TRACK TRAIN DYNAMICS
MATHEMATICAL MODEL

...RNATIONAL GOVERNMENT-INDUSTRY RESEARCH PROGRAM ON TRACK-TRAIN DYNAMICS

[redacted]

Association of American Railroads
Research and Test Department

INTERACTIVE SIMULATION AND COMPUTER GRAPHICS FOR THE QUASI-STATIC LATERAL TRAIN STABILITY MODEL

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13. ABSTRACT

The AAR's Quasi-Static Lateral Train Stability (QLTS) Model has been modified to include interactive graphics for a visual display of the simulated results. The interface program also allows the user to select the variables of interest prior to plotting the results.

The program development utilized Tektronix PLOT-10 and Advanced Graphing II packages, and the final program is now operational on the AAR's DEC 2050 computer system.

The procedures for using the interactive graphics with the QLTS program is documented in this report.

14. SUBJECT TERMS
Advanced Graphing II (Tektronix)
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Quasi-Static Lateral Train Stability (QLTS) Model
PLOT-10 (Tektronix)

15. AVAILABILITY STATEMENT
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EXECUTIVE SUMMARY

This report concerns a portion of the study under AAR Contract TTD79-171-3 for the enhancement of railroad dynamic, finite-element computer programs. This part of the study is concerned specifically with the conversion of an existing AAR train dynamics program: the Quasi-Static Lateral Train Stability (QLTS) Model to include interactive simulation and computer graphics. An interactive execution of this large program permits a continuous check and conversational feedback during the simulation phase. The display of some of the input data, and the intermediate and final results in a graphical format, rather than numerically, aids in its interpretation by visual perception.

The conversion of this program involved the following primary tasks:

1) Modify the Tektronix PLOT-10 and Advanced Graphing II (AG II) software packages and install and verify them on the AAR's DEC 2050 computer system.
2) Change the data describing the model to be simulated into a free format for easy entry through a terminal.
3) Develop interactive programming to allow the user to specify the simulation tasks, to modify and edit the model description files and to control the display of the results.

4) Interface the QLTS program with the DEC 2050 computer and interactive graphics terminals through the use of PLOT-10 and Advanced Graphing II.

5) Complete the validation runs to assure the completeness of the program and, specifically, the new interactive graphics phase, and

6) Prepare examples and documentation to explain the interactive simulation and graphics to the user.

The computer graphics software that was employed consists of Tektronix PLOT-10 and Advanced Graphing II (AG II) packages. These packages were modified by converting some machine language, run on the IIT computer and then installed on the AAR DEC 2050 computer. They were verified by writing the routine VERIFY. The User's Manual for PLOT-10 and AG II, and a listing of all of the programs have been submitted separately.

This report deals only with the example and documentation to explain the interactive simulation and graphics for the user. A listing of the program, with modifications for interactive simulation, and of programs that have been written to control the computer graphics have been submitted separately.

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1.0 INTRODUCTION

The Quasi-Static Lateral Train Stability (QLTS) Model is a computer simulation program developed by the AAR [1, 2, 3]. The model calculates lateral forces at the bolster centers and coupler pins; coupler angles; moments due to alignment control; bolster displacements; and centifugal and superelevation forces. When the lateral forces at the bolster centers and coupler pins are combined with the lateral curve negotiation forces and vehicle weight, the derailment tendencies can be determined by evaluating the L/V ratios for both wheel climb and rail rollover. The program is useful for the investigation of track geometry and curve negotiation characteristics, and for parametric studies, such as the effect of carbody overhang, optimum bolster spacing, coupler length and vehicle weight.

The program models a train consist for force equilibrium for each vehicle. The detailed mathematical model is described in the Technical Documentation [1]. The train consist is limited to 100 vehicles. The train consist is moved along the track and is examined at each time step,as specified by the user. The track length is limited to 2500 feet.

The objective of the study reported here was to modify the existing program, in order to make it suitable for interactive

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*The numbers in square brackets [ ] designate the references, shown in Section 5.0 of this report.

simulation, and to introduce interactive computer graphics so that the intermediate and final results could be displayed graphically on a video terminal. Permanent records of the plots and graphs can be retained by using a hard copier.

For this purpose, it was necessary to modify the format of the existing program and to prepare files for plotting. In addition, two new programs have been written for the purpose of storing the complete simulation history in a format suitable for plotting the results, and for the actual interactive graphic display of the results. The display employs the Tektronix PLOT-10 and Advanced Graphing II (AG II) packages. These packages have been modified and implemented on the AAR's DEC 2050 computer. This task required some conversion of machine language into a form suitable for the DEC 2050 computer, and writing of a suitable verification routine: VERIFY. User manuals for PLOT 10 and Advanced Graphing II have been submitted separately, but a knowledge of these manuals is not required for an interactive computer graphics simulation of QLTS.

2.0 PROGRAM STRUCTURE

The QLTS computer simulation, as now implemented on the AAR's DEC 2050 computer, consists of the following four programs:

1) QTRACK accepts the track data input, and generates two files for its output. One of these files, which is here named TRACK, contains the track profile data to be used later as input to the next program. The other output

file, named TRKPLT.DAT, contains data for plotting the track profile.

2) QTRAIN is used to simulate the train on the previously generated track profile. It accepts inputs from the file TRACK and from the train simulation data, which is supplied either interactively,or from a previously generated file,which is named TRAIN. For its output, QTRAIN generates two files, PLTVAR.DAT AND TRNPLT.DAT.

3) CONVRT accepts the PLTVAR.DAT and TRNPLT.DAT files as input and prepares an output file, QLTPLT.DAT, which stores the complete simulation history in a format suitable for plotting. After the preparation of the QLTPLT.DAT file, the TRNPLT.DAT file is deleted.

4) PLOTQL accepts inputs from the three files TRKPLT.DAT, PLTVAR.DAT and QLTPLT.DAT,and interactively displays the plots on Tektronix 4006 and 4010 terminals.

The foregoing programs and their interactions are shown in Table 1 and also illustrated in Figure 1.

Table 1. Four QLTS Programs

Program	Input	Output	Remarks
QTRACK	Track data	TRACK (data profile) TRKPLT.DAT	Original AAR program modified. It prepares the TRKPLT.DAT file, which contains data for plotting the track profile
QTRAIN	Train simulation data or TRAIN file TRACK file	PLTVAR.DAT TRNPLT.DAT	Original AAR program modified. It prepares two plot files: PLTVAR.DAT and TRNPLT.DAT
CONVRT	PLTVAR.DAT TRNPLT.DAT	QLTPLT.DAT	New program written for storing the complete simulation in a format suitable for plotting. After preparing QLTPLT. DAT, the TRNPLT.DAT file is deleted.
PLOTQL	PLTVAR.DAT QLTPLT.DAT TRKPLT.DAT	Graphs and plots on Tektronix 4006 and 4010 terminals	New program written for interactive graphics to display the plots

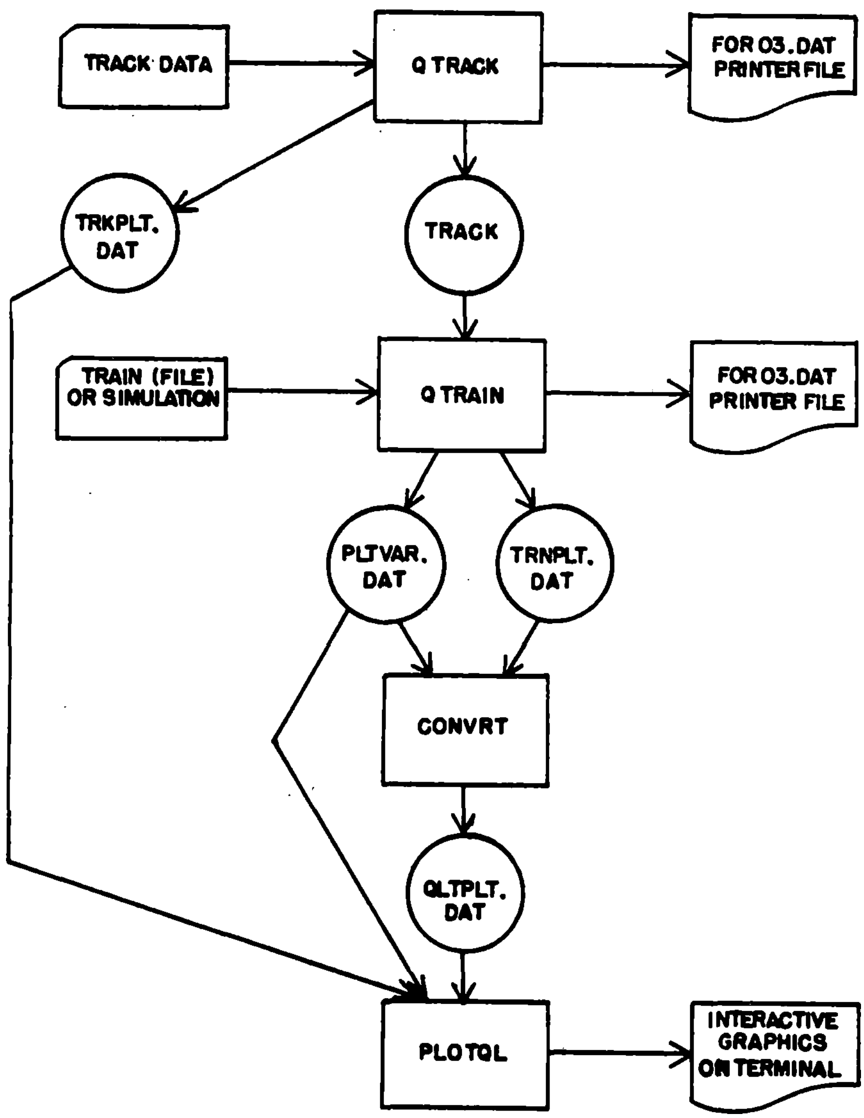

Figure 1. Flow Chart for the Four QLTS Programs.

