R 492

TRACK TRAIN DYNAMICS MATHEMATICAL MODEL

TRACK TRAIN DYNAMICS
AAR

AN INTERNATIONAL GOVERNMENT - INDUSTRY RESEARCH PROGRAM ON TRACK - TRAIN DYNAMICS

Association of American Railroads

Research and Test Department

INTERACTIVE SIMULATION AND COMPUTER GRAPHICS FOR THE DETAILED LONGITUDINAL TRAIN ACTION MODEL

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13. ABSTRACT

The AAR's Detailed Longitudinal Train Action (DTAM) 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 procedure for using the interactive graphics with the DTAM program is documented in this report.

14. SUBJECT TERMS	**15. AVAILABILITY STATEMENT**
Advanced Graphing II (Tektronix) Detailed Longitudinal Train Action (DTAM) Model Interactive Graphics PLOT-10 (Tektronix)	J. G. Britton, Executive Director Association of American Railroads Technical Center 3140 South Federal Street Chicago, Illinois 60616

EXECUTIVE SUMMARY

This report concerns a portion of the study under AAR Contract TTD 79-171-3 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 Detailed Longitudinal Train Action (DTAM) 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, aid in its interpretation by visaul 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 to a free format for easy entry through a terminal.
3) Develop interactive programmming 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 DTAM program with the DEC 2050 computer and interactive graphics terminals though the use of PLOT-10 and Advanced Graphing II.
5) Complete the validation runs to assure the completeness of the programs 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 the programs have been submitted separately.

This report deals only with the examples 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 Detailed Longitudinal Train Action (DTAM) Model has been developed by the AAR [1, 2, 3]* for the study and simulation of longitudinal train dynamics. Special differentials between various vehicles in a train can give rise to excessive longitudinal compressive or tensile forces. These coupler forces can, in turn, cause failures of draft gears, jack-knifing of cars, or derailments due to wheel climb. The program can be used by the railroads as an operational tool for determining optimum train make-up and improvements in train handling practices to prevent excessive longitudinal train action.

The model considers only the longitudinal surge motion, and a vehicle having no sliding sill has one degree-of-freedom in the longitudinal direction. A vehicle with a sliding sill has two degrees-of-freedom. Several mathematical models are employed to obtain the longitudinal forces acting on a given vehicle. The forces between vehicles are obtained from models of end-of-car cushioning devices. The journal, rolling, air and non-curving flange resistances are modeled using the Davis equation. Other forces are caused by grade, curving resistance, tractive effort/dynamic brake, and pneumatic braking. The details of the mathematical model are given in the Technical Documentation [1].

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

Each vehicle's acceleration is obtained by summing the forces acting on it and then dividing by the vehicle's mass. The corresponding velocity and displacement of each vehicle is then obtained by a forward integration technique. There is a choice of using one of the following three integration methods: Fourth order Runge-Kutta; Hamming's Predictor-Corrector; and the Newmark Beta method. However, because of numerical instability problems, only the fourth order Runge-Kutta Method is currently working satisfactorily.

The objective of this study was to modify the existing DTAM program, in order to make it suitable for interactive simulation, and to introduce interactive computer graphics, in order to display the graphical plots on a suitable video terminal, e.g., Tektronix 4006 or 4010. The existing program has been modified so that the simulation data can be entered interactively through the terminal, and the simulation results can be stored in a format suitable for plotting. A program: PLOTDT, has been written for the interactive graphic display of the results. The Tektronix PLOT-10 and Advanced Graphing II (AG II) software packages were used to develop the DTAM computer graphics.

The maximum number of vehicles in the train consist is limited to 153. The maximum number of vehicles, for which details can be printed out and plots of coupler forces can be displayed, is limited to 21. These numbers can, however, be increased, if necessary, by changing the dimensions of the variables and the storage allocations in the program.

2.0 PROGRAM STRUCTURE

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

2.1 Standard Library

The purpose of this program is to prepare data concerning the vehicle characteristics, which includes the tractive effort and dynamic brake curves for the locomotives. These data can then be used by the (following) Run Library program to form a train consist. It should be noted that, unless each vehicle is identified in the Standard Library by a four letter identification code, unique to the vehicle, the Run Library program is not able to access the data concerning that vehicle. Input to the Standard Library comes from the SLDATA.DAT file, which prepares two files for its output. The SLLOG.DAT file is a printing file, and the INVEHL.DAT file is an internal file, which is not in a format for printing, but can be accessed by the Run Library. This is shown in Figure 1.

2.2 Run Library

The purpose of this program is to prepare data for the following Forward Integration Simulator program. The prepared data includes milepost, station, speed limits, track data, profile (elevation), initial train brake settings and train consist characteristics. The characteristics of a vehicle in

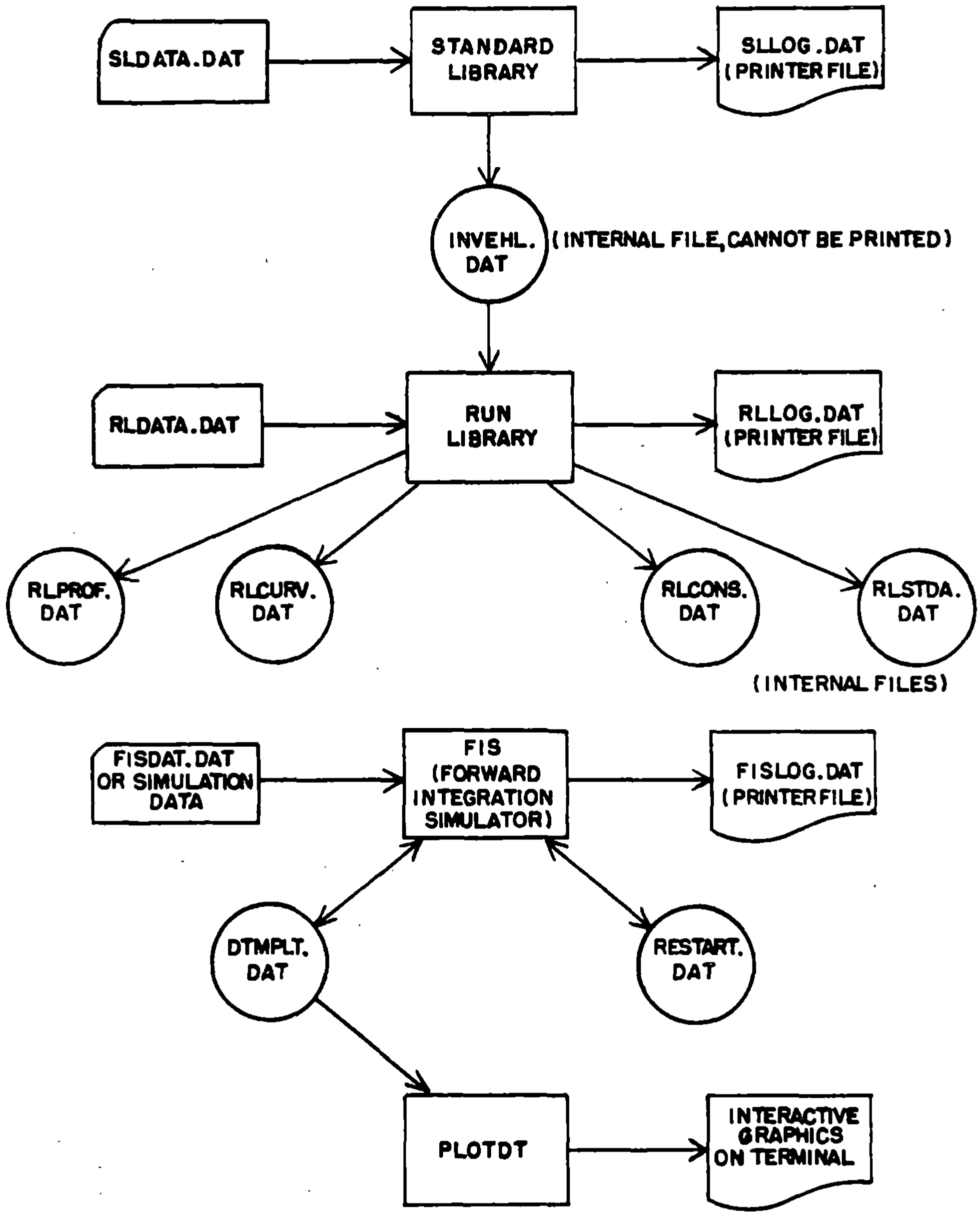

Figure 1. Flow Diagram for the Four DTAM Programs.

in the train consist that has been identified in the Standard Library is accessed through the INVEHL.DAT file and may be overridden by the Run Library. The characteristics of any vehicle not identified in the Standard Library must be supplied by the Run Library.

The input to the Run Library comes from two sources: the RLDATA.DAT and INVEHL.DAT files. The INVEHL.DAT file is not required if the characteristic data for each vehicle in the train consist is supplied by the RLDATA.DAT file.

The output of the Run Library program consists of RLLOG.DAT, which is a printing file, and four internal files. The four internal files, which supply data to the following Forward Integration Simulator program, are not in a format suitable for printing. They are called RLPROF.DAT, RLCURV.DAT, RLCONS.DAT and RSSTDA.DAT, respectively, and are shown in Figure 1.

2.3 Forward Integration Simulator

The purpose of this program is to model the behavior of the train as a function of time, and obtain a solution to the equations of motion by employing one of the available integration techniques.

The input to this program comes from two sources. The primary source can be supplied by the file FISDAT.DAT or interactively through the terminal. The primary input consists mainly of train operation and integration control instructions. The secondary source of input consists of the four internal files prepared by the Run Library program, e.g., RLPROF.DAT, RLCURV.DAT, RLCONS.DAT and RLSTDA.DAT.

The output of the Forward Integration Simulator program consists of FISLOG.DAT, which is a printing file,and two internal files. One of these internal files, RESTART.DAT, if selected by the input data values, is used to store data necessary to perform a restart. The other internal file, DTMPLT.DAT, contains the simulation results in a format suitable for later plotting.

2.4 PLOTDT Program

The purpose of this program is to display the simulation results. It accepts input from the internal file DTMPLT.DAT and interactively displays the plots on Tektronix Type 4006 and 4010 terminals. The program's graphic output is discussed in Section 4.0 of this report.

3.0 INPUT DATA

Input data to the forward integration simulator (FIS) is supplied from the following two sources:

a) Data from file RLLOG.DAT, which is the output from the Run Library program. It includes speed limits, station names and equations, curves, profiles (elevations), consists, vehicle characteristics, and initial brake settings.

b) Primary input data, which can be supplied interactively through the terminal, or from a file named FISDAT. The fixed format method of supplying these data is described in the DTAM User's Manual [2]. Hence, only the free format interactive method of supplying the data is discussed in this report.

The interactive method of supplying data and for obtaining computer plots of the results are illustrated for a sample problem taken from the DTAM Technical Documentation [1]. This example is Special Event 6 in the Steel Coil Train Tests. The test train was made up of four SD-45T-2 locomotives, 52 cars with approximately equal loads of coiled steel, and 4 other cars. The details of the train consist are listed in Table 1.

Event 6 from Southern Pacific's Steel Coil Train Tests occurred on the main line between Mile Posts 801 and 802 near Stoval. The grade varied from 0.1 to 0.4% and there was no curvature, as shown in Figure 2. The train was traveling at a steady speed of 41 miles per hour, until it passed Mile Post 801 plus 62/100, at which time the brakes became applied in

Table 1. Southern Pacific Steel Coil Test Train Consist

Four Type SD-45T-2 Locomotives, 3600 hp and 205 tons, each.

Car	Car Number	Gross Weight Tons	Notes
1	SP 595596	122	Instrumented Car
2	SP 595538	128	
3	SP 595559	127	
4	SP 595548	125	
5	SP 595526	122	
6	SP 595570	124	
7	SP 595503	124	
8	SP 595531	120	
9	SP 595593	130	
10	SP 595612	130	
11	SP 595573	124	Instrumented Car
12	SP 595563	123	
13	SP 595614	124	
14	SP 595529	123	
15	SP 595622	124	
16	SP 595615	130	
17	SP 595555	130	
18	SP 595519	125	
19	SP 595564	120	
20	SP 595510	127	
21	SP 595568	125	Instrumented Car
22	SP 595539	128	
23	SP 595572	126	
24	SP 595536	127	
25	SP 595556	125	
26	SP 595578	128	
27	SP 595511	120	
28	SP 595611	130	
29	SP 595605	129	
30	SP 595620	124	
31	SP 595610	123	Instrumented Car
32	SP 595619	124	
33	SP 595621	125	
34	SP 595582	129	
35	SP 595581	130	
36	SP 595522	124	
37	SP 595565	124	
38	SP 595590	124	
39	SP 595518	124	
40	SP 595534	124	

Table 1. Southern Pacific Steel Coil Test Train Consist

Four Type SD-45T-2 Locomotives, 3600 hp and 205 tons, each.

