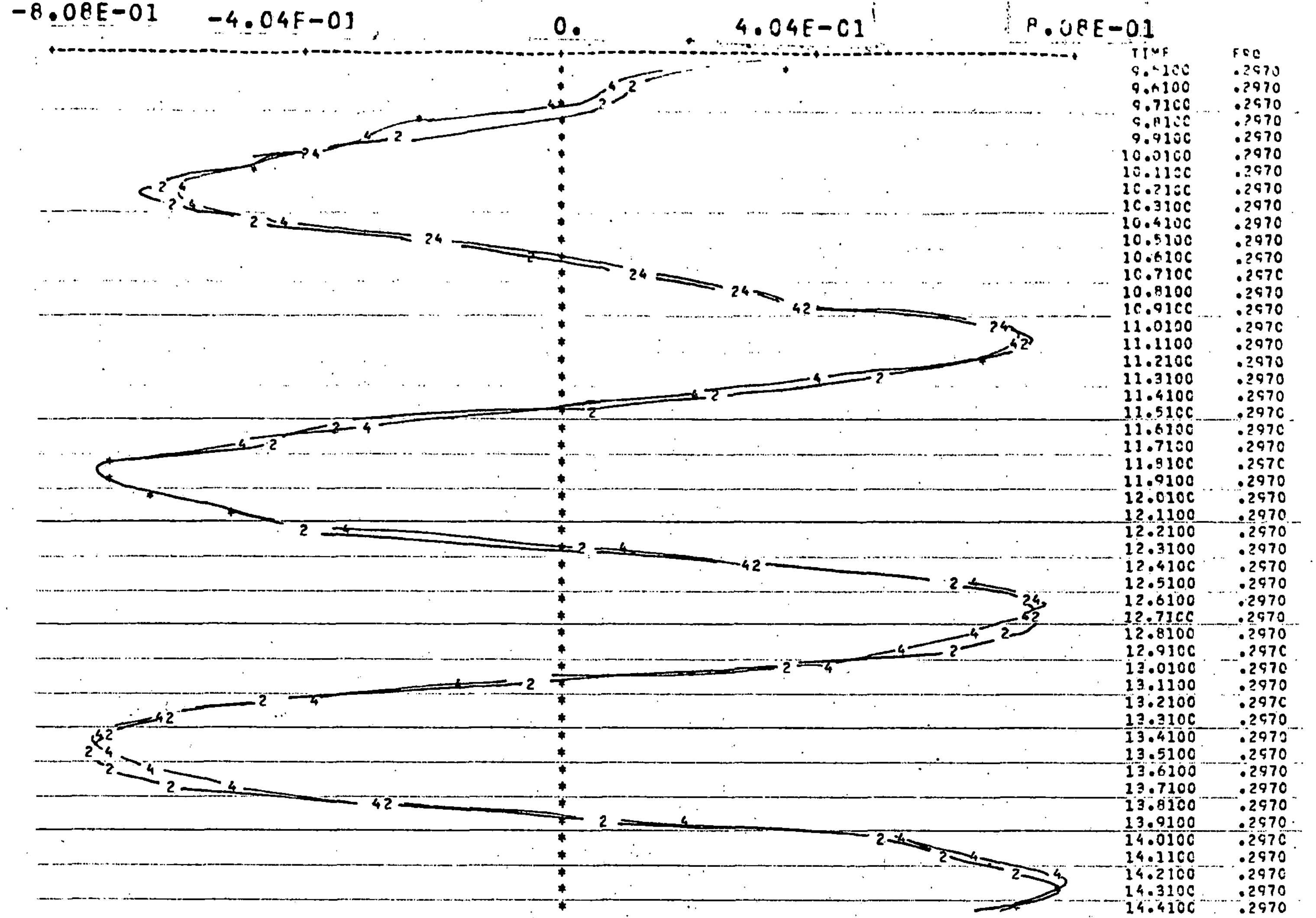
FIGURE 4.8. EXAMPLE FRATX1 RUN TIME HISTORY PLOT 1

MULTIPLE PLOT TIME HISTORY

FRATX1 RUN .11 SWEEP RATE = 0. INPUT MOTION: DIN= .500

PLOT 2 LATERAL (X) INPUT MOTION

1 = LATERAL (X) INPUT, B TRUCK, INCHES
2 = LATERAL RESPONSE, B TRUCK, INCHES
3 = LATERAL INPUT, A TRUCK, INCHES
4 = LATERAL RESPONSE, A TRUCK, INCHES



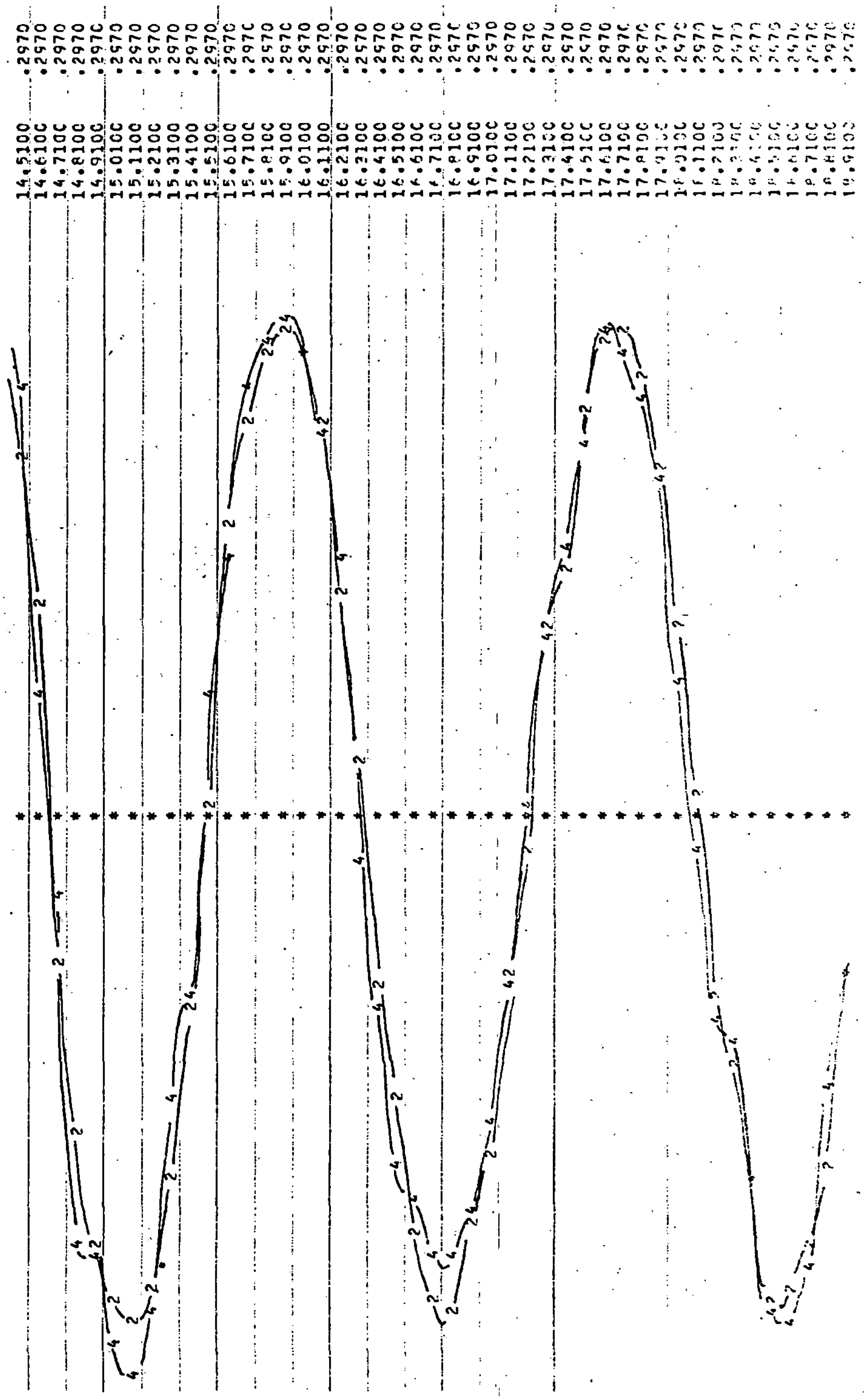


FIGURE 4.9. EXAMPLE FRATX1 RUN TIME HISTORY PLOT 2

```
                                                    MULTIPLE PLOT TIME HISTORY
        FRATX1 RUN      .11  SWEEP RATE = 0.              INPUT MOTION: DIN=  .500

                        PLOT 3            ROLL MOTIONS

1 = INPUT CROSS LEVEL, B TRUCK, DEGREES
2 = ROLL RESPONSE, B TRUCK, DEGREES
3 = ROLL RESPONSE, A TRUCK, DEGREES
4 = ROLL RESPONSE, CARBODY CG, DEGREES
```

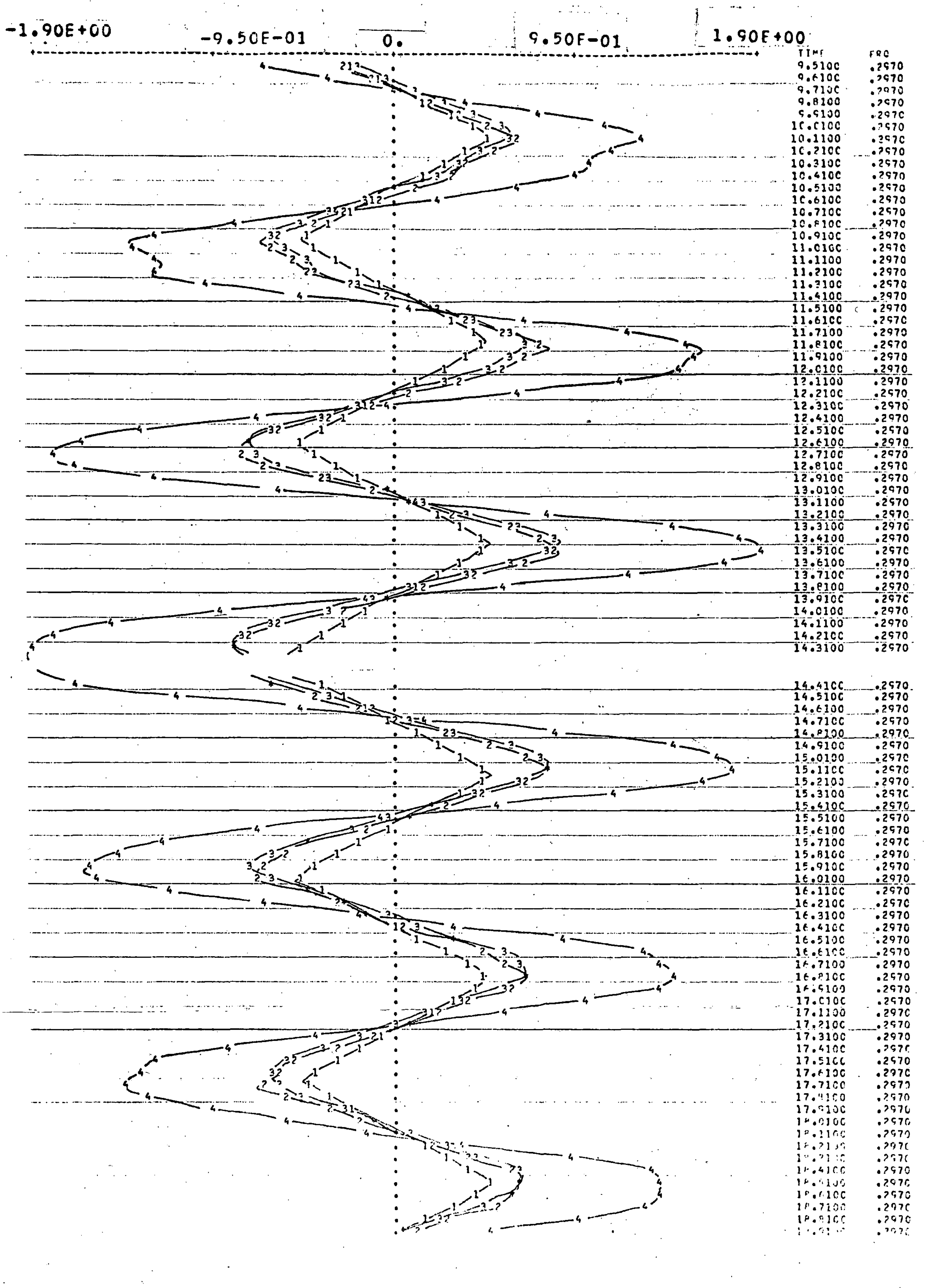


FIGURE 4.10. EXAMPLE FRATX1 RUN TIME HISTORY PLOT 3

MULTIPLE PLOT TIME HISTORY

FRATX1 RUN .11 SWEEP RATE = 0. INPUT MOTION: DIN= .500

PLOT 4 WHEEL-RAIL FORCES, B TRUCK

1 = VERTICAL FORCE, LEFT SIDE, POUNDS
2 = LATERAL FORCE, POUNDS
3 = VERTICAL FORCE, RIGHT SIDE, POUNDS
4 = ROLL MOMENT AT CENTERPLATE / 25., IN.LB.

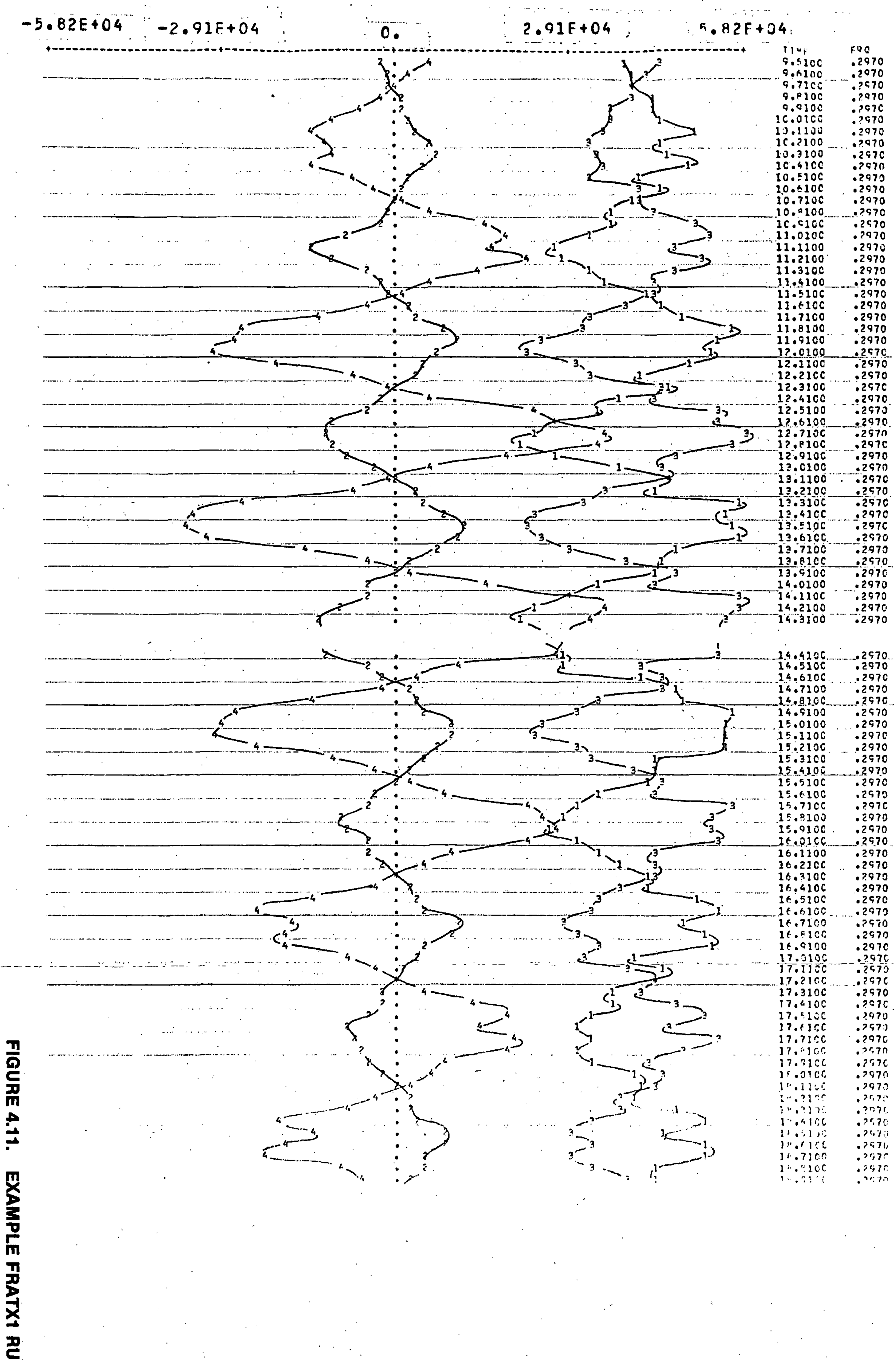
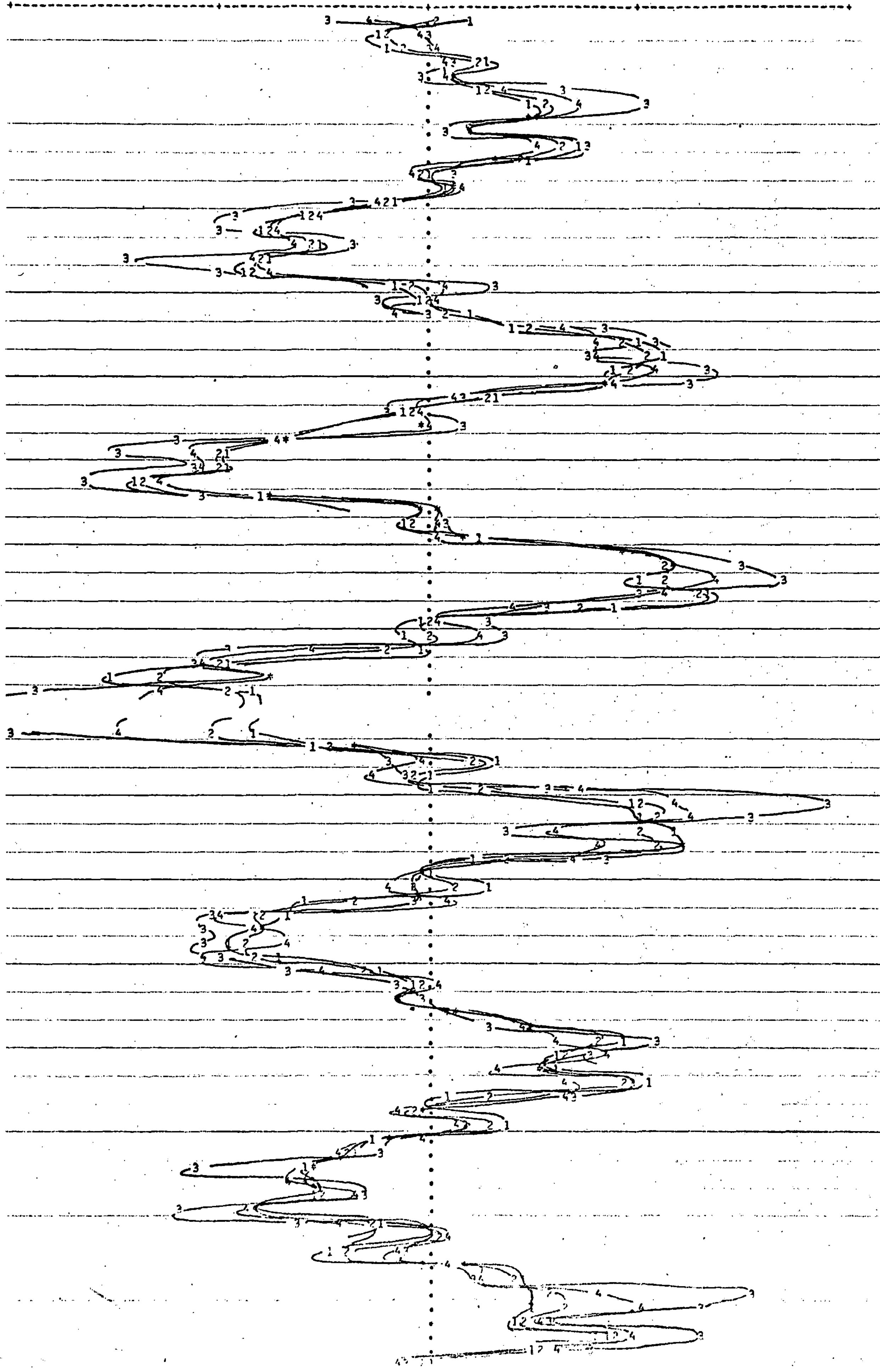