3.0 INPUT DATA

The input data is supplied in two parts: the track coordinate data and the train consist data. The fixed format method of supplying these data is described in the QLTS User's Manual [2]. Hence, only the free format interactive method of supplying the data is discussed in this report. The User's Manual [2] explains the available options of modeling and provides a description of all of the parameters. Hence, this report should be used along with the User's Manual,as a complete guide for interaction simulation and computer graphics.

The interactive method of supplying the data and of obtaining computer plots of the results is illustrated for a sample problem taken from the User's Manual [2]. In this example, the train consisted of 7 vehicles on 1030 feet of track. The train starts from Cleveland, heading south. The track consisted of 400 feet of tangent track, followed by a 50 foot spiral leading to a 150 foot right hand curve of $6^{\circ}30'$, with 4.5 inches of superelevation. This was followed by 70 feet of trailing spiral and 40 feet of tangent track. This was followed by a 60 foot spiral leading to a 200 foot left hand curve of 4°, with 5 inches of superelevation. A 60 foot trailing spiral leading to tangent track completed the track description. This track section is illustrated in Figure 2.

The train consisted of an SD-40 locomotive, 70-ton hopper car, 100-ton hopper car, LB5 (box)car, two 100-ton hopper cars, and a 70-ton hopper car.

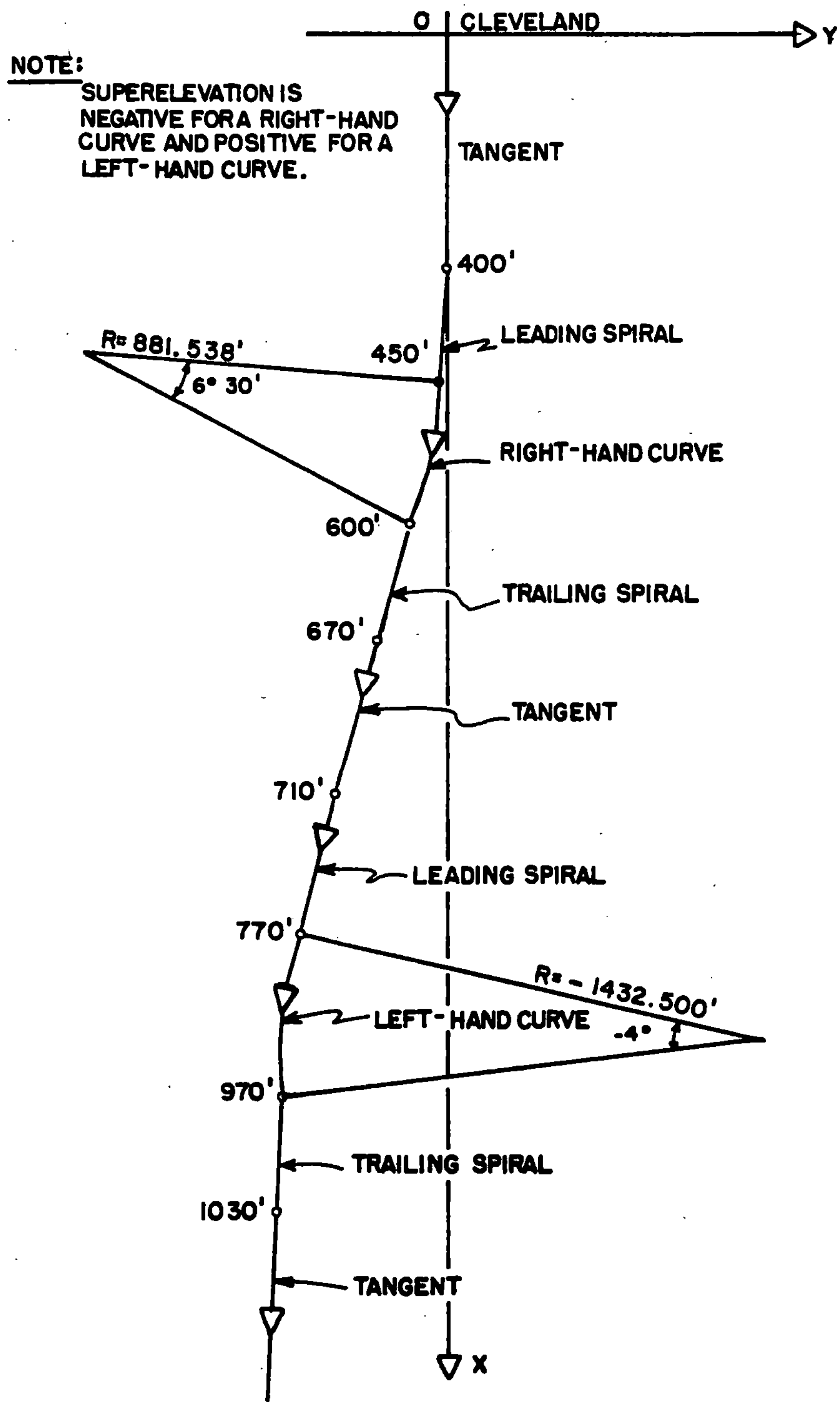

Figure 2. Sample Track Section [2].

For this sample run, the net CPU time to execute the QTRACK program on the AAR's DEC 2050 computer was 6.0 seconds. The net CPU time to execute the QTRAIN program, which simulated the seven vehicle consist on 1030 feet of track for ten, one second intervals, was 7.94 seconds. The CPU time for the execution of the CONVRT program was 1.55 seconds. When the train simulation data was supplied to QTRAIN through the file TRAIN, the execution took only 4.15 seconds of CPU time.

Following this discussion is a listing of the interactive method for running the QTRACK program for this sample problem.