(Continued)

Car	Car Number	Gross Weight Tons	Notes
41	SP 595551	120	Instrumented Car
42	SP 595547	122	
43	SP 595617	127	
44	SP 595618	125	
45	SP 595583	128	
46	SP 595586	124	
47	SP 595537	128	
48	SP 595549	128	
49	SP 595523	127	
50	SP 595577	126	
51	SP 595516	127	Instrumented Car
52	SP 595512	127	
53	AAR 100	64	Research Car
54	SP 138	66	Sleeping Car for Crew
55	SP 137	69	Kitchen and Support
56	SP 1741	26	Caboose

Gross Weight of the Loaded Revenue Cars (Cars 1 thru 52):	6,524 Tons
Gross Weight of the Locomotives (@205 tons):	820 Tons
Gross Weight of the Entire Train:	7,569 Tons
Length of the Entire Train:	2,959 Feet

The entire train had Type ABD brakes, with the exception of the AAR-100 which had Type AB brakes.

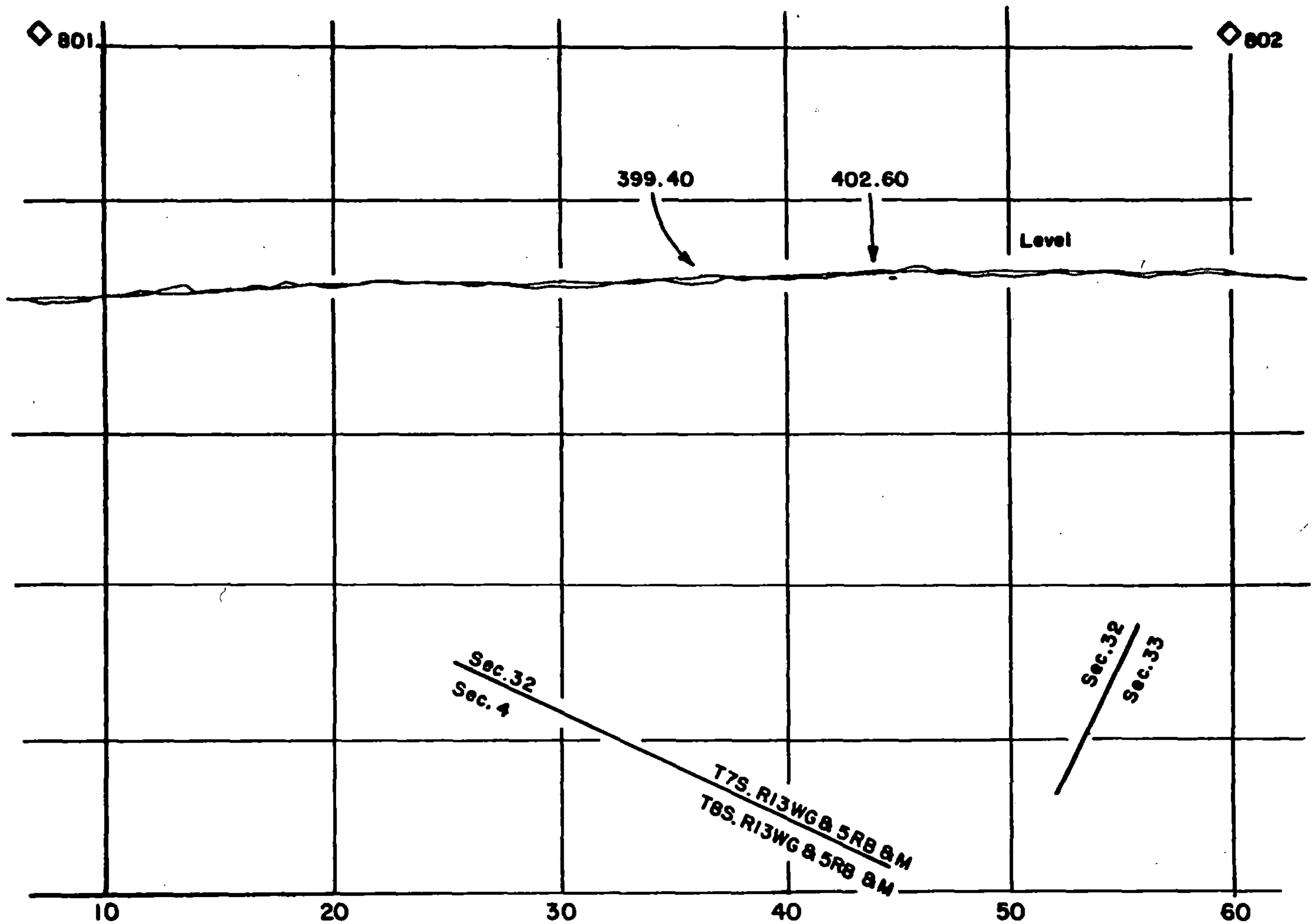

Figure 2. Main Line Track Profile Associated With Event #6 in the Southern Pacific's Steel Coil Train Tests.

emergency. Although the locomotive brakes were released almost immediately, the engineman operated the independent brake until the train came to a stop. Event 6 lasted 43 seconds and the train traveled a distance of 1548 feet before coming to a stop.

In the following Section, a listing is given of the interactive method of running the forward integration simulator (FIS) program for this sample problem. A listing is also given for running the FIS program, in which the simulation data is supplied through the file, FISDAT. The method, although illustrating the sample problem,can be used as a guide to supply data and run the program interactively, to simulate any particular problem.

```
@RUN (PROGRAM) FIS034.EXE.103

WELCOME TO DTAM-FIS INTERACTIVE PROGRAM

DO YOU WANT TO ENTER INPUT FROM TTY ?
(ANSWER YES' OR NO. IF NO, INPUT WILL BE TAKEN FROM FILE)
?
YES



ENTER LOCATION OF THE FIRST VEHICLE: (ILOW)
     (USUAL ILOW = 1)
?
1

ENTER LOCATION OF THE LAST VEHICLE: (IHIGH)
     (IHIGH =< 151)
?
60

ENTER # VEH. FOR WHICH DETAILS ARE TO BE PRINTED (NCOP)
     ( 0 =< NCOP =< 21 )
?
7

INTEGRATION METHOD (ITER = 1,2 OR 3)
     1: HAMMING PREDICTOR CORRECTOR
     2: RUNGA-KUTTA FOURTH ORDER
     3: BETA
    (AT PRESENT ONLY "2" WORKS)
?
2
```

```
SAND ON THE RAIL ? (ISAND)(0=NO, 1=YES)
?
0

WET RAIL ? (IWETR)  ( 0=NO, 1=YES )
?
0

# AUTOMATIC BRAKE OPERATIONS: (NBRAKT)
    ( 0 =< NBRAKT =< 50 )
?
2

# INDEPENDENT BRAKE OPERATIONS: (NBRAKI)
    ( 0 =< NBRAKI =< 50 )
?
35

# THROTTLE-DYNAMIC BRAKE CHANGES: (NTHTLC)
    ( 0 =< NTHTLC =< 50)
?
1

ORIGINAL THROTTLE POSITION: (ITHTLE)
    (-8 =< ITHTLE =< -1 : DYNAMIC BRAKE)
    (                0 : IDLE )
    ( 1 =< ITHTLE =< 8  : THROTTLE )
?
5

READ FORCE HISTORY AT THE END OF THE CONSIST ? (IEND)
    ( 0=NO, 1=YES )
?
0

ENTER TIME INCREMENT (SEC) FOR FORWARD INTEGRATION: (DT)
    (TYPICAL DT = 0.2)
?
.02

ENTER PRINTING TIME INTERVAL(SEC) FOR SIMULATION HISTORY': (WS)
?
.5

ENTER TIME (SEC.) AT WHICH FORWARD INTEGRATION STOPS:' (TTS)
?
45.0

 ENTER RST:      RST      RESTART      CHECKPOINT
                 <0         NO          YES
                 =0         NO          NO
                 >0         YES         YES
IF RST <> 0, ABS(RST) IS THE TIME INTERVAL BETWEEN WRITING CHECKPOINT
INFORMATION
?
0.0
```

```
ENTER 80% OF TOTAL TRAVEL OF SLIDING SILL BEFORE IT RUNSHARD (FT.): (SILL80)
?
0.0

ENTER TIME INTERVAL (SEC.) USED BY RUNGE-KUTTA INTEGRATION WHEN SILL IS
BETWEEN 80% & 90% OF ITS TOTAL TRAVEL: (DT80)
   (DT80 < DT)
?
0.0

ENTER 90% OF TOTAL TRAVEL OF SLIDING SILL BEFORE IT RUNSHARD (FT.): (SILL90
?
0.0

ENTER TIME INTERVAL (SEC.) USED BY RUNGE-KUTTA INTEGRATION WHEN SILL IS
BETWEEN 90% & 95% OF ITS TOTAL TRAVEL: (DT90)
   (DT90 < DT80)
?
0.0

ENTER 95% OF TOTAL TRAVEL OF SLIDING SILL BEFORE IT RUNSHARD (FT.): (SILL95)
?

0.0

ENTER TIME INTERVAL (SEC.) USED BY RUNGE-KUTTA INTEGRATION WHEN SILL IS
BETWEEN 95% & 100% OF ITS TOTAL TRAVEL: (DT95)
   (DT95 < DT90)
?
0.0

ENTER INITIAL SPEED OF TRAIN IN FT./SEC.: (VEL)
?
60.8

ENTER DISTANCE FROM START OF TRACK TO REAR OF LAST ' VEHICLE AT
STARTING TIME (FT.): (XSTART)
?
5510.

TIME INTERVAL BETWEEN CALLS TO BRAKING ROUTINES (SEC.): '(TBRAKE)
   (TYPICAL VALUE .2)
?
.2

ENTER TIME INTERVAL BETWEEN CALLS TO GRADE & CURVE RTNS.' (SEC.): (TGRADI)
(TGRADI > TTS, IF GRADE & CURVE DO NOT ' CHANGE OVER TRACK SEGMENT
 OF SIMULATION; ELSE 'SUGGESTED TGRADI = .2)
?
.2

ENTER PARAMETER IN THE BETA METHOD OF INTEGRATION: (BE)
    (IF OTHER METHOD IS USED, ENTER 0.)
?
.6667
```

```
YOU HAVE REQUESTED      7  DISPLAY VEHICLES.
ENTER 'POSITIONS OF THESE VEHICLES IN THE TRAIN CONSIST

ENTER POSITION OF DISPLAY VEHICLE #  1
?
1

ENTER POSITION OF DISPLAY VEHICLE #  2
?
5

ENTER POSITION OF DISPLAY VEHICLE #  3
?
15

ENTER POSITION OF DISPLAY VEHICLE #  4
?
25

ENTER POSITION OF DISPLAY VEHICLE #  5
?
35

ENTER POSITION OF DISPLAY VEHICLE #  6
?
45

ENTER POSITION OF DISPLAY VEHICLE #  7
?
55

ENTER    2  SETS OF VALUES DENOTING SCHEDULES OF TRAIN 'HANDLING
   FOR AUTOMATIC BRAKE:

ENTER SET #   1

ENTER IBROPT: -1=RELEASE;0=BAIL-OFF;1=APPLICATION
?
1

ENTER BRAKE CYLINDER PRESSURE ON LEAD LOCO. FOLLOWING
INITIATION (PSI): BCPT
?
86.0

ENTER TIME OF INITIATION (SEC.): BTIMET (DEFAULT VALUE =' 999999.9)
?
1.0

ENTER DISTANCE OF INITIATION (FT): BDISTT (DEFAULT VALUE' = 999999.9)
?
0.0

ENTER SPEED OF INITIATION (FT./SEC.): BVELT (DEFAULT 'VALUES:
          INITIAL SPEED        BVELT
               >0              -.000000001
              =<0              999999.9
?
0
```

```
ENTER SET #    2

ENTER IBROPI: -1=RELEASE;0=BAIL-OFF;1=APPLICATION
?
1

ENTER BRAKE CYLINDER PRESSURE ON LEAD LOCO. FOLLOWING
INITIATION (PSI): BCPI
?
5.36

ENTER TIME OF INITIATION (SEC.): BTIMEI (DEFAULT VALUE =' 999999.9)
?
3.0

ENTER DISTANCE OF INITIATION (FT): BDISTI (DEFAULT VALUE' = 999999.9)
?
0.0

ENTER SPEED OF INITIATION (FT./SEC.): BVELI (DEFAULT 'VALUES:
          INITIAL SPEED          BVELT
               >0                -.000000001
              =<0                999999.9
?
0

ENTER SET #    3

ENTER IBROPI: -1=RELEASE;0=BAIL-OFF;1=APPLICATION
?
1

ENTER BRAKE CYLINDER PRESSURE ON LEAD LOCO. FOLLOWING
INITIATION (PSI): BCPI
?
12.33

ENTER TIME OF INITIATION (SEC.): BTIMEI (DEFAULT VALUE =' 999999.9)
?
4.0

ENTER DISTANCE OF INITIATION (FT): BDISTI (DEFAULT VALUE' = 999999.9)
?
0.0

ENTER SPEED OF INITIATION (FT./SEC.): BVELI (DEFAULT 'VALUES:
          INITIAL SPEED          BVELT
               >0                -.000000001
              =<0                999999.9
?
0
```