FIGURE 4.11. EXAMPLE FRATX1 RUN TIME HISTORY PLOT 4

```
                                        MULTIPLE PLOT TIME HISTORY
        FRATX1 RUN      .11  SWEEP RATE = 0.          INPUT MOTION: DIN=  .500
                         PLOT 9            X ACCEL. AT CORNER OF LADING
1 = X ACCEL. CORNER LADING NO 1,  G↑S
2 = X ACCEL. CORNER LADING NO 2,  G↑S
3 = X ACCEL. CORNER LADING NO 3,  G↑S
4 = X ACCEL. CORNER LADING NO 4,  G↑S

   -3.64E-01   -1.82E-01          0.          1.82E-01     3.64E-01
```



```
TIME      FRC
 9.5100   .2970
 9.6100   .2970
 9.7100   .2970
 9.8100   .2970
 9.9100   .2970
10.0100   .2970
10.1100   .2970
10.2100   .2970
10.3100   .2970
10.4100   .2970
10.5100   .2970
10.6100   .2970
10.7100   .2970
10.8100   .2970
10.9100   .2970
11.0100   .2970
11.1100   .2970
11.2100   .2970
11.3100   .2970
11.4100   .2970
11.5100   .2970
11.6100   .2970
11.7100   .2970
11.8100   .2970
11.9100   .2970
12.0100   .2970
12.1100   .2970
12.2100   .2970
12.3100   .2970
12.4100   .2970
12.5100   .2970
12.6100   .2970
12.7100   .2970
12.8100   .2970
12.9100   .2970
13.0100   .2970
13.1100   .2970
13.2100   .2970
13.3100   .2970
13.4100   .2970
13.5100   .2970
13.6100   .2970
13.7100   .2970
13.8100   .2970
13.9100   .2970
14.0100   .2970
14.1100   .2970
14.2100   .2970
14.3100   .2970

14.4100   .2970
14.5100   .2970
14.6100   .2970
14.7100   .2970
14.8100   .2970
14.9100   .2970
15.0100   .2970
15.1100   .2970
15.2100   .2970
15.3100   .2970
15.4100   .2970
15.5100   .2970
15.6100   .2970
15.7100   .2970
15.8100   .2970
15.9100   .2970
16.0100   .2970
16.1100   .2970
16.2100   .2970
16.3100   .2970
16.4100   .2970
16.5100   .2970
16.6100   .2970
16.7100   .2970
16.8100   .2970
16.9100   .2970
17.0100   .2970
17.1100   .2970
17.2100   .2970
17.3100   .2970
17.4100   .2970
17.5100   .2970
17.6100   .2970
17.7100   .2970
17.8100   .2970
17.9100   .2970
18.0100   .2970
18.1100   .2970
18.2100   .2970
18.3100   .2970
18.4100   .2970
18.5100   .2970
18.6100   .2970
18.7100   .2970
18.8100   .2970
18.9100   .2970
```

FIGURE 4.12. EXAMPLE FRATX1 RUN TIME HISTORY PLOT 9

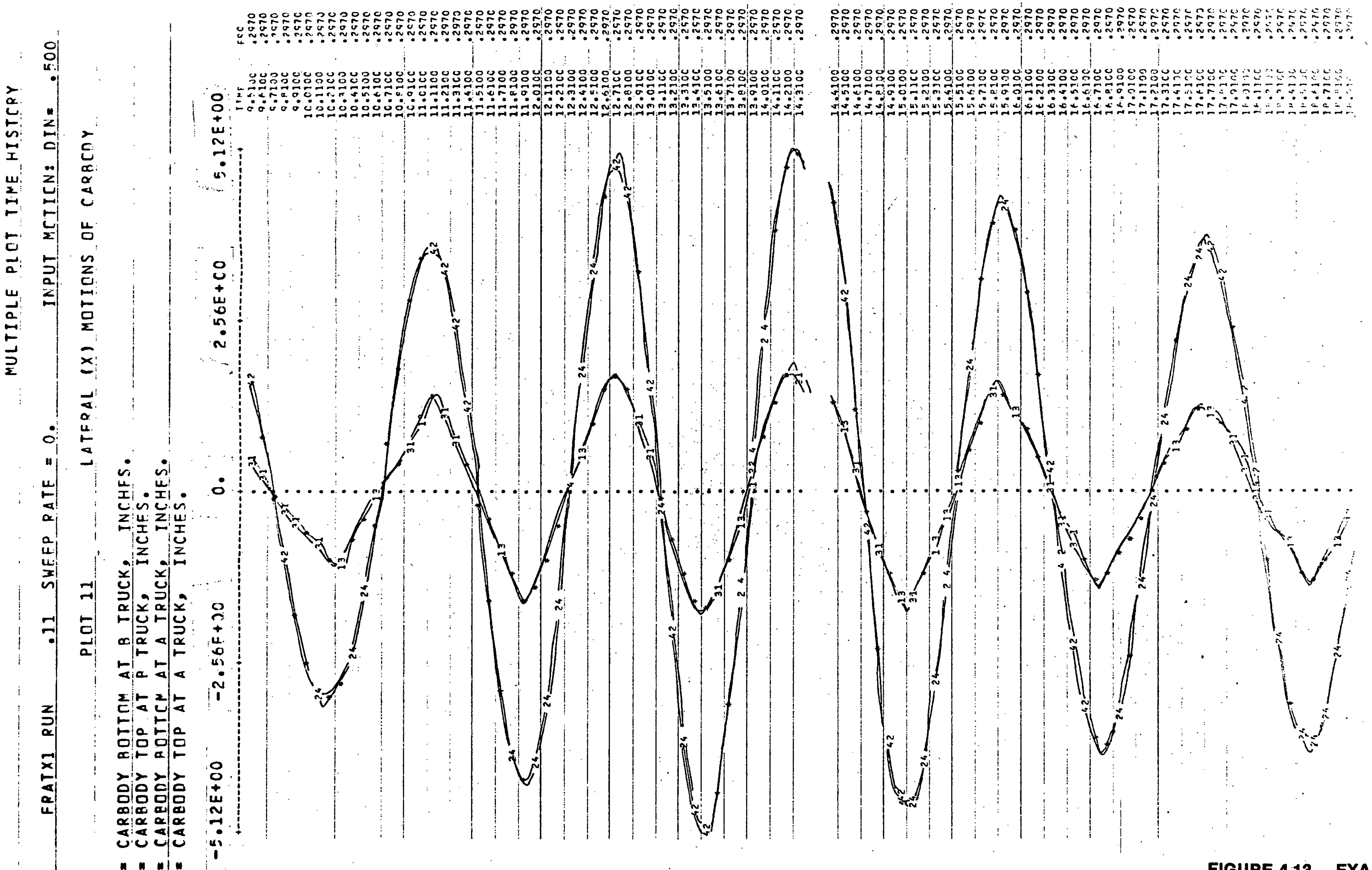


FIGURE 4.13. EXAMPLE FRATX1 RUN TIME HISTORY PLOT 11

MULTIPLE PLOT TIME HISTORY

FRATX1 RUN .11 SWEEP RATE = 0. INPUT MOTION: DIN= .500

PLOT 12 CG MOTIONS OF LADING NO 1.

1 = Z INPUT, INCHES.
2 = ZRESPONSE, INCHES.
3 = X INPUT, INCHES.
4 = X RESPONSE, INCHES.

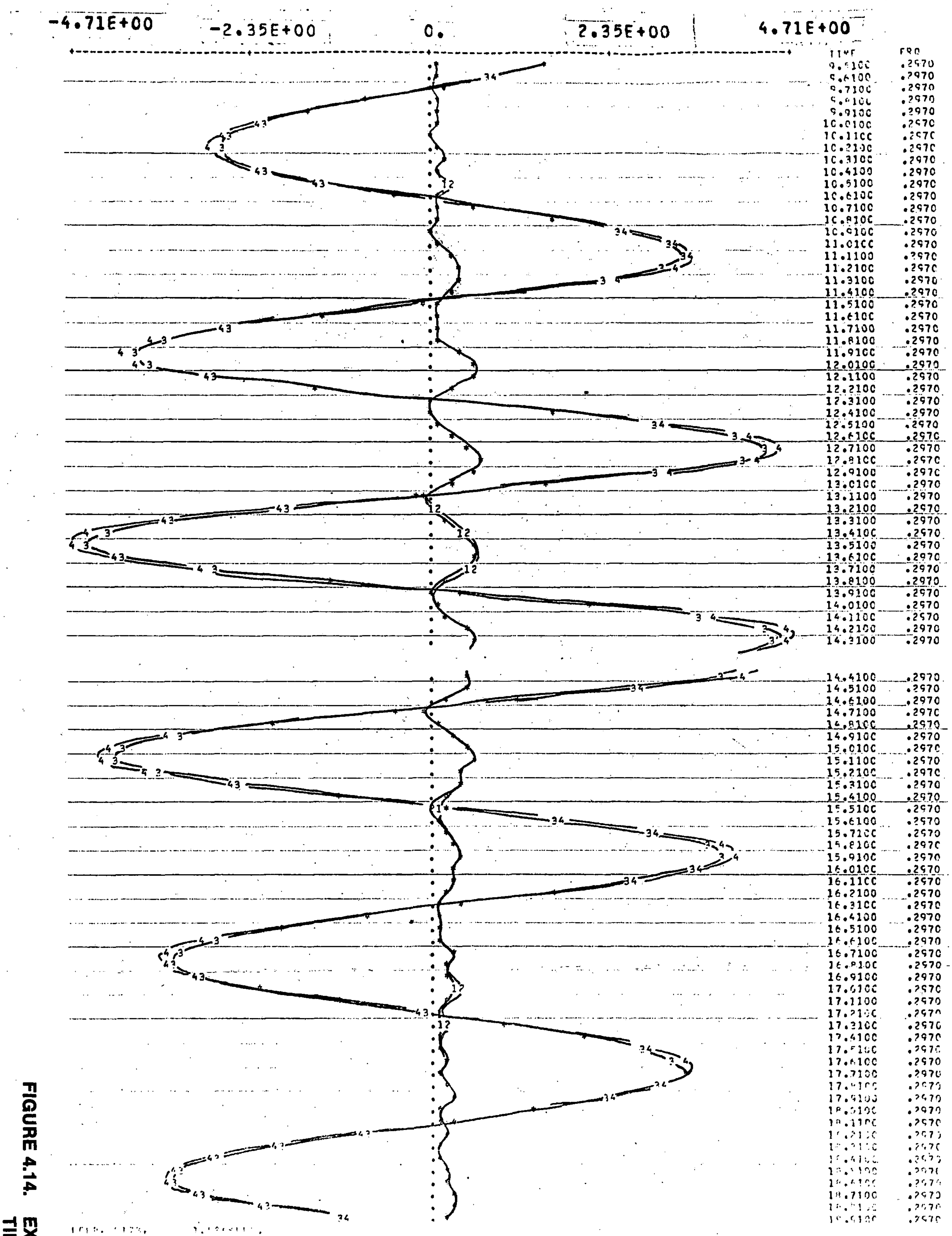


FIGURE 4.14. EXAMPLE FRATX1 RUN TIME HISTORY PLOT 12

5. FRATF1 - TOFC SIMULATION

This section provides information needed for use of the flatcar version of FRATE. The model used, input data required and output options available are described.

5.1 Lumped Mass/Spring Model, FRATF1

FRATF1 uses a lumped mass model of a trailer on flatcar (TOFC) as configured in Figure 5.1. This figure identifies the lumped mass connecting spring systems and coordinate system. Dimensional notations are shown in Figures 5.2 and 5.3.

Including the four lading masses, there are a total of eleven lumped masses and 43 degrees of freedom. This is the maximum number of masses that can be included. The mass items and associated degrees of freedom are summarized in Table 5-1. As discussed in Section 3.1, the user has several options as to the size of the TOFC model. These options are as follows:

a. Empty flatcar with 15 degrees of freedom;

b. Flatcar with a B trailer and 0, 1 or 2 lading masses with 23, 26 or 29 degrees of freedom; and

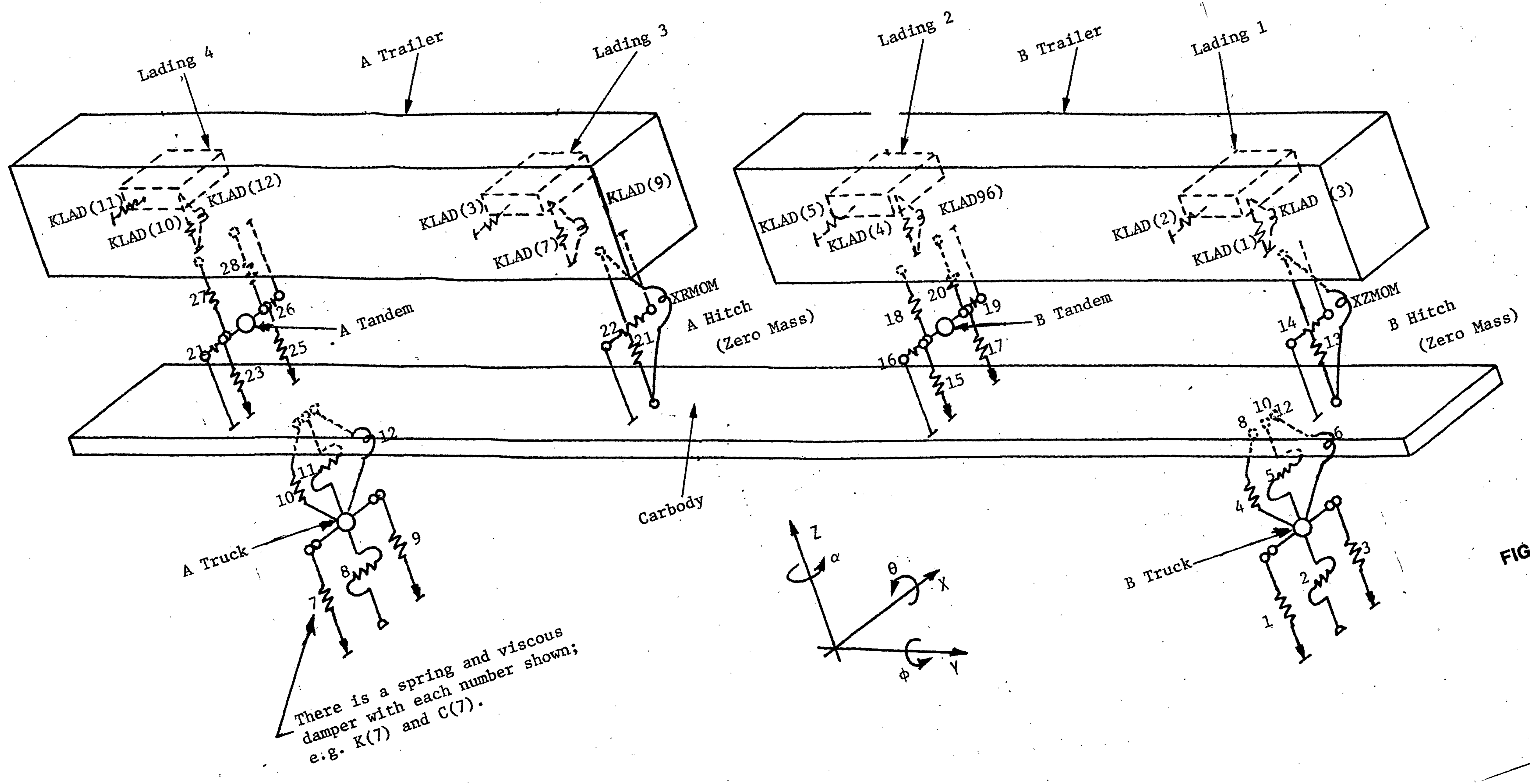
c. Flatcar with two trailers and 0 to 4 lading mass with 31, 34, 37, 40 or 43 degrees of freedom.

Selection of forcing function options is detailed in Section 6.

The truck suspension system model used in FRATF1 is identical to FRATX1 and the discussions in Sections 3.3 and 4.1 are applicable to both. Variations within the model, such as changes in type of snubber, car weight, or spring group can be effected by coefficient changes.

5.2 Example Model Parameter Values for a Trailer on Flatcar (TOFC)

Model parameter values of dimension, stiffness, damping, mass and inertia are presented in this section as an example for FRATF1. Table 5-2 contains all dimensional values. Spring/damper values are presented in Tables 5-3 and 5-4. Mass properties are presented in Tables 5-5 and 5-6.



There is a spring and viscous damper with each number shown; e.g. K(7) and C(7).

FIGURE 5.1. MATH MODEL SCHEMATIC FOR FRATF1

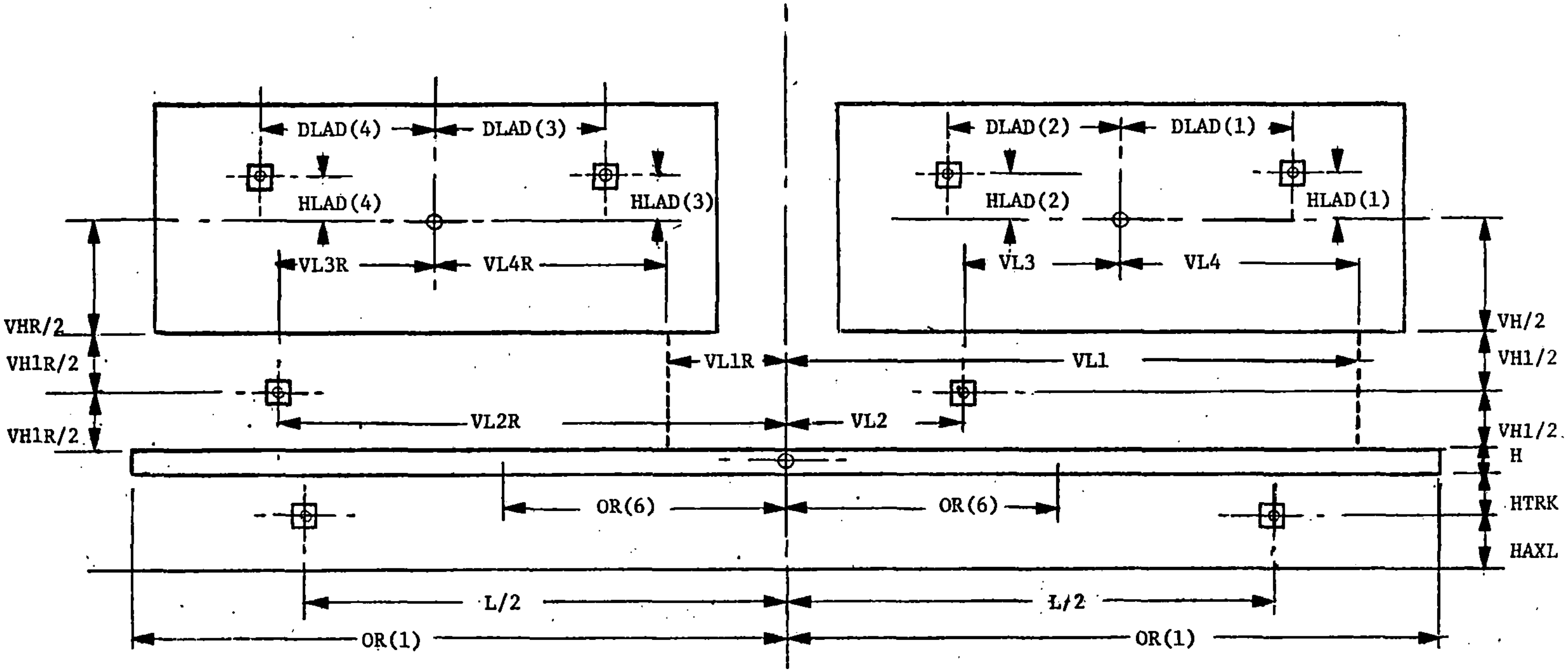
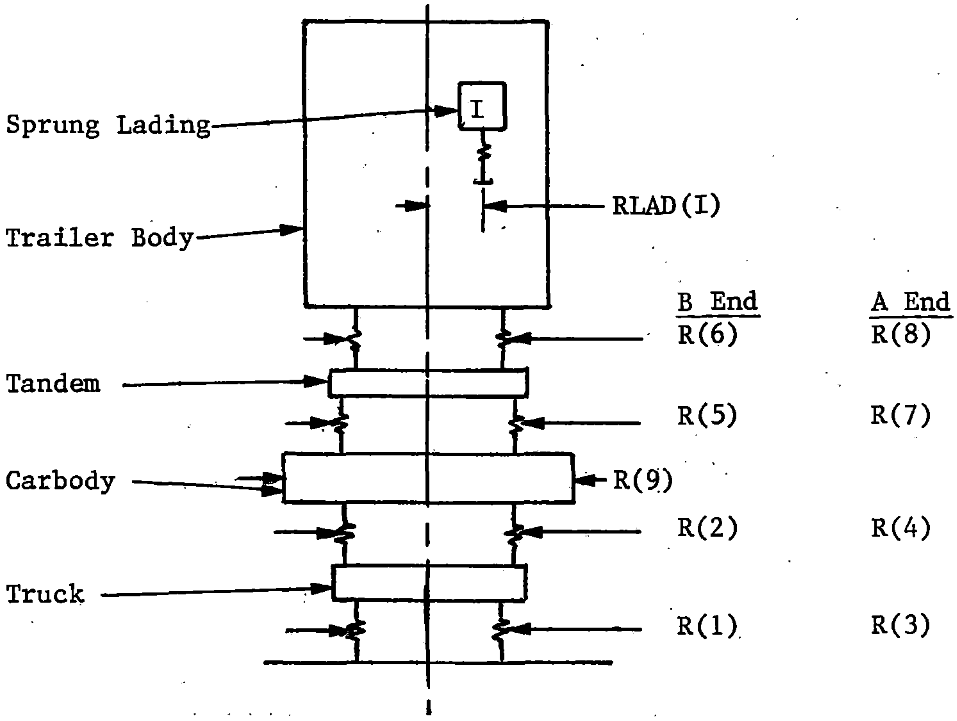


FIGURE 5.2. FRATE/TOFC GEOMETRY NOTATION



R(1) = Wheel Gage Distance, B Truck
R(2) = Distance Between Spring Nest Centroids, B Truck
R(3) = Wheel Gage Distance, A Truck
R(4) = Distance Between Spring Nest Centroids, A Truck
R(5) = Effective Width of Tandem Tread of B End Trailer
R(6) = Effective Width Between Tandem Spring Centroids of B End Trailer
R(7) = Effective Width of Tandem Tread of A End Trailer
R(8) = Effective Width Between Tandem Spring Centroids of A End Trailer
RLAD(I) = X Distance of Lading Mass I CG from Trailer Center Line
R(9) = Width of Carbody
R(10) = Distance Between Side Bearings (Not Shown)
R(11) = Distance Between Hydraulic Snubbers (Not Shown)
R(12) = Distance Between Friction Snubbers (Not Shown)

FIGURE 5.3. TOFC LATERAL DIMENSION NOTATION

TABLE 5-1 - FRATF1 DEGREES OF FREEDOM

Mass	Degrees of Freedom
B Truck	X(1), Z(1), ϕ(1)
A Truck	X(2), Z(2), ϕ(2)
Carbody	X(3), Z(3), ϕ(3), θ, α
B Tandem	X(4), Z(4), ϕ(4)
B Trailer Body	X(5), Z(5), ϕ(5), θV, αV
A Tandem	X(6), Z(6), ϕ(6)
A Trailer Body	X(7), Z(7), ϕ(7), θT, αT
Carbody Flexibility	η(1), η(2), η(3), η(4)
Lading: MLAD (I) I = 1, 4	XLAD(I), ZLAD(I), ϕLAD(I)