This is followed by a listing of the interactive method of running the QTRAIN and CONVRT programs, where the simulation data to the QTRAIN program is supplied through the terminal. A listing is also given of running the QTRAIN program, where the simulation data is supplied through the file TRAIN. These methods, though illustrating a sample problem, can be used as a guide to supply data and run the program interactively to simulate any particular problem.

```
@RUN (PROGRAM) QTRACK.EXE.2

PLEASE ENTER TRACK FILE NAME TO BE GENERATED
       (NOTE: THIS FILE WILL BE USED FOR TRAIN
              PROGRAM EXE. MAX # OF CHAR. IS 6
TRACK



*** HELLO, WELCOME TO QLTS TRACK PROGRAM ***



YOU ARE NOW IN AN INTERACTIVE MODE WITH
THE     D E C  2 0    COMPUTER SYSTEM
AT      THE  A A R  CHICAGO TECHNICAL CENTER.



THIS IS HOW TO RUN THE QLTS TRACK PROGRAM:
------------------------------------------

 (1) HAVE THE TRACK INPUT DATA READY
     (REF. TO USERS MANUEL)
 (2) RESPOND TO EACH INSTRUCTION BY ENTERING
     THE REQUESTED DATA DIRECTLY ONTO THE
     KEYBOARD, AND PRESS THE RETURN KEY.


     NOTE: ALL DATA CAN BE ENTERED AS FREE
           FORMAT UNLESS OTHERWISE SPECIFIED.


 (3) WAIT FOR PROGRAM EXECUTION
 (4) YOUR PRINTED OUTPUT CAN BE MAILED TO YOU
     AT YOUR REQUEST. (GIVE US YOUR MAILING
     ADDRESS)


               -   GOOD LUCK   -

OUTPUT DISPLAYED ON YOUR KEYBOARD TERMINAL ?
IF      NO     OUTPUT ON LINE PRINTER
ANSWER      YES      OR      NO :
NO

STANDARD GAUGE IS 56.5 INCHES
ENTER     GAUGE:
56.5
```

```
PRINTL CAN BE 1,2,3,4 OR 5
ENTER     PRINTL:
1

GIVE TRACK LOCATION, MAX. IS 10 ALPHABETS:
CLEVELAND

START     IS THE STARTING PT. OF TRACK IN FT.
ENTER     START:
0.0

ENTER INITIAL TRACK DIRECTION IN DEG. , MIN. :
0.0 0.0

ENTER TRACK DIRECTION, MAX. 10 ALPHABETS:
SOUTH

DDEG   IS THE DEGREE OF THE CURVE
IF NO MORE TRACK ENTER   9999.0
OTHERWISE ENTER ITS PROPER VALUE.
ENTER     DDEG:
6.

DMIN     IS THE ADDITIONAL CURVATURE
         IN MINUTES.
ENTER     DMIN:
30.

PTS    IS THE PT. WHERE TANGENT MEETS
       SPIRAL IN FT. ALONG THE TRACK
ENTER     PTS:
400.

PSC    IS THE PT. WHERE SPIRAL MEETS
       CURVE IN FT. ALONG THE TRACK
ENTER     PSC:
450.

PCS    IS THE PT. WHERE CURVE MEETS
       TRAILING SPIRAL IN FT.
ENTER     PCS:
600.

PST    IS THE PT. WHERE TRAILING
       SPIRAL MEETS TANGENT IN FT.
ENTER     PST:
670.

SUPELV  IS SUPERELEVATION IN INCHES
ENTER     SUPELV:
4.5
```

```
DDEG   IS THE DEGREE OF THE CURVE
IF NO MORE TRACK ENTER   9999.0
OTHERWISE ENTER ITS PROPER VALUE.
ENTER      DDEG:
-4.

DMIN       IS THE ADDITIONAL CURVATURE
           IN MINUTES.
ENTER      DMIN:
0.0

PTS    IS THE PT. WHERE TANGENT MEETS
       SPIRAL IN FT. ALONG THE TRACK
ENTER      PTS:
710.

PSC    IS THE PT. WHERE SPIRAL MEETS
       CURVE IN FT. ALONG THE TRACK
ENTER      PSC:
770.

PCS    IS THE PT. WHERE CURVE MEETS
       TRAILING SPIRAL IN FT.
ENTER      PCS:
970.

PST    IS THE PT. WHERE TRAILING
       SPIRAL MEETS TANGENT IN FT.
ENTER      PST:
1030.

SUPELV  IS SUPERELEVATION IN INCHES
ENTER      SUPELV:
5.0

DDEG   IS THE DEGREE OF THE CURVE
IF NO MORE TRACK ENTER   9999.0
OTHERWISE ENTER ITS PROPER VALUE.
ENTER      DDEG:
9999.0


INPUT DATA COMPLETED....PROGRAM EXECUTING....


STOP

END OF EXECUTION
CPU TIME: 6.00  ELAPSED TIME: 3:45.67
EXIT
```

```
@RUN (PROGRAM) QTRAIN.EXE.2

ENTER FIRST THE TRACK DATA FILE NAME YOU CREATED
             (MAX. # OF CHAR. IS 6)
TRACK


DO YOU WANT OUTPUT TO BE DISPLAYED ON KEYBOARD TERMINAL ?
IF     NO     OUTPUT ON LINE PRINTER
ANSWER     YES     OR     NO :
NO

TYPE THE TITLE FOR THIS RUN (20A4)

TEST RUN FOR QLTS PROGRAM

DO YOU WANT TO INPUT DATA THRU FILE (YES=1,NO=0)

0


 NU      IS NO. OF VEHICLES
 ENTER     NU:
7

SPEED     IS SPEED OF TRAIN IN MPH
ENTER   SPEED:
40.

TIME     IS STARTING TIME OF SIMULATION IN SEC.
ENTER     TIME:
0.

TTIME     IS FINAL TIME FOR SIMULATION IN SEC.
ENTER     TTIME:
10.

STP     IS TIME INTERVAL FOR CALCULATION IN SEC.
ENTER     STP:
1.

IDROPT     IS DRAWBAR FORCE OPTION (REF. USERS MANUEL)
 0     FOR     ACTUAL DRAWBAR FORCE
 1     FOR     ACCUMULATED UNTIL DRAWBAR READS 0.0
               FORCES DECREASES LINEARLY.
 2     FOR     ACCUMULATED UNTIL DRAWBAR READS 0.0
               NO DECREASE IN TRAILING DRAWBAR FORCES
ENTER     IDROPT:
1

IMODE     IS BOLSTER DISPLACEMENT MODE
 1     FOR INITIAL BOSTER DISPL. MODE
 2     FOR SKEWED MODES CONSIDERATION
ENTER     IMODE:
1
```

```
ILV      WANT L/V CALCULATIONS ?
1       FOR      YES
0       FOR      NO
ENTER     ILV:
1

BF(I)      DRAWBAR FORCE ON PRESENT VEHICLE IN LBS
NTER      BF(  1) :
40000.0

BF(I)      DRAWBAR FORCE ON PRESENT VEHICLE IN LBS
NTER      BF(  2) :
40000.0

BF(I)      DRAWBAR FORCE ON PRESENT VEHICLE IN LBS
NTER      BF(  3) :
40000.0

BF(I)      DRAWBAR FORCE ON PRESENT VEHICLE IN LBS
NTER      BF(  4) :
0.0

BF(I)      DRAWBAR FORCE ON PRESENT VEHICLE IN LBS
NTER      BF(  5) :
0.0

BF(I)      DRAWBAR FORCE ON PRESENT VEHICLE IN LBS
NTER      BF(  6) :
0.0

BF(I)      DRAWBAR FORCE ON PRESENT VEHICLE IN LBS
NTER      BF(  7) :
0.0

ALPHA(I,1) & ALPHA(I,2)      FOR VEHICLE DESCPT.
ENTER      ALPHA(  1,1) & ALPHA(  1,2) :
SD-40

A(I)      IS BOLSTER CENTER DIST. IN INCHES
ENTER      A(  1) :
480.

B(I,1)      IS DIST. BETWEEN B.C. & C. P., FRONT
ENTER      B(  1) :
120.

B(I,2)      IS DIST. BETWEEN B.C. & C. P., REAR
ENTER      B(  1,2) :
120.

CL(I,1)      IS FRONT COUPLER LENGTH IN INCHES
ENTER      CL(  1,1) :
28.25

CL(I,2)      IS REAR COUPLER LENGTH IN INCHES
ENTER      CL(  1,2) :
28.25
```

```
DELMX(I)      MAX. BOLSTER CENTER DISPL. IN INCHES
ENTER      DELMX(  1) :
1.25

JAC(I)     ALIGNMENT CONTROL CODE
 0       FOR      NO ALIGNMENT CONTROL
 1       FOR      M-380,381 LOCOMOTIVE DRAFT GEAR
 3       FOR      F-BUTT TYPE COUPLER
ENTER      JAC(  1) :
1

DEL(I,1)      INITIAL FRONT B.C. DISPL. IN INCHES
ENTER      DEL(  1,1) :
0.0

DEL(I,2)      INITIAL REAR B.C. DISPL. IN INCHES
ENTER      DEL(  1,2) :
0.0

HCOG(I)      VEH. C.G. HEIGHT FROM RAIL IN INCHES
ENTER       HCOG(  1) :
52.0

ALPHA(I,1) & ALPHA(I,2)     FOR VEHICLE DESCPT.
ENTER      ALPHA(  2,1) & ALPHA(  2,2) :
HOPPER-70

A(I)      IS BOLSTER CENTER DIST. IN INCHES
ENTER      A(  2) :
380.

B(I,1)      IS DIST. BETWEEN B.C. & C. P., FRONT
ENTER      B(  2) :
32.

B(I,2)      IS DIST. BETWEEN B.C. & C. P., REAR
ENTER      B(  2,2) :
32.

CL(I,1)      IS FRONT COUPLER LENGTH IN INCHES
ENTER      CL(  2,1) :
43.

CL(I,2)      IS REAR COUPLER LENGTH IN INCHES
ENTER      CL(  2,2) :
43.

DELMX(I)      MAX. BOLSTER CENTER DISPL. IN INCHES
ENTER      DELMX(  2) :
1.25

JAC(I)     ALIGNMENT CONTROL CODE
 0       FOR      NO ALIGNMENT CONTROL
 1       FOR      M-380,381 LOCOMOTIVE DRAFT GEAR
 3       FOR      F-BUTT TYPE COUPLER
ENTER      JAC(  2) :
0
```

```
DEL(I,1)      INITIAL FRONT B.C. DISPL. IN INCHES
ENTER      DEL(  2,1) :
0.0

DEL(I,2)      INITIAL REAR B.C. DISPL. IN INCHES
ENTER      DEL(  2,2) :
0.0

HCOG(I)      VEH. C.G. HEIGHT FROM RAIL IN INCHES
ENTER       HCOG(  2) :
0.0

ALPHA(I,1) & ALPHA(I,2)      FOR VEHICLE DESCPT.
ENTER      ALPHA(  3,1) & ALPHA(  3,2) :
HOPPER-100

A(I)      IS BOLSTER CENTER DIST. IN INCHES
ENTER      A(  3) :
380.

B(I,1)      IS DIST. BETWEEN B.C. & C. P., FRONT
ENTER      B(  3) :
32.

B(I,2)      IS DIST. BETWEEN B.C. & C. P., REAR
ENTER      B(  3,2) :
32.

CL(I,1)      IS FRONT COUPLER LENGTH IN INCHES
ENTER      CL(  3,1) :
43.

CL(I,2)      IS REAR COUPLER LENGTH IN INCHES
ENTER      CL(  3,2) :
43.

DELMX(I)      MAX. BOLSTER CENTER DISPL. IN INCHES
ENTER      DELMX(  3) :
1.25

JAC(I)      ALIGNMENT CONTROL CODE
 0      FOR      NO ALIGNMENT CONTROL