ENTER SET # 4

ENTER IBROPI: -1=RELEASE;0=BAIL-OFF;1=APPLICATION
?
1

ENTER BRAKE CYLINDER PRESSURE ON LEAD LOCO. FOLLOWING
INITIATION (PSI): BCPI
?
24.34

ENTER TIME OF INITIATION (SEC.): BTIMEI (DEFAULT VALUE =' 999999.9)
?
5.0

ENTER DISTANCE OF INITIATION (FT): BDISTI (DEFAULT VALUE' = 999999.9)
?
0.0

ENTER SPEED OF INITIATION (FT./SEC.): BVELI (DEFAULT 'VALUES:

INITIAL SPEED	BVELT
>0	-.000000001
=<0	999999.9

?
0

ENTER SET # 5

ENTER IBROPI: -1=RELEASE;0=BAIL-OFF;1=APPLICATION
?
1

ENTER BRAKE CYLINDER PRESSURE ON LEAD LOCO. FOLLOWING
INITIATION (PSI): BCPI
?
35.66

ENTER TIME OF INITIATION (SEC.): BTIMEI (DEFAULT VALUE =' 999999.9)
?
6.0

ENTER DISTANCE OF INITIATION (FT): BDISTI (DEFAULT VALUE' = 999999.9)
?
0.0

ENTER SPEED OF INITIATION (FT./SEC.): BVELI (DEFAULT 'VALUES:

INITIAL SPEED	BVELT
>0	-.000000001
=<0	999999.9

?
0

```
ENTER SET #   6

ENTER IBROPI:  -1=RELEASE;0=BAIL-OFF;1=APPLICATION
?
1

ENTER BRAKE CYLINDER PRESSURE ON LEAD LOCO. FOLLOWING
INITIATION (PSI): BCPI
?
43.89

ENTER TIME OF INITIATION (SEC.): BTIMEI (DEFAULT VALUE =' 999999.9)
?
7.0

ENTER DISTANCE OF INITIATION (FT): BDISTI (DEFAULT VALUE' = 999999.9)
?
0.0

ENTER SPEED OF INITIATION (FT./SEC.): BVELI (DEFAULT 'VALUES:
                INITIAL SPEED           BVELT
                     >0                 -.000000001
                    =<0                 999999.9
?
00

ENTER SET #    7

ENTER IBROPI: -1=RELEASE;0=BAIL-OFF;1=APPLICATION
?
1

ENTER BRAKE CYLINDER PRESSURE ON LEAD LOCO. FOLLOWING
INITIATION (PSI): BCPI
?
36.25

ENTER TIME OF INITIATION (SEC.): BTIMEI (DEFAULT VALUE =' 999999.9)
?
8.0

ENTER DISTANCE OF INITIATION (FT): BDISTI (DEFAULT VALUE' = 999999.9)
?
0.0

ENTER SPEED OF INITIATION (FT./SEC.): BVELI (DEFAULT 'VALUES:
                INITIAL SPEED           BVELT
                     >0                 -.000000001
                    =<0                 999999.9
?
0
```

```
ENTER SET #    8

ENTER IBROPI: -1=RELEASE;0=BAIL-OFF;1=APPLICATION
?
1

ENTER BRAKE CYLINDER PRESSURE ON LEAD LOCO. FOLLOWING
INITIATION (PSI): BCPI
?
27.53

ENTER TIME OF INITIATION (SEC.): BTIMEI (DEFAULT VALUE =' 999999.9)
?
9.0

ENTER DISTANCE OF INITIATION (FT): BDISTI (DEFAULT VALUE' = 999999.9)
?
0.0

ENTER SPEED OF INITIATION (FT./SEC.): BVELI (DEFAULT 'VALUES:
          INITIAL SPEED          BVELT
               >0                -.000000001
              =<0                999999.9
?
0

ENTER SET #    9

ENTER IBROPI: -1=RELEASE;0=BAIL-OFF;1=APPLICATION
?
1

ENTER BRAKE CYLINDER PRESSURE ON LEAD LOCO. FOLLOWING
INITIATION (PSI): BCPI
?
31.7

ENTER TIME OF INITIATION (SEC.): BTIMEI (DEFAULT VALUE =' 999999.9)
?
10.0

ENTER DISTANCE OF INITIATION (FT): BDISTI (DEFAULT VALUE' = 999999.9)
?
0.0

ENTER SPEED OF INITIATION (FT./SEC.): BVELI (DEFAULT 'VALUES:
          INITIAL SPEED          BVELT
               >0                -.000000001
              =<0                999999.9
?
0
```

```
ENTER SET #  10

ENTER IBROPI: -1=RELEASE;0=BAIL-OFF;1=APPLICATION
?
1

ENTER BRAKE CYLINDER PRESSURE ON LEAD LOCO. FOLLOWING
INITIATION (PSI): BCPI
?
34.41

ENTER TIME OF INITIATION (SEC.): BTIMEI (DEFAULT VALUE =' 999999.9)
?
11.0

ENTER DISTANCE OF INITIATION (FT): BDISTI (DEFAULT VALUE' = 999999.9)
?
0.0

ENTER SPEED OF INITIATION (FT./SEC.): BVELI (DEFAULT 'VALUES:
                INITIAL SPEED           BVELT
                      >0                -.000000001
                     =<0                999999.9

?
0

ENTER SET #  11

ENTER IBROPI: -1=RELEASE;0=BAIL-OFF;1=APPLICATION
?
1

ENTER BRAKE CYLINDER PRESSURE ON LEAD LOCO. FOLLOWING
INITIATION (PSI): BCPI
?
37.89

ENTER TIME OF INITIATION (SEC.): BTIMEI (DEFAULT VALUE =' 999999.9)
?
12.0

ENTER DISTANCE OF INITIATION (FT): BDISTI (DEFAULT VALUE' = 999999.9)
?
0.0

ENTER SPEED OF INITIATION (FT./SEC.): BVELI (DEFAULT 'VALUES:
                INITIAL SPEED           BVELT
                      >0                -.000000001
                     =<0                999999.9

?
0
```

```
ENTER SET # 12

ENTER IBROPI: -1=RELEASE;0=BAIL-OFF;1=APPLICATION
?
40.99 XXX
1

ENTER BRAKE CYLINDER PRESSURE ON LEAD LOCO. FOLLOWING
INITIATION (PSI): BCPI
?
40.99

ENTER TIME OF INITIATION (SEC.): BTIMEI (DEFAULT VALUE =' 999999.9)
?
13.0

ENTER DISTANCE OF INITIATION (FT): BDISTI (DEFAULT VALUE' = 999999.9)
?
0.0

ENTER SPEED OF INITIATION (FT./SEC.): BVELI (DEFAULT 'VALUES:
          INITIAL SPEED          BVELT
               >0                -.000000001
              =<0                999999.9
?
0

ENTER SET # 13

ENTER IBROPI: -1=RELEASE;0=BAIL-OFF;1=APPLICATION
?
1

ENTER BRAKE CYLINDER PRESSURE ON LEAD LOCO. FOLLOWING
INITIATION (PSI): BCPI
?
42.15

ENTER TIME OF INITIATION (SEC.): BTIMEI (DEFAULT VALUE =' 999999.9)
?
14.0

ENTER DISTANCE OF INITIATION (FT): BDISTI (DEFAULT VALUE' = 999999.9)
?
0.0

ENTER SPEED OF INITIATION (FT./SEC.): BVELI (DEFAULT 'VALUES:
          INITIAL SPEED          BVELT
               >0                -.000000001
              =<0                999999.9
?
0
```

```
ENTER SET #  14

ENTER IBROPI: -1=RELEASE;0=BAIL-OFF;1=APPLICATION
?
1

ENTER BRAKE CYLINDER PRESSURE ON LEAD LOCO. FOLLOWING
INITIATION (PSI): BCPI
?
42.64

ENTER TIME OF INITIATION (SEC.): BTIMEI (DEFAULT VALUE =' 999999.9)
?
15.0

ENTER DISTANCE OF INITIATION (FT): BDISTI (DEFAULT VALUE' = 999999.9)
?
0.0

ENTER SPEED OF INITIATION (FT./SEC.): BVELI (DEFAULT 'VALUES:
           INITIAL SPEED         BVELT
                >0               -.000000001
               =<0               999999.9
?
0

ENTER SET #  15

ENTER IBROPI: -1=RELEASE;0=BAIL-OFF;1=APPLICATION
?
1

ENTER BRAKE CYLINDER PRESSURE ON LEAD LOCO. FOLLOWING
INITIATION (PSI): BCPI
?
43.7

ENTER TIME OF INITIATION (SEC.): BTIMEI (DEFAULT VALUE =' 999999.9)
?
16.0

ENTER DISTANCE OF INITIATION (FT): BDISTI (DEFAULT VALUE' = 999999.9)
?
0.0

ENTER SPEED OF INITIATION (FT./SEC.): BVELI (DEFAULT 'VALUES:
           INITIAL SPEED         BVELT
                >0               -.000000001
               =<0               999999.9
?
0
```

```
ENTER SET #  16

ENTER IBROPI: -1=RELEASE;0=BAIL-OFF;1=APPLICATION
?
1

ENTER BRAKE CYLINDER PRESSURE ON LEAD LOCO. FOLLOWING
INITIATION (PSI): BCPI
?
46.02

ENTER TIME OF INITIATION (SEC.): BTIMEI (DEFAULT VALUE =' 999999.9)
?
17.0

ENTER DISTANCE OF INITIATION (FT): BDISTI (DEFAULT VALUE' = 999999.9)
?
0.0

ENTER SPEED OF INITIATION (FT./SEC.): BVELI (DEFAULT 'VALUES:
            INITIAL SPEED           BVELT
                >0                  -.000000001
                =<0                 999999.9
?
0

ENTER SET #  17

ENTER IBROPI: -1=RELEASE;0=BAIL-OFF;1=APPLICATION
?
1

ENTER BRAKE CYLINDER PRESSURE ON LEAD LOCO. FOLLOWING
INITIATION (PSI): BCPI
?
47.03

ENTER TIME OF INITIATION (SEC.): BTIMEI (DEFAULT VALUE =' 999999.9)
?
18.0

ENTER DISTANCE OF INITIATION (FT): BDISTI (DEFAULT VALUE' = 999999.9)
?
0.0

ENTER SPEED OF INITIATION (FT./SEC.): BVELI (DEFAULT 'VALUES:
            INITIAL SPEED           BVELT
                >0                  -.000000001
                =<0                 999999.9
?
0
```

```
ENTER SET #  18

ENTER IBROPI: -1=RELEASE;0=BAIL-OFF;1=APPLICATION
?
1

ENTER BRAKE CYLINDER PRESSURE ON LEAD LOCO. FOLLOWING
INITIATION (PSI): BCPI
?
47.86

ENTER TIME OF INITIATION (SEC.): BTIMEI (DEFAULT VALUE =' 999999.9)
?
19.0

ENTER DISTANCE OF INITIATION (FT): BDISTI (DEFAULT VALUE' = 999999.9)
?
0.0

ENTER SPEED OF INITIATION (FT./SEC.): BVELI (DEFAULT 'VALUES:
          INITIAL SPEED          BVELT
               >0                -.000000001
              =<0                999999.9
?
0

ENTER SET #  19

ENTER IBROPI: -1=RELEASE;0=BAIL-OFF;1=APPLICATION
?
1

ENTER BRAKE CYLINDER PRESSURE ON LEAD LOCO. FOLLOWING
INITIATION (PSI): BCPI
?
48,,\.15

ENTER TIME OF INITIATION (SEC.): BTIMEI (DEFAULT VALUE =' 999999.9)
?
20.0

ENTER DISTANCE OF INITIATION (FT): BDISTI (DEFAULT VALUE' = 999999.9)
?
.0

ENTER SPEED OF INITIATION (FT./SEC.): BVELI (DEFAULT 'VALUES:
          INITIAL SPEED          BVELT
               >0                -.000000001
              =<0                999999.9
?
0
```

```
ENTER SET #  20

ENTER IBROPI: -1=RELEASE;0=BAIL-OFF;1=APPLICATION
?
1

ENTER BRAKE CYLINDER PRESSURE ON LEAD LOCO. FOLLOWING
INITIATION (PSI): BCPI
?
48.54

ENTER TIME OF INITIATION (SEC.): BTIMEI (DEFAULT VALUE =' 999999.9)
?
21.0

ENTER DISTANCE OF INITIATION (FT): BDISTI (DEFAULT VALUE' = 999999.9)
?
0.0

ENTER SPEED OF INITIATION (FT./SEC.): BVELI (DEFAULT 'VALUES:
        INITIAL SPEED         BVELT
              >0              -.000000001
             =<0              999999.9
?
0

ENTER SET #  21

ENTER IBROPI: -1=RELEASE;0=BAIL-OFF;1=APPLICATION
?
1

ENTER BRAKE CYLINDER PRESSURE ON LEAD LOCO. FOLLOWING
INITIATION (PSI): BCPI
?
51.83

ENTER TIME OF INITIATION (SEC.): BTIMEI (DEFAULT VALUE =' 999999.9)
?
36.0

ENTER DISTANCE OF INITIATION (FT): BDISTI (DEFAULT VALUE' = 999999.9)
?
0.0

ENTER SPEED OF INITIATION (FT./SEC.): BVELI (DEFAULT 'VALUES:
        INITIAL SPEED         BVELT
              >0              -.000000001
             =<0              999999.9
?
0
```

```
ENTER SET # 22

ENTER IBROPI: -1=RELEASE;0=BAIL-OFF;1=APPLICATION
?
1

ENTER BRAKE CYLINDER PRESSURE ON LEAD LOCO. FOLLOWING
INITIATION (PSI): BCPI
?
53.83

ENTER TIME OF INITIATION (SEC.): BTIMEI (DEFAULT VALUE =' 999999.9)
?
37.0

ENTER DISTANCE OF INITIATION (FT): BDISTI (DEFAULT VALUE' = 999999.9)
?
0.0

ENTER SPEED OF INITIATION (FT./SEC.): BVELI (DEFAULT 'VALUES:
          INITIAL SPEED          BVELT
               >0                -.000000001
              =<0                999999.9
?
0

ENTER SET # 23

ENTER IBROPI: -1=RELEASE;0=BAIL-OFF;1=APPLICATION
?
1

ENTER BRAKE CYLINDER PRESSURE ON LEAD LOCO. FOLLOWING
INITIATION (PSI): BCPI
?
55.32

ENTER TIME OF INITIATION (SEC.): BTIMEI (DEFAULT VALUE =' 999999.9)
?
38.0

ENTER DISTANCE OF INITIATION (FT): BDISTI (DEFAULT VALUE' = 999999.9)
?
0.0

ENTER SPEED OF INITIATION (FT./SEC.): BVELI (DEFAULT 'VALUES:
          INITIAL SPEED          BVELT
               >0                -.000000001
              =<0                999999.9
?
0
```

```
ENTER SET #  24

ENTER IBROPI: -1=RELEASE;0=BAIL-OFF;1=APPLICATION
?
1

ENTER BRAKE CYLINDER PRESSURE ON LEAD LOCO. FOLLOWING
INITIATION (PSI): BCPI
?
57.06

ENTER TIME OF INITIATION (SEC.): BTIMEI (DEFAULT VALUE =' 999999.9)
?
39.0

ENTER DISTANCE OF INITIATION (FT): BDISTI (DEFAULT VALUE' = 999999.9)
?
0.0

ENTER SPEED OF INITIATION (FT./SEC.): BVELI (DEFAULT 'VALUES:
          INITIAL SPEED          BVELT
               >0                -.000000001
              =<0                999999.9
?
0

ENTER SET #  25

ENTER IBROPI: -1=RELEASE;0=BAIL-OFF;1=APPLICATION
?
1

ENTER BRAKE CYLINDER PRESSURE ON LEAD LOCO. FOLLOWING
INITIATION (PSI): BCPI
?
58.03

ENTER TIME OF INITIATION (SEC.): BTIMEI (DEFAULT VALUE =' 999999.9)
?
40.0

ENTER DISTANCE OF INITIATION (FT): BDISTI (DEFAULT VALUE' = 999999.9)
?
0.0

ENTER SPEED OF INITIATION (FT./SEC.): BVELI (DEFAULT 'VALUES:
          INITIAL SPEED          BVELT
               >0                -.000000001
              =<0                999999.9
?
0
```

```
ENTER SET #  26

ENTER IBROPI: -1=RELEASE;0=BAIL-OFF;1=APPLICATION
?
1

ENTER BRAKE CYLINDER PRESSURE ON LEAD LOCO. FOLLOWING
INITIATION (PSI): BCPI
?
59.00

ENTER TIME OF INITIATION (SEC.): BTIMEI (DEFAULT VALUE =' 999999.9)
?
41.00

ENTER DISTANCE OF INITIATION (FT): BDISTI (DEFAULT VALUE' = 999999.9)
?
0.0

ENTER SPEED OF INITIATION (FT./SEC.): BVELI (DEFAULT 'VALUES:
          INITIAL SPEED          BVELT
               >0                -.000000001
               =<0               999999.9
?
0

ENTER SET #  27

ENTER IBROPI: -1=RELEASE;0=BAIL-OFF;1=APPLICATION
?
1

ENTER BRAKE CYLINDER PRESSURE ON LEAD LOCO. FOLLOWING
INITIATION (PSI): BCPI
?
59.87

ENTER TIME OF INITIATION (SEC.): BTIMEI (DEFAULT VALUE =' 999999.9)
?
42.0

ENTER DISTANCE OF INITIATION (FT): BDISTI (DEFAULT VALUE' = 999999.9)
?
0.0

ENTER SPEED OF INITIATION (FT./SEC.): BVELI (DEFAULT 'VALUES:
          INITIAL SPEED          BVELT
               >0                -.000000001
               =<0               999999.9
?
0
```

```
ENTER SET #  28

ENTER IBROPI: -1=RELEASE;0=BAIL-OFF;1=APPLICATION
?
1

ENTER BRAKE CYLINDER PRESSURE ON LEAD LOCO. FOLLOWING
INITIATION (PSI): BCPI
?
61.52

ENTER TIME OF INITIATION (SEC.): BTIMEI (DEFAULT VALUE =' 999999.9)
?
43.0

ENTER DISTANCE OF INITIATION (FT): BDISTI (DEFAULT VALUE' = 999999.9)
?
0.0

ENTER SPEED OF INITIATION (FT./SEC.): BVELI (DEFAULT 'VALUES:
            INITIAL SPEED          BVELT
                 >0                -.000000001
                =<0                999999.9
?
0

ENTER SET #  29

ENTER IBROPI: -1=RELEASE;0=BAIL-OFF;1=APPLICATION
?
1

ENTER BRAKE CYLINDER PRESSURE ON LEAD LOCO. FOLLOWING
INITIATION (PSI): BCPI
?
62.29

ENTER TIME OF INITIATION (SEC.): BTIMEI (DEFAULT VALUE =' 999999.9)
?
44.0

ENTER DISTANCE OF INITIATION (FT): BDISTI (DEFAULT VALUE' = 999999.9)
?
622\6\0.0

ENTER SPEED OF INITIATION (FT./SEC.): BVELI (DEFAULT 'VALUES:
            INITIAL SPEED          BVELT
                 >0                -.000000001
                =<0                999999.9
?
0
```

```
ENTER SET #  30

ENTER IBROPI: -1=RELEASE;0=BAIL-OFF;1=APPLICATION
?
1

ENTER BRAKE CYLINDER PRESSURE ON LEAD LOCO. FOLLOWING
INITIATION (PSI): BCPI
?
62.69

ENTER TIME OF INITIATION (SEC.): BTIMEI (DEFAULT VALUE =' 999999.9)
?
45.0

ENTER DISTANCE OF INITIATION (FT): BDISTI (DEFAULT VALUE' = 999999.9)
?
0.0

ENTER SPEED OF INITIATION (FT./SEC.): BVELI (DEFAULT 'VALUES:
          INITIAL SPEED          BVELT
                >0               -.000000001
               =<0               999999.9
?
0

ENTER SET #  31

ENTER IBROPI: -1=RELEASE;0=BAIL-OFF;1=APPLICATION
?
1

ENTER BRAKE CYLINDER PRESSURE ON LEAD LOCO. FOLLOWING
INITIATION (PSI): BCPI
?
62.87

ENTER TIME OF INITIATION (SEC.): BTIMEI (DEFAULT VALUE =' 999999.9)
?
46.0

ENTER DISTANCE OF INITIATION (FT): BDISTI (DEFAULT VALUE' = 999999.9)
?
0.0

ENTER SPEED OF INITIATION (FT./SEC.): BVELI (DEFAULT 'VALUES:
          INITIAL SPEED          BVELT
                >0               -.000000001
               =<0               999999.9
?
0
```

```
ENTER SET #  32

ENTER IBROPI: -1=RELEASE;0=BAIL-OFF;1=APPLICATION
?
1

ENTER BRAKE CYLINDER PRESSURE ON LEAD LOCO. FOLLOWING
INITIATION (PSI): BCPI
?
63.16

ENTER TIME OF INITIATION (SEC.): BTIMEI (DEFAULT VALUE =' 999999.9)
?
47.0

ENTER DISTANCE OF INITIATION (FT): BDISTI (DEFAULT VALUE' = 999999.9)
?
0.0

ENTER SPEED OF INITIATION (FT./SEC.): BVELI (DEFAULT 'VALUES:
          INITIAL SPEED          BVELT
              >0                 -.000000001
              =<0                999999.9
?
0

ENTER SET #  33

ENTER IBROPI: -1=RELEASE;0=BAIL-OFF;1=APPLICATION
?
1

ENTER BRAKE CYLINDER PRESSURE ON LEAD LOCO. FOLLOWING
INITIATION (PSI): BCPI
?
63.65

ENTER TIME OF INITIATION (SEC.): BTIMEI (DEFAULT VALUE =' 999999.9)
?
48.0

ENTER DISTANCE OF INITIATION (FT): BDISTI (DEFAULT VALUE' = 999999.9)
?
0.0

ENTER SPEED OF INITIATION (FT./SEC.): BVELI (DEFAULT 'VALUES:
          INITIAL SPEED          BVELT
              >0                 -.000000001
              =<0                999999.9
?
0
```

```
ENTER SET #  34

ENTER IBROPI: -1=RELEASE;0=BAIL-OFF;1=APPLICATION
?
1

ENTER BRAKE CYLINDER PRESSURE ON LEAD LOCO. FOLLOWING
INITIATION (PSI): BCPI
?
64.03

ENTER TIME OF INITIATION (SEC.): BTIMEI (DEFAULT VALUE =' 999999.9)
?
49.0

ENTER DISTANCE OF INITIATION (FT): BDISTI (DEFAULT VALUE' = 999999.9)
?
0.0

ENTER SPEED OF INITIATION (FT./SEC.): BVELI (DEFAULT 'VALUES:
          INITIAL SPEED          BVELT
                >0               -.000000001
               =<0               999999.9
?
0

ENTER SET #  35

ENTER IBROPI: -1=RELEASE;0=BAIL-OFF;1=APPLICATION
?
1

ENTER BRAKE CYLINDER PRESSURE ON LEAD LOCO. FOLLOWING
INITIATION (PSI): BCPI
?
64.23

ENTER TIME OF INITIATION (SEC.): BTIMEI (DEFAULT VALUE =' 999999.9)
?
50

ENTER DISTANCE OF INITIATION (FT): BDISTI (DEFAULT VALUE' = 999999.9)
?
0.0

ENTER SPEED OF INITIATION (FT./SEC.): BVELI (DEFAULT 'VALUES:
          INITIAL SPEED          BVELT
                >0               -.000000001
               =<0               999999.9
?
0
```

```
ENTER    1  SETS OF VALUES DENOTING SCHEDULES OF TRAIN 'HANDLING
     FOR THROTTLE CHANGES:

ENTER SET #    1

ENTER THROTTLE POSITION: (ITHTLC)
  (-8 ... -1='DYNAMIC BRAKE, 0=IDLE, 1 ... 8=THROTTLE
?
0

ENTER TIME OF INITIATION (SEC.): TTIME (DEFAULT VALUE =' 999999.9)
?
1.0

ENTER DISTANCE OF INITIATION (FT): TDIST (DEFAULT VALUE' = 999999.9)
?
0.0

ENTER SPEED OF INITIATION (FT./SEC.): TVEL (DEFAULT 'VALUES:
          INITIAL SPEED          BVELT
               >0                -.000000001
               =<0               999999.9
?
0
```

```
RUN (PROGRAM) FIS034.EXE.96

WELCOME TO DTAM-FIS INTERACTIVE PROGRAM

DO YOU WANT TO ENTER INPUT FROM TTY ?
(ANSWER YES' OR NO. IF NO, INPUT WILL BE TAKEN FROM FILE)
?
NO

ENTER NAME OF THE INPUT FILE
(MAX. 6 CHAR.)
?
FISDAT

MSG 2
```

4.0 GRAPHIC OUTPUT

Plots of the results are obtained by executing the PLOTDT program interactively, as shown in Section 4.1.