TABLE 5-2 - DIMENTIONAL VALUES FOR EXAMPLE TOFC

Item	Value*	Description
L	792.0	Distance Between Track Centers
R(1), R(3)	58.0	Wheel Gage Distance
R(2), R(4)	79.0	Distance Between Spring Nest Centers
R(5), R(7)	62.2	Distance Between Tandem Center
R(6), R(8)	38.0	Distance Between Tandem Springs
R(9)	108.0	Width of Flatcar
R(10)	50.0	Distance Between Side Bearings
R(11)	89.0	Distance Between Hydraulic Snubbers
R(12)	79.0	Distance Between Friction Snubbers
H	16.0	Height of Carbody
HTRK	9.0	Effective Height of Truck
HAXL	16.5	Wheel Radius
VH1, VH1R	47.0	Vertical Distance from Top of Flatcar to Bottom of Trailer
VH, VHR	53.5	Twice Vertical Distance, Trailer Bottom to Trailer C.G.
VL1	469.0	Distance from Carbody Center to B Trailer Hitch
VL2	109.0	Distance from Carbody Center to B Trailer Tandem
VL3	156.0	Distance from B Trailer C.G. to Hitch
VL4	204.0	Distance from B Trailer C.G. to Tandem
VL1R	-85.0	Distance from Carbody Center to A Trailer Hitch
VL2R	-445.0	Distance from Carbody Center to A Trailer Tandem
VL3R	156.0	Distance from A Trailer C.G. to Hitch
VL4R	204.0	Distance from A Trailer C.G. to Tandem
OR(1)	536.0	Distance from Carbody C.G. to B End
OR(2)	-536.0	Distance from Carbody C.G. to A End

TABLE 5-2 - DIMENTIONAL VALUES FOR EXAMPLE TOFC (CONCLUDED)

Item	Value*	Description
OR(6)	224.0	Distance from Carbody C.G. to Plot Data Point
OR(7), OR(9)	240.0	Distance from Trailer C.G. to Hitch End
OR(8), OR(10)	240.0	Distance from Trailer C.G. to Tandem End
GAPB, GAPA	0.01**	Side Bearing Gap
GAGEB, GAGEA	0.60	One-Half Gage Clearance
DLAD(1)	120.0	Y Distance from B Trailer C.G. to Lading 1 C.G.
DLAD(2)	-120.0	Y Distance from B Trailer C.G. to Lading 2 C.G.
DLAD(3)	120.0	Y Distance from A Trailer C.G. to Lading 3 C.G.
DLAD(4)	-120.0	Y Distance from A Trailer C.G. to Lading 4 C.G.
RLAD(I)	0.0	X Distance from Trailer C.G. to Lading C.G.
HL(I)	35.31	Z Distance from Trailer C.G. to Lading C.G.
BX	48.0	X Distance from Lading C.G. to Lading Corner
BY	-120.0	Y Distance from Lading C.G. to Lading Corner
BZ	9.9	Z Distance from Lading C.G. to Lading Corner

---

* Units are in inches unless otherwise noted

**Radian

TABLE 5-3 – SPRING AND DAMPER VALUES AND DESCRIPTIONS OF FRATE WITH EXAMPLE TOFC

Name	Value/Units	Location	Descriptions
K(1), K(3) K(7), K(9)	0.91 E5 lbs./in.	Wheel-Rail, Vertical	Compressive Load Only
C(1), C(3) C(7), C(9)	300 lbs./in./sec.		Full Time Viscous But Zero With Wheel Lift
K(2), K(8) KFCB, KFCA	0.10 E5 lbs./in.^{1} 0.95 E5 lbs./in.^{2}	Wheel-Rail, Lateral	Bilinear: ^{1}No Flange Contact. ^{2}Flange Contact
C(2), C(8)	1,100 lbs./in./sec.		
K(4), K(10)	0.48 E5 lbs./in.	Truck Suspension Vertical	Compression Only
C(4), C(10)	450 lbs./in./sec.		Full Time Viscous But Zero with Centerplate Lift
K(5), K(11)	0.16 E5 lbs./in.^{1} 0.10 E6 lbs./in.^{2}	Truck Suspension Lateral	^{1}Without Gib Contact--Varies with G.W--See Figure 3-4. ^{2}With Gib Contact
C(5), C(11)	400 lbs./in./sec.		
KCP6, KCP12	0.20 E8 in. lbs./rad	Centerplate, Roll	In Effect Before Side Bearing Contact --Viscous Damping
CCP6, CCP12	0.20 E6 in. lbs./rad./sec.		
K(6), K(12)	0.75 E8 in. lbs./rad.	Truck Suspension Roll	In Effect After Side Bearing Contact and Before Centerplate Lift--Viscous Damping
C(6), C(12)	0.60 E6 in. lbs./rad./sec.		
KLSB, KLSA	0.10 E6 lbs./in.	Structure Local to Friction Snubbers	Compression Only--Force Limited by FFSB and FFSA KS4 = 2 * KLSB KS10 = 2 * KLSA KS6 = KLSB * $(R(12)/2)^2$ KS12 = KLSA * $(R(12)/2)^2$
CLSB, CLSA	0.10 E4 lbs./in./sec.		

TABLE 5-3 - SPRING, DAMPER VALUES, AND DESCRIPTIONS OF FRATE1 WITH EXAMPLE TOFC (CONCLUDED)

Name	Value/Units	Location	Descriptions
FFSB, FFSA	2,000 lbs.	Friction Snubber Force	Compression Only MFS4 = 2 * FFSB MFS10 = 2 * FFSA MFS6 = FFSB * R(12)/2 MFS12 = FFSA * R(12)/2
CHSB, CHSA	0.0 lbs./in./sec.	Hydraulic Snubber Rate	Compression Only CHS4 = 2 * CHSB CHS10 = 2 * CHSA CHS6 = CHSB * $(R(11)/2)^2$ CHS12 = CHSA * $(R(11)/2)^2$
KLAD (1)(4) (7)(10)	0.69 E5 lbs./in.	Lading Support, Vertical	Linear with Viscous Damping--Assumed
CLAD (1)(4) (7)(10)	164 lbs./in./sec.		fn = 9.5 Q = 7.0
KLAD (2)(5) (8)(11)	0.19 E5 lbs./in.	Lading Support, Lateral	
CLAD (2)(5) (8)(11)	151 lbs./in./sec.		fn = 5.0 Q = 4.0
KLAD (3)(6) (9)(12)	0.148 E9 in. lbs./rad.	Lading Support, Roll	
CLAD (3)(6) (9)(12)	0.190 E6 in. lbs./rad./sec.		fn = 15.0 Q = 8.3

TABLE 5-4 - TRAILER SPRING AND DAMPER VALUES, EXAMPLE TOFC

Item	Value/Units	Location & Description
K(13), K(21)	0.225 E6 (lbs./in.)	Trailer Hitch, Vertical
C(13), C(21)	1,000 (lbs./in./sec.)	
K(14), K(22)	0.150 E5 (lbs./in.)	Trialer Hitch, Lateral
C(14), C(22)	200 (lbs./in./sec.)	
K(15), K(17) K(23), K(25)	0.225 E5 (lbs./in.)	Tandem Tires, Vertical, Compression Only
C(15), C(17) C(23), C(25)	330 (lbs./in./sec.)	
K(16), K(24)	0.180 E5 (lbs./in.)	Tandem Tires, Lateral
C(16), C(24)	200 (lbs./in./sec.)	
K(18), K(20) K(26), K(28)	0.527 E5 (lbs./in.)	Tandem Suspension, Vertical
C(18), C(20) C(26), C(28)	775 (lbs./in./sec.)	
K(19), K(27)	0.180 E5 (lbs./in.)	Tandem Suspension, Lateral
C(19), C(27)	200 (lbs./in./sec.)	
XZKMOM, XRKMOM	0.30 E8	Trailer Hitch Roll Restraint
XZCMOM, XRCMOM	0.10 E6	

TABLE 5-5 - TOFC WEIGHT BREAKDOWN AND C.G. LOCATION

Item	Weight	Height From Top of Rail (in.)	W x H (in. lbs.)
Trailer Body (ea.)	9,100	106.5	0.96915 E6
Fixed Lading (ea.)	34,650	117.6	4.0748 E6
Body and Fixed Lading	43,750	115.29	5.0440 E6
Sprung Lading (ea.)	7,425	150.6	1.1182 E6
Tandem (ea.)	3,157	65.0	0.2052 E6
Flatcar Body	48,250	33.5	1.6164 E6
Trucks (ea.)	8,618	16.5	0.1422 E6
Trailer Total	61,757	121.21	7.4856 E6
TOFC Total	189,000	89.27	16.820 E6

Note: See Figure 7.3 for sketch of configuration.

TABLE 5-6 - TOFC MASS PROPERTIES WITH TWO IDENTICAL VAN TRAILERS EACH HAVING FLEXIBILITY MOUNTED LADING MASSES

Symbol	Description	Value (Mass Units)	Weight Units
M(1), M(2)	B Truck Mass, A Truck Mass	22.23	8,618
M(3)	Carbody Mass (Empty)	125.00	48,250
M(4), M(6)	Tandem Masses, B and A Trailers	8.179	3,157
M(5), M(7)	Trailer Body Masses, B and A*	113.34	43,750
MLAD(1) - MLAD(4)	Flexibly Mounted Lading Masses	19.24	7,425
I(1), I(2)	Truck Roll Inertias, B and A	0.02208 E6	8.523 E6
I(3)	Carbody Roll Inertia	0.1085 E6	41.88 E6
I(4)	Carbody Pitch Inertia	1.50 E7	5.79 E9
I(5)	Carbody Yaw Inertia	1.50 E7	5.79 E9
I(6), I(10)	Tandem Roll Inertia, Trailers B and A	2.0 E4	7.72 E6
I(7), I(11)	Trailer Body Roll Inertias, B and A*	1.20 E5	4.65 E7
I(8), I(12)	Trailer Body Pitch Inertias, B and A*	2.21 E6	8.52 E8
I(9), I(13)	Trailer Body, Yaw Inertia, B and A*	2.26 E6	8.72 E8
INLAD(1) - INLAD(4)	Roll Inertia of Sprung Lading Masses	0.01666 E6	6.43 E6

Note: Units: M(I) = lbs. sec.^{2}/in. or lbs.
I(I) = in. lbs. sec.^{2}, or lbs. in.^{2}

---

*Trailer body mass and inertia values include that portion of lading assumed to be a rigid integral part of the trailer.

This example model is of an 89 foot TOFC with two highway trailer Truck spacing is 66 feet. The flatcar light weight is 65,486 pounds. The trailers each weigh 61,757 pounds. The total weight at the rails is 189,000 pounds.

5.3 FRATF1 Output Options

The output provided by the FRATE programs consists of five parts (1) a listing of the input data as contained in the four Namelist; (2) the initial deflections of the vertical and pitch degrees of freedom; (3) a listing of separating spring and time of separation for the first 100 separations; (4) the DEBUG option listing, and (5) time histories of selected input and response functions. This section contains details of the specific functions available in FRATF1 for time history plotting, and how selections are made.

Time histories are plotted in groups of four as shown in the example run in Section 5.5. Each of the four functions plotted is identified by numbers, 1-4, and its number is used as the plotting symbol. Where two or more functions have the same value an asterisk is used for the plot symbol. In the example time histories of Section 5.5, the plot points have been connected by hand to help in studying the results.

There are 20 groups of output functions to choose from; i.e. a total of 80 functions. The choice of groups is made through the input parameter IPLOT(I): any integer for (I) will cause that group to be plotted and 0 (zero) will cause it to be omitted. A listing of available output functions by group is shown in Table 5-7.

5.4 Carbody Flexibility

Carbody flexibility is included in FRATE by a superposition of normal modes of the empty carbody in a free-free boundary condition, i.e., less trucks. Input data required are the mode frequencies an estimate of modal damping coefficient and deflection coefficients normalized for unit modal mass. Thus, for a give flatcar the normal mode input data is not changed by loading conditions. Deflection coefficients are required for the points where each spring attaches to the carbody and those points on the carbody where a measure of response motion is desired. The deflection coefficient numbering system used in the example TOFC is shown

TABLE 5-7 - OUTPUT DATA

IPLOT Number	Curve Number	Description of Output Data
1		Input Motions, Vertical
	1	Z Input, B Truck, Left Side, in.
	2	Crosslevel, B Truck, in.
	3	Z Input, A Truck, Left Side, in.
	4	Crosslevel, A Truck, in.
2		Truck Motions, Lateral
	1	X Input, B Truck at Track, in.
	2	X Motion, B Truck C.G., in.
	3	X Input, A Truck at Track, in.
	4	X Motion, A Truck C.G., in.
3		Wheel-Rail Forces, B Truck
	1	Vertical, Left Side, lbs.
	2	Lateral, lbs.
	3	Vertical, Right Side, lbs.
	4	Roll Moment at Centerplate /25., in. lbs.
4		Wheel-Rail Forces, A Truck
	1	Vertical, Left Side, lbs.
	2	Lateral, lbs.
	3	Vertical, Right Side, lbs.
	4	Roll Moment at Centerplate /25., in. lbs.
5		Truck and Carbody Roll Motions
	1	Roll Angle, B Truck C.G., Degrees
	2	Roll Angle, Carbody at B Truck, Degrees
	3	Roll Angle, A Truck C.G., Degrees
	4	Roll Angle, Carbody at A Truck, Degrees
6		Trailer Roll Motions
	1	Tandem, B Trailer, Degrees
	2	Body, B Trailer, Degrees
	3	Tandem, A Trailer, Degrees
	4	Body, A Trailer, Degrees
7		Carbody Vertical Motion, Left Side, (-R(9)/2.)
	1	At B Truck (L/2 from Center), in.
	2	At +OR(6) From Center, in.
	3	At Carbody Center, in.
	4	At A Truck, in.
8		Carbody Vertical Motion, Right Side, (+R(9)/2.)
	1	At B Truck, in.
	2	At +OR(6) From Center, in.
	3	At Carbody Center, in.
	4	At A Truck, in.
9		Trailer Vertical Motions
	1	B Trailer, B End, in.
	2	B Trailer, A End, in.
	3	A Trailer, B End, in.
	4	A Trailer, A End, in.

TABLE 5-7 - OUTPUT DATA (CONCLUDED)

IPLOT Number	Curve Number	Description of Output Data
10.		Trailer Lateral Motions, Trailer Bottom
	1	B Trailer, B End, in.
	2	B Trailer, A End, in.
	3	A Trailer, B End, in.
	4	A Trailer, A End, in.
11.		Z Motion of Lading in B Trailer
	1	Input Lading 1, in.
	2	Response Lading 1, in.
	3	Input Lading 2, in.
	4	Response Lading 2, in.
12.		X Motion of Lading in B Trailer
	1	Input Lading 1, in.
	2	Response Lading 1, in.
	3	Input Lading 2, in.
	4	Response Lading 2, in.
13		Z Motion of Lading in A Trailer
	1	Input Lading 3, in.
	2	Response Lading 3, in.
	3	Input Lading 4, in.
	4	Response Lading 4, in.
14		X Motion of Lading in A Trailer
	1	Input Lading 3, in.
	2	Response Lading 3, in.
	3	Input Lading 4, in.
	4	Response Lading 4, in.
15		Z Acceleration, Lading C.G.
	1	Lading 1, g's
	2	Lading 2, g's
	3	Lading 3, g's
	4	Lading 4, g's
16		X Acceleration of Lading C.G.
	1	Lading 1, g's
	2	Lading 2, g's
	3	Lading 3, g's
	4	Lading 4, g's
17		Acceleration at Corner of Lading
	1	Z Acceleration, Corner Lading 1, g's
	2	Z Acceleration, Corner Lading 4, g's
	3	X Acceleration, Corner Lading 1, g's
	4	X Acceleration, Corner Lading 4, g's
18		Acceleration of B Truck and Carbody
	1	Z Acceleration, B Truck C.G, g's
	2	X Acceleration, B Truck C.G., g's
	3	Z Acceleration, B Truck at Right Wheel, g's
	4	Z Acceleration, Carbody at B Truck, g's
19		Acceleration of A Truck and Carbody
	1	Z Acceleration, A Truck C.G., g's
	2	X Acceleration, A Truck C.G., g's
	3	Z Acceleration, A Truck at Right Wheel, g's
	4	Z Acceleration of Carbody at A Truck, g's

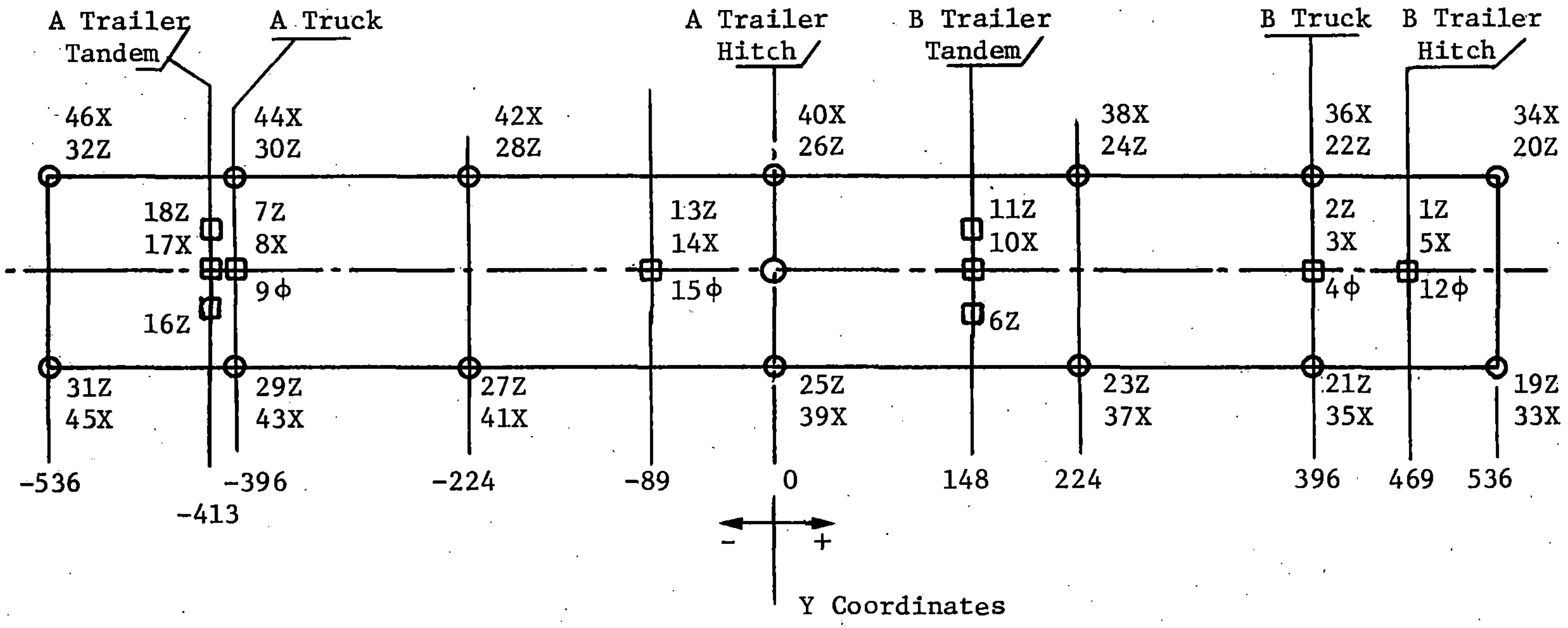
in Figure 5.4. The modal frequencies and coefficients are listed in Table 5-8. The first four body modes have been included. The predominant motions in each mode are: mode 1, vertical bending; mode 2, lateral bending with torsion; mode 3, torsion with lateral bending; and mode 4, second vertical bending.

5.5 Example FRATF1 Run

The following pages contain the Namelist input data as submitted to the CDC computer system and the resulting printout. The input data file is given in Figure 5.5. The input data as listed with the computer printout is given in Figure 5.6. Example DEBUG printouts are given in Figure 5.6. Representative time history plots are given in Figures 5.7 through 5.14.

The example is for a flatcar with two fully loaded highway trailers and with two spring mounted lading masses in each trailer. The input excitation function is a rectified sine simulation of 39 foot staggered joint bolted rail at a track speed of 14.0 miles per hour.

Lading assumptions and development of the lading model can be found in Section 7.2.