 1      FOR      M-380,381 LOCOMOTIVE DRAFT GEAR
 3      FOR      F-BUTT TYPE COUPLER
ENTER      JAC(  3) :
0

DEL(I,1)      INITIAL FRONT B.C. DISPL. IN INCHES
ENTER      DEL(  3,1) :
0.0

DEL(I,2)      INITIAL REAR B.C. DISPL. IN INCHES
ENTER      DEL(  3,2) :
0.0

HCOG(I)      VEH. C.G. HEIGHT FROM RAIL IN INCHES
ENTER       HCOG(  3) :
50.
```

```
ALPHA(I,1) & ALPHA(I,2)      FOR VEHICLE DESCPT.
ENTER      ALPHA(  4,1) & ALPHA(  4,2) :
LB5

A(I)       IS BOLSTER CENTER DIST. IN INCHES
ENTER      A(  4) :
528.

B(I,1)      IS DIST. BETWEEN B.C. & C. P., FRONT
ENTER      B(  4) :
51.

B(I,2)      IS DIST. BETWEEN B.C. & C. P., REAR
ENTER      B(  4,2) :
51.

CL(I,1)      IS FRONT COUPLER LENGTH IN INCHES
ENTER      CL(  4,1) :
33.

CL(I,2)      IS REAR COUPLER LENGTH IN INCHES
ENTER      CL(  4,2) :
33.

DELMX(I)      MAX. BOLSTER CENTER DISPL. IN INCHES
ENTER      DELMX(  4) :
1.

JAC(I)      ALIGNMENT CONTROL CODE
 0       FOR      NO ALIGNMENT CONTROL
 1       FOR      M-380,381 LOCOMOTIVE DRAFT GEAR
 3       FOR      F-BUTT TYPE COUPLER
ENTER      JAC(  4) :
0

DEL(I,1)      INITIAL FRONT B.C. DISPL. IN INCHES
ENTER      DEL(  4,1) :
0.

DEL(I,2)      INITIAL REAR B.C. DISPL. IN INCHES
ENTER      DEL(  4,2) :
0.

HCOG(I)      VEH. C.G. HEIGHT FROM RAIL IN INCHES
ENTER      HCOG(  4) :
48.

ALPHA(I,1) & ALPHA(I,2)      FOR VEHICLE DESCPT.
ENTER      ALPHA(  5,1) & ALPHA(  5,2) :
HOPPER-100

A(I)       IS BOLSTER CENTER DIST. IN INCHES
ENTER      A(  5) :
486.75

B(I,1)      IS DIST. BETWEEN B.C. & C. P., FRONT
ENTER      B(  5) :
47.
```

```
B(I,2)       IS DIST. BETWEEN B.C. & C. P., REAR
ENTER       B(  5,2) :
47.

CL(I,1)       IS FRONT COUPLER LENGTH IN INCHES
ENTER       CL(  5,1) :
28.25

CL(I,2)       IS REAR COUPLER LENGTH IN INCHES
ENTER       CL(  5,2) :
28.25

DELMX(I)       MAX. BOLSTER CENTER DISPL. IN INCHES
ENTER       DELMX(  5) :
1.25

JAC(I)       ALIGNMENT CONTROL CODE
 0       FOR       NO ALIGNMENT CONTROL
 1       FOR       M-380,381 LOCOMOTIVE DRAFT GEAR
 3       FOR       F-BUTT TYPE COUPLER
ENTER       JAC(  5) :
0

DEL(I,1)       INITIAL FRONT B.C. DISPL. IN INCHES
ENTER       DEL(  5,1) :
0.0

DEL(I,2)       INITIAL REAR B.C. DISPL. IN INCHES
ENTER       DEL(  5,2) :
0.

HCOG(I)       VEH. C.G. HEIGHT FROM RAIL IN INCHES
ENTER        HCOG(  5) :
60.

ALPHA(I,1) & ALPHA(I,2)      FOR VEHICLE DESCPT.
ENTER       ALPHA(  6,1) & ALPHA(  6,2) :
HOPPER-100

A(I)      IS BOLSTER CENTER DIST. IN INCHES
ENTER       A(  6) :
486.75

B(I,1)       IS DIST. BETWEEN B.C. & C. P., FRONT
ENTER       B(  6) :
47.

B(I,2)       IS DIST. BETWEEN B.C. & C. P., REAR
ENTER       B(  6,2) :
47.

CL(I,1)       IS FRONT COUPLER LENGTH IN INCHES
ENTER       CL(  6,1) :
28.25

CL(I,2)       IS REAR COUPLER LENGTH IN INCHES
ENTER       CL(  6,2) :
28.25
```

```
DELMX(I)       MAX. BOLSTER CENTER DISPL. IN INCHES
ENTER       DELMX(  6) :
1.25

JAC(I)      ALIGNMENT CONTROL CODE
 0       FOR      NO ALIGNMENT CONTROL
 1       FOR      M-380,381 LOCOMOTIVE DRAFT GEAR
 3       FOR      F-BUTT TYPE COUPLER
ENTER       JAC(  6) :
0

DEL(I,1)       INITIAL FRONT B.C. DISPL. IN INCHES
ENTER       DEL(  6,1) :
0.

DEL(I,2)       INITIAL REAR B.C. DISPL. IN INCHES
ENTER       DEL(  6,2) :
0.

HCOG(I)       VEH. C.G. HEIGHT FROM RAIL IN INCHES
ENTER        HCOG(  6) :
40.

ALPHA(I,1) & ALPHA(I,2)      FOR VEHICLE DESCPT.
ENTER       ALPHA(  7,1) & ALPHA(  7,2) :
HOPPER-70

A(I)      IS BOLSTER CENTER DIST. IN INCHES
ENTER      A(  7) :
380.

B(I,1)      IS DIST. BETWEEN B.C. & C. P., FRONT
ENTER      B(  7) :
32.

B(I,2)      IS DIST. BETWEEN B.C. & C. P., REAR
ENTER      B(  7,2) :
32.

CL(I,1)      IS FRONT COUPLER LENGTH IN INCHES
ENTER      CL(  7,1) :
43.

CL(I,2)      IS REAR COUPLER LENGTH IN INCHES
ENTER      CL(  7,2) :
43.

DELMX(I)       MAX. BOLSTER CENTER DISPL. IN INCHES
ENTER      DELMX(  7) :
1.25

JAC(I)      ALIGNMENT CONTROL CODE
 0       FOR      NO ALIGNMENT CONTROL
 1       FOR      M-380,381 LOCOMOTIVE DRAFT GEAR
 3       FOR      F-BUTT TYPE COUPLER
ENTER      JAC(  7) :
0
```

```
DEL(I,1)      INITIAL FRONT B.C. DISPL. IN INCHES
ENTER       DEL(  7,1) :
0.0

DEL(I,2)      INITIAL REAR B.C. DISPL. IN INCHES
ENTER       DEL(  7,2) :
0.0

HCOG(I)      VEH. C.G. HEIGHT FROM RAIL IN INCHES
ENTER        HCOG(  7) :
51.

IVEH(I)      TYPE OF VEHICLE:
 1      FOR      FREIGHT CAR
 2      FOR      GP LOCOMOTIVES
 3      FOR      SD LOCOMOTIVES
 4      FOR      DD LOCOMOTIVES
ENTER       IVEH(  1) :
3

WGHT(I)      TOTAL VEHICLE WEIGHT IN LBS.
ENTER       WGHT(  1) :
410000.

WLL(I)      NET LATERAL FORCE ON LEADING OUTER WHEEL
ENTER       WLL(  1) :
7500.

IVEH(I)      TYPE OF VEHICLE:
 1      FOR      FREIGHT CAR
 2      FOR      GP LOCOMOTIVES
 3      FOR      SD LOCOMOTIVES
 4      FOR      DD LOCOMOTIVES
ENTER       IVEH(  2) :
1

WGHT(I)      TOTAL VEHICLE WEIGHT IN LBS.
ENTER       WGHT(  2) :
120000.

WLL(I)      NET LATERAL FORCE ON LEADING OUTER WHEEL
ENTER       WLL(  2) :
9500.

IVEH(I)      TYPE OF VEHICLE:
 1      FOR      FREIGHT CAR
 2      FOR      GP LOCOMOTIVES
 3      FOR      SD LOCOMOTIVES
 4      FOR      DD LOCOMOTIVES
ENTER       IVEH(  3) :
1

WGHT(I)      TOTAL VEHICLE WEIGHT IN LBS.
ENTER       WGHT(  3) :
172000.
```

```
WLL(I)      NET LATERAL FORCE ON LEADING OUTER WHEEL
ENTER       WLL(  3) :
9500.

IVEH(I)       TYPE OF VEHICLE:
 1      FOR      FREIGHT CAR
 2      FOR      GP LOCOMOTIVES
 3      FOR      SD LOCOMOTIVES
 4      FOR      DD LOCOMOTIVES
ENTER        IVEH(  4) :
1

WGHT(I)       TOTAL VEHICLE WEIGHT IN LBS.
ENTER       WGHT(  4) :
210000.

WLL(I)      NET LATERAL FORCE ON LEADING OUTER WHEEL
ENTER       WLL(  4) :
9500.

IVEH(I)       TYPE OF VEHICLE:
 1      FOR      FREIGHT CAR
 2      FOR      GP LOCOMOTIVES
 3      FOR      SD LOCOMOTIVES
 4      FOR      DD LOCOMOTIVES
ENTER        IVEH(  5) :
1

WGHT(I)       TOTAL VEHICLE WEIGHT IN LBS.
ENTER       WGHT(  5) :
176000.

WLL(I)      NET LATERAL FORCE ON LEADING OUTER WHEEL
ENTER       WLL(  5) :
9500.

IVEH(I)       TYPE OF VEHICLE:
 1      FOR      FREIGHT CAR
 2      FOR      GP LOCOMOTIVES
 3      FOR      SD LOCOMOTIVES
 4      FOR      DD LOCOMOTIVES
ENTER        IVEH(  6) :
1

WGHT(I)       TOTAL VEHICLE WEIGHT IN LBS.
ENTER       WGHT(  6) :
212000.

WLL(I)      NET LATERAL FORCE ON LEADING OUTER WHEEL
ENTER       WLL(  6) :
9500.

IVEH(I)       TYPE OF VEHICLE:
 1      FOR      FREIGHT CAR
 2      FOR      GP LOCOMOTIVES
 3      FOR      SD LOCOMOTIVES
 4      FOR      DD LOCOMOTIVES
ENTER        IVEH(  7) :
1
```

```
WGHT(I)      TOTAL VEHICLE WEIGHT IN LBS.
ENTER     WGHT(  7) :
183500.

WLL(I)      NET LATERAL FORCE ON LEADING OUTER WHEEL
ENTER     WLL(  7) :
9500.


INPUT DATA COMPLETED.....PROGRAM EXECUTING.....


STOP

END OF EXECUTION
CPU TIME: 7.94  ELAPSED TIME: 14:7.90
EXIT
```

```
@RUN (PROGRAM) CONVRT.EXE.1

STOP

END OF EXECUTION
CPU TIME: 1.55  ELAPSED TIME: 3.85
EXIT
```

```
@DIRECTORY (OF FILES) *.DAT

   BETA:<RCD-QLT>
 PLTVAR.DAT.3
 QLTPLT.DAT.1
 TRACK.DAT.4
 TRAIN.DAT.1
 TRKPLT.DAT.4

 Total of 5 files
```

```
 RUN (PROGRAM) QTRAIN.EXE.2

ENTER FIRST THE TRACK DATA FILE NAME YOU CREATED
            (MAX. # OF CHAR. IS 6)
TRACK


DO YOU WANT OUTPUT TO BE DISPLAYED ON KEYBOARD TERMINAL ?
IF     NO     OUTPUT ON LINE PRINTER
ANSWER     YES     OR     NO :
NO

TYPE THE TITLE FOR THIS RUN (20A4)

TEST-RUN FOR QLTS PROGRAM

DO YOU WANT TO INPUT DATA THRU FILE (YES=1,NO=0)

1

PLEASE TYPE THE INPUT FILE NAME

TRAIN

STOP

END OF EXECUTION
CPU TIME: 4.15  ELAPSED TIME: 59.39
EXIT
@
 DIRECTORY (OF FILES) *.DAT

  BETA:<RCD-QLT>
 PLTVAR.DAT.2
 TRACK.DAT.3
 TRAIN.DAT.1
 TRKPLT.DAT.3
 TRNPLT.DAT.3

 Total of 5 files
```