It can be seen that the following plots are available:

1) Speed and distance travelled versus time,

2) Throttle setting and amperes versus time,

3) Grade and curvature versus time,

4) Automatic and independent brake settings versus time,

5) Maximum and minimum coupler forces for the entire train versus time, and

6) Coupler forces and displacements versus time, for up to a maximum of 21 selected vehicles.

These plots are shown in Figures 3 through 7 for this sample problem. Only seven vehicles: Nos. 1, 5, 15, 25, 35, 45 and 55 were selected apriori for displaying the coupler forces, as shown in Figures 8 through 14, respectively.

4.1 Execution of the PLOTDT Program and Sample Output Results

```
RUN PLOTDT

 ENTER TERMINAL SPEED IN CHAR/SEC.
?960



 * WELCOME TO DTAM-PLOT PROGRAM

 * THE FOLLOWING PLOTS ARE AVAILABLE:
   S.NO.              NAME                                         CODE

   1       SPEED & DISTANCE  V/S  TIME ..................       SDT
   2       THROTTLE & AMPS  V/S  TIME  ..................       TAT
   3       GRADE & CURVE  V/S  TIME    ..................       GCT
   4       BRAKE SETTING(AUTO & INDEPENDENT) V/S TIME  ..       BST
   5       MAX/MIN COUPLER FORCE V/S TIME OVER ENTIRE TRAIN     CFT
   6       COUPLER FORCES & DISPLACEMENTS  V/S  TIME  ...       CDT

 * ENTER THE THREE LETTER CODE OR THE SEQ. NO. FOR EACH OF THE PLOTS
   YOU ARE INTERESTED IN. PRESS <CR> AFTER ENTERING EACH CODE.
   ENTER "ALL" TO DRAW ALL THE PLOTS.
   ENTER "END" TO TERMINATE THE LIST.

 * ENTER THE CODES NOW:
? ALL

? END
```

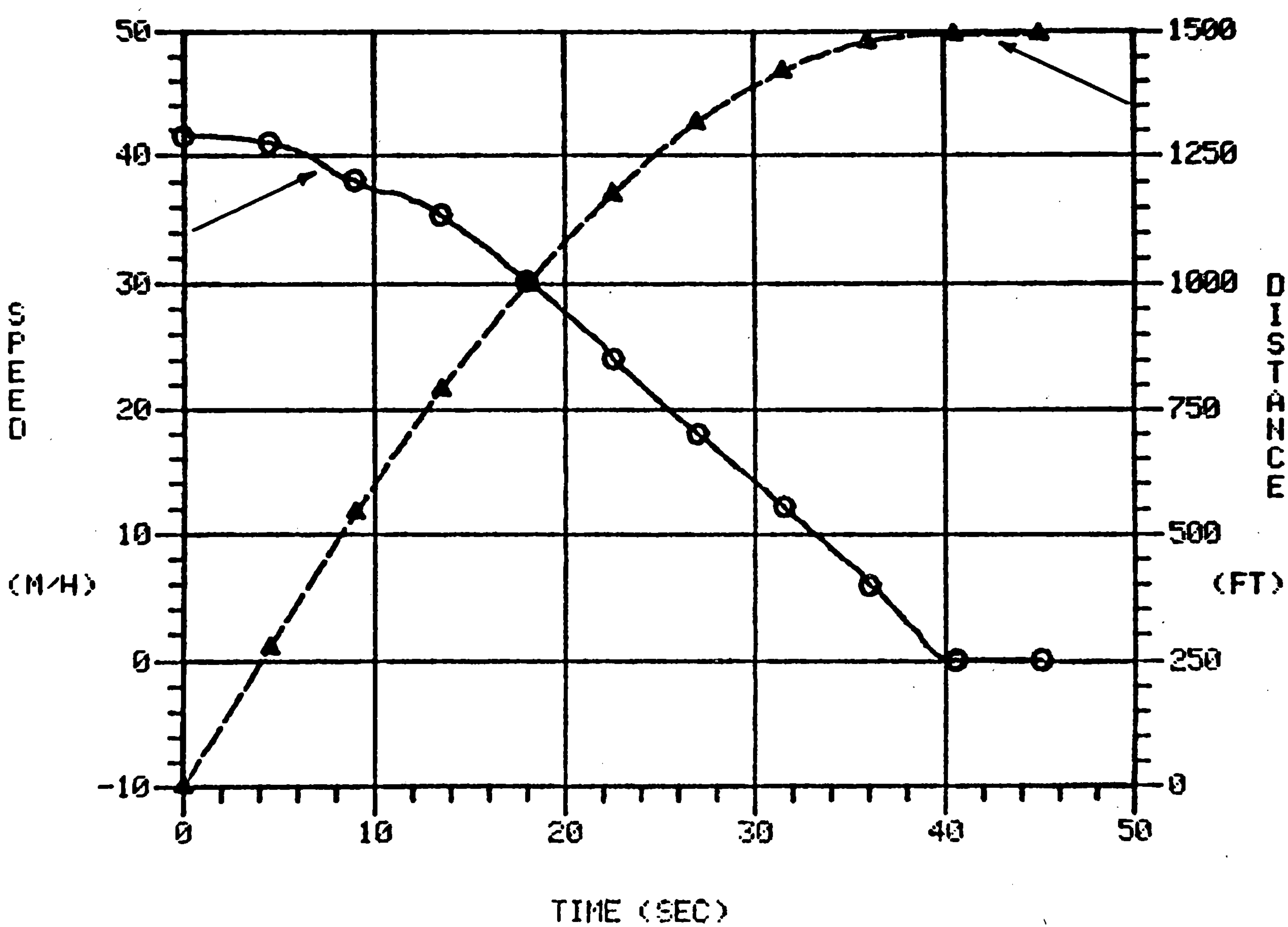

Figure 3. Train Speed and Distance Travelled vs. Time, for the Sample Run.

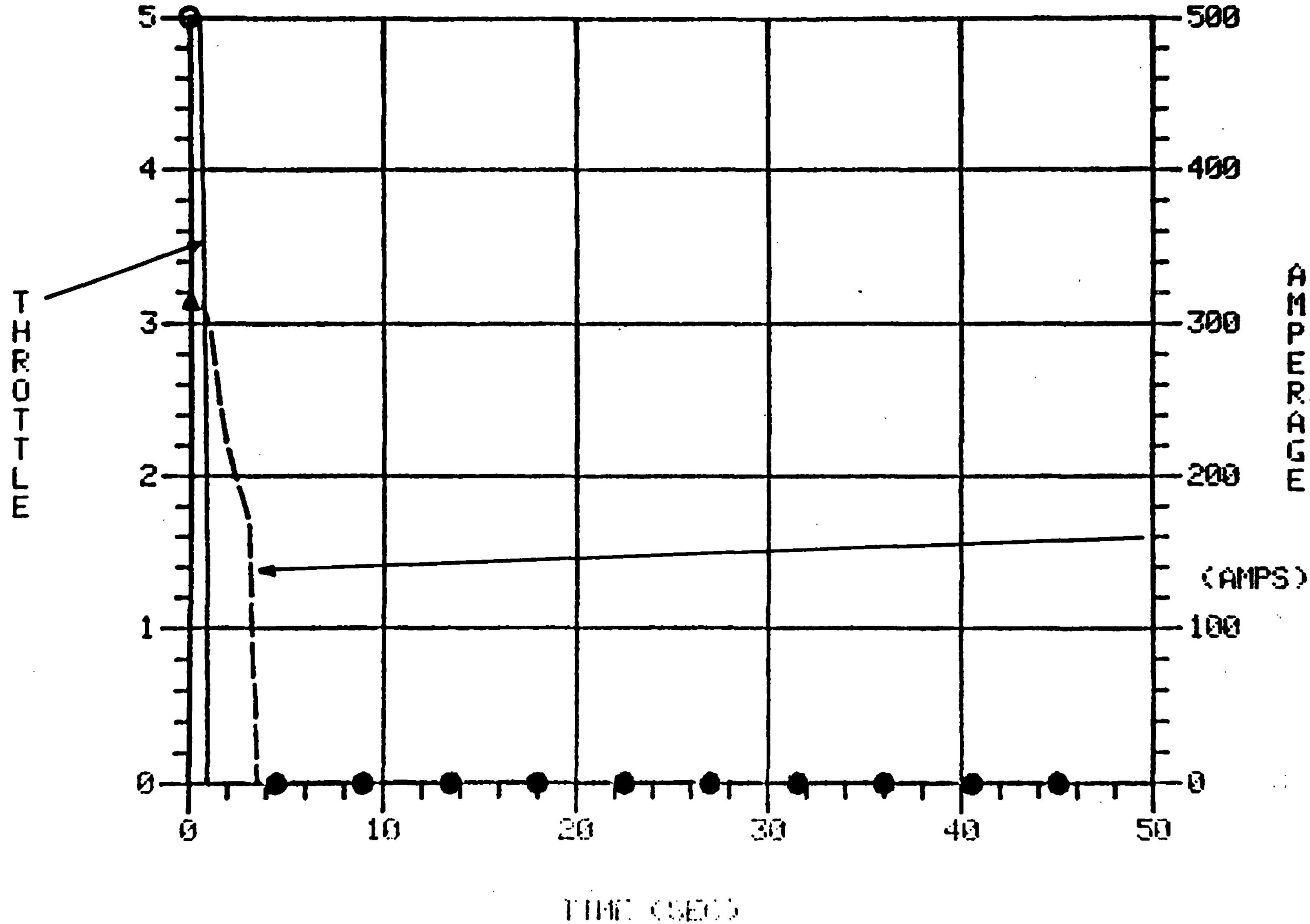

Figure 4. Locomotive Throttle Setting and Motor Current (Amperage) vs. Time, for the Sample Run.

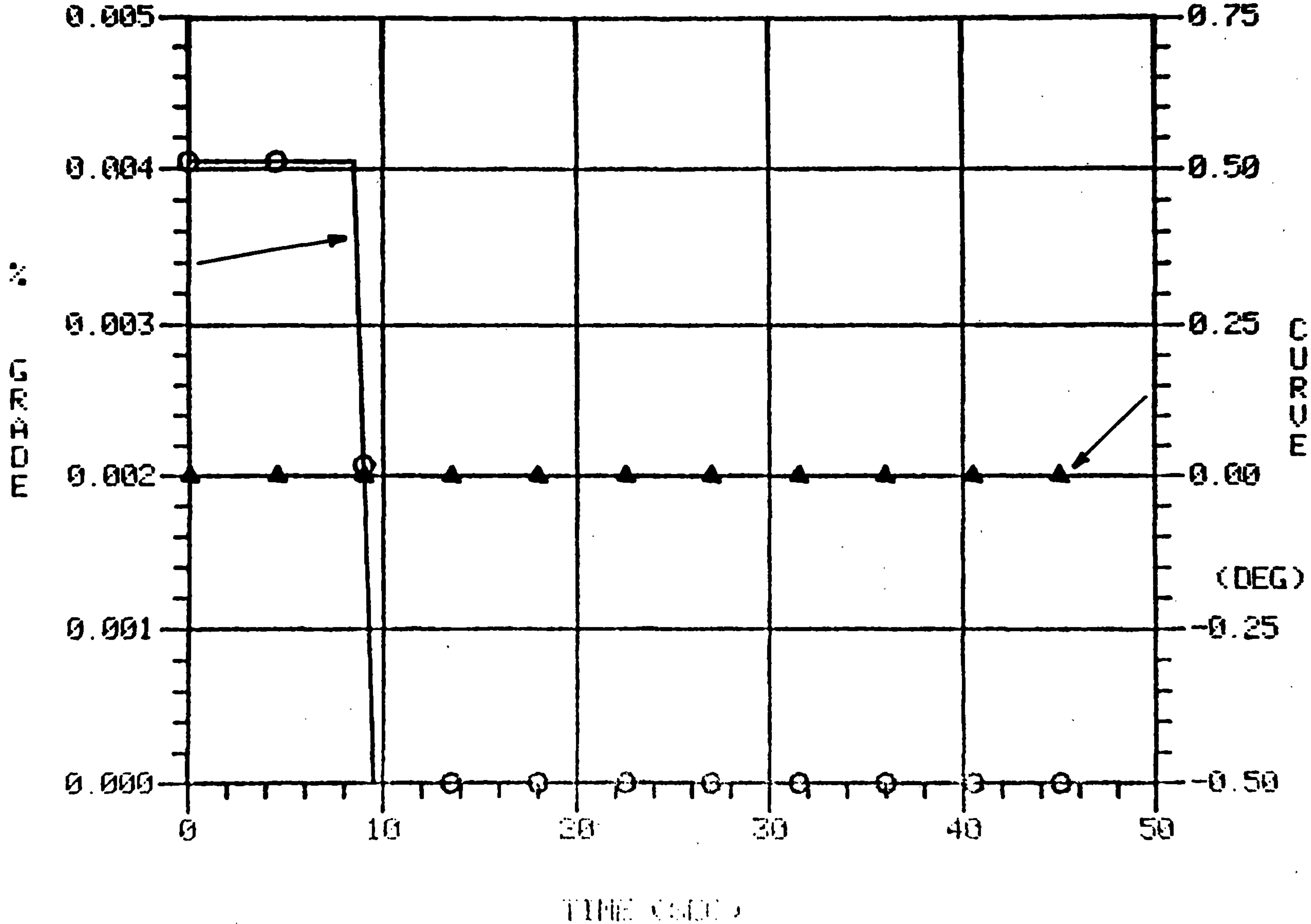

Figure 5. Track Gradient and Curvature *vs.* Time, for the Sample Run.