Modal Coefficient Locations

○ - used in carbody response measurement
☐ - used in equations of motion - spring attachment points

FIGURE 5.4. NUMBERING SYSTEM FOR CARBODY FLEXIBLE MODE COEFFICIENTS

TABLE 5-8 - CARBODY FLEXIBLE MODE COEFFICIENTS

Location	Mode 1 f = 4.253 Hz.	Mode 2 f = 8.873 Hz.	Mode 3 f = 9.417 Hz.	Mode 4 f = 9.629 Hz.
1Z	.13913E+00	.10770E-05	.54590E-05	.12234E+00
2Z	.68378E-01	.33196E-08	-.49114E-06	-.15435E-01
3X	.51200E-06	.56691E-01	.22910E-01	.35450E-05
4φ	-.12532E-10	-.86347E-03	.25528E-02	-.11870E-06
5X	.59200E-06	.10023E+00	.38352E-01	.17500E-05
6Z	-.62628E-01	.12993E-01	-.48615E-01	-.75540E-01
7Z	.82416E-01	-.18479E-06	-.31169E-06	-.12350E-02
8X	-.52900E-06	.70426E-01	.27362E-01	-.65180E-05
9φ	.23266E-09	.85568E-03	-.24210E-02	.11127E-06
10X	.22700E-06	-.50729E-01	-.16349E-01	.56870E-05
11Z	-.62628E-01	-.12994E-01	.48609E-01	-.75542E-01
12φ	0.	-.93066E-03	.26759E-02	-.12530E-06
13Z	-.76877E-01	.32500E-06	.20030E-05	.48542E-01
14X	.15200E-06	.59838E-01	.22612E-01	.11150E-05
15φ	0.	.31250E-03	-.72860E-03	.32000E-07
16Z	.92463E-01	-.30591E-01	.86550E-01	-.20347E-01
17X	-.52900E-06	.70426E-01	.27362E-01	-.65180E-05
18Z	.92463E-01	.30590E-01	-.86552E-01	-.20339E-01
19Z	.19473E+00	.53109E-01	-.15010E+00	.23060E+00
20Z	.19473E+00	-.53105E-01	.15012E+00	.23059E+00
21Z	.68378E-01	.46627E-01	-.13785E+00	-.15429E-01
22Z	.68378E-01	-.46627E-01	.13785E+00	-.15452E-01
23Z	-.36883E-01	.30467E-01	-.10681E+00	-.94654E-01
24Z	-.36883E-01	-.30468E-01	.10680E+00	-.94664E-01
25Z	-.90388E-01	-.44789E-02	.79877E-03	.23972E-02
26Z	-.90388E-01	.44790E-02	-.79840E-03	.23973E-02
27Z	-.27713E-01	-.37982E-01	.10500E+00	.88031E-01
28Z	-.27713E-01	.37983E-01	-.10499E+00	.88040E-01
29Z	.82416E-01	-.46207E-01	.13073E+00	-.12409E-02
30Z	.82416E-01	.46206E-01	-.13073E+00	-.12289E-02
31Z	.20960E+00	-.49600E-01	.14143E+00	-.24311E+00
32Z	.20960E+00	.49596E-01	-.14145E+00	-.24310E+00
33X	0.	.19818E+00	.68382E-01	-.91500E-05
34X	0.	.19818E+00	.68382E-01	-.91500E-05
35X	0.	.56691E-01	.22910E-01	.35400E-05
36X	0.	.56691E-01	.22910E-01	.35400E-05
37X	0.	-.37963E-01	-.10659E-01	.74500E-05
38X	0.	-.37963E-01	-.10659E-01	.74500E-05
39X	0.	-.79144E-01	-.29014E-01	.17700E-05
40X	0.	-.79144E-01	-.29014E-01	.17700E-05
41X	0.	-.26967E-01	-.11710E-01	-.60200E-05
42X	0.	-.26967E-01	-.11710E-01	-.60200E-05
43X	0.	.70426E-01	.27362E-01	-.65200E-05
44X	0.	.70426E-01	.27362E-01	-.65200E-05
45X	0.	.20547E+00	.85956E-01	-.34900E-06
46X	0.	.20547E+00	.85956E-01	-.34900E-06

Note: See Figure 5-4 for location definition.

```
OLD.FRADF1
READY.
LNH
 $CONTRL
 RUNO=000.04,
 STARTM=.5,   DELTAT=.005,   STOPTM=1.0,
 IPRINT=2,
 IPLOT=1,2,3,0,5,6,7,0,0,10,0,12,0,14,6*0,
 DEBUG=.T.,  STARDB=0.00.  STOPDB=0.01,$
 $EXCIT
 SINEIN=.F.,
 RECSIN=.T.,
 S1= 1.,   S2= 0.0,   S3=.0,
 AMP =  1.0,   00.,   1.00,   1.0,   00.,   01.0,
 PHAS=  0.,    .00,   90.0,   304.6,   0.00,   34.6,
 FQ=0.260,  FQDOT=.0,  BETA=0.,  NDECAY=5000,
 DIN=.50,      VIN=0.00,    GIN=.0,
 PULSE=.F.,   BFRONT=.T.,   PL=  33.0,   SPEED=70.0,
 HUNT = .F.,  FCRB=0.0,    FCRA=0.0,
              PHASB=0.0,   PHASA=0.0,$
 $VEHIC
 NMAS=7,
 M=2*22.33,125.0,8.179,113.34,8.179,113.34,
 INERT=22080.,22080.,.1085E6,.15E8,.15E8,
       .20E5,  .12E6,  .221E7,  .226E7,
       .20E5,  .12E6,  .221E7,  .226E7,
 R=58.,79.,58.,79.,62.25,38.0,62.25,38.0,108.,50.,89.,79.,2*0.,
 H=16.,HAXL=16.5,HTRK=9.,VH=53.58,VH1=47.0,VHR=53.58,VH1R=47.0,
 L=792.,VL1=469.,VL2=109.,VL3=156.0,VL4=204.0,
 VL1R=-85.,VL2R=-445.,VL3R=156.0,VL4R=204.0,
 OR=536.,-536.,3*0.0,224.,240.,240.,240.,240.,
 GAGEB=.60,   GAGEA=.60,
 GAPB=.01,   GAPA=.01,
 K=.91E5,.10E5,.91E5,.48E5,.16E5,.75E8,
   .91E5,.10E5,.91E5,.48E5,.16E5,.75E8,
   .225E6,.15E5,.225E5,.18E5,.225E5,.5276E5,.18E5,.5276E5,
   .225E6,.15E5,.225E5,.18E5,.225E5,.5276E5,.18E5,.5276E5,
 XZKMOM=.30E8,      XRKMOM=.30E8,
 KLSB=.10E6,  KLSA=.10E6,  CLSB=.10E4,  CLSA=.10E4,
 KCP6=.20E8,  KCP12=.20E8,  CCP6=.20E6,  CCP12=.20E6,
 KFCB=.95E5,  KFCA=.95E5,
 C=300.,1100.,300.,450.,400.,.60E6,300.,1100.,300.,450.,400.,.60E6,
   1000.,200.,330.,200.,330.,775.,200.,775.,
     1000.,200.,330.,200.,330.,775.,200.,775.,
 XZCMOM=.10E6,     XRCMOM=.10E6,
 FFSB=2000.,     FFSA=2000.,     CHSB=0.0,     CHSA=0.0,
 MLAD = 19.24, 19.24, 19.24, 19.24,
 INLAD = .1666E5, .1666E5, .1666E5, .1666E5,
 HL = 35.31,  35.31,  35.31,  35.31,
 DLAD = 120.0, -120.0, 120.0, -120.0,
 RLAD = 0.0, 0.0, 0.0, 0.0,
 BX = 48.0,      BY = -120.0,      BZ = 9.9,
 KLAD = .69E5, .19E5, .148E9, .69E5, .19E5, .148E9,
        .69E5, .19E5, .148E9, .69E5, .19E5, .148E9,
 CLAD = 158., 125., .1512E6, 158., 125., .1512E6,
        158., 125., .1512E6, 158., 125., .1512E6,$
```

FIGURE 5.5. INPUT DATA FILE EXAMPLE FRATF1 RUN

```
$MODAL
NMODES=4,
RF=4.253,  8.873,  9.417,  9.629,
ZETA=4*0.02,
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,.531085E-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,.239728E-2,.880306E-1,
.880400E-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,
$END
-END OF FILE-
```

FIGURE 5.5. INPUT DATA FILE EXAMPLE FRATF1 RUN (CONCLUDED)

```
INPUT PARAMETERS FOR FRATF1, RUN NO.      .04

TIME HISTORY RUN PARAMETERS

          START TIME   =   9.500
          DELTAT       =    .005
          STOPTM     = 19.000
          IPRINT     = 2
          IPLOT     =  1   2   3   0   5   6   7   0   0 10   0 12   0 14   0   0   0   0   0   0

          DEBUG          =   T
          STARDB         =   0.000
          STOPDB         =    .010

EXCITATION PARAMETERS

          SINEIN    = F
          RECSIN   = T

          AMP(I)     =      1.0000    0.0000    1.0000    1.0000    0.0000    1.0000
          PHAS(I)    =      0.0000    0.0000   90.0000  304.6000    0.0000   34.6000

          FO         =     .2600
          FODOT      =   0.0000
          BETA       =   0.0000

          DIN        =     .5000
          VIN        =   0.0000
          GIN        =   0.0000
          NDECAY     =   5000

          SHAPE    =   S1+(1-COS(OMEGA(T)/S2))/2.+(1-EXP(3.FO(T))/S3))
            S1  =   1.0000
            S2  =   0.0000   WHERE S2 = LENGTH OF 1-COS IN CYCLES OF FO
            S3  =   0.0000   WHERE S3 = CYCLES OF FO FOR SHAPE TO REACH .95

          PULSE      = F       BFRONT    = T       PL    = 33.0000FT      SPEED     =   70.000FT/SEC
             (NOTE: DIN EQUALS 1/2 PULSE HEIGHT)

          HUNT    = F       FCRB =   0.0000      FRCA =   0.0000
                           PHASB   =   0.0000       PHASA   =   0.0000
```

FIGURE 5.6. COMPUTER PRINTOUT, EXAMPLE FRATF1 RUN

```
MODEL PARAMETERS

          NMAS     =    7

          M        =     .2233E+02  .2233E+02  .1250E+03  .8179E+01  .1133E+03  .8179E+01  .1133E+03

          INERT    =     .2208E+05  .2208E+05  .1085E+06  .1500E+08  .1500E+08  .2000E+05  .1200E+06
                         .2210E+07  .2260E+07  .2000E+05  .1200E+06  .2210E+07  .2260E+07

          K        =
              .9100E+05     .1000E+05     .9100E+05     .4800E+05     .1600E+05     .7500E+08
              .9100E+05     .1000E+05     .9100E+05     .4800E+05     .1600E+05     .7500E+08
              .2250E+06     .1500E+05     .2250E+05     .1800E+05     .2250E+05     .5276E+05     .1800E+05     .5276E+05
              .2250E+06     .1500E+05     .2250E+05     .1800E+05     .2250E+05     .5276E+05     .1800E+05     .5276E+05

          XZKMOM =       .3000E+08        XRKMOM =       .3000E+08

          KCP6     =       .2000E+08        KCP12    =       .2000E+08
          KLSB     =       .1000E+06        KLSA     =       .1000E+06


          CLSB     =     .1000E+04        CLSA     =     .1000E+04
          KFCB     =     .9500E+05        KFCA     =     .9500E+05

          C        =
              .3000E+03     .1100E+04     .3000E+03     .4500E+03     .4000E+03     .6000E+06
              .3000E+03     .1100E+04     .3000E+03     .4500E+03     .4000E+03     .6000E+06
              .1000E+04     .2000E+03     .3300E+03     .2000E+03     .3300E+03     .7750E+03     .2000E+03     .7750E+03
              .1000E+04     .2000E+03     .3300E+03     .2000E+03     .3300E+03     .7750E+03     .2000E+03     .7750E+03

          XZCMOM =       .1000E+06        XRCMOM =       .1000E+06

          CCP6     =       .2000E+06        CCP12    =       .2000E+06
          CHSB     =     0.                 CHSA     =     0.
```

FIGURE 5.6. COMPUTER PRINTOUT, EXAMPLE FRATF1 RUN (CONTINUED)

```
R     =       58.000     79.000     58.000     79.000     62.250     38.000     62.250
              38.000    108.000     50.000     89.000     79.000      0.000      0.CCC

OR    =      536.000   -536.000      0.000      0.000      0.000
             224.000    240.000    240.000    240.000    240.000

L     = 792.000
H     =  16.CC0     HTRK  =    9.000     HAXL  =  16.500

VH    =    53.580          VHR    =    53.580
VH1   =    47.000          VH1R   =    47.000
VL1   =   469.000          VL1R   =   -85.000
VL2   =   109.000          VL2R   =  -445.000
VL3   =   156.000          VL3R   =   156.000
VL4   =   204.000          VL4R   =   204.000

GAGEB     =       .600     GAGEA     =       .600

GAPB    =  .0100     GAPA    =  .C100

FFSB    =      .2000E+04     FFSA     =     .2000E+04


NORMAL MODE PARAMETERS

         NMODES   =   4

         FREQ     =   4.253    8.873    9.417    9.629

         ZETA     =    .020     .020     .020     .020

         NLOC     =  46
```

FIGURE 5.6. COMPUTER PRINTOUT, EXAMPLE FRATF1 RUN (CONTINUED)

```
    MODE SHAPES FOLLOW

      .13913E+00        .10770E-05        .54590E-05        .12234E+00
      .68378E-01        .33196E-08       -.49114E-06       -.15435E-01
      .51200E-06        .56691E-01        .22910E-01        .35450E-05
     -.12532E-10       -.86347E-03        .25528E-02       -.11870E-06
      .59200E-06        .10023E+00        .38352E-01        .17500E-05
     -.62628E-01        .12993E-01       -.48615E-01       -.75540E-01
      .82416E-01       -.18479E-06       -.31169E-06       -.12350E-02
     -.52900E-06        .70426E-01        .27362E-01       -.65180E-05
      .23266E-09        .85568E-03       -.24210E-02        .11127E-06
      .22700E-06       -.50729E-01       -.16349E-01        .56870E-05
     -.62628E-01       -.12994E-01        .48609E-01       -.75542E-01
     0.                -.93066E-03        .26799E-02       -.12500E-06
     -.76877E-01        .32500E-06        .20030E-05        .48542E-01
      .15200E-06        .59838E-01        .22612E-01        .11150E-05
     0.                 .31250E-03       -.72860E-03        .32000E-07
      .92463E-01       -.30591E-01        .86550E-01       -.20347E-01
     -.52900E-06        .70426E-01        .27362E-01       -.65180E-05
      .92463E-01        .30590E-01       -.86552E-01       -.20339E-01
      .19473E+00        .53109E-01       -.15010E+00        .23060E+00
      .19473E+00       -.53105E-01        .15012E+00        .23059E+00
      .68378E-01        .46627E-01       -.13785E+00       -.15429E-01
      .68378E-01       -.46627E-01        .13785E+00       -.15452E-01
     -.36883E-01        .30467E-01       -.10681E+00       -.94654E-01
     -.36883E-01       -.30468E-01        .10680E+00       -.94664E-01
     -.90388E-01       -.44789E-02        .79877E-03        .23972E-02
     -.90388E-01        .44790E-02       -.79840E-03        .23973E-02
     -.27713E-01       -.37982E-01        .10500E+00        .88031E-01
     -.27713E-01        .37983E-01       -.10499E+00        .88040E-01
      .82416E-01       -.46207E-01        .13073E+00       -.12409E-02
      .82416E-01        .46206E-01       -.13073E+00       -.12289E-02
      .20960E+00       -.49600E-01        .14143E+00       -.24311E+00
      .20960E+00        .49596E-01       -.14145E+00       -.24310E+00
     0.                 .19818E+00        .68382E-01       -.91500E-05
     0.                 .19818E+00        .68382E-01       -.91500E-05
     0.                 .56691E-01        .22910E-01        .35400E-05
     0.                 .56691E-01        .22910E-01        .35400E-05
     0.                -.37963E-01       -.10659E-01        .74500E-05
     0.                -.37963E-01       -.10659E-01        .74500E-05
     0.                -.79144E-01       -.29014E-01        .17700E-05
     0.                -.79144E-01       -.29014E-01        .17700E-05
     0.                -.26967E-01       -.11710E-01       -.60200E-05
     0.                -.26967E-01       -.11710E-01       -.60200E-05
     0.                 .70426E-01        .27362E-01       -.65200E-05
     0.                 .70426E-01        .27362E-01       -.65200E-05
     0.                 .20547E+00        .85956E-01       -.34900E-06
     0.                 .20547E+00        .85956E-01       -.34900E-06
```

FIGURE 5.6. COMPUTER PRINTOUT, EXAMPLE FRATF1 RUN (CONTINUED)

```
LADING PARAMETERS

          MLAD    =     .1924E+02  .1924E+02  .1924E+02  .1924E+02

          INLAD   =     .1666E+05  .1666E+05  .1666E+05  .1666E+05

          DLAD    =     .1200E+03 -.1200E+03  .1200E+03 -.1200E+03

          RLAD    =   0.         0.         0.         0.

          KLAD    =     .6900E+05  .1900E+05  .1480E+09  .6900E+05  .1900E+05  .1480E+09
                        .6900E+05  .1900E+05  .1480E+09  .6900E+05  .1900E+05  .1480E+09

          CLAD    =     .1580E+03  .1250E+03  .1512E+06  .1580E+03  .1250E+03  .1512E+06
                        .1580E+03  .1250E+03  .1512E+06  .1580E+03  .1250E+03  .1512E+06

          HL      =     .3531E+02  .3531E+02  .3531E+02  .3531E+02

          BX      =     .4800E+02     BY     =  -.1200E+03      BZ      =   .9900E+01


                THE INITIAL DEFLECTIONS ARE

            Z(1) = -.5021       Z(2) = -.5364       Z(3) = -3.404       THETA =  .4525E-03

            Z(4) = -5.023       Z(5) = -3.619      THETAV =  .1103E-01

            Z(6) = -3.064       Z(7) = -3.950      THETAT = -.3663E-02

          ZLAD(1) = -2.405    ZLAD(2) = -5.052    ZLAD(3) = -4.498    ZLAD(4) = -3.618
```

FIGURE 5.6. COMPUTER PRINTOUT, EXAMPLE FRATF1 RUN (CONTINUED)

```
DEBUG AT TIME =  0.0000

ZI(I) =     -2.5000E-01     0.              2.5000E-01    1.6157E-01     0.              3.3921E-02

   I          F(I)                 ACCELERATION               VELOCITY                  DISPLACEMENT
             (LBS)              (GS OR RAD/SEC.SQ)      (IN/SEC OR RAD/SEC)          (IN OR RAD)
   1       2.2944E+04               -8.2505E-02               0.                         0.
   2      -7.1121E+02                2.1057E-02               0.                         0.
   3       6.8444E+04                9.3465E-08               0.                         0.
   4       8.2769E+04               -5.2796E-07               0.                        -5.0214E-01
   5      -6.5618E-02                2.0640E+00               0.                        -5.3637E-01
   6      -5.1905E-02               -6.0531E-04               0.                        -3.4042E+00
   7       6.3513E+04                1.5413E-01               0.                         0.
   8       1.8158E+02               -3.9350E-02               0.                         0.
   9       5.1896E+04                3.4159E-08               0.                         0.
  10       8.9000E+04               -2.4988E-06               0.                         4.5251E-04
  11       8.0633E-02               -2.3872E-08               0.                         0.
  12      -2.4735E-02                3.9563E-06               0.                         0.
  13       2.5425E+04                1.9028E-06               0.                         0.
  14       8.3246E-02                3.4844E-03               0.                        -5.0226E+00
  15       1.8183E+04                4.4697E-04               0.                        -3.6186E+00
  16       1.2490E-02               -1.2973E-07               0.                         0.
  17       1.8183E+04                9.2546E-08               0.                         0.
  18       1.6599E+04                9.3342E-06               0.                         1.1027E-02
  19       0.                        1.9467E-08               0.                         0.
  20       1.6599E+04               -2.8733E-05               0.                         0.
  21       2.5393E+04                1.2526E-07               0.                         0.
  22       5.4801E-03               -1.3979E-04               0.                        -3.0638E+00
  23       1.8183E+04               -2.0746E-05               0.                        -3.9501E+00
  24      -9.0712E-02               -1.0691E-08               0.                         0.
  25       1.8183E+04                5.8439E-09               0.                         0.
  26       1.6604E+04               -3.8774E-07               0.                        -3.6628E-03
  27       0.                        1.2815E-09               0.                         0.
  28       1.6604E+04               -1.1286E-02               0.                         1.4464E+01
```

FIGURE 5.6. COMPUTER PRINTOUT, EXAMPLE FRATF1 RUN (CONTINUED)

DEBUT AT TIME = 0.0000, concluded

```
   1     7.4266E+03              2.3374E-12              0.                      -2.4051E+00
   2     0.                      0.                      0.                       0.
   3     0.                      0.                      0.                       0.
   4     7.4266E+03              2.3374E-12              0.                      -5.0516E+00
   5     0.                      0.                      0.                       0.
   6     0.                      0.                      0.                       0.
   7     7.4266E+03              2.0782E-12              0.                      -4.4975E+00
   8     0.                      0.                      0.                       0.
   9     0.                      0.                      0.                       0.
  10     7.4266E+03              2.0782E-12              0.                      -3.6184E+00
  11     0.                      0.                      0.                       0.
  12     0.                      0.                      0.                       0.

MODE       ETADD                   ETAD                  ETA
   1    -4.3562E+00              0.                      1.4464E+01


   2     5.8004E-05              0.                     -7.8828E-06


   3     8.9794E-04              0.                     -3.0035E-05


   4    -3.6825E+00              0.                     -6.1198E-01
```