4.0 GRAPHIC OUTPUT

The plots of the results are obtained by executing the PLOTQL program, as shown in the next Section 4.1. It is seen that eight figures and 15 graphs are available for each vehicle, and an additional graph shows the track profile. Typical plots for Vehicle 1 are shown in Figures 3 through 10, and the track profile is shown in Figure 11.

4.1 Execution of the PLOTQL Program and Typical Output Results

```
@RUN (PROGRAM) PLOTQL.EXE.6

 ENTER TERMINAL SPEED IN CHAR/SEC.
?30



* WELCOME TO QLTS-PLOT PROGRAM
* THE  TRAIN CONSIST HAS   7  VEHICLES. THE FOLLOWING PLOTS ARE
  AVAILABLE FOR THESE VEHICLES:
  S.NO.              NAME                                          CODE
  1       ALIGNMENT CONTROL MOMENT (FRONT & REAR) V/S TIME  ..     AMT
  2       BOLSTER DISPLACEMENT (FRONT & REAR) V/S TIME  ......     BDT
  3       BOLSTER REACTION    (FRONT & REAR) V/S TIME  .......     BRT
  4       COUPLER ANGLE    (FRONT & REAR) V/S TIME  ..........     CAT
  5       COUPLER REACTION (FRONT & REAR) V/S TIME  ..........     CRT
  6       L/V RATIO FOR ROLLOVER    (FRONT & REAR) V/S TIME  .     LRT
  7       L/V RATIO FOR WHEEL CLIMB (FRONT & REAR) V/S TIME  .     LWT
  8       NET FORCE V/S TIME  ................................     NFT
  9       TRACK PROFILE  .....................................     TRK

* TO OBTAIN PLOTS, ENTER VEH. NO. & CONFIRM WITH <CR>. THEN,
  ENTER THE CODE OR THE SEQ. NO. OF THE PLOT & CONFIRM WITH <CR>.
  ENTER "ALL" TO DRAW ALL THE PLOTSFOR THE SELECTED VEH.
  A NEGATIVE VEH. NO. TERMINATES THE LIST.

?       ?ALL
 1
```

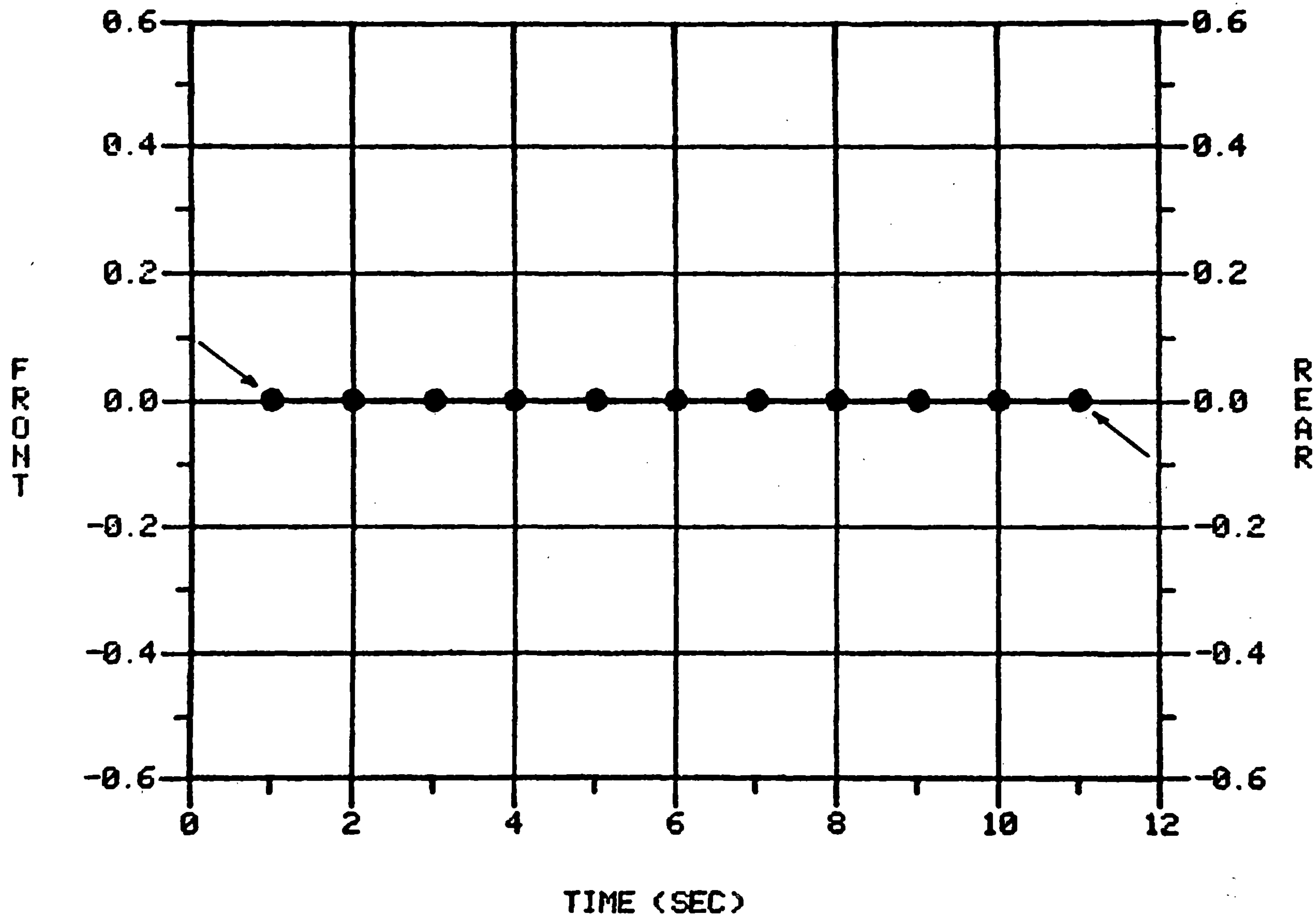

Figure 3. Alignment Control Moment vs. Time for the Sample Run.

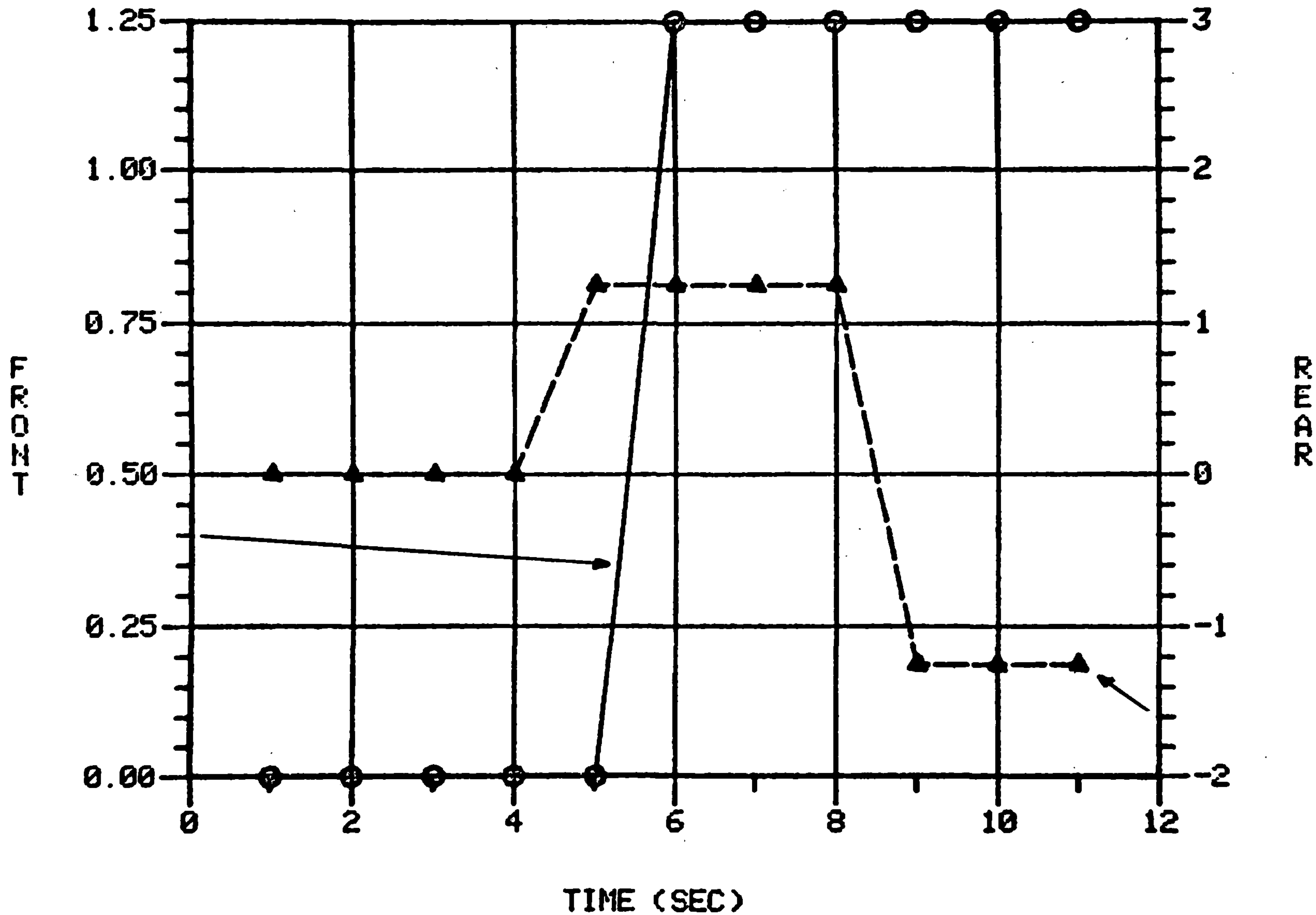

Figure 4. Bolster Displacement vs. Time for the Sample Run.