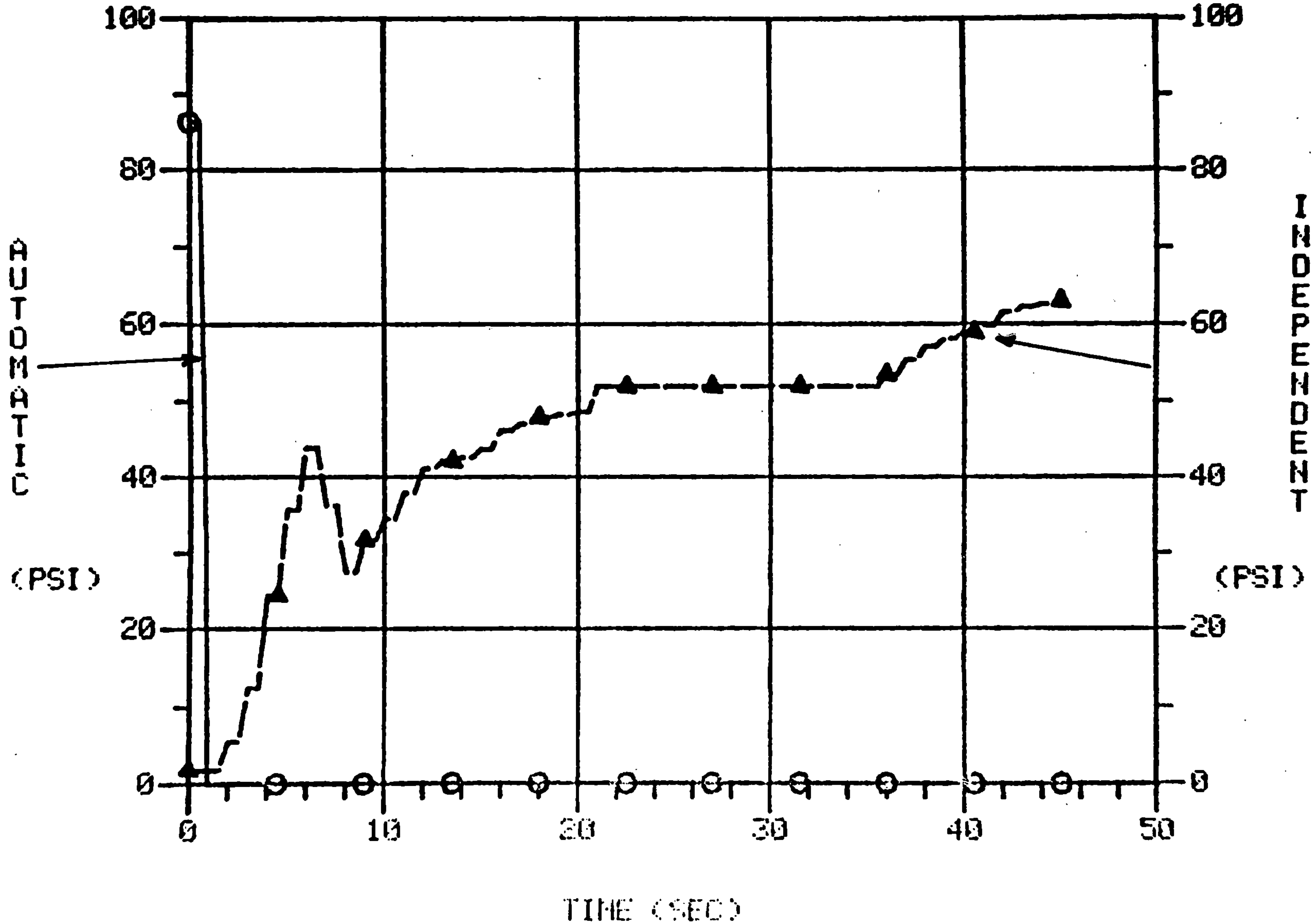

Figure 6. Locomotive Automatic and Independent Air Brake Control Valve Settings vs. Time, for the Sample Run.

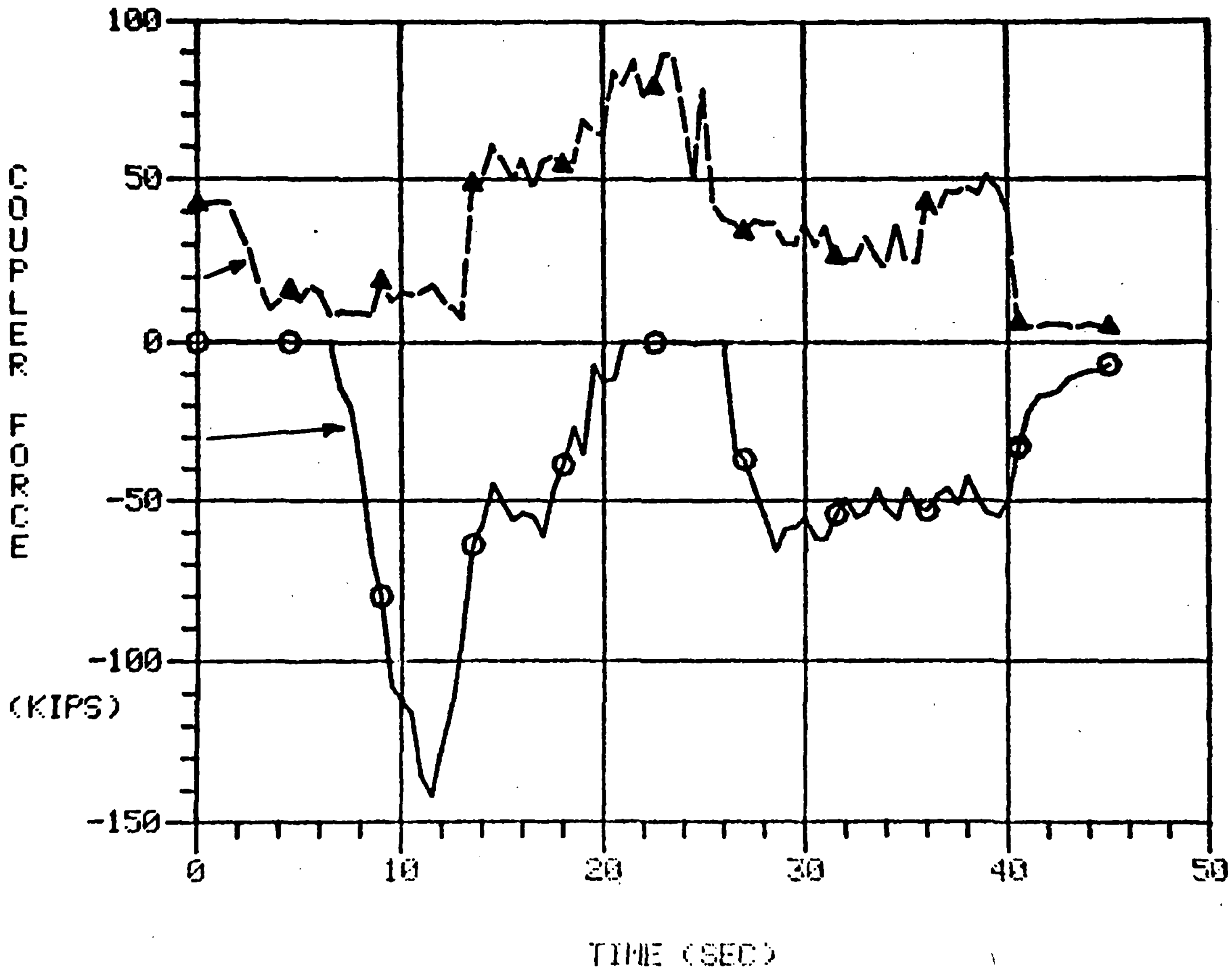

Figure 7. Coupler Force Extremes Over the Entire Length of the Train vs. Time, for the Sample Run.

```
* MAX/MIN COUPLER FORCES & DISPLACEMENT V/S TIME PLOTS ARE AVAILABLE FOR
  VEHICLE# :
    1,  5, 15, 25, 35, 45, 55,
* PLEASE ENTER THE VEHICLE NOS. FOR WHICH YOU WANT CDT PLOTS.
  ENTER 0 TO DRAW ALL THE AVAILABLE PLOTS.
  TERMINATE THE LIST BY ENTERING  -1

? 0

? -1
```

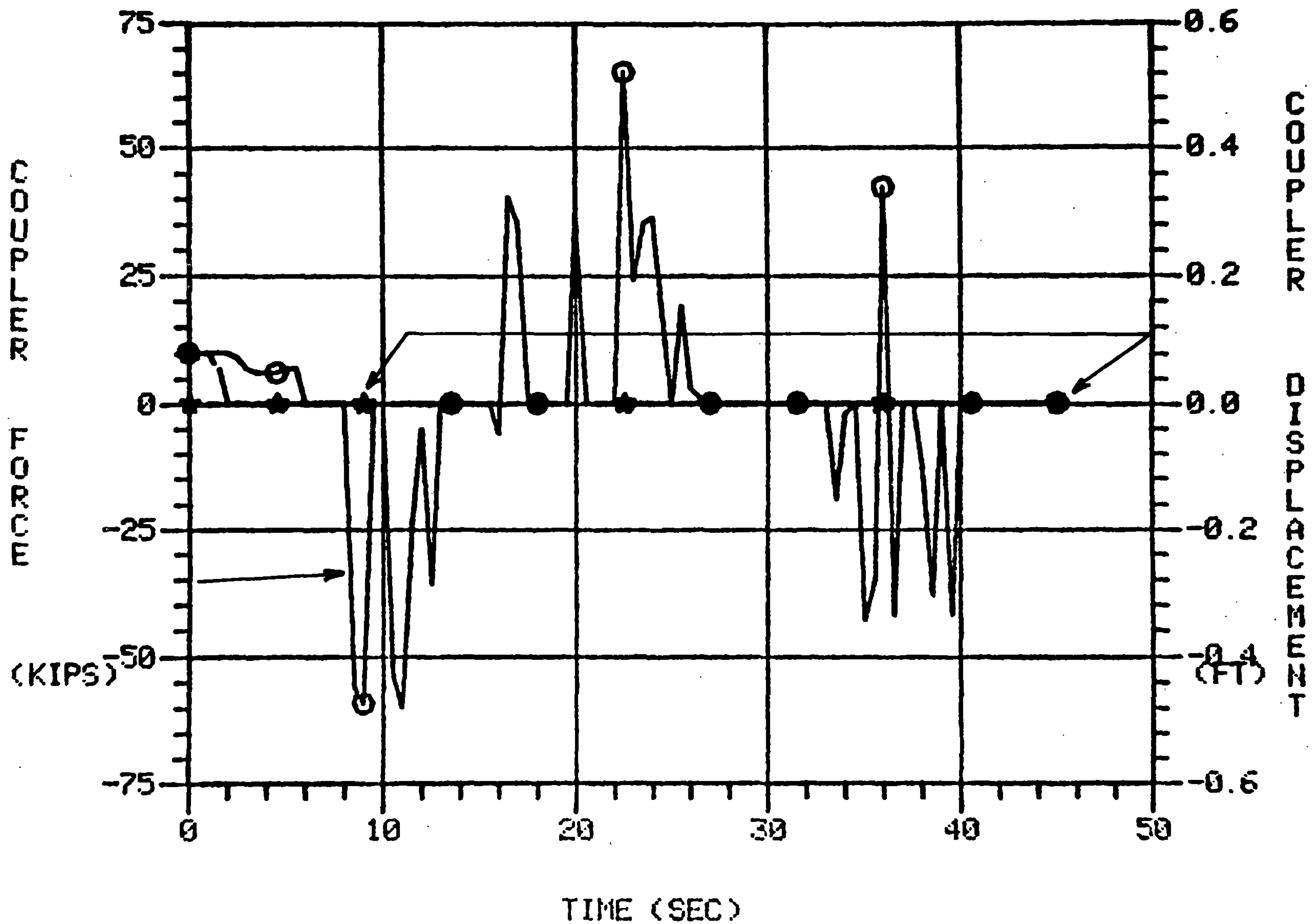

Figure 8. Coupler Force and Displacement vs. Time, for Vehicle No. 1 in the Test Train.

