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A DESCRIPTION OF THE TESTS CONDUCTED AND DATA OBTAINED DURING THE PERTURBED TRACK TEST

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16. Abstract

This report describes the Perturbed Track Test, Pilot Test and Freight Test conducted at the Transportation Test Center in Pueblo, Colorado, in November and December 1978, August 1978, and February 1979, respectively. The tests involved two typical AMTRAK six-axle locomotives and two typical four-axle freight locomotives.

The report documents the objectives of the test, the preparation, the test conduct, the data obtained, and the potential uses of the data. Discussions of instrumentation effectiveness and track geometry measuring procedures are included, and selected typical results are presented.

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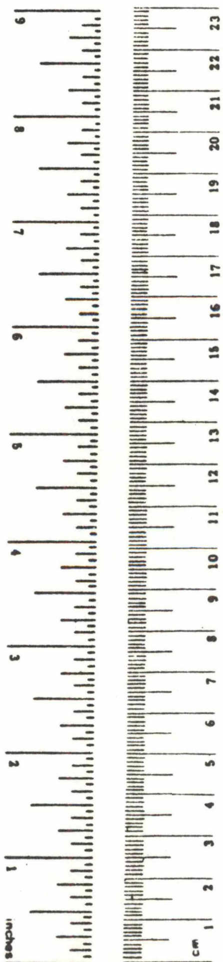
Approximate Conversions to Metric Measures

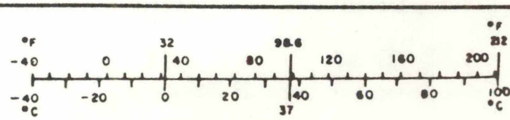
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	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

METRIC CONVERSION FACTORS



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



PREFACE

The purpose of this report is to provide detailed information about how the Perturbed Track Test was planned and conducted, and how and what data on vehicle and track dynamic performance was gathered. This will enable interested parties to assess how the data can fulfill their own needs. The data gathered in this test is available on request.

No analysis will be attempted in this report. There will be reports separately addressing each of the test objectives presenting the results of analyses as conducted by the various participants of the PTT program.

ACKNOWLEDGMENTS

The work described in this report was sponsored by the Office of Rail Safety Research of the Federal Railroad Administration (FRA). Guidance for the planning and design of the test was provided by a Government-Industry coordinating group composed of representatives of FRA, Transportation Systems Center (TSC), Association of American Railroads (AAR), AMTRAK, Electro-Motive Division of General Motors (EMD), and General Electric (GE). Test design and preparation were supported by the following agencies and companies: the Transportation Test Center (TTC) - track construction; The Analytic Sciences Corporation (TASC) - track design; ENSCO - onboard instrumentation; Arthur D. Little, Inc. (ADL) - test variables; Battelle Columbus Laboratories (BCL) - wayside instrumentation; R.A. Vanstone - instrumentation design; and Aerospace Corp. - freight test design.

During the tests, onboard instrumentation and data collection support was provided by ENSCO, wayside instrumentation by BCL, and photographic and physical measurement data by TTC. TTC also provided the test operational support.

A very special acknowledgement is due Mr. Edward F. Lind of AAR, whose active participation proved invaluable in providing guidance during planning and preparation of the test. Mr. Lind also served as the test director for the SDP-40F test series. Thanks are also due Mr. Vanstone for his assistance in designing part of the instrumentation and directing the tests. Finally, special thanks are due AMTRAK for providing the equipment used in these tests and the AAR for providing the signal conditioning equipment for the wheelsets.

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EXECUTIVE SUMMARY

During November and December of 1978, the Perturbed Track Test (PTT) involving the E-8 and SDP-40F locomotives was conducted at the Transportation Test Center (TTC) in support of the Federal Railroad Administration's (FRA) Track Research Program and the Vehicle/Track Interaction Subtask of the Track Train Dynamics (TTD) Program. In addition, a pilot test was conducted in August 1978 to provide design data for this test, and a follow-up freight test was conducted in February 1979 to provide supplemental data on four-axle locomotives and freight vehicles. The Transportation Systems Center (TSC) provided the FRA with support in technical planning and program management.

Presented here is a detailed explanation of the PTT conduct, the data that was collected, and some of the possible applications. Included in this explanation is the documentation of the instrumentation deployment and functionality, perturbed track layout, consist run sequence, and the preliminary results of the direct wayside/onboard instrumentation comparison.

Finally, selected representative results from both the E-8 and SDP-40F test series are presented to provide an indication of the type, quality, and magnitude of the data collected. Reports presenting the analyses relevant to each objective will be presented by the appropriate members of the PTT program in the future; therefore, no analyses have been attempted here.

1. INTRODUCTION

1.1 BACKGROUND

The SDP-40F locomotive was introduced into AMTRAK passenger service during the period between June 1973 and August 1974. Since then, 150 SDP-40F's have been used in all parts of the country. This locomotive is one of the heaviest in use today, weighing approximately 396,000 pounds when fully loaded with fuel and water. It is very similar to the SD-40-2 locomotive widely used in freight service and is equipped with identical HTC trucks. The primary differences between the SDP-40F and SD-40-2 locomotives are that the vehicle has been regeared to allow high speed passenger service, the vehicle length and truck center spacing have been increased by about 6 feet to accommodate a steam generator supplying hotel power, and the resulting loaded weight has increased by about 7.5% over the 368,000 pounds of the SD-40-2.

By January 1978, passenger trains powered by the SDP-40F locomotive had been involved in 21 derailments at speeds of 30 mph or greater. This derailment record caused concern among various safety interests. Between 1974 and 1977, several special tests were conducted to examine different aspects of the dynamic performance of the SDP-40F locomotive and to determine the derailment tendencies of these consists as operated on major railroads. The major tests include: tests on the Santa Fe Railroad in 1974[1] to study the influence of new and worn wheel profiles on vehicle stability and to evaluate the ride quality of locomotives equipped with HTC trucks; tests on the Illinois Central Gulf (ICG) Railroad in March 1976[2,3] to evaluate the ride quality of the SDP-40F locomotive and the associated potential safety problems; tests on the Southern Pacific (SP) Railroad in November 1976[4] to evaluate the dynamic performance of HTC trucks; tests on the Burlington Northern (BN) Railroad in March 1977[5] to investigate possible "trigger" mechanisms or underlying causes of SDP-40F locomotive derailments; tests on the Chessie System track in June 1977[6] to establish experimentally the differences between the dynamic performance of the SDP-40F and the E-8 locomotives and the characteristics of the SDP-40F locomotive/track interaction for vehicle parameters simulating different stages of maintenance.

These tests for evaluating vehicle dynamic performance, conducted <u>after the fact</u> of a perceived safety problem, demonstrated the need for <u>before the fact</u> guidelines for assessing new equipment prior to introduction into revenue service. These after the fact field tests involved many organizations from the railroad community as well as the Government, and consumed extensive resources. The methodologies and conditions of these tests were generally different, which makes relating the results of one test series to another difficult if not impossible. Because of these problems, it has become apparent that there is a need for a standardized test and analysis methodology which could identify for a vehicle type the potential for undesirable response charcteristics in revenue service. To achieve this highly desirable objective, it has been proposed that a permanent facility be designed in order to conduct standardized tests related to dynamic performance safety under controlled, consistent conditions. Such a facility would be the proposed Safety Assessment Facility for Equipment (SAFE). This facility could be used not only to establish the safe operating boundaries of a vehicle at different stages of maintenance, but also as a common basis for comparing the dynamic performance of different vehicles.

One of the major objectives of the Perturbed Track Test is to demonstrate the feasibility of such a concept and to provide data and guidelines for the design of such a facility.

1.2 PTT OVERVIEW

The Perturbed Track Test (PTT) program consists of three sets of tests: a Pilot Test in August of 1978, the main 6-Axle Locomotive Test Series in November and December of 1978, and a follow-up Freight Test in February of 1979. These tests were performed at the Transportation Test Center and were developed under a cooperative Government-Industry effort to provide an extensive data base on vehicle/track interaction, using controlled track geometry perturbations. The specific PTT objectives and the contributions of the participating organizations are discussed in Chapters 1.3 and 1.4, respectively. A detailed discussion of each test series is contained in Chapters 2 (Pilot Test) and 3 (Main Test and Freight Test). Following is a general overview of the testing program.

The Pilot Test was conducted using an E-8 locomotive consist operating over a trial set of perturbations. This test was intended primarily to aid in the design and execution of the main tests.

In the main 6-Axle Locomotive Test Series, E-8 and SDP-40F locomotive consists were operated at speeds between 35 and 80 mph over two perturbed track test zones: a tangent zone on the Railroad Test Track (RTT) and a 1.5°, 3" superelevation curved zone on the Train Dynamics Track (TDT). Balance speed in the latter zone was 53 mph with 3 inches of underbalance corresponding to 76 mph. Both zones consisted of 136 lb. bolted joint rail (BJR) with hardwood ties having a 19.5" tie center spacing. The test consists were generally made up of one or two locomotives, a shared baggage car, and a data acquisition vehicle, T-5 for the E-8 consist and T-7 for the SDP-40F consist.

The perturbed track test zones, designed to excite significant dynamic responses under controlled conditions, included isolated sections of alignment, crosslevel, and profile perturbations, as well as a section of combined alignment and crosslevel perturbations on both the tangent and curve. The perturbation fundamental wavelengths (78' and 39') and shapes (piecewise linear and rectified sine) were varied from section to section. The effect of lateral track stiffness was also investigated by altering the spiking pattern in a rectified sine alignment section to simulate laterally "soft" track. In addition, a curve section of high-rail-only misalignment was divided into three subsections of varying superelevation so that the effects of balance speed could be isolated.

Aside from the perturbed track sections, the principal test variables were: speed, vehicle type and loading, locomotive position and orientation, rail surface condition, primary suspension damping, and restricted vertical coupler freedom.

An extensive amount of instrumentation, both onboard and wayside, was used to measure the response of the test vehicles to the perturbed track. Five instrumented wheelsets were used to measure lateral and vertical wheel loads: three on the trailing truck of the SDP-40F locomotive, one on the lead axle of the trailing truck of the E-8 locomotive, and one on the lead axle of the leading truck of the baggage car. In addition, both instrumented locomotives and the baggage car were equipped with carbody accelerometers to assess ride quality, and the instrumented locomotives were further equipped with displacement transducers to measure truck yaw on the lead and trailing trucks. The SDP-40F also had extensive instrumentation on its trailing truck to measure accelerations and relative displacements of its primary and secondary truck suspension components. Finally, the coupler between the SDP-40F and the baggage car was instrumented to measure coupler forces and angles.

Seven sites of wayside instrumentation were used during the PTT, six of which were in the curved test zone. These included four sites measuring vertical and lateral rail forces: one in each of the three subsections of varying superelevation, and one in the combined piecewise linear alignment and crosslevel section. This latter site was extensively instrumented and also included measurements of rail and tie displacement through the use of mechanical and electronic displacement transducers. Two additional sites on the curve, in the rectified sine alignment subsection of nominal and "soft" track, were also equipped with mechanical and electric displacement transducers. Finally, one section in the tangent test zone (a combined piecewise linear alignment and crosslevel section) was equipped with mechanical displacement transducers measuring tie shift and dynamic gage.

After completion of the main tests, a follow-up Freight Test was conducted using only the curved test zone and its wayside instrumentation. The principal variables in this test were vehicle type, loading, and speed. The test consists varied from 5 to 30 cars, including hoppers, gondolas, tanks and trailer-on-flatcars (TOFC), and were pulled by four 4-axle locomotives (three GP-40's and one U-30-B).

Throughout all the tests, track geometry was carefully measured using several measuring procedures as discussed in Chapter 4. This data will be used to generate a complete track geometry data base to be used in conjunction with the vehicle response data and the dynamic rail deflection data.

1.3 THE PERTURBED TRACK TEST OBJECTIVES

The Perturbed Track Test (PTT) has been designed to provide a broad base of experimental information to relate dynamic performance characteristics of the SDP-40F and E-8 locomotives measured under controlled track inputs to those experienced under revenue service conditions. The specific tests were designed to support both the FRA Track Research Program and the Vehicle/Track Interaction Subtask of the Track Train Dynamics (TTD) Program. The major objectives of the test program are defined as follows:

1. To demonstrate and evaluate the capability of controlled perturbed track testing for the

determination of vehicle safety-related dynamic performance and to provide design data for SAFE.

2. To establish a basis for simulating revenue service track responses by experimentally determining the relations between key controlled track, equipment and operational parameters and safety-related dynamic performance

3. To obtain information for the validation of analytical models of locomotive dynamic performance for the enhancement of the ability to interpret the test results and extrapolate to the full range of track and operational configurations.

4. To provide data for the validation of analyses being conducted for specifying improved track safety standards.

The follow-up PTT Freight Test was conducted with the above objectives in mind. However, the specific objectives of the test were different, reflecting the very different test plan, consist makeup, and data collected. These objectives are defined as follows:

1. To identify types of perturbations which excite freight car response and to further aid in the design of SAFE.

2. To increase the available data base of wheel/rail forces with additional freight cars and locomotives in support of the development of improved track safety standards.

3. To compare the dynamic performance characteristics of different generic types of freight vehicles, under both loaded and unloaded conditions.

4. To initiate a Safety Lifecycle data base of vehicle dynamic responses for known states of component degradation.

Within the general framework of these objectives, the Perturbed Track Test was designed to answer several specific questions relating to locomotive performance and testing methodology. Each test variable, including the perturbed track sections, addresses one or more of the objectives. While the test variables are discussed in detail later in the report, the general objectives which they address are presented here for clarity.

A primary objective of the PTT was to determine the legitimacy of testing with controlled track perturbations. The questions answered here relate to SAFF design and locomotive performance. Specifically, the track inputs address questions relating to the ability to superimpose perturbation types, the effects of lateral track stiffness, and the importance of tangent versus curved track testing. In addition, the effects of balance speed, input frequencies, decay rates, and the importance of perturbation waveform were investigated.

The other primary objective of the PTT was to evaluate the dynamic performance of rail vehicles and to supply data to quantitatively assess the factors contributing to variations in wheel/rail forces. This objective was addressed with a series of test variables including speed, locomotive and vehicle type, locomotive position and orientation, rail surface condition, suspension damping, and restricted vertical coupler freedom. The revenue track tests discussed previously showed that there were definite differences in the dynamic response of the SDP-40F and E-8 locomotives and trailing baggage cars. These variables were also included to determine how each affects the response and whether this effect is vehicle-dependent. In addition, the follow-up PTT Freight Test provided important data for four-axle locomotives and various types of freight vehicles, allowing a comparison between the dynamic response of four-axle and six-axle locomotives and passenger and freight type vehicles.

The absolute levels of maximum allowable dynamic responses to assure vehicle safety and to minimize track deterioration are yet to be established. However, the comparative testing of one vehicle against a generically similar vehicle with an established history that has been considered acceptable will still be a sound experimental approach for identifying possible problem areas. Thus, both SDP-40F and E-8 locomotives were included for testing.

1.4 DISTRIBUTION OF RESPONSIBILITIES

The Perturbed Track Test (PTT) program was developed under a cooperative Government-Industry effort. Sponsorship and overall direction was provided through the Office of Rail Safety Research of the Federal Railroad Administration (FRA). Guidance for the planning and design of the test program was provided by a Government-Industry review group composed of representatives of the Federal Railroad Administration (FRA), Transportation Systems Center (TSC), Association of American Railroads (AAR), AMTRAK, Electro-Motive Division of General Motors (GM-EMD), and General Electric (GE). In support of this effort, TSC was assigned responsibility for technical planning and program management. To facilitate this effort, the test program was divided into four phases and is summarized in Figure 1-1. Additional technical support was provided by the following contractors: Arthur D. Little (ADL), Battelle Columbus Laboratories (BCL), ENSCO, The Analytic Sciences Corp. (TASC), R. A. Vanstone, and T.K. Dyer. Aerospace Corp. assisted in the design of the Freight Test.

Test planning was the responsibility of TSC with the assistance of the PTT Planning Committee made up of the Steering Committee and five subcommittees (Figure 1-2). Members of the committees included representatives from Government, the railroad industry, and contractors. The Steering Committee was responsible for the overall direction of the subcommittees. Each subcommittee was responsible for preparing specific elements of the overall plan. Within its area, the subcommittee provided guidance for and reviewed the work of contractors and consultants assisting in the planning activities. Each subcommittee chairperson was responsible for coordination with other subcommittees.

Test preparation consisted of all activities involving construction, installation, and calibration prior to the execution of a test. The responsibility for technical management of test preparation resided with TSC, and was directed by the project manager. Actual control of test preparation activities at TTC was the responsibility of the TTC Test Controller.

Test execution consisted of all on-site activities that directly affected the execution of a test series, beginning with the final calibration checks and briefing of test support personnel, and continuing until the final run of the series had been made. The General Manager-Test had the responsibility for insuring that the tests were conducted within the prescribed time frame and that useful data were collected.

Perturbed Track Test data analysis plans, methods, and conclusions drawn from the data will be reviewed by a review group composed of representatives of at least the FRA, AAR, TSC, TTC, AMTRAK, EMD, and GE. TSC will support this phase

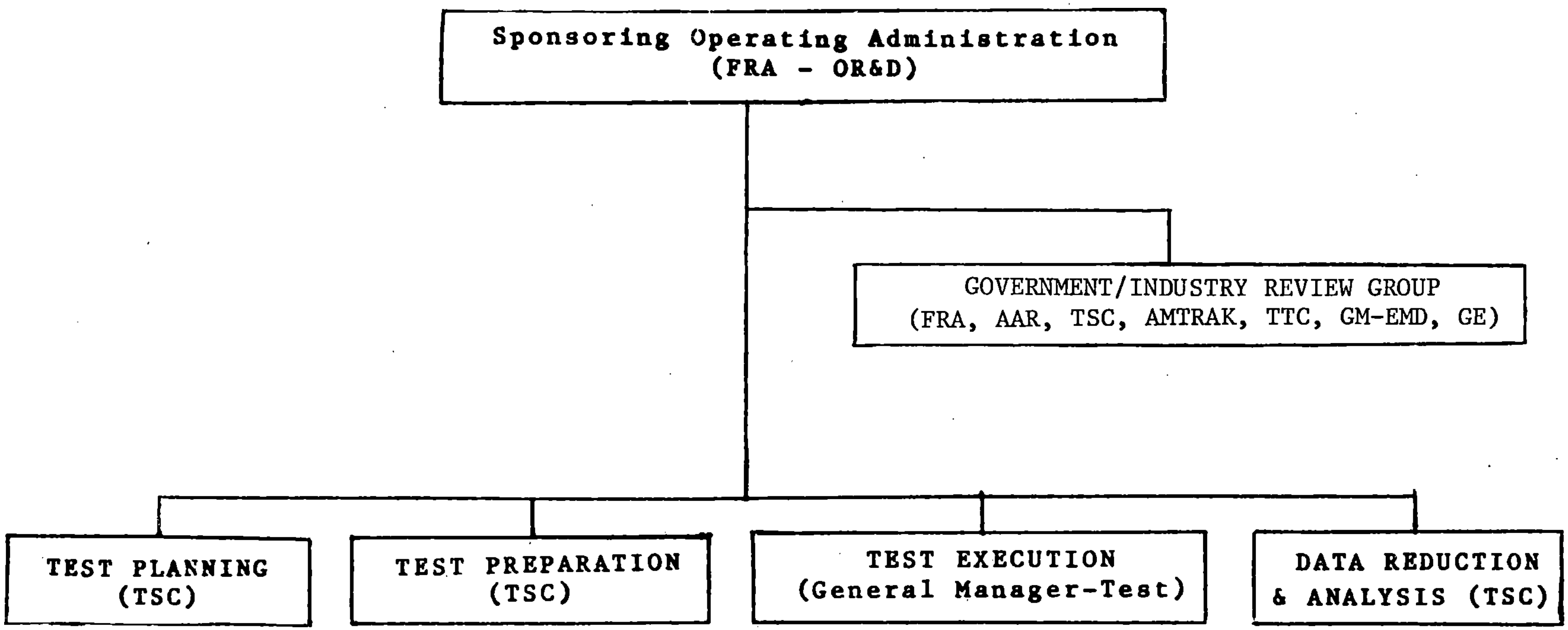
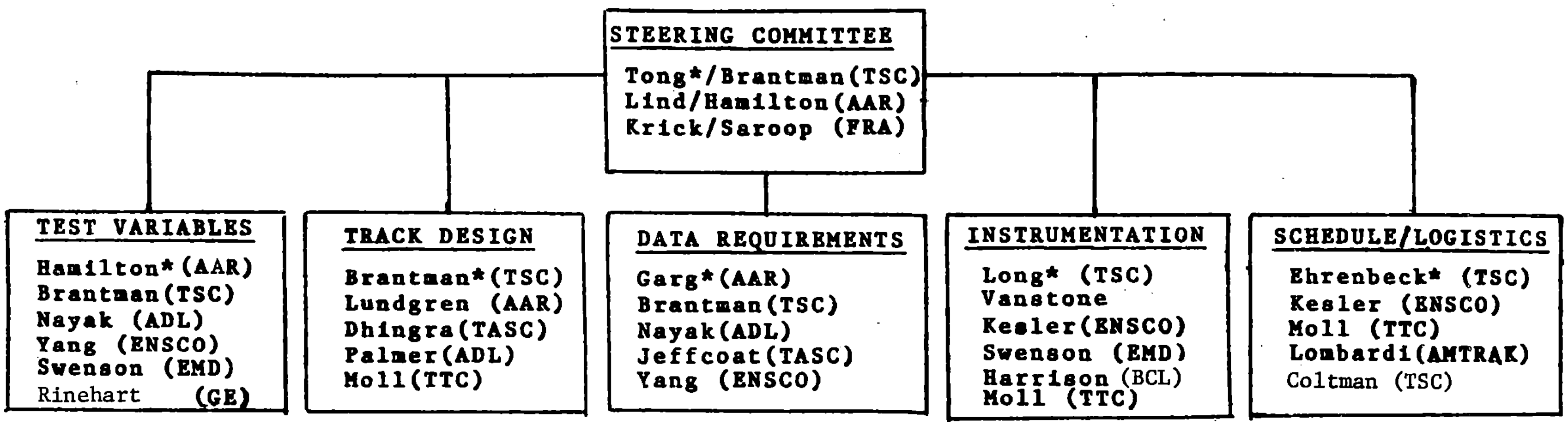


FIGURE 1-1. GENERAL ORGANIZATION



*Committee Chairperson

FIGURE 1-2. ORGANIZATION OF PTT PLANNING COMMITTEE of the test with a task force responsible for data reduction/analysis.

The Task Force Leader provides overall direction of the data reduction/analysis effort. The leader assures that coordination is maintained between data and error analysis and that test results are applied to establish the design for SAFE. The Task Force Leader is responsible for the presentation of test results and conclusions to the Review Group.

1.5 ORGANIZATION OF REPORT

A great deal of data pertaining to the dynamic performance of the SDP-40F and the E-8 locomotives and their trailing baggage car was gathered in the main test series. The freight test supplied additional data for four-axle locomotives and various types of freight vehicles. This data is available at the request of any interested party. The purpose of this report is to provide detailed information on how the tests were conducted and how and what data was gathered. This is to provide any interested party a guide to the available data for their assessment of how this data might meet their needs.

Chapter 2, Pilot Test, provides an overview of the objectives and results of the pilot program with a brief description of the actual test. Chapter 3, Main Test Description, gives details on the test consists and configurations, track design, onboard and wayside instrumentation design and deployment, and test matrix and significant test events. Chapter 4 describes the type of data collected from the onboard and wayside instrumentation. Also included is a description of the track geometry and vehicle parameter data collected. It also gives data tape formats and a log of the functionality during the test of the data collection systems. Chapter 5 provides a detailed discussion of the physical measurements and calibrations performed during the test and preliminary results of the direct wayside/onboard instrumentation comparison. Some typical test data is presented in Chapter 6. It is intended as an illustration and is by no means comprehensive, nor is any analysis of the data attempted in this report.

It is presently anticipated that there will be separate analysis activities addressing each of the test objectives. These analyses will be performed by the various participants in the PTT program. Results of these analyses will be presented in separate reports. Some of the potential data applications are presented in Chapter 7. A pictorial record of the test is presented in Appendix A. A compilation of the test matrices, as run and as planned, and a discussion of the objectives of each test series is included in Appendix B.

2. PILOT TEST

In August of 1978, a pilot test was conducted at TTC to provide data for the design of the main Perturbed Track Tests. This chapter presents an overview of the test, including the objectives and conclusions drawn from the data collected. The test is described in detail in Reference [7].

2.1 OBJECTIVES

The Perturbed Track Pilot Test was conducted with the following objectives:

1. To compare two perturbation types (piecewise linear and rectified sine) in order to select the form to be used in the final perturbed track design.

2. To establish the required amplitude of these perturbations in order to produce significant force levels, while still remaining within the acknowledged boundaries of safe operation.

3. To assess the feasibility and accuracy of the currently proposed track perturbation installation procedures.

4. To assess the stability of the perturbations under repeated loading, and to provide recommendations on maintainability and controllability.

5. To provide a checkout of the wayside instrumentation under dynamic conditions on perturbed track, and to dynamically compare the Battelle and TTC lateral force circuits.

2.2 TEST OVERVIEW

2.2.1 Test Consists

Three consist configurations were used during the pilot test, all using E-8 locomotives for tractive effort. The first consist was made up of the Transportation Safety Institute (TSI) 210 locomotive and the FRA's T-5 data acquisition vehicle. The next was just the TSI 210 locomotive, and the third was made up of the Amtrak 417 locomotive, the TSI 210, and the T-5 data acquisition vehicle. The single locomotive consist (without the T-5 car) was used to test the stability of the track geometry.

2.2.2 Track

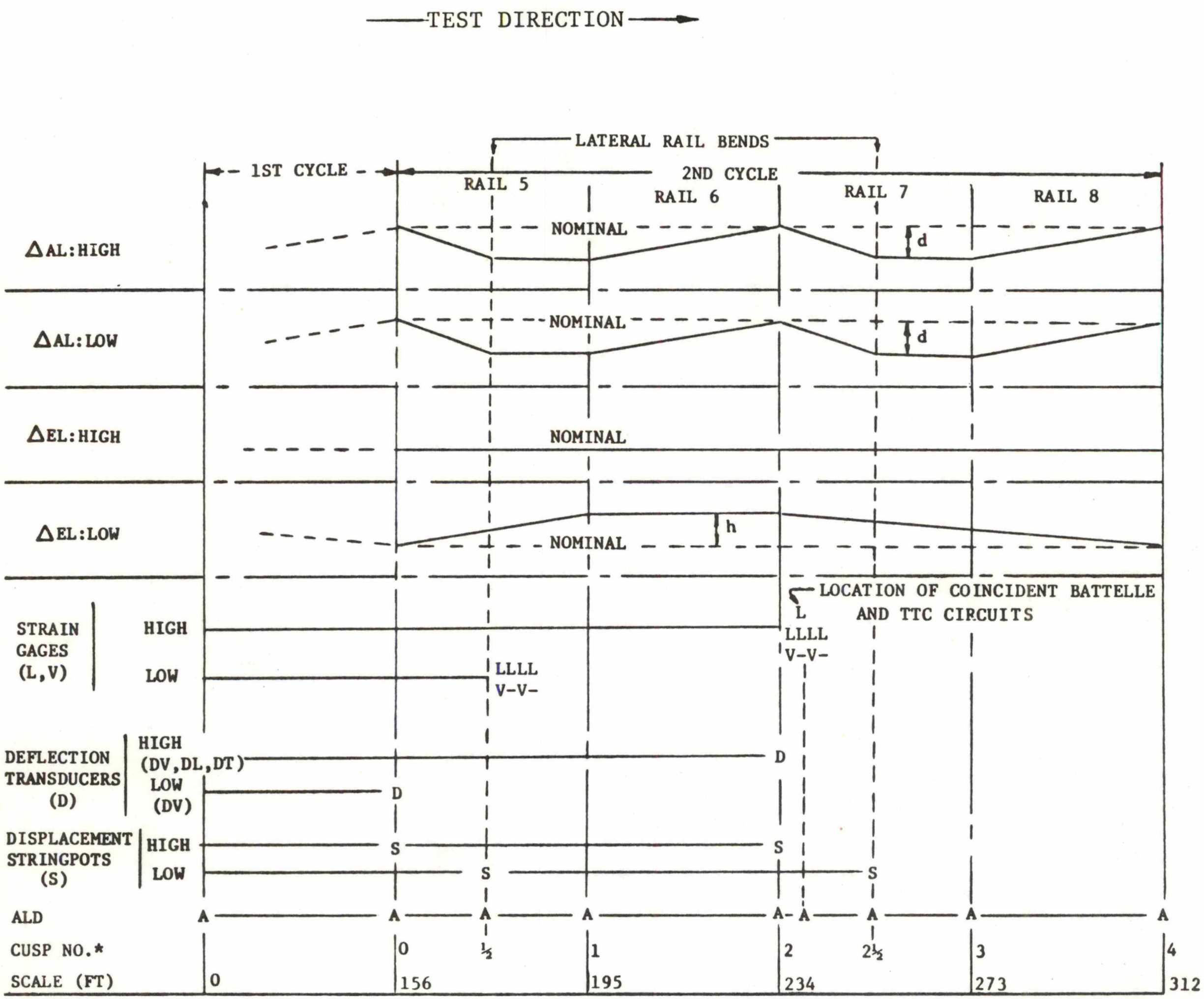
There were two types of track geometry used in the pilot test: piecewise linear alignment and crosslevel, and rectified sine alignment and crosslevel. The piecewise linear alignment perturbation had a fundamental wavelength of 78 feet, two rail lengths. The piecewise linear crosslevel perturbation was imposed by shimming the low rail and had a fundamental wavelength of 156 feet, four rail lengths. The rectified sine alignment and rectified sine crosslevel perturbations both had 39-foot fundamental wavelengths. Figures 2-1 and 2-2 show representations of the two sections. The perturbations were built on curved track, so the nominal views of alignment should include a 1.5 degree curvature.

During the pilot test, the track geometry was adjusted after two days of test runs. Therefore, two stages of track geometry existed for the pilot test: Stage 1 and Stage 2. The Stage 1 track geometry contained one section of piecewise linear perturbations and one section of rectified sine perturbations. Each section contained four repeated alignment cycles as defined in Figures 2-1 and 2-2. After two days of testing, the track geometry was modified to Stage 2. Changes from Stage 1 track geometry included modifications of both sections, plus the addition of two new sections. The modifications of the Stage 1 sections adjusted the alignment of the last two cycles of each section to match the larger amplitude design specifications of the new sections. The two new sections were designed with the same waveshape as in Stage 1, but with two cycles each instead of four.

The Plasser Car and the Track Survey Device were used to measure the "as built" track geometry. These devices are discussed in detail in Chapter 4.

2.2.3 Instrumentation

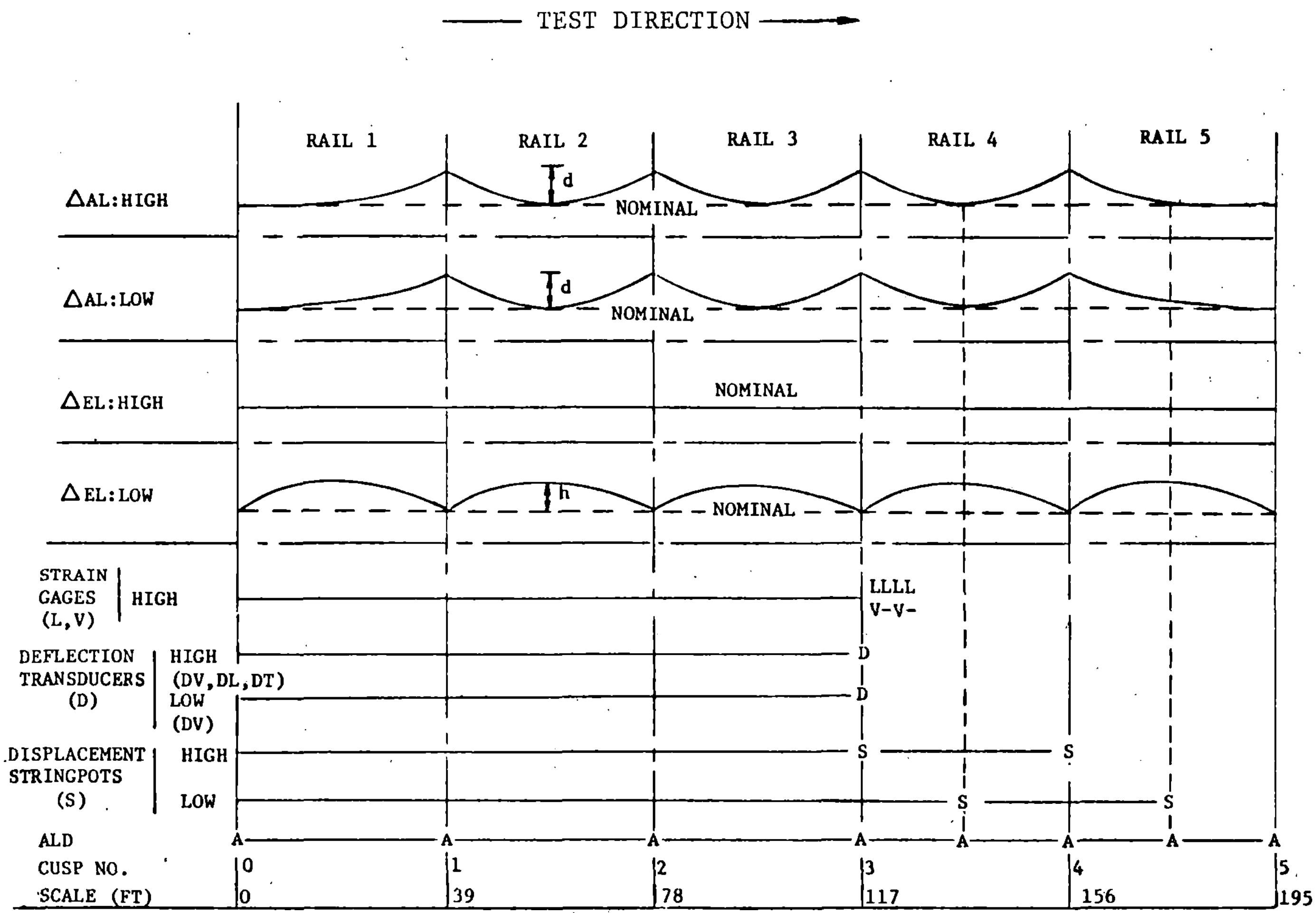
The onboard instrumentation consisted of one instrumented wheelset positioned on the leading axle of the trailing truck of the TSI 210 locomotive, an Automatic Location Detector (ALD) at this axle, and a ride quality package positioned over the trailing truck. The ride



* IN REPEATED CYCLES, CUSP NO. 0 AND CUSP NO. 4 ARE THE SAME.

TRACK GEOMETRY STAGE 1: h = 1.5", d = 1.5"
TRACK GEOMETRY STAGE 2: h ≤ 2.0", d ≤ 2.5"

FIGURE 2-1. TEST SECTION 1, PIECEWISE LINEAR WAVEFORM AND WAYSIDE INSTRUMENTATION



TRACK GEOMETRY STAGE 1: h = 1.5", d = 1.5"
TRACK GEOMETRY STAGE 2: h ≤ 2.0", d ≤ 2.5"

FIGURE 2-2. TEST SECTION 2, RECTIFIED SINE WAVEFORM AND WAYSIDE INSTRUMENTATION quality package measured linear and angular accelerations in the three principal axes of the locomotive. This data was recorded on a digital tape and displayed on brush charts. The channel assignments for the tapes are presented in Table 2-1.

Wayside instrumentation consisted of 19 channels of force measurements and 8 channels of displacement measurements installed, calibrated, and recorded by Battelle. Strain gages were obtained by TTC. In addition, 8 mechanical stringpots to measure maximum rail head lateral deflection were installed, maintained, and recorded by TTC. ALD magnetic targets were installed and maintained by TTC.

The locations of these gages are shown in Figures 2-1 and 2-2. L = lateral force, V = vertical force, D = electrically recorded displacement measurements, DV = joint vertical displacement, DL = rail head lateral displacement, DT = tie lateral displacement, S = mechanical stringpot measurement of maximum rail head lateral deflection, A = ALD target. Instrumentation is located as follows:

a. At each force measurement site, L circuits (Battelle type) were located in the four consecutive cribs following the cusp, while V circuits were located only in the 1st and 3rd crib.

b. Battelle and TTC lateral circuits were located together in the 2nd crib of the high rail site on the piecewise linear test section.

c. D and S measurements were made directly at the indicated cusps.

d. ALD magnetic targets were placed, and secured from movement, directly at every cusp in the two test sections and at the station where the Battelle and TTC lateral circuits were compared. In addition, ALD targets were placed equidistant at 4 rail length intervals in the nominal section between the two test sections.

2.2.4 Test Sequence

The test sequence was divided into four test series, Series I through IV. Table 2-2 gives a summary of the four test series performed. The test parameters varied were:

TABLE 2-1. PTT PILOT TEST T-5 COMPUTER INPUT CHANNEL ASSIGNMENTS

CHANNEL #	DESCRIPTION
0	** #4 AXLE VERTICAL FORCE LEFT
1	** #4 AXLE VERTICAL FORCE RIGHT
2	** #4 AXLE LATERAL FORCE LEFT
3	** #4 AXLE LATERAL FORCE RIGHT
4	** #4 L/V LATERAL FORCE LEFT
5	** #4 L/V LATERAL FORCE RIGHT
6	* #4 AXLE VERTICAL BRIDGE #1 LEFT (0° & 180°)
7	* #4 AXLE VERTICAL BRIDGE #1 RIGHT (0° & 180°)
8	* #4 AXLE VERTICAL BRIDGE #2 LEFT (90° & 270°)
9	* #4 AXLE VERTICAL BRIDGE #2 RIGHT (90° & 270°)
10	* #4 AXLE LATERAL BRIDGE #3 LEFT SINE
11	* #4 AXLE LATERAL BRIDGE # 3 RIGHT SINE
12	* #4 AXLE LATERAL BRIDGE # 4 LEFT COSINE
13	* #4 AXLE LATERAL BRIDGE #4 RIGHT COSINE
14	SPEED (T-5)
15	AUTOMATIC LOCATION DETECTOR (E-8)
16	* #4 AXLE ENCODER (BRIDGE LOCATION) #1 (22.5°) LEFT
17	* #4 AXLE ENCODER (BRIDGE LOCATION) #2 (67.5°) LEFT
18	* #4 AXLE ENCODER (BRIDGE LOCATION) #3 (112.5°) LEFT
19	* #4 AXLE ENCODER (BRIDGE LOCATION) #4 (337.5°) LEFT
20	* RQP "A" VERTICAL
21	* RQP "A" LONGITUDINAL
22	* RQP "A" LATERAL
23	* RQP "A" PITCH
24	* RQP "A" ROLL

* J-BOX SIGNALS FROM E-8 LOCOMOTIVE
** SIGNALS FROM ENSCO WHEEL PROCESSING CHASSIS

TABLE 2-2. SUMMARY OF PERTURBED TRACK PILOT TEST

	CONSIST	TRACK* GEOMETRY	NUMBER OF RUNS	SPEED RANGE, MPH	RAIL SURFACE
Series I (August 16 & 19)	T-5 TS1 210	Stage 1	14 12	5 to 67 15 to 67	Dry Sand
Series II (August 30)	T-5 TS1 210	Stage 2	10 11	15 to 60 25 to 65	Dry Sand
Series III (August 31)	TS1 210	Stage 2	10 10 5	45 50 55	Dry Dry Dry
Series IV (September 1)	T-5 TS1 210 417 Instrumented Wheelset	Stage 2	9 6	26 to 61 26 to 49	Dry Sand

*See accompanying text for explanation of Stage 1 and Stage 2 track geometry.

Track geometry - Stage 1, Stage 2;

Consists - E-8 locomotive, E-8 locomotive and T-5, two E-8 locomotives and T-5;

Speed - 5 to 67 mph;

Rail surface condition - dry, sanded.

Data collected during Series I and II can be compared to show the effects of Stage 1 versus Stage 2 track geometry. Series III is meant to test the track geometry stability after repeated runs. Series IV can be used to show the effects of two locomotives as compared to one locomotive in the consist.

2.3 CONCLUSIONS

Several issues were investigated, using the results of the pilot test. The following conclusions are derived from these investigations.

- Both the piecewise linear and rectified sine perturbation types provided sufficient vehicle response.
- Bent rails and bent joint bars provided accuracy no greater than obtained from bolting cut rail sections.
- Four contiguous alignment cycles are sufficient to build vehicle response to a steady-state level.
- Battelle's strain gage circuits were satisfactory in static and dynamic comparisons with other types.
- Improved rail instrumentation calibration techniques should be developed.
- Unperturbed sections are required to separate perturbed sections.
- An unperturbed length of 10 rail lengths between sections is sufficient.
- Test results have excellent repeatability.

- At the forces measured, the track geometry is stable to within .30 inches.

- Maximum construction deviations from the intended track geometry occurred at the rectified sine joints.

- Rectified sine profile perturbations greater than .5" lead to suspended joints.

- Improvements in track construction techniques should allow accurate construction to within .20 inches lateral effect.

3. MAIN TEST DESCRIPTION

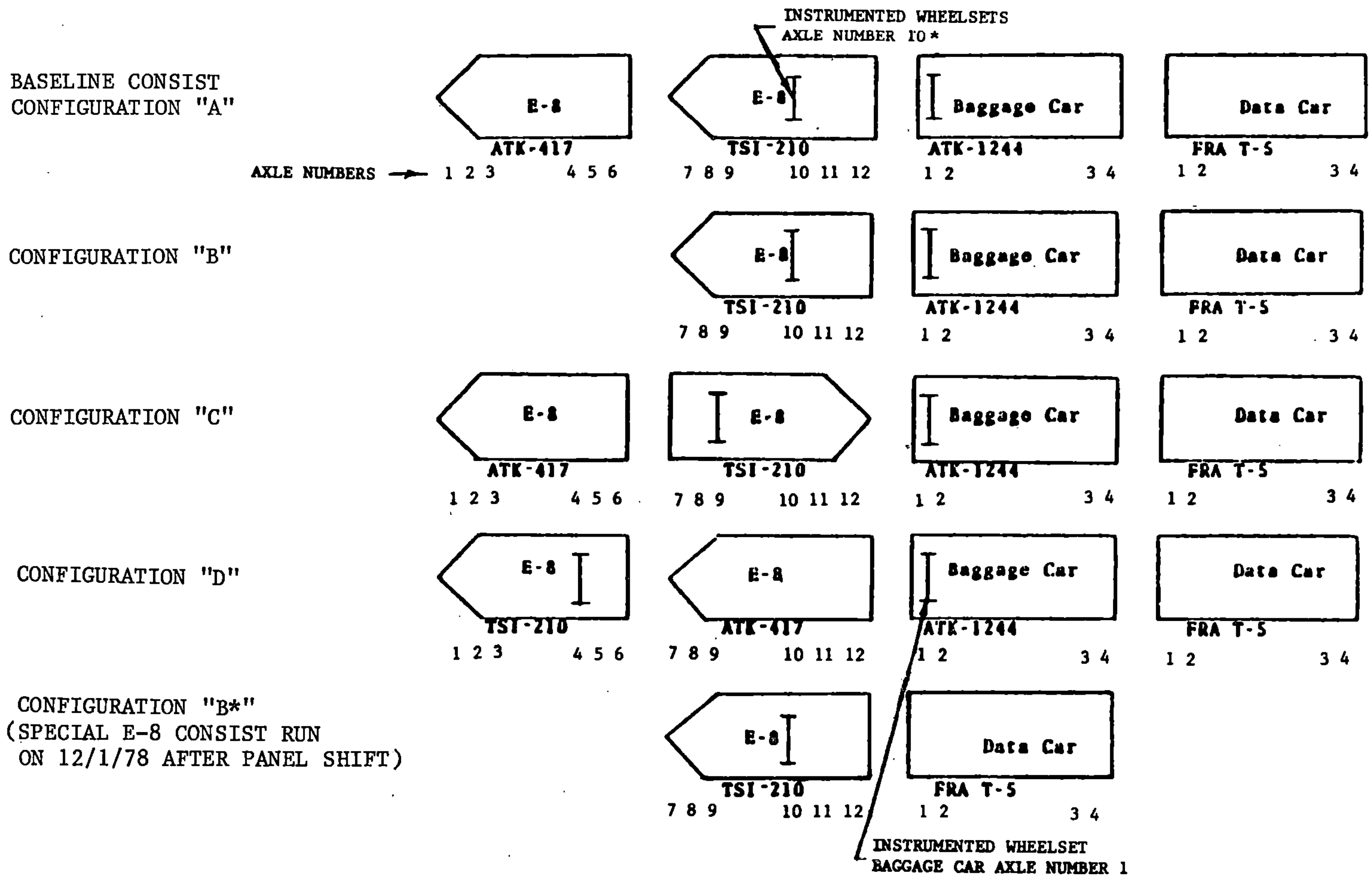
3.1 TEST CONSISTS

Three separate test consists were operated over the Perturbed Track Test sites at TTC: two during the main testing period in November and December; and a third during the follow-up freight tests in February. The main tests were conducted with six-axle, E-8 and SDP-40F locomotives and a shared Amtrak baggage car. The specific locomotives and baggage car chosen were the same ones that had been used in the Chessie Test in June 1977. The baggage car was the one that had been pulled in the SDP-40F consist. However, since the time of the Chessie Test, Amtrak has made some modifications to the baggage car. The most significant changes being the installation of vertical snubbers on the baggage car, and the modification of the baggage car's coupler draft gear, providing a softer spring resistance. Both the SDP-40F locomotives were equipped with the original, stiffer secondary suspensions. The freight test used four-axle locomotives, three GP-40's and one U-30-B, and a variety of freight vehicles, all obtained from either the Facility for Accelerated Service Testing (FAST) or TTC. A description of the consists is provided below. Detailed data pertaining to the weights and physical dimensions of the vehicles is presented in Chapter 5.

In the following discussion, a consistent axle numbering convention has been used to prevent confusion. For the locomotives, the axles are always numbered consecutively: from 1 to 16 for the freight test, and from 1 to 12 for the main test (as if there were always a two-locomotive consist). The axles for all other cars have been labeled from 1 to 4 and are referenced to vehicle number for the freight test, or to vehicle name for the main test. The principal exception to this convention is in the instrumentation channel assignment tables where the axles are referenced from the "A" end of the specific vehicle.

3.1.1 E-8 Test Consist

The baseline E-8 test consist was made up of the Transportation Safety Institute (TSI) 210 locomotive, the Amtrak 417 locomotive, the Amtrak baggage car Number 1244 (old Number 1025) and the FRA data acquisition vehicle T-5. The configuration of the consist was an independent variable of the test. These variations are shown in Figure 3-1. The instrumented locomotive was the TSI 210 which was not the



* LOCOMOTIVE AXLES REFERENCED ACCORDING TO SPACIAL POSITION AS IF THERE WERE ALWAYS 2 LOCOMOTIVES

FIGURE 3-1. E-8 LOCOMOTIVE TEST CONSISTS case in the Chessie Test. This was necessitated by scheduling requirements on the locomotives.

3.1.2 SDP-40F Test Consist

The baseline SDP-40F test consist was comprised of the Amtrak 620 locomotive, the Amtrak 586 locomotive, Amtrak baggage car Number 1244 (old Number 1025) and the FRA data acquisition vehicle, T-7. As with the E-8 test consist, the SDP-40F consist was tested in a variety of configurations. (See Figure 3-2.) The instrumented locomotive, as in the Chessie Test, was the Amtrak 620.

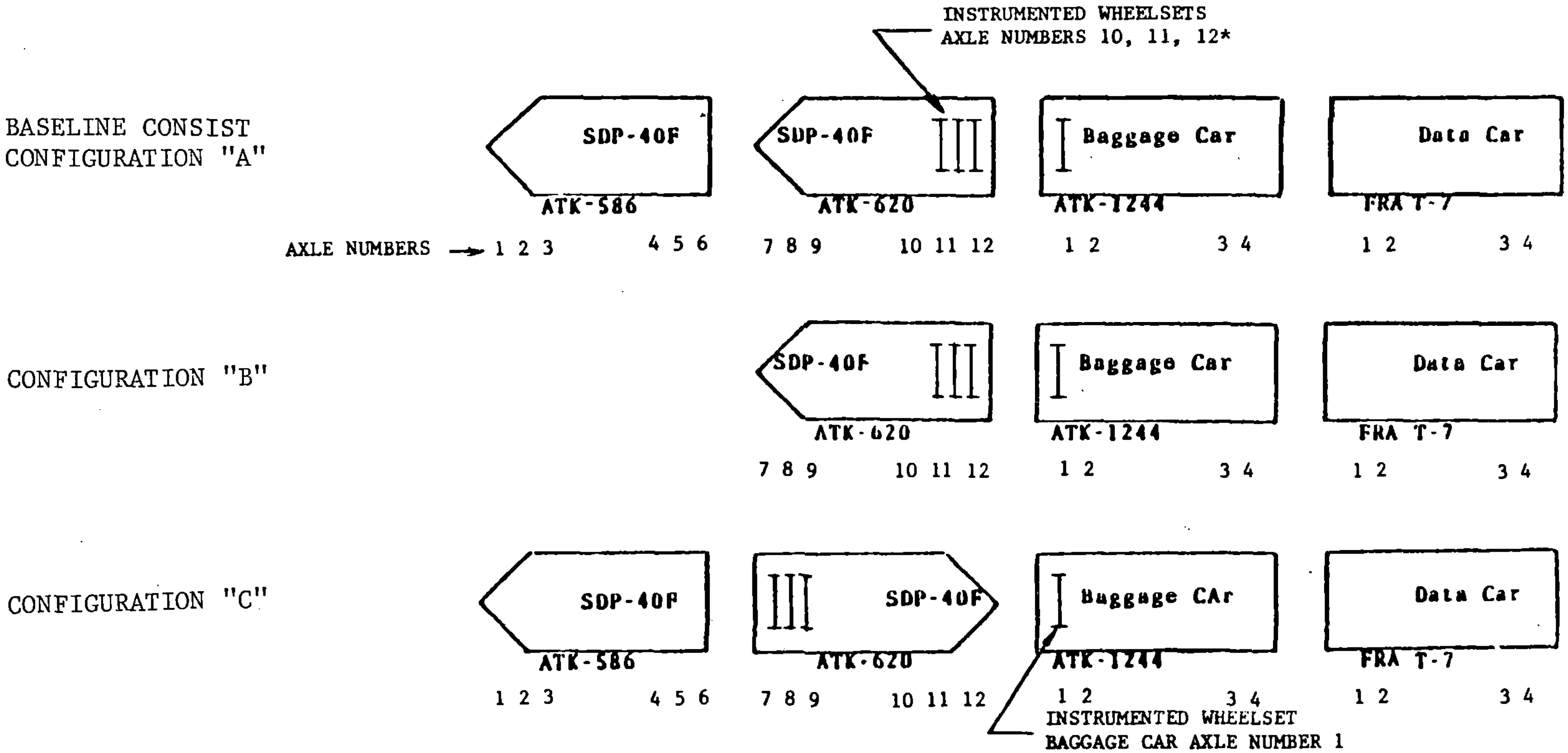
3.1.3 Freight Test Consists

During early February, two freight consists were operated over the curved PTT zone. Tractive effort for both consists was supplied by four locomotives: the DOT 003, the Alaska Railroad 3011 and 3001, and the Chessie 8208. The first day's consist contained loaded and unloaded hopper, tank, and trailer-on-flat cars (TOFC). At the highest speed runs, however, only the loaded hoppers were included. A listing of this consist is shown in Table 3-1. The second day's consist contained up to 30 cars from the FAST consist, all of which were loaded. During the test, cars were dropped from the lead end of the consist to attain higher speeds, (a broken rail in the FAST loop restricted the length of track available for accelerating the consist to speed). The consist configuration is listed in Table 3-2 with some pertinent information about the physical characteristics of each car.

3.2 TRACK

The PTT utilized two perturbed track test zones: a tangent zone on the RTT, and a 1.5°, 3" superelevation curved zone on the TDT. Balance speed in the latter zone is 53 mph, with 3 inches of underbalance corresponding to 76 mph. Both zones consisted of 136 lb. bolted joint rail (BJR) with hardwood ties having a 19.5" tie center spacing.

Within these zones, nine sections of perturbed track, five in the curved zone and four in the tangent zone, were built with the goal of providing controlled vertical and lateral excitations satisfying Class 4 track standards. These perturbed sections were separated by sections of high-quality nominal track of either 11 or 12 rail lengths so

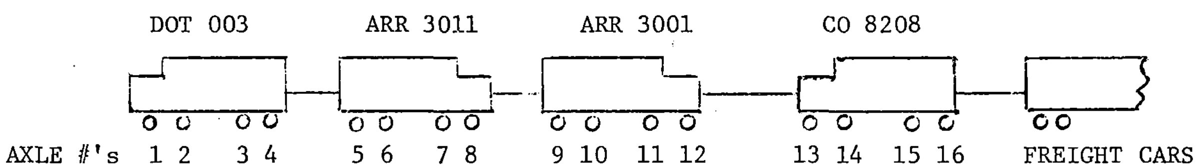


* LOCOMOTIVE AXLES REFERENCED ACCORDING TO SPACIAL POSITION AS IF THERE WERE ALWAYS 2 LOCOMOTIVES

FIGURE 3-2. SDP-40F LOCOMOTIVE TEST CONSISTS

TABLE 3-1. PTT FREIGHT VEHICLES
CONSISTS 2/3/79

RAILROAD CAR NUMBER	AXLE OR CAR NUMBER	TYPE	CAR WEIGHTS	WHEEL LOADS	FAST NUMBER	CONSISTS
		LOCOMOTIVES	(kip)	(kip)		
DOT 003	1 - 4	GP-40-2 4-AXLE	256	32.0	-	5 AND 11 CAR CONSISTS
AAR 3011	5 - 8	GP-40-2 4-AXLE	256	32.0	-	
ARR 3001	9 - 12	GP-40-2 4-AXLE	256	32.0	-	
CO 8208	13 - 16	U-30-B 4-AXLE	255	31.9	-	
CN 330092	1	LOADED HOPPER	263	32.8	52	
NW 140086	2	LOADED HOPPER	263	32.9	22	
BN 526327	3	LOADED HOPPER	264	33.0	2	
BN 527077	4	LOADED HOPPER	262	32.8	33	
UP 37605	5	LOADED HOPPER	265	33.1	41	
SOU 79339	6	UNLOADED HOPPER	70	8.8	-	11 CAR CONSIST ONLY
TP 588257	7	UNLOADED HOPPER	61	7.6	-	
USN 319612	8	LOADED TANK	230	28.8	-	
USN 319611	9	UNLOADED TANK	58	7.2	-	
TTX 160569	10	LOADED TOFC	196	24.5	67	
TTX 160546	11	UNLOADED TOFC	66	8.2	69	



TEST DIRECTION

←

TOFC = 70 TON CAPACITY
REST = 100 TON CAPACITY

TABLE 3-2. FREIGHT

CONSIST CAR NO.	FAST NO.	RAILROAD CAR NO.	WHEELS A	WHEELS B	WHEEL COUNTOUR	TRUCK TYPE
1	29	CN 330033	J36C	CJ36C	AAR	S2A
2	91	CP 351874	J36C	J36C	AAR	S2C
3	8	CO 183553	H36U	CH36U	AAR	S2C
4	74	NATX 35018	J36U	CJ36C H36C	AAR	RC S2A
5	15	BO 199408	J36U	CJ36U	AAR	S2C
6	93	CP 351834	CJ36C	J36C	AAR	S2C
7	94	CN 330025	J36C CJ36C	J36C	AAR	S2A
8	10	BN 526116	J36U	CJ36U	AAR	RC
9	3	CEI 588383	H36U	CH36U	AAR	RC
10	77	DUPX 20457	CJ36C H36U	H36C J36C	AAR	RC
11	1	CEI 588380	H36U	CH36U	AAR	RC
12	27	LN 196400	J36C	CJ36C	CN AAR	RC
13	75	UTLX 30430	H36U H36C	J36C H36C	AAR	S2C
14	57	NW 120334	J36U H36U	CJ36C J36B	AAR	S2C
15	56	LN 195679	CJ36C	CJ36C CH36U	AAR	S2C
16	35	BN 527085	J36C	J36C	AAR	SM
17	34	BN 527078	J36C	CJ36C	AAR	SM
18	28	BN 527067	J36C	CJ36C	AAR-CN AAR	RC
19	84	GATX 92557	H36U CH36B	CH36C	AAR	S2A
20	36	PPLX 226	CJ36C	CJ36C	AAR	RC
21	85	NATX 34436	J36U	CJ36U	AAR	S2A
22	37	PPLX 244	J36C	J36C	AAR	RC
23	61	NW 120452	J36C	CJ36C	AAR	S2C
24	63	CO 63668	CJ36C J36C	J36C CJ36C	AAR	S2C
25	86	UTLX 88207	CH36U	H36C	AAR	S2A
26	38	PPLX 306	CJ36C	CJ36C	AAR	RC
27	24	NW 14087	H36C	CH36C	AAR	S2C
28	20	BN 526372	H36C	CH36C	AAR	RC
29	32	NW 14089	J36C	CJ36C	CN AAR	S2C
30	18	BN 526345	H36C	CH36C	AAR	RC

CONSIST 2/4/79

CENTER PLATE	SPRING TYPE	COUPLER TYPE	CAR TYPE (ALL 100 TON CAPACITY)	CAR WEIGHTS (KIP)	WHEEL LOADS (KIP)	CONSISTS
14	D3	E	HOPPER	263	32.8	30 CAR CONSIST
14	D5	F	B.T. GONDOLA	263	32.9	
16	D5	E	HOPPER	262	32.8	
14	D5	F	TANK	263	32.8	
14	D5	E	HOPPER	262	32.8	
14		F	B.T. GONDOLA	262	32.7	
14	D3	E	HOPPER	256	32.0	
16	D5	F	HOPPER	263	32.9	
14	D5	E	HOPPER	265	33.1	
14	D3	E	TANK	262	32.8	
14	D5	E	HOPPER	263	32.9	20 CAR CONSIST
14	D5	E	HOPPER	263	32.9	
14	D3	F	TANK	264	33.0	
14	D5	E	HOPPER	264	33.0	17 CAR CONSIST
14	D5	E	HOPPER	262	32.7	
16	D5	F	HOPPER	264	33.0	
16	D5	F	HOPPER	263	32.9	
16	D5	F	HOPPER	264	33.0	
14	D3	E	TANK	117	14.6	
16	D7	F	HOPPER	263	32.9	
14	D3	E	TANK	260	32.5	
16	D7	F	HOPPER	264	33.1	
14	D5	E	HOPPER	264	33.0	
14	D5	E	HOPPER	263	32.9	
14	D3	E	TANK	261	32.6	
16	D7	F	HOPPER	262	32.8	
16	D5	E	HOPPER	263	32.9	
16	D5	F	HOPPER	265	33.1	
16	D5	E	HOPPER	263	32.9	
16	D5	F	HOPPER	262	32.8	

that the response to each section could be isolated. The curved test zone was used during both the main PTT and the follow-up freight test while the tangent zone was only used during the main testing period. The location of the test zones at TTC and test directions are shown in Figure 3-3.

The perturbation sections are sequentially numbered, with 1 through 5 comprising the curved test zone, and 6 through 9 comprising the tangent test zone. The transitions (if present) and individual cycles in a particular perturbed section are indicated as: section number, decimal point, perturbation number. The perturbation number zero is reserved for those cases where an entry transition rail is needed before the intended perturbation can actually begin. As an example: 7.0 means perturbation section 7 (tangent track, piecewise linear crosslevel), cycle 0 (perturbation entry rail); and 7.1 means perturbation section 7, cycle 1 (first piecewise linear crosslevel cycle) and so on.

A summary of the curve and tangent perturbation sections with their waveforms and the first ten fourier coefficients (based on designed shape and amplitude) is shown in Figure 3-4.

3.2.1 Curved Track Test Zone

The curved track test zone, as schematically shown in Figure 3-5, is 117 rail lengths long (4560 ft.), and is located on the 1.5 degree curve within the Train Dynamics Track. The nominal superelevation for the curve is 3", providing a balance speed of 53 mph. Most of the zone is on a 0.9% ascending grade. The zone contains five perturbed sections which are, in order, 5 cycles of piecewise linear crosslevel, 5 cycles of piecewise linear alignment, 6 cycles of rectified sine alignment, 5 cycles of combined piecewise linear crosslevel and alignment, and 26 cycles of rectified sine high rail misalignment with three subsections of varying superelevation. Each subsection contains six cycles of uniform superelevation separated by four cycles of transition track. The first subsection has 3" of superelevation, the second 2", and the third 1". The high rail misalignment was maintained in these transition cycles. The reduction in superelevation was obtained by shimming the low rail. The concepts of piecewise linear perturbations and of varying superelevation were first proposed by TASC and are described in detail in Reference [8]. Note that all perturbations are constructed using parallel joints.

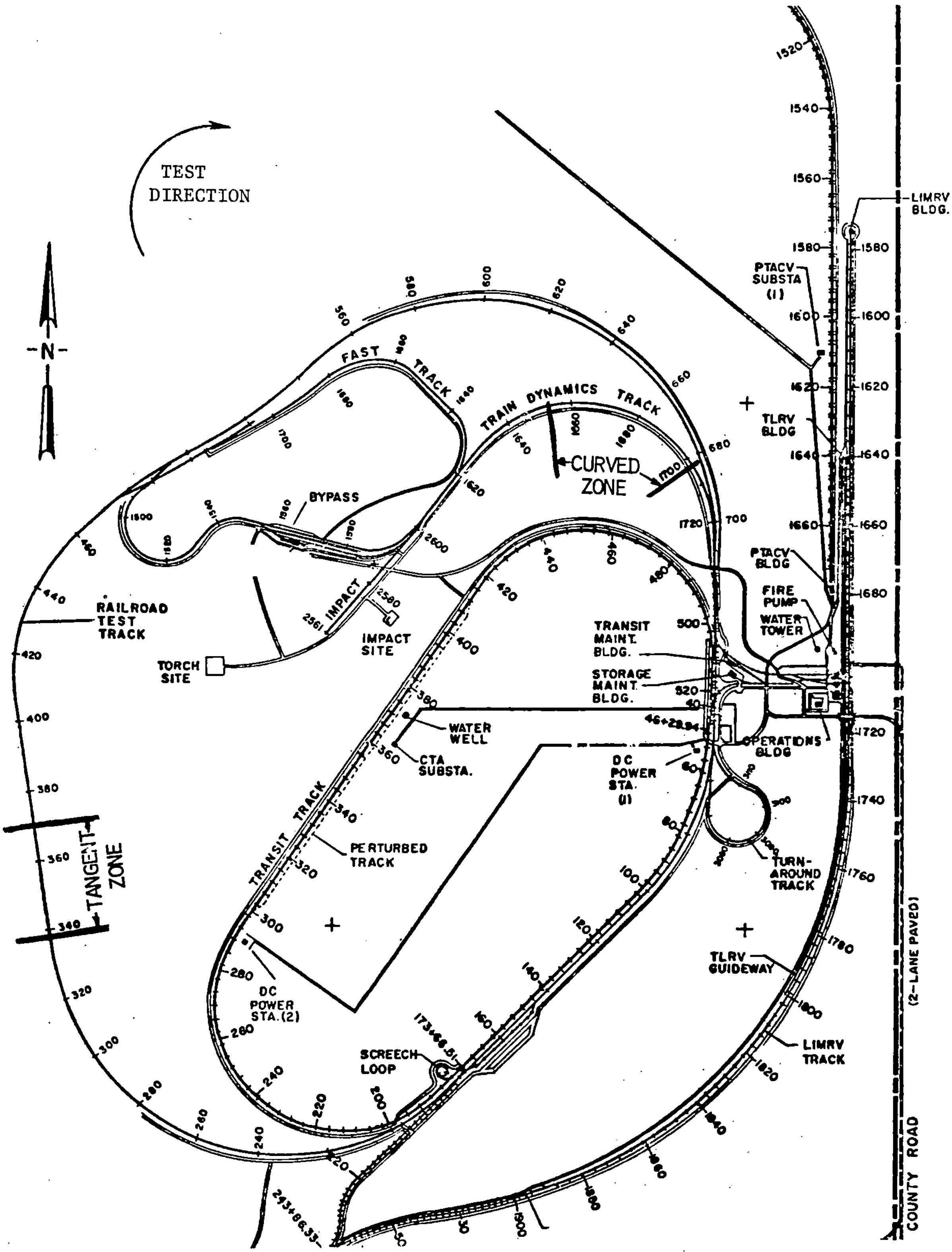
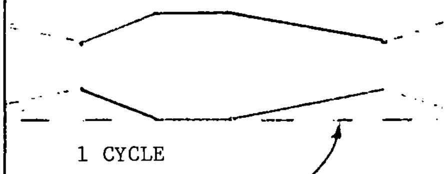
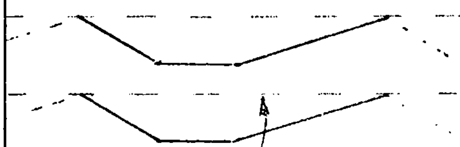
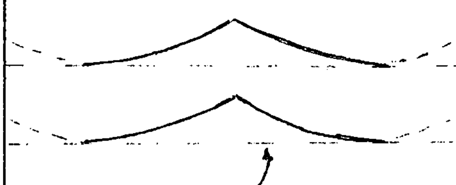
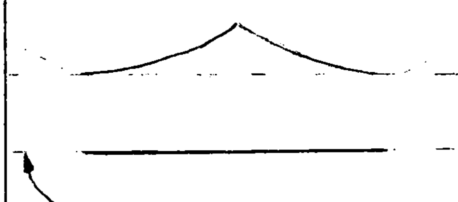
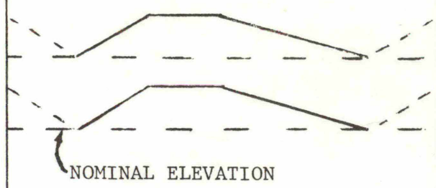
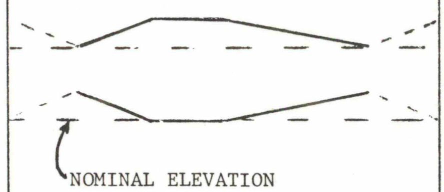
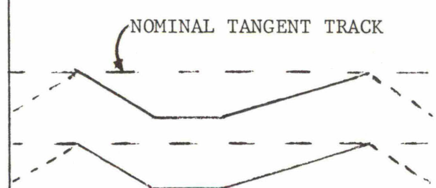


FIGURE 3-3. TRANSPORTATION TEST CENTER (TTC)

CURVED TEST ZONE (1.5 CURVE, 3" SUPERELEVATION)		NUMBER OF CYCLES	AVERAGE BALANCE SPEED (MPH)	FUNDAMENTAL WAVELENGTH AND FOURIER AMPLITUDE
SECTION 1 1/2" CROSSLEVEL PIECEWISE LINEAR		5	53	λ = 78' A = 1.0"
SECTION 2 1 1/2" ALIGNMENT PIECEWISE LINEAR		5	53	λ = 78' A = 1.5"
SECTION 3 1" ALIGNMENT RECTIFIED SINE		6 LAST 2 CYCLES "SOFT" TRACK	53	λ = 39' A = 1.0"
SECTION 4 1 1/2" ALIGNMENT 1/2" CROSSLEVEL PIECEWISE LINEAR	SUPERPOSITION OF SECTIONS 1 AND 2	5	53	λ = 78' Alignment A = 1.5" Crosslevel A = 1.0"
SECTION 5 1" HIGH LEVEL ALIGNMENT RECTIFIED SINE 3", 2", AND 1" SUPERELEVATION SUBSECTIONS		3"*- 6 2" - 6 1" - 6	53 44 31	λ = 39' Alignment A = 0.5" Gage A = 1.0"

*SUPERELEVATION

FIGURE 3-4. SUMMARY OF PTT PERTURBATIONS

TANGENT TEST ZONE		NUMBER OF CYCLES	FUNDAMENTAL WAVELENGTH AND FOURIER AMPLITUDE
SECTION 6 1 1/2" PROFILE PIECEWISE LINEAR		5	λ = 78' A = 1.5"
SECTION 7 1/2" CROSSLEVEL PIECEWISE LINEAR		5	λ = 78' A = 1.0"
SECTION 8 1 1/2" ALIGNMENT PIECEWISE LINEAR		5	λ = 78' A = 1.5"
SECTION 9 1 1/2" ALIGNMENT 1/2" CROSSLEVEL PIECEWISE LINEAR	SUPERPOSITION OF SECTIONS 7 AND 8	5	λ = 78' Alignment A = 1.5" Crosslevel A = 1.0"

$$f(x) = \frac{c_o}{2} + A \sum \sqrt{a_n^2 + b_n^2} \cos\left(\frac{n\pi x}{\lambda_1} - \tan^{-1}\left(\frac{b_n}{a_n}\right)\right), \quad c_n = \sqrt{a_n^2 + b_n^2}$$

RECTIFIED SINE PERTURBATIONS

n	1	2	3	4	5	6	7	8	9	10
λ	39	19.5	13	9.75	7.8	6.5	5.571	4.875	4.333	3.9
c_n	0.4244	0.0849	0.0364	0.0202	0.0129	0.0089	0.0065	0.0050	0.0039	0.0032

PEICEWISE LINEAR PERTURBATIONS

n	1	2	3	4	5	6	7	8	9	10
λ	78	39	26	19.5	15.6	13	11.11	9.75	8.667	7.8
c_n	0.4531	0.1013	0.0504	0	0.0181	0.0113	0.0092	0	0.0056	0.0041

FIGURE 3-4. (Continued)

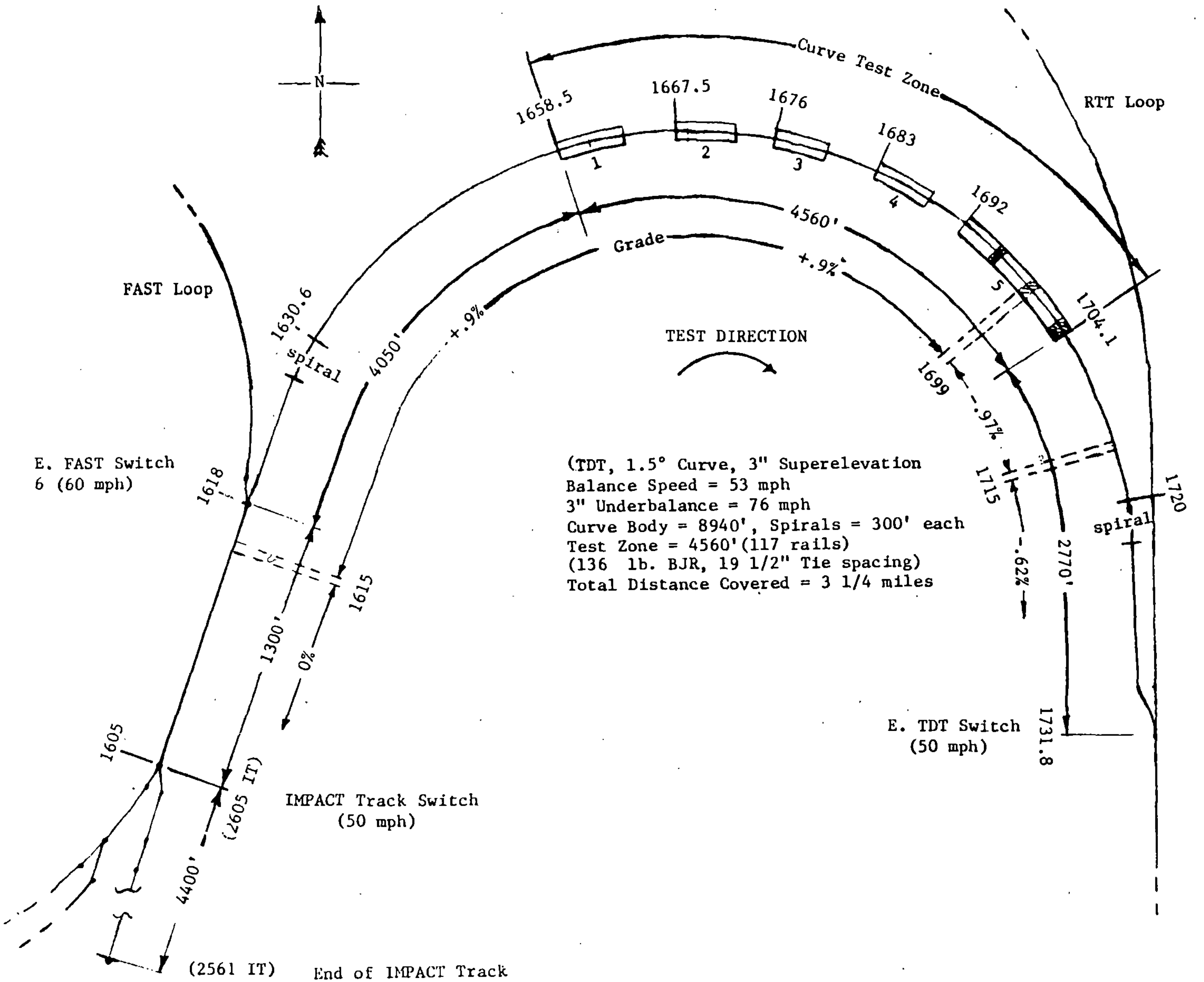


FIGURE 3-5. PTT CURVED TEST ZONE SCHEMATIC

The spiking pattern throughout the zone was four spikes per tie plate, except for the last two cycles of section 3 in which only two spikes were used with every other tie being completely unspiked. The last two cycles of section 3 were designed to simulate laterally "soft" track, and represent the minimum spiking requirements for Class 4 track. This "soft" track was used only for the SDP-40F test series.

3.2.1.1 Description of Piecewise Linear Crosslevel Perturbation on Curved Track - Section 1

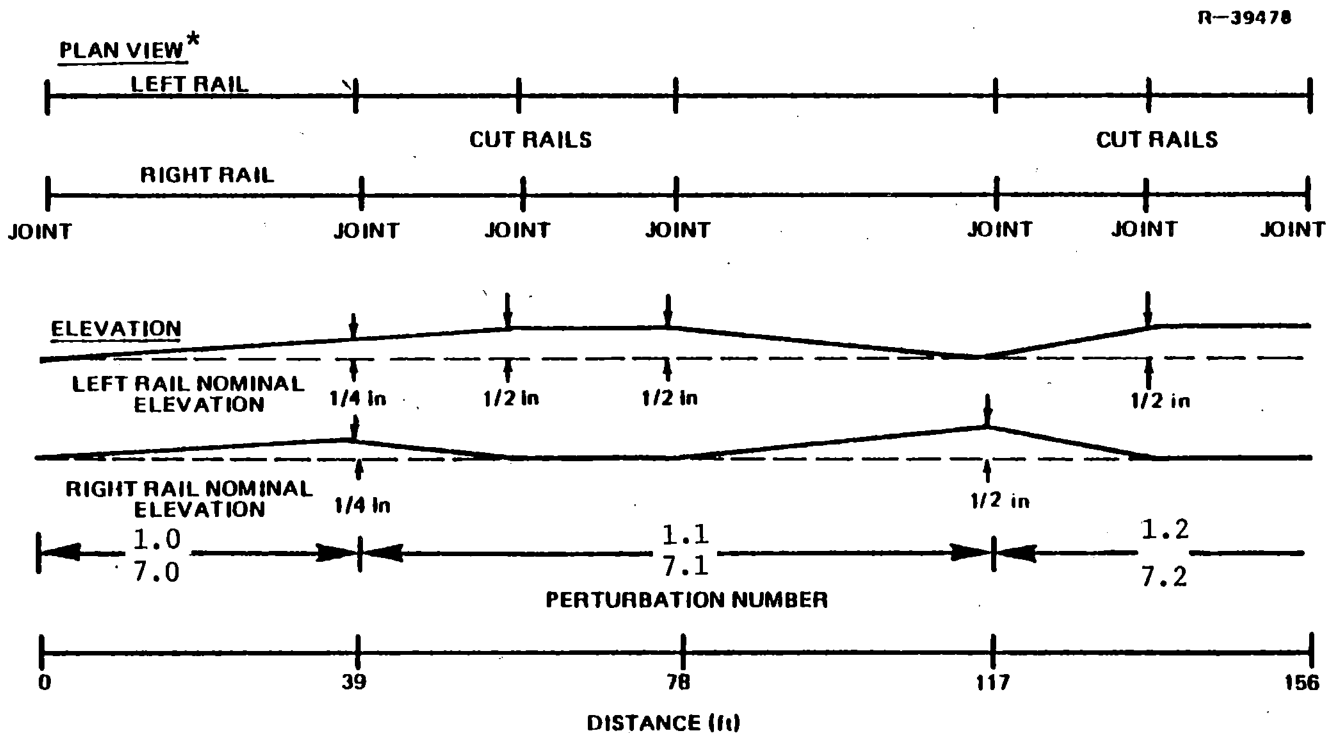
There are 5 cycles of crosslevel perturbation, each 2 rail-lengths long, in addition to 1 rail-length entry transition and 1 rail-length exit transition. This perturbation is identical to that used in section 7 of the tangent zone. Figures 3-6 through 3-8 illustrate the perturbations in section 1 except that the plan view should show the nominal 1.5 degree curve. This section contains a rail length entry transition (1.0), five perturbations of 2 rail lengths each (1.1 through 1.5, where 1.2, 1.3 and 1.4 are identical) and an exit transition of one rail length (1.6). Hence, the total length of the perturbed section is 12 rail lengths and there are 10 cut rails included. The perturbation amplitude is .5", which provides a 1" twist in 19.5 feet.

3.2.1.2 Description of Piecewise Linear Alignment Perturbation on Curved Track - Section 2

The alignment perturbation varies linearly in magnitude with distance along the track; however, the nominal reference from which the track is perturbed is curved. Hence, the actual rail shape as laid is curved as shown in Figure 3-9. The illustration also gives the quarter-rail offsets (from a 78 foot chord) which can be used to describe this rail shape. The perturbation section consists of five identical alignment perturbations; hence, the total length is 10 rail lengths and 10 cut rails are required. The perturbation amplitude is 1.5".

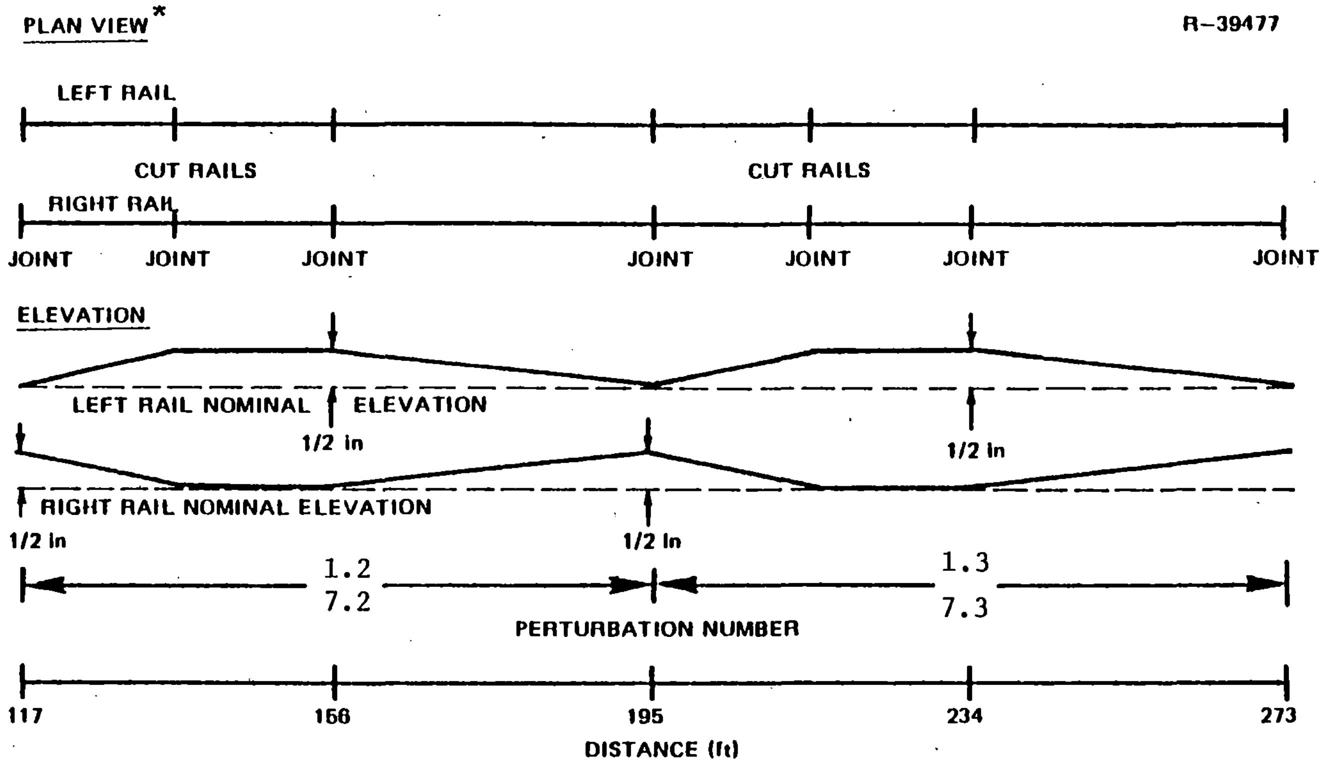
3.2.1.3 Description of Rectified Sine Alignment Perturbation on Curved Track - Section 3

The rectified sine alignment perturbation section consists of six identical perturbations, each of which is one rail-length long. Figure 3-10 illustrates the overview of the first half of this section, and Figure 3-11 details



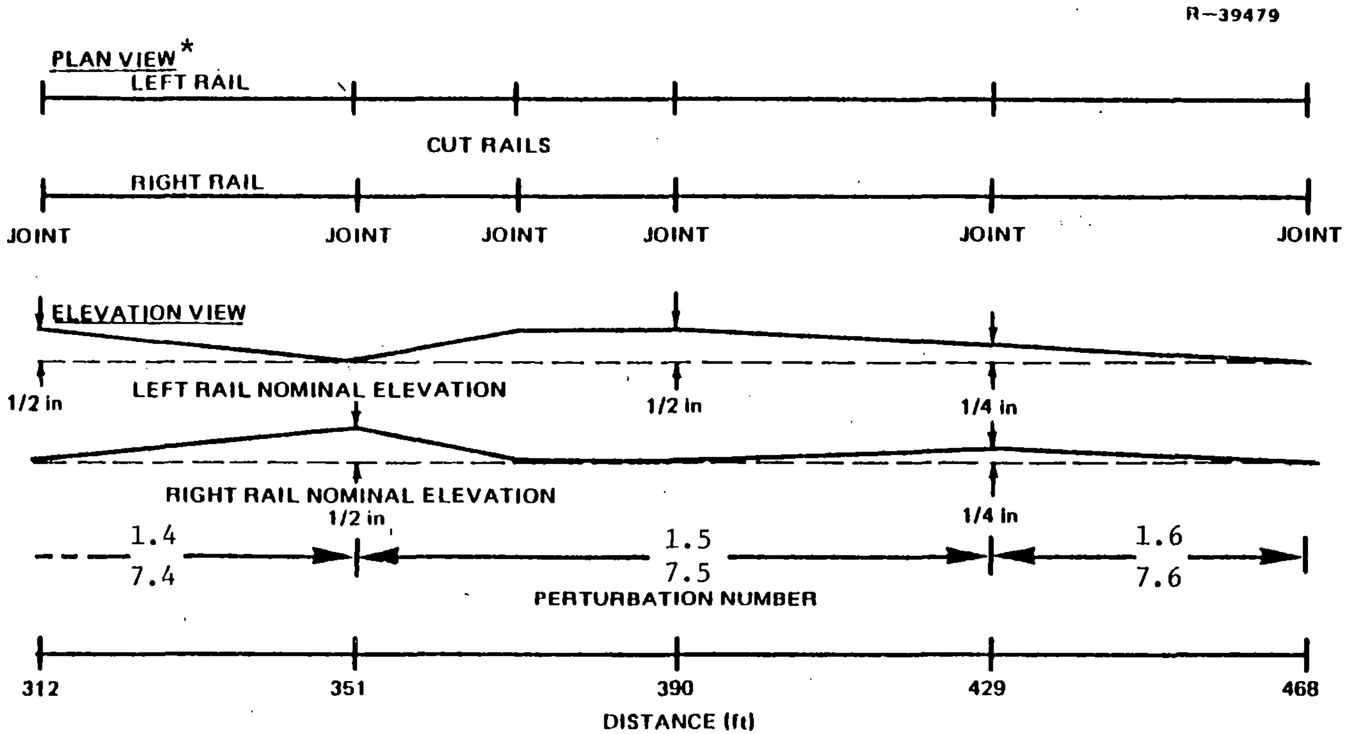
* CROSSLEVEL PERTUBATION ON CURVED TRACK IS IDENTICAL EXCEPT PLAN VIEW SHOULD SHOW NOMINAL 1.5 DEG CURVE. LEFT RAIL IS HIGH RAIL ON CURVE.

FIGURE 3-6. SECTIONS 1 AND 7: PIECEWISE LINEAR CROSSLEVEL PERTURBATION - ENTRY TRANSITION AND FIRST CYCLE



* CROSSLEVEL PERTURBATION ON CURVED TRACK IS IDENTICAL EXCEPT PLAN VIEW SHOULD SHOW NOMINAL 1.5 DEG CURVE. LEFT RAIL IS HIGH RAIL ON CURVE.

FIGURE 3-7. SECTIONS 1 AND 7: PIECEWISE LINEAR CROSSLEVEL PERTURBATION - MAIN BODY (CYCLES .2 THROUGH .4 ARE IDENTICAL.)



* CROSSLEVEL PERTURBATION ON CURVED TRACK IS IDENTICAL EXCEPT PLAN VIEW SHOULD SHOW NOMINAL 1.5 DEG CURVE. LEFT RAIL IS HIGH RAIL ON CURVE.

FIGURE 3-8. SECTIONS 1 AND 7: PIECEWISE LINEAR CROSSLEVEL PERTURBATION - LAST CYCLE AND EXIT TRANSITION

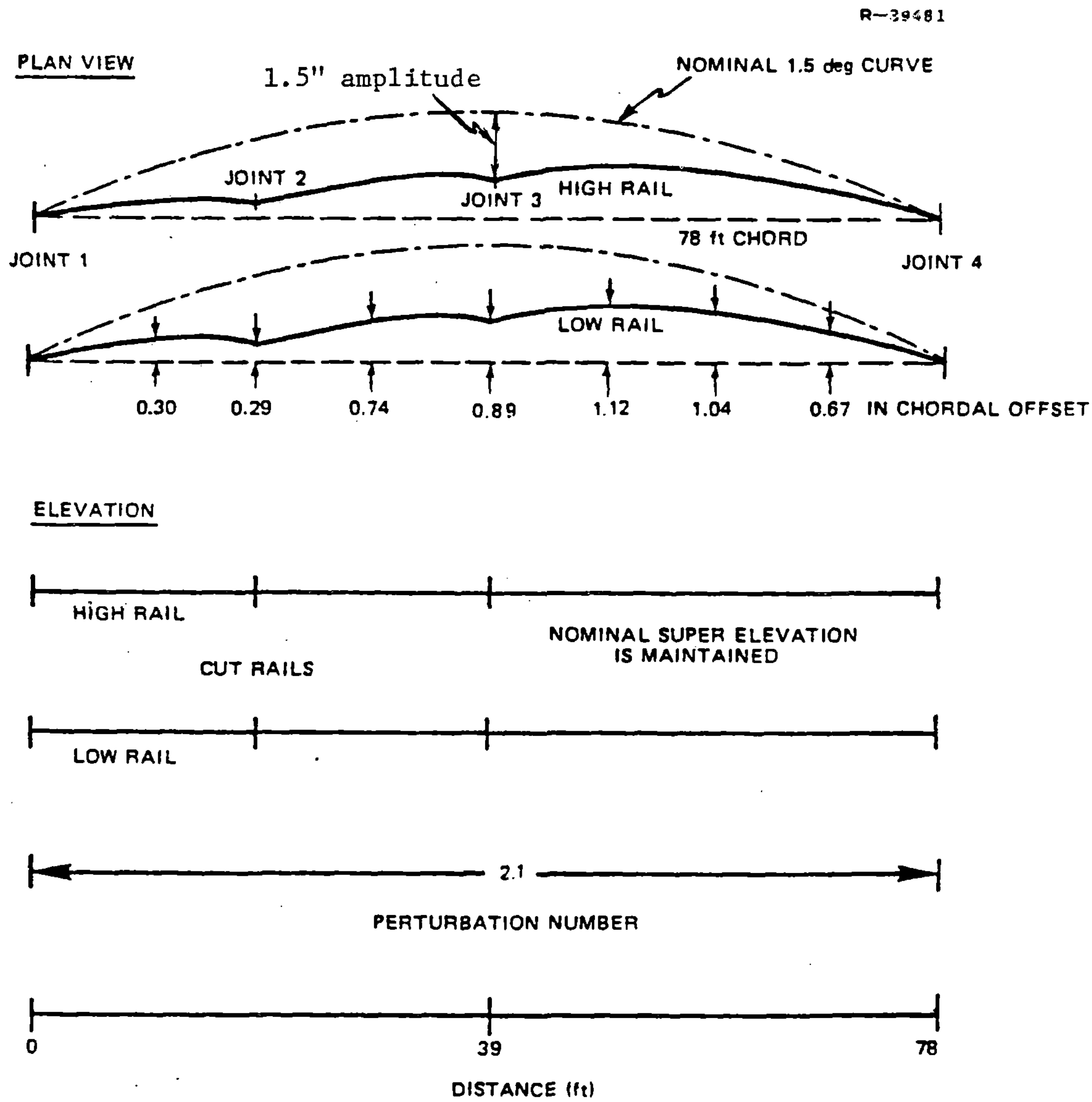


FIGURE 3-9. SECTION 2: PIECEWISE LINEAR ALIGNMENT PERTURBATION ON CURVED TRACK. (PERTURBATIONS 2.1 THROUGH 2.5 ARE ALL IDENTICAL.)

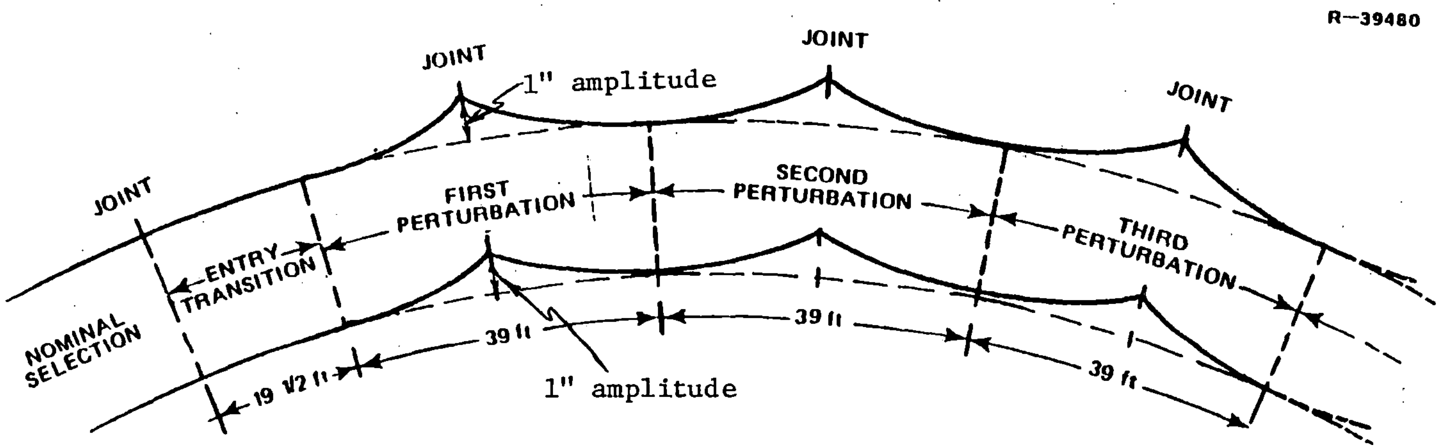
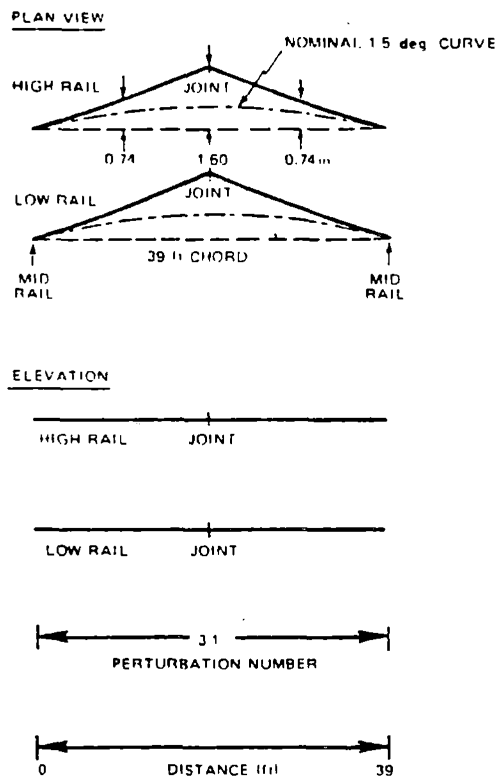
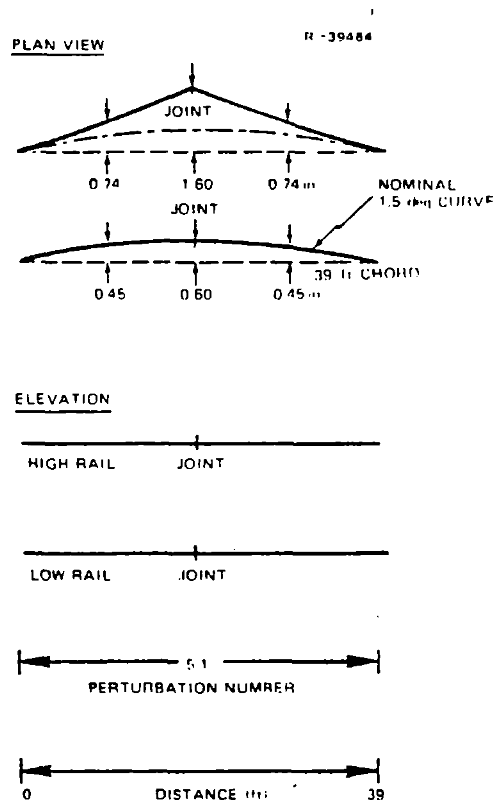


FIGURE 3-10. SECTION 3: RECTIFIED SINE ALIGNMENT PERTURBATION ON CURVED TRACK SHOWING 19.5 FT ENTRY TRANSITION (NO CUT RAILS ARE REQUIRED.)



RECTIFIED SINE ALIGNMENT PERTUBATION
SECTION 3



RECTIFIED SINE HIGH-RAIL MISALIGNMENT
SECTION 5

FIGURE 3-11. SECTIONS 3 AND 5: RECTIFIED SINE ALIGNMENT PERTURBATION AND RECTIFIED SINE HIGH-RAIL MISALIGNMENT PERTURBATION. (PERTURBATIONS 3.1 THROUGH 3.6 ARE IDENTICAL; PERTURBATIONS 5.1 THROUGH 5.26 ARE IDENTICAL IN ALIGNMENT.)

an individual perturbation. Note that since each perturbation begins and ends at a rail mid-point, 19.5 ft. entry transitions (3.0 and 3.7) are included to extend the section to the next rail joint. Note that this does not require rail cutting. The transition section actually is unperturbed (i.e., follows the nominal 1.5 degree curve at nominal superelevation). The perturbation amplitude is 1".

Section 3 was altered, making two subsections for the SDP-40F test series. The first four cycles of the section were left with a nominal (four spikes per tie plate) spiking pattern. The last two cycles, however, had the spikes for every other tie removed. In addition, two spikes were removed from the remaining tie plates (minimum Class 4 standards). This laterally "soft" track was used only for the SDP-40F test series. The exact spiking pattern is shown in Figure 3-27 (on page 65) under Wayside Instrumentation.

3.2.1.4 Description of Piecewise Linear Crosslevel and Alignment Perturbation on Curved Track - Section 4

Section 4 represents a superposition of the piecewise linear crosslevel perturbation (section 1) and the piecewise linear alignment perturbation (section 2). The entry and exit transitions (4.0 and 4.6) are identical to sections 1.0 and 1.6, while the 5 perturbations, each 2 rail lengths long, correspond to 1.1 through 1.5 in elevation (shimming) and 2.1 through 2.5 in alignment. Hence, the total length is 12 rail lengths, and 10 cut rails are needed.

3.2.1.5 Description of Rectified Sine High Rail Misalignment with Varying Superelevation on Curved Track - Section 5

The high rail in this perturbation section assumes the same shape as in section 3, while the low rail is unperturbed in alignment. An individual perturbation is shown in Figure 3-11. Section 5 contains 26 of these perturbations, six each at nominal superelevation, at 1 inch less than nominal superelevation, and at 2 inches less than nominal superelevation. There are four rails of superelevation transition separating the three subsections of constant superelevation, and four rails at the end of the test section on which the superelevation returns to its nominal value. The reduction in superelevation is achieved by shimming the low rail. Additionally, since rectified sine perturbations start at mid-rail, section 5 contains two half-rail length transition sections, each unperturbed in alignment. No cut rails are needed in the rectified sine perturbation section. Hence, the total length of section 5 is 31 rail lengths with sections 5.1 through 5.26 having continuous rectified sine high rail misalignment perturbations.

3.2.2 Tangent Track Test Zone

The tangent track test zone, as schematically shown in Figure 3-12, is 77 rail lengths long (3000 ft), and is located on the outer Railroad Test Track. There are four perturbed sections within the tangent test zone. The section numbers are 6 through 9. Each of the four sections contains 5 perturbation cycles, each 78 ft. long. The perturbed sections test profile, crosslevel, alignment, and combined crosslevel and alignment, and are all piecewise linear in construction.

3.2.2.1 Description of Piecewise Linear Profile Perturbation on Tangent Track - Section 6

There are 5 identical cycles, each 78 ft. long, which make up test section 6. Figure 3-13 describes one of these perturbations. The first rail in each perturbation is cut in the middle. Hence, the entire test section contains 10 cut rails. The perturbation is formed by shimming both rails up to 1.5" in one-half rail lengths, holding that elevation for one-half rail length and decreasing the shim thickness to zero over the second rail length. The rails maintain their nominal tangent alignment.

3.2.2.2 Description of Piecewise Linear Crosslevel Perturbation on Tangent Track - Section 7

This perturbation is identical to the crosslevel perturbation in the curved test zone (section 1), except that it is on tangent track. The total length of the perturbed section is 12 rail lengths. Figure 3-6 shows the entry transition (section 7.0) and the first perturbation (section 7.1). The perturbation amplitude is .5", which provides a 1.0" twist in 19.5 feet.

Figure 3-7 illustrates two of the middle three cross-level perturbations, as 7.2, 7.3, and 7.4 are identical. The final perturbation (section 7.5), and the exit transition of 1 rail length (section 7.6), are shown in Figure 3-8.

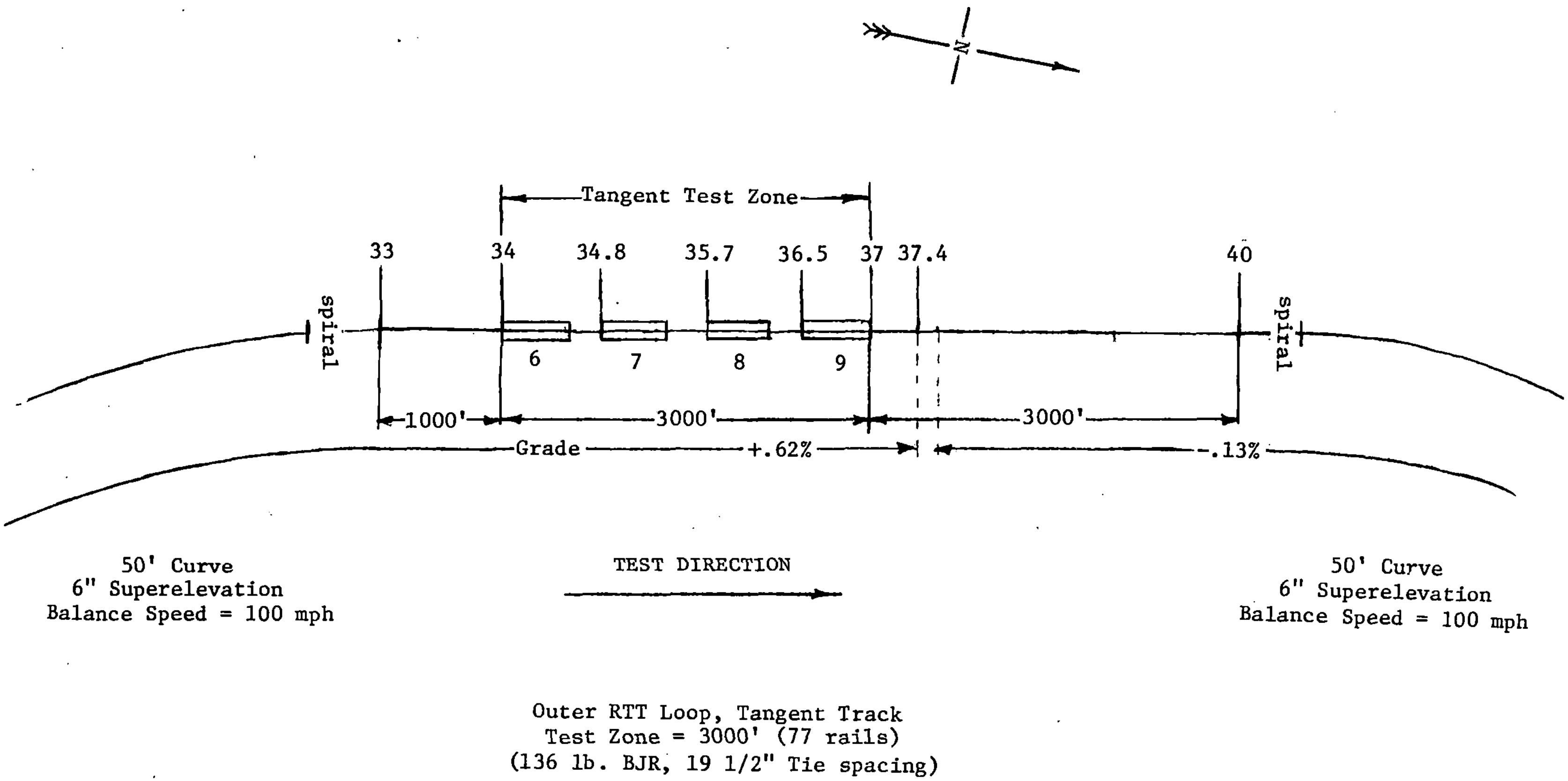


FIGURE 3-12. PTT TANGENT TEST ZONE SCHEMATIC

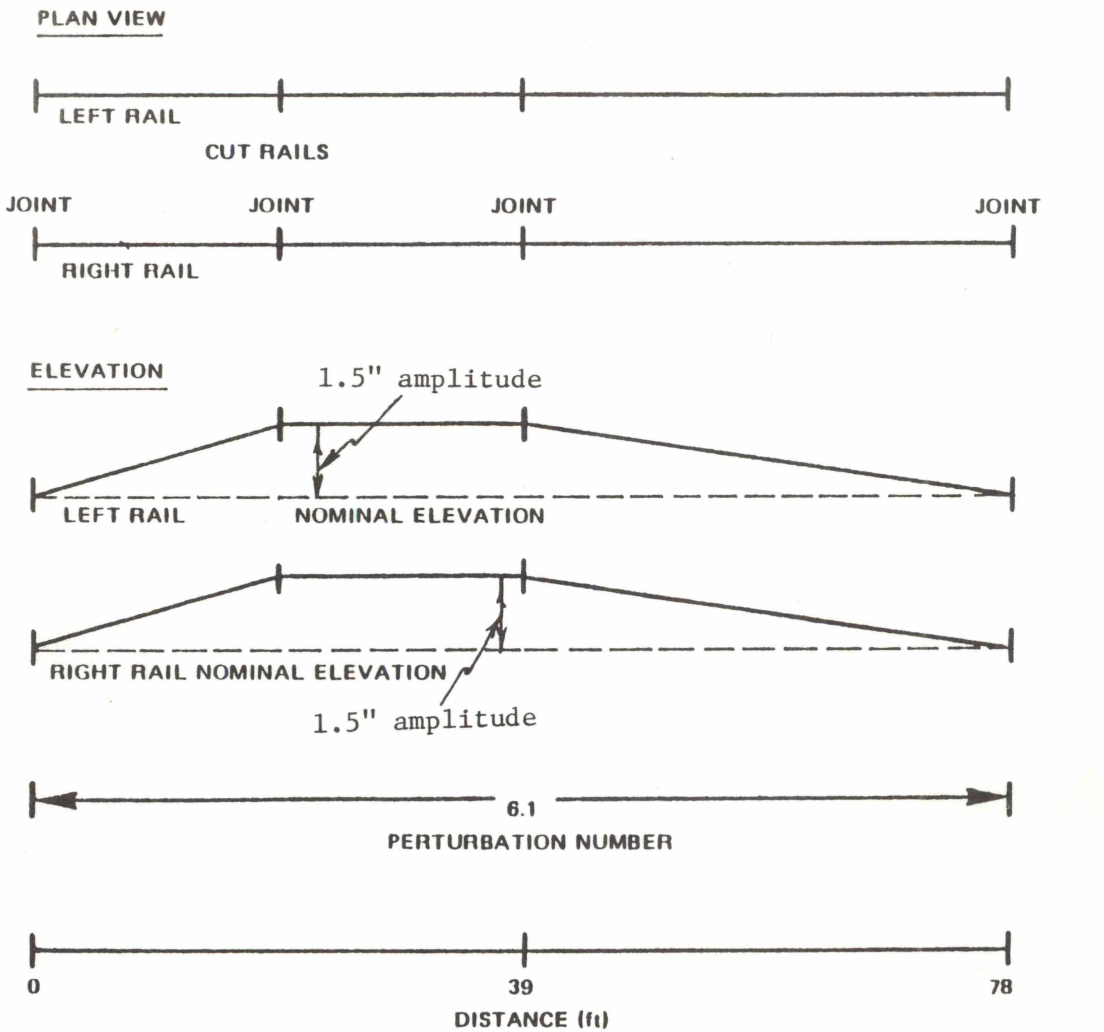


FIGURE 3-13. SECTION 6: PIECEWISE LINEAR PROFILE PERTURBATION ON TANGENT TRACK (PERTURBATIONS 6.1 THROUGH 6.5 ARE ALL IDENTICAL.)

3.2.2.3 Description of Piecewise Linear Alignment Perturbation on Tangent Track - Section 8

Perturbation section 8 consists of 5 piecewise linear alignment perturbations, each of which is 2 rail lengths long and is identical to section 2 of the curved test zone, except that it is on tangent track. The first rail length of each perturbation involves cut rails, as shown in Figure 3-14. Hence, this perturbation section requires 10 cut rails. The perturbation is formed by a linearly increasing chordal offset during the first half-rail to 1.5". This offset is held for half a rail length and then decreases to zero during the second rail length.

3.2.2.4 Description of Piecewise Linear Crosslevel and Alignment Perturbation on Tangent Track - Section 9

Perturbation section 9 consists of a superposition of rail alignment perturbations identical to those of section 8 and rail crosslevel perturbations identical to section 7, and is comparable to section 4 of the curved test zone. The first rail length (section 9.0) comprises a crosslevel perturbation entry transition identical to section 7.0 with straight alignment. The first perturbation (section 9.1) exhibits crosslevel (shimming) according to Figure 3-6 (section 7.1) and alignment according to Figure 3-14. The middle three perturbations (9.2, 9.3, and 9.4) exhibit crosslevel as shown in Figure 3-7 and alignment according to Figure 3-14. The last perturbation (9.5) matches the crosslevel of section 7.5 shown in Figure 3-8 and the alignment of section 8.5 and the exit transition has straight alignment and elevation (shimming) as in section 7.6. This section is 12 rail lengths long and contains 10 cut rails.

3.3 ONBOARD INSTRUMENTATION

All locomotive instrumentation was independent for the SDP-40F and E-8 consists. A list of the different types of data collected is shown in Table 3-3. The general locations of instrumentation for the E-8, SDP-40F, and baggage car are shown in Figures 3-15, 3-16, and 3-17.

3.3.1 SDP-40F Consist Instrumentation and Data Recording

The on-board instrumentation for the SDP-40F consist included the following: four instrumented wheelsets (three

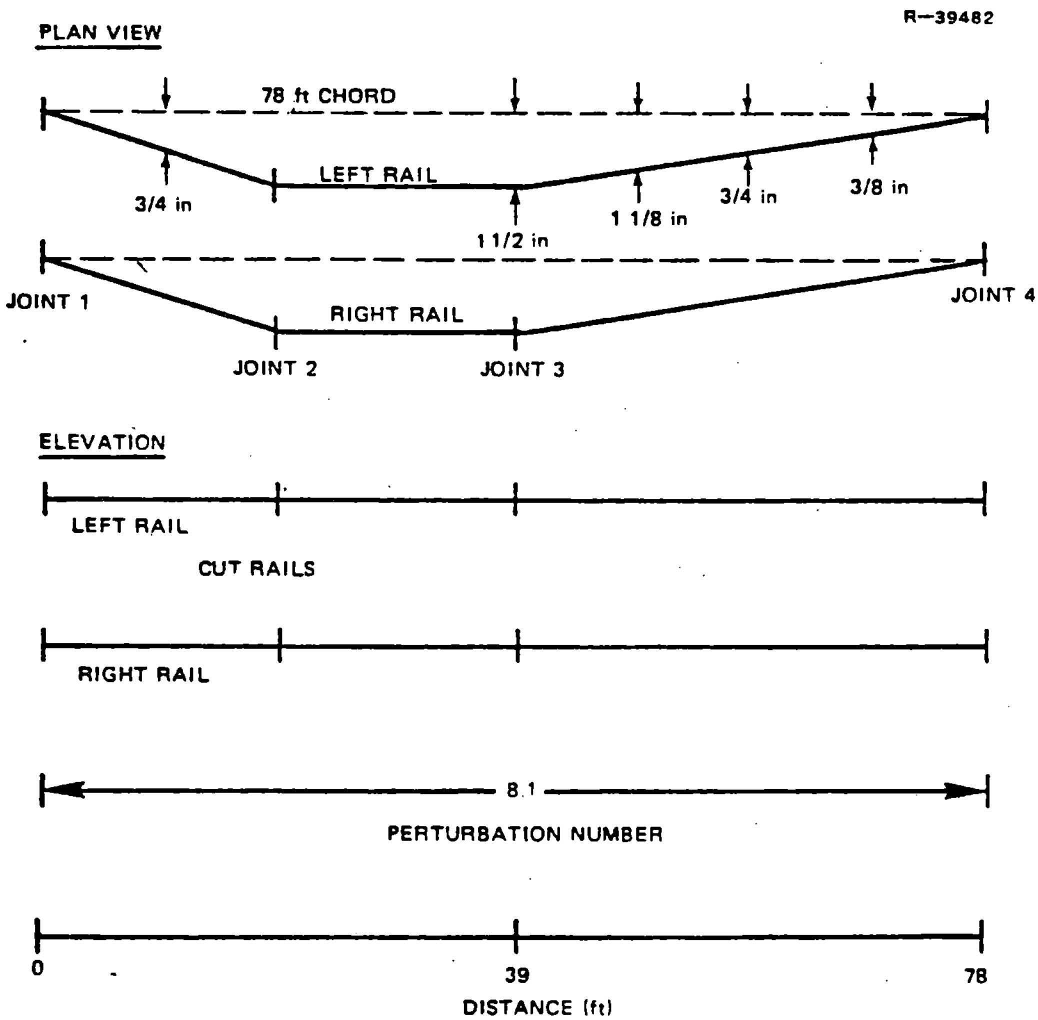


FIGURE 3-14. SECTION 8: PIECEWISE LINEAR ALIGNMENT PERTURBATION ON TANGENT TRACK (PERTURBATIONS 8.1 THROUGH 8.5 ARE ALL IDENTICAL.)

TABLE 3-3. ONBOARD INSTRUMENTATION

MEASUREMENT	NUMBER OF DATA TAPE CHANNELS SDP-40F	E-8
Relative vertical journal displacement (primary spring deflections)	6	
Relative lateral displacement between truck and axle	3	
Relative lateral motion between bolster and truck frame	2	
Truck yaw	2	2
Linear accelerations to resolve pitch, roll, yaw, vertical, lateral, and bending acceleration (SDP-40F only) of carbody	7	5
Lateral and vertical wheel force	12	4
Raw wheel data	18	8
Wheel L/V ratio	*	2
Truck L and L/V	**	
Axle vertical and lateral acceleration	9	
Truck frame lateral acceleration	2	
Wind velocity and direction	2	
Vertical lateral and longitudinal coupler force	3	
Coupler angle (loco-lateral and vertical)	2	

*NOT RECORDED ON RAW TAPE - PROCESSED IN REAL TIME FOR ALL 6 WHEELS

**NOT RECORDED ON RAW TAPE - PROCESSED IN REAL TIME FOR BOTH TRUCK SIDES

TABLE 3-3. (Continued)

BAGGAGE CAR*

MEASUREMENT	SDP-40F or E-8
Coupler angle (baggage - lateral and vertical	2
Lateral and vertical wheel load of lead axle on car	4
Linear accelerations to resolve vertical, lateral, roll, pitch and yaw accelerations of carbody	5

*Same baggage car and instrumentation were used in each consist.

GENERAL

MEASUREMENT	SDP-40F	E-8
ALD	1	1
Time	1	1
Speed	1	1
Traction motor current	1	
Sanding	1	
Brake cylinder pressure	1	1
Distance/record	1	

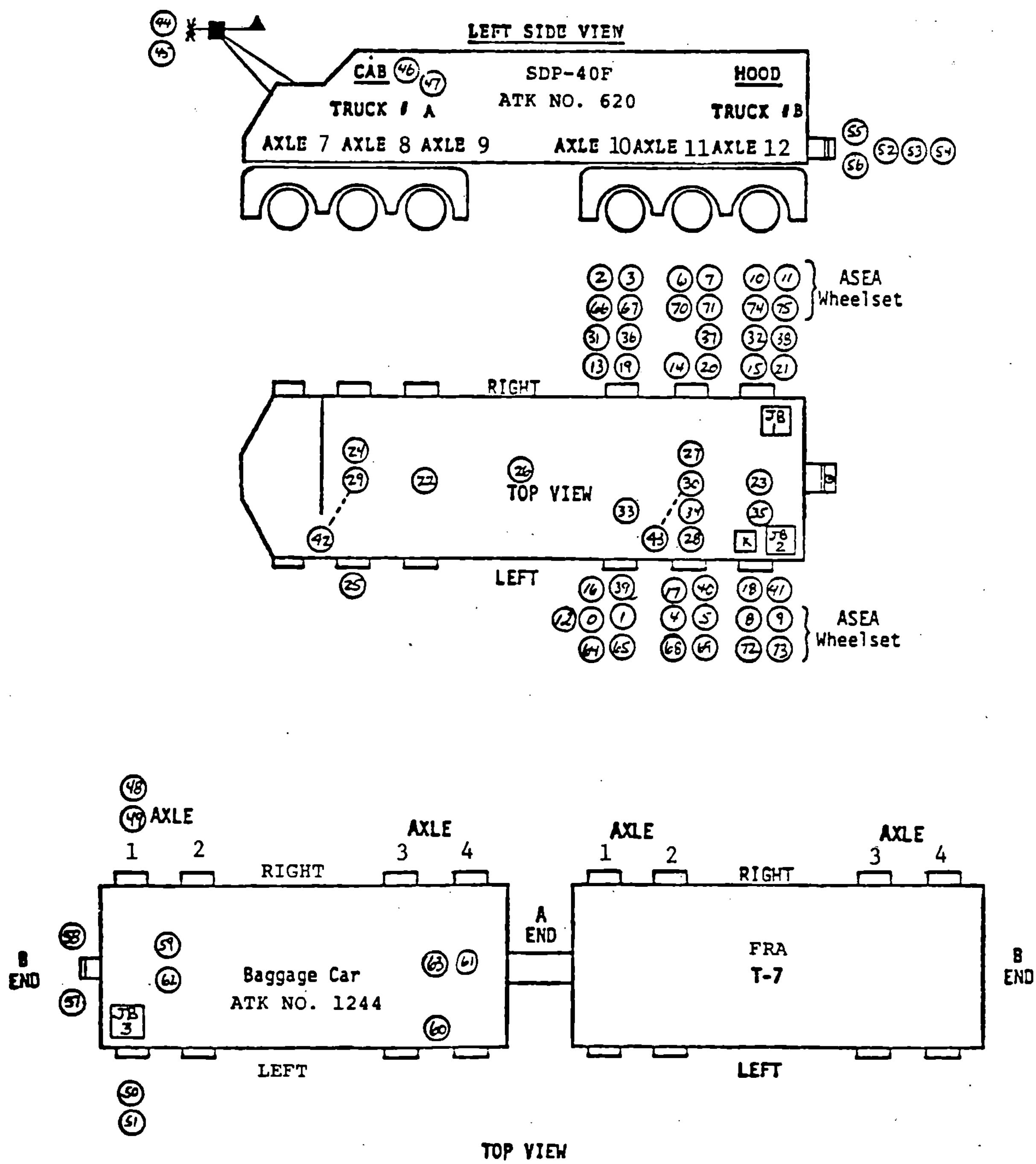


FIGURE 3-15. SDP-40F CONSIST INSTRUMENTATION LOCATIONS*

*Reference, SDP-40F Consist Data Channel Assignments

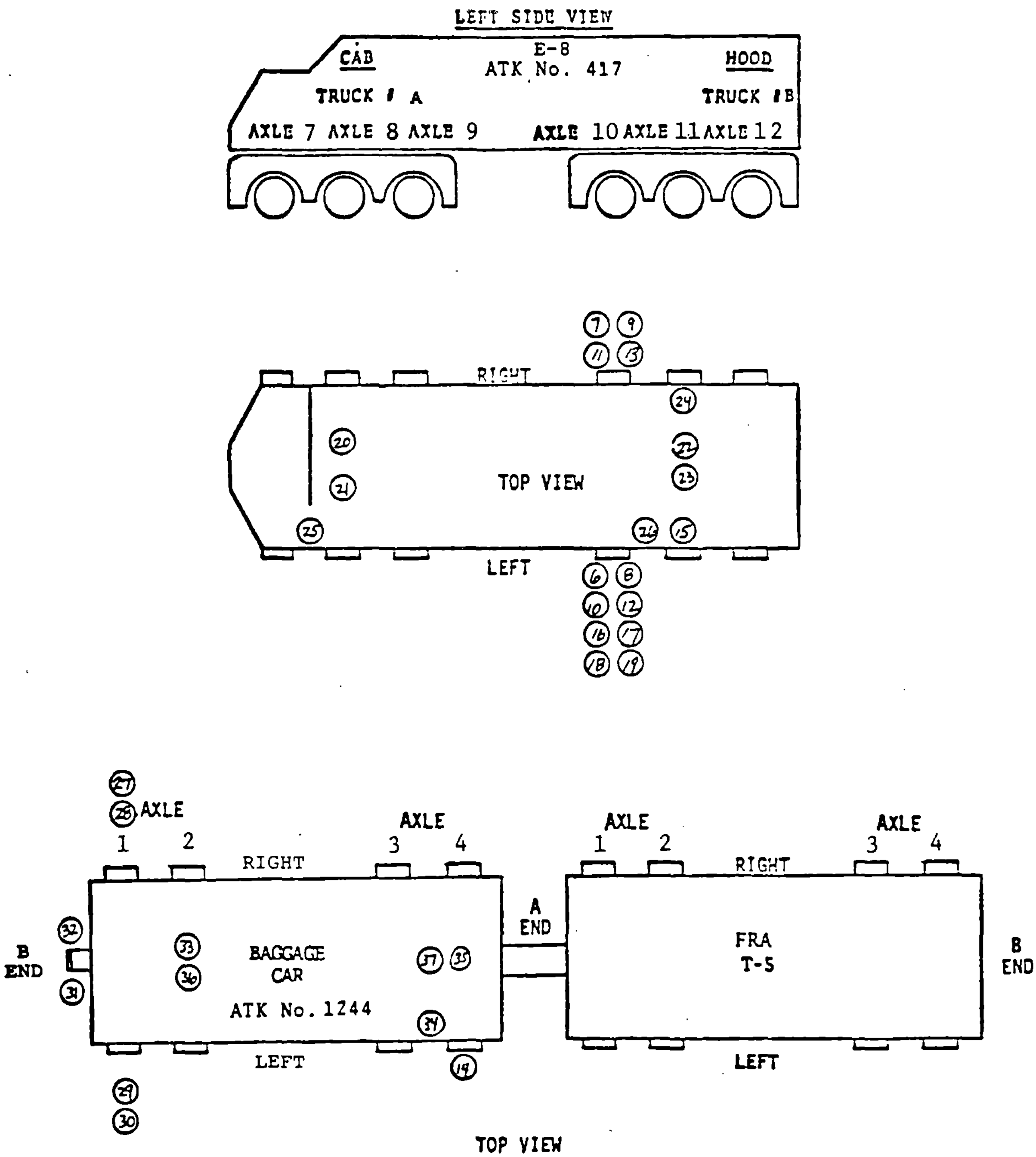


FIGURE 3-16. E-8 CONSIST INSTRUMENTATION LOCATIONS*

*Reference, E-8 Consist Data Channel Assignments

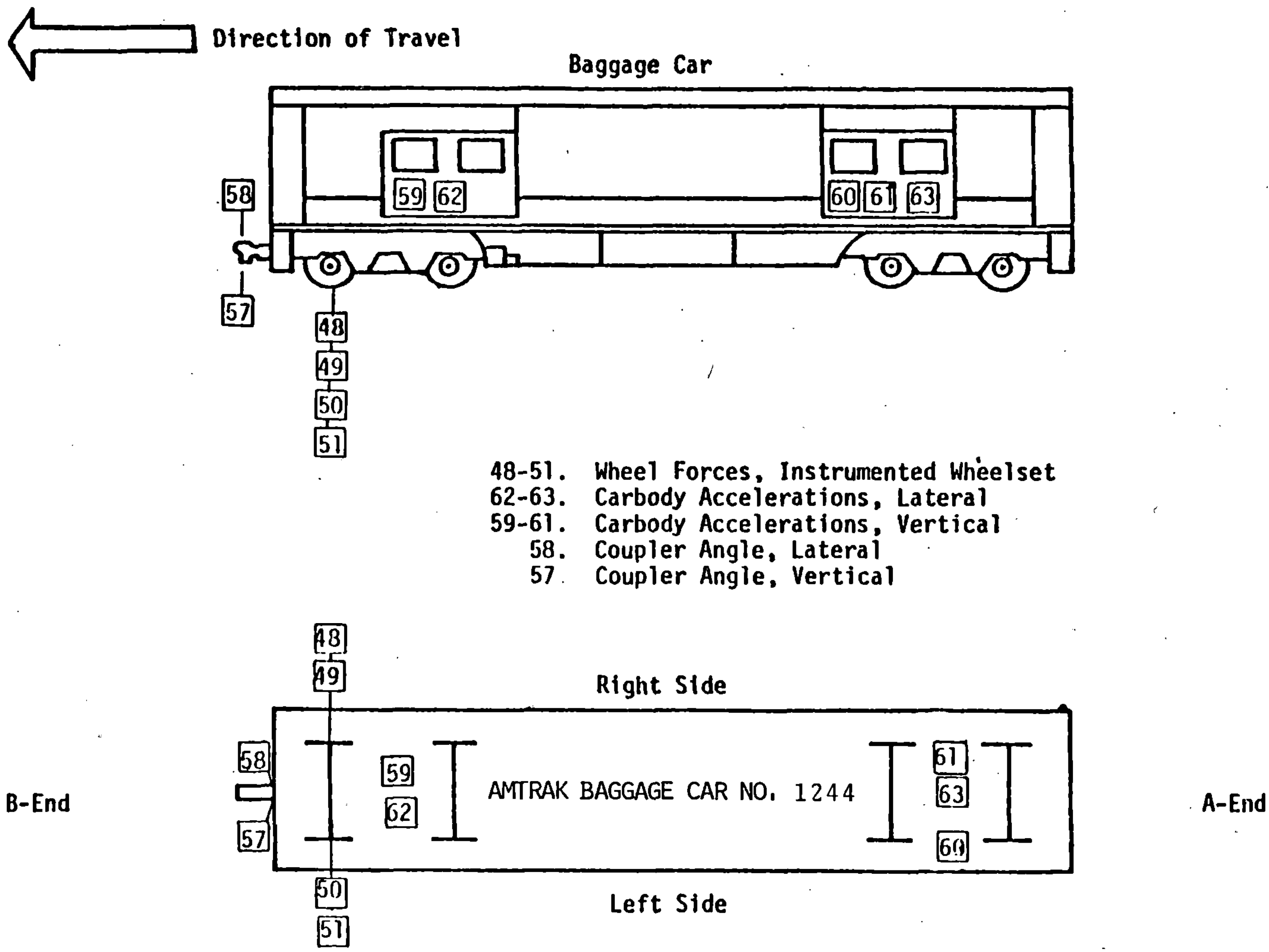


FIGURE 3-17. BAGGAGE CAR INSTRUMENTATION LOCATIONS FOR E-8 AND SDP-40 CONSISTS

NOTE: Numbers refer to SDP-40F/T-7 Channel Assignments for the SDP-40F and one for the baggage car); accelerometers on the locomotive carbody, instrumented truck, and instrumented axles; accelerometers on the baggage car carbody; and displacement transducers on the locomotive primary and secondary suspension. In addition, a variety of special instrumentation was used to get the following information: truck yaw for both locomotive trucks; locomotive coupler forces; locomotive and baggage car lateral and vertical coupler angles; wind velocity and direction; and an Automatic Location Detector (ALD) for the locomotive lead instrumented axle. The location of the SDP-40F carbody accelerometers and ALD sensor is shown in Figure 3-18. In Table 3-4 the locations of the various truck and axle displacement and acceleration transducers are presented relative to the appropriate axle vertical, lateral, and longitudinal centerlines. The location of the baggage car accelerometers is shown in Figure 3-19.

During the SDP-40F test, some changes were made in the full-scale recording range for the SDP-40F wheel forces (to provide for additional range) and in the baggage car accelerations (to allow for transducer substitutions). In Table 3-5, the channel assignment table for the SDP-40F consist instrumentation is shown.

All data were recorded with a 256 Hz sample rate after the anti-aliasing filtering indicated in the channel assignment tables.

3.3.2 E-8 Consist Instrumentation and Data Recording

The onboard instrumentation for the E-8 test consist included one instrumented wheelset, five locomotive carbody accelerometers (to resolve vertical, lateral, pitch, roll and yaw), truck yaw transducers for both locomotive trucks, an ALD sensor (at the E-8 instrumented wheelset), and the same baggage car with its instrumentation as in the SDP-40F consist. A list of all digital channel assignments is shown in Table 3-6. All data were digitally recorded at 256 Hz. All filter corners were set as prescribed in the T-5 list of channel assignments. The location of the E-8 locomotive carbody accelerometers and ALD sensor is shown in Figure 3-20.

3.3.3 Sign Conventions

In general, the sign convention for all acceleration and displacement transducers has been defined so that

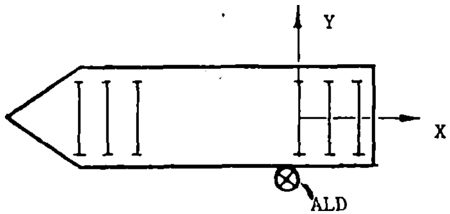
ALD

CONSIST	LOCATION COORDINATES (INCHES) X	Y
A and B	-18.5	-55.0
C	-18.5	-55.0

CARBODY ACCELEROMETERS

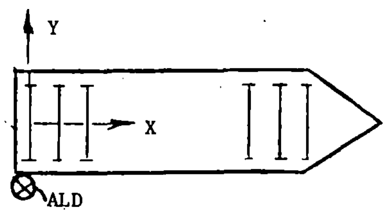
CHANNEL	DESCRIPTION	LOCATION COORDINATES (INCHES) X_A	Y_A	X_B	Y_B
24	Vert. Accel.	-7.0	0		
25	Vert. Accel.	-13.0	-54.0		
26	Vert. Accel.			-22.4	+3.0
27	Vert. Accel.			+42.0	0
28	Vert. Accel.			-1.0	-58.0
29	Lat. Accel.	-13.0	0		
30	Lat. Accel.			+36.0	0

CONSISTS "A and B"

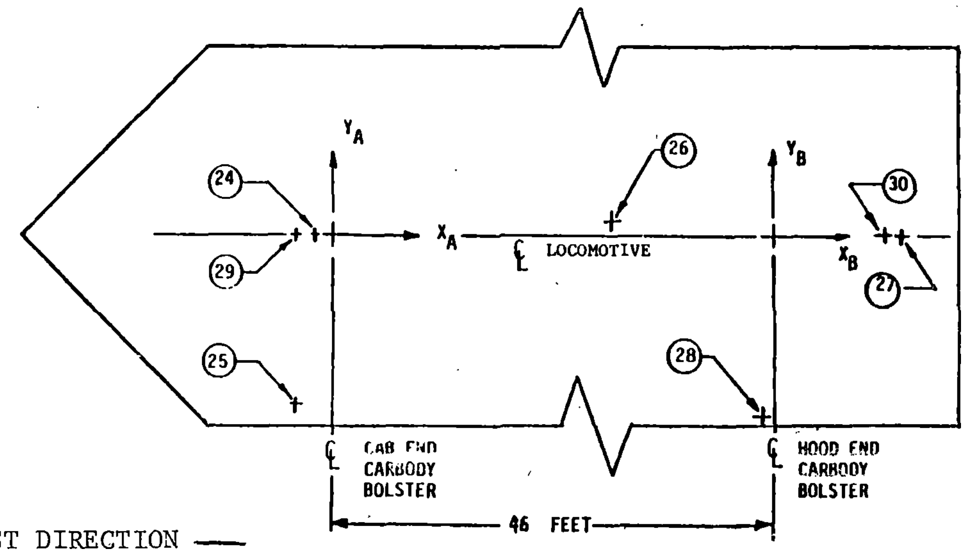


ALD FORWARD OF LEADING INSTRUMENTED AXLE (NUMBER 10)

CONSIST "C"



ALD FORWARD OF LEADING INSTRUMENTED AXLE (NUMBER 7)



← TEST DIRECTION —

FIGURE 3-18. SDP-40F LOCOMOTIVE ACCELEROMETER AND ALD SENSOR LOCATIONS

TABLE 3-4. TRUCK AND AXLE DISPLACEMENT AND ACCELEROMETER TRANSDUCER LOCATIONS

Channel Number		Channel Description	Axle Reference Coordinates (Inches)**		
Raw Tape	Processed Tape		Z	Y	X
13	14	10R Primary Spring Disp.	--	+46.0	-8.0
14	15	11R Primary Spring Disp.	--	+46.0	+8.0
15	16	12R Primary Spring Disp.	--	+46.0	+8.0
16	17	10L Primary Spring Disp.	--	-46.0	-8.0
17	18	11L Primary Spring Disp.	--	-46.0	+8.0
18	19	12L Primary Spring Disp.	--	-46.0	+8.0
31	32	Truck Frame Lateral Acceleration	4.0*	+46.0*	-98.0*
32	33	Truck Frame Lateral Acceleration	4.0*	+46.0*	+94.5*
33	34	10 Lateral Axle Accel.	0	-18.0	+9.0
34	35	11 Lateral Axle Accel.	0	-18.0	+9.0
35	36	12 Lateral Axle Accel.	0	-18.0	+9.0
36	37	10R Vertical Axle Accel.	0	+55.0	-7.5
37	38	11R Vertical Axle Accel.	0	+55.0	-7.5
38	39	12R Vertical Axle Accel.	0	+55.0	·7.5
39	40	10L Vertical Axle Accel.	0	-55.0	-7.5
40	41	11L Vertical Axle Accel.	0	-55.0	-7.5
41	42	12L Vertical Axle Accel.	0	-55.0	·7.5

* REFERENCED TO AXLE #11

** ALL COORDINATES MEASURED FROM AXLE LATERAL, VERTICAL, AND LONGITUDINAL CENTER LINE
Z - VERTICAL (POSITIVE UPWARDS)
Y - LATERAL (POSITIVE TOWARD RIGHT)
X - LONGITUDINAL (POSITIVE TOWARD REAR)

CHANNEL*	DESCRIPTION	LOCATION COORDINATES (INCHES)			
		XA	YA	XB	YB
59	Vertical Accel.			-2.0	-2.0
60	Vertical Accel.	+2.0	-46.0		
61	Vertical Accel.	-2.0	-2.0		
62	Lateral Accel.			+2.0	-2.0
63	Lateral Accel.	+2.0	-2.0		

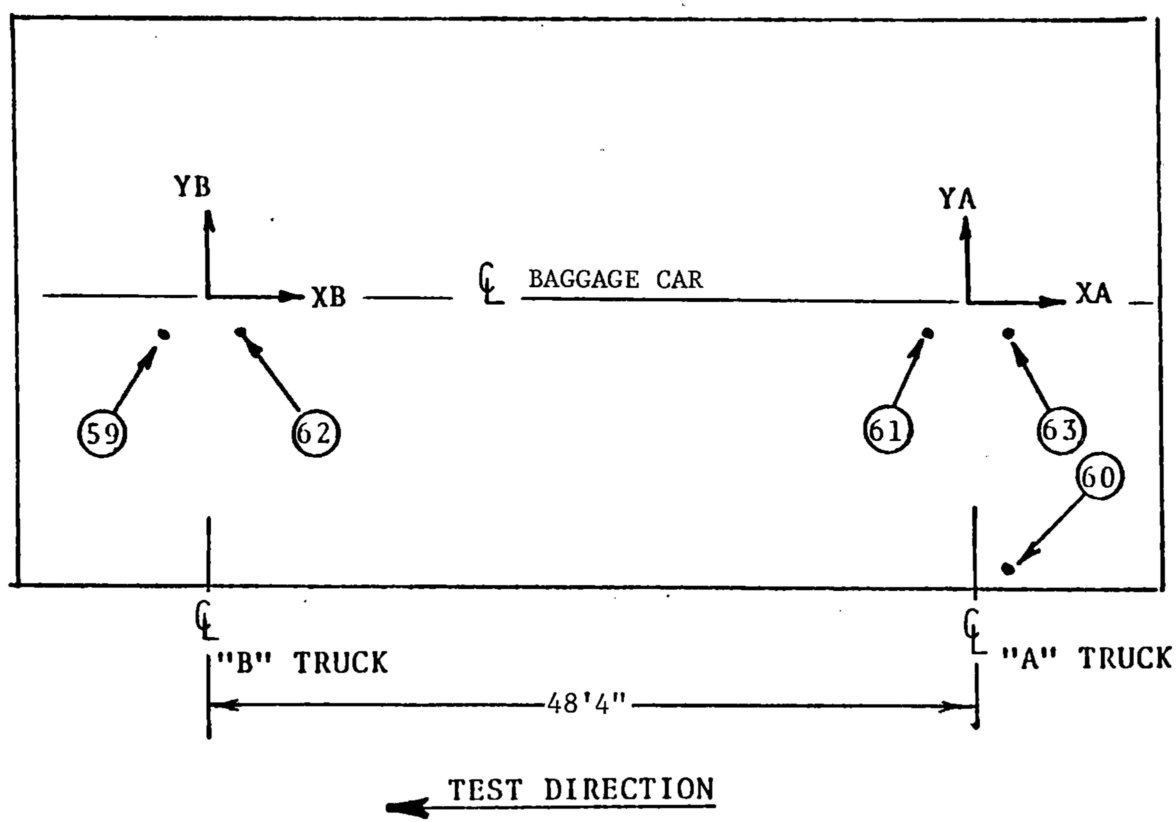


FIGURE 3-19. BAGGAGE CAR CARBODY ACCELEROMETER LOCATIONS

TABLE 3-5. CHANNEL ASSIGNMENTS

PGE. 1
PERTURBED TRACK TEST, SDP-4ØF CONSIST DATA CHANNEL ASSIGNMENTS, T-7
EFFECTIVE DATE :12/Ø1/78 EFFECTIVE RUN: 12Ø1ØØ $= NO VALUE.

Note	CHNL	TYPE		LOCATION	SOURCE	+1ØV RNG	UNITS	CTF FRQ	EL CAL	PH CAL
SEE NOTE 1	Ø	VERT FORCE	*	#4 AXL LFT LOCO	ASEA WH	5Ø.Ø	KIPS	85.Ø	$$$$$$ V	$$$$$$ V
SEE NOTE 1	1	LAT FORCE	*	#4 AXL LFT LOCO	ASEA WH	5Ø.Ø	KIPS	85.Ø	$$$$$$ V	$$$$$$ V
SEE NOTE 1	2	VERT FORCE	*	#4 AXL RGHT LOCO	ASEA WH	5Ø.Ø	KIPS	85.Ø	$$$$$$ V	$$$$$$ V
SEE NOTE 1	3	LAT FORCE	*	#4 AXL RGHT LOCO	ASEA WH	5Ø.Ø	KIPS	85.Ø	$$$$$$ V	$$$$$$ V
SEE NOTE 1	4	VERT FORCE	*	#5 AXL LFT LOCO	ASEA WH	5Ø.Ø	KIPS	85.Ø	$$$$$$ V	$$$$$$ V
SEE NOTE 1	5	LAT FORCE	*	#5 AXL LFT LOCO	ASEA WH	5Ø.Ø	KIPS	85.Ø	$$$$$$ V	$$$$$$ V
SEE NOTE 1	6	VERT FORCE	*	#5 AXL RGHT LOCO	ASEA WH	5Ø.Ø	KIPS	85.Ø	$$$$$$ V	$$$$$$ V
SEE NOTE 1	7	LAT FORCE	*	#5 AXL RGHT LOCO	ASEA WH	5Ø.Ø	KIPS	85.Ø	$$$$$$ V	$$$$$$ V
SEE NOTE 1	8	VERT FORCE	*	#6 AXL LFT LOCO	ASEA WH	5Ø.Ø	KIPS	85.Ø	$$$$$$ V	$$$$$$ V
SEE NOTE 1	9	LAT FORCE	*	#6 AXL LFT LOCO	ASEA WH	5Ø.Ø	KIPS	85.Ø	$$$$$$ V	$$$$$$ V
SEE NOTE 1	1Ø	VERT FORCE	*	#6 AXL RGHT LOCO	ASEA WH	5Ø.Ø	KIPS	85.Ø	$$$$$$ V	$$$$$$ V
SEE NOTE 1	11	LAT FORCE	*	#6 AXL RGHT LOCO	ASEA WH	5Ø.Ø	KIPS	85.Ø	$$$$$$ V	$$$$$$ V
SEE NOTE 1	12	ALD	*	#4 AXL LFT LOCO	ALD SNSR	1.Ø	EVENT	85.Ø	$$$$$$ V	$$$$$$ V
	13	VERT DSPLCMNT	*	JRNL 4 R	STRNG PT	5.Ø	IN.	2Ø.Ø	2.94 V	3.33 V
	14	VERT DSPLCMNT	*	JRNL 5 R	STRNG PT	5.Ø	IN.	2Ø.Ø	2.94 V	3.3Ø V
	15	VERT DSPLCMNT	*	JRNL 6 R	STRNG PT	5.Ø	IN.	2Ø.Ø	3.Ø1 V	3.28 V
	16	VERT DSPLCMNT	*	JRNL 4 L	STRNG PT	5.Ø	IN.	2Ø.Ø	3.62 V	3.29 V
	17	VERT DSPLCMNT	*	JRNL 5 L	STRNG PT	5.Ø	IN.	2Ø.Ø	3.Ø4 V	3.34 V
	18	VERT DSPLCMNT	*	JRNL 6 L	STRNG PT	5.Ø	IN.	2Ø.Ø	2.89 V	3.29 V
	19	AXLE DSPLCMNT	*	TRCK/AXL 4	KAMEN	1.Ø	IN.	85.Ø	$$$$$$ V	$$$$$$ V
	2Ø	AXLE DSPLCMNT	*	TRCK/AXL 5	KAMEN	1.Ø	IN.	85.Ø	$$$$$$ V	$$$$$$ V
	21	AXLE DSPLCMNT	*	TRCK/AXL 6	KAMEN	1.Ø	IN.	85.Ø	$$$$$$ V	$$$$$$ V
	22	FRAME MOTION		#1 BLSTR/TRCK F	STRNG PT	5.Ø	IN.	2Ø.Ø	3.33 V	3.32 V
	23	FRAME MOTION		#2 BLSTR/TRCK R	STRNG PT	5.Ø	IN.	2Ø.Ø	3.22 V	3.3Ø V
	24	VERT ACCLRTN		#1 CRBDY	ACCLRMTR	1.Ø	G	1Ø.Ø	4.13 V	1Ø.ØØ V
	25	VERT ACCLRTN		#2 CRBDY	ACCLRMTR	1.Ø	G	1Ø.Ø	4.66 V	1Ø.ØØ V
	26	VERT ACCLRTN		#3 CRBDY	ACCLRMTR	1.Ø	G	1Ø.Ø	4.24 V	1Ø.ØØ V
	27	VERT ACCLRTN		#4 CRBDY	ACCLRMTR	1.Ø	G	1Ø.Ø	3.98 V	1Ø.ØØ V
	28	VERT ACCLRTN		#5 CRBDY	ACCLRMTR	1.Ø	G	1Ø.Ø	3.97 V	1Ø.ØØ V
	29	LAT ACCLRTN		#6 CRBDY	ACCLRMTR	1.Ø	G	1Ø.Ø	2.Ø6 V	1Ø.ØØ V
	3Ø	LAT ACCLRTN		#7 CRBDY	ACCLRMTR	1.Ø	G	1Ø.Ø	1.97 V	1Ø.ØØ V
	31	LAT ACCLRTN		#1 TRCK FRM F	ACCLRMTR	5.Ø	G	2Ø.Ø	2.28 V	2.ØØ V
	32	LAT ACCLRTN		#2 TRCK FRM R	ACCLRMTR	5.Ø	G	2Ø.Ø	2.52 V	2.ØØ V
	33	LAT ACCLRTN	*	#4 AXLE	ACCLRMTR	25.Ø	G	85.Ø	1.76 V	.4Ø V
	34	LAT ACCLRTN	*	#5 AXLE	ACCLRMTR	25.Ø	G	85.Ø	1.7Ø V	.4Ø V
	35	LAT ACCLRTN	*	#6 AXLE	ACCLRMTR	25.Ø	G	85.Ø	1.75 V	.4Ø V
	36	VERT ACCLRTN	*	#4 AXLE R	ACCLRMTR	25.Ø	G	85.Ø	1.72 V	.4Ø V
	37	VERT ACCLRTN	*	#5 AXLE R	ACCLRMTR	25.Ø	G	85.Ø	2.26 V	.4Ø V
	38	VERT ACCLRTN	*	#6 AXLE R	ACCLRMTR	25.Ø	G	85.Ø	2.12 V	.4Ø V
	39	VERT ACCLRTN	*	#4 AXLE L	ACCLRMTR	25.Ø	G	85.Ø	1.59 V	.4Ø V
	4Ø	VERT ACCLRTN	*	#5 AXLE L	ACCLRMTR	25.Ø	G	85.Ø	1.88 V	.4Ø V
	41	VERT ACCLRTN	*	#6 AXLE L	ACCLRMTR	25.Ø	G	85.Ø	1.47 V	.4Ø V
	42	YAW		#1 TRCK F	STRNG PT	2Ø.Ø	DGRS	2Ø.Ø	4.39 V	1.32 V
	43	YAW		#2 TRCK R	STRNG PT	2Ø.Ø	DGRS	2Ø.Ø	3.32 V	1.23 V
	44	WIND VELOCITY		LOCO	ANMMTR	1ØØ.Ø	MPH	2Ø.Ø	$$$$$$ V	$$$$$$ V
	45	WIND DRCTN		LOCO	ANMMTR	1ØØ.Ø	DGRS	2Ø.Ø	$$$$$$ V	$$$$$$ V
	46	TRCTN MTR CRRNT		LOCO	SPECIAL	1ØØØ.Ø	AMPS	2Ø.Ø	$$$$$$ V	$$$$$$ V
	47	BRAKE PRSSR		LOCO	SPECIAL	1ØØ.Ø	PSI	[illegible]	$$$$$$ V	$$$$$$ V
	48	VERT FORCE		BGG CAR RGHT	STRN GGE	5Ø.Ø	KIPS	85.Ø	3.45 V	$$$$$$ V
	49	LAT FORCE		BGG CAR RGHT	STRN GGE	5Ø.Ø	KIPS	85.Ø	6.17 V	$$$$$$ V
	5Ø	VERT FORCE		BGG CAR LEFT	STRN GGE	5Ø.Ø	KIPS	85.Ø	3.64 V	$$$$$$ V

NOTE: 1. Full-scale range for raw data tapes increased to 100 kips on Channels 0 through 11 for all testing on 12/7/78 through 12/16/78.

* AXLES OR WHEELSETS 4 THROUGH 6 CORRESPOND TO AXLES 10 THROUGH 12 FOR THE "A" CONSIST CONFIGURATION

TABLE 3-5. (Continued)

PGE. 2
PERTURBED TRACK TEST, SDP-4ØF CONSIST DATA CHANNEL ASSIGNMENTS, T-7
EFFECTIVE DATE :12/Ø1/78 EFFECTIVE RUN: 12Ø1ØØ $= NO VALUE.

	CHNL	TYPE		LOCATION	SOURCE	+1ØV RNG	UNITS	CTF FRQ	EL CAL	PH CAL
	51	LAT FORCE		BGG CAR LEFT	STRN GGE	5Ø.Ø	KIPS	85.Ø	5.51 V	$$$$$$ V
	52	LAT FORCE		LOCO CPLR	STRN GGE	5Ø.Ø	KIPS	85.Ø	6.73 V	$$$$$$ V
	53	VERT FORCE		LOCO CPLR	STRN GGE	5Ø.Ø	KIPS	85.Ø	5.36 V	$$$$$$ V
	54	LONG FORCE		LOCO CPLR	STRN GGE	2ØØ.Ø	KIPS	85.Ø	1.Ø6 V	$$$$$$ V
	55	VERT ANGLE		LOCO CPLR	STRNG PT	4Ø.Ø	DGRS	2Ø.Ø	3.65 V	1.38 V
	56	LAT ANGLE		LOCO CPLR	STRNG PT	4Ø.Ø	DGRS	2Ø.Ø	4.21 V	1.57 V
	57	VERT ANGLE		BGG CAR CPLR	STRNG PT	2Ø.Ø	DGRS	2Ø.Ø	2.Ø9 V	2.87 V
	58	LAT ANGLE		BGG CAR CPLR	STRNG PT	2Ø.Ø	DGRS	2Ø.Ø	2.49 V	3.42 V
	59	VERT ACCLRTN		#1 CRBDY BGG CAR	ACCLRMTR	4.Ø	G	1Ø.Ø	1.Ø9 V	1.25 V
	6Ø	VERT ACCLRTN		#2 CRBDY BGG CAR	ACCLRMTR	4.Ø	G	1Ø.Ø	.99 V	2.5Ø V
	61	VERT ACCLRTN		#3 CRBDY BGG CAR	ACCLRMTR	4.Ø	G	1Ø.Ø	2.6Ø V	2.5Ø V
	62	LAT ACCLRTN		#4 CRBDY BGG CAR	ACCLRMTR	4.Ø	G	1Ø.Ø	2.66 V	2.5Ø V
SEE NOTE 2	63	LAT ACCLRTN		#5 CRBDY BGG CAR	ACCLRMTR	2.Ø	G	1Ø.Ø	1.Ø4 V	5.ØØ V
	64	VERT FORCE Q1		#1 AXL LFT LOCO	ASEA WH	125.Ø	KIPS	85.Ø	1.Ø1 V	$$$$$$ V
	65	VERT FORCE Q2		#1 AXL LFT LOCO	ASEA WH	125.Ø	KIPS	85.Ø	1.Ø4 V	$$$$$$ V
	66	LAT FORCE		#1 AXL LFT LOCO	ASEA WH	5Ø.Ø	KIPS	85.Ø	2.12 V	$$$$$$ V
	67	VERT FORCE Q1		#1 AXL RGHT LOCO	ASEA WH	125.Ø	KIPS	85.Ø	1.Ø1 V	$$$$$$ V
	68	VERT FORCE Q2		#1 AXL RGHT LOCO	ASEA WH	125.Ø	KIPS	85.Ø	1.Ø6 V	$$$$$$ V
	69	LAT FORCE		#1 AXL RGHT LOCO	ASEA WH	5Ø.Ø	KIPS	85.Ø	2.Ø6 V	$$$$$$ V
	7Ø	VERT FORCE Q1		#2 AXL LFT LOCO	ASEA WH	125.Ø	KIPS	85.Ø	1.14 V	$$$$$$ V
	71	VERT FORCE Q2		#2 AXL LFT LOCO	ASEA WH	125.Ø	KIPS	85.Ø	1.13 V	$$$$$$ V
	72	LAT FORCE	**	#2 AXL LFT LOCO	ASEA WH	5Ø.Ø	KIPS	85.Ø	2.ØØ V	$$$$$$ V
	73	VERT FORCE Q1		#2 AXL RGHT LOCO	ASEA WH	125.Ø	KIPS	85.Ø	1.Ø5 V	$$$$$$ V
	74	VERT FORCE Q2		#2 AXL RGHT LOCO	ASEA WH	125.Ø	KIPS	85.Ø	1.Ø4 V	$$$$$$ V
	75	LAT FORCE		#2 AXL RGHT LOCO	ASEA WH	5Ø.Ø	KIPS	85.Ø	2.1Ø V	$$$$$$ V
	76	VERT FORCE Q1		#3 AXL LFT LOCO	ASEA WH	125.Ø	KIPS	85.Ø	1.Ø5 V	$$$$$$ V
	77	VERT FORCE Q2		#3 AXL LFT LOCO	ASEA WH	125.Ø	KIPS	85.Ø	1.Ø7 V	$$$$$$ V
	78	LAT FORCE		#3 AXL LFT LOCO	ASEA WH	5Ø.Ø	KIPS	85.Ø	2.Ø6 V	$$$$$$ V
	79	VERT FORCE Q1		#3 AXL RGHT LOCO	ASEA WH	125.Ø	KIPS	85.Ø	1.Ø3 V	$$$$$$ V
	8Ø	VERT FORCE Q2		#3 AXL RGHT LOCO	ASEA WH	125.Ø	KIPS	85.Ø	1.Ø3 V	$$$$$$ V
	81	LAT FORCE		#3 AXL RGHT LOCO	ASEA WH	5Ø.Ø	KIPS	85.Ø	2.Ø9 V	$$$$$$ V
	82	LAT ACCLRTN		T-7 CRBDY	ACCLRMTR	1.Ø	G	1Ø.Ø	$$$$$$ V	1Ø.ØØ V
	83	SPEED		#3 AXL RGHT T-7	ENCDR	1ØØ.Ø	MPH	2Ø.Ø	$$$$$$ V	$$$$$$ V
	84	ALD(RAW)		#4 AXL LFT LOCO	ALD SNSR	1.Ø	EVENT	85.Ø	$$$$$$ V	$$$$$$ V
	2ØØ	L/V		#4 WHL LFT LOCO	CMPUTD	2.Ø	-	85.Ø	$$$$$$ V	$$$$$$ V
	2Ø1	L/V	*	#4 WHL RGHT LOCO	CMPUTD	2.Ø	-	85.Ø	$$$$$$ V	$$$$$$ V
	2Ø2	L/V		#5 WHL LFT LOCO	CMPUTD	2.Ø	-	85.Ø	$$$$$$ V	$$$$$$ V
	2Ø3	L/V		#5 WHL RGHT LOCO	CMPUTD	2.Ø	-	85.Ø	$$$$$$ V	$$$$$$ V
	2Ø4	L/V		#6 WHL LFT LOCO	CMPUTD	2.Ø	-	85.Ø	$$$$$$ V	$$$$$$ V
	2Ø5	L/V		#6 WHL RGHT LOCO	CMPUTD	2.Ø	-	85.Ø	$$$$$$ V	$$$$$$ V
	2Ø6	L/V		TRK LFT LOCO	CMPUTD	1.Ø	-	85.Ø	$$$$$$ V	$$$$$$ V
	2Ø7	L/V		TRK RGHT LOCO	CMPUTD	1.Ø	-	85.Ø	$$$$$$ V	$$$$$$ V
	2Ø8	NET FORCE		#4 AXL LOCO	CMPUTD	5Ø.Ø	KIPS	85.Ø	$$$$$$ V	$$$$$$ V
	2Ø9	NET FORCE	*	#5 AXL LOCO	CMPUTD	5Ø.Ø	KIPS	85.Ø	$$$$$$ V	$$$$$$ V
	21Ø	NET FORCE		#6 AXL LOCO	CMPUTD	5Ø.Ø	KIPS	85.Ø	$$$$$$ V	$$$$$$ V
	211	LAT FORCE		TRK LFT LOCO	CMPUTD	15Ø.Ø	KIPS	85.Ø	$$$$$$ V	$$$$$$ V
	212	LAT FORCE		TRK RGHT LOCO	CMPUTD	15Ø.Ø	KIPS	85.Ø	$$$$$$ V	$$$$$$ V

NOTE 2. FULLSCALE RANGE FOR RAW DATA TAPES DECREASED TO 1G ON CHANNEL 63 FOR ALL TESTING ON 12/12/78 THROUGH 12/16/78

* SEE PREVIOUS PAGE

** ASEA WHEELSETS 1 THROUGH 3 CORRESPOND TO AXLES 10 THRU 12 FOR THE "A" CONSIST CONFIGURATION (THESE ARE THE SAME WHEELSETS NOTED PREVIOUSLY)

TABLE 3-6. PERTURBED TRACK TEST, E-8 LOCOMOTIVE T-5 COMPUTER INPUT CHANNEL ASSIGNMENTS

Channel	Description	Full-Scale Range ±10 v	Filter Corner (Hz)
0	** #10 Axle Vertical Force Left	50 kips	85
1	** #10 Axle Vertical Force Right	50 kips	85
2	** #10 Axle Lateral Force Left	50 kips	85
3	** #10 Axle Lateral Force Right	50 kips	85
4	** #10 L/V Lateral Force Left	50 kips	85
5	** #10 L/V Lateral Force Right	50 kips	85
6	* #10 Axle Vertical Bridge #1 Left (0° and 180°)	50 kips	85
7	* #10 Axle Vertical Bridge #1 Right (0° and 180°)	50 kips	85
8	* #10 Axle Vertical Bridge #2 Left (90° and 270°)	50 kips	85
9	* #10 Axle Vertical Bridge #2 Right (90° and 270°)	50 kips	85
10	* #10 Axle Lateral Bridge #3 Left Sine	50 kips	85
11	* #10 Axle Lateral Bridge #3 Right Sine	50 kips	85
12	* #10 Axle Lateral Bridge #4 Left Cosine	50 kips	85
13	* #10 Axle Lateral Bridge #4 Right Cosine	50 kips	85
14	Filtered ALD (Automatic Location Detector)	0 - 10V	85
15	Automatic Location Detector (E-8)	0 - 10 v	85
16	* #10 Axle Encoder (Bridge Location) #1 (22.5°) Left	0 - 10 v	85
17	* #10 Axle Encoder (Bridge Location) #2 (67.5°) Left	0 - 10 v	85
18	* #10 Axle Encoder (Bridge Location) #3 (112.5°) Left	0 - 10 v	85
19	* #10 Axle Encoder (Bridge Location) #4 (337.5°) Left	0 - 10 v	85

* J-Box Signals from E-8 Locomotive.

** Signals From ENSCO Wheel Processing Chassis.

TABLE 3-6. (Continued)

Channel	Description	Full-Scale Range ±10 v	Filter Corner (Hz)
20	* RQP "A" Vertical	±1.0 g	10
21	* RQP "A" Lateral	±1.0 g	10
22	* RQP "B" Vertical	±1.0 g	10
23	* RQP "B" Lateral	±1.0 g	10
24	* "B" Vertical Side Sill Acceleration	±1.0 g	20
25	* Truck Yaw "A"	±10°	20
26	* Truck Yaw "B"	±10°	20
27	Baggage Car Vertical Force Left	0-50 kips	85
28	Baggage Car Lateral Force Left	0-50 kips	85
29	Baggage Car Vertical Force Right	0-50 kips	85
30	Baggage Car Lateral Force Right	0-50 kips	85
31	Coupler Angle Vertical Baggage Car	±20°	20
32	Coupler Angle Lateral Baggage Car	±20°	20
33	#1 Vertical Carbody Acceleration Baggage Car	±1.0 g	10
34	#2 Vertical Carbody Acceleration Baggage Car	±1.0 g	10
35	#3 Vertical Carbody Acceleration Baggage Car	±1.0 g	10
36	#4 Lateral Carbody Acceleration Baggage Car	±1.0 g	10
37	#5 Lateral Carbody Acceleration Baggage Car	±1.0 g	10
38	Speed		
39	T-5 Lateral Acceleration, Carbody, Trailing Truck		

*J-Box Signals From E-8 Locomotive.

NOTES: 1. Baggage wheel forces are from AAR instrumented wheelset.
2. Baggage car accelerometers are Setra 114 ±5 g.

ALD

CONSIST	LOCATION COORDINATES (INCHES) X	Y
A, B, B*, and D	-18.5	-55.0
C	+18.5	-55.0

CARBODY ACCELEROMETERS

CHANNEL	DESCRIPTION	LOCATION COORDINATES (INCHES) X_A	Y_A	X_B	Y_B
20	Vert. Accel.	-36.5	-7.0		
21	Lat. Accel.	-32.0	-7.0		
22	Vert. Accel.			+34.5	-2.0
23	Lat. Accel.			+39.0	-2.0
24	Vert. Accel.			+36.5	+51.0

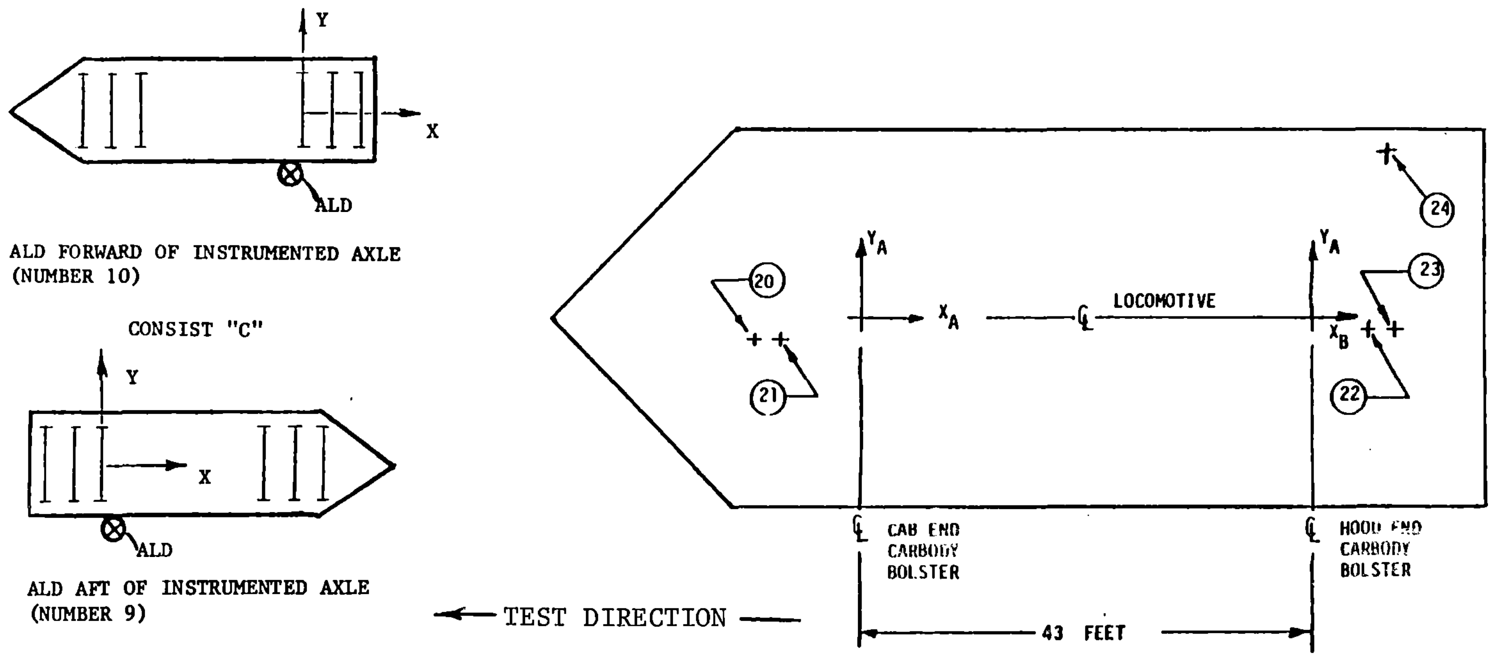


FIGURE 3-20. E-8 LOCOMOTIVE ACCELEROMETER AND ALD SENSOR LOCATIONS

positive is upward, toward the right relative to the locomotive, forward, or clockwise looking down on the consist. An important counterintuitive convention is that an inward force on the wheel flange is negative. For the Brush charts, this was reversed. Spring extensions are positive, as are longitudinal coupler forces in compression. Downward coupler motions are defined as positive vertical coupler angles; and looking down on the coupler, counterclockwise rotations relative to the attached carbodies are defined as positive lateral coupler angles. These conventions are summarized in Figure 3-21.

3.4 WAYSIDE INSTRUMENTATION

There were seven sites of wayside instrumentation used for the PTT. Six of these were in the curved track test zone and one was in the tangent test zone. The type, number, and general locations of the transducers are listed in Table 3-7.

3.4.1 Rail Loads Instrumentation

One site in section 4 and three sites in section 5, one for each subsection of superelevation, contained most of the wayside instrumentation which was installed and maintained by Battelle Columbus Laboratories (BCL). Vertical and lateral rail force, comprising 60 channels of data, were measured over two rail lengths surrounding the perturbation cusp at the junction of sections 4.3 and 4.4. In addition, five electronic and one mechanical deflection transducers, measuring various rail deflections, and one electronic transducer measuring tie lateral displacement, were located approximately where peak lateral loads were expected. The mechanical displacement gage was used to provide a quality check on the electronic gages and was not included in the BCL data base. A schematic of the wayside instrumentation is shown in Figure 3-22 for section 4. The specific locations of the sensors according to crib number are shown in Figure 3-23. The location relative to the rail of the deflection sensors is shown in Figure 3-24. A schematic of the vertical and lateral force sensor layout in the three subsections of varying superelevation in section 5 are shown in Figure 3-25 with the specific locations of the sensors according to crib number shown in Figure 3-26.

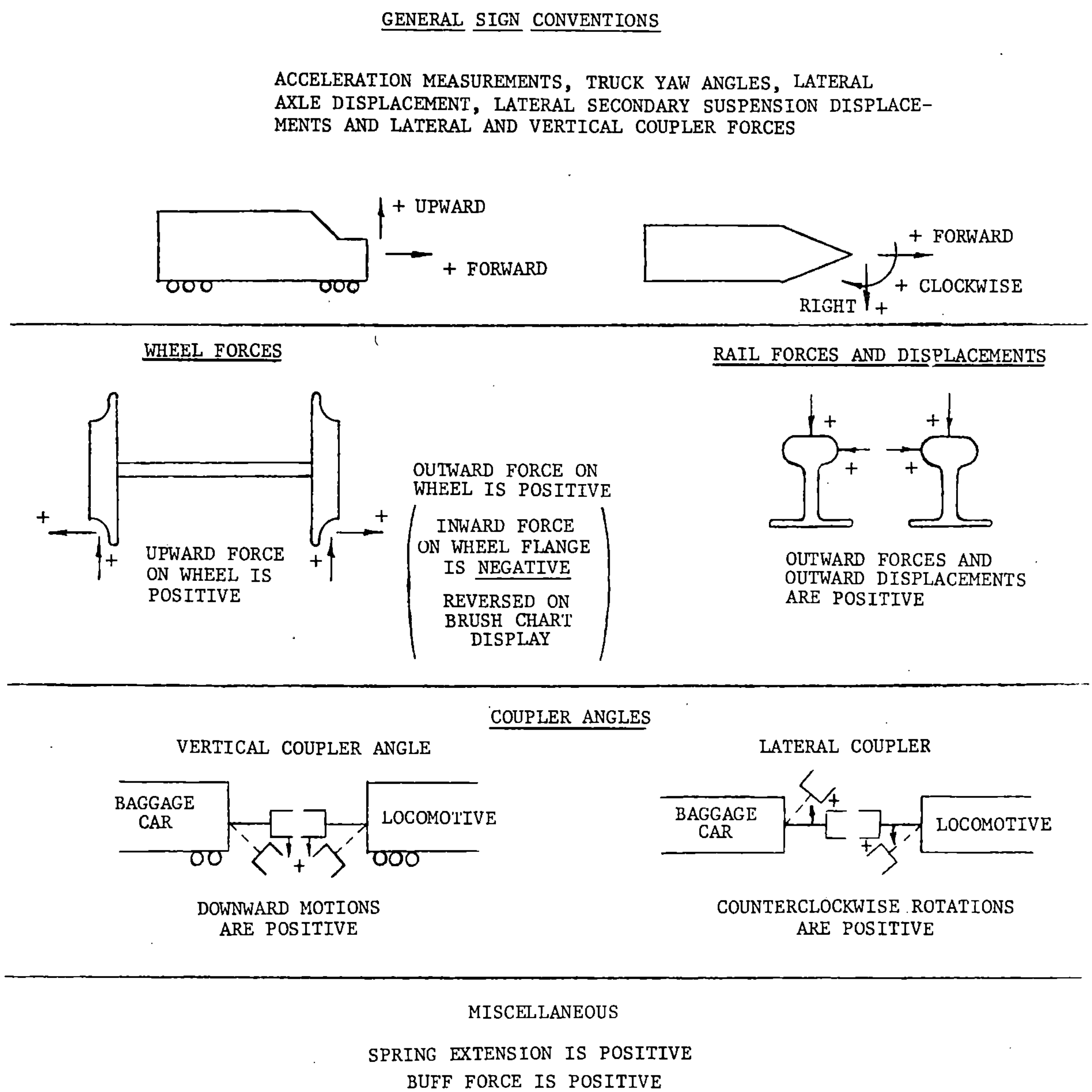
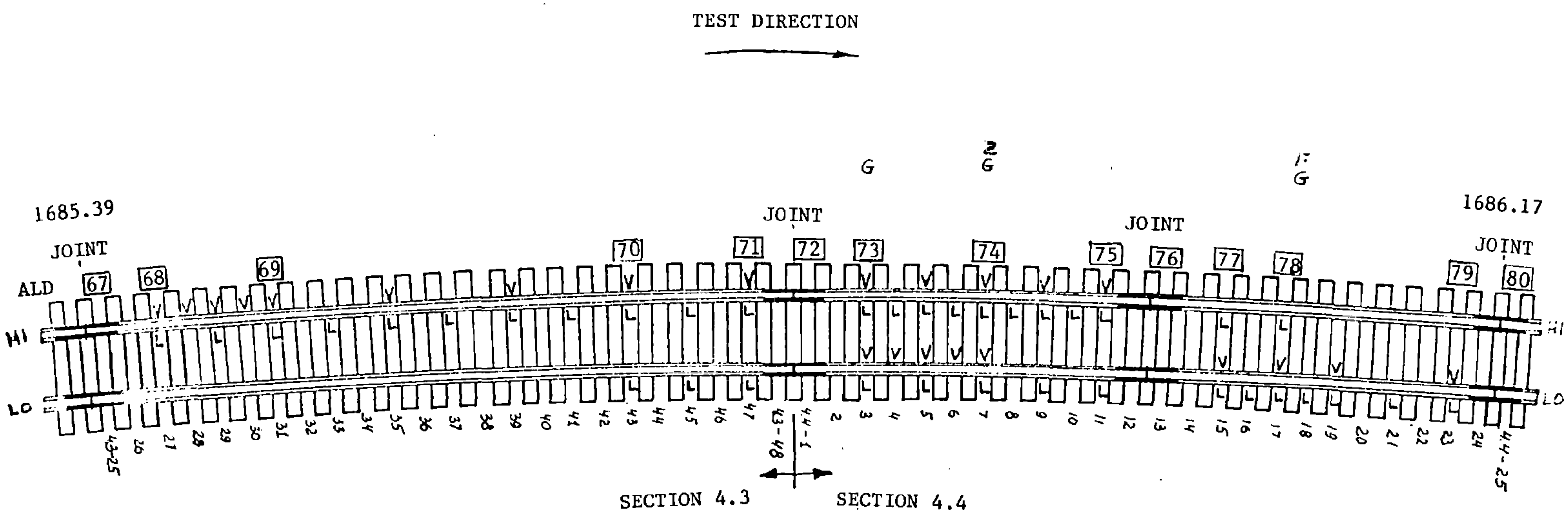


FIGURE 3-21. SIGN CONVENTIONS

TABLE 3-7. WAYSIDE INSTRUMENTATION LOCATIONS

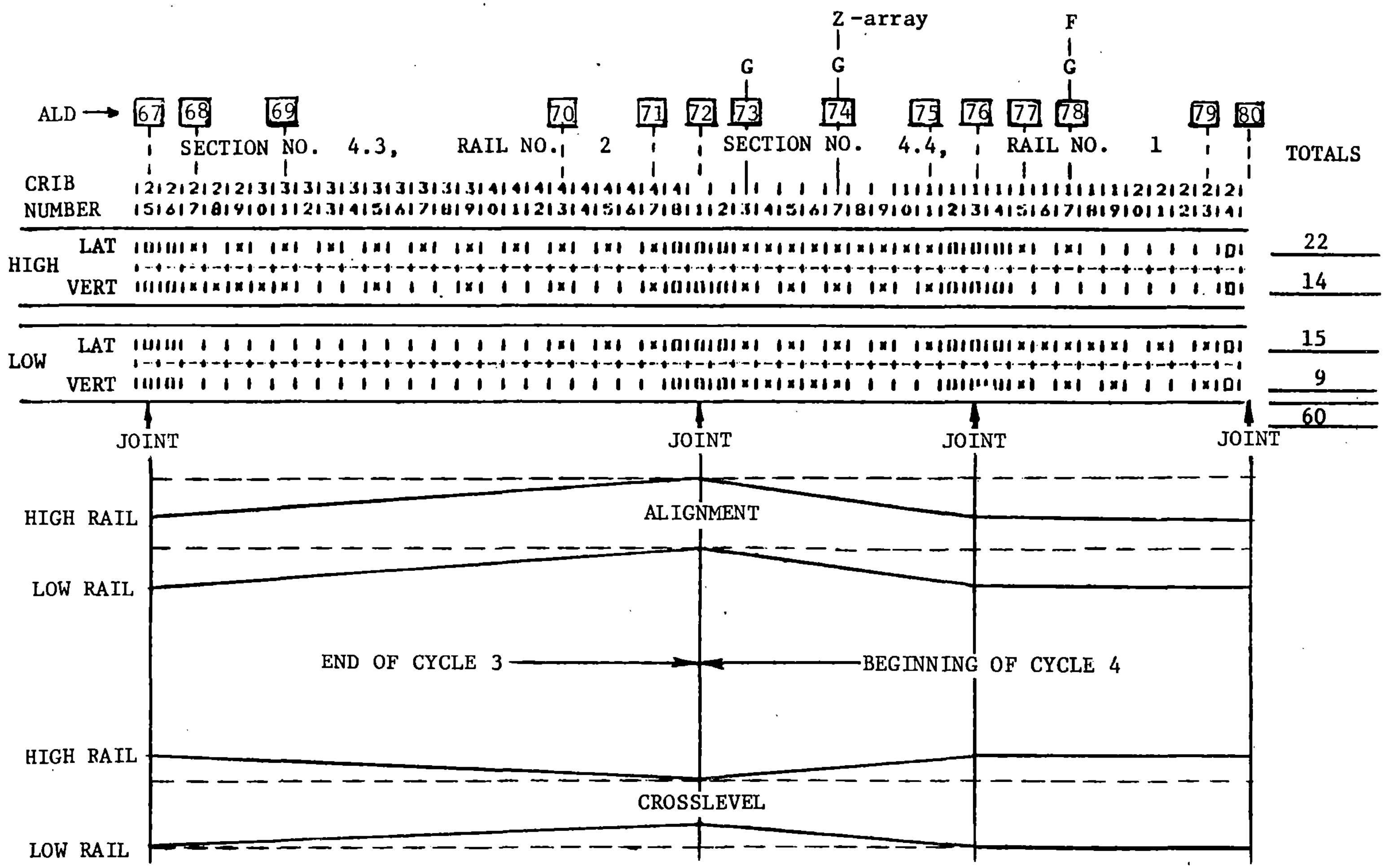
SECTION	TYPE OF TRANSDUCER	NUMBER OF TRANSDUCERS
3.3 (NOT INCLUDED IN BCL DATA BASE)*	MECHANICAL DEFLECTION - DYNAMIC GAGE WIDENING	2
	MECHANICAL DEFLECTION - TIE SHIFT	2
	LVDT ELECTRONIC RAIL DEFLECTION	5
	VERTICAL STRAIN GAGE WHEEL DETECTOR	1
	LVDT ELECTRONIC TIE DISPLACEMENT	1
3.5 (NOT INCLUDED IN BCL DATA BASE)*	MECHANICAL DEFLECTION - DYNAMIC GAGE WIDENING	2
	MECHANICAL DEFLECTION - TIE SHIFT	2
	LVDT ELECTRONIC RAIL DEFLECTION	5
	LVDT ELECTRONIC TIE DISPLACEMENT	1
4.3-4	HIGH RAIL LATERAL FORCE	22
	LOW RAIL LATERAL FORCE	15
	HIGH RAIL VERTICAL FORCE	14
	LOW RAIL VERTICAL FORCE	9
	LVDT ELECTRONIC RAIL DEFLECTION	5
	MECHANICAL DEFLECTION - DYNAMIC GAGE WIDENING	1
	HIGH RAIL LONGITUDINAL FORCE	1
	LVDT ELECTRONIC TIE DISPLACEMENT	1
5.3	HIGH RAIL LATERAL FORCE	10
	HIGH RAIL VERTICAL FORCE	4
5.13	HIGH RAIL LATERAL FORCE	10
	HIGH RAIL VERTICAL FORCE	4
5.23	HIGH RAIL LATERAL FORCE	10
	HIGH RAIL VERTICAL FORCE	4
9.3-4 (NOT INCLUDED IN BCL DATA BASE)*	MECHANICAL DEFLECTION - DYNAMIC GAGE WIDENING	5
	MECHANICAL DEFLECTION - TIE SHIFT	5

* RECORDED BY TTC, TO BE USED IN RAIL STIFFNESS STUDIES BY THE AAR AND BCL



L = LOCATION OF LATERAL FORCE MEASUREMENT
V = LOCATION OF VERTICAL FORCE MEASUREMENT
Z = LOCATION OF TTD'S TRACK STRENGTH DYNAMIC MEASUREMENTS
G = LOCATION OF ELECTRONIC DYNAMIC GAGE MEASUREMENTS
F = LOCATION OF FISHSCALE DYNAMIC GAGE MEASUREMENT

FIGURE 3-22. SCHEMATIC OF WAYSIDE INSTRUMENTATION IN SECTION 4 PIECEWISE LINEAR ALIGNMENT AND CROSSLEVEL

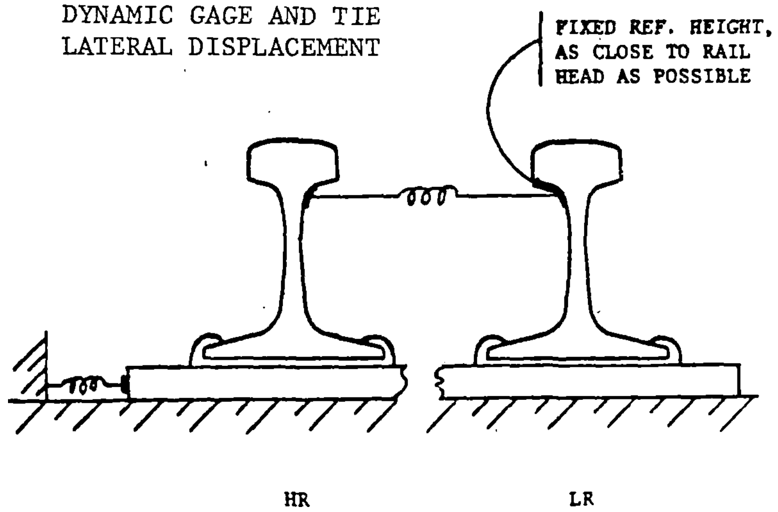


X = LOCATION OF WAYSIDE FORCE MEASUREMENT
G = LOCATION OF ELECTRONIC DYNAMIC GAGE MEASUREMENT
Z = LOCATION OF TTD's TRACK STRENGTH DYNAMIC MEASUREMENTS
F = LOCATION OF FISHSCALE DYNAMIC GAGE MEASUREMENT

(STIFFNESS MEASUREMENTS MADE BEFORE AND AFTER TESTS AT LOCATIONS G)

FIGURE 3-23. WAYSIDE TRANSDUCER LOCATIONS FOR PIECEWISE LINEAR ALIGNMENT PLUS CROSSLEVEL SECTION 4

FISHSCALE ARRANGEMENT FOR
DYNAMIC GAGE AND TIE
LATERAL DISPLACEMENT



Z - ARRAY

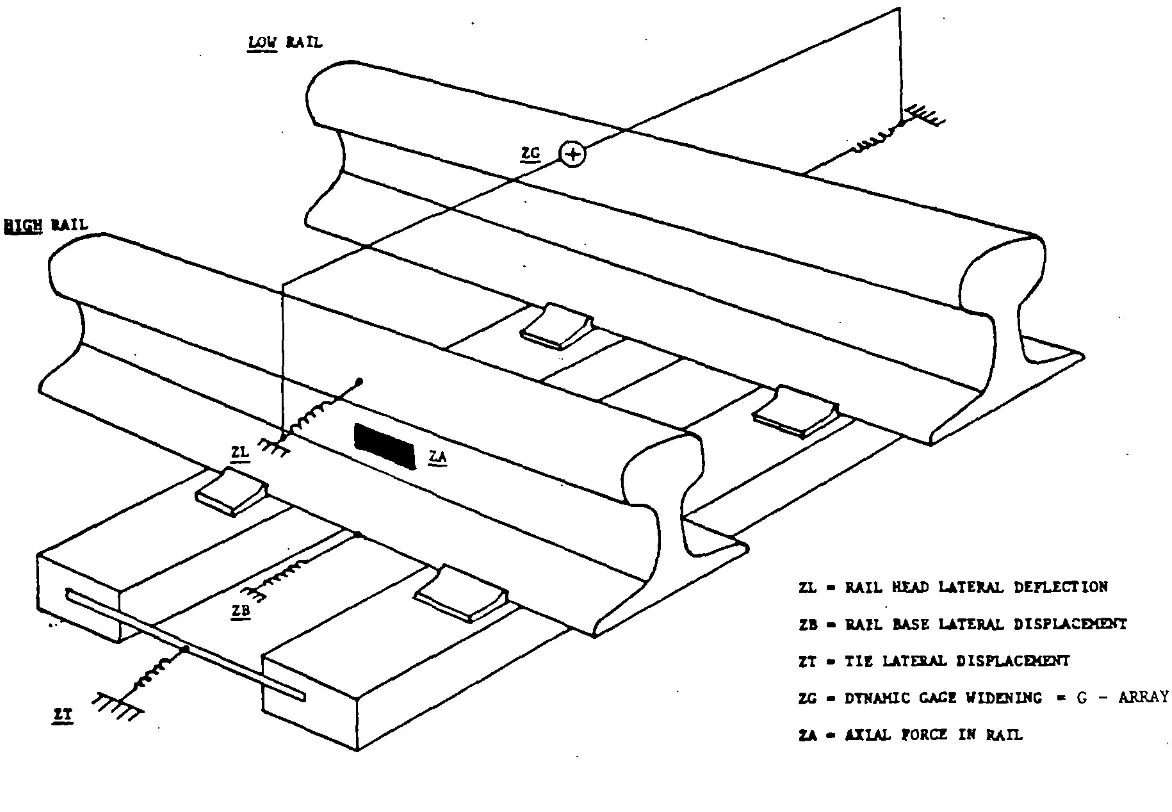
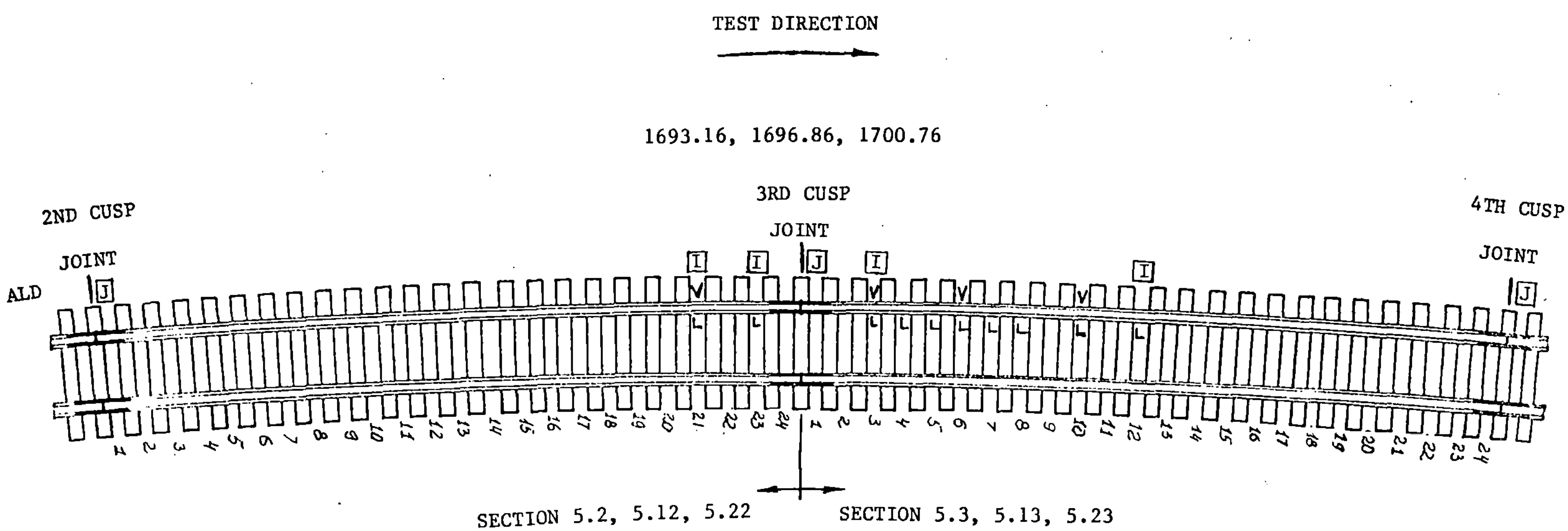
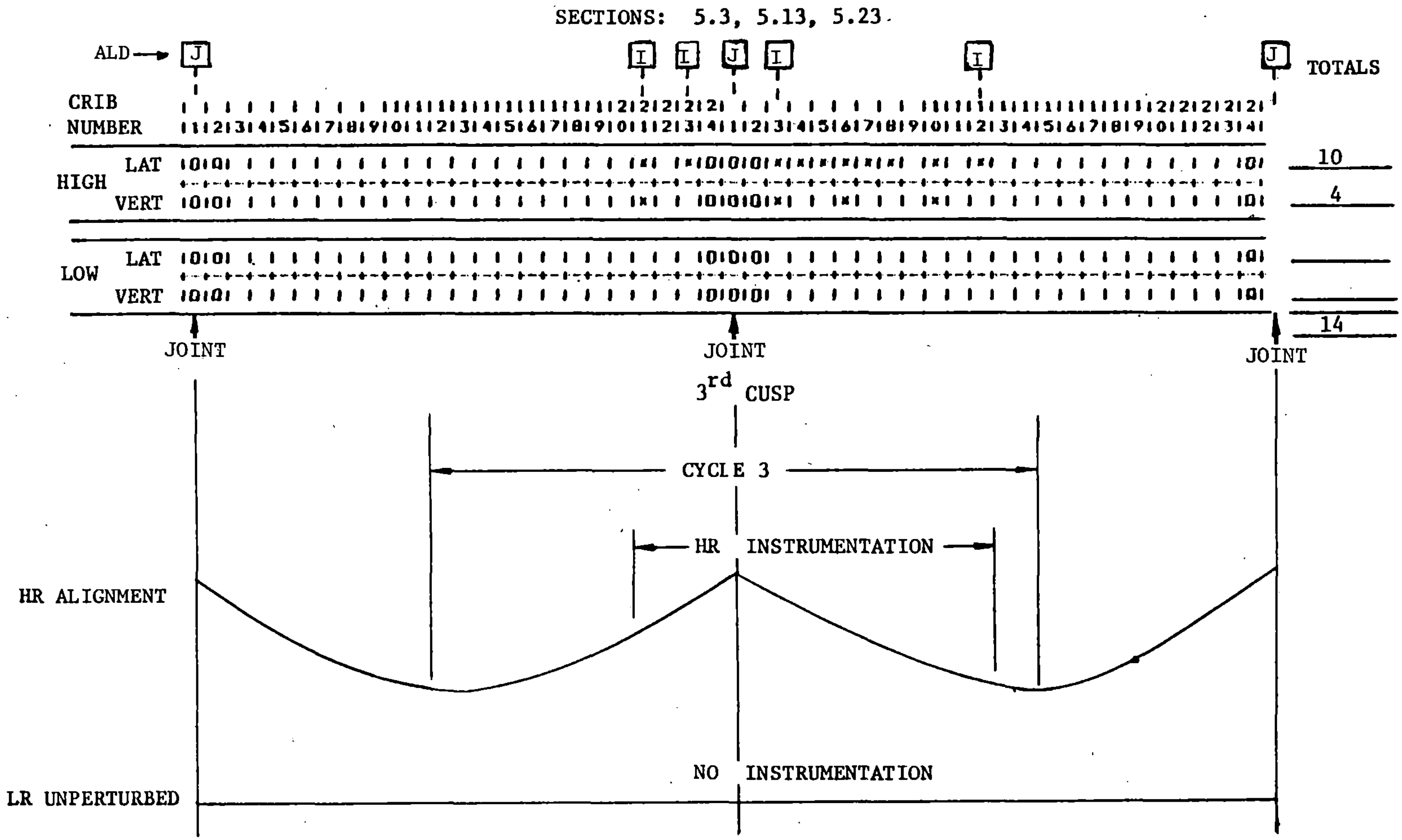


FIGURE 3-24. SCHEMATIC OF DISPLACEMENT TRANSDUCER ARRAYS



L = LOCATION OF LATERAL FORCE MEASUREMENT
V = LOCATION OF VERTICAL FORCE MEASUREMENT

FIGURE 3-25. SCHEMATIC OF WAYSIDE INSTRUMENTATION IN SECTION 5 HIGH RAIL ONLY RECTIFIED SINE ALIGNMENT WITH VARYING SUPERELEVATION



I = LOCATION OF ALD MARKING INSTRUMENTATION
J = LOCATION OF ALD MARKING JOINT (NOT PRESENT IN SECTION 5.23)
X = LOCATION OF WAYSIDE FORCE MEASUREMENT

FIGURE 3-26. WAYSIDE TRANSDUCER LOCATIONS FOR HIGH RAIL MISALIGNMENT SECTION 5

3.4.2 Track Deflection Instrumentation

Section 3 contained two subsections, one with a nominal spiking pattern and the other with every other tie unspiked, and the ties which were spiked contained only two per tie plate (minimum Class 4 standards). Each subsection contained a site of electronic and mechanical deflection gages to record the variation in rail and tie lateral deflections resulting from the different spiking patterns. The specific locations of the various transducers according to crib number are shown in Figure 3-27. The location of the sensors within the section is shown in Figure 3-28.

3.4.3 Deflection Gages for Section 9

To monitor the safety of the consist, 10 mechanical deflection gages, or "fishscales," were located in perturbed track section 9. These measured maximum dynamic gage widening and tie shift. The locations of these gages are shown according to crib number in Figure 3-29.

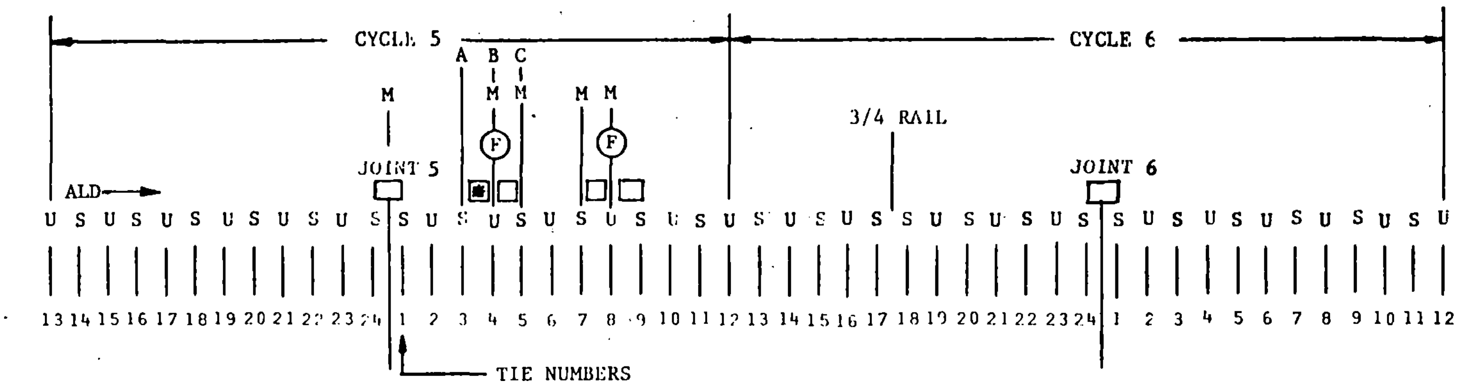
3.4.4 PTT Freight Follow-up

The wayside instrumentation for the follow-up freight test included only the BCL sensors in sections 4 and 5 of the curved test zone. No changes were made in section 5; however, the deployment of gages in section 4 was changed slightly to accommodate 5 wheel detectors. The locations of the added wheel detectors and of the sensors which were dropped are shown in Figure 3-30.

3.5 AUTOMATIC LOCATION DETECTORS

The Automatic Location Detectors (ALD) represent an important aspect of the tests in that they provide an accurate and recurring reference between onboard response data and the track locations. In Figures 3-31 and 3-32, the ALD trace for each test zone is shown with a sketch of the perturbation shapes and the ALD numbering. The intent of these figures is to provide a "map" of the ALD's in each section. For the specific location of ALD's marking instrumentation sites, refer to the appropriate instrumentation layout figure in Chapter 3.4.

The ALD sensor was mounted 18.5 inches forward of the leading instrumented axle (axle 10) on the E-8 and SDP-40F locomotives in the forward facing orientations. For the



U = UNSPIKED (HIGH AND LOW RAILS)

S = SPIKED (2 SPIKES PER TIE PLATE, HIGH AND LOW RAILS)

F = FISHSCALES MEASURING MAXIMUM DYNAMIC GAGE AND TIE SHIFT (CYCLES 3 AND 5, TTC)

M = LOCATIONS OF STIFFNESS MEASUREMENTS, MADE BEFORE AND AFTER TESTS (CYCLES 3 AND 5, BATTELLE)

A = LVDT RAILHEAD, B = LVDT RAILHEAD AND BASE, C = LVDT RAILHEAD, BASE, AND TIE

☐ = ALD LOCATION

NOTES (1) THE TIES ON EITHER SIDE OF A JOINT ARE SPIKED TIES

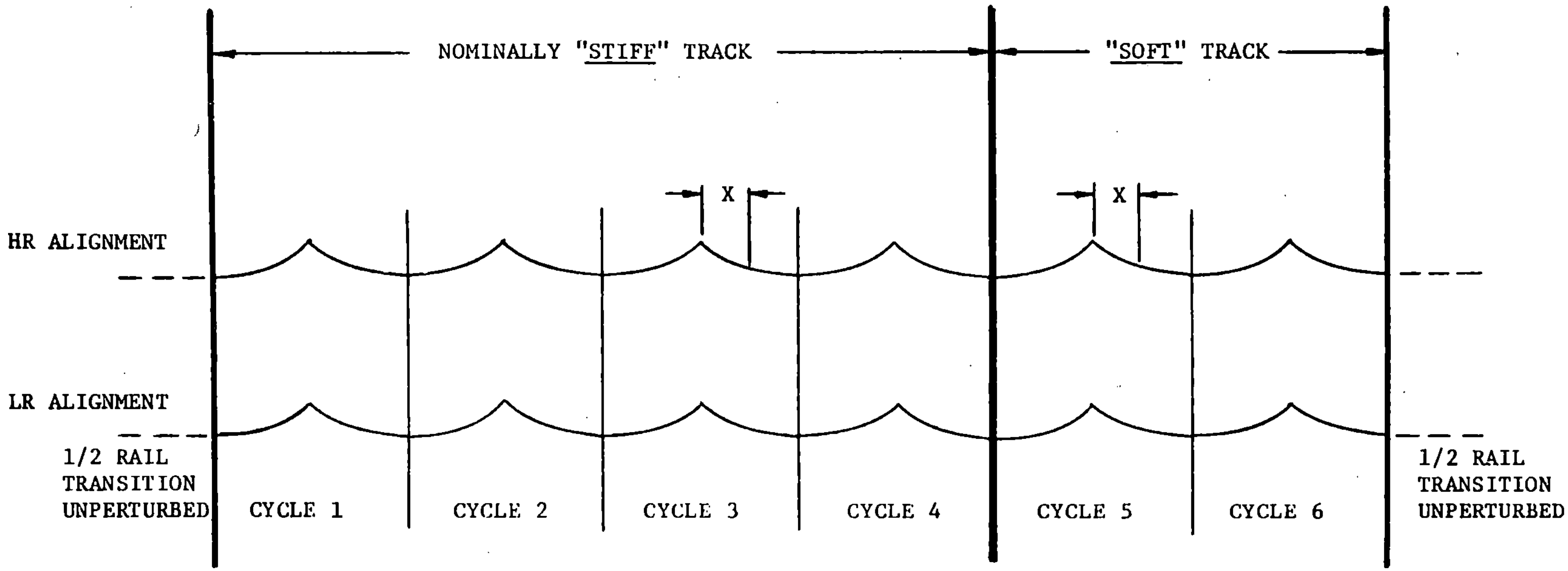
(2) EVERY OTHER TIE IS THEN UNSPIKED (EXCEPT AT THE 3/4 RAIL POINT BEFORE JOINT 6)

(3) ALL SPIKED TIES ARE 2 SPIKES PER TIE PLATE

(4) ☒ NOT PRESENT IN SECTION 3.3 THROUGHOUT THE TEST - HAS BEEN DELETED FROM PROCESSED TAPES

(5) INSTRUMENTATION LAYOUT IN SECTION 3.3 IS IDENTICAL TO LAYOUT SHOWN

FIGURE 3-27. CONSTRUCTION SPECIFICATION FOR "SOFT" TRACK SECTIONS 3.5 AND 3.6 AND TEST MEASUREMENT SPECIFICATIONS FOR SECTIONS 3.3 AND 3.5

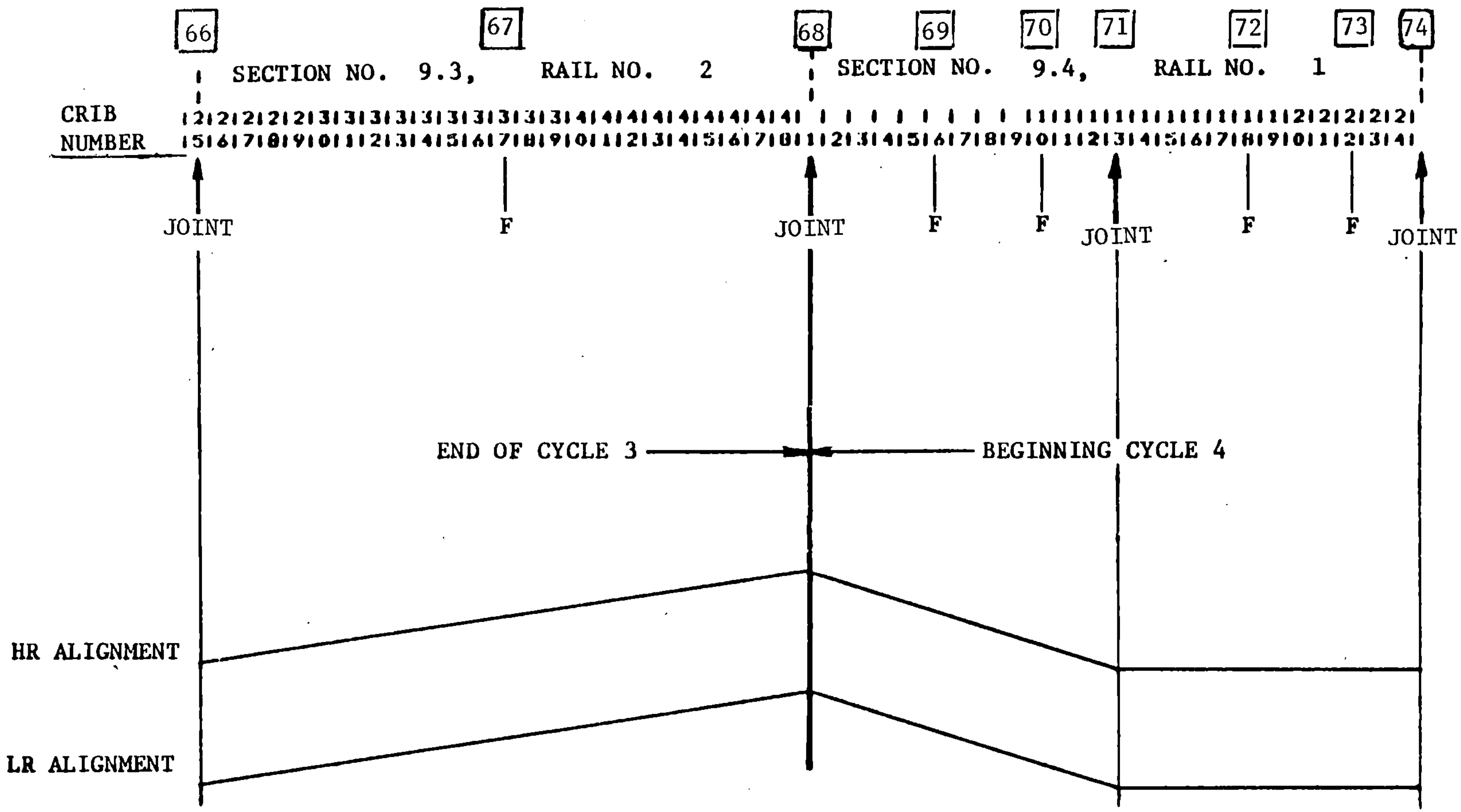


NOTES

(1) X = TEST MEASUREMENT SITE (DYNAMIC DEFLECTION AND STIFFNESS MEASUREMENTS)

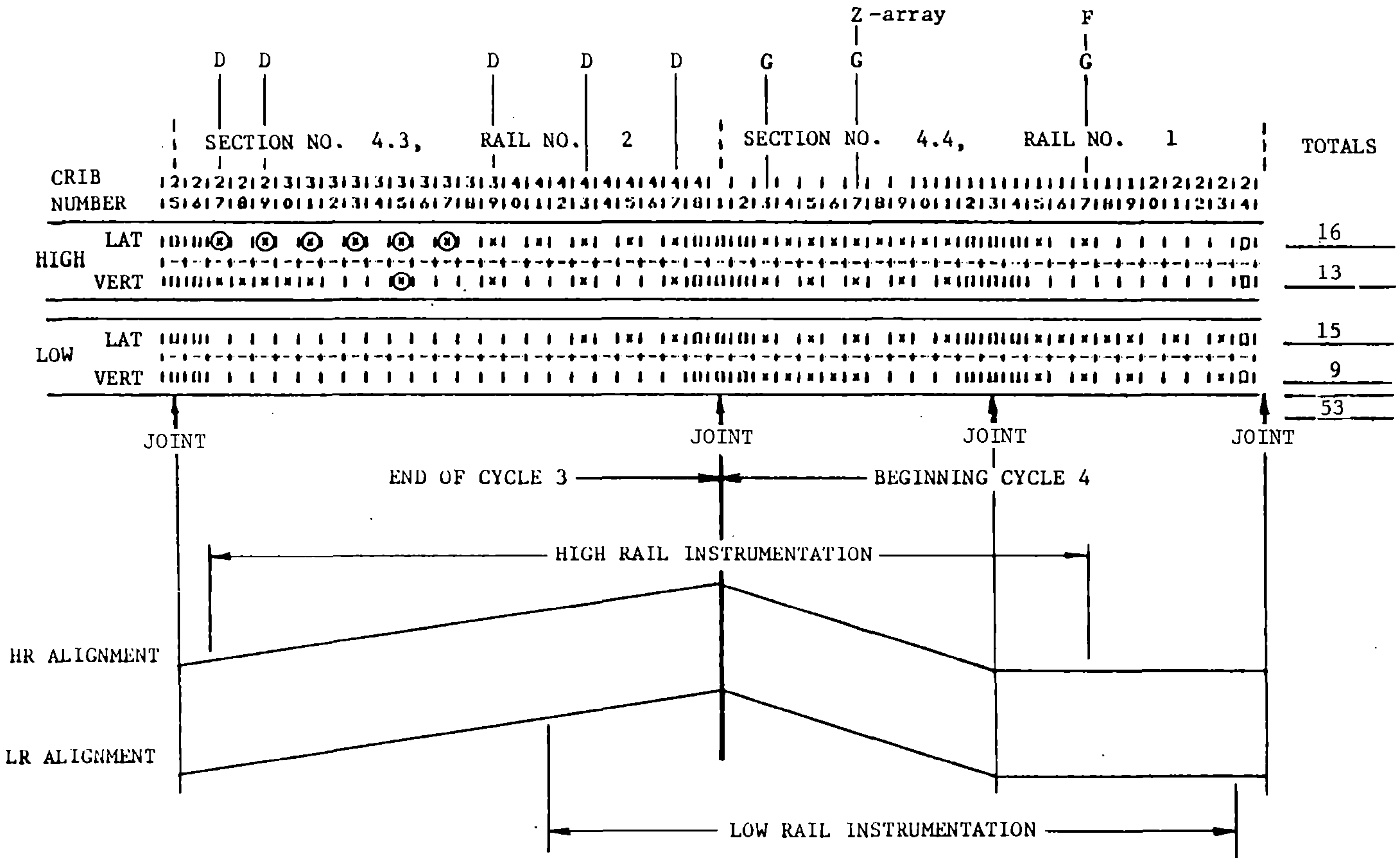
(2) ALL CYCLES ARE 1" RECTIFIED SINE ALIGNMENT PERTURBATIONS, AS ORIGINALLY SPECIFIED

FIGURE 3-28. OVERVIEW OF MODIFIED SECTION 3



F = FISHSCALES MEASURING MAXIMUM DYNAMIC GAGE AND TIE SHIFT (TTC)

FIGURE 3-29. FISHSCALE LOCATIONS FOR TANGENT TRACK PIECEWISE LINEAR ALIGNMENT PLUS CROSSLEVEL SECTION 9



X = LOCATION OF WAYSIDE FORCE MEASUREMENT
G = LOCATION OF ELECTRONIC DYNAMIC GAGE MEASUREMENT
Z = LOCATION OF TTD'S TRACK STRENGTH DYNAMIC MEASUREMENTS
F = LOCATION OF FISHSCALE DYNAMIC GAGE MEASUREMENT
D = LOCATION OF WHEEL DETECTORS

(STIFFNESS MEASUREMENTS MADE BEFORE FREIGHT TESTS AT LOCATIONS G)

⊗ = REMOVED LATERAL AND VERTICAL CIRCUITS

FIGURE 3-30. WAYSIDE TRANSDUCER LOCATIONS FOR PIECEWISE LINEAR ALIGNMENT PLUS CROSSLEVEL SECTION 4 FOR PTT FREIGHT TEST

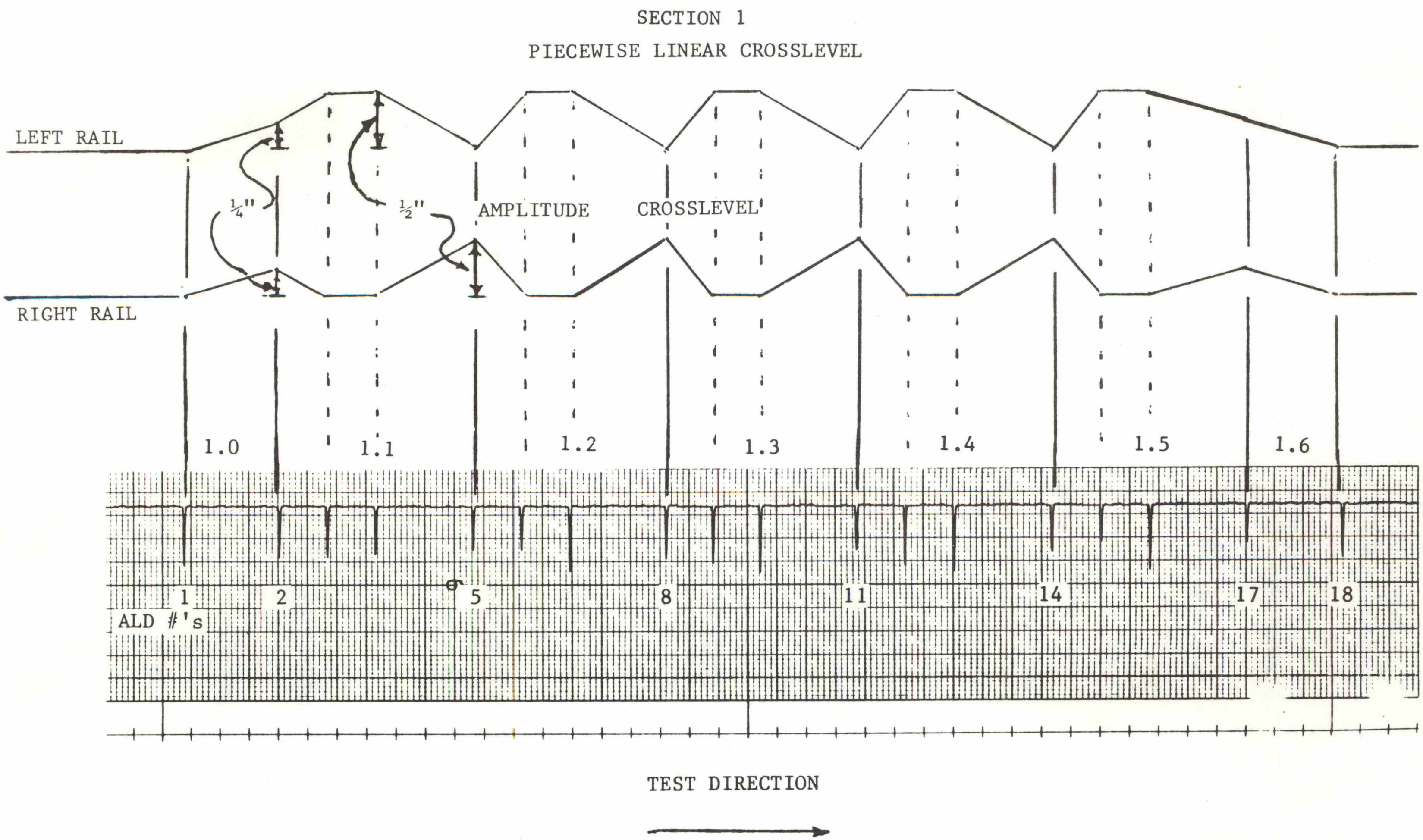
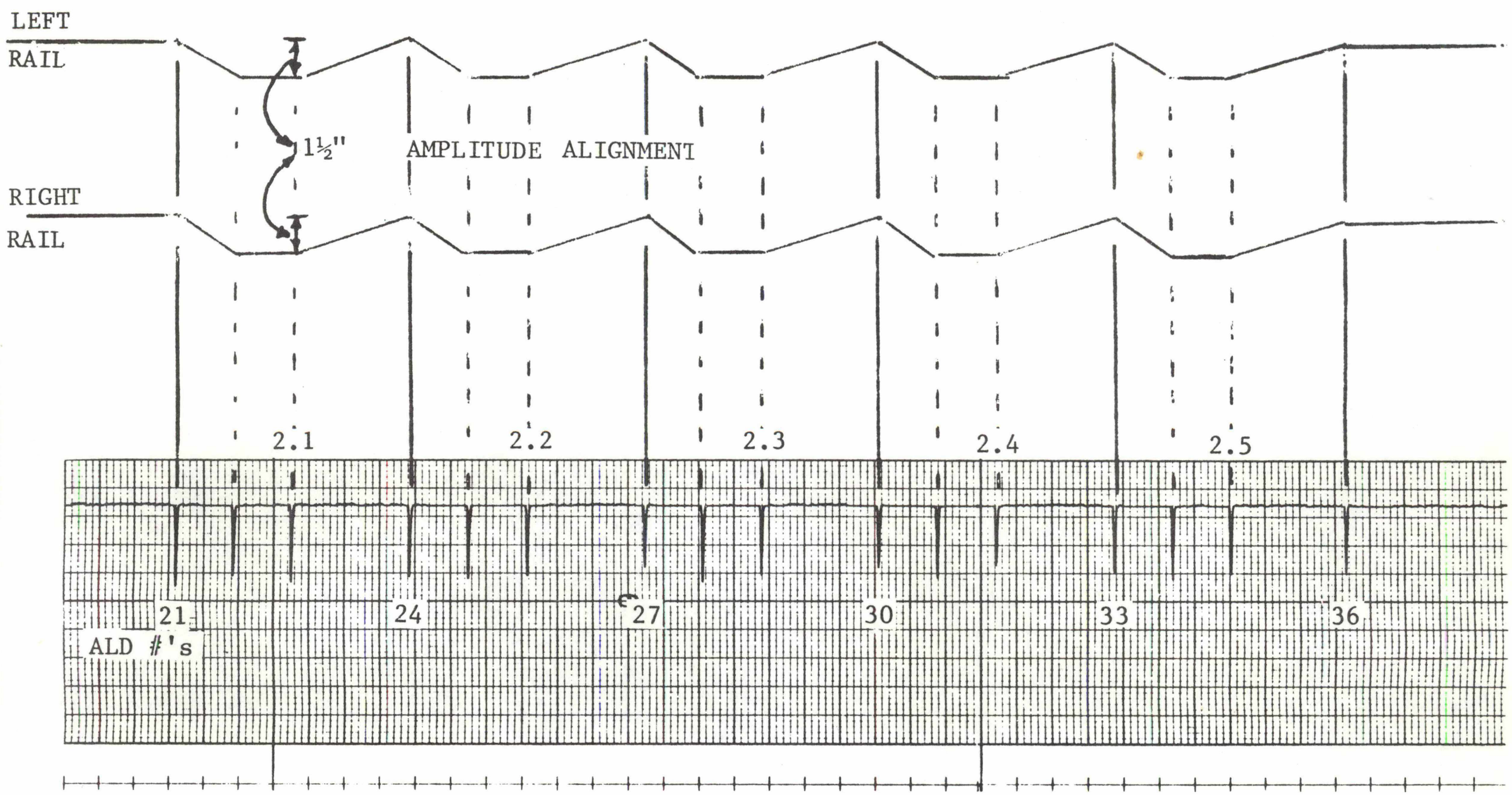


FIGURE 3-31. ALD MAPPING - CURVED TEST ZONE



TEST DIRECTION

FIGURE 3-31. (Continued)

SECTION 3

RECTIFIED SINE ALIGNMENT

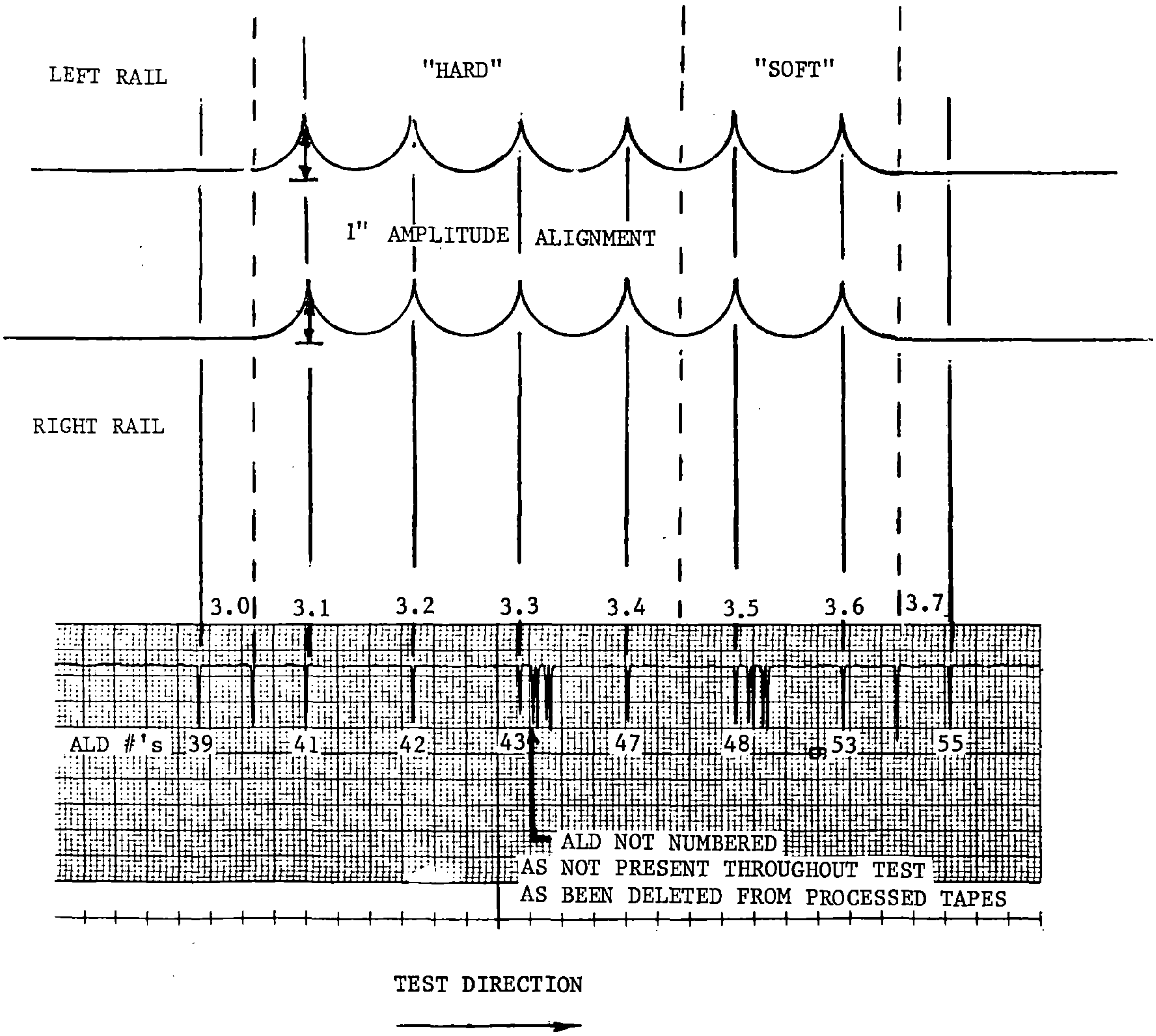


FIGURE 3-31. (Continued)*

*Further details in Figure 3-37.

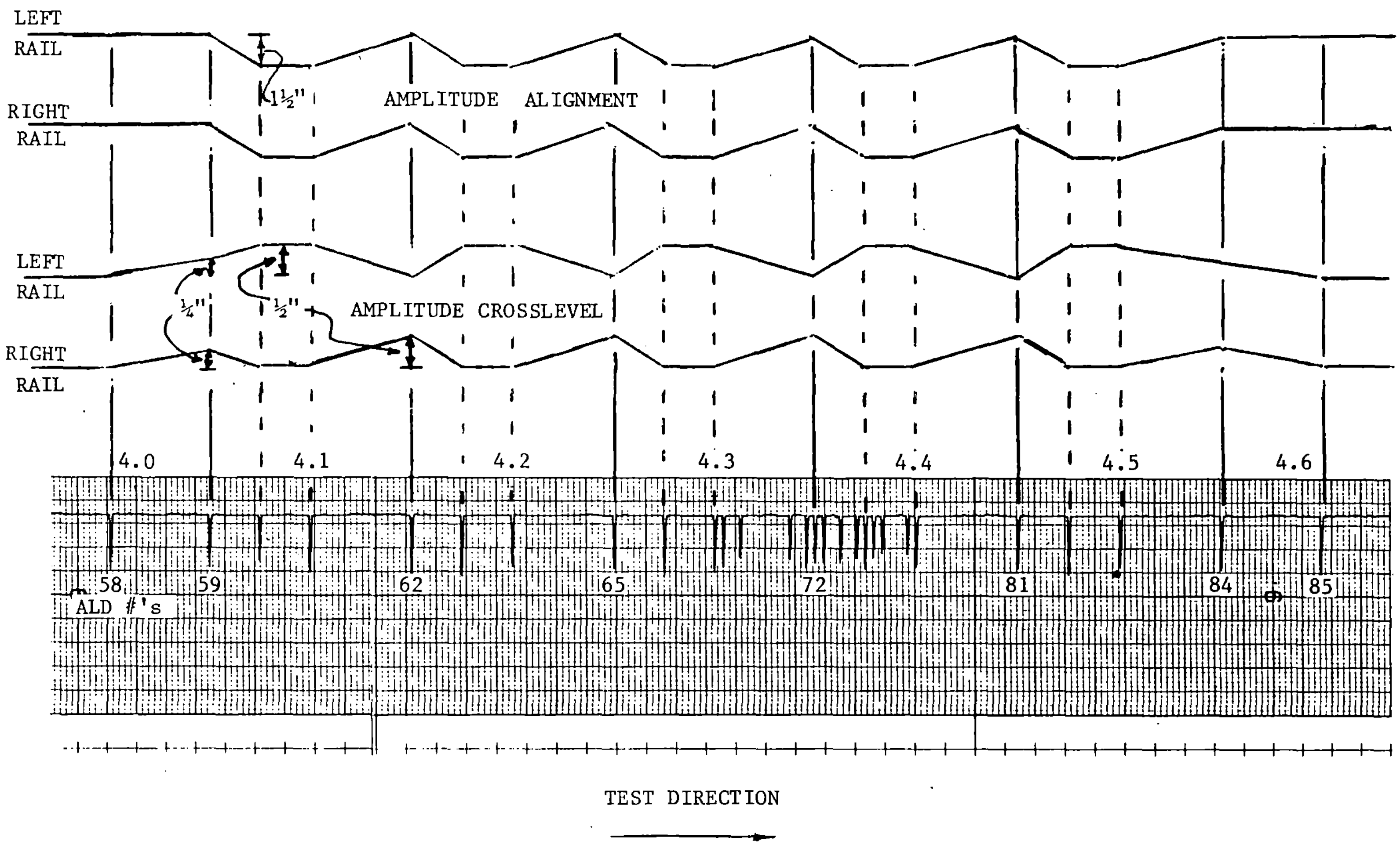


FIGURE 3-31. (Continued)*

*Further details in Figure 3-23.

SECTION 5

HIGH RAIL ONLY RECTIFIED SINE ALIGNMENT
WITH VARYING SUPERELEVATION

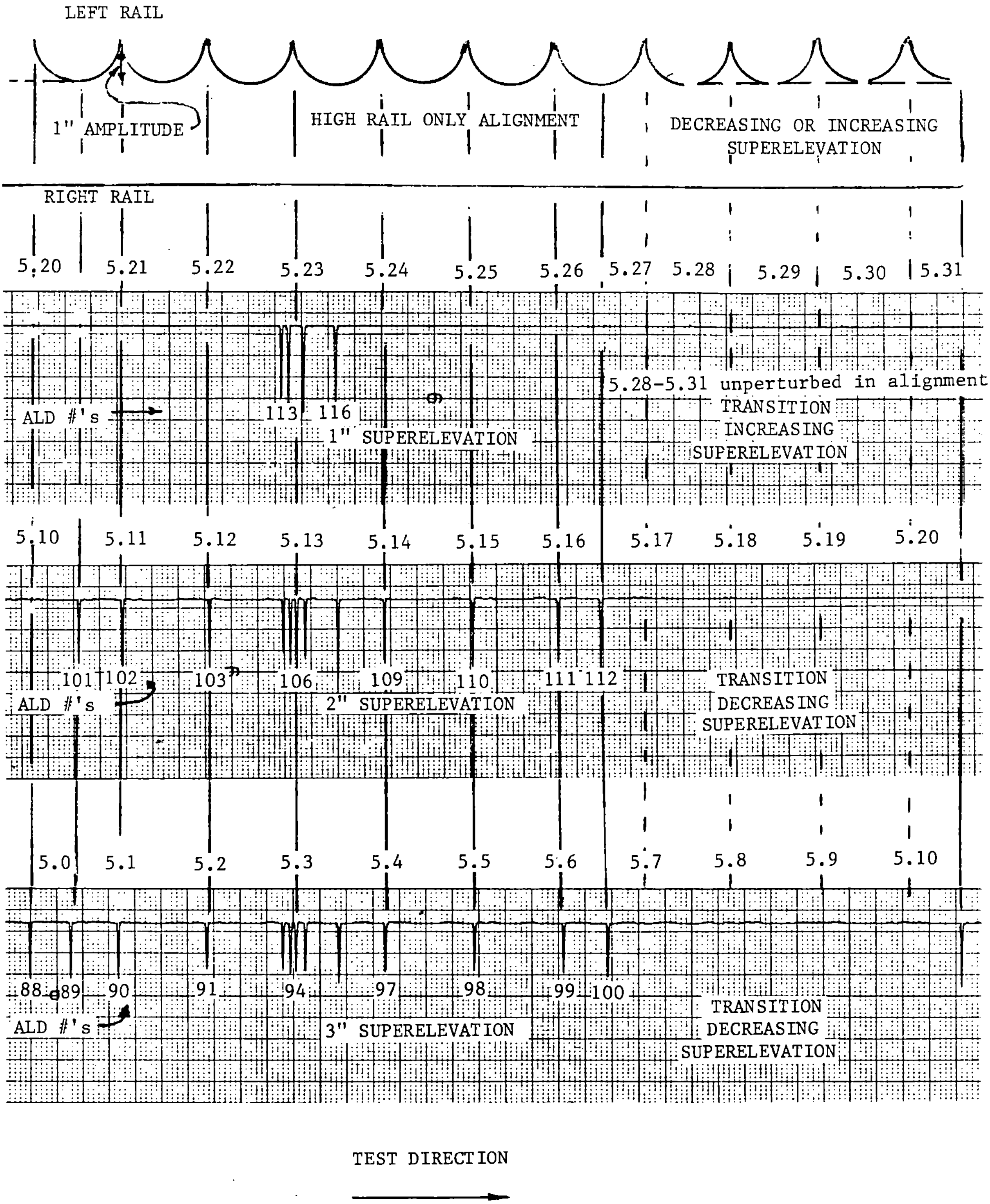


FIGURE 3-31. (Continued)*

*Further details in Figure 3-26.

SECTION 6
PIECEWISE LINEAR PROFILE

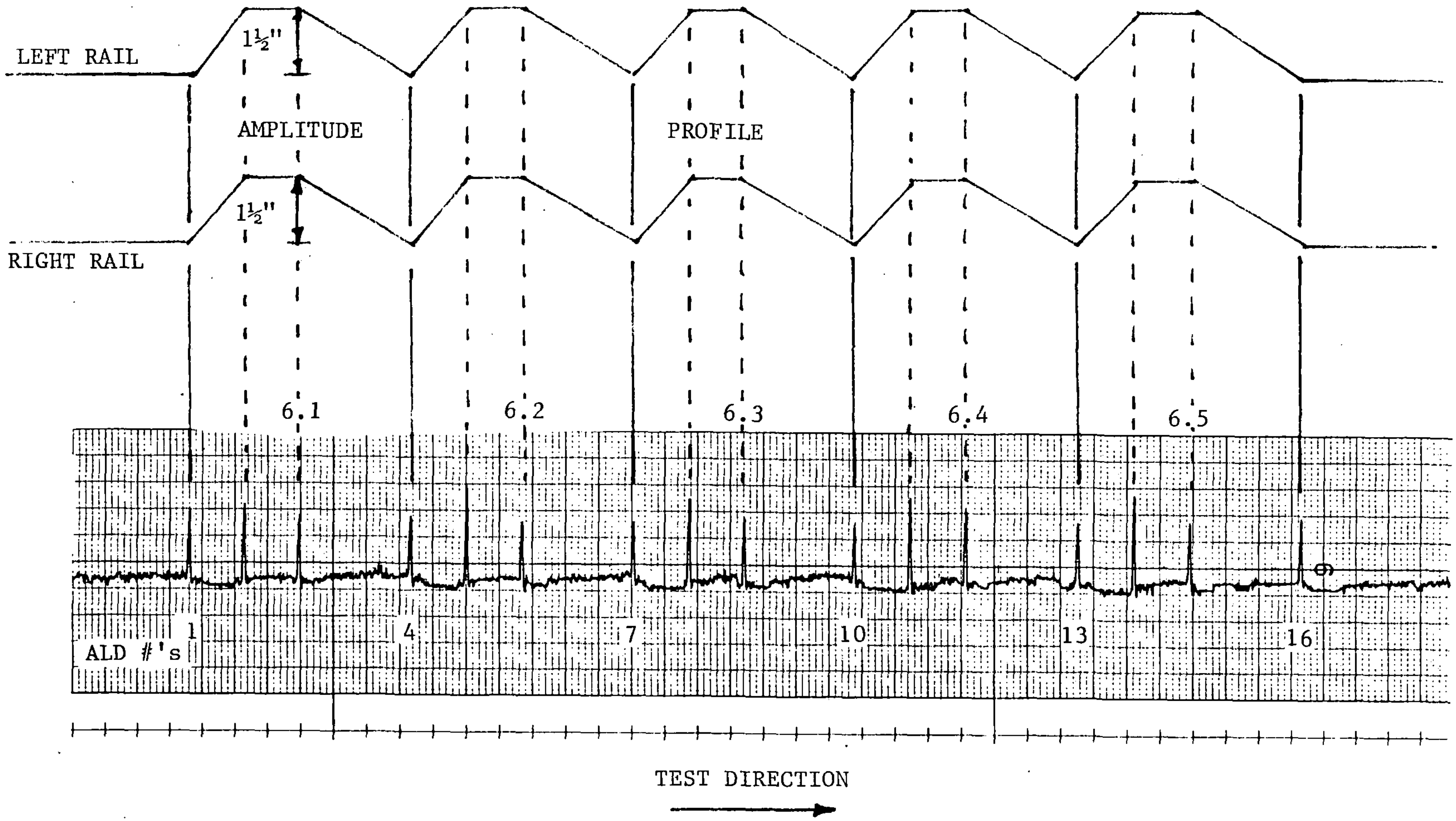


FIGURE 3-32. ALD MAPPING - TANGENT TEST ZONE

SECTION 7
PIECEWISE LINEAR CROSSLEVEL

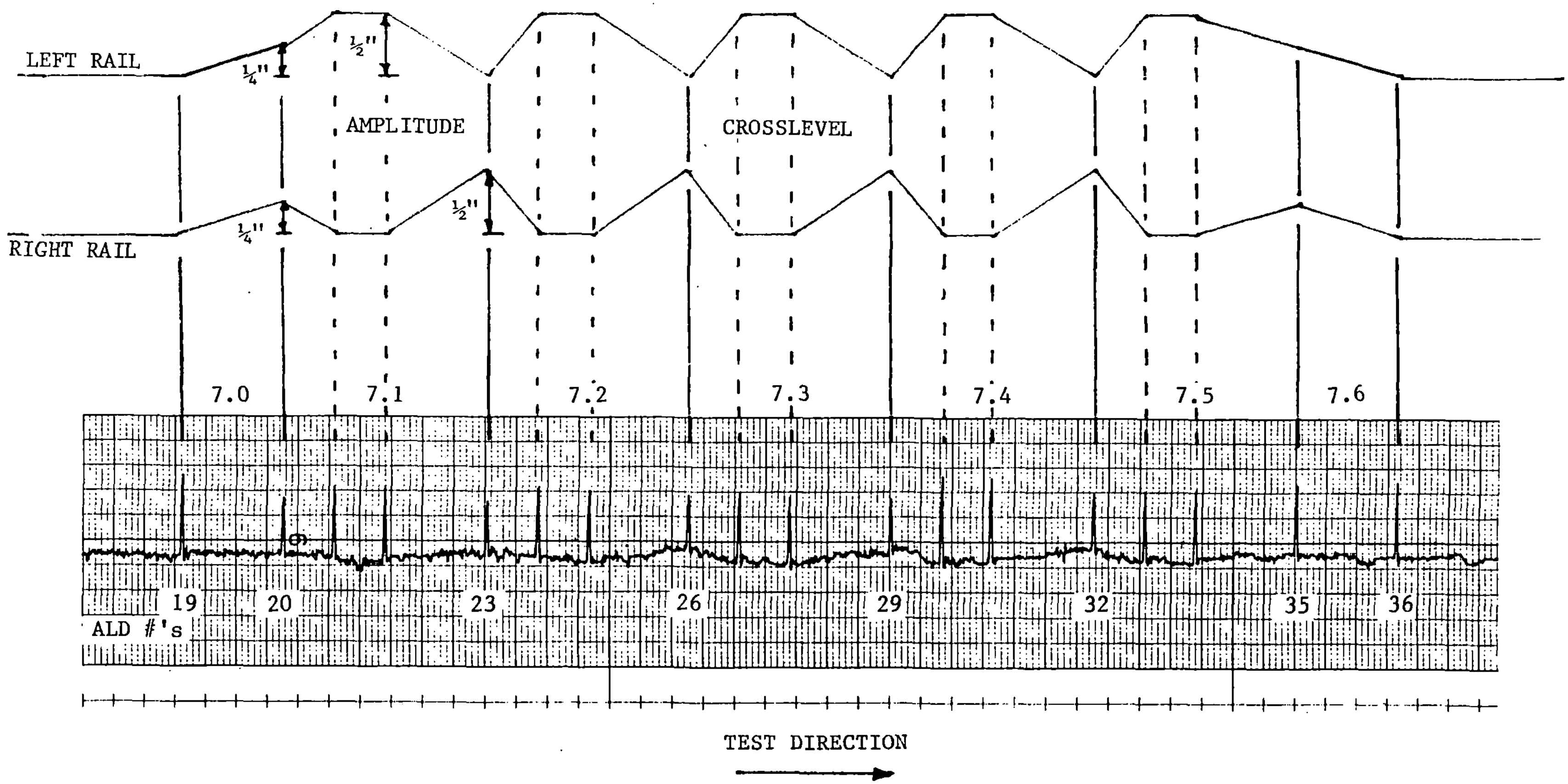


FIGURE 3-32 (Continued)

SECTION 8

PIECEWISE LINEAR ALIGNMENT

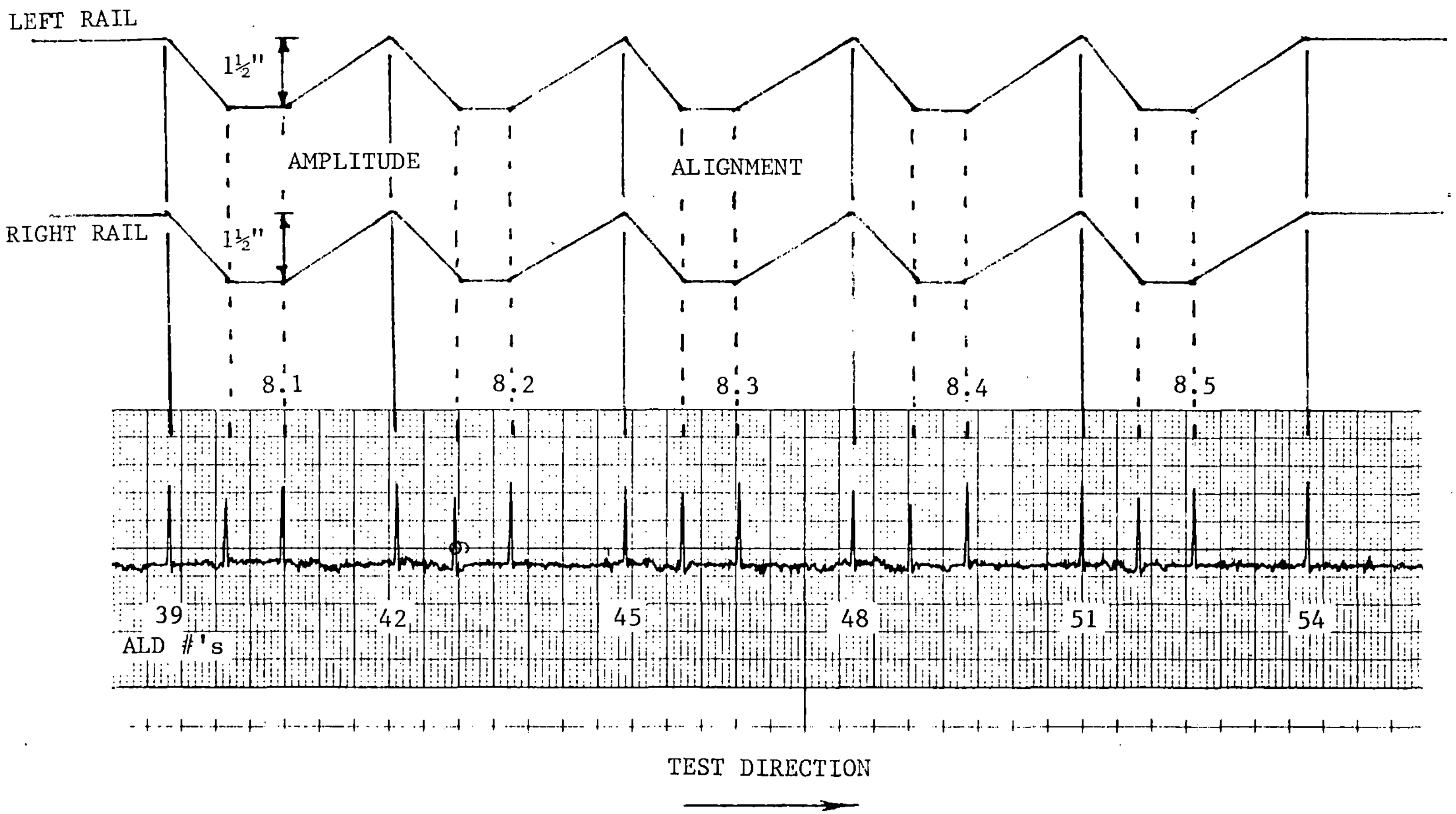
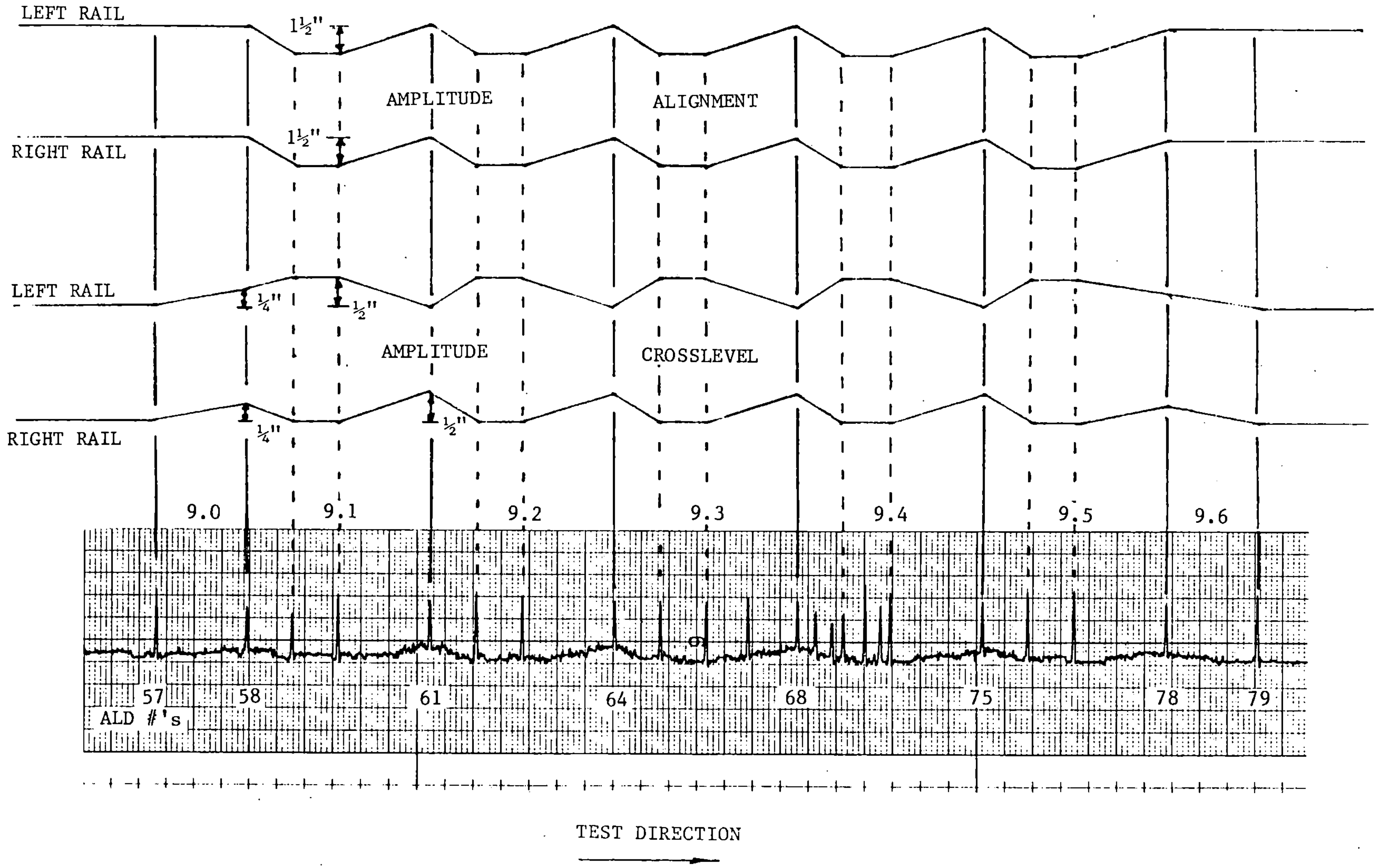


FIGURE 3-32. (Continued)

SECTION 9

PIECEWISE LINEAR COMBINED ALIGNMENT AND CROSSLEVEL



*Further details in Figure 3-29.

FIGURE 3-32. (Continued)*

position of the sensor in the "C" consist, refer to Figure 3-18 for the SDP-40F and Figure 3-20 for the E-8. Therefore, the targets were placed 18.5 inches ±1 inch ahead of the location they were to represent.

3.6 DATELINE OF PTT EVENTS

During the PTT, a total of 248 test runs were completed with the SDP-40F and E-8 locomotive consists. In addition, 22 runs were conducted during the follow-up Freight Test.

Aside from the different sections of perturbed track, the seven principal test variables investigated during the PTT were:

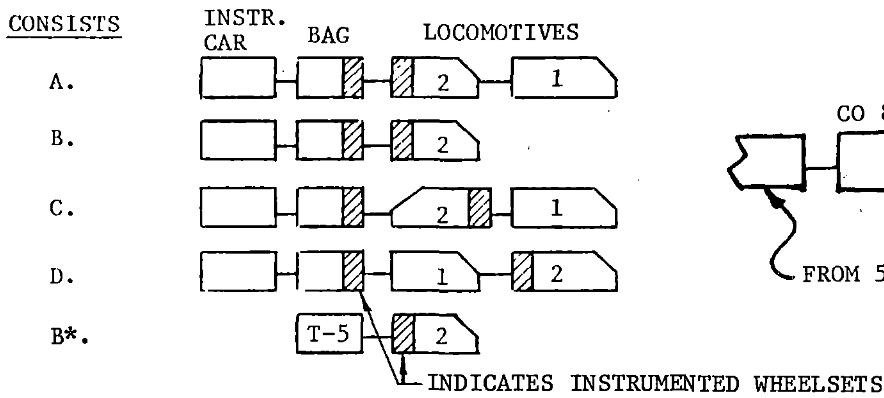
1. Speed,
2. Vehicle Type,
3. Locomotive Position and Orientation,
4. Rail Surface Condition,
5. Primary Suspension Damping,
6. Restricted Vertical Coupler Freedom, and
7. Loaded versus Unloaded (Freight Test only).

A summary of the test conditions and of the notation used in the test matrices is presented in Figure 3-33. The individual test matrices for the E-8, SDP-40F, and Freight Test series are shown in Figures 3-34 through 3-36, respectively.

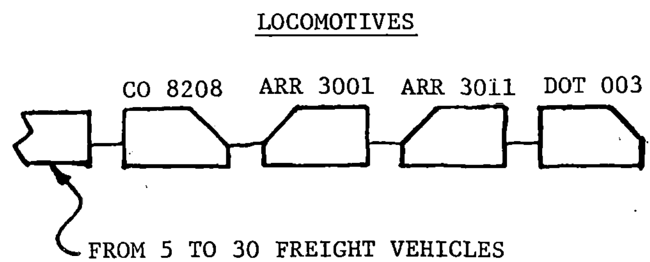
The test consists were operated over the perturbed zones at speeds between 30 and 80 mph. Speeds are generally grouped in 5 mph increments in the test matrices with in-between run speeds rounded to the closest group.

A variety of vehicle types were tested during the program. These included: the 6-axle E-8 and SDP-40F locomotives, two of each; a shared baggage car and the T-7 and T-5 data acquisition cars, representing passenger-type vehicles; four 4-axle freight locomotives; and, in the freight consist, hopper cars, gondolas, tanks and TOFC's. In the main test, the effect of locomotive position and

LOCOMOTIVE ORIENTATION



FREIGHT TEST CONSISTS



RAIL SURFACE CONDITION

D - DRY
DS - DRY SAND
RL - RAIL LUBRICANT (MANUALLY APPLIED TO HIGH RAIL)

SUSPENSION DAMPING (VERTICAL PRIMARY)

NOM - 1800/1800 SHOCK ABSORBERS
NS - NO SHOCK ABSORBERS
AS - ASYMMETRIC SHOCK ABSORBERS (NO SHOCKS ON LEFT SIDE)

COUPLER MISALIGNMENT (RESTRICTED VERTICAL COUPLER FREEDOM)

NOM - STANDARD ALIGNMENT
SHIMT - SHIMMING OF TOP OF COUPLER HOUSING REDUCING FREE CLEARANCE BY - .75"
SHIMB - SHIMMING OF BOTTOM OF COUPLER HOUSING REDUCING FREE CLEARANCE BY - 1.5"

B* - SPECIAL E-8 CONSIST. RUN AFTER SDP-40F PANEL SHIFT

FIGURE 3-33. NOTATION USED IN TEST MATRIX

TOTAL RUNS = 89

		SPEED										LOCOMOTIVE ORIENTATION				RAIL SURFACE CONDITION			SUSPENSION DAMPING			COUPLER ALIGNMENT			# OF RUNS
		35-40	40-43	43-47	47-50	50-55	55-60	60-65	65-70	70-75	75-80	A	B	C	D	D	DS	RL	NOM	NS	AS	NOM	SHIMT	SHIMB	
CURVE	BASELINE DUAL	1	1	1	3	1	2	2	2	2	1	X				X			X			X			16
	LOCOMOTIVE ORIENTATION	1	1	1		1	1	1	1				X*			X			X			X			7
			1		2	2	2	2	1	1	1			X		X			X			X			12
			2		1	2o	2	2	1	2	1				Xo	X			X			X			13
	BASELINE SINGLE		1	1	2	1	3	2					X			X			X			X			10
																									58
TANGENT	BASELINE DUAL	1	2	1	2	2	3	3	2	1	2	X				X			X			X			19
	BASELINE SINGLE	1	1		1	2	1	3	1	2			X			X			X			X			12
																									31

* CONSIST "B*" w/o BAGGAGE CAR

o LAST RUN DONE w/SAND AT 50 MPH

FIGURE 3-34. E-8 TEST MATRIX

TOTAL RUNS = 159

		SPEED										LOCOMOTIVE ORIENTATION			RAIL SURFACE CONDITION			SUSPENSION DAMPING			COUPLER ALIGNMENT			# OF RUNS
		35-40	40-43	43-47	47-50	50-55	55-60	60-65	65-70	70-75	75-80	A	B	C	D	DS	RL	NOM	NS	AS	NOM	SHIMT	SHIMB	
CURVE	BASELINE DUAL 12/1/78	1	1	1	1	1	1	2	3	1	1	X			X			X			X			13
CURVE	BASELINE DUAL 12/14/78	1	2	2		1	2	1	2	2	1	X			X			X			X			14
CURVE	LOCOMOTIVE ORIENTATION	2	2	2		2	1	2	1	1	1			X	X			X			X			14
CURVE, SINGLE LOCOMOTIVE	BASELINE SINGLE	4	2	1	2	2	1	1	1	2	1		X		X			X			X			17
CURVE, SINGLE LOCOMOTIVE	RAIL SURFACE CONDITION	2	2	1		1	1		1				X			X		X			X			8
	**	1	2	2		1	1	1	1				X			X		X			X			9
	***		3	1		2	1	2	1	1			X				X	X			X			11
CURVE, SINGLE LOCOMOTIVE	SUSPENSION DAMPING	2	1	2	1		1	1	1	1			X		X				X		X			10
		1	2	1	2		1	2	1	1			X		X					X	X			11
																								107
TANGENT	BASELINE DUAL	1	1	2	1	1	1	1	2	1	2	X			X			X			X			13
TANGENT, SINGLE LOCOMOTIVE	BASELINE SINGLE	2	1	1		1	1	1	1	1	2		X		X			X			X			11
TANGENT, SINGLE LOCOMOTIVE	RAIL SURFACE CONDITION		1				1		1				X		X				X				X	3
			1	1	1	1	1	2	1				X			X			X				X	8
TANGENT, SINGLE LOCOMOTIVE	SUSPENSION DAMPING		2	1	1	2	2	1	1	1			X		X				X		X			11
TANGENT, SINGLE LOCOMOTIVE	COUPLER MISALIGNMENT	1	1	2		1		1					X		X				X			X	*	6
																								52

* SEE "RAIL SURFACE CONDITION"
** SECOND DAY OF RAIL SURFACE 12/9/75. NO WAYSIDE INSTRUMENTATION
*** FIRST RUN AT 40 MPH, ATTEMPT AT FLANGE LUBRICATION TEST - NOT FUNCTIONING

FIGURE 3-35. SDP-40F TEST MATRIX

TOTAL RUNS = 22

CONSISTS	SPEED (MPH) 30	35	40	45	50	55	60	65	COMMENTS
FEBRUARY 3, 1979									
11 CAR	1	1	2	1	3	1	2	—	LOADED VS UNLOADED
5 CAR	—	—	—	—	—	—	—	2	DROPPED LAST 6 CARS FOR HIGH SPEED RUNS
FEBRUARY 4, 1979									ALL LOADED
30 CAR	1	—	3*	—	—	—	—	—	*RAIL BREAK AFTER 4th RUN IN FAST LOOP
20 CAR	—	—	1	1	1**	—	—	—	DROPPED 1st 10 CARS FROM LEAD END **TOP SPEED 47 MPH
17 CAR	—	—	—	—	2	—	—	—	DROPPED 1st 3 CARS TO MAKE 50 MPH

NOTE: TRACTIVE EFFORT FOR ALL CONSISTS SUPPLIED BY FOUR 4-AXLE LOCOMOTIVES:
DOT 003
ARR 3011
ARR 3001
CO 8208

FIGURE 3-36. FREIGHT TEST MATRIX

orientation was also investigated as shown in the summary figure, Figure 3-33.

An important test variable was rail surface condition. This variable was complicated due to the presence of snow on some of the test days and the extreme cold experienced during much of the testing. Three variations from nominally dry rail were planned: sanded rail (using all available truck sanders), flange lubricators (using all available), and rail lubrication (rail lubricator grease applied by hand to the high rail through the entire curved test zone). The flange lubricators installed on the SDP-40F locomotive did not function acceptably, so after an initial attempt, the test series was dropped. Again, due to the cold, the operation of the sanders on the first day's attempt at the sanded rail series was questionable, so a second day was added, but only the onboard instrumentation was available. The rail lubrication test series was accomplished with no problems and was run last so as not to have any residual affect on any of the other tests.

The primary suspension damping test series involved the use of: all four shock absorbers (nominal condition), no shocks, and an asymetric shock absorber configuration (in which only the two left side shocks were removed). It should be noted that 1800/1800 shock absorbers were adopted as the nominal configuration since all new SD series locomotives are so equipped. Previously (e.g., at the time of the Chessie Test), the nominal shock absorbers were 1200/400, and the 1800/1800 shock absorbers were considered "heavy duty" shocks.

Restricted vertical coupler freedom was the test series simulating vertical coupler misalignment (i.e., mismatched coupler heights). Aside from the nominal configuration, two cases were tested, the first with a .75" shim on the top of the coupler housing, and the second with a 1.5" shim on the bottom of the coupler housing.

Finally, during the Freight Test, loaded and unloaded vehicles of nominally the same type were tested to assess the differences in the dynamic response characteristics as a function of vehicle loading. The second day's test series was conducted with all loaded vehicles to assess the variations in response between vehicles of the same type.

In the Freight Test, five different consists were used. This was the result of safety considerations on the first day and of the inability to reach higher speeds (due to the rail break in the FAST loop) on the second day.

In addition to the actual test runs, many important events occurred which shaped the overall test process and data collected. As an example, the changes in the perturbation shape due to the panel shift and rebuilds strongly affects the comparability of data from section 4. The sequence of track geometry surveys represent significant additional data. In an attempt to clarify the sequence of major events such as instrument failures and run series, Figure 3-37 shows a dateline accounting of the important test activities. The table is broken into five categories: run series, mechanical and instrumentation problems, track perturbation changes, track geometry measurements, and miscellaneous test events such as the joint wayside/onboard calibrations or unusual weather events.

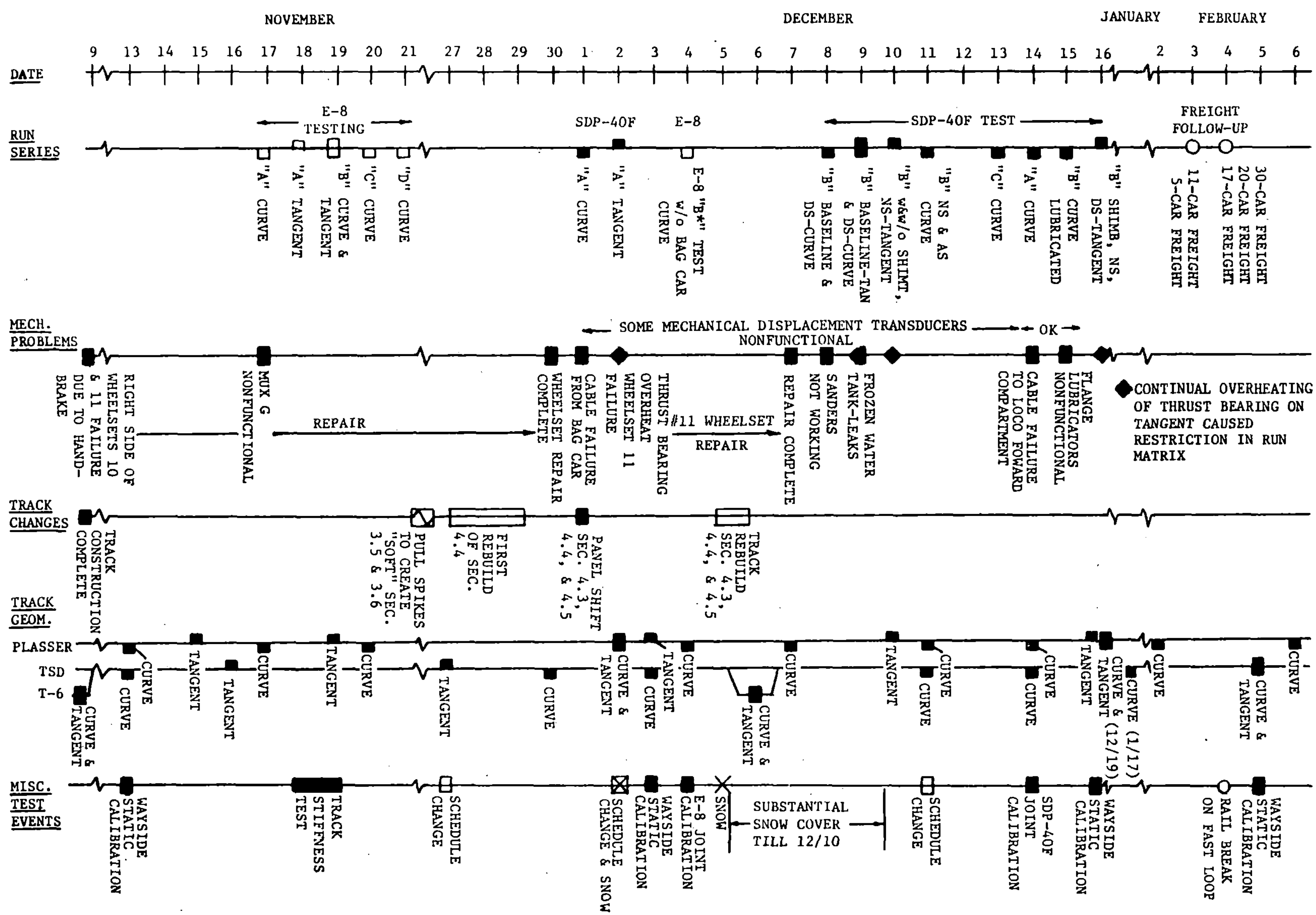


FIGURE 3-37. DATELINE OF TEST EVENTS

4. DATA DESCRIPTION

4.1 ONBOARD DATA COLLECTED

As described in Chapter 3.3, Onboard Instrumentation, the data collected and instrumentation used on the E-8 and SDP-40F locomotives were different in several respects. The SDP-40F instrumentation provided a comprehensive data source for the evaluation and analysis of the locomotive response, including use for model validation. The E-8 locomotive instrumentation plan provided the basic response data, including single-axle wheel/rail forces, rigid body carbody accelerations, and truck yaw measurements. The baggage car instrumentation which was identical for both consists provided basic response data including single-axle wheel rail forces and carbody accelerations.

Each level of SDP-40F locomotive instrumentation was applied to satisfy specific objectives. The objective of the carbody acceleration measurements onboard the SDP-40F was to describe five rigid body acceleration modes (bounce, pitch, lateral, yaw and roll) and two elastic body modes (primary bending and torsion). These elastic body modes provide the data that may validate the assumption made in the locomotive model that only rigid body vibration modes are important for the locomotives.

The objective of the SDP-40F locomotive instrumented wheelset measurements was to provide simultaneous and continuous lateral and vertical force data from all wheels of the three-axle locomotive truck. From this primary data, total truck forces and L/V ratios can be calculated.

For the purpose of investigating locomotive/baggage car dynamic interaction, displacement transducers were applied to the couplers connecting the locomotive and the baggage car to provide coupler (lateral and vertical) angle measurements, and the EMD-instrumented coupler was used to determine the locomotive coupler forces.

Accelerometers and displacement transducers were installed on the instrumented locomotive truck to measure the lateral and vertical accelerations and displacements of the primary and secondary suspension elements for purposes of model validation and to obtain a better understanding of the truck mechanics. In line with this purpose, displacement transducers were also mounted on the locomotive trucks to determine the truck yaw angles of the instrumented locomotive.

An automatic location detector (ALD) sensor was mounted to the lead instrumented axle for each consist to provide for accurate determination of track location used in the correlation of track geometry, wayside force data, and onboard force data. Finally, an anemometer providing wind velocity and direction relative to the instrumented SDP-40F locomotive was installed to enable estimates of wind loads which could significantly contribute to the truck curving forces.

Generally, the onboard instrumentation used on both the E-8 and SDP-40F consists functioned as designed. Due to extreme weather conditions and certain mechanical problems, several channels of data were inoperative at various times during the test. Occasionally, these failures were not complete, and as the need arises, the actual data may be recoverable. A complete listing of all the data channel failures, run-by-run, will be generated by ENSCO in a separate report. However, in Table 4-1 a listing for the 6 channels which experienced the worst failure history is presented.

4.2 WAYSIDE DATA COLLECTED

As described in Chapter 3.4, Wayside Instrumentation, a variety of deflection and force transducers were used in the PTT. The lateral and vertical force sensors provide data for all uninstrumented axles, a check of onboard instrumentation, and an evaluation of the performance of wayside force sensing schemes. The deflection transducers in section 3 of the curved test zone provide a comprehensive data source for investigations into track strength. The array of deflection transducers in section 4 provide additional data for these investigations. Finally, the mechanical deflection transducers, or "fishscale" gages, in both these sections, as well as section 9, provide readily used summary data on dynamic gage and tie shift, as well as checks of the electronic transducers.

A relatively large number of wayside lateral and vertical force sensors were used since these sensors provide not only all individual axle forces but also total truck forces. In addition, they supply the only force measuring system common to both the E-8 and SDP-40F locomotives.

Table 4-2 shows the data recovered by the Battelle Wayside Instrumentation. The testing dates are shown on the left side of each table. Across the top of each table, data channels are designated. The established designation of

TABLE 4-1. ONBOARD INSTRUMENTATION FUNCTIONALITY

Run Number	Bad Data Channel 17	44	56	57	58	59	Others
120101	X	X	X	X	X	X	
120102	X	X	X	X	X	X	-65
120103	*	X	X	X	X	X	
120104	*	X	X	X	X	X	
120105	*	X	X	X	X	X	
120106	X	X	X	X	X	X	
120107	X	X	X	X	X	X	
120108	X	X	X	X	X	X	
120109	X	X	X	X	X	X	
120110		X	X	X	X	X	
120111		X	X	X	X	X	-51
120112		X	X	X	X	X	-51,52
120113		X	X	X	X	X	-51,52
120201		X	X	X	X	X	-43,24
120202		X	X	X	X	X	-24,43
120203		X	X	X	X	X	-24,43
120204		X	X	X	X	X	-24,43
120205		X	X	X	X	X	- 7,24,43
120206		X	X	X	X	X	- 7,24,43
120207		X	X	X	X	X	-19,43
120208		X	X	X	X	X	- 5, 7
120209		X	X	X	X	X	- 5, 7
120210		X	X	X	X	X	- 5, 7
120211			X	X	X	X	- 5, 7
120212			X	X	X	X	- 5, 7
120213			X	X	X	X	- 5, 7
120801		X	X	X	X	X	
120802		X	X	X	X	X	
120803		X	X	X	X	X	
120804		X	X	X	X	X	
120805		X	X	X	X	X	
120806		X	X	X	X	X	
120807		X	X	X	X	X	
120808		X	X	X	X	X	
120809		X	X	X	X	X	
120810		X	X	X	X	X	
120811		X	X	X	X	X	
120812		X	X	X	X	X	
120813		X	X	X	X	X	
120814		X	X	X	X	X	
120815		X	X	X	X	X	
120816		X	X	X	X	X	
120817		X	X	X	X	X	
120818		X	X	X	X	X	
120819		X	X	X	X	X	
120820		X	X	X	X	X	
120821		X	X	X	X	X	
120822		X	X	X	X	X	
120823		X	X	X	X	X	
120824		X	X	X	X	X	
120825		X	X	X	X	X	-19

* NOISY
X IRRETRIEVABLE

NOTE-ALL CHANNELS INDICATED AS BAD HAVE BEEN ZEROED ON THE AFFECTED OUTPUT TAPE. CHANNEL NUMBERS CORRESPOND TO THOSE ON THE FINAL REFORMATTED TAPES.

TABLE 4-1. (Continued)

Run Number	Bad Data Channel 17	44	56	57	58	59	Others
120901		X	X	X	X	X	
120902	*	X	X	X	X	X	
120903		X	X	X	X	X	
120904		X	X	X	X	X	
120905		X	X	X	X	X	-49
120905		X	X	X	X	X	-49,50
120906		X	X	X	X	X	-49,50
120907		X	X	X	X	X	-49,50
120908		X	X	X	X	X	-49,50
120909		X	X	X	X	X	-49,50
120910		X	X	X	X	X	-49,50
120911		X	X	X	X	X	
120912		X	X	X	X	X	
120913		X	X	X	X	X	
120914		X	X	X	X	X	
120915		X	X	X	X	X	
120916		X	X	X	X	X	
120917		X	X	X	X	X	
120918		X	X	X	X	X	
121001		X	X	X	X	X	-41
121002	*	X	X	X	X	X	-41
121003	*	X	X	X	X	X	-41
121004		X	X	X	X	X	-41
121005		X	X	X	X	X	-41
121006		X	X	X	X	X	-41
121007		X	X	X	X	X	-41
121008		X	X	X	X	X	-41
121009		X	X	X	X	X	-41
121010		X	X	X	X	X	-41
121011		X	X	X	X	X	-41
121012		X	X	X	X	X	-41
121013	*	X	X	X	X	X	-41
121014	*	X	X	X	X	X	-41
121015	*	X	X	X	X	X	-41
121016	*	X	X	X	X	X	-41
121017	*	X	X	X	X	X	-41
121101	X	X	X	X	X	X	-41
121102	X	X	X	X	X	X	-41
121103	X	X	X	X	X	X	-41
121104	X	X					
121105	X	X	X	X	X	X	-41
121106	X	X	X	X	X	X	-41
121107	X	X	X	X	X	X	-41
121108	X	X	X	X	X	X	-41
121109	X	X	X	X	X	X	-41
121110	X	X	X	X	X	X	-41
121111		X	X	X	X	X	-41
121112		X	X	X	X	X	-41
121113		X	X	X	X	X	-41
121114	*	X	X	X	X	X	
121115	*	X	X	X	X	X	
121116	*	X	X	X	X	X	
121117	*	X	X	X	X	X	

* NOISY
X IRRETRIEVABLE

TABLE 4-1. (Continued)

Run Number	Bad Data Channel						
	17	44	56	57	58	59	Others
121118	*	X	X	X	X	X	
121119	*	X	X	X	X	X	
121120	*	X	X	X	X	X	
121121	*	X	X	X	X	X	
121301+		X	X	X	X	X	-9,10,11,12,41
121302		X	X	X	X	X	-9,10,11,12,41
121303		X	X	X	X	X	-9,10,11,12,41
121304		X	X	X	X	X	-9,10,11,12,41
121305		X	X	X	X	X	-9,10,11,12,41
121306		X	X	X	X	X	-41
121307		X	X	X	X	X	-41
121308		X	X	X	X	X	-41
121309	*	X	X	X	X	X	-41
121310	*	X	X	X	X	X	-41
121311	*	X	X	X	X	X	-41
121312	*	X	X	X	X	X	-41
121313	*	X	X	X	X	X	-41
121314	*	X	X	X	X	X	-41
121401	*	X	X	X	X	X	
121402	*	X	X	X	X	X	
121403	*	X	X	X	X	X	
121404	*	X	X	X	X	X	
121405	*	X	X	X	X	X	
121406	*	X			X	X	-47
121407	*	X					-47
121408	*	X					-47
121409	*	X					-47
121410	*	X					-47
121411	*	X					-47
121412	*	X					-47
121413	*	X		X			-47
121414	*	X	X				-47
121501	*	X					
121502	*	X					
121503	*	X					
121504	*	X					
121505	*						
121506	*						
121507	*						
121508	*						
121509	*						
121510	*						
121511	*						
121601	*	X					
121602	*						
121603		X					
121604							
121605							
121606	*						
121607	*						
121608	*						
121609	*						
121610	*						
121611	*						

* NOISY
X IRRETRIEVABLE
\+ LOCOMOTIVE COUPLER NOT USED IN THIS CONFIGURATION (12/13/78)
CHANNELS 53, 54, 55 AND 56 NOT FUNCTIONING.

TABLE 4-2. DATA RECOVERY BY DAY AND CHANNEL

	V43-27H	L43-27H	V43-28H	V43-29H	V43-29H	V43-30H	V43-31H	L43-31H	L43-33H	V43-35H	L43-35H	L43-37H	V43-39H	L43-39H	L43-41H	V43-43H	L43-43H	L43-43L	L43-45H	L43-45L	V43-47H	L43-47H	L43-47L	V44-4L	V44-6L	V44-3H
11-17															x				x		x	x	x		x	
11-19															x				x		x	x	x			
11-20															x				x							
11-21															x											
12-01															x											
12-04															x										x	
12-08															x											
12-11															x											
12-13															x											
12-14															x											
12-15															x											
2-03		x			x		x	x	x	x	x															
2-04		x			x		x	x	x	x	x															

	L44-3H	G44-3H	V44-3L	L44-3L	L44-4H	V44-5H	L44-5H	V44-5L	L44-5L	L44-6H	V44-7L	L44-7L	V44-7H	L44-7H	G44-7H	RMD44-7H	PBD44-7H	TLD44-7H	L44-8H	V44-9H	L44-9H	L44-9L	L44-10H	V44-11H	L44-11H	L44-11L	
11-17										x						x										x	
11-19	x															x	x									x	
11-20	x															x	x									x	
11-21	x															x	x									x	
12-01																	x									x	
12-04																x	x									x	
12-08																		x								x	
12-11																		x								x	
12-13																		x								x	
12-14																		x								x	
12-15																		x								x	
2-03																										x	
2-04																										x	

REMOVED TO INSTALL WHEEL DETECTORS FOR FREIGHT TEST

	V44-15L	L44-15L	L44-15H	L44-16L	V44-17L	L44-17L	L44-17H	G44-17H	L44-18L	V44-19L	L44-19L	L44-21L	V44-23L	L44-23L	V52-21H	L52-21H	L52-23H	V53-3H	L53-3H	L53-4H	L53-5H	V53-6H	L53-6H	L53-7H	L53-8H	V53-10H	L53-10H	L53-12H
11-17														x								x						
11-19										x	x	x										x						
11-20										x	x	x										x						
11-21																						x						
12-01																						x						
12-04																						x						
12-08																						x						
12-11																						x						
12-13																						x						
12-14																						x						
12-15																						x						
2-03										x												x						
2-04										x												x						

	V512-21H	L512-21H	L512-23H	V513-3H	L513-3H	L513-4H	L513-5H	V513-6H	L513-6H	L513-7H	L513-8H	V513-10H	L513-10H	L513-12H	V522-21H	L522-21H	L522-23H	V523-3H	L523-3H	L523-4H	L523-5H	V523-6H	L523-6H	L523-7H	L523-8H	V523-10H	L523-10H	L523-12H
11-17	x	x	x	x	x	x	x	x	x	x	x	x	x	x				x										
11-19																		x										
11-20																		x										
11-21																		x										
12-01																		x										
12-04																		x										
12-08																		x										
12-11																		x										
12-13																		x										
12-14																		x										
12-15																		x										
2-03																		x										x
2-04																		x										x

x Denotes non-recovered data.

TS.SS-CCX is used. "T" is channel type: vertical load, lateral load, gage measurement, etc.; "S.SS" is the section number, 5.22 being an example (consistent with track descriptions); and "CCX" is the channel transducer's location, with the "CC" standing for the crib number and "X" the rail, high or low. "10H" is the designation of a crib ten, high rail transducer, while "10L" locates a crib ten, low rail transducer. For each day on which data for a particular channel was not entered into the data base, an "x" is placed in the table. The data may have been lost at a number of different stages of the data base construction process. If it is deemed important, a part of the data which is not currently in the data base could be added by reprocessing the raw data tapes. An overall data recovery rate of 92.2% was achieved.

A large percentage of the missing data was lost on the first day of testing. On this day, one entire multiplex unit (MUX G, section 5.12-5.13) was inoperative. Several other channels were inoperative on that day and were repaired after the initial day of testing. If the first day of testing is excluded, 94% of the data was recovered. There were four channels (L4.3-41H, L4.4-11L, L5.3-6H, and L5.23-3H) which were inoperative for the entire test. This data was lost due to bad gages, bad multiplex units, or a programming error. The remainder of the nonrecovered data was lost due to a number of different sporadic failures.

The displacement measurements had the highest percentage of data lost, approximately 25% of total measurements attempted. The majority of this data was lost due to transducer and signal condition unit failure.

There are small segments of data which were lost which do not appear on this table, but these segments are restricted to the loss of a single channel for a small number of runs.

The array of mechanical and electrical deflection transducers in section 3 of the curved test zone were used during the SDP-40F test series to evaluate the effect on lateral track stiffness of a spiking pattern simulating minimum Class 4 requirements. The first instrumented site had a nominal spike pattern, four spikes per tie plate. The second site had spikes only in every other tie and had only two spikes per tie plate. This instrumentation was supported during the SDP-40F baseline test series and was stopped, except to monitor the safety of the consist, when sufficient data had been collected.

The mechanical displacement transducers were monitored throughout the tests to meet the safety criteria for each run and to evaluate the rate at which the track and perturbation shapes degraded. This data was recorded by TTC and is not included in the Battelle data base.

4.3 TRACK GEOMETRY MEASUREMENTS

4.3.1 Objectives

Perturbations in track geometry installed for the PTT were designed specifically to excite individual or selectively combined modes of locomotive and vehicle dynamics. Several methods of measuring the geometrical properties of the test track were necessary for various reasons:

- To be used as the reference during the installation of the track perturbation.
- To define the as-installed geometric input under load for correlation with vehicle response.
- To measure the elastic and permanent movements of the track at locations of peak/dynamic loads.

These objectives result from requirements in test implementation, operational safety, and test data analysis. Several measurement techniques were used in an attempt to jointly satisfy all of these objectives.

The measurement methods and their primary application are given below:

- Hand measurements (with gage-crosslevel bar and string line) - used during initial perturbation construction, subsequent re-adjustments, and periodic spot checks.
- Track Survey Device - used at regular intervals throughout the test to provide a fairly continuous monitoring of the test track.
- Plasser EM80 - used once (when possible) before each day of testing to survey the appropriate test zone and thereby provide an independent source for data verification.

- T-6 - available at two times during the main testing period to provide loaded measurements of the track for comparison with the TSD, and for defining the track excitation input into the vehicle.

- Dynamic Displacement Measurements - installed at selected locations to measure gage changes or lateral track movements, to provide run-to-run monitoring for safety, and for correlation with vehicle forces in the assessment of track strength.

The characteristics of the first four methods and the procedures used are given in more detail below.

4.3.2 Characteristics of the Track Geometry Measurements and the Application Procedures

There are advantages and disadvantages in each of the measurement methods used. There are also practical limitations in the applications of these methods. Discussions are presented here on each of the methods, followed by a description of the actual procedure used in carrying out each of the track geometry measuring methods.

4.3.2.1 Hand Measurements

Perturbations used in the PTT consist of distinct wave shapes in one or a combination of track geometry parameters. These wave shapes are defined by prescribing the magnitude of the deviation of the rails from a perfect track. (See Chapter 3.2, Track.)

Gage and crosslevel perturbations are described as deviations from uniform gage or crosslevel. Profile and alignment perturbations on tangent track are given as deviations from a straight line. In the case of curved track, alignment perturbations are given as deviations from a perfect 1.5 degree circular curve.

In the process of installing the prescribed perturbations in existing trackage, gage and crosslevel for any point along the track can be measured directly with a standard gage and crosslevel bar. Profile and alignment, on the other hand, require the use of precision survey instruments if exact spatial positions of the rails are to be pinpointed with respect to an absolute reference. The use of survey instruments was not at all practical considering the number of rails which were perturbed. A manual stringline technique was therefore used to provide a relative rather than an absolute reference in the spatial coordinate system.

A stringline technique involves the use of either one or two rail lengths, depending on the basic wavelength of the perturbation, stretched between the intended end points of a basic cycle of perturbation so that the offsets from the string may be measured.

The rail segment between the two end points is then moved vertically (by shimming) or laterally (by respiking) to the prescribed positions as required by distances from the stringline chord. Vertical and lateral distances from the stringline chord are given for every 1/8 of a rail length. After the entire cycle of perturbation is installed, the stringline chord is moved to the next cycle of perturbation and the process is repeated.

Advantages and Limitations

The use of a relative measurement technique, such as the stringline process described above, is considerably simpler than any survey procedure. No special equipment other than hand tools are needed to perform these measurements. A crew of three can perform these measurements on short notice and the data is immediately obtained. Therefore, a broad reliance was placed on the use of hand measurements during the PTT.

There are many disadvantages in the hand measurement methods. The accuracy and repeatability is not as good as automated methods. The procedure is cumbersome so that measurement stations are usually spaced relatively far apart (1/2 rail length to 1/8 rail length). The measurements are made with no vertical or lateral loads so that slack in the track would make the measurements differ from the actual inputs to the vehicle.

The most serious disadvantage of using the cycle-by-cycle stringlining method for installing profile and alignment perturbations is in the relative nature of a chord measurement technique. Since the end points of each chord are the only reference points in the measurement, the final wave shape of the perturbed track would have all the end points of the chords remain in the unperturbed postion. If the original track were a perfectly lined tangent or circular curve, then the perturbed track would conform to the design. However, if the end points of the chords happened to be out of alignment, the resulting perturbed track would retain those errors. The individual cycles within each chord length would conform to the prescribed wave shape, the transitions between adjacent cycles may contain significant errors. This effect was actually observed in the alignment perturbations in section 4. Adjustment to the track was necessary to remove the dissimilarity between successive cycles of perturbation.

4.3.2.2 Track Survey Device

The Track Survey Device (TSD) is a LASER based precision track geometry measurement vehicle. The TSD consists of two separate portions. A LASER source is mounted on a small rail car which can be pushed on the track. When a track segment is to be surveyed, the LASER source is placed at one end of the track segment with the light beam pointing along the track. The second portion is the survey vehicle itself, which is driven by a gasoline engine. The survey vehicle is driven on the track towards the LASER source during the survey. A target screen on the survey vehicle continuously intercepts the stationary LASER beam as the vehicle moves forward. The portion of the intercept point on the screen provides the absolute reference for the track measuring mechanisms installed on the vehicle. Two contact wheels on the vehicle are hydraulically loaded against the gage measurement points of the left and right rails. A gravitational pendulum is installed in the vehicle to measure the crosslevel of the track. The positions of the contact wheels and the crosslevel angle are used to determine the positions of the two rails relative to the stationary LASEP beam. The rail position information is measured at six-inch intervals and recorded on magnetic tape.

Advantages and Limitations

The TSD uses a stationary light beam external to the vehicle as a reference to determine track geometry. The principle employed is similar to that used by standard optical survey methods, which is better than the relative reference or inertial reference principles employed by other vehicle-borne track geometry systems.

The system is self-contained in the sense that it requires no supporting equipment such as a locomotive. It can be operated by a crew of three, and requires minimal setup time. The survey speed is relatively slow compared with a typical automated track geometry vehicle. However, it is considerably faster than manual stringlining. A typical six-hour operating period (usually from dusk to midnight) can cover as much as 1.5 miles of track.

The sampling frequency of the TSD can be adjusted to provide a fine resolution along the distance of the track. (Six-inch sample rate is used.) A software package exists to process the data tape and provide the results in the form of pseudospace curves or midchord offsets of several popular chord lengths.

Even though the TSD measurements are based on an absolute light beam reference, there are significant limitations in the measurement of track geometry perturbation of long wavelength. On tangent track, the LASER beam can provide a thin reference line up to 150 feet long, beyond which the increase in beam aperture and loss in intensity would reduce the accuracy of the geometry measurements. A track section surveyed with respect to a common LASER beam is called a survey sequence. The LASER light source has to be moved forward to the next track section to establish a new reference light beam for the next survey sequence. Maximum sequence length for surveying curved track is further restricted because of the size of the target screen. On a 1.5 degree curve, the sequence length is limited to 80 feet.

Since each survey sequence is referenced to a different light beam, the track geometry data from one sequence cannot be tied to the adjacent sequences. An overlay series of sequences are made to overcome this limitation. Each of the overlay sequences covers from mid-point to mid-point of two adjacent sequences from the original survey series. A software package then performs the "splicing" of the data using survey data from the original and the overlay sequences. The accuracy of the long wavelength information in the spliced data is relatively poor. Since the same light beam is used within the length of each sequence, the accuracy does not begin to degrade until the wavelength is longer than the sequence length, which is 80 feet for the surveys conducted on the perturbed track.

The axle weight of the TSD is approximately 7000 pounds, which is sufficient to take up all or at least a large portion of the vertical slack in the track. There is, nevertheless, essentially no lateral load applied to the track. The speed of vehicle motion during a survey is usually less than 5 mph, which is considerably below the balance speed of the 1.5 degree test curve. The lateral track load due to gravity is on the order of a few hundred pounds applied to the low rail; there is essentially no lateral load applied to the high rail.

There are some other limitations of the TSD which should be mentioned. The TSD data output is not available during the survey, which limits the capability of the crew to verify that the system is collecting data properly. The unenclosed design and the use of hydraulic controls hampers the operation of the TSD in cold weather. These factors affected the use of the TSD during the Perturbed Track Test.

Operating Procedure and Schedule

Operating procedure and schedule are defined in "Operations Plan, TSD Survey in Support of the Perturbed Track Test at TTC," dated November 2, 1978.[9] The actual test procedure followed the test plan closely. In summary, the TSD was operated in a direction opposite to the locomotive test direction (due to mechanical limitations in the TSD). During the survey of each track section (tangent or curved), an end-to-end series of sequences is made first, covering the entire test zone. The TSD is then returned to the starting area to perform a series of overlay sequences. All survey sequences are 80 feet long, and the overlay sequences are performed from mid-point to mid-point of two adjacent sequences from the first survey series.

The actual TSD survey schedule was modified from the planned schedule due to the adjustments in the PTT test schedule and the condition of the weather. The actual TSD test runs are summarized in the dateline of test events presented in Chapter 3.6, Figure 3-37.

4.3.2.3 Plasser EM80

The Plasser EM80 is a light-weight, self-propelled track geometry measuring vehicle. The rated top measuring speed of the vehicle is 80 km/hr. (The same model is sometimes identified as a EM50, signifying a 50 mph top speed.) The EM80 used in the PTT is the vehicle leased by the AAR from the Plasser American Corporation to support the FAST experiment.

The EM80 has two load-bearing axles, each carrying approximately 15 tons of vertical load. One of the two axles is used to measure crosslevel. Gage, profile and alignment are measured by six measuring axles which do not carry significant vertical or lateral loads. The measuring axles have flanged wheels that are 22 inches in diameter. The measuring axles are placed as three pairs — in the center, the front, and the aft ends of the vehicle. The lead axle in each pair is pneumatically loaded laterally against the trailing axle located two feet behind. The lateral loads force the lead axles in the three pairs to flange against the left rail forming the three contact points for a 10-meter mid-chord offset (MCO) alignment measurement. The trailing axles are forced in the opposite direction forming a 10-meter MCO alignment measurement for the right rail.

The vertical movements of the measuring wheels are measured from the carbody to provide the 10-meter MCO measurements for the left and the right rails.

The 10-meter MCO's for profile and alignment are converted to 62-foot MCO's by algorithms in the onboard computer. Low-pass filtering is used on the 62-foot MCO outputs to smooth out undesirable noise in the conversion process. It should be noted that the profile and alignment measurements use the carbody as the reference beam to provide the 10-meter chord.

One of the six measuring axles is made to have the wheel-flange gage wider than the standard track gage. This axle is hinged at the middle so that the two axle-wheel halves can be cambered at an angle for the wheel flanges to fit within track gage. The axle halves are pneumatically loaded to maintain simultaneous flanging of both the left and right wheels at all times. Track gage is measured by the distance between the wheel flanges, which is calculated from the measured camber angle between the axle halves.

Crosslevel is measured on one of the two running axles. A gyro-stabilized pendulum is installed in the vehicle for measuring roll angle of the carbody. Displacement transducers are used to measure carbody-to-axle roll angle.

A fixed-base twist is measured by the roll angle between a running axle and the adjacent outboard measuring axle. This parameter is not used in the FRA Track Safety Standards.

Advantages and Limitations

The Plasser EM80 was available throughout the test period except for certain days of breakdown. The survey vehicle was used before the start of test runs on each test day. No locomotive or train crew was needed for making the run.

The measuring systems have several limitations. The gyro-stabilized pendulum is not fully compensated for curvature and drift effects. Therefore, the vertical reference is subject to error on curves. Testing at relatively low test speeds can reduce the magnitude of the error. The alignment and profile measurement wheels are essentially not loaded; slack in the track may introduce errors. The low-pass filters used for smoothing the converted 62-foot MCO profile and alignment data are time-based filters. These filters will have different spatial corner frequency at different test speeds.

The data output is in the form of distance-based paper pen charts. Permanent magnetic tape recording capability is featured in the EM80 design. Tapes are available from the TTC file.

Operating Procedures and Schedule

On those days that the EM80 was used, it was operated in the morning prior to the start of the locomotive test runs. The survey speed is maintained at approximately 10 mph through the test zone for all tests.

The days of EM80 operation are shown in the dateline of test events, Figure 3-37 of Chapter 3.6.

4.3.2.4 Track Geometry Vehicle T-6 System Description

The T-6 is the latest track measurement vehicle of the three used by the FRA Office of Safety for track inspection. The T-6 contains the most recent version of the inertial-based track geometry measuring instruments, and it is the only vehicle that contains the inertial alignment system.

The T-6 system is capable of measuring gage, crosslevel, profile, alignment, and curvature at track speeds up to 120 mph. The sample rate is selectable from 6 inches to 8 feet. The six-inch option was used as the primary mode of measurement, and a few runs were made at a 1-foot sample rate for the purpose of data verification.

The on-line chart display is limited to a 62-foot mid-chord offset format for profile and alignment. An off-line software package is capable of converting the data to pseudospace curves or chord data of other chord lengths.

Advantages and Limitations

The T-6 has a total weight of approximately 80 tons, or 20 tons per axle. The test speeds used were up to 50 mph. The vertical and lateral loads, though not as high as locomotives, are representative of a typical heavy vehicle.

The data collected on tape is continous over the entire test section (as opposed to 80-foot segments for the TSD), and can be used easily for downstream data analysis and research.

Operating Procedures and Schedule

The main limitation in the use of T-6 data was the schedule constraints on the vehicle. Only two test periods could be obtained for the T-6 to support the PTT. These two periods offered two snapshots of the track geometry status. One occurred before the E-8 testing, and one in the middle of the SDP-40F testing. The actual survey days were November 9 and December 6, as shown in Figure 3-37 in Chapter 3.6.

4.4 VEHICLE PARAMETER DATA COLLECTED

The objectives of the main PTT included model validation and the assessment of alternative wheel/rail force measuring procedures. To accomplish these goals, several measurements of the physical components of the test vehicles were required. These included axle weight, wheel profiles, wheelset dimensions, coupler height, and an assortment of suspension clearances. In addition, an assessment of the relative wear states of several components, such as the center plate, was requested.

The objectives of the follow-up freight test were rather different from those of the main tests. This is especially true for the last day's testing, which was primarily conducted to investigate the importance of component wear on vehicle dynamic performance. For this reason, more extensive measurements of the cars were required. These are listed in Table 4-3 and are referenced to measurements taken for the FAST program wherever possible.

4.5 DATA TAPE FORMAT

4.5.1 Data Acquisition Vehicles

All of the data obtained from the onboard instrumentation is recorded on data tapes. The raw tapes for the data acquisition vehicles (T-5 and T-7) are not in a readily usable, standardized format. The original tapes have been copied and are being stored. For the purposes of data analyses, these tapes have been reprocessed into a standardized, IBM compatible, format, i.e.:

- Character data is EBCDIC-coded (E).
- Integers are stored on 32-bit positive integers (I).
- Floating point data is 32 bit, IBM compatible (F).
- There are 8 bits per byte.

Each tape consists of a variable number of files separated by an industry standard end-of-file mark. Two consecutive marks indicate the end of the information for that tape.

Each file consists of a variable number of fixed length records (11,176 bytes for the T-7). The first record is a file header record; subsequent records are data records.

For the data tapes generated from the T-7 acquisition vehicle, the file header record contains:

- Most of the original T-7 file header.
- The channel assignment table.
- Channel statistics.
- A speed-distance processing indicator.
- A scale factor for converting tack counts to distances.

TABLE 4-3. VEHICLE MEASUREMENTS REQUESTED FOR FOLLOW-UP PTT

MEASUREMENT REFERENCES (FAST TEST SPECIFICATION VOL. III) - PTT TESTS

(SAFETY LIFE CYCLE (SLC) PROGRAM DATA COLLECTION)

PRIMARY MEASUREMENTS FOR SLC DATA ANALYSES

MEASUREMENT TITLE	TITLE NUMBER	TEST DATA REF. PAGE	ILLUSTRATIONS PAGE #	FORMS PAGE #	PROCEDURE PAGE #	VALUES MEASURED BY TTC
WHEELS:						
• Gage (Back-to-Back)	None	See A.A.R - Wheel & Axle Manual			Fig. 2.C.11	
• Profile	1a, 1b,	2.6.6	2.6.5	2.6.5.1	II - 2-18	
• Flange Thickness/Height	1c, 1d	2.6.7	No Illus.	III-2-17	(WH.31)	
• Circumference		2.6.9	(Use WH31) Form			
AXLES/AXLE BOXES:			2.7.5			
• Roller Brg-Lat. Movement	2d	2.7.9	None	2.7.5.1	2.7.5.2	
• Pedestal Sides at Journal Outer Ring - Lat. Movement	2f	2.7.11	2.7.5	2.7.5.1	2.7.5.2	
• Brg Adapter Thrust Shoulder	32	2.8.10				
• Adapter Lugs at Pedestal - Total Lat.	3j	2.8.15	2.8.5	2.8.5.1	2.8.5.2	
• Pedestal Lug at Adapter - Total Lat. Wear	3k	2.8.16				
TRUCKS:						
• Friction Casting - Total Wear	4c	2.9.8	2.9.5	2.9.5.1	2.9.5.2 (FC31)	
• Bolster at Frict. Cast'g - Total Wear	4e, f	2.9.10 2.9.11	2.9.10.5	2.9.10.5.2	2.9.5.10.5.3	
• Side Frame Col. Plate - Total Wear	4h	2.9.13	2.9.13.5	2.9.13.5.1/.2	---	
• Stabilizer Assembly - Total Wear	4j	2.9.15	2.9.15.5	2.9.15.5.1/.2	---	
• Bolster Gib - Total Wear	4l	2.9.17	2.9.17.5	2.9.17.5.1	---	
• Side Frame Col Guides - Total Wear	4o	2.9.20	2.9.20.5	2.9.20.5.1/.2	---	
• Bolster Rotation Stops - Total Wear	4r	2.9.23	2.9.23.5	2.9.23.5.1	---	

TABLE 4-3. (Continued)

MEASUREMENT REFERENCES (FAST TEST SPECIFICATION VOL. III) - PTT TESTS

(SLC PROGRAM DATA COLLECTION)

SECONDARY MEASUREMENTS FOR SLC DATA ANALYSES

MEASUREMENT TITLE	TITLE NUMBER	TEST DATA REF. PAGE	ILLUSTRATIONS PAGE #	FORMS PAGE #	PROCEDURE PAGE #	VALUES MEASURED BY TTC
WHEELS:						
• Thin Rim-Wear	1d	2.6.9	2.6.9.5	2.6.9.5.1		
• Cracked or Broken Flange	1g	Describe length and depth of damage. (Accuracy $\pm$1/32 or best estimate)				
• Thermal cracks	1h		"			
• Built-up Tread	1i		"			
• Grooved Tread	1j		"			
• Shelled Tread	1k		"			
• Slid-Flat Tread	1l		"			
• Cracked or Broken Rim	1m		"			
• Burnt Rim	1n		"			
• Shattered Rim	1o		"			
• Spread Rim	1p		"			
• Overheated Wheel	1q		"			
• Cracked or Broken Plate	1r		"			
• Cracked or Broken Hub	1s		"			
AXLES/AXLE BOXES:						
• Crown Wear-Roller Bearing Adaptor	3a	2.8.6	2.8.6.5	2.8.6.5.1		
• Bearing Outer Ring Wear	3g	2.8.12				
• Adaptor Lug at Pedestal Wear	3i	2.8.14	2.8.14.5	2.8.14.5.1		
• Cracked Pedestal, Adaptor Parts, etc.		Visual Inspection Details				

TABLE 4-3. (Continued)

MEASUREMENT REFERENCES (FAST TEST SPECIFICATION VOL. III) - PTT TESTS

(SLC PROGRAM DATA COLLECTION)

PRIMARY MEASUREMENTS FOR SLC DATA ANALYSES

MEASUREMENT TITLE	TITLE NUMBER	TEST DATA REF. PAGE	ILLUSTRATIONS PAGE #	FORMS PAGE #	PROCEDURE PAGE #	VALUES MEASURED BY TTC
WEIGHT DISTRIBUTION:						
(Loaded Vehicle)						
• Weight on each Axle	Actual weight on Wheel Scales (Accuracy ± .1 Ton)					
OR						
• Total Weight on all Axles	Actual weight on Rail Car Weighing Facility (Accuracy ± .5 Ton)					

TABLE 4-3. (Continued)

MEASUREMENT REFERENCES (FAST TEST SPECIFICATION VOL. III) - PTT TESTS

(SLC PROGRAM DATA COLLECTION)

PRIMARY MEASUREMENTS FOR SLC DATA ANALYSES

MEASUREMENT TITLE	TITLE NUMBER	TEST DATA REF. PAGE	ILLUSTRA-TIONS PAGE #	FORMS PAGE #	PROCEDURE PAGE #	VALUES MEASURED BY TTC
TRUCKS (cont.)						
• Side Frame Rotation Stop - Total Wear	4t	2.9.25	2.9.25.5	2.9.25.5.1/.2	---	
• Bolster Lat. Stop - Wear	4u	2.9.26	2.9.26.5	---	---	
• Transom Lat. Stop - Wear	4v	2.9.27	2.9.27.5	---	---	
• Truck Centerplate, Vert. Wall Wear	6a	2.11.6	2.11.6.5	2.11.6.5.1	---	
• Truck Centerplate, Diameter Wall Wear	6b	2.11.7	2.11.7.5	---	---	
• Body Centerplate, Vert. Wall Wear	6d	2.11.9	2.11.9.5	---	---	
• Truck Centerplate, Hor. Surf. Wall Wear	6e	2.11.10	2.11.10.5	2.11.10.5.1		
SIDE BEARINGS:						
• Side Brg. Cage Wear	7a	2.12.6	2.12.5.1 2.12.6.5	2.12.5.2	2.12.5.3	
• Side Brg. Roller Wear	7c	2.12.8	2.12.8.5	---	---	
• Const. Contact Brg. PermSet	7d	2.12.9	2.12.9.5	---	---	
• Const. Contact Brg. PreCompn.	7e	2.12.10	2.12.10.5	---	---	
COUPLERS:						
• Coupler Shank Plate - Wear	9a	2.14.6	2.14.6.5	2.14.5.1 2.14.6.5.1	2.14.5.2/3	
• Coupler Carrier - Wear	9d	---	---	---	---	
• Coupler Lateral Play	--	---	---	---	---	
• Coupler Travel	(Measure distance between Horn & striker) - accuracy within ± 1/32					
• Coupler Height above rail (loaded vehicle)	--	---	---	---	---	
	(Measure Height above rail, within ± 1/32) (Place a steel bar transversely across rail tops and measure coupler shank ℄ from bottom edge of steel bar)					

TABLE 4-3. (Continued)

MEASUREMENT REFERENCES (FAST TEST SPECIFICATION VOL. III) - PTT TESTS

(SLC PROGRAM DATA COLLECTION)

SECONDARY MEASUREMENTS FOR SLC DATA ANALYSES

MEASUREMENT TITLE	TITLE NUMBER	TEST DATA REF. PAGE	ILLUSTRATIONS PAGE#	FORMS PAGE #	PROCEDURE PAGE #	VALUES MEASURED BY TTC
TRUCKS:						
• Side Frame Pocket for Rocker Seat Bearing	4x	2.9.29				
• Rocker Seat Bearing Wear	4y	2.9.30				
• Rocker Seat Wear	4aa	2.9.32				
• Any Casting/Component of Side Frame/Bolster Cracked		Visual Inspection Details				
• Primary/Secondary Springs	5d	2.10.4 Measure Spring Deflection Rates				
• Snubbers (Loss of Fluid)		Visual Inspection Details				
• Inspect for Components Rubbing, Peening, Gouging, Welding						
COUPLERS						
• Head and Knuckle Wear	10a	2.15.6	2.15.5.1	2.15.6.5		
• Coupler Pulling Lug-Upper Wear	10d	2.15.9	2.15.9.3	2.15.9.5		
• Key Slot/Draft Slot Wear	10h, 10i	2.15.13 2.15.14				
• Draft/Buffer Gear-Travel, AAR Specifications on "Couplers"						

- The ALD table.

The data records contain:

- A record header, 24 bytes long.
- Floating point data for:
  - 68 channels.
  - 41 scans per channel.

The format of the data tapes for T-5 data acquisition vehicle will be very similar to that of the T-7. The principal difference being that only 30 channels of information will be included, reflecting the limited amount of instrumentation installed on the E-8 locomotive consist.

In general, all data channels contain values in engineering units where applicable. The baggage car instrumented wheelset data will still contain the deviations in signal from the temperature and inertial effects inherent in the design. The channel statistics will give an indication of the magnitude of these deviations.

4.5.1.1 File Header Record

This record contains different groups of information. The first group contains most of the available information in the original T-7 file record header. The 200 bytes of information for this group are described below.

Variable		Type	Bytes
Sample Rate	256	I	4
Number of Channels Per Scan	68	I	4
Number of Scans Per Record	41	I	4
Tape Number		I	4
Date			
Month		E	2
Blank		E	1
Day		E	2
Blank		E	1
Year		E	2
File Number		E	2
Test Description (144 Characters)		E	144
Test Number		E	6
Track Number		I	4
Direction of Travel		E	6
Blanks or Remaining Information from T-7		E	14
		Total Bytes	200

The next set of data in the header record is the channel assignment table as given in Table 4-4. Each line in the table is stored in 80 bytes, i.e., card image. The table requires 5,440 bytes of EBCDIC data.

Part of the processing includes computation of the maximum, minimum and average for all the channels except two: the filtered ALD and distance channel. Let [$XMAX_i$, $XMIN_i$, AVG_i; i=1,68] denote these statistics. These statistics constitute the next set of data in the record header, requiring 792 bytes. They are stored as:

$$[(XMAX_i,\ i=1,\ldots 66),\ (XMIN_i,\ i=1,\ldots 66),$$
$$(AVG_i,\ i=1,\ldots 66)]$$

The next two items in the record are concerned with the speed-distance processing. The first variable, ISPD, is an integer indicating the procedure used for computing the distance channel and possibly the speed channel. The second item is a floating point variable, SF. This variable is a scaling factor for converting tach counts to feet. The possible speed-distance processing options are:

ISPD = 1 if the analog speed was used in the distance computation. In this case, the speed channel is the analog speed in mph.

2 if the digital speed was used in the distance computation. In this case, the speed channel is the digital speed in mph.

3 if tach counts per interval were used in the distance computation. In this case, SF is the scale factor used in computing the distance channel. The speed channel in this situation is the tack counts per interval.

4 same as 3, but available scale factor is used. The stored value of SF is the overall average of the scale factors used in computing distances.

The last set of data in the header record is the ALD table described in Table 4-5. This set of data uses (N*24+4) bytes of storage, where N denotes the number of detected ALD's.

The elements of the ALD table are:

TABLE 4-4. CHANNEL ASSIGNMENTS

Output Channel	T-7 Channel #	Type	Location	Source	Max Range	Units	CTF FRQ
1	0	Vert Force	#4 Axl Lft Loco	ASEA Wh	100.0	Kips	85.0
2	1	Lat Force	#4 Axl Lft Loco	ASEA Wh	100.0	Kips	85.0
3	2	Vert Force	#4 Axl Right Loco	ASEA Wh	100.0	Kips	85.0
4	3	Lat Force	#4 Axl Right Loco	ASEA Wh	100.0	Kips	85.0
5	4	Vert Force	#5 Axl Lft Loco	ASEA Wh	100.0	Kips	85.0
6	5	Lat Force	#5 Axl Lft Loco	ASEA Wh	100.0	Kips	85.0
7	6	Vert Force	#5 Axl Right Loco	ASEA Wh	100.0	Kips	85.0
8	7	Lat Force	#5 Axl Right Loco	ASEA Wh	100.0	Kips	85.0
9	8	Vert Force	#6 Axl Lft Loco	ASEA Wh	100.0	Kips	85.0
10	9	Lat Force	#6 Axl Lft Loco	ASEA Wh	100.0	Kips	85.0
11	10	Vert Force	#6 Axl Right Loco	ASEA Wh	100.0	Kips	85.0
12	11	Lat Force	#6 Axl Right Loco	ASEA Wh	100.0	Kips	85.0
13	12	ALD on Brush charts	#4 Axl Lft Loco	ALD Snsr	1.0	Event	85.0
14	13	Vert Displcmnt	Jrnl 4 R	String Pt	5.0	In	20.0
15	14	Vert Displcmnt	Jrnl 5 R	String Pt	5.0	In	20.0
16	15	Vert Displcmnt	Jrnl 6 R	String Pt	5.0	In	20.0
17	16	Vert Displcmnt	Jrnl 4 L	String Pt	5.0	In	20.0
18	17	Vert Displcmnt	Jrnl 5 L	String Pt	5.0	In	20.0
19	18	Vert Displcmnt	Jrnl 6 L	String Pt	5.0	In	20.0
20	19	Axle Displcmnt	Trck/Axl 4	Kamen	1.0	In	85.0
21	20	Axle Displcmnt	Trck/Axl 5	Kamen	1.0	In	85.0
22	21	Axle Displcmnt	Trck/Axl 6	Kamen	1.0	In	85.0
23	22	Frame Motion	#1 Blstr/Trck F	String Pt	5.0	In	20.0
24	23	Frame Motion	#2 Blstr/Trck R	String Pt	5.0	In	20.0
25	24	Vert Acclrtn	#1 Crbdy	Acclrmtr	1.0	g	10.0
26	25	Vert Acclrtn	#2 Crbdy	Acclrmtr	1.0	g	10.0
27	26	Vert Acclrtn	#3 Crbdy	Acclrmtr	1.0	g	10.0
28	27	Vert Acclrtn	#4 Crbdy	Acclrmtr	1.0	g	10.0
29	28	Vert Acclrtn	#5 Crbdy	Acclrmtr	1.0	g	10.0
30	29	Lat Acclrtn	#6 Crbdy	Acclrmtr	1.0	g	10.0

NOTE: Axles Numbered 4 through 6 Correspond to Axles 10 through 12 for the "A" Consist Configuration

TABLE 4-4. (Continued)

Output Channel	T-7 Channel #	Type	Location	Source	Max Range	Units	CTF FRQ
31	30	Lat Acclrtn	#7 Crbdy	Acclrmtr	1.0	g	10.0
32	31	Lat Acclrtn	#1 Trck Frm F	Acclrmtr	5.0	g	20.0
33	32	Lat Acclrtn	#2 Trck Frm R	Acclrmtr	5.0	g	20.0
34	33	Lat Acclrtn	#4 Axle	Acclrmtr	25.0	g	85.0
35	34	Lat Acclrtn	#5 Axle	Acclrmtr	25.0	g	85.0
36	35	Lat Acclrtn	#6 Axle	Acclrmtr	25.0	g	85.0
37	36	Vert Acclrtn	#4 Axle R	Acclrmtr	25.0	g	85.0
38	37	Vert Acclrtn	#5 Axle R	Acclrmtr	25.0	g	85.0
39	38	Vert Acclrtn	#6 Axle R	Acclrmtr	25.0	g	85.0
40	39	Vert Acclrtn	#4 Axle L	Acclrmtr	25.0	g	85.0
41	40	Vert Acclrtn	#5 Axle L	Acclrmtr	25.0	g	85.0
42	41	Vert Acclrtn	#6 Axle L	Acclrmtr	25.0	g	85.0
43	42	Yaw	#1 Trck F	String Pt	20.0	Dgrs	20.0
44	43	Yaw	#2 Trck R	String Pt	20.0	Dgrs	20.0
45	44	Wind Velocity	Loco	Anmmtr	100.0	Mph	20.0
46	45	Wind Drctn	Loco	Anmmtr	180.0	Dgrs	20.0
47	46	Trctn Mtr Crrnt	Loco	Special	1000.0	Amps	20.0
48	47	Brake Prssr	Loco	Special	100.0	Psi	20.0
49	48	Vert Force	Bgg Car Rght	Strn Gge	50.0	Kips	85.0
50	49	Lat Force	Bgg Car Rght	Strn Gge	50.0	Kips	85.0
51	50	Vert Force	Bgg Car Left	Strn Gge	50.0	Kips	85.0
52	51	Lat Force	Bgg Car Left	Strn Gge	50.0	Kips	85.0
53	52	Lat Force	Loco Cplr	Strn Gge	50.0	Kips	85.0
54	53	Vert Force	Loco Cplr	Strn Gge	50.0	Kips	85.0
55	54	Long Force	Loco Cplr	Strn Gge	200.0	Kips	85.0
56	55	Vert Angle	Loco Cplr	String Pt	40.0	Dgrs	20.0
57	56	Lat Angle	Loco Cplr	String Pt	40.0	Dgrs	20.0
58	57	Vert Angle	Bgg Car Cplr	String Pt	20.0	Dgrs	20.0
59	58	Lat Angle	Bgg Car Cplr	String Pt	20.0	Dgrs	20.0
60	59	Vert Acclrtn	#1 Crbdy Bgg Car	Acclrmtr	8.0	g	10.0
61	60	Vert Acclrtn	#2 Crbdy Bgg Car	Acclrmtr	4.0	g	10.0
62	61	Vert Acclrtn	#3 Crbdy Bgg Car	Acclrmtr	4.0	g	10.0
63	62	Lat Acclrtn	#4 Crbdy Bgg Car	Acclrmtr	4.0	g	10.0
64	63	Lat Acclrtn	#5 Crbdy Bgg Car	Acclrmtr	2.0	g	10.0
65	82	Lat Acclrtn	T-7 Crbdy	Acclrmtr	1.0	g	10.0
66		Speed		Processed		mph	
67		Filtered ALD					
68		Distance (ft) from first ALD		Processed		ft	

NOTE: AXLES NUMBERED 4 THROUGH 6 CORRESPOND TO AXLES 10 THROUGH 12 FOR THE "A" CONSIST CONFIGURATION

TABLE 4-5. AUTOMATIC LOCATION DETECTOR MAPPING

$$\{(I_k,\ J_k,\ L_k,\ M_k,\ X_F,\ \Delta X_F),\ k = 1,N\}$$

Variable	Type	Description
N	I	Number of detected ALD's
I_k	I	Spurious ALD switch
J_k	I	ALD ID number
L_k	I	Record number for ALD
M_k	I	Scan within record at which peak located
X_k	F	Peak location (feet from ALD #1)
ΔX_k	F	Distance from previous ALD
.	.	.
.	.	.
.	.	.
I_N	I	
.	.	.
.	.	.
.	.	.
ΔX_N	F	

For each detected peak

- A spurious ALD switch.

  0 if detected peak is not an ALD peak.

  1 otherwise.

- An ALD number. This is a unique number; spurious detected peaks are given a number zero.

- The tape record and scan within that record where peak is located in filtered ALD channel.

- The peak location in feet from ALD #1.

- The distance from previous ALD.

4.5.1.2 Data Records

Data records consist of two portions, a record header and channel information.

The record header consists of six integer variables:

- Record number.

- Time from T-7 real time clock (3 integers).

- The number of the first ALD in the record (0 if none).

- The number of the last ALD in the record (0 if none).

All channel information is in floating point. There are 68 channels and 41 scans per channel. The selected channels are described in the Channel Selection Table (4-4).

4.5.2 <u>Track Geometry Data Tapes</u>

The raw tapes from the track geometry data acquisition vehicles (T-6 and TSD) are also not in a standardized, readily usable format. The originals have been copied and stored. These tapes have been extensively processed and put in a similar, IBM-compatible format, as the T-7 and T-5 tapes were. The differences in the formats are necessitated by the difference in the data stored. For example, the T-6 has only 18 channels of data. The TSD tapes require even more processing, necessitated by the surveying procedure discussed earlier in this chapter. Further, the TSD did not record the ALD locations.

The necessary record length for T-6 data is 7,216 bytes. This record length takes into account:

- 18 data channels, floating point data.
- 100 scans per channel.
- A data record header 16 bytes long.

The speed-distance processing and the generation of the filtered ALD channels are different than for the T-7. First, there are two available channels for speed-distance computations:

- Time between samples.
- Analog speed.

Secondly, the expected distance between samples is 6 inches. Some test runs were made at a 1-foot sample interval, but it was only used to verify new software for six-inch sampled test data. The filtering of the ALD channel will require additional logic for identifying ALD peaks.

These differences will be reflected in a new format for the ALD table.

4.5.2.1 File Header Record

The file header will contain the following information:

- Header information (82 bytes).
- T-6 channel assignment table (1,440 bytes).
- Channel statistics (384 bytes).
- The ALD table (NALDS*24 bytes).

The channel assignments are shown in Table 4-6.

TABLE 4-6. CHANNEL ASSIGNMENT FOR T-6 TRACK GEOMETRY

Channel #	Description
1	Smoothed curvature, low-pass filtered
2	Gage
3	Crosslevel
4	Time between samples
5	Left profile 62-foot chord
6	Right profile 62-foot chord
7	Left profilometer space curve
8	Right profilometer space curve
9	Left alignment 62-foot chord
10	Right alignment 62-foot chord
11	Left alignment space curve
12	Right alignment space curve
13	Crosslevel for exceptions
14	ALD
15	Speed
16	Gage sensor status indicator*
17	Filtered ALD - processed
18	Distance channel - processed

*
0 - Sensor down
1 - Sensor up - gage and alignment data not available
2 - Sensor right-protected - gage and right alignment not available
4 - Sensor left-protected - gage and left alignment not available

4.5.2.2 Data Records

The data records consist of two portions: a record header and channel information. The record header will be four integer variables:

- Record sequence number.
- Milepost number.
- First ALD number in record, 0 if none.
- Last ALD number in record, 0 if none.

All channel information is in floating point format. There are 100 scans per record. Distance is computed by summing the number of samples beyond the first ALD in the test zone times 0.5 feet per sample. Channel 16, the gage sensor status indicator, contains the following values:

0 - Down
1 - Up
2 - Right-protected
4 - Left-protected.

5. PHYSICAL MEASUREMENTS AND CALIBRATIONS

During the PTT, extensive measurements of the physical parameters of the vehicles and track were made to identify the reference conditions for the dynamic response analyses and to establish the input parameters for model validation. These measurements include records of the vehicle weights and dimensions, track characteristics, and the correlation and calibration of the wayside/onboard force measuring systems. The intent of this chapter is to provide an indication of the physical measurements collected and the quality of the force measuring systems.

5.1 VEHICLE PARAMETERS

During the PTT, extensive measurements were made of the physical characteristics of the locomotives and test vehicles. The weights of all the vehicles used during the main test are presented in Table 5-1. The SDP-40F locomotives were weighed twice — before and after the extreme cold experienced during the test damaged the overhead water tank and boiler in the steam generating system of the instrumented locomotive (AMTRAK 620). Significant differences in the vehicle weights are attributed to this damage and to the variations in the amounts of sand, water, and fuel onboard the locomotives. (The SDP-40F carries approximately 55,000 pounds of supplies.)

The overall physical dimensions of the locomotives used during the PTT are presented in Figures 5-1 through 5-4. These dimensions have generally come from the Car and Locomotive Encyclopedia.[10] Wheel diameters shown are typical values. The carbody center of gravity locations are approximated typical values based on fully loaded nominal weight. The coupler heights were measured during the PTT. However, the exact height is dependent on the vehicle weight which changed as discussed above. In Figure 5-5, similar dimensions are shown for the baggage car.

Several other important dimensions and clearances were measured for the E-8 and SDP-40F locomotives. These included wheel profiles, side bearing clearances, and coupler slack. Subjective judgments as to the relative condition or wear states of several of the vehicle components were also made. In Tables 5-2 and 5-3 several important wheelset dimensions and vehicle parameters are presented. Some of these have been measured, while others

TABLE 5-1. VEHICLE WEIGHTS

VEHICLE WEIGHTS MEASURED NOVEMBER 30, 1978
(POUNDS)

			A-END	B-END	TOTAL
AMTRAK	620	SDP-40F	194,120	197,460	391,580
AMTRAK	586	SDP-40F	182,480	179,280	361,760
AMTRAK	417	E-8	156,000	167,020	323,020
TSI	210	E-8	153,540	161,280	314,820
AMTRAK 1244 (BAGGAGE CAR)			51,200	52,980	104,180
DOTX	205	(T-5)	83,020	86,940	169,960
DOTX	207	(T-7)	83,260	80,100	163,360

SDP-40F WEIGHTS MEASURED AFTER
DAMAGE TO OVERHEAD WATER TANK DUE TO COLD
DECEMBER 12, 1978

		A-END	B-END	TOTAL
AMTRAK	620	191,060	186,260	377,320
AMTRAK	586	182,200	177,920	360,120

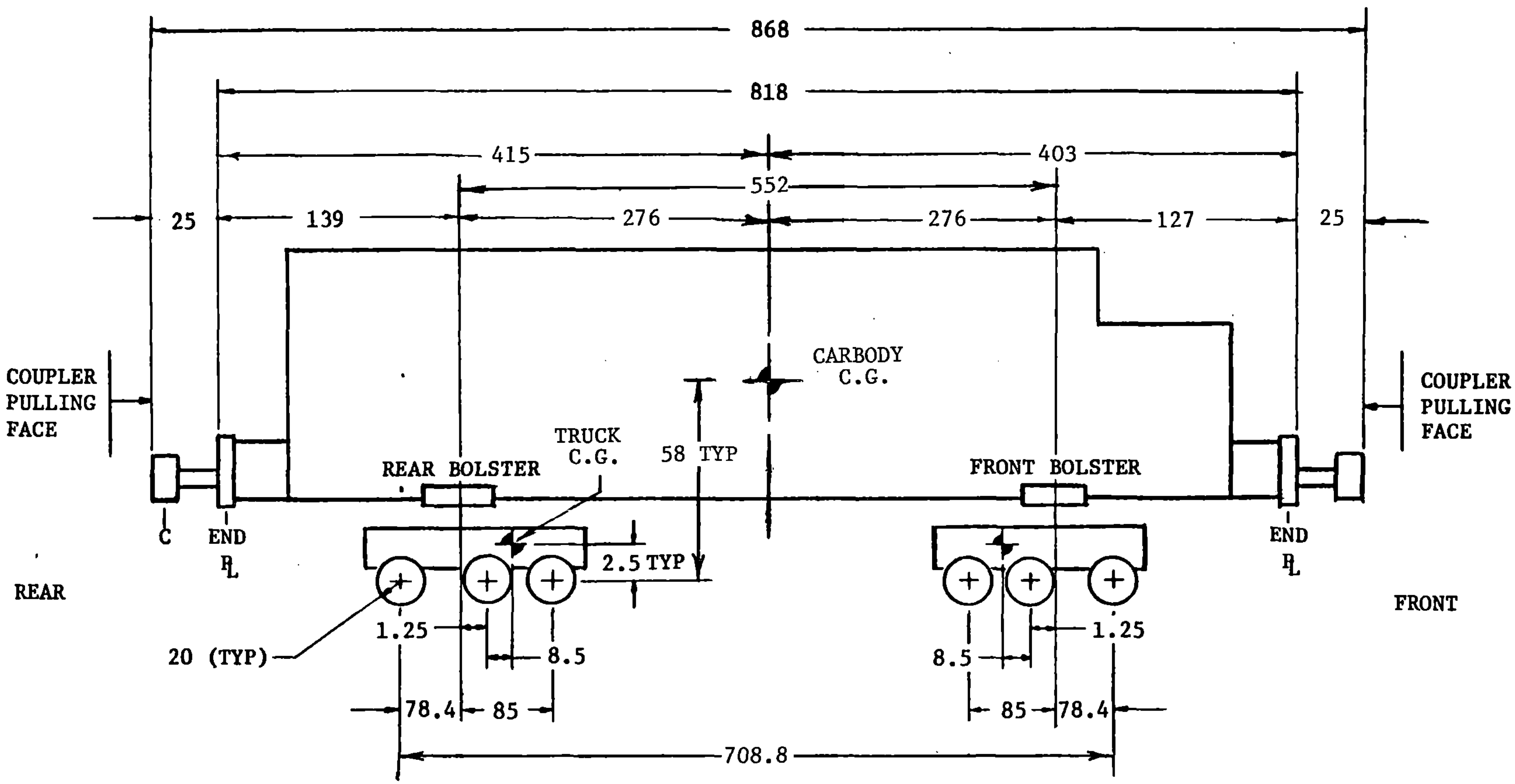


FIGURE 5-1. SDP-40F VEHICLE DIMENSIONS (INCHES)

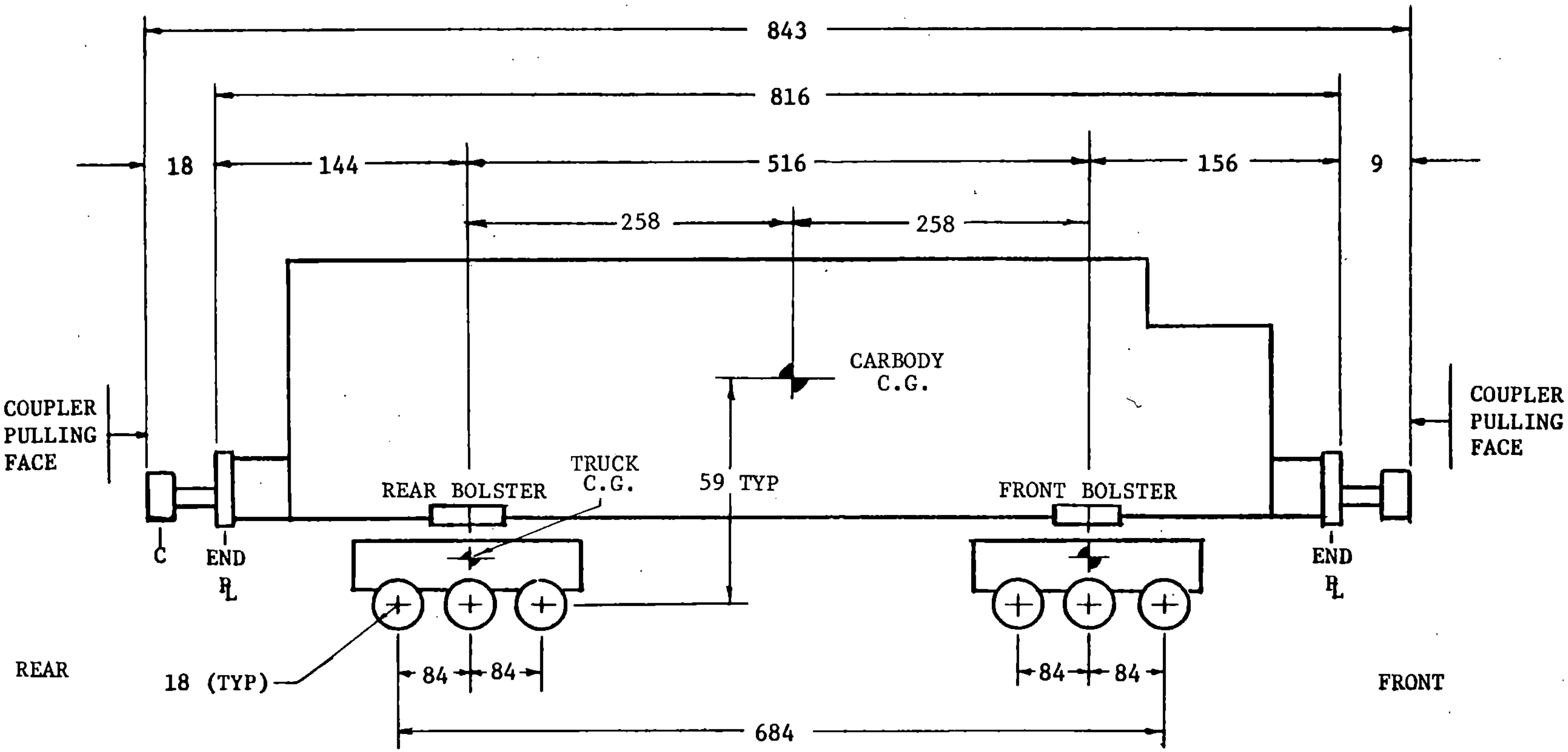


FIGURE 5-2. E-8 VEHICLE DIMENSIONS (INCHES)

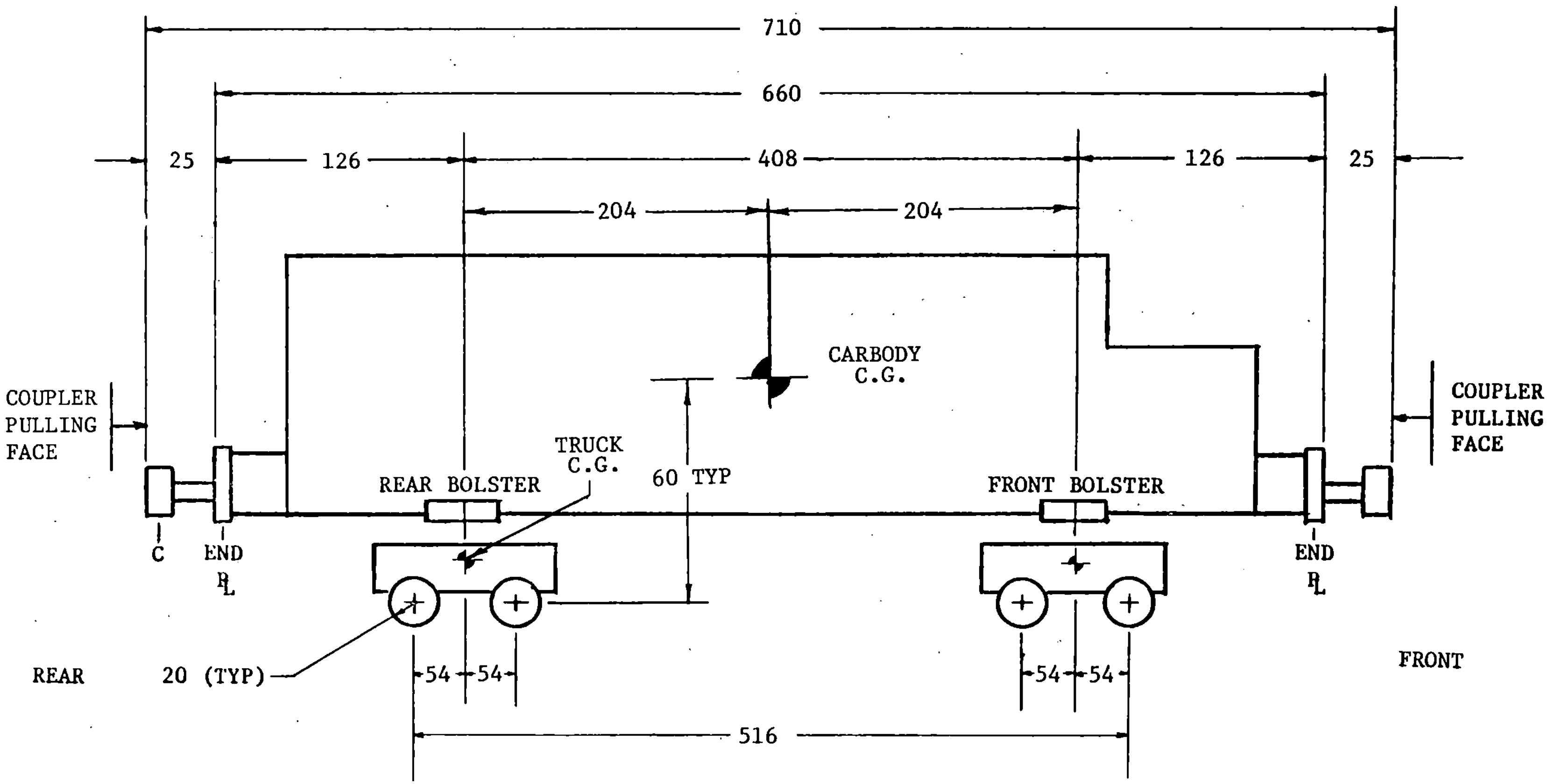


FIGURE 5-3. GP-40-2 VEHICLE DIMENSIONS (INCHES)

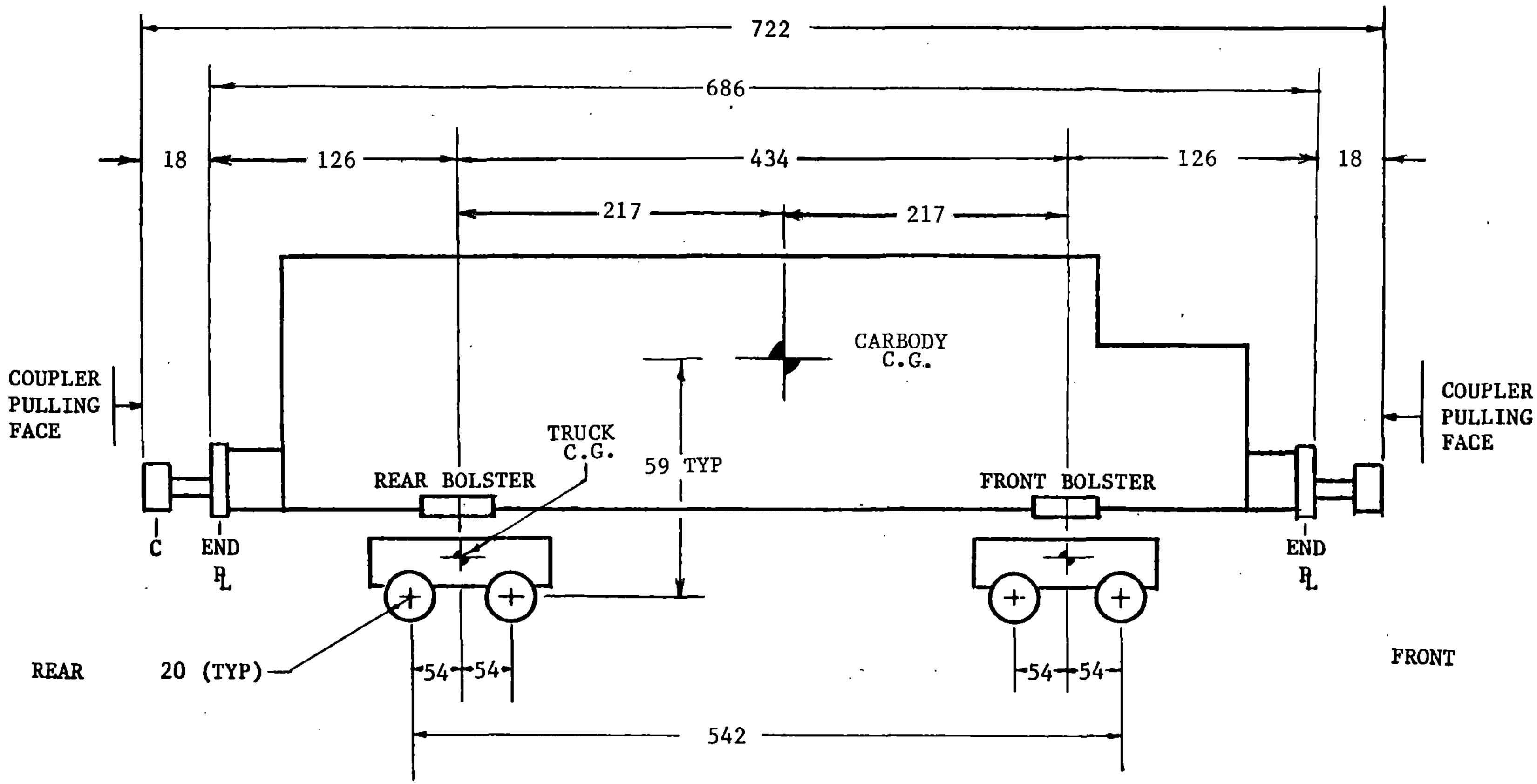


FIGURE 5-4. U-30-B VEHICLE DIMENSIONS (INCHES)

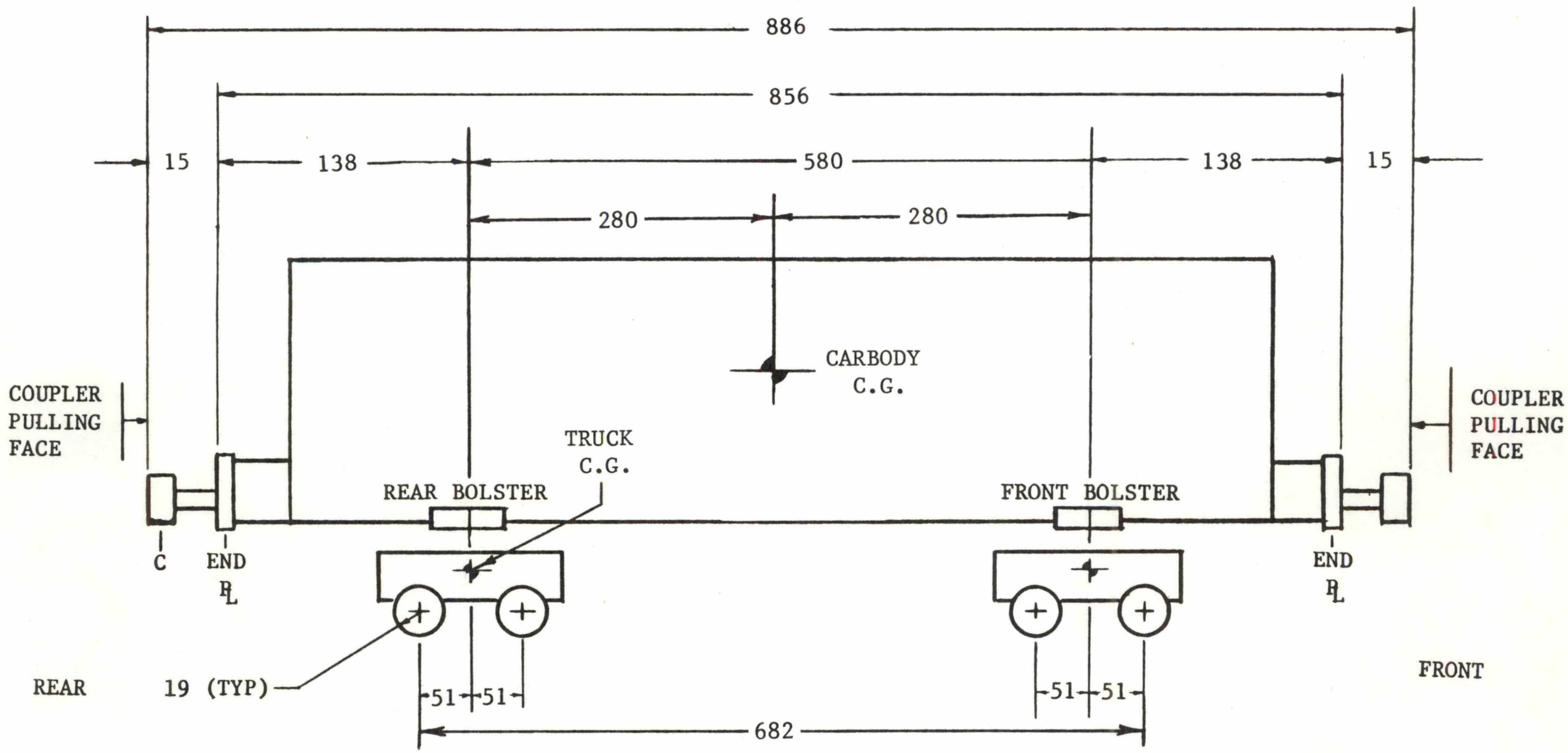


FIGURE 5-5. BAGGAGE CAR DIMENSIONS (INCHES)

TABLE 5-2. E-8 CARBODY AND WHEELSET DATA

CARBODY:

MASS = 624 $LB\text{-}SEC^2/IN$ ②

I_{YAW} = 17×10^6 $LB\text{-}IN\text{-}SEC^2$ ③

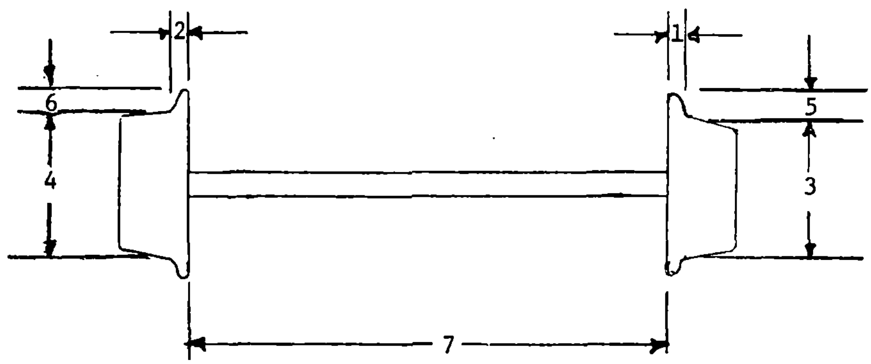
I_{ROLL} = 2×10^6 $LB\text{-}IN\text{-}SEC^2$ ④

I_{PITCH} = 17×10^6 $LB\text{-}IN\text{-}SEC^2$ ③

C.G. HEIGHT = 77 IN ④
ABOVE RAIL

TRUCK AND WHEELSET DATA NOT AVAILABLE SEE REF. 12

NOTE: ONLY 4 OF 6 AXLES (2 PER TRUCK, LEAD AND TRAIL) EQUIPED WITH TRACTION MOTORS.



WHEELSET DIMENSIONS ① (INCHES)

E-8 LOCOMOTIVES	AXLE #	1 RIGHT FLANGE THICKNESS	2 LEFT FLANGE THICKNESS	3 RIGHT WHEEL DIAMETER AT TAPING LINE	4 LEFT WHEEL DIAMETER AT TAPING LINE	5 RIGHT FLANGE HEIGHT	6 LEFT FLANGE HEIGHT	7 WHEELSET WIDTH	COUPLER HEIGHT
417	1	1 7/32	1 15/64	36.194	36.088	1 1/8	1 3/16		
	2	1 17/64	1 15/64	36.439	36.290	1 3/16	1 7/32		34 1/2
	3	1 7/32	1 15/64	35.477	35.442	1 1/32	1 1/16	N/A	
	4	1 17/64	1 5/32	36.060	35.988	1 3/16	1 15/64		
	5	1 17/64	1 17/64	36.352	36.410	1 1/4	1 3/16		34
	6	1 5/32	1 7/32	36.065	36.023	1 3/16	1 1/8	53 1/4	
210	7	1 17/64	1 15/64	33.674	33.602	1 1/16	1 1/16	53 3/8	
	8	1 5/32	1 5/32	34.274	34.152	1 7/64	1	53 3/8	33
	9	1 17/64	1 7/64	34.247	34.158	1 1/4	1 1/4	53 1/2	
	10	1 5/32	1 17/64	36.450	36.432	1 1/4	1 7/64	53 5/16	
	11	1 7/32	1 17/64	36.145	35.907	1 23/64	1 7/64	53 3/8	33 1/4
	12	1 5/32	1 17/64	36.247	36.153	1 1/4	1 1/4	53 3/8	

① MEASURED DURING PTT
② NOMINAL VALUE FROM DESIGN
③ CALCULATED VALUE OBTAINED THROUGH COMPONENT TESTS
④ ESTIMATED VALUE FROM EXPERIENCE

TABLE 5-3. SDP-40F CARBODY AND WHEELSET DATA

CARBODY:

MASS = 766 $LB\text{-}SEC^2/IN$ (2)

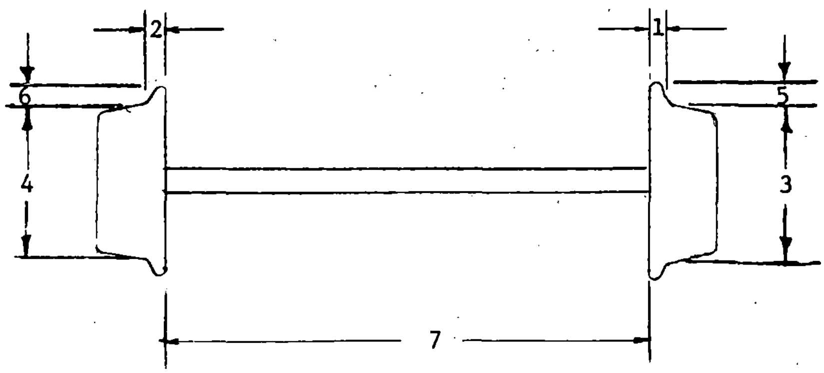
I_{YAW} = $40x10^6$ $LB\text{-}IN\text{-}SEC^2$ (3)

I_{ROLL} = $5x10^6$ $LB\text{-}IN\text{-}SEC^2$ (4)

I_{PITCH} = $40x10^6$ $LB\text{-}IN\text{-}SEC^2$ (3)

C.G. HEIGHT = 78 IN (4)
ABOVE RAIL

TRUCK AND WHEELSET DATA NOT AVAILABLE SEE REF. 11



WHEELSET DIMENSIONS (1) (INCHES)

SDP-40F LOCOMOTIVES	AXLE #	1 RIGHT FLANGE THICKNESS	2 LEFT FLANGE THICKNESS	3 RIGHT WHEEL DIAMETER AT TAPING LINE	4 LEFT WHEEL DIAMETER AT TAPING LINE	5 RIGHT FLANGE HEIGHT	6 LEFT FLANGE HEIGHT	7 WHEELSET WIDTH	COUPLER HEIGHT
586	1	1 5/32	1 7/32	40.342	40.153	1 5/16	1 3/16		
	2	1 5/32	1 5/32	39.510	39.452	1 1/16	1 1/16		33 15/16
	3	1 15/64	1 15/64	40.094	40.040	1 1/4	1 1/4		
	4	1 3/64	1 7/64	39.852	39.841	1	1	N/A	34 3/8
	5	63/64	1 7/32	39.273	39.011	1 3/16	1 1/32		
	6	1 1/32	1 7/64	39.480	39.449	1	1		
620	7	1 3/16	1 7/32	40.031	40.107	1 7/32	1 1/8	N/A	
	8	1 7/32	1 17/64	38.906	39.312	1 1/4	1 1/16	53 3/16	33 3/4
	9	1 7/32	1 7/32	39.875	39.875	1 15/64	1 17/64	N/A	
	10	1 17/64	1 17/64	39.671	39.750	1 3/64	1 1/16	53 5/16	
	11	1 17/64	1 17/64	38.953	39.078	1 1/16	1 3/64	53 3/8	34 31/64
	12	1 17/64	1 17/64	39.312	39.343	1 1/32	1 3/64	53 3/8	

(1) MEASURED DURING PTT
(2) NOMINAL VALUE FROM DESIGN
(3) CALCULATED VALUE OBTAINED THROUGH COMPONENT TESTS
(4) ESTIMATED VALUE FROM EXPERIENCE

are estimates or nominal values. A code relating the confidence in the presented values is included in the tables.

Characterizations of the various components of the locomotive trucks are beyond the scope of this report and were not extensively investigated during the PTT. Reports have been published or are to be published in the near future documenting the results of tests conducted to define the various load deflection characteristics of typical HTC (SDP-40F) and Swing Hanger (E-8) Trucks.[11,12]

Finally, sample rail head profiles were measured to provide data needed to characterize the wheel-rail contact geometry.

5.2 TRACK PARAMETERS

Each section of perturbed track represents an important variable in the PTT program. The determination of the relationship between vehicle response and variations in track input is a primary objective of the PTT. For this reason, track geometry was measured in a variety of ways (discussed in Chapter 4) throughout the testing period. In this section of the report, samples of the results from the T-6 track survey car, processed in space curve format, are presented to give an indication of the type of data available.

Figures 5-6 through 5-10 show the alignment deviations from the computed mean curve and the crosslevel deviations from the nominal superelevation for sections 1 through 5 of the curved test zone. This data was recorded with the T-6 track geometry car on either November 9, 1978, prior to the actual start of the testing, or December 6, 1978, after the second rebuild of section 4 as noted in the figures.

Similarly, Figures 5-11 through 5-14 show the alignment and profile deviations from the computed mean of the data and the crosslevel deviations from the nominal for the tangent test zone sections 6, 7, 8, and 9. This data was recorded on December 6, 1978, after the E-8 test series and the first day's SDP-40F testing.

The T-6 data will be used extensively to correlate the TSD data, which provides the most complete sampling of track geometry. The T-6 data is important in that it is the only survey device with revenue service measuring capabilities. In addition, the Plasser Car and the stringline measurements

T-6 SURVEY DATE 6 DEC 78

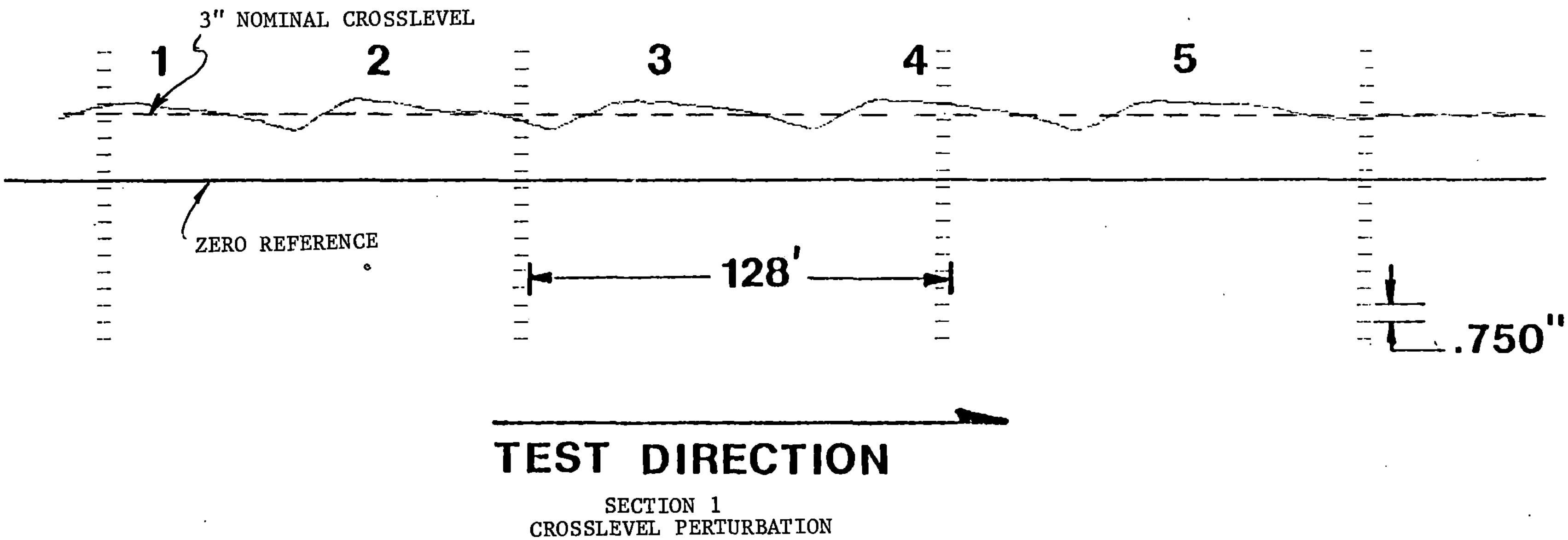
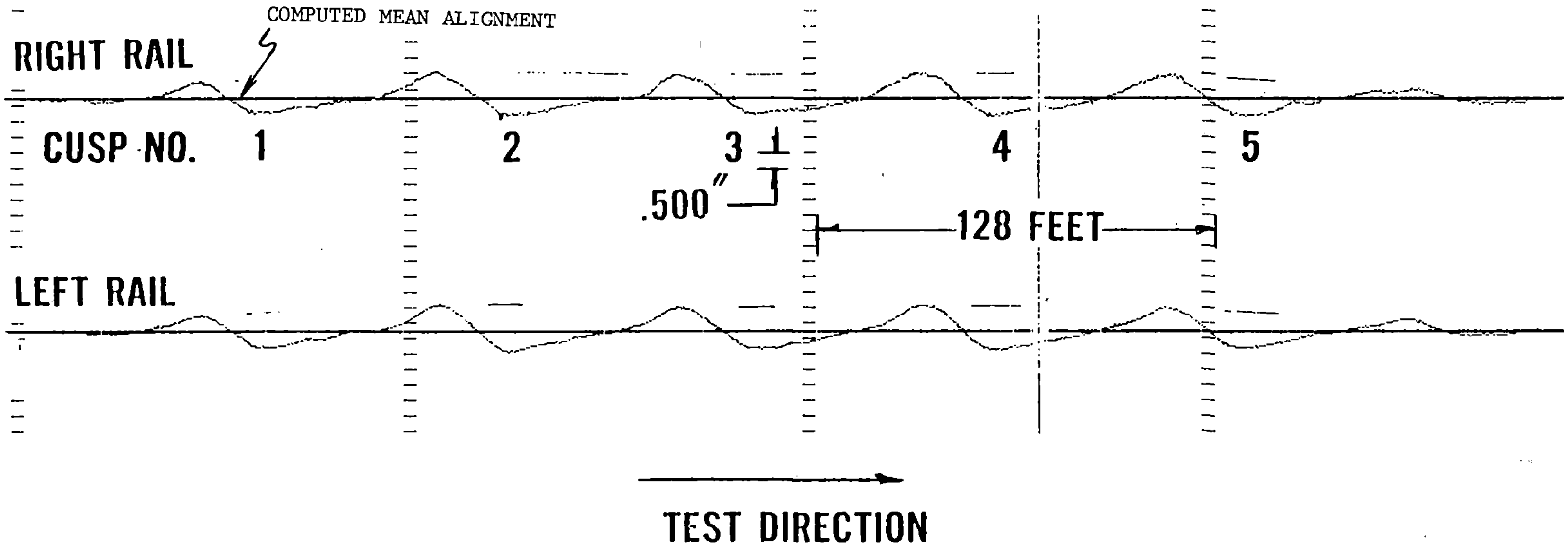


FIGURE 5-6. PIECEWISE LINEAR CROSSLEVEL PERTURBATION; SECTION 1

T-6 SURVEY DATE 9 NOV 78



SECTION 2
ALIGNMENT PERTURBATION

FIGURE 5-7. PIECEWISE LINEAR ALIGNMENT PERTURBATION: SECTION 2

T-6 SURVEY DATE 9 NOV 78

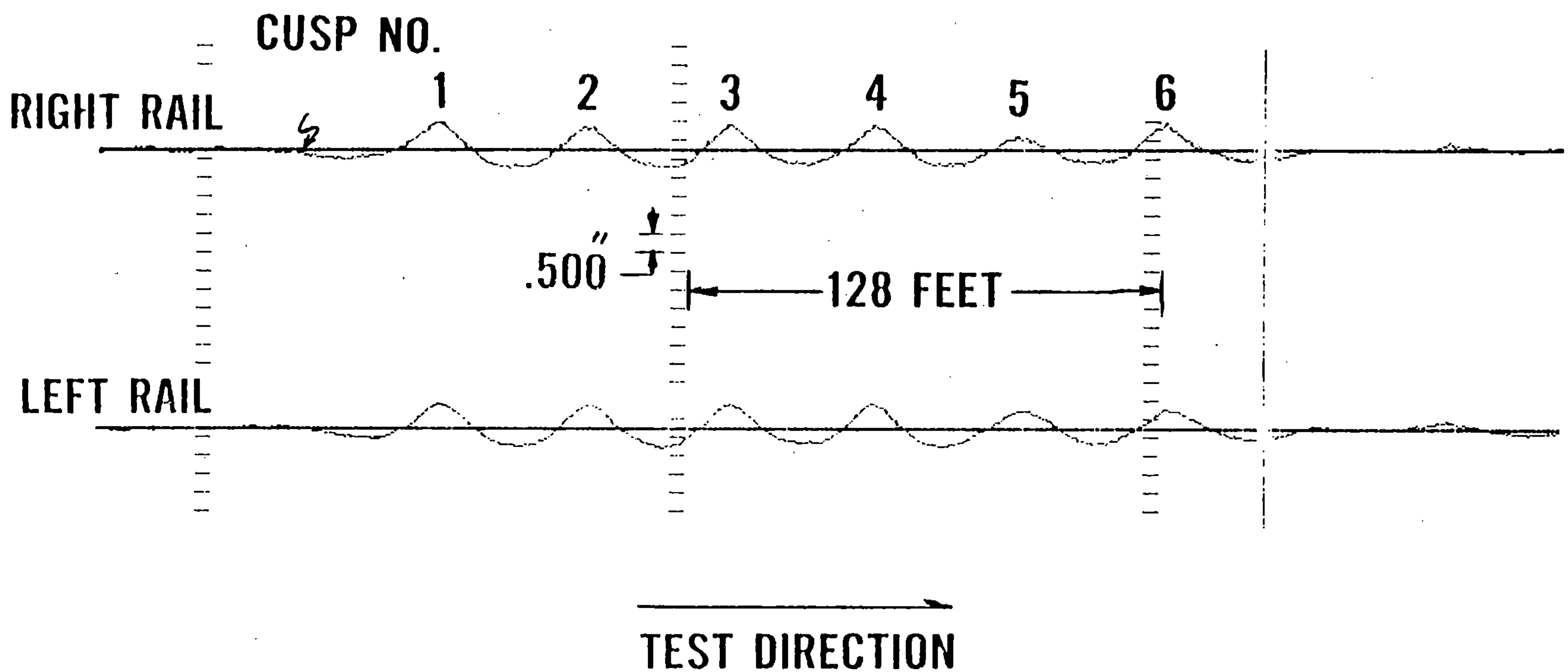


FIGURE 5-8. RECTIFIED SINE ALIGNMENT PERTURBATION: SECTION 3

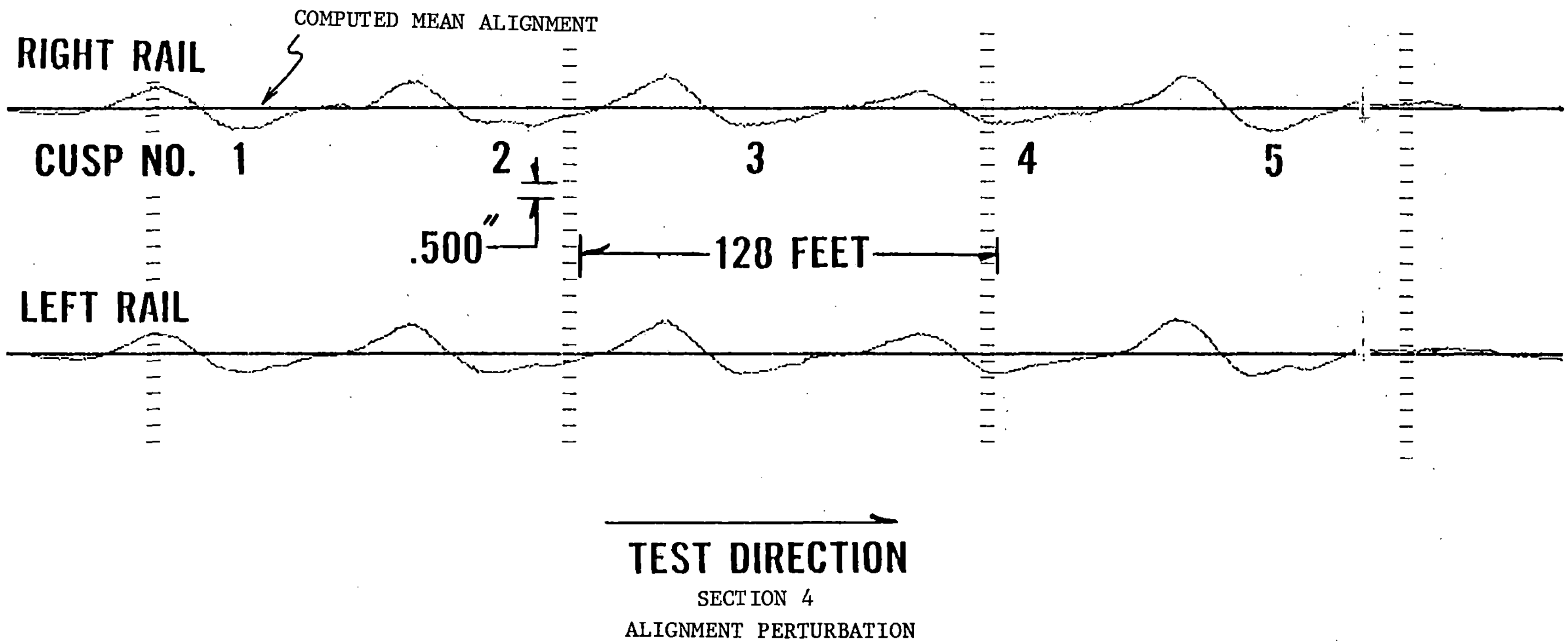
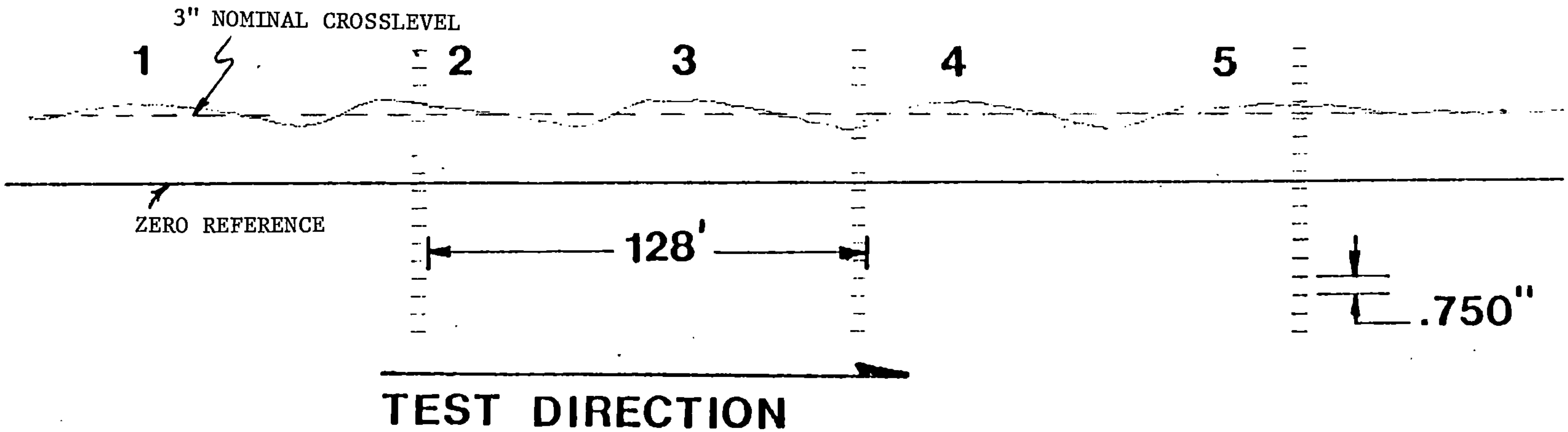


FIGURE 5-9. PIECEWISE LINEAR ALIGNMENT AND CROSSLEVEL PERTURBATION: SECTION 4

T-6 SURVEY DATE 6 DEC 78



SECTION 4
CROSSLEVEL PERTURBATION

FIGURE 5-9. (Continued)

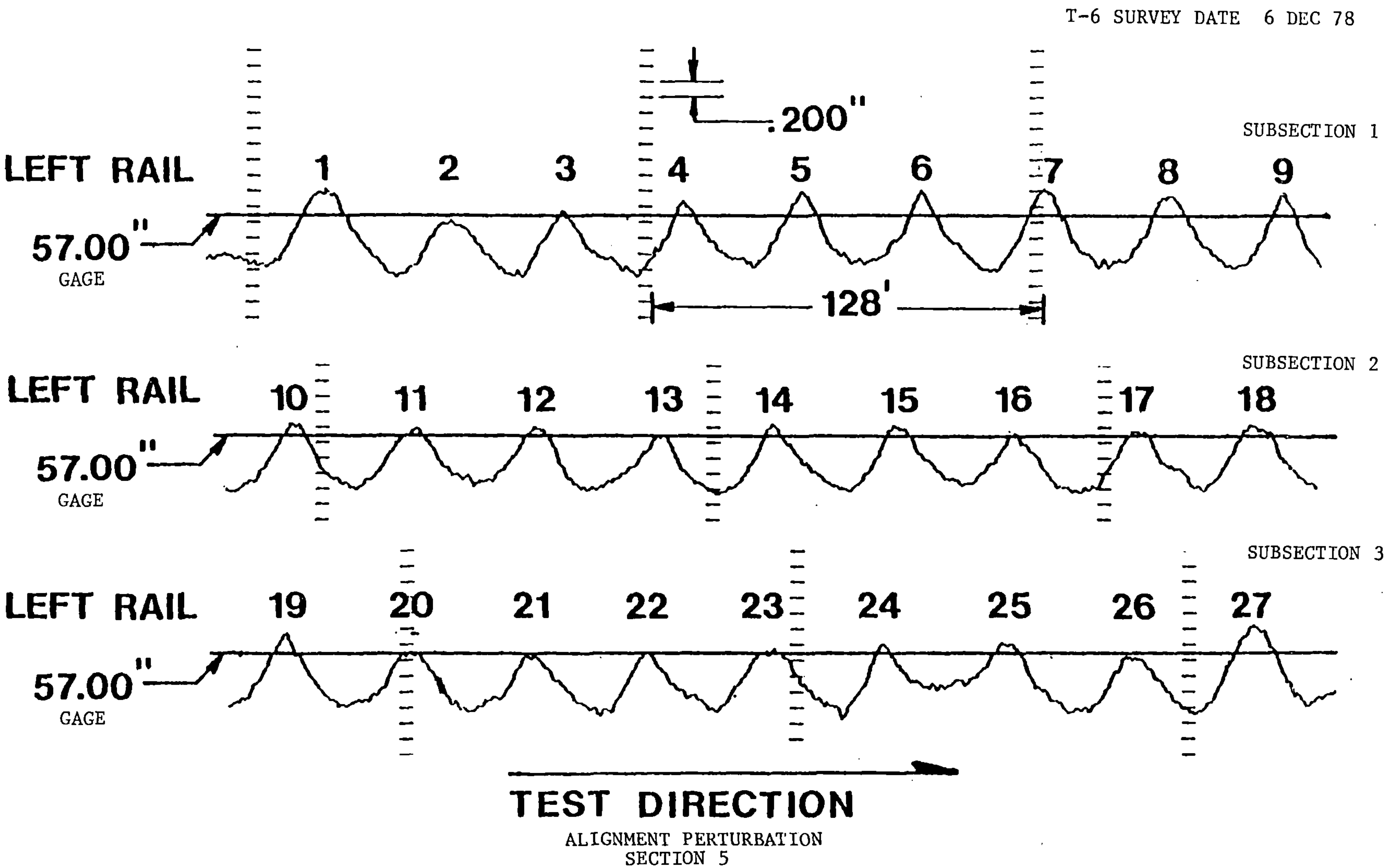


FIGURE 5-10. HIGH RAIL RECTIFIED SINE ALIGNMENT PERTURBATION WITH DECREASING SUPERELEVATION: SECTION 5

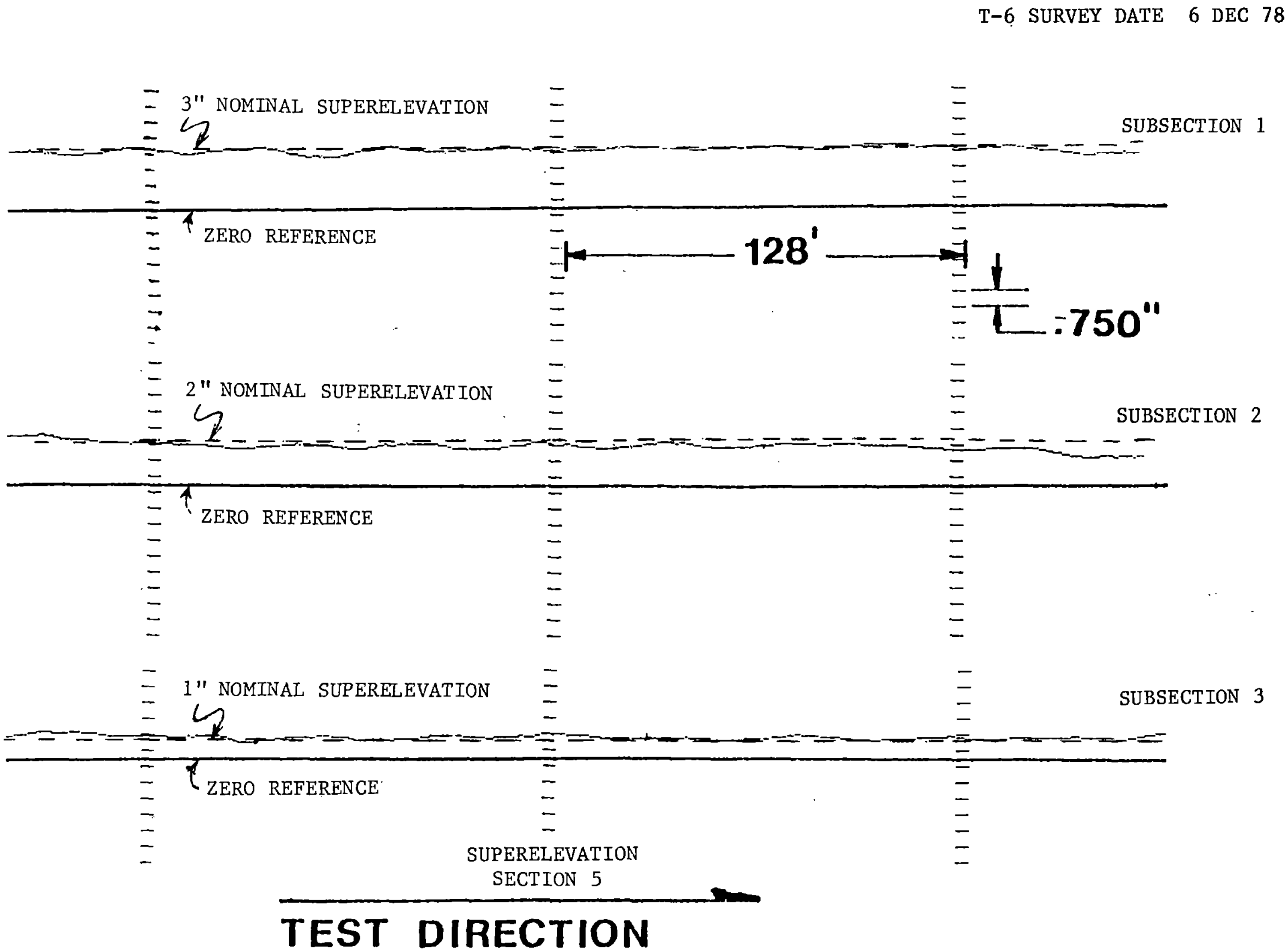


FIGURE 5-10. (Continued)

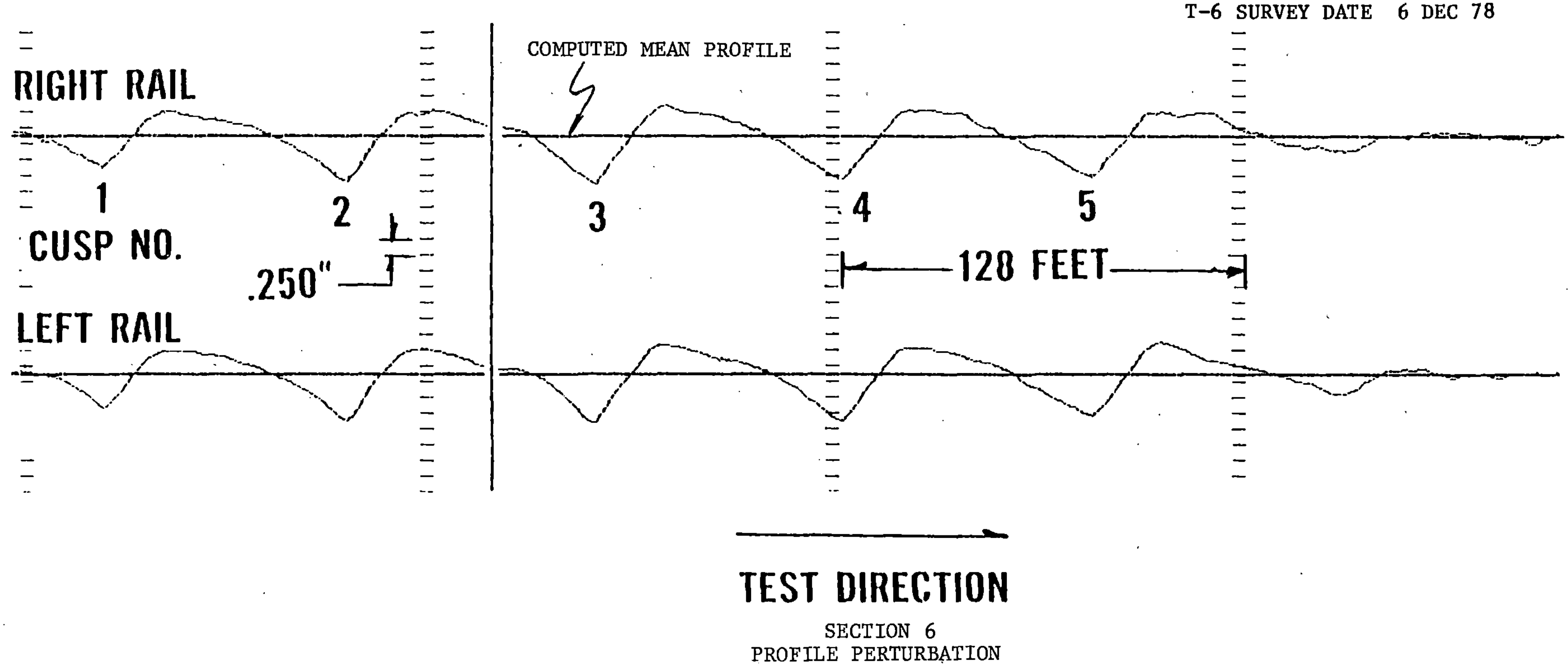
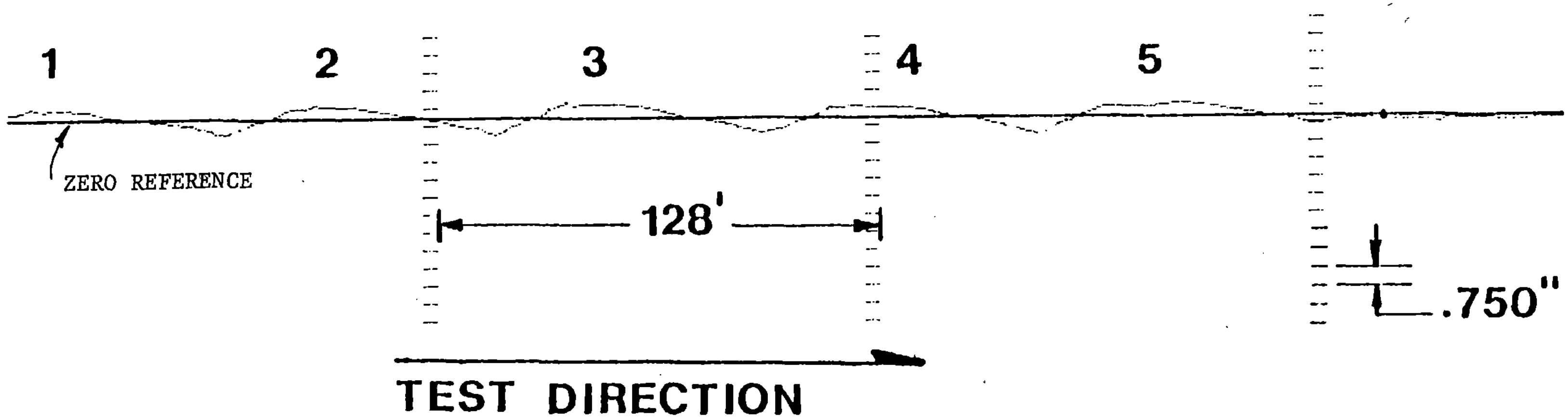


FIGURE 5-11. PIECEWISE LINEAR PROFILE PERTURBATION: SECTION 6

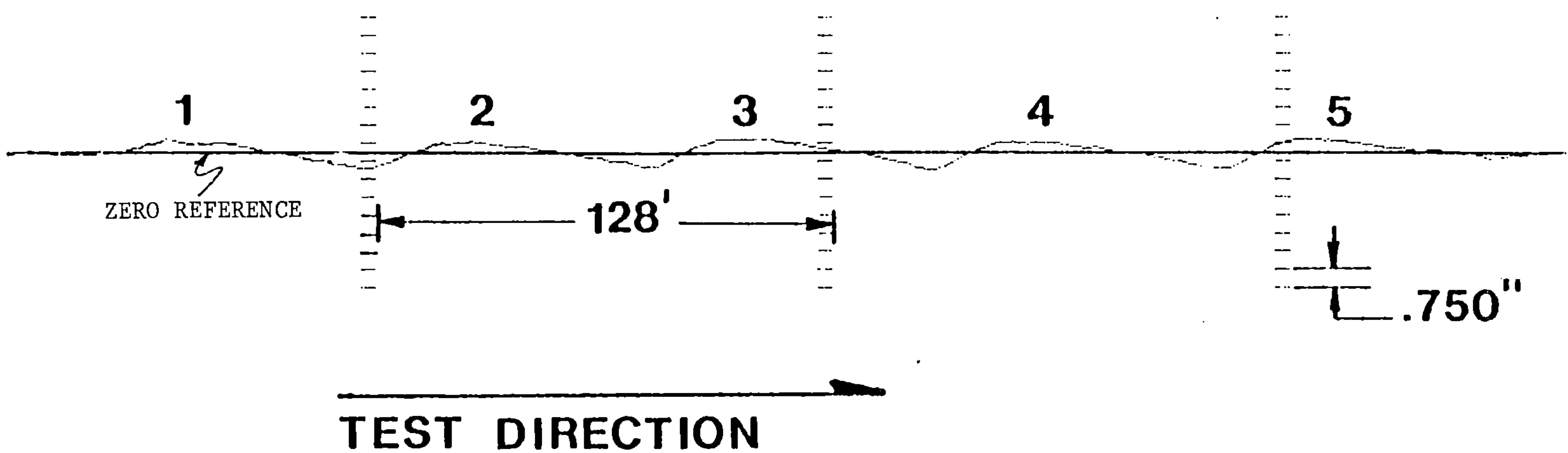
T-6 SURVEY DATE 6 DEC 78



SECTION 7 CROSSLEVEL PERTURBATION

FIGURE 5-12. PIECEWISE LINEAR CROSSLEVEL PERTURBATION: SECTION 7

T-6 SURVEY DATE 6 DEC 78



SECTION 9
CROSSLEVEL PERTURBATION

FIGURE 5-13. PIECEWISE LINEAR ALIGNMENT PERTURBATION: SECTION 8

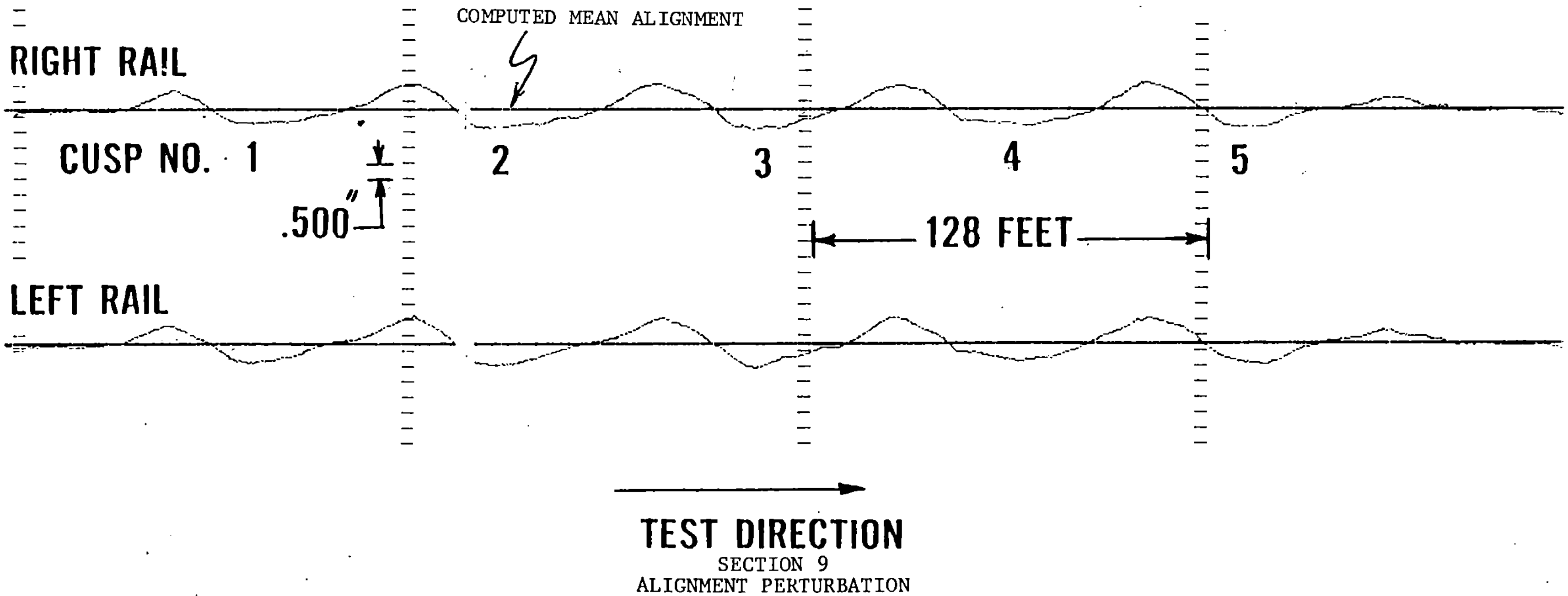
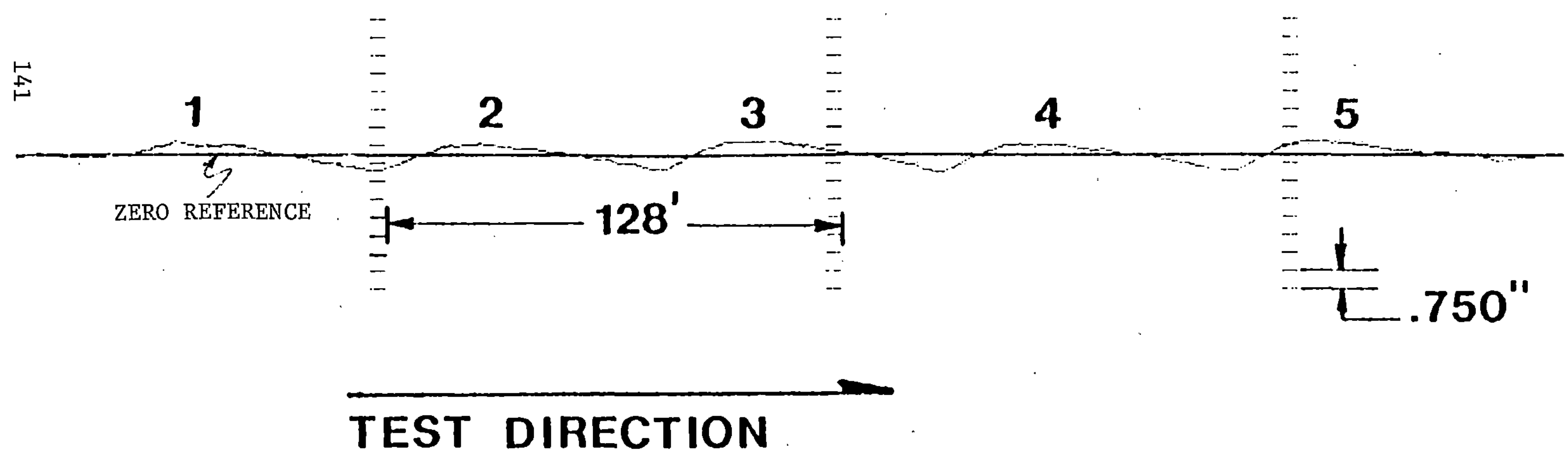


FIGURE 5-14. PIECEWISE LINEAR ALIGNMENT AND CROSSLEVEL PERTURBATION: SECTION 9

T-6 SURVEY DATE 6 DEC 78



SECTION 9
CROSSLEVEL PERTURBATION

FIGURE 5-14. (Continued)

taken throughout the testing period will be used to verify data quality. In Figures 5-15 through 5-17, typical results of Plasser Car surveys are shown for the tangent and curved test zones. This data was collected on December 2, 1978, directly after the panel shift in section 4, and December 19, 1978, directly after the main testing period. All the data presented is based on a 62-foot mid-chord offset measurement conversion except the crosslevel or super-elevation data, which are absolute measures. (Speed and curvature are responsible for some drift.)

5.3 WAYSIDE/ONBOARD INSTRUMENTATION CALIBRATION AND CORRELATION

In this section, the results of a preliminary evaluation and comparison of the various wheel/rail force measurement methods employed during the PTT are presented. Included here are discussions of the instrumented wheelsets, the wayside circuits, and the calibration techniques used, including a direct wheelset-wayside calibration. Also included is a statistical analysis comparing selected onboard dynamic response data from both the SDP-40F and E-8 locomotives, with wayside instrumentation data recorded simultaneously. This discussion is intended to provide information as to how the force measurement systems work, how they were calibrated, and indications as to how the systems compare. A more detailed discussion of the PTT instrumentation is presented in reports by R.A. Vanstone.[13,14] The following discussion is essentially taken from the latter references.

5.3.1 Transducer Systems

E-8 Wheelset

The E-8 wheelset was instrumented for the FRA in 1977 specifically for the Chessie Test. Strain gage instrumentation of the wheel plates was essentialy identical to that of the EMD wheelset, which was used on the SDP-40F for the BN and Chessie tests. A lateral force analog is computed from the outputs of two wheel plate bending bridges so oriented as to produce signals proportional to the sine and the cosine of wheel position.

The vertical force is sensed at four discrete locations by measuring the localized stress concentrated in holes drilled through the wheel plate near the rim. Peaks are

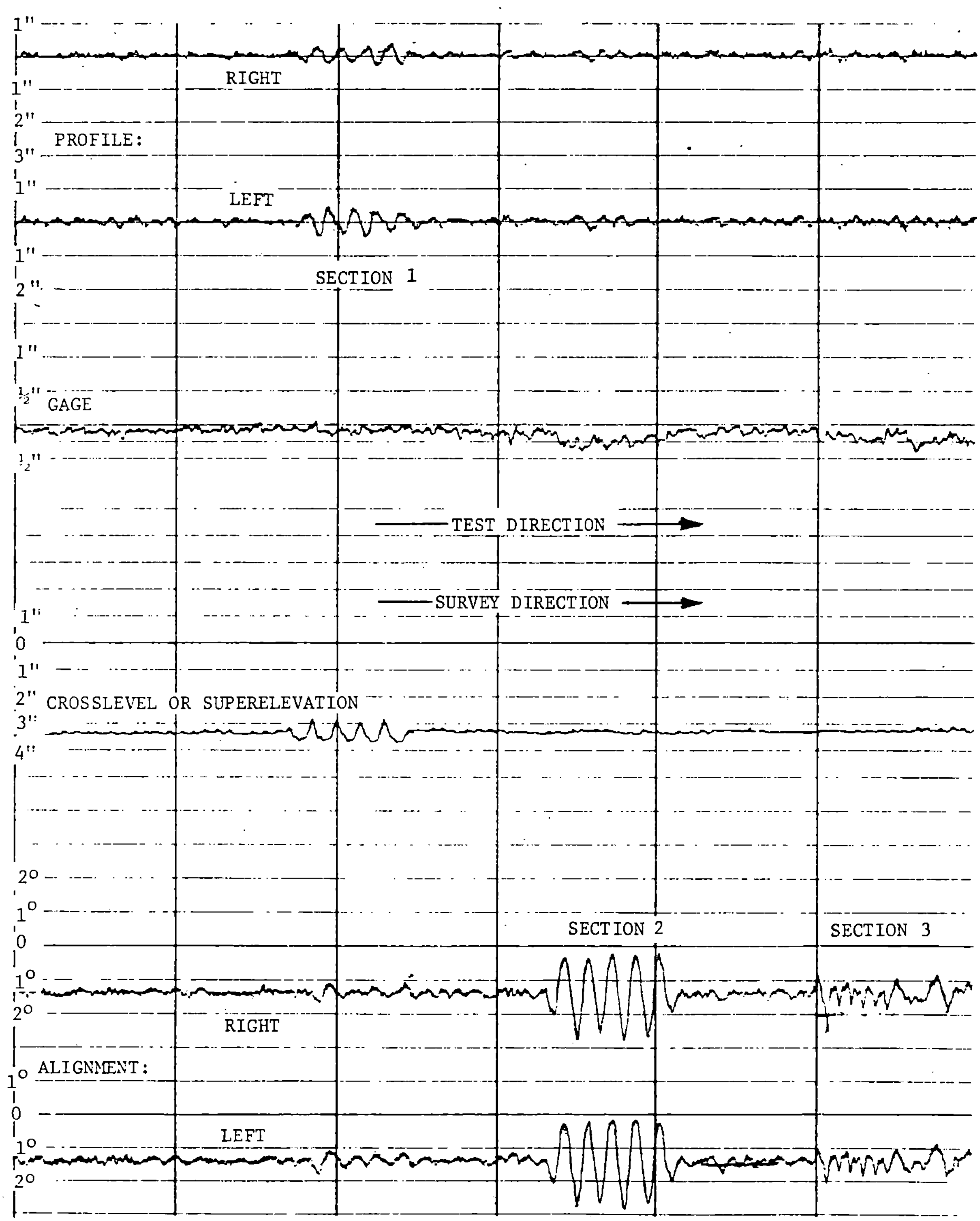


FIGURE 5-15. PLASSER CAR SURVEY CHART 12/2/78 CURVED TEST ZONE AFTER PANEL SHIFT IN SECTION 4 ON 12/1/78

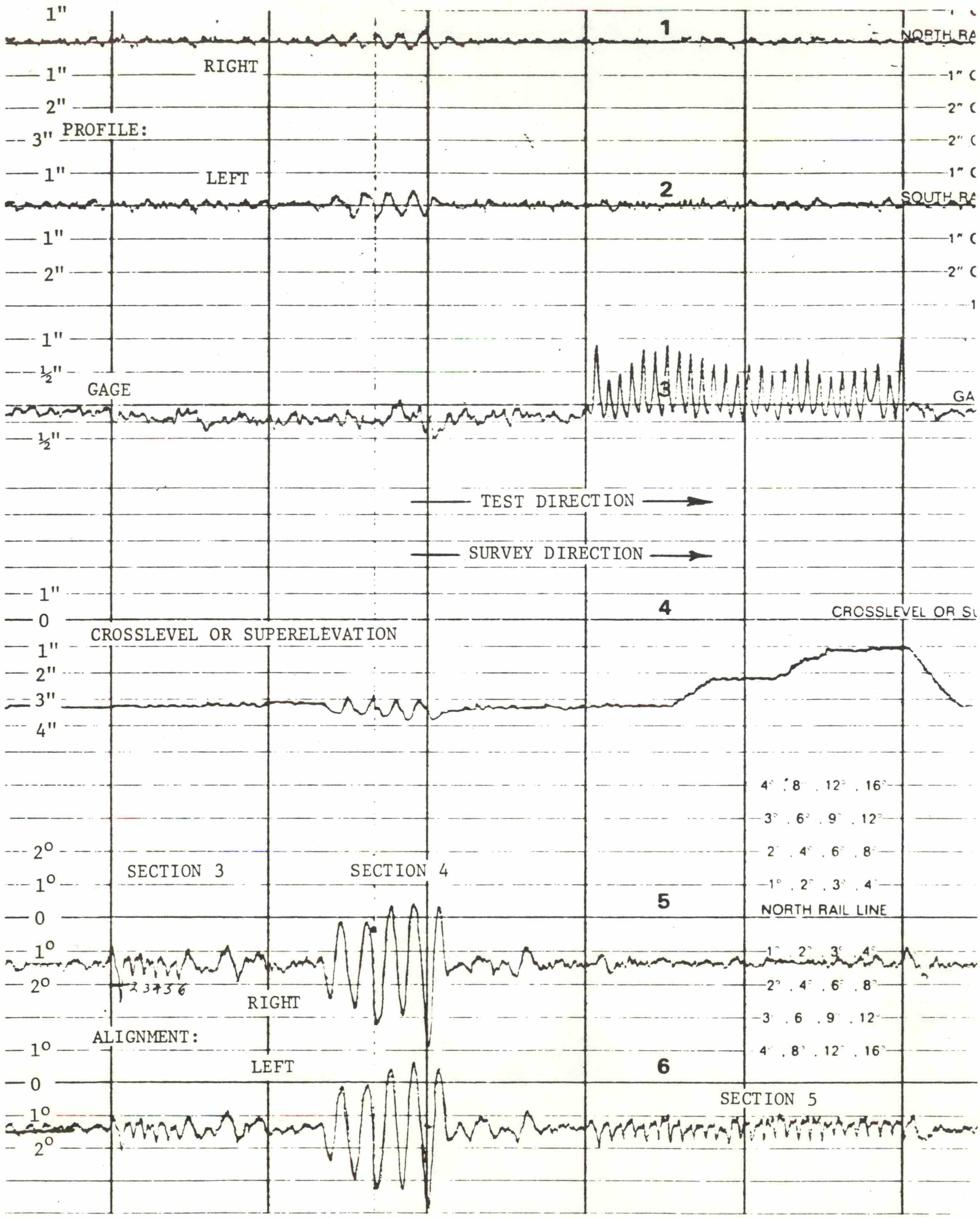


FIGURE 5-15. (Continued)

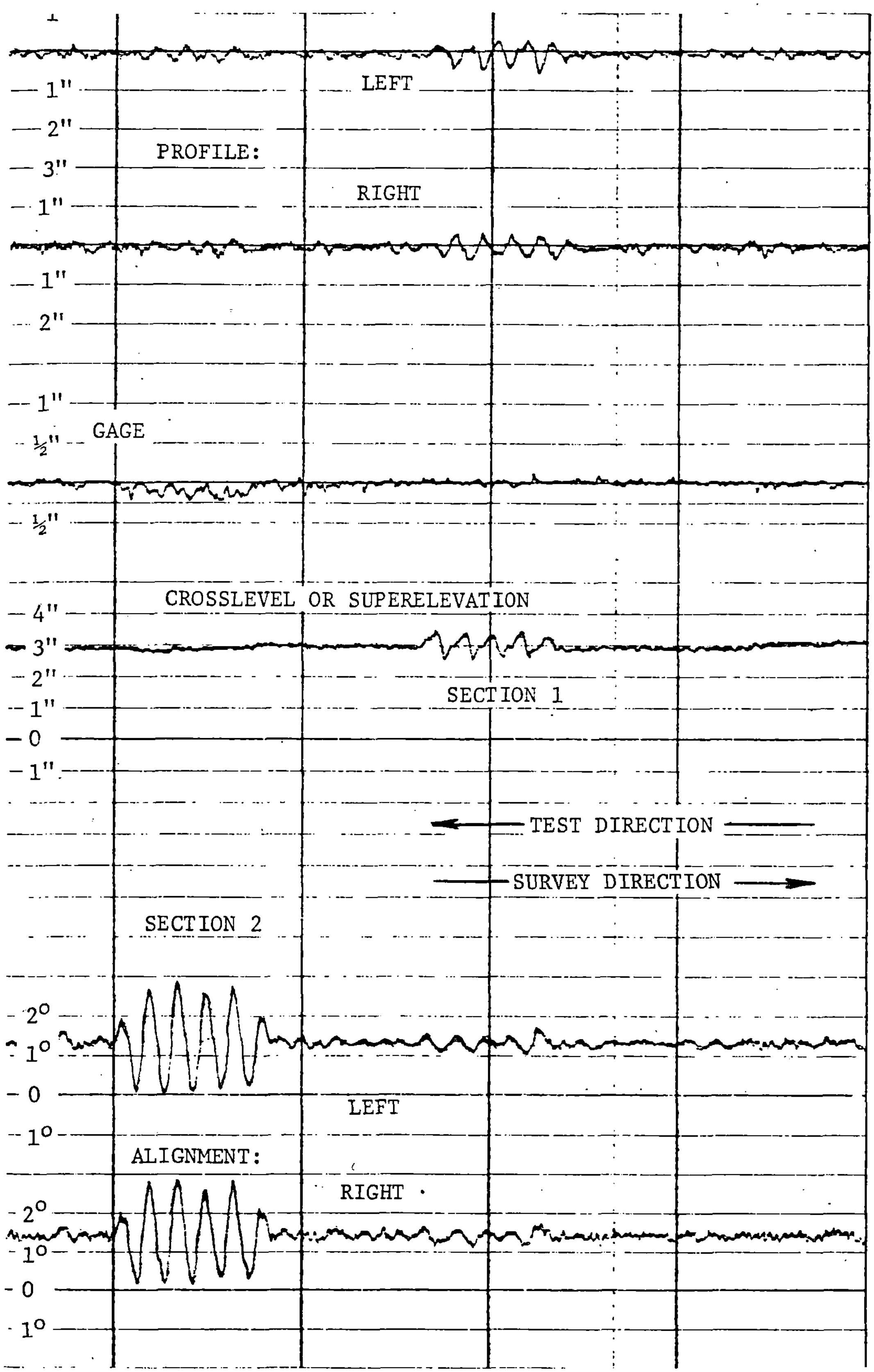


FIGURE 5-16. PLASSER CAR SURVEY CHART 12/19/78 CURVED TEST ZONE AFTER MAIN TEST COMPLETION

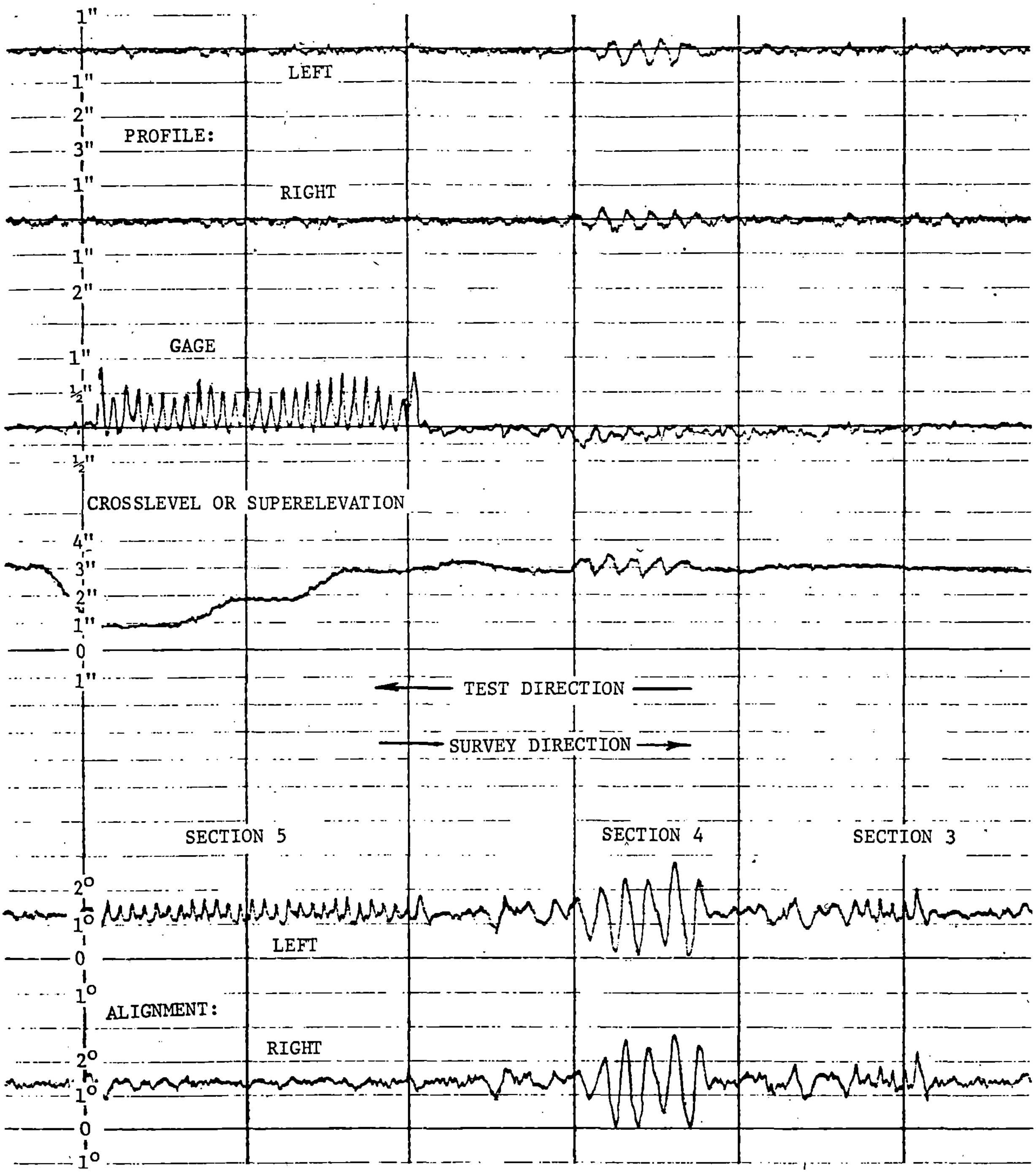


FIGURE 5-16. (Continued)