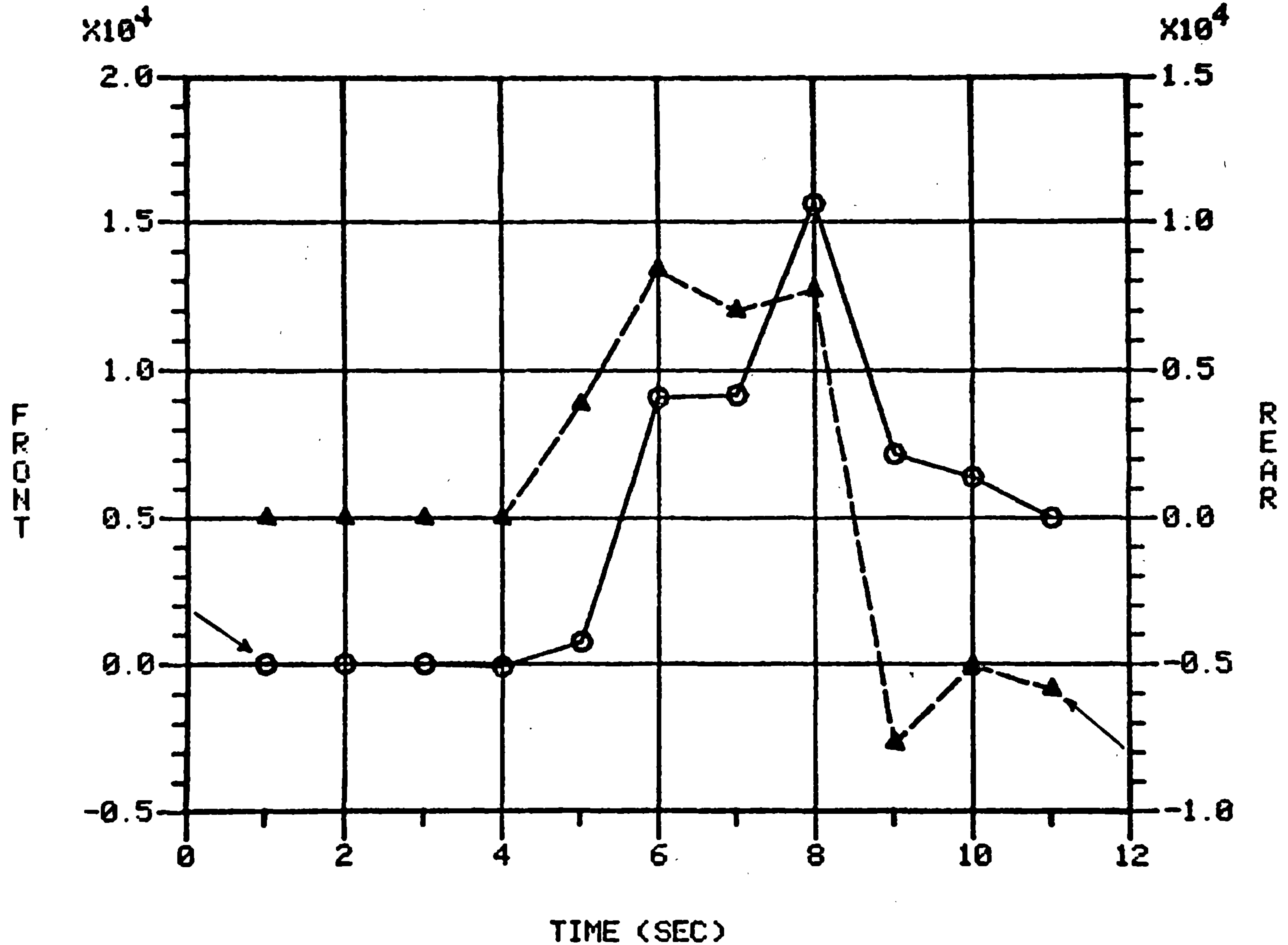

Figure 5. Bolster Reaction vs. Time for the Sample Run.

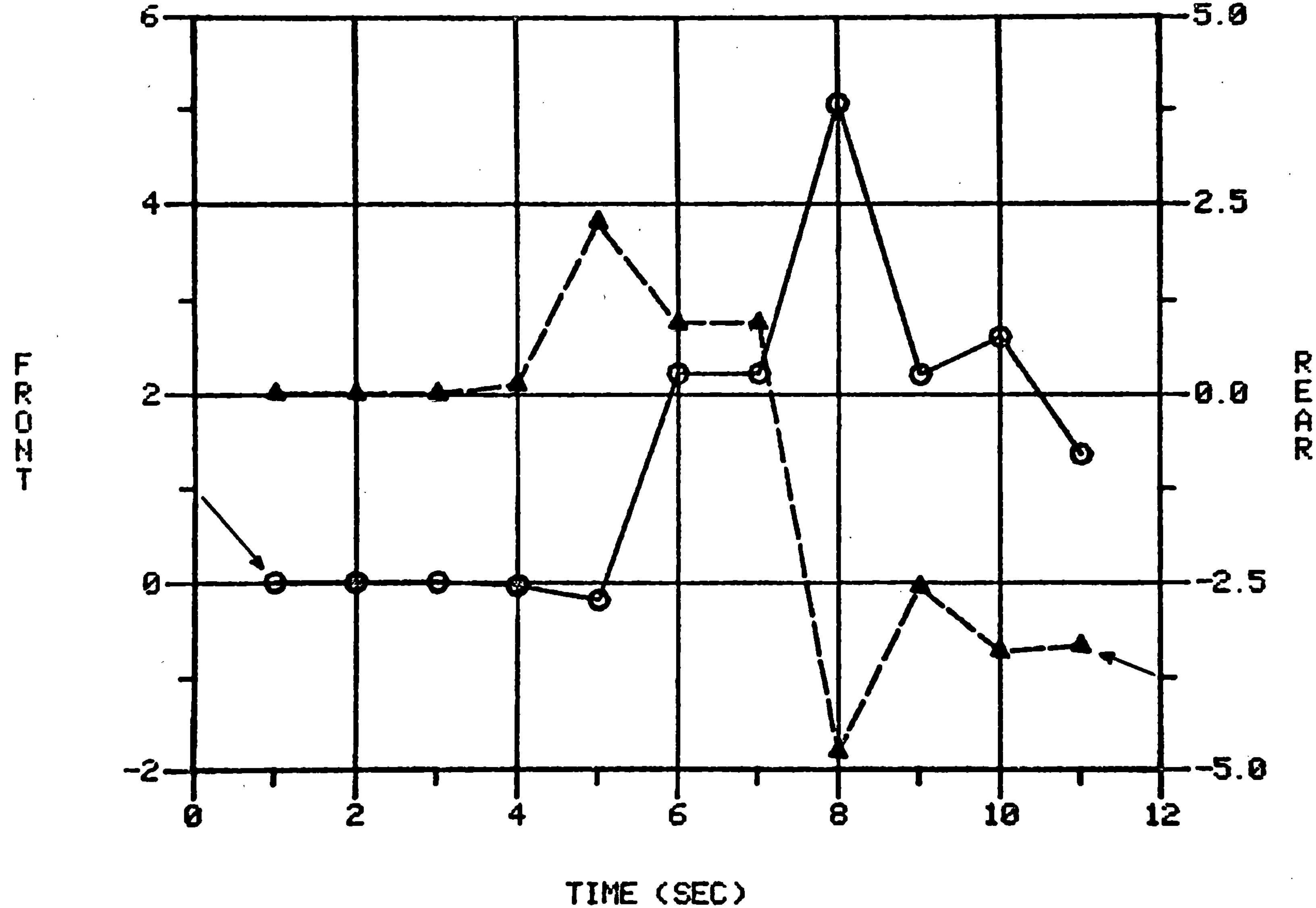

Figure 6. Coupler Angle vs. Time for the Sample Run.