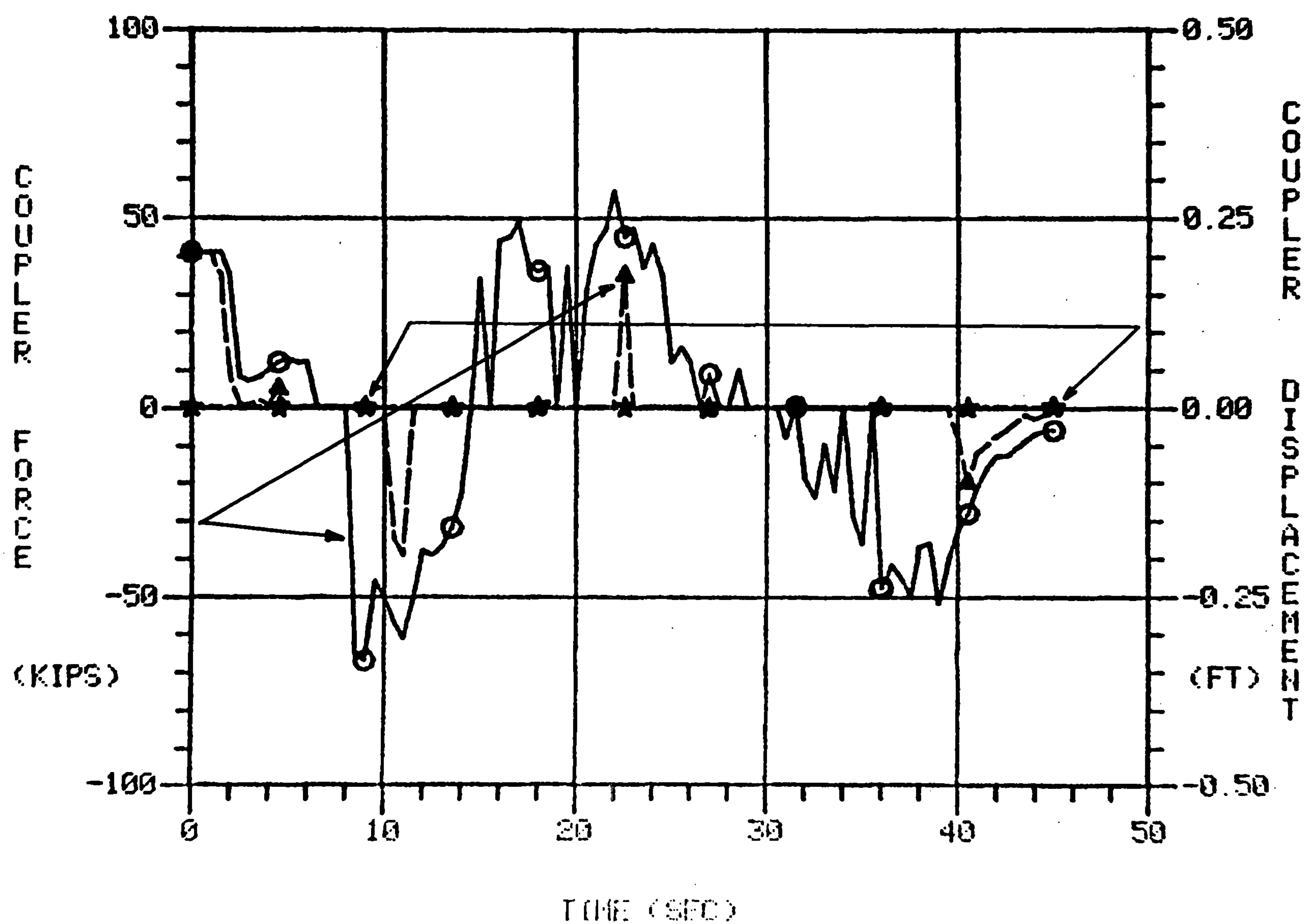

Figure 9. Coupler Force and Displacement vs. Time, for Vehicle No. 5 in the Test Train.

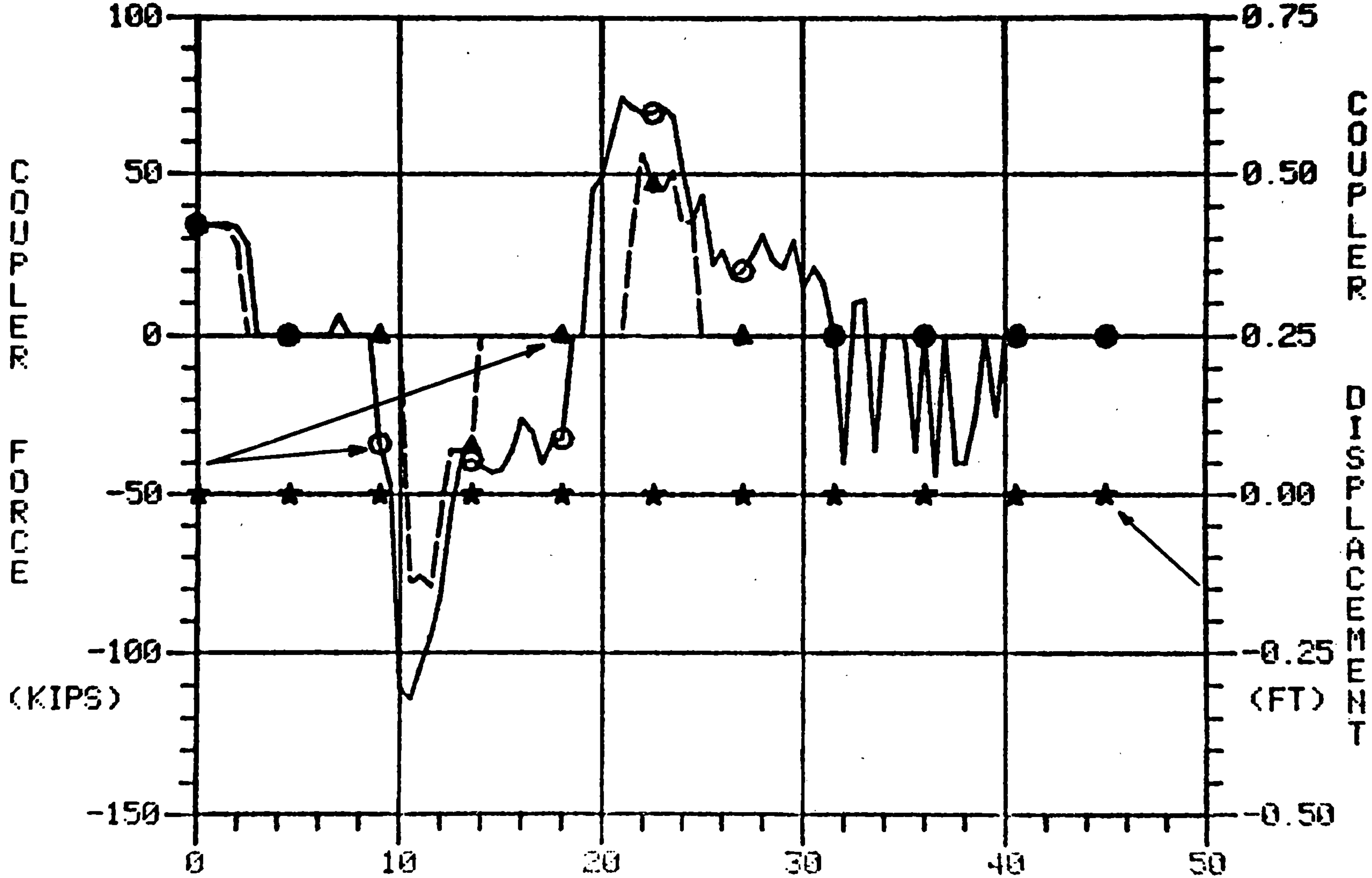

Figure 10. Coupler Force and Displacement vs. Time, for Vehicle No. 15 in the Test Train.

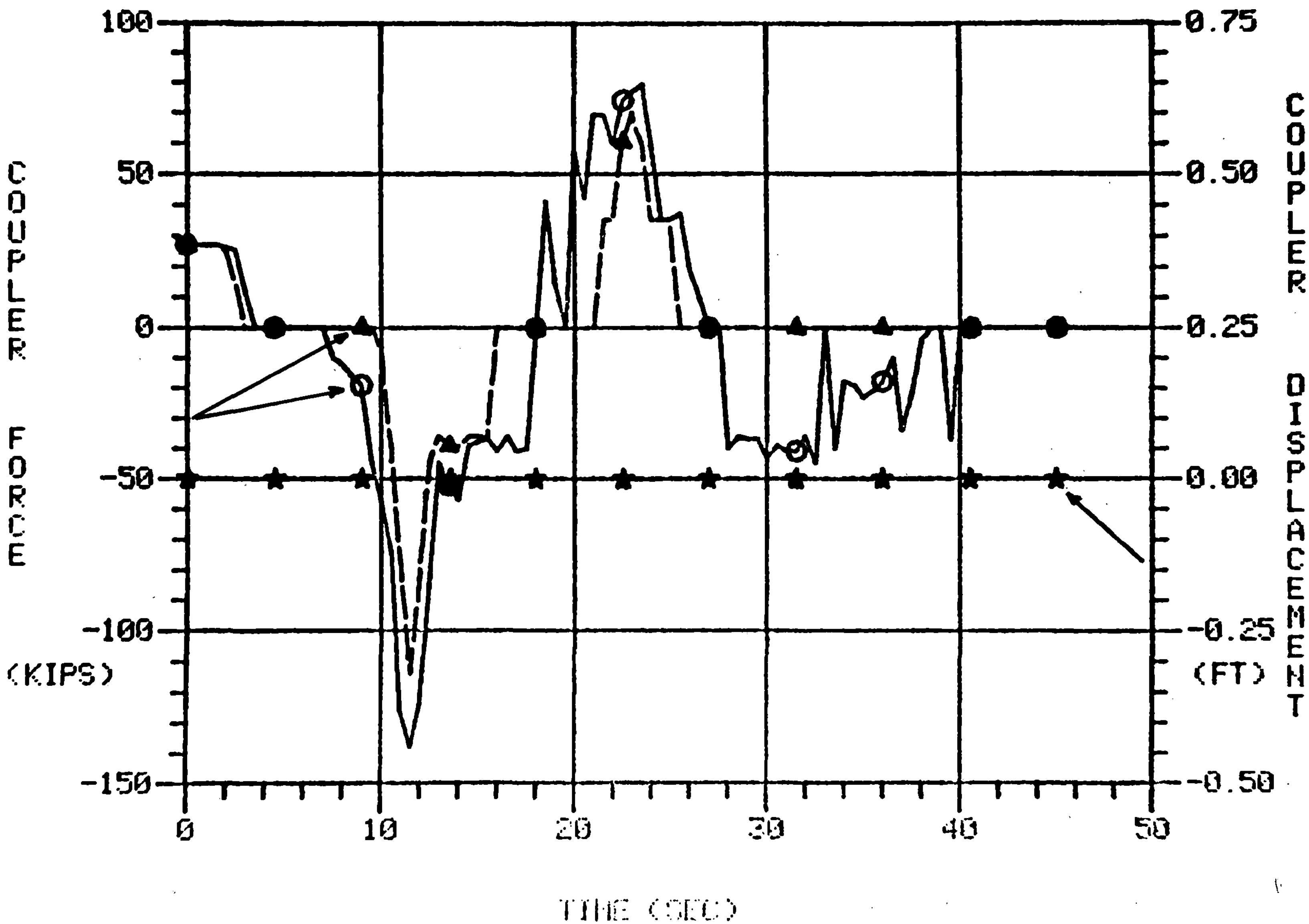

Figure 11. Coupler Force and Displacement vs. Time, for Vehicle No. 25 in the Test Train.