FIGURE 5.6. COMPUTER PRINTOUT, EXAMPLE FRATF1 RUN (CONTINUED)

```
 DEBUG AT TIME =    .0050

 ZI(I) =     -2.4592E-01     0.               2.4998E-01    1.5924E-01     0.               3.7273E-02

   I          F(I)                     ACCELERATION                  VELOCITY                     DISPLACEMENT
              (LBS)                  (GS OR RAD/SEC.SQ)         (IN/SEC OR RAD/SEC)              (IN OR RAD)
   1       2.7390E+04                  -2.4456E-01                 -3.3470E-01                   -7.0755E-04
   2      -2.7657E+03                   6.1470E-02                  8.4549E-02                    1.7906E-04
   3       6.4331E+04                  -9.5882E-03                 -9.2211E-03                   -1.5569E-05
   4       8.2745E+04                   4.1403E-02                  4.1248E-02                   -5.0206E-01
   5      -6.5780E+02                   8.6813E-01                  2.7683E+00                   -5.2854E-01
   6       6.5620E+04                   1.3818E-01                  1.5141E-01                   -3.4039E+00
   7       6.0729E+04                   1.1435E-01                  2.6214E-01                    6.8676E-04
   8       6.8876E+02                  -2.7934E-02                 -6.5651E-02                   -1.7314E-04
   9       5.1686E+04                   9.6766E-04                  9.2779E-04                    1.5620E-06
  10       9.6313E+04                  -4.8727E-04                 -5.2700E-04                    4.5157E-04
  11       1.5893E+02                  -5.4916E-05                 -5.2321E-05                   -8.7762E-08
  12      -1.6498E+04                  -2.6984E-03                 -1.7351E-03                   -1.9520E-06
  13       2.5566E+04                  -3.5088E-04                 -2.1713E-04                   -2.3038E-07
  14      -1.5009E+01                   3.3582E-05                  2.6533E-03                   -5.0226E+00
  15       1.8163E+04                   3.8696E-03                  3.3008E-03                   -3.6185E+00
  16      -8.8695E+00                   1.4581E-04                  9.5157E-05                    1.1156E-07
  17       1.8201E+04                  -7.4733E-06                 -5.1669E-06                   -6.9613E-09
  18       1.6602E+04                   4.0912E-05                  3.8952E-05                    1.1027E-02
  19      -3.5038E-01                  -3.4368E-06                 -2.1619E-06                   -2.3576E-09
  20       1.6605E+04                  -1.2655E-03                 -8.5469E-04                   -1.0474E-06
  21       2.5492E+04                  -1.9150E-04                 -1.2040E-04                   -1.3138E-07
  22      -8.2122E+00                   8.2771E-02                  5.3520E-02                   -3.0637E+00
  23       1.8365E+04                   4.2865E-03                  3.0131E-03                   -3.9501E+00
  24      -4.1461E+00                  -5.0710E-05                 -3.3092E-05                   -3.7864E-08
  25       1.8352E+04                  -7.6878E-06                 -4.8627E-06                   -5.3771E-09
  26       1.6650E+04                   6.5623E-06                  2.7470E-06                   -3.6628E-03
  27      -1.5078E-01                  -1.8877E-06                 -1.2005E-06                   -1.3364E-09
  28       1.6649E+04                   1.4205E+00                  1.5512E+00                    1.4467E+01
```

FIGURE 5.6. COMPUTER PRINTOUT, EXAMPLE FRATF1 RUN (CONTINUED)

DEBUG AT TIME = 0.0050, concluded

```
   1     7.4288E+03             2.8811E-04             1.4743E-04            -2.4051E+00
   2    -4.1632E-02            -5.6057E-06            -1.7304E-06             6.1654E-11
   3    -1.8051E+00            -2.8069E-07            -5.7067E-08             1.4643E-11
   4     7.4262E+03            -5.7942E-05            -4.0228E-05            -5.0516E+00
   5     2.3527E-02             4.5144E-06             1.9119E-06            -2.1986E-10
   6    -1.8051E+00            -2.8069E-07            -5.7067E-08             1.4643E-11
   7     7.4274E+03             1.0402E-04             2.7760E-05            -4.4975E+00
   8    -1.3448E-02            -1.8108E-06            -6.6056E-07             1.0077E-11
   9    -1.5238E+00            -2.3696E-07            -4.8615E-08             7.1840E-13
  10     7.4270E+03             5.3845E-05            -2.3683E-06            -3.6184E+00
  11     2.8402E-02             3.8243E-06             1.4201E-06            -1.5264E-11
  12    -1.5238E+00            -2.3696E-07            -4.8615E-08             7.1840E-13


MODE      ETADD                  ETAD                   ETA
   1     5.4831E+02             1.5512E+00             1.4467E+01


   2    -9.2120E+01            -2.2888E-01            -3.9396E-04


   3     1.8967E+02             4.7029E-01             7.6209E-04


   4    -2.6725E+01            -6.8607E-02            -6.1210E-01
```

FIGURE 5.6. COMPUTER PRINTOUT, EXAMPLE FRATF1 RUN (CONTINUED)

```
 DEBUG AT TIME =    .0100

 ZI(I) =     -2.4183E-01     0.             2.4993E-01    1.5688E-01     0.              4.0606E-02

    I         F(I)                 ACCELERATION              VELOCITY               DISPLACEMENT
              (LBS)             (GS OR RAD/SEC.SQ)      (IN/SEC OR RAD/SEC)         (IN OR RAD)
    1      3.3867E+04              -2.9132E-01              -8.6879E-01              -3.6783E-03
    2     -3.8365E+03               7.2725E-02               2.1827E-01               9.2690E-04
    3      5.8076E+04              -1.8006E-02              -3.6227E-02              -1.2263E-04
    4      8.2798E+04               6.1056E-02               1.4483E-01              -5.0161E-01
    5     -1.3255E+03               1.5115E-01               3.6823E+00              -5.1184E-01
    6      1.3338E+05               1.6614E-01               4.5885E-01              -3.4024E+00
    7      5.7209E+04               6.1067E-02               4.3262E-01               2.4657E-03
    8      9.2740E+02              -1.3508E-02              -1.0587E-01              -6.1333E-04
    9      5.1708E+04               1.8404E-03               3.6721E-03               1.2380E-05
   10      9.8995E+04              -6.3259E-04              -1.6535E-03               4.4624E-04
   11      3.0055E+02              -1.0700E-04              -2.1007E-04              -7.0290E-07
   12     -3.3012E+04              -1.1030E-02              -1.4154E-02              -3.4913E-05
   13      2.5911E+04              -1.5703E-03              -1.9202E-03              -4.5734E-06
   14     -6.5660E+01              -2.7619E-03              -1.0253E-04              -5.0225E+00
   15      1.8106E+04               1.1826E-02               1.8211E-02              -3.6185E+00
   16     -3.8094E+01               5.6940E-04               7.4767E-04               1.8777E-06
   17      1.8263E+04              -2.1788E-05              -3.3558E-05              -9.3098E-08
   18      1.6597E+04               1.1902E-04               1.9105E-04               1.1028E-02
   19     -3.2697E+00              -1.4668E-05              -1.8381E-05              -4.4556E-08
   20      1.6624E+04              -5.0097E-03              -6.5546E-03              -1.6540E-05
   21      2.5767E+04              -8.3959E-04              -1.0381E-03              -2.4970E-06
   22     -3.5357E+01               1.8126E-01               3.1172E-01              -3.0628E+00
   23      1.8766E+04               2.0526E-02               2.5463E-02              -3.9500E+00
   24     -1.7050E+01              -1.9928E-04              -2.6141E-04              -6.5413E-07
   25      1.8712E+04              -3.2885E-05              -4.1185E-05              -9.9911E-08
   26      1.6878E+04              -9.9021E-06               3.3750E-06              -3.6628E-03
   27     -1.2342E+00              -7.9916E-06              -1.0062E-05              -2.4518E-08
   28      1.6871E+04               1.7143E+00               4.7172E+00               1.4482E+01
```

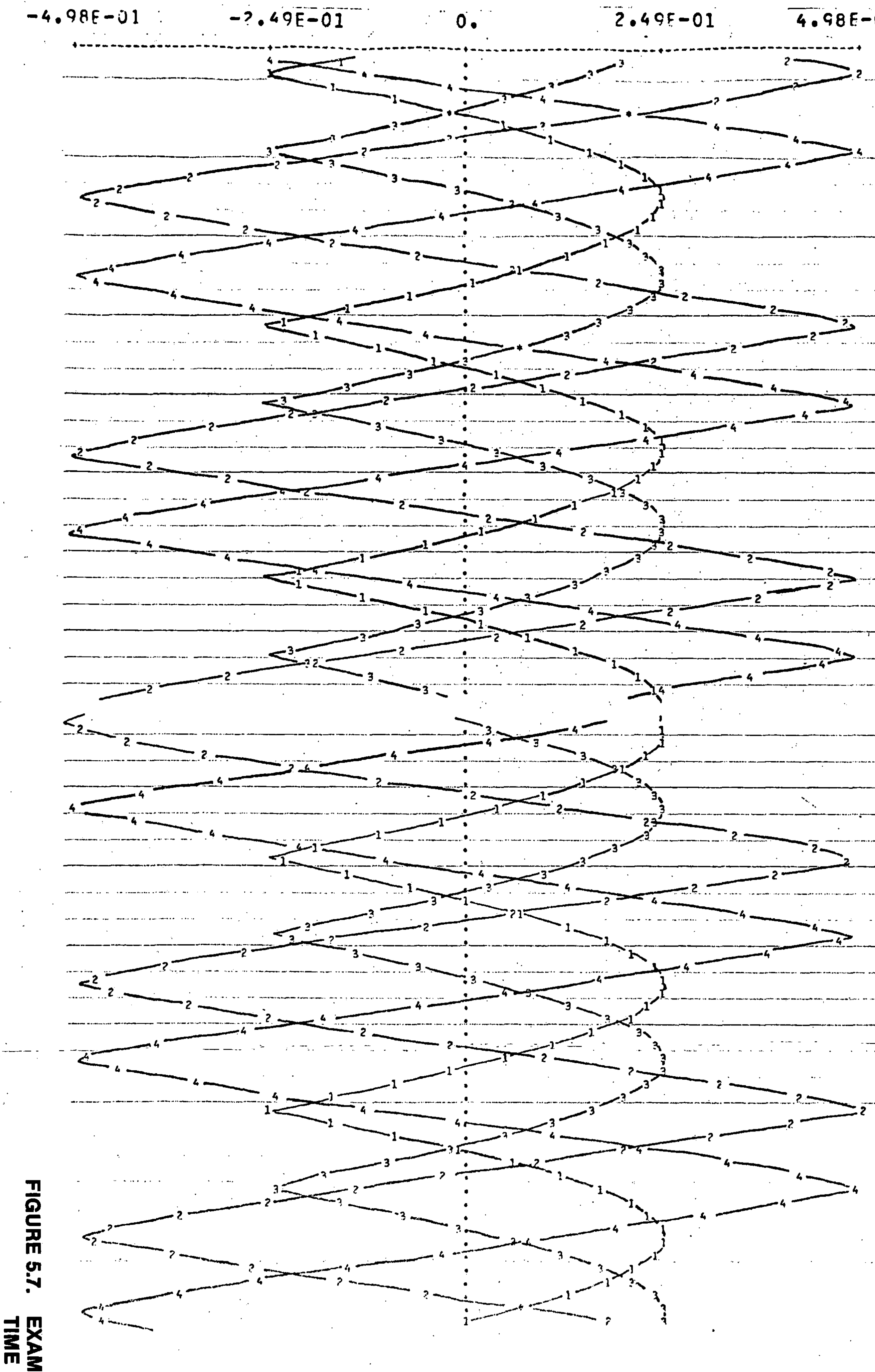
FIGURE 5.6. COMPUTER PRINTOUT, EXAMPLE FRATF1 RUN (CONTINUED)

DEBUG AT TIME = 0.0100, concluded

```
  1     7.4410E+03            1.9338E-03            1.9406E-03            -2.4051E+00
  2    -4.8530E-01           -6.5345E-05           -5.3610E-05            -8.7089E-08
  3    -1.7901E+01           -2.7836E-06           -2.4151E-06            -3.9640E-09
  4     7.4248E+03           -2.5181E-04           -3.0619E-04            -5.0516E+00
  5     2.5553E-01            3.4407E-05            3.3849E-05             6.3101E-08
  6    -1.7901E+01           -2.7836E-06           -2.4151E-06            -3.9640E-09
  7     7.4350E+03            1.1217E-03            9.4929E-04            -4.4975E+00
  8    -1.3277E-01           -1.7877E-05           -1.5623E-05            -2.6888E-08
  9    -2.0087E+01           -3.1235E-06           -2.4498E-06            -3.7633E-09
 10     7.4341E+03            1.0057E-03            7.1983E-04            -3.6184E+00
 11     2.7329E-01            3.6799E-05            3.2559E-05             5.6484E-08
 12    -2.0087E+01           -3.1235E-06           -2.4498E-06            -3.7633E-09


MODE       ETADD                 ETAC                  ETA
  1     6.6170E+02            4.7172E+00            1.4482E+01


  2    -1.7258E+02           -9.0134E-01           -3.0578E-03


  3     3.5785E+02            1.8602E+00            6.2500E-03


  4    -6.6966E+01           -3.0188E-01           -6.1294E-01
```

FIGURE 5.6. COMPUTER PRINTOUT, EXAMPLE FRATF1 RUN (CONCLUDED)

```
                                                   MULTIPLE PLOT TIME HISTORY
        FRATF1 RUN      .04  SWEEP RATE = 0.           INPUT MOTION: DIN=   .500
                        PLOT 1                         VERTICAL (Z) INPUT MOTION
1=VERTICAL INPUT ,R TRUCK, LEFT SIDE, INCHES
2=CROSS LEVEL INPUT ,R TRUCK, INCHES
3=VERTICAL INPUT, A TRUCK, LEFT SIDE, INCHES
4=CROSS LEVEL INPUT, A TRUCK, INCHES
```



```
  TIME      FRQ
  9.5100   .2600
  9.6100   .2600
  9.7100   .2600
  9.8100   .2600
  9.9100   .2600
 10.0100   .2600
 10.1100   .2600
 10.2100   .2600
 10.3100   .2600
 10.4100   .2600
 10.5100   .2600
 10.6100   .2600
 10.7100   .2600
 10.8100   .2600
 10.9100   .2600
 11.0100   .2600
 11.1100   .2600
 11.2100   .2600
 11.3100   .2600
 11.4100   .2600
 11.5100   .2600
 11.6100   .2600
 11.7100   .2600
 11.8100   .2600
 11.9100   .2600
 12.0100   .2600
 12.1100   .2600
 12.2100   .2600
 12.3100   .2600
 12.4100   .2600
 12.5100   .2600
 12.6100   .2600
 12.7100   .2600
 12.8100   .2600
 12.9100   .2600
 13.0100   .2600
 13.1100   .2600
 13.2100   .2600
 13.3100   .2600
 13.4100   .2600
 13.5100   .2600
 13.6100   .2600
 13.7100   .2600
 13.8100   .2600
 13.9100   .2600
 14.0100   .2600
 14.1100   .2600
 14.2100   .2600
 14.3100   .2600

 14.4100   .2600
 14.5100   .2600
 14.6100   .2600
 14.7100   .2600
 14.8100   .2600
 14.9100   .2600
 15.0100   .2600
 15.1100   .2600
 15.2100   .2600
 15.3100   .2600
 15.4100   .2600
 15.5100   .2600
 15.6100   .2600
 15.7100   .2600
 15.8100   .2600
 15.9100   .2600
 16.0100   .2600
 16.1100   .2600
 16.2100   .2600
 16.3100   .2600
 16.4100   .2600
 16.5100   .2600
 16.6100   .2600
 16.7100   .2600
 16.8100   .2600
 16.9100   .2600
 17.0100   .2600
 17.1100   .2600
 17.2100   .2600
 17.3100   .2600
 17.4100   .2600
 17.5100   .2600
 17.6100   .2600
 17.7100   .2600
 17.8100   .2600
 17.9100   .2600
 18.0100   .2600
 18.1100   .2600
 18.2100   .2600
 18.3100   .2600
 18.4100   .2600
 18.5100   .2600
 18.6100   .2600
 18.7100   .2600
 18.8100   .2600
 18.9100   .2600
```

FIGURE 5.7. EXAMPLE FRATF1 RUN TIME HISTORY PLOT 1

```
                                                    MULTIPLE PLOT TIME HISTORY

       FRATF1 RUN      .04  SWEEP RATE = 0.          INPUT MOTION: DIN=  .500

                     PLOT 2           LATERAL MOTION OF TRUCKS

1 = LATERAL (X) INPUT, B TRUCK, INCHES
2 = LATERAL RESPONSE, B TRUCK, INCHES
3 = LATERAL INPUT, A TRUCK, INCHES
4 = LATERAL RESPONSE, A TRUCK, INCHES
```

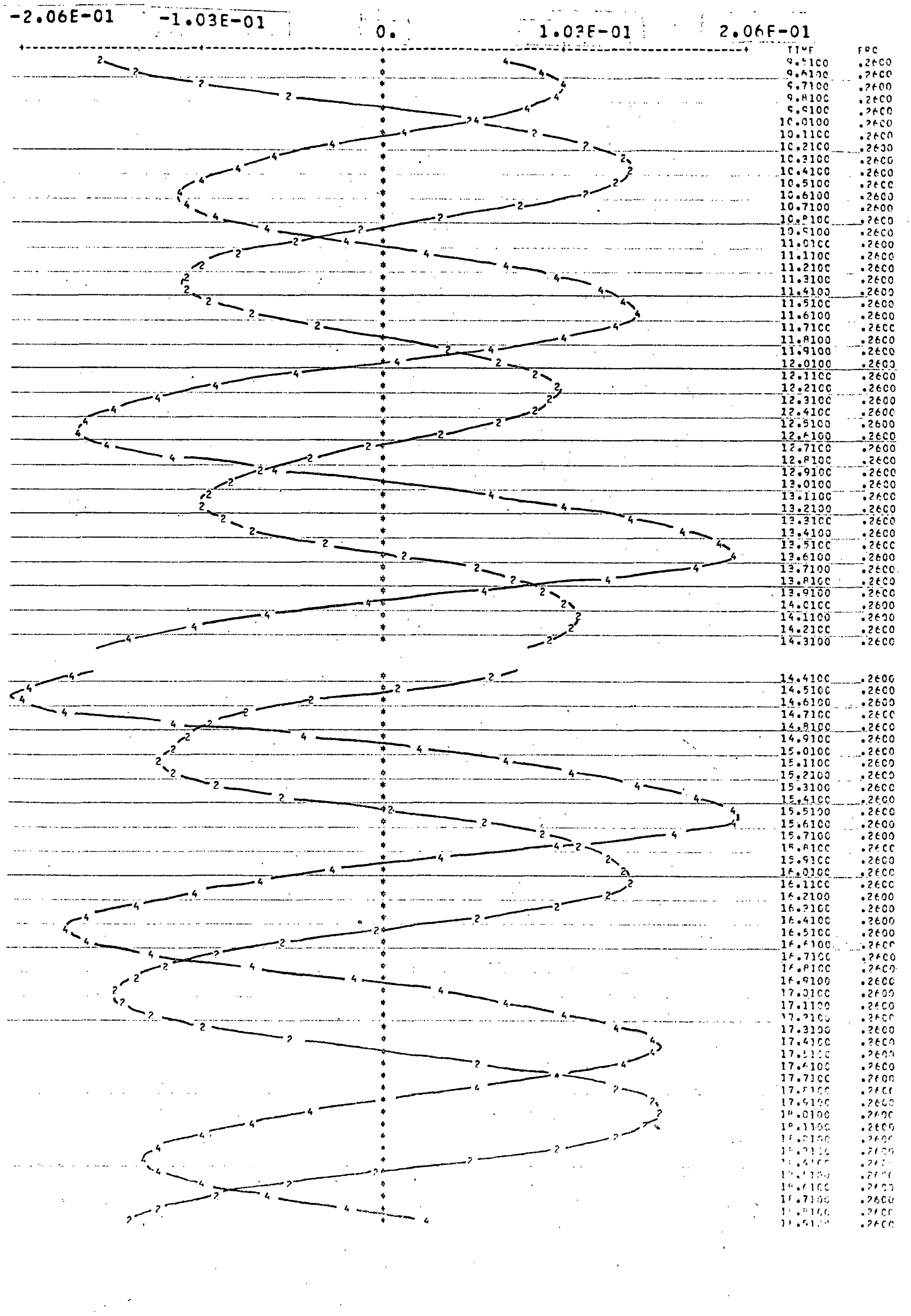


FIGURE 5.8. EXAMPLE FRATF1 RUN TIME HISTORY PLOT 2

```
                                                  MULTIPLE PLOT TIME HISTORY
        FRATF1 RUN      .04  SWEEP RATE = 0.          INPUT MOTION: DIN=  .500

                   PLOT 3          WHEEL-RAIL FORCES, B TRUCK

1 = VERTICAL FORCE, LEFT SIDE, POUNDS
2 = LATERAL FORCE, POUNDS
3 = VERTICAL FORCE, RIGHT SIDE, POUNDS
4 = ROLL MOMENT AT CENTERPLATE B / 25., IN.LB.
```

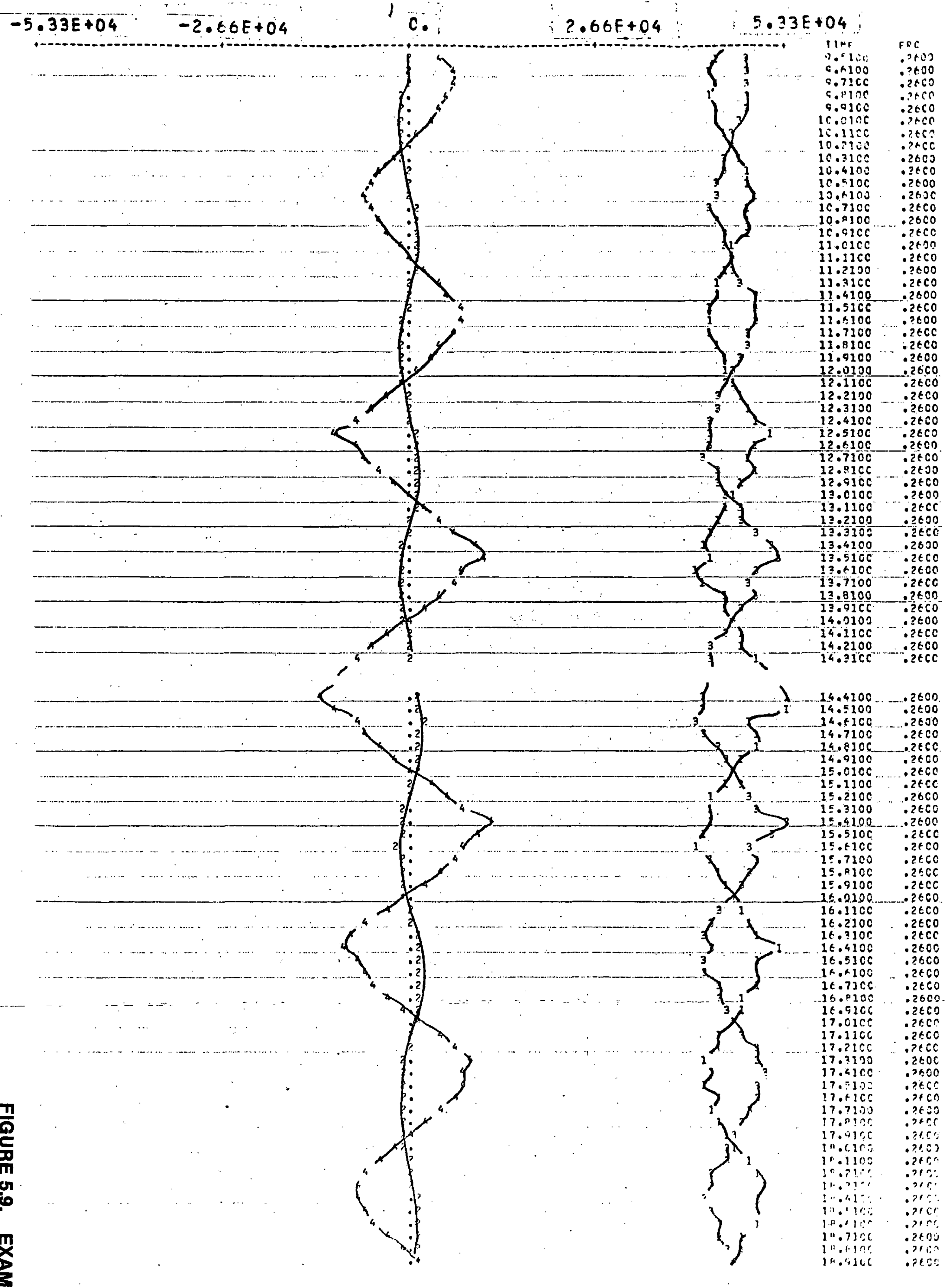


FIGURE 5.9. EXAMPLE FRATF1 RUN
TIME HISTORY PLOT 3

MULTIPLE PLOT TIME HISTORY

FRATF1 RUN .04 SWEEP RATE = 0. INPUT MOTION: DIN= .500

PLOT 5 TRUCK AND CARBODY.ROLL MOTIONS

1 = ROLL ANGLE, B TRUCK CG, DEGREES
2 = ROLL ANGLE, CARBODY AT B TRUCK, DEGREES
3 = ROLL ANGLE, A TRUCK CG, DEGREES
4 = ROLL ANGLE, CARBODY AT A TRUCK, DEGREES