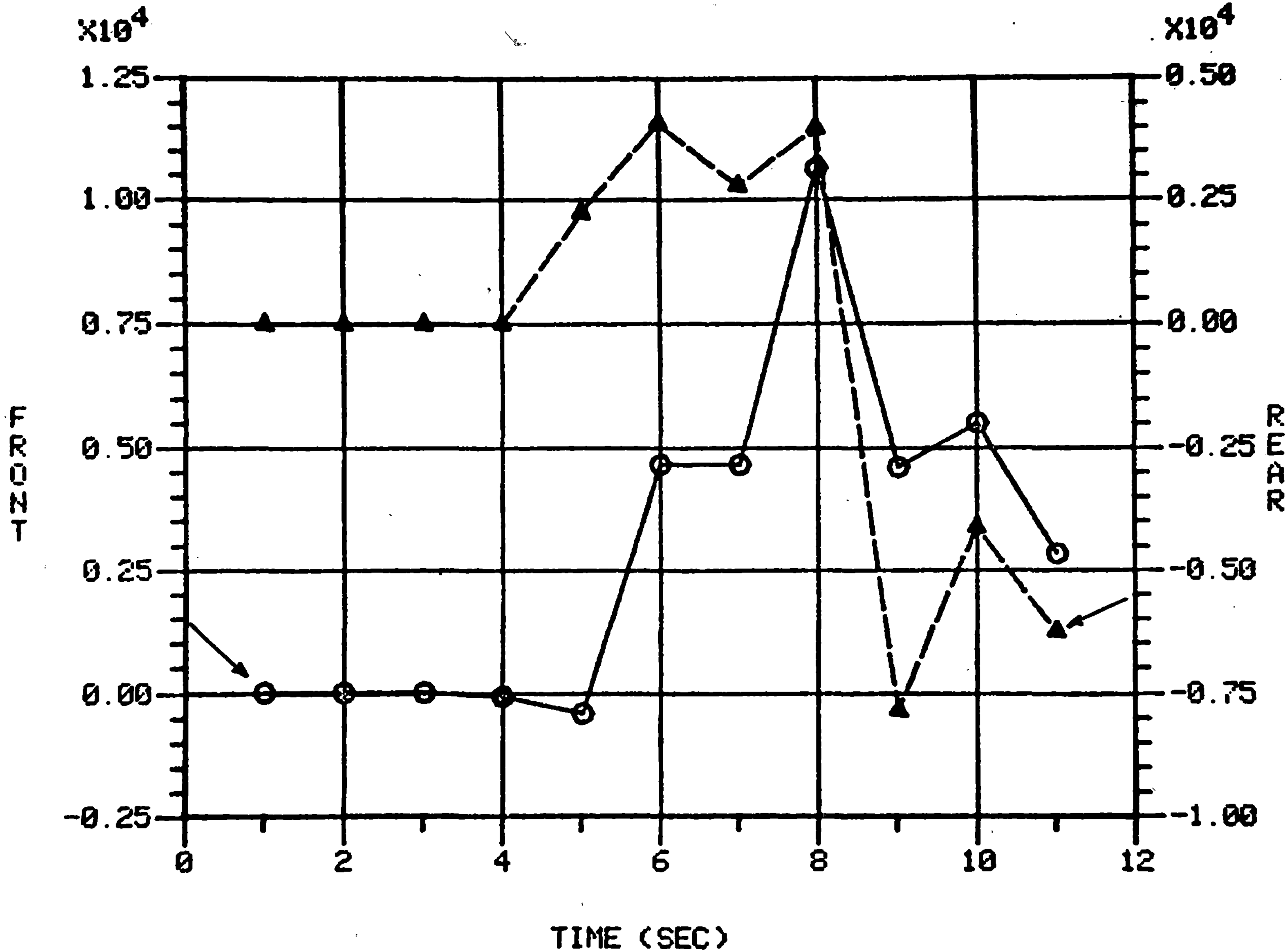

Figure 7. Coupler Reaction vs. Time for the Sample Run.

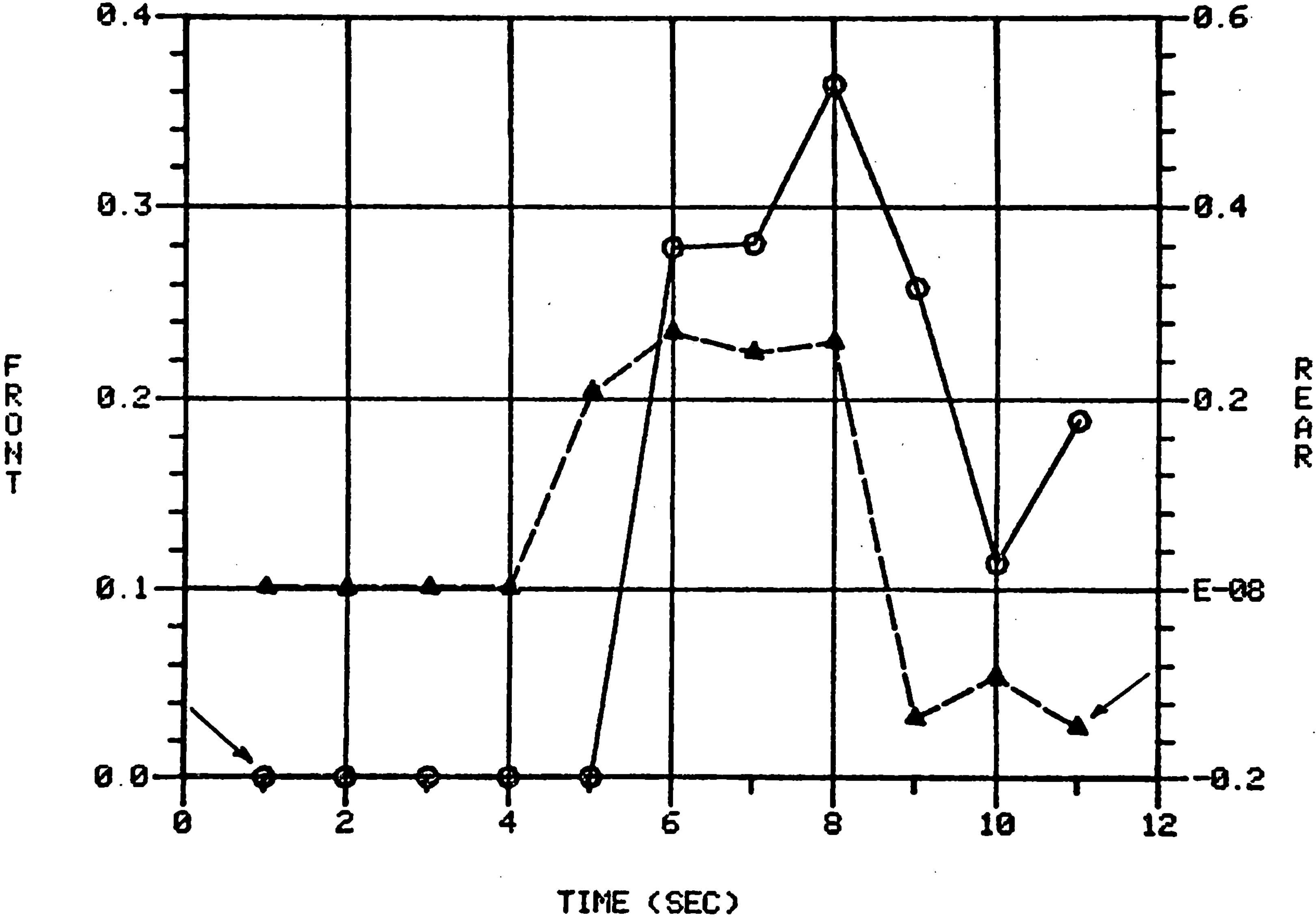

Figure 8. L/V Ratios for Rail Rollover vs. Time, for the Sample Run.

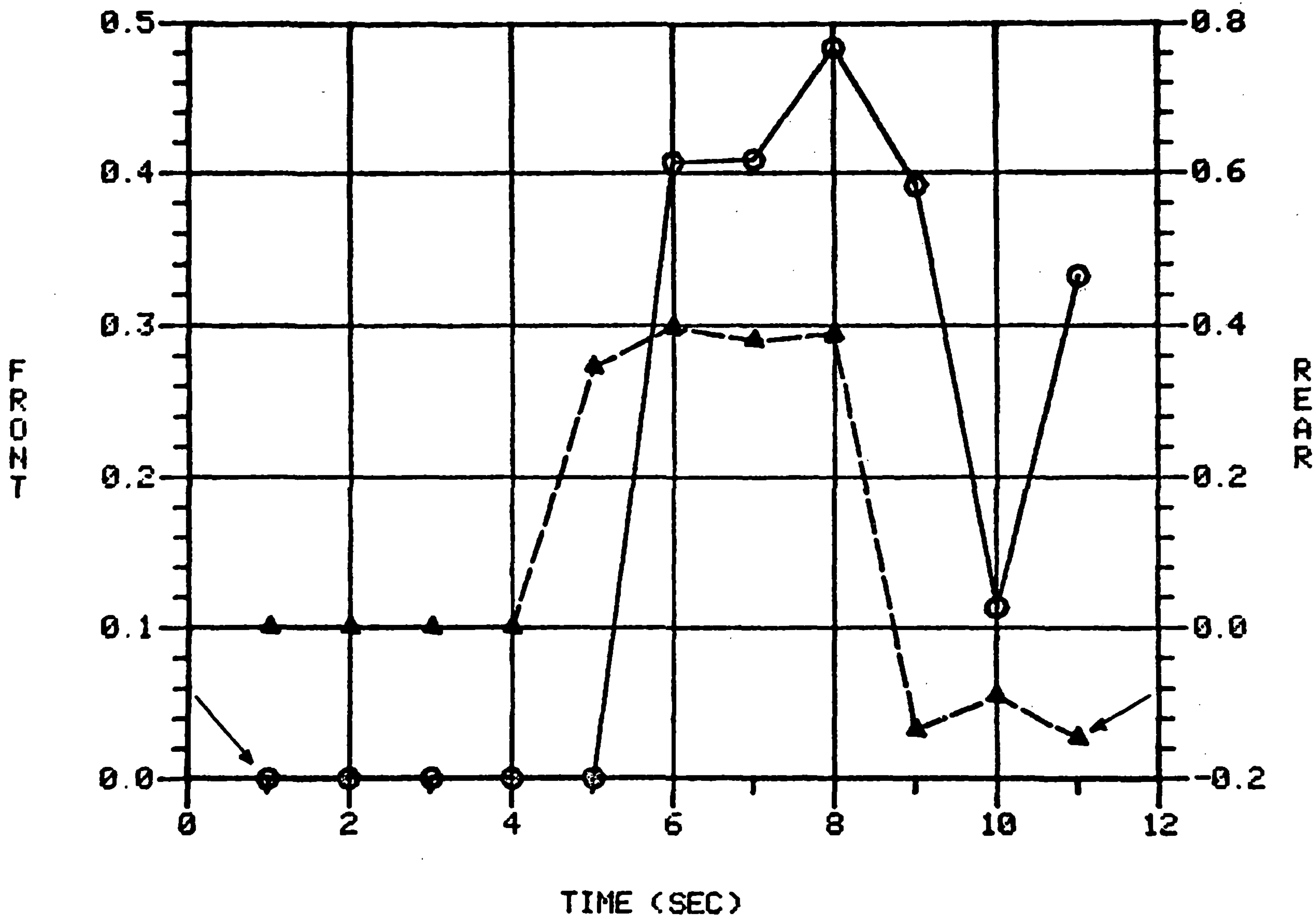

Figure 9. L/V Ratios for Wheel Climb vs. Time, for the Sample Run.