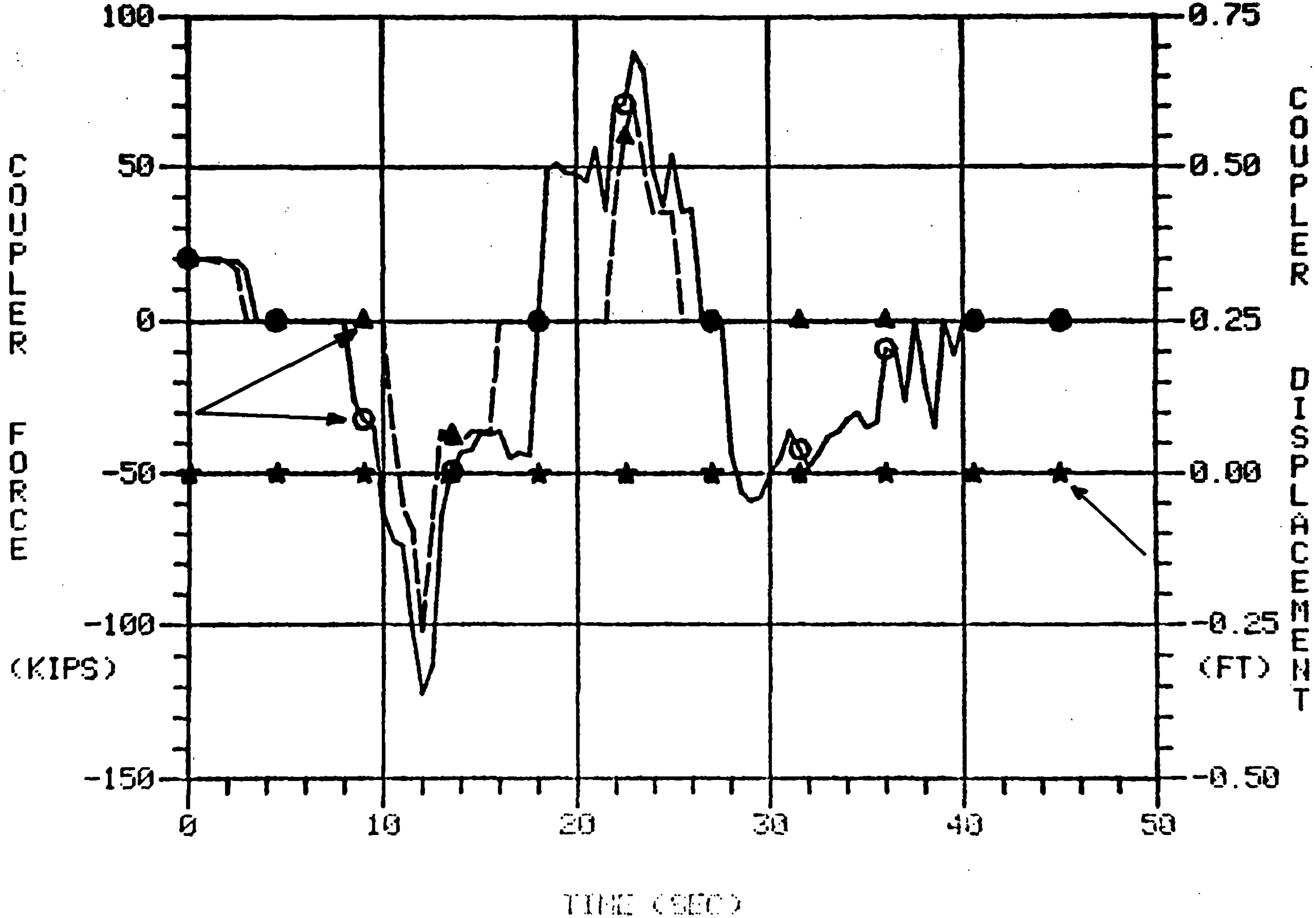

Figure 12. Coupler Force and Displacement vs. Time, for Vehicle No. 35 in the Test Train.

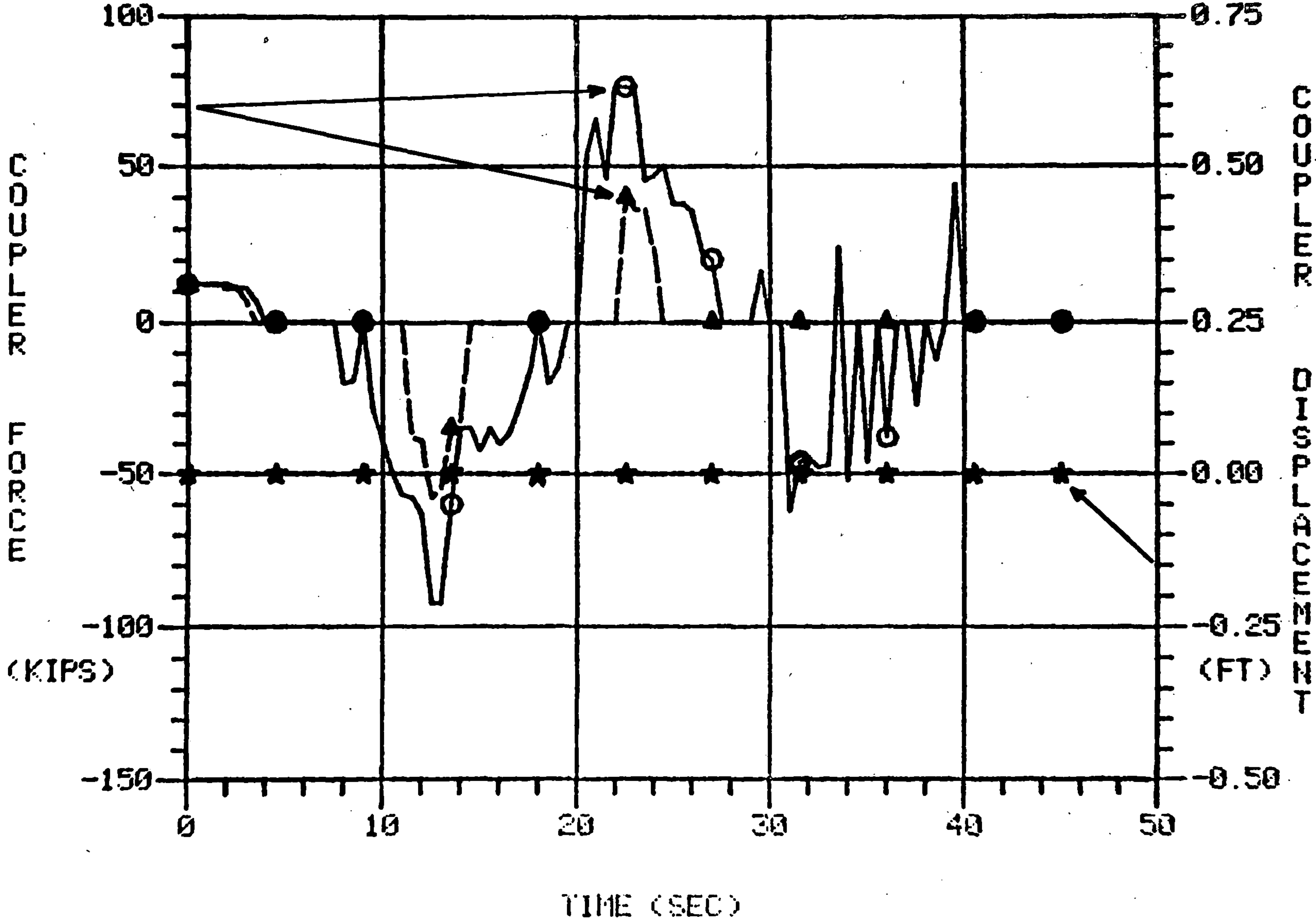

Figure 13. Coupler Force and Displacement vs. Time, for Vehicle No. 45 in the Test Train.

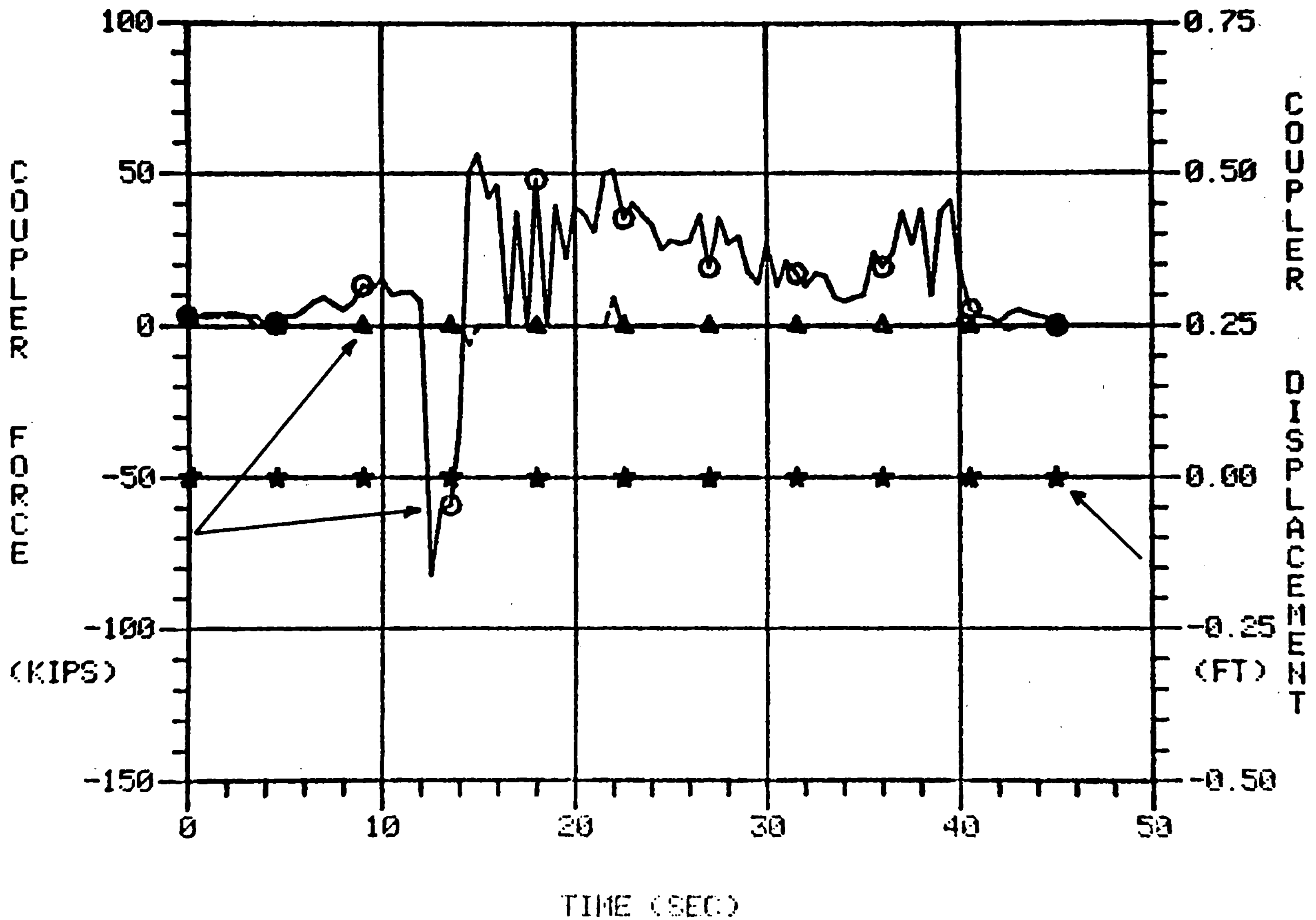

Figure 14. Coupler Force and Displacement vs. Time, for Vehicle No. 55 in the Test Train.

```
* DO YOU WANT ANY MORE COUPLER FORCE & DISPLACEMENT V/S TIME PLOTS ?
   (ANSWER YES OR NO )
? NO
```

5.0 REFERENCES

1. Martin G.C., and Tideman, H., "Technical Documentation, Detailed Longitudinal Train Action Model," Association of American Railroads, Report R-221, Chicago, Illinois.

2. Martin, G.C., Plouffe, W.E., Ahmed, S., Antezak, H. and Tideman, H., "User's Manual, Detailed Longitudinal Train Action Model," Association of American Railroads, Report R-220, Chicago, Illinois.

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