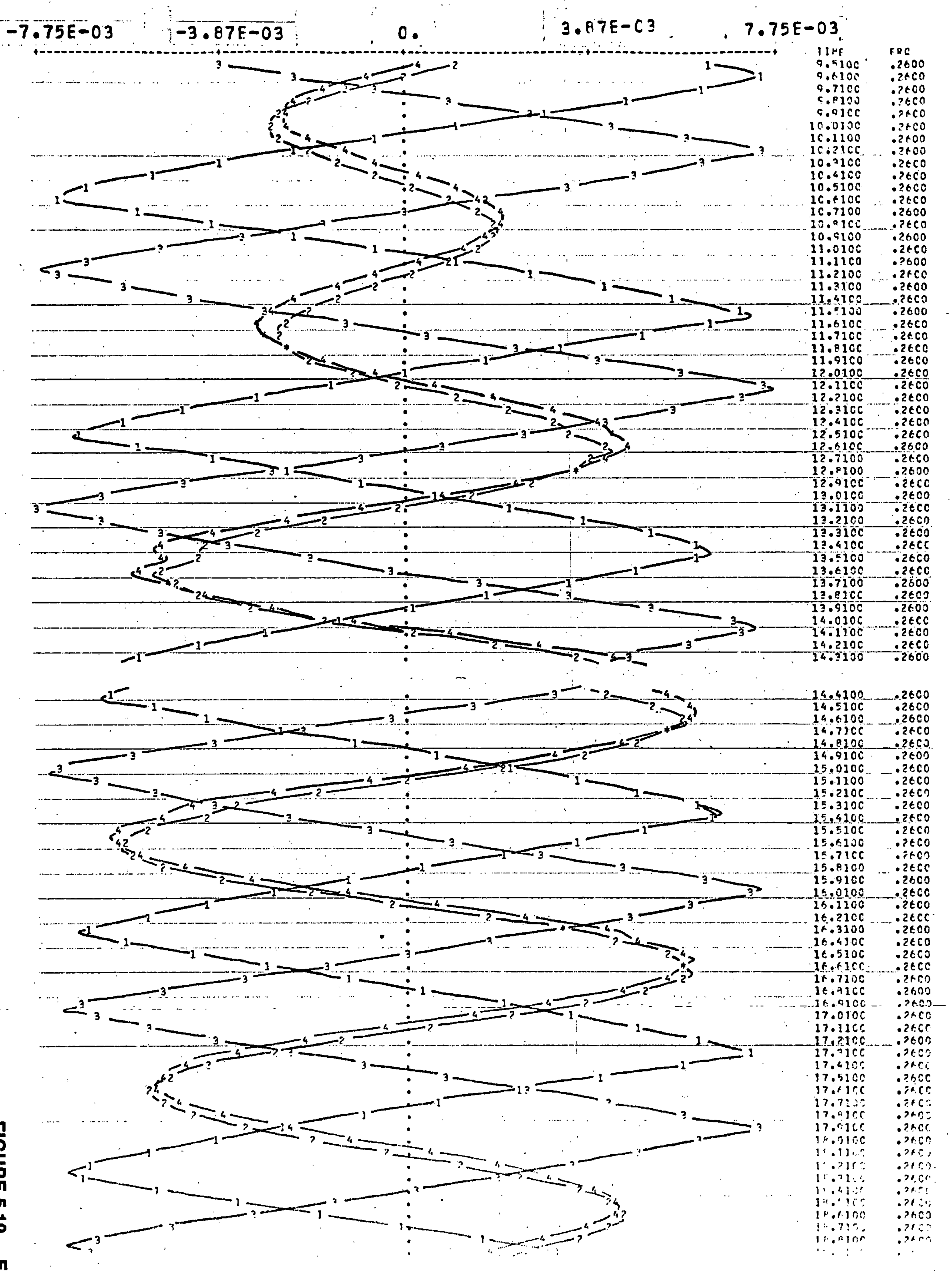


FIGURE 5.10. EXAMPLE FRATF1 RUN TIME HISTORY PLOT 5

MULTIPLE PLOT TIME HISTORY

FRATF1 RUN .04 SWEEP RATE = 0. INPUT MOTION: DIN= .500

PLOT 6 TRAILER ROLL MOTIONS

1 = TANDEM, B TRAILER, DEGREES
2 = BODY, B TRAILER, DEGREES
3 = TANDEM, A TRAILER, DEGREES
4 = BODY, A TRAILER, DEGREES

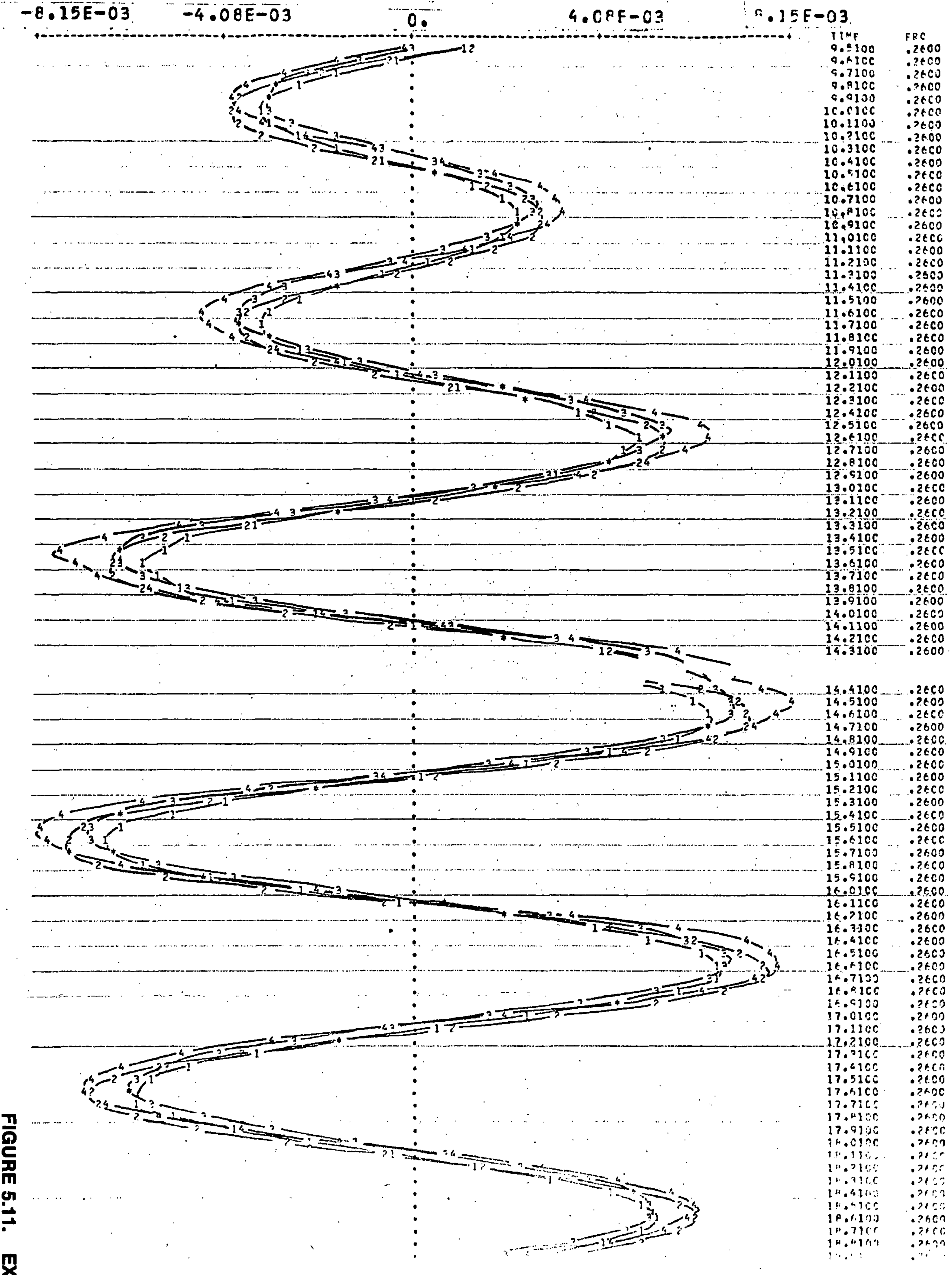


FIGURE 5.11. EXAMPLE FRATF1 RUN TIME HISTORY PLOT 6

MULTIPLE PLOT TIME HISTORY

FRATF1 RUN .04 SWEEP RATE = 0. INPUT MOTION: DIN= .500

PLOT 7 CARBODY VERTICAL MOTION, LEFT SIDE (AT -R(9)/2.)

1 = AT B TRUCK (L/2 FROM CENTER), INCHES
2 = AT +OR(6) FROM CENTER, INCHES
3 = AT CARBODY CENTER, INCHES
4 = AT A TRUCK (-L/2 FROM CENTER), INCHES

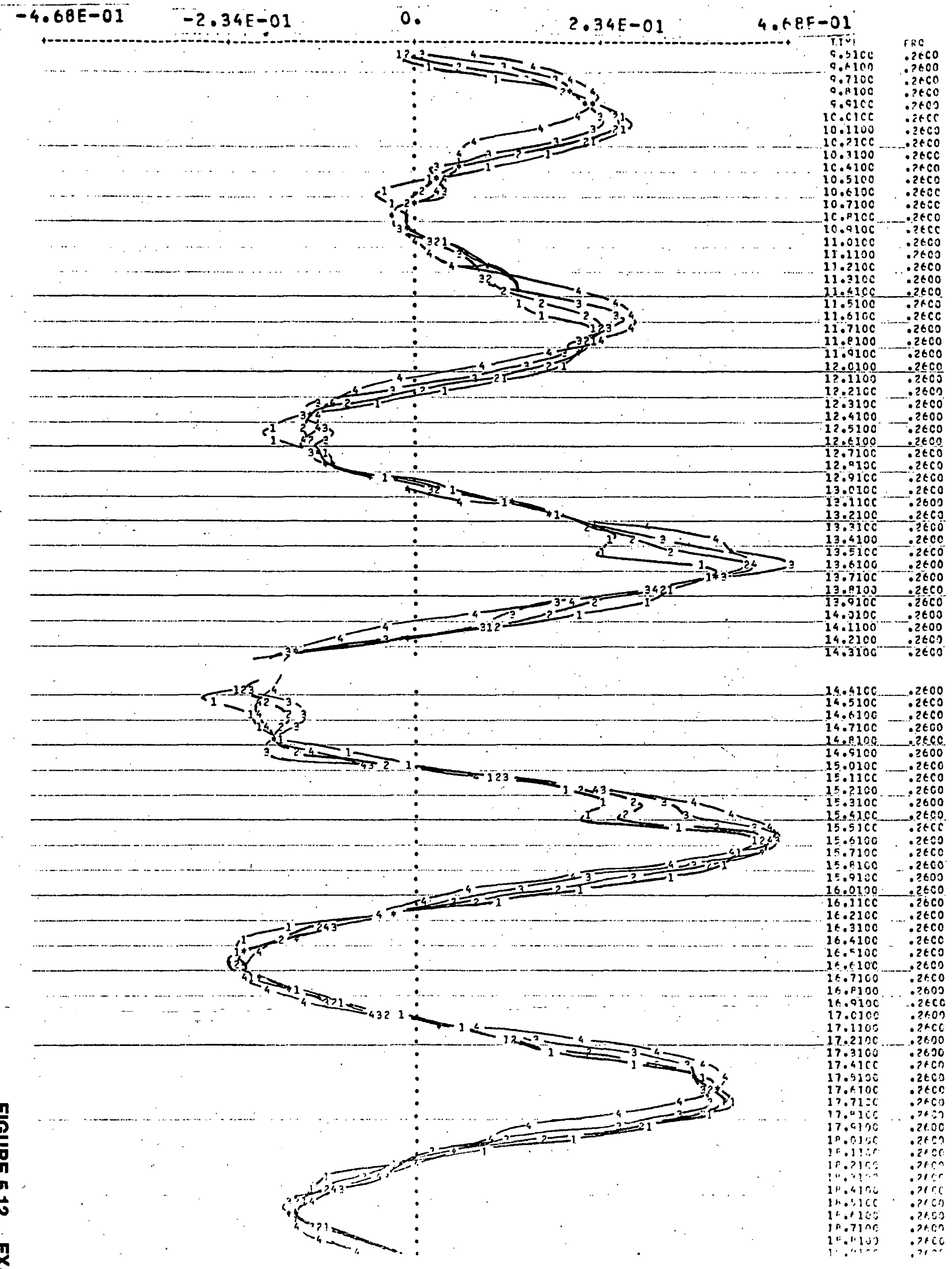
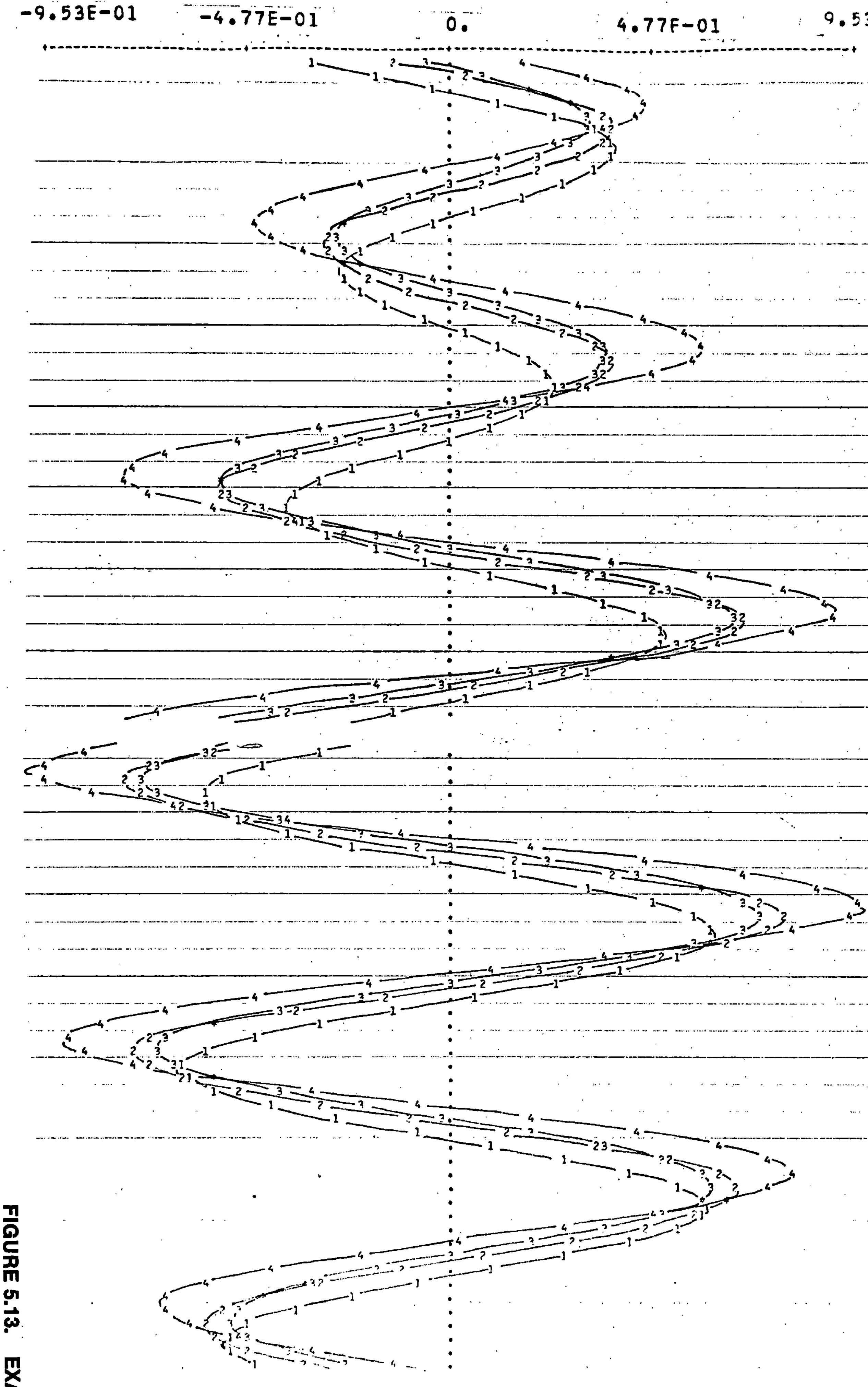


FIGURE 5.12. EXAMPLE FRATF1 RUN TIME HISTORY PLOT 7

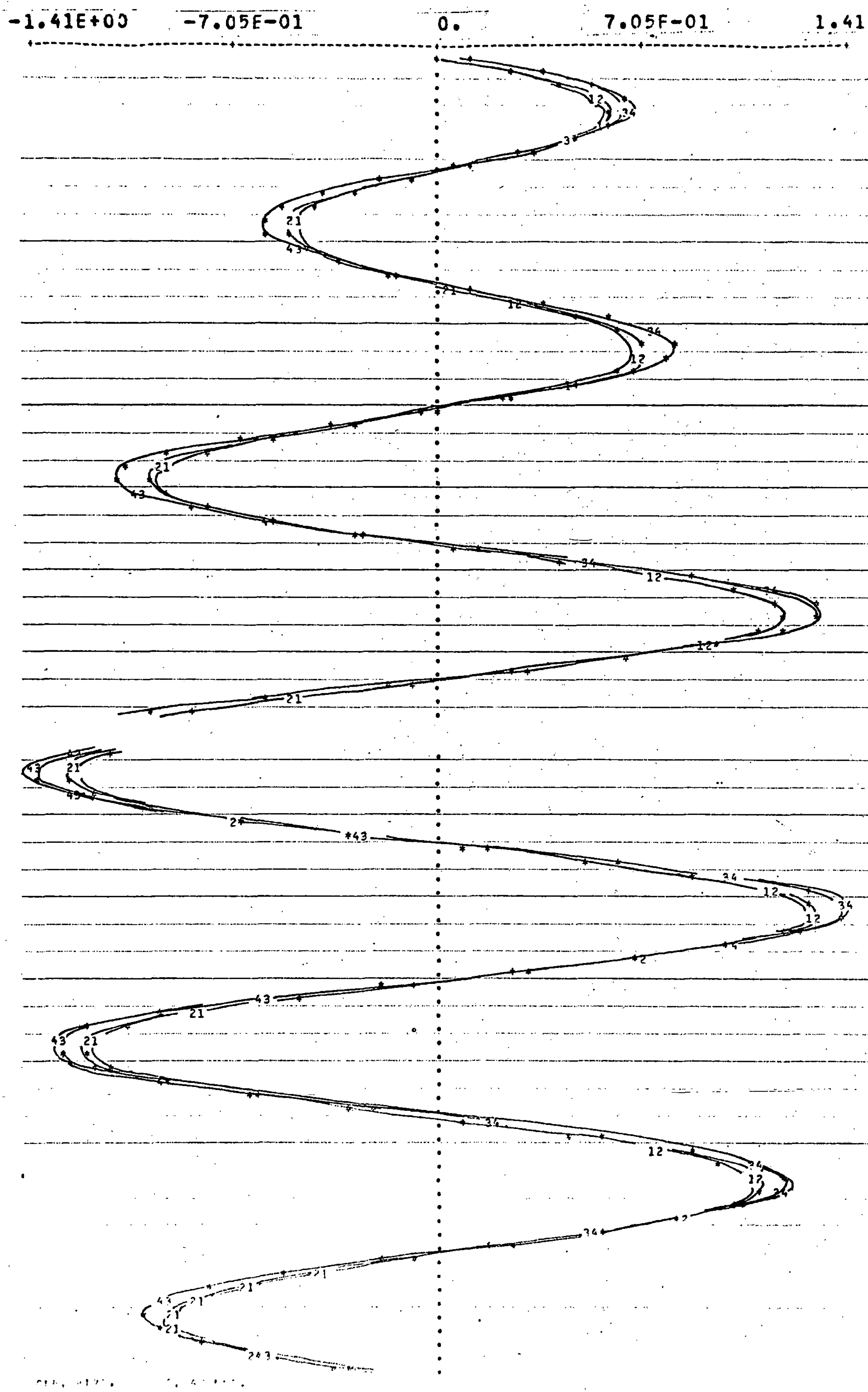
```
                                              MULTIPLE PLOT TIME HISTORY
      FRATF1 RUN       .C4  SWEEP RATE = 0.          INPUT MOTION: DIN=   .500

                    PLOT 10        LATERAL MOTIONS AT BOTTOM OF TRAILER

1 = B TRAILER, B END, INCHES
2 = B TRAILER, A END, INCHES
3 = A TRAILER, B END, INCHES
4 = A TRAILER, A END, INCHES
```



```
 TIME       FRQ
 9.5100    .2600
 9.6100    .2600
 9.7100    .2600
 9.8100    .2600
 9.9100    .2600
10.0100    .2600
10.1100    .2600
10.2100    .2600
10.3100    .2600
10.4100    .2600
10.5100    .2600
10.6100    .2600
10.7100    .2600
10.8100    .2600
10.9100    .2600
11.0100    .2600
11.1100    .2600
11.2100    .2600
11.3100    .2600
11.4100    .2600
11.5100    .2600
11.6100    .2600
11.7100    .2600
11.8100    .2600
11.9100    .2600
12.0100    .2600
12.1100    .2600
12.2100    .2600
12.3100    .2600
12.4100    .2600
12.5100    .2600
12.6100    .2600
12.7100    .2600
12.8100    .2600
12.9100    .2600
13.0100    .2600
13.1100    .2600
13.2100    .2600
13.3100    .2600
13.4100    .2600
13.5100    .2600
13.6100    .2600
13.7100    .2600
13.8100    .2600
13.9100    .2600
14.0100    .2600
14.1100    .2600
14.2100    .2600
14.3100    .2600

14.4100    .2600
14.5100    .2600
14.6100    .2600
14.7100    .2600
14.8100    .2600
14.9100    .2600
15.0100    .2600
15.1100    .2600
15.2100    .2600
15.3100    .2600
15.4100    .2600
15.5100    .2600
15.6100    .2600
15.7100    .2600
15.8100    .2600
15.9100    .2600
16.0100    .2600
16.1100    .2600
16.2100    .2600
16.3100    .2600
16.4100    .2600
16.5100    .2600
16.6100    .2600
16.7100    .2600
16.8100    .2600
16.9100    .2600
17.0100    .2600
17.1100    .2600
17.2100    .2600
17.3100    .2600
17.4100    .2600
17.5100    .2600
17.6100    .2600
17.7100    .2600
17.8100    .2600
17.9100    .2600
18.0100    .2600
18.1100    .2600
18.2100    .2600
18.3100    .2600
18.4100    .2600
18.5100    .2600
18.6100    .2600
18.7100    .2600
18.8100    .2600
18.9100    .2600
```

FIGURE 5.13. EXAMPLE FRATF1 RUN TIME HISTORY PLOT 10

```
                                                  MULTIPLE PLOT TIME HISTORY

          FRATF1 RUN        .04  SWEEP RATE = 0.           INPUT MOTION: DIN=  .500

                       PLOT 14               X MOTION OF LADING IN A TRAILER

1 = X INPUT TO LADING 3, INCHES
2 = X RESPONSE OF LADING 3, INCHES
3 = X INPUT TO LADING 4, INCHES
4 = X RESPONSE OF LADING 4, INCHES
```



```
 TIME      INC
 9.5100   .2600
 9.6100   .2600
 9.7100   .2600
 9.8100   .2600
 9.9100   .2600
10.0100   .2600
10.1100   .2600
10.2100   .2600
10.3100   .2600
10.4100   .2600
10.5100   .2600
10.6100   .2600
10.7100   .2600
10.8100   .2600
10.9100   .2600
11.0100   .2600
11.1100   .2600
11.2100   .2600
11.3100   .2600
11.4100   .2600
11.5100   .2600
11.6100   .2600
11.7100   .2600
11.8100   .2600
11.9100   .2600
12.0100   .2600
12.1100   .2600
12.2100   .2600
12.3100   .2600
12.4100   .2600
12.5100   .2600
12.6100   .2600
12.7100   .2600
12.8100   .2600
12.9100   .2600
13.0100   .2600
13.1100   .2600
13.2100   .2600
13.3100   .2600
13.4100   .2600
13.5100   .2600
13.6100   .2600
13.7100   .2600
13.8100   .2600
13.9100   .2600
14.0100   .2600
14.1100   .2600
14.2100   .2600
14.3100   .2600

14.4100   .2600
14.5100   .2600
14.6100   .2600
14.7100   .2600
14.8100   .2600
14.9100   .2600
15.0100   .2600
15.1100   .2600
15.2100   .2600
15.3100   .2600
15.4100   .2600
15.5100   .2600
15.6100   .2600
15.7100   .2600
15.8100   .2600
15.9100   .2600
16.0100   .2600
16.1100   .2600
16.2100   .2600
16.3100   .2600
16.4100   .2600
16.5100   .2600
16.6100   .2600
16.7100   .2600
16.8100   .2600
16.9100   .2600
17.0100   .2600
17.1100   .2600
17.2100   .2600
17.3100   .2600
17.4100   .2600
17.5100   .2600
17.6100   .2600
17.7100   .2600
17.8100   .2600
17.9100   .2600
18.0100   .2600
18.1100   .2600
18.2100   .2600
18.3100   .2600
18.4100   .2600
18.5100   .2600
18.6100   .2600
18.7100   .2600
18.8100   .2600
18.9100   .2600
```

FIGURE 5.14. EXAMPLE FRATF1 RUN TIME HISTORY PLOT 14

6. FORCING FUNCTION DESCRIPTIONS

Forcing function inputs are made through the Namelist EXCIT. The analysis procedure used by FRATE is to input a forcing function and solve for the resulting response motions of the vehicle The forcing function can be either motions at the wheel-rail interface or forces applied laterally to the truck masses. The forcing function options available are detailed in this section.

6.1 Input Location Notation

The input motions are denoted by ZI(I) where (I) = 1 to 6, and are applied at the wheel-rail interface. Input forces used in the hunting simulation are denoted by FCRB and FCRA. The input locations are shown in Figure 6.1.

6.2 Sinusoidal Input Motions

SINEIN = .T. is used for either sinusoidal input motions applied at the wheel rail interface or a sinusoidal force applied at the truck masses for the hunt simulation. The sine motions are defined within FRATE with the expression:

ZI(I) = AMP(I)*FIN*SIN(TH + PH(I))*SHAPE

where: AMP(I) = user input, the relative amplitude, usually 1.0 or 0.0, of the six input motions, (non-dimensional)

FIN = the vector amplitude of the input sine motion defined within FRATE in terms of DIN, VIN/OM or 386GIN/OM^2, (inches)

DIN, VIN, GIN = user input, input vector amplitude, (inches, inches/second and g's)

OM = circular frequency of input motion at any instant of time (radians per second)

TH = the angle of the sine function, measured from run time zero, calculated within FRATE as a function of time, frequency and rate of change of frequency (radians)

PH(I) = phase angles between the six input ZI(I) motions, (radians)

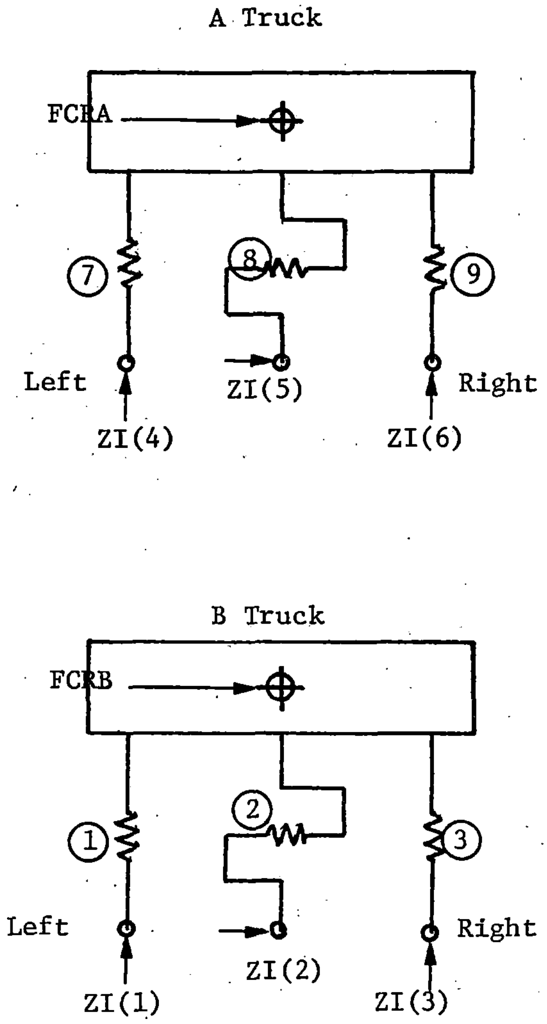


FIGURE 6.1. FORCING FUNCTION INPUT LOCATIONS

PHAS(I)= user input form of PH(I), (degrees)

SHAPE = shaping function (see Section 6.6)

An example EXCIT namelist for a sine input is given in Figure 6.2. The example is for a roll input with the crosslevel difference varying between +.40 inches and -.40 inches at a constant frequency of 0.60 Hertz. Assuming 39 foot rail and 39 foot truck spacing, this would correspond to a track speed of 16.0 miles per hour.

Notice that the input motion can be specified as displacement (DIN), velocity (VIN) or acceleration (GIN). This permits the user to perform a frequency variation with constant amplitude displacement, velocity or acceleration. A frequency variation (sweep) can be performed at a constant rate by assigning FQDOT a non-zero value. FQDOT units are Hertz/second. Logarithmic rate can be effected with BETA whose units are octaves per minute. For both FQDOT and BETA positive values effect increasing frequencies and negative values effect decreasing frequencies.

6.3 Rectified Sine Input Motion

Rectified sine motions are generally used to simulate the cusp shaped rail joints found in bolted track. The rectified sine is affected in FRATE with the input SINEIN = .F. and RECSIN = .T. The rectified sine functions are then defined within FRATE using the expression:

ZI(I) = AMP(I)*FIN*SHAPE*(ABS(SIN(TH + PH(I)) - 0.5)

This expression is seen to differ from the one for SINEIN in that the absolute value of the sine function is used and its zero is shifted down 0.5. Other than this the definitions given under paragraph 6.2 are applicable here.

An example EXCIT name list for a rectified sine input is given in Figure 6.3, which simulates a staggered joint track with ± 0.40 inches crosslevel variation. Assuming 39 foot rail and 39 foot truck spacing, the FQ and FQDOT equate to a slow-down from 26 miles per hour at the rate of .53 miles per hour per second.

```
$EXCIT
SINEIN=.T..
RECSIN=.F.,
S1= 1.,   S2= 0.0,   S3=.0,
AMP =  1.0.   00.,   1.00,   1.0,   00.,   01.0.
PHAS=  0.,    .00.   180.0,   0.0,   0.00,   180.0,
FQ=0.60,  FQDOT=.0,  BETA=0..  NDECAY=5000,
DIN=.20,       VIN=0.00,     GIN=.0,
PULSE=.F.,   BFRONT=.T.,   PL=  33.0,    SPEED=70.0,
HUNT = .F..  FCRB=0.0,     FCRA=0.0,
             PHASB=0.0,    PHASA=0.0,$
```

FIGURE 6.2. EXAMPLE EXCIT NAMELIST FOR SINEIN INPUT

```
$EXCIT
SINEIN=.F..
RECSIN=.T..
S1= 1..   S2= 0.0.   S3=.0,
AMP =  1.0.   00.,   1.00,   1.0,   00.,   01.0,
PHAS=  0.,    .00,   90.0.   0.0,   0.00,   90.0.
FQ=0.50,  FQDOT=.01.  BETA=0..  NDECAY=5000,
DIN=.40,       VIN=0.00,     GIN=.0,
PULSE=.F.,   BFRONT=.T..   PL=  33.0,    SPEED=70.0,
HUNT = .F.,  FCRB=0.0,     FCRA=0.0,
             PHASB=0.0,    PHASA=0.0,$
```

FIGURE 6.3. EXAMPLE EXCIT NAMELIST FOR RECSIN INPUT

6.4 Track Profile Anomaly Input, PULSE

It is not infrequent for a spot to occur in a track road bed which is inconsistent with the rest of the road bed. For example, a crossing has the tendency to be relatively rigid, resulting in a hard spot or a slightly higher elevation relative to adjacent track. A second example is a soft spot or dip in the track brought about by poor drainage. Although this type of track anomaly does not cause as severe loading conditions as other track-vehicle dynamics problems, it is a real problem and does need to be evaluated.

The PULSE option in FRATE generates a (1-cosine)/2 function. The height, or depth, of the pulse is determined by the input DIN. The program will apply the pulse to the B truck and A truck with a time lag that is dependent on track speed and truck spacing

An example EXCIT Namelist for a pulse input is given in Figure 6.4. Maximum response will usually occur when PL, pulse length in feet, and SPEED, in feet per second, are tuned to the vehicle pitch frequency.

6.5 Vehicle Hunting Simulation, HUNT

The hunting simulation analysis in FRATE is based on assuming that a hunting condition exists and performing analyses to quantify the vehicle responses and loads. The analyses can also then be used to look for track, truck and vehicle parameters which have an influence on lessening the severity of the hunting loads and motions.

The motion of a rail car truck in a hunting condition is primarily a lateral oscillation. Since the vehicle is moving at some speed the truck follows a path that is roughly sinusoidal. For mild conditions the sine motion will vary in amplitude, sometimes making flange-to-flange contact. In a full hunting condition the motion will be sustained with hard flange-to-flange contact and the path followed is a flattened sine wave.

The hunting motions are simulated in FRATE by inputing a lateral sinusoidal force to the mass center of either or both trucks. Since the objective is to force certain truck motions, it is not necessary that the input force be applied at the wheel-rail interface. Computer programming becomes much easier when the forcing function is applied to the truck mass. Body hunting condition of carbody yaw resonance coupling with the truck motions.

```
$EXCIT
SINEIN=.F..
RECSIN=.F.,
S1= 1.,     S2= 0.0,    S3=.0,
AMP =  1.0,    00.,     1.00,     1.0,     00.,     01.0,
PHAS=   0.,     .00,    00.0,     0.0,     0.00,    00.0,
FQ=0.00,  FQDOT=.0,  BETA=0.,  NDECAY=5000,
DIN=.30,        VIN=0.00,      GIN=.0,
PULSE=.T.,   BFRONT=.T.,   PL=   33.0,   SPEED=70.0,
HUNT = .F.,  FCRB=0.0,     FCRA=0.0,
             PHASB=0.0,    PHASA=0.0,$
```

FIGURE 6.4. EXAMPLE EXCIT NAMELIST FOR PULSE INPUT

```
$EXCIT
SINEIN=.F..
RECSIN=.F..
S1= 1..     S2= 0.0,    S3=.0,
AMP =  1.0,    00.,     1.00,     1.0,     00.,     01.0,
PHAS=   0.,     .00,    00.0,     0.0,     0.00,    00.0,
FQ=1.70,  FQDOT=.0,  BETA=0.,  NDECAY=5000,
DIN=.00,        VIN=0.00,      GIN=.0,
PULSE=.F..   BFRONT=.T..   PL=   33.0,   SPEED=70.0,
HUNT = .T.,  FCRB=1000.,    FCRA=1000.,
             PHASB=180..   PHASA=0.0,$
```

FIGURE 6.5. EXAMPLE EXCIT NAMELIST FOR HUNT INPUT

are duplicated when the applied forces are phased and frequency tuned to the carbody yaw mode. Further the lateral spring at the wheel-rail interface has been made bilinear. Without flange contact the spring is soft to correspond to lateral centering force in a rolling condition. With flange contact the spring is stiff to correspond to the combined lateral stiffness of wheel and rail. The flange contact point is a function of gage clearances (GAGEB & GAGEA).

An example EXCIT namelist for a hunt analysis is given in Figure 6.5. Because of the approximating nature of this analysis the 1000 pound excitation forces are arbitrary and should be made larger or smaller to achieve the desired truck motion.

6.6 Shape

SHAPE is a multiplying factor on the SINE, RECSIN and HUNT input functions. The form and value of SHAPE is controlled through the input prameters S1, S2 and S3 in EXCIT. S1, S2 and S3 are real numbers.

If S1 is not zero then SHAPE = S1

If S1 is zero and S2 is not zero then:

SHAPE = (1 - cos(TH/S2))/2.)
= 0. when TH/S2 is greater than 2π

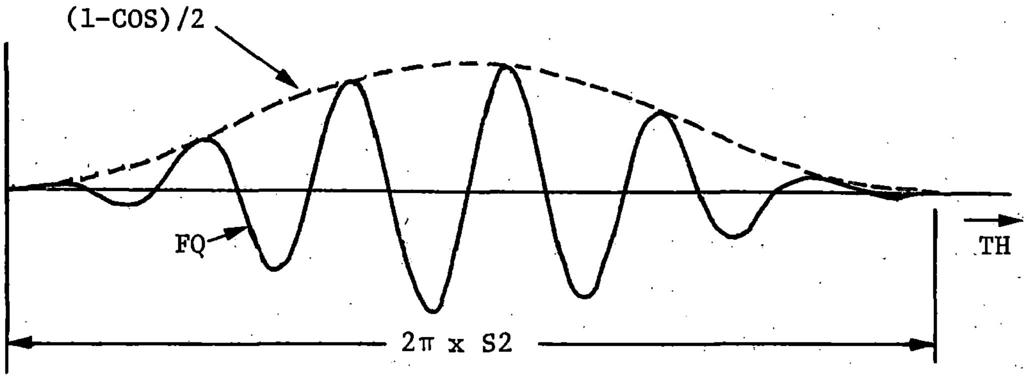
S2 = the number of cycles of FQ desired within the 1-cos shape, see Figure 6.6

TH = the total angle of rotation of the sinusoidal forcing function from time zero, radians

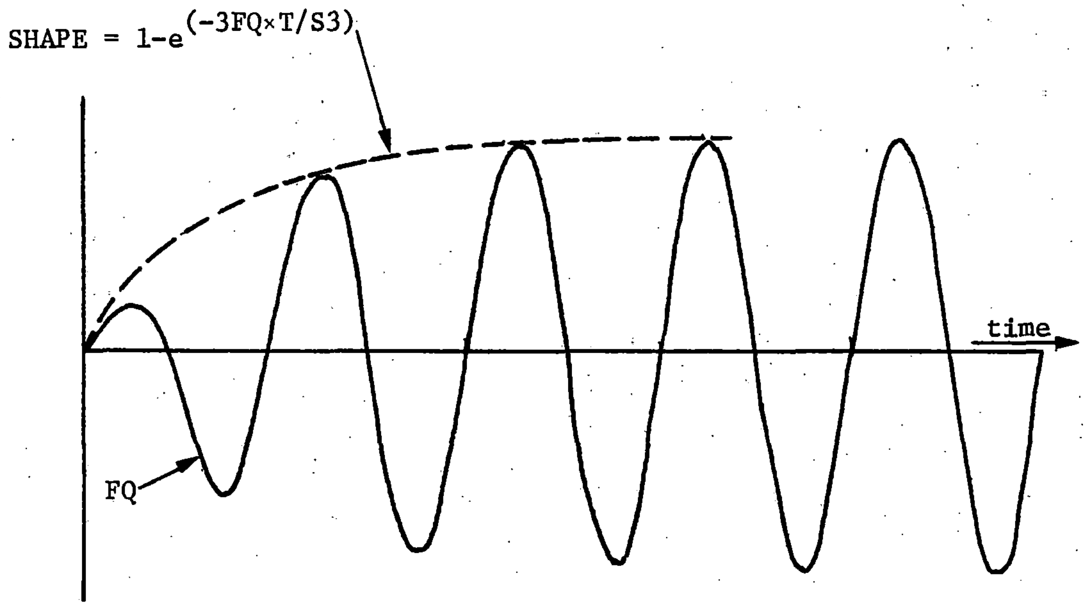
If S1 and S2 are zero and S3 is not zero then:

$$\text{SHAPE} = (1 - e^{(-3.\text{FQT}/\text{S3})})$$

S3 = the number of cycles of FQ desired for SHAPE to reach the value .95
See Figure 6.6



where S2 = 6



SHAPE = .95 at S3 = 2

FIGURE 6.6. EXAMPLES OF SHAPE

7. LADING MODEL

Lading is most frequently loaded into freight cars and highway trailers in pallet stacks. The pallet stacks will have resonance characteristics which are dependent on such things as the stack height, its foot print, density of the contents, type of packaging, dunnage and tie down. There are two resonance of the lading which need to be simulated--the lateral or roll resonance and the vertical or bounce resonance.

Lading dynamics are simulated in FRATF1 and FRATX1 with spring supported masses each having the three degrees of freedom of vertical translation (Z), lateral translation (X) and roll (ϕ). The size of the mass is made equal to the top 30 percent of the stack or group of stacks being simulated. This results in approximately the same base reaction loads at resonance compared to a continuous cantilever beam.

The resonant characteristics of lading that is canned, cartoned and stacked on pallets have been estimated in Appendix A of Reference 9. These results have been modified slightly and are shown here in Figure 7.1 in terms of variation of resonant frequency and amplification factor as a function of layers of stack height. The data of Figure 7.1 must be used as very approximate. It is based on limited data and there are other variables which affect frequency and Q.

7.1 Lading Model Used in Boxcar Model

The assumptions made in generating the boxcar model of this manual are as follows:

a. 100,000 pounds of total lading weight.

b. 70,000 pounds of lading assumed integral with carbody.

c. 30,000 pounds of lading divided into four equal parts of 7,500 pounds each and each assumed spring mounted.

d. Height of the lading assumed to be 8 layers of shipper.

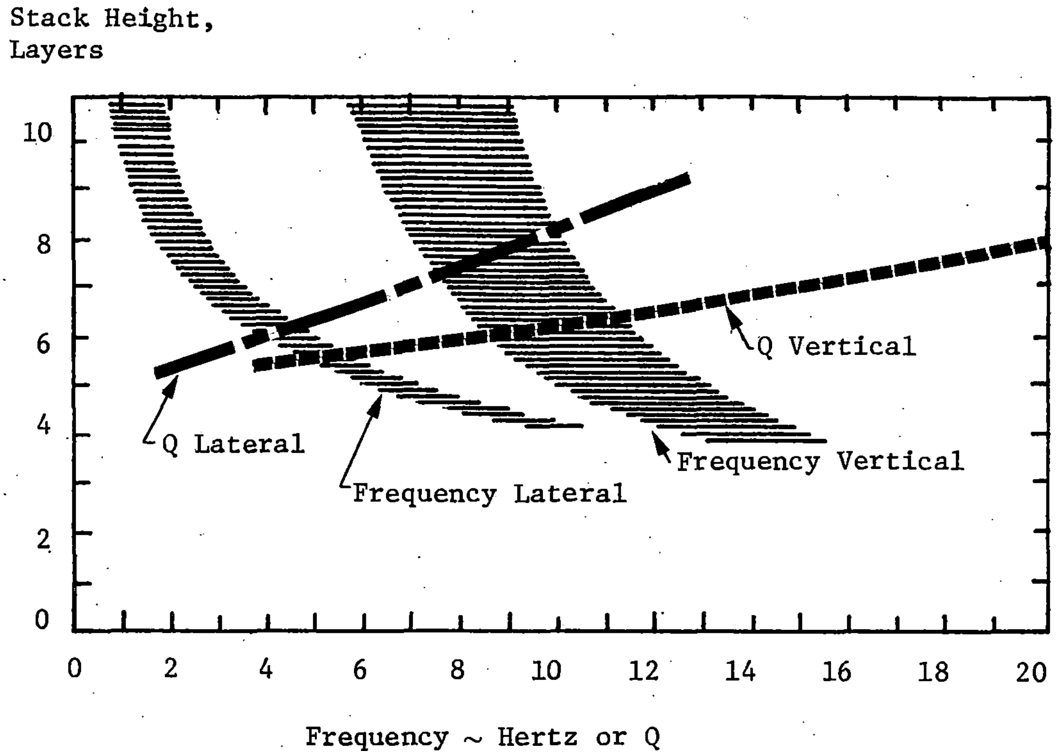


FIGURE 7.1. RESONANT CHARACTERISTICS OF STACKED CARTONED LADING

e. Overall dimensions of lading:
   - 80 inches high
   - 100 inches wide
   - 600 inches long

f. Top of floor is assumed 44.0 inches from top of rail.

g. Lading geometry is assumed as shown in Figure 7.2.

h. Each spring mounted lading mass is given three degrees of freedom: Z, vertical translation; x, lateral translation; and ϕ, roll. The natural frequencies and amplification factors assumed are listed in Table 7.1.

i. Spring and damper values were calculated assuming each degree of freedom is uncoupled as shown below.

The solution equations for a single degree of freedom spring/mass/viscous damper system at resonance are:

$$f = \frac{1}{2\pi}\sqrt{\frac{K}{M}}$$

$$C_c = 2\sqrt{KM}$$

$$Q = \frac{1}{2\eta}$$

$$\eta = C/C_c$$

Using these equations and the mass data in Figure 7.2 and the resonance data in Table 7-1, the spring/damper values given in Table 7-2 were calculated.

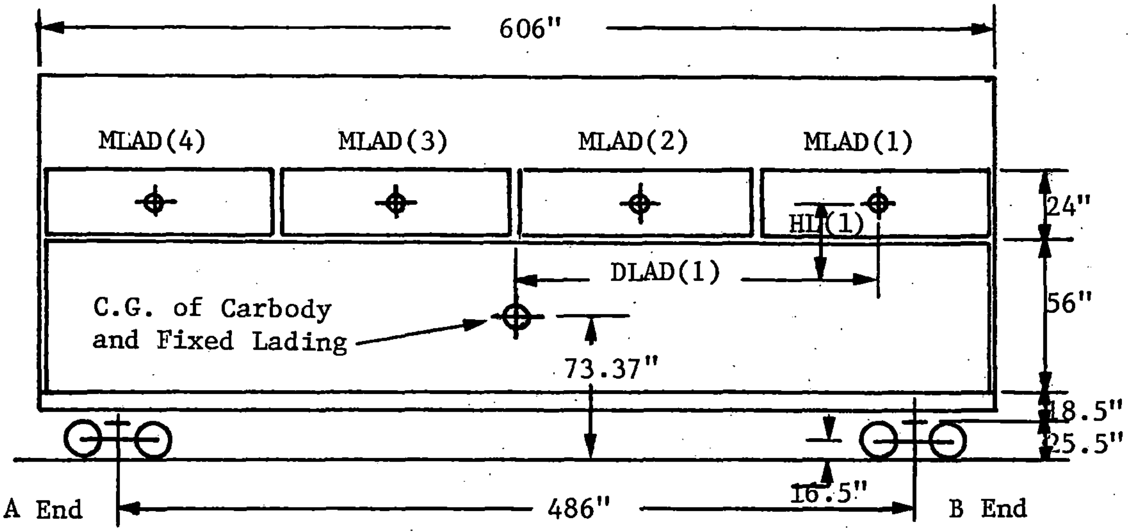
7.2 Lading Model Used in TOFC Model

The example TOFC model of this manual contains two identical van trailers. Each van trailer has lading configured as shown in Figure 7.3. The following assumptions were made in the development of the lading model for each trailer:

a. 49,500 pounds of lading was assumed in each trailer.

b. 34,650 pounds (70 percent) was assumed integral with each trailer body.

c. The remaining 14,850 pounds of lading was divided into two equal parts of 7,425 each assumed to be spring mounted.



DLAD(1) = 225 in.
DLAD(2) = 75 in.
DLAD(3) = -75 in.
DLAD(4) = -225 in.

HL(I) = 38.63 inches, I = 1, 4

MLAD(I) = 7500/386 = 19.43 lb.sec.^{2}/in., I = 1, 4

INLAD(I)= 17100 lb.in.sec.^{2}, I = 1,4

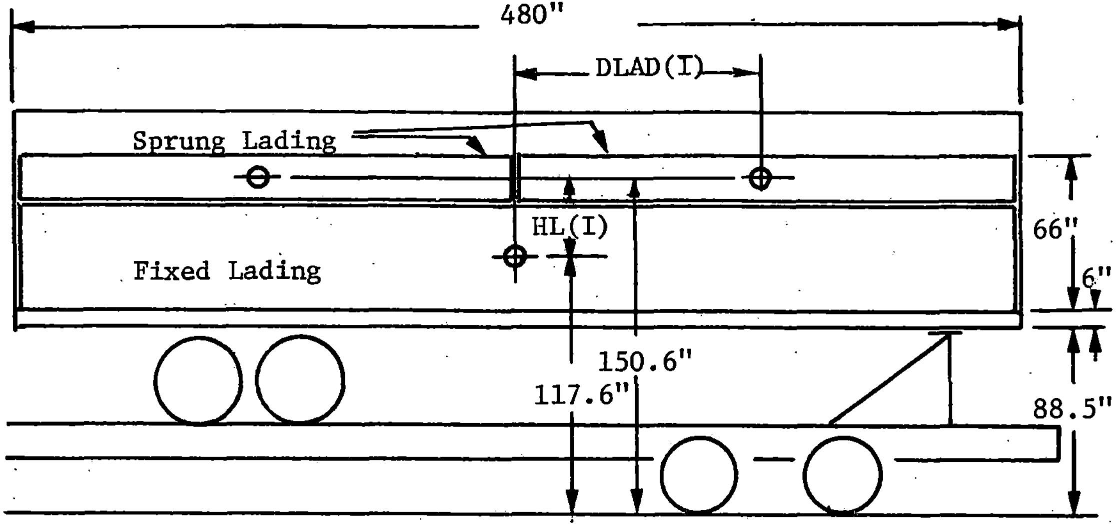
FIGURE 7.2. GEOMETRY OF BOXCAR LADING MODEL USED IN EXAMPLE

TABLE 7-1 - BOXCAR LADING FREQUENCIES AND Q'S

Direction	Frequency (Hz.)	Amplification Factor	Source
X (Lateral)	3.0	7.0	Figure 7.1
Z (Vertical)	9.0	16.0	Figure 7.1
ϕ (Roll)	13.0	10.0	Assumed

TABLE 7-2 - LADING MODEL SPRING AND DAMPER VALUES

Direction	Stiffness	Damping
X (Lateral)	0.69 E4 (lbs./in.)	52.0 (lbs./in./sec.)
Z (Vertical)	0.621 E5 (lbs./in.)	70.0 (lbs./in./sec.)
ϕ (Roll)	0.114 E9 (in. lbs./rad.)	0.14 E6 (in. lbs./rad./sec.



MLAD(I) = 7425/386 = 19.24 $\text{lb.sec.}^2/\text{in.}$
INLAD(I) = 16660 lb.in.sec.^2
DLAD(1) = DLAD(3) = 120 in.
DLAD(2) = DLAD(4) = -120 in.
HL(1) = 35.31 in.

FIGURE 7.3. GEOMETRY OF TRAILER LADING MODEL USED IN FRATF1 EXAMPLE

d. Height of the lading was assumed to be 6 layers of shippers.

e. Overall dimensions of the lading was assumed at 480, 100 and 66 inches in length, width and height.

f. Each spring mounted lading mass was given the three degrees of freedom of Z, X and ϕ. Natural frequencies and amplification factors assumed are listed in Table 7-3.

Using the single degree of freedom equations shown in Section 7.1 with the values assumed above and the resonance data in Table 7.3 the spring and damper values shown in Table 7.4 were calculated.

TABLE 7-3 - FREQUENCIES AND AMPLIFICATION FACTORS ASSUMED FOR LADING MODEL IN TRAILERS

Direction	Frequency (Hz.)	Amplification Factor	Source
X (Lateral)	5.0	4.0	Figure 7.1
Z (Vertical)	9.5	7.0	Figure 7.1
ϕ (Roll)	15.0	8.3	Assumed

TABLE 7-4 - SPRING AND DAMPER VALUES FOR TRAILER LADING MODEL

Direction	Stiffness*	Damping*
X (Lateral)	0.1899 E5	151.0
Z (Vertical)	0.6855 E5	164.0
ϕ (Roll)	0.1480 E9	0.1892 E6

---

*Refer to Table 7-2 for units

APPENDIX A - REFERENCES

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

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

(3) Kachadourian, G., N. Sussman and J. Anderes, "FRATE Volume 1: User's Manual," NTIS Report FRA/ORD-78/59, The MITRE Corporation, McLean, Virginia, September 1978.

(4) Abbot, P., G. Morosow and J. MacPherson, "Track-Train Dynamics," SAE National Aerospace and Engineering and Manufacturing Meeting, Culver City, California, SAE Paper No. 751058, November 1975.

(5) Johnson, A Gilchrist, M. Healy, C. Bush and G. Sheldon, "Truck Design Optimization Project Phase II Analytical Tool Assessment Report," Report No. FRA/ORD-79/36, August 1979.

(6) Kachadourian, G. and N. Sussman, "Validation of FRATE, Freight Car Response Analysis and Test Evaluation," MTR-8007, The MITRE Corporation, McLean, Virginia, December 1978.

(7) Heller, R., J. Tuters, P. Kadala and E. Law, "Analog and Digital Computer Simulation of Coulomb Friction," Report No. FRA/ORD-78-07, Interim Report, December 1977.

(8) Track-Train Dynamics, Harmonic Roll Series, Volume 2, "70 Ton Truck Component Data, Physical Restraints, Mechanical Properties, Damping Characteristics," 1974.

(9) Kachadourian, G., "TOFC Lading Response Analyses for Several Track Profile and Hunting Conditions," MITRE Report Number MTR-79W00318, NTIS Report FRA/ORD-80/3, The MITRE Corporation, McLean, Virginia, April 1980.

APPENDIX B - FORTRAN NOTATION

CARBODY FORTRAN NOTATION

Notation		Variable	Notation		Variable
DER(1)	=	$\ddot{X}(1)$	VAR(1)	=	$\dot{X}(1)$
DER(2)	=	$\dot{X}(1)$	VAR(2)	=	$X(1)$
DER(3)	=	$\ddot{X}(2)$	VAR(3)	=	$\dot{X}(2)$
DER(4)	=	$\dot{X}(2)$	VAR(4)	=	$X(2)$
DER(5)	=	$\ddot{X}(3)$	VAR(5)	=	$\dot{X}(3)$
DER(6)	=	$\dot{X}(3)$	VAR(6)	=	$X(3)$
DER(7)	=	$\ddot{Z}(1)$	VAR(7)	=	$\dot{Z}(1)$
DER(8)	=	$\dot{Z}(1)$	VAR(8)	=	$Z(1)$
DER(9)	=	$\ddot{Z}(2)$	VAR(9)	=	$\dot{Z}(2)$
DER(10)	=	$\dot{Z}(2)$	VAR(10)	=	$Z(2)$
DER(11)	=	$\ddot{Z}(3)$	VAR(11)	=	$\dot{Z}(3)$
DER(12)	=	$\dot{Z}(3)$	VAR(12)	=	$Z(3)$
DER(13)	=	$\ddot{\phi}(1)$	VAR(13)	=	$\dot{\phi}(1)$
DER(14)	=	$\dot{\phi}(1)$	VAR(14)	=	$\phi(1)$
DER(15)	=	$\ddot{\phi}(2)$	VAR(15)	=	$\dot{\phi}(2)$
DER(16)	=	$\dot{\phi}(2)$	VAR(16)	=	$\phi(2)$
DER(17)	=	$\ddot{\phi}(3)$	VAR(17)	=	$\dot{\phi}(3)$
DER(18)	=	$\dot{\phi}(3)$	VAR(18)	=	$\phi(3)$
DER(19)	=	$\ddot{\theta}$	VAR(19)	=	$\dot{\theta}$
DER(20)	=	$\dot{\theta}$	VAR(20)	=	θ

CARBODY FORTRAN NOTATION (CONCLUDED)

Notation		Variable	Notation		Variable
DER(21)	=	$\ddot{\alpha}$	VAR(21)	=	$\dot{\alpha}$
DER(22)	=	$\dot{\alpha}$	VAR(22)	=	α

TRAILER FORTRAN NOTATION

DER(23)	=	$\ddot{X}(4)$	VAR(23)	=	$\dot{X}(4)$
DER(24)	=	$\dot{X}(4)$	VAR(24)	=	$X(4)$
DER(25)	=	$\ddot{X}(5)$	VAR(25)	=	$\dot{X}(5)$
DER(26)	=	$\dot{X}(5)$	VAR(26)	=	$X(5)$
DER(27)	=	$\ddot{Z}(4)$	VAR(27)	=	$\dot{Z}(4)$
DER(28)	=	$\dot{Z}(4)$	VAR(28)	=	$Z(4)$
DER(29)	=	$\ddot{Z}(5)$	VAR(29)	=	$\dot{Z}(5)$
DER(30)	=	$\dot{Z}(5)$	VAR(30)	=	$Z(5)$
DER(31)	=	$\ddot{\phi}(4)$	VAR(31)	=	$\dot{\phi}(4)$
DER(32)	=	$\dot{\phi}(4)$	VAR(32)	=	$\phi(4)$
DER(33)	=	$\ddot{\phi}(5)$	VAR(33)	=	$\dot{\phi}(5)$
DER(34)	=	$\dot{\phi}(5)$	VAR(34)	=	$\phi(5)$
DER(35)	=	$\ddot{\theta}V$	VAR(35)	=	$\dot{\theta}V$
DER(36)	=	$\dot{\theta}V$	VAR(36)	=	θV
DER(37)	=	$\ddot{\alpha}V$	VAR(37)	=	$\dot{\alpha}V$
DER(38)	=	$\dot{\alpha}V$	VAR(38)	=	αV
DER(39)	=	$\ddot{X}(6)$	VAR(39)	=	$\dot{X}(6)$
DER(40)	=	$\dot{X}(6)$	VAR(40)	=	$X(6)$

TRAILER FORTRAN NOTATION (CONCLUDED)

Notation		Variable	Notation		Variable
DER(41)	=	$\ddot{X}(7)$	VAR(41)	=	$\dot{X}(7)$
DER(42)	=	$\dot{X}(7)$	VAR(42)	=	$X(7)$
DER(43)	=	$\ddot{Z}(6)$	VAR(43)	=	$\dot{Z}(6)$
DER(44)	=	$\dot{Z}(6)$	VAR(44)	=	$Z(6)$
DER(45)	=	$\ddot{Z}(7)$	VAR(45)	=	$\dot{Z}(7)$
DER(46)	=	$\dot{Z}(7)$	VAR(46)	=	$Z(7)$
DER(47)	=	$\ddot{\phi}(6)$	VAR(47)	=	$\dot{\phi}(6)$
DER(48)	=	$\dot{\phi}(6)$	VAR(48)	=	$\phi(6)$
DER(49)	=	$\ddot{\phi}(7)$	VAR(49)	=	$\dot{\phi}(7)$
DER(50)	=	$\dot{\phi}(7)$	VAR(50)	=	$\phi(7)$
DER(51)	=	$\ddot{\theta}T$	VAR(51)	=	$\dot{\theta}T$
DER(52)	=	$\dot{\theta}T$	VAR(52)	=	θT
DER(53)	=	$\ddot{\alpha}T$	VAR(53)	=	$\dot{\alpha}T$
DER(54)	=	$\dot{\alpha}T$	VAR(54)	=	αT

FLEXIBLE MODE FORTRAN NOTATION

DER(NQP+1)	=	$\ddot{\eta}(1)$	VAR(NQP+1)	=	$\dot{\eta}(1)$
DER(NQP+2)	=	$\dot{\eta}(1)$	VAR(NQP+2)	=	$\eta(1)$
DER(NQP+3)	=	$\ddot{\eta}(2)$	VAR(NQP+3)	=	$\dot{\eta}(2)$
DER(NQP+4)	=	$\dot{\eta}(2)$	VAR(NQP+4)	=	$\eta(2)$
DER(NQP+5)	=	$\ddot{\eta}(3)$	VAR(NQP+5)	=	$\dot{\eta}(3)$
DER(NQP+6)	=	$\dot{\eta}(3)$	VAR(NQP+6)	=	$\eta(3)$

FLEXIBLE MODE FORTRAN NOTATION (CONCLUDED)

Notation	Variable	Notation	Variable
DER(NQP+7) =	$\ddot{\eta}(4)$	VAR(NQP+7) =	$\dot{\eta}(4)$
DER(NQP+8) =	$\dot{\eta}(4)$	VAR(NQP+8) =	$\eta(4)$

Where:

NQP = 22 when NMAS = 3 –Boxcar or Empty Flatcar
NQP = 38 when NMAS = 5 –Flatcar and One Trailer
NQP = 54 when NMAS = 7 –Flatcar and Two Trailers

LADING FORTRAN NOTATION

DER(NQR+1) =	$\ddot{Z}L(1)$	VAR(NQR+1) =	$\dot{Z}L(1)$
DER(NQR+2) =	$\dot{Z}L(1)$	VAR(NQR+2) =	$ZL(1)$
DER(NQR+3) =	$\ddot{X}L(1)$	VAR(NQR+3) =	$\dot{X}L(1)$
DER(NQR+4) =	$\dot{X}L(1)$	VAR(NQR+4) =	$XL(1)$
DER(NQR+5) =	$\ddot{\phi}L(1)$	VAR(NQR+5) =	$\dot{\phi}L(1)$
DER(NQR+6) =	$\dot{\phi}L(1)$	VAR(NQR+6) =	$\phi L(1)$
DER(NQR+7) =	$\ddot{Z}L(2)$	VAR(NQR+7) =	$\dot{Z}L(2)$
DER(NQR+8) =	$\dot{Z}L(2)$	VAR(NQR+8) =	$ZL(2)$
DER(NQR+9) =	$\ddot{X}L(2)$	VAR(NQR+9) =	$\dot{X}L(2)$
DER(NQR+10)=	$\dot{X}L(2)$	VAR(NQR+10)=	$XL(2)$
DER(NQR+11)=	$\ddot{\phi}L(2)$	VAR(NQR+11)=	$\dot{\phi}L(2)$
DER(NQR+12)=	$\dot{\phi}L(2)$	VAR(NQR+12)=	$\phi L(2)$
DER(NQR+13)=	$\ddot{Z}L(3)$	VAR(NQR+13)=	$\dot{Z}L(3)$
DER(NQR+14)=	$\dot{Z}L(3)$	VAR(NQR+14)=	$ZL(3)$
DER(NQR+15)=	$\ddot{X}L(3)$	VAR(NQR+15)=	$\dot{X}L(3)$

LADING FORTRAN NOTATION (CONCLUDED)

Notation	Variable	Notation	Variable
DER(NQR+16)=	$\dot{X}L(3)$	VAR(NQR+16)=	XL(3)
DER(NQR+17)=	$\ddot{\phi}L(3)$	VAR(NQR+17)=	$\dot{\phi}L(3)$
DER(NQR+18)=	$\dot{\phi}L(3)$	VAR(NQR+18)=	$\phi L(3)$
DER(NQR+19)=	$\ddot{Z}L(4)$	VAR(NQR+19)=	$\dot{Z}L(4)$
DER(NQR+20)=	$\dot{Z}L(4)$	VAR(NQR+20)=	ZL(4)
DER(NQR+21)=	$\ddot{X}L(4)$	VAR(NQR+21)=	$\dot{X}L(4)$
DER(NQR+22)=	$\dot{X}L(4)$	VAR(NQR+22)=	XL(4)
DER(NQR+23)=	$\ddot{\phi}L(4)$	VAR(NQR+23)=	$\dot{\phi}L(4)$
DER(NQR+24)=	$\dot{\phi}L(4)$	VAR(NQR+24)=	$\phi L(4)$

Where:

NQR = NQP + 2 * NMODES

User's Manual for FRATXI and FRATFI Freight Car Dynamic Analysis Computer Programs,
1981
US DOT, FRA, George Kachadourian