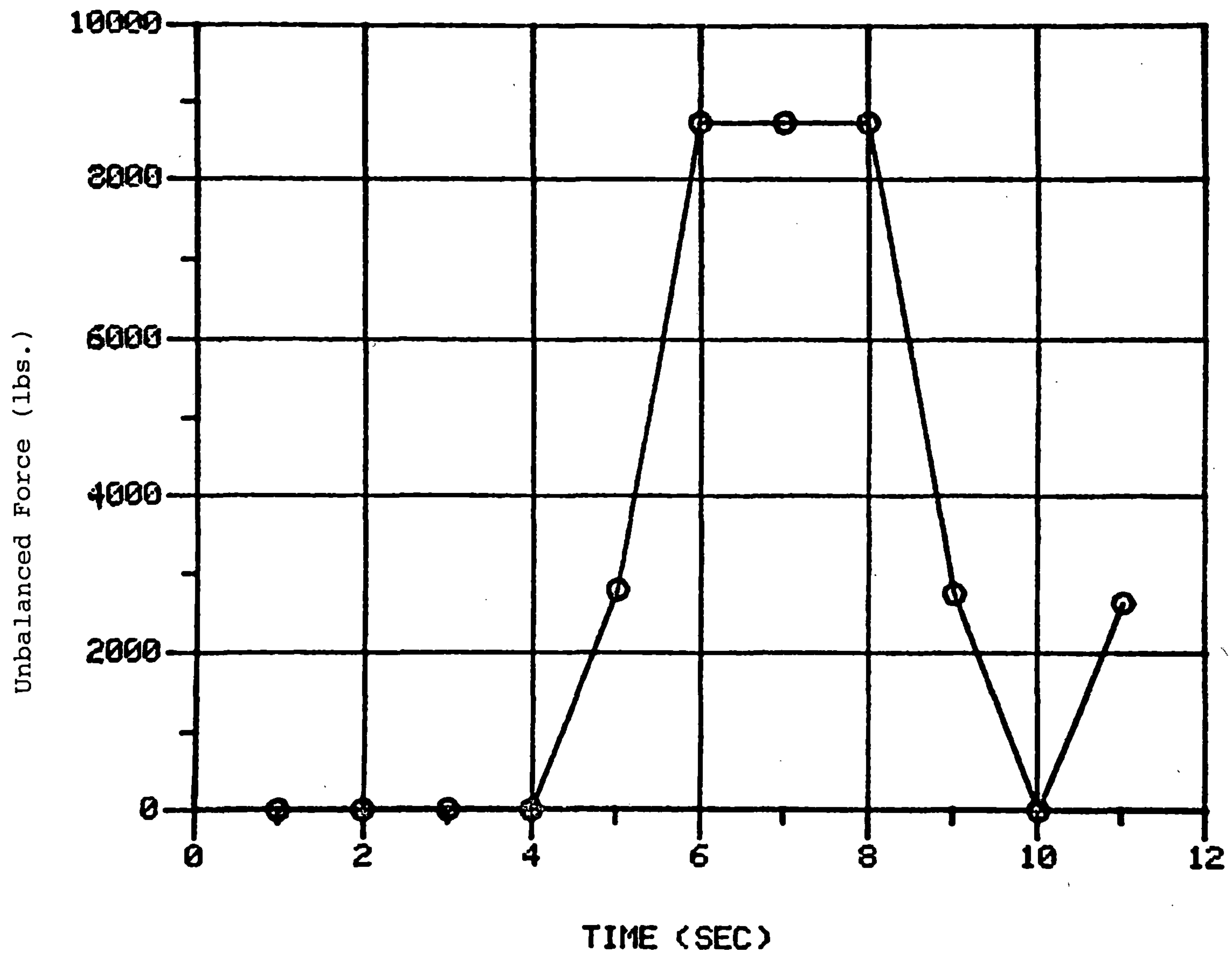

Figure 10. Unbalanced Force vs. Time for the Sample Run.

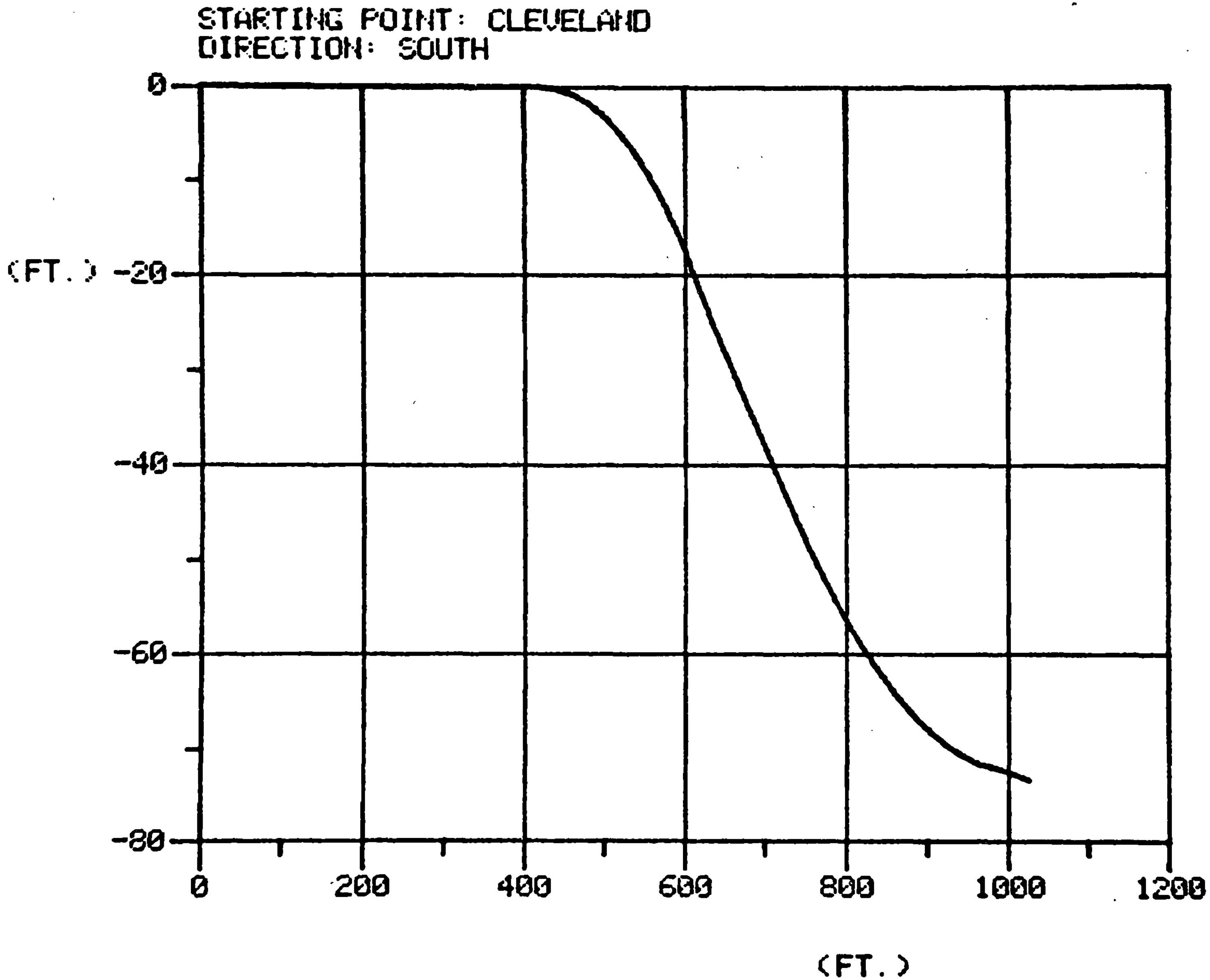

Figure 11. Track Profile *vs.* Distance for the Sample Run.

5.0 REFERENCES

1. Thomas, L.R., MacMillan, R.D., and Martin, G.C., "Technical Documentation, Quasi-Static Lateral Train Stability Model," Association of American Railroads, Report R-209, Chicago, Illinois, February, 1976.

2. Thomas, L.R., MacMillan, R.D., and Martin, G.C., "User's Manual, Quasi-Static Lateral Train Stability Model," Association of American Railroads, Report R-207, Chicago, Illinois, February, 1976.

3. Thomas, L.R., MacMillan, R.D., and Martin, G.C., "Programming Manual, Quasi-Static Lateral Train Stability Model," Association of American Railroads, Report R-208, Chicago, Illinois, February, 1976.

4. PLOT-10 Terminal Control System User's Manual, Tektronix, Inc., Document No. 062-1474-00.

5. PLOT-10 ADVANCED GRAPHING II User's Manual Tektronix, Inc., Document No. 062-1530-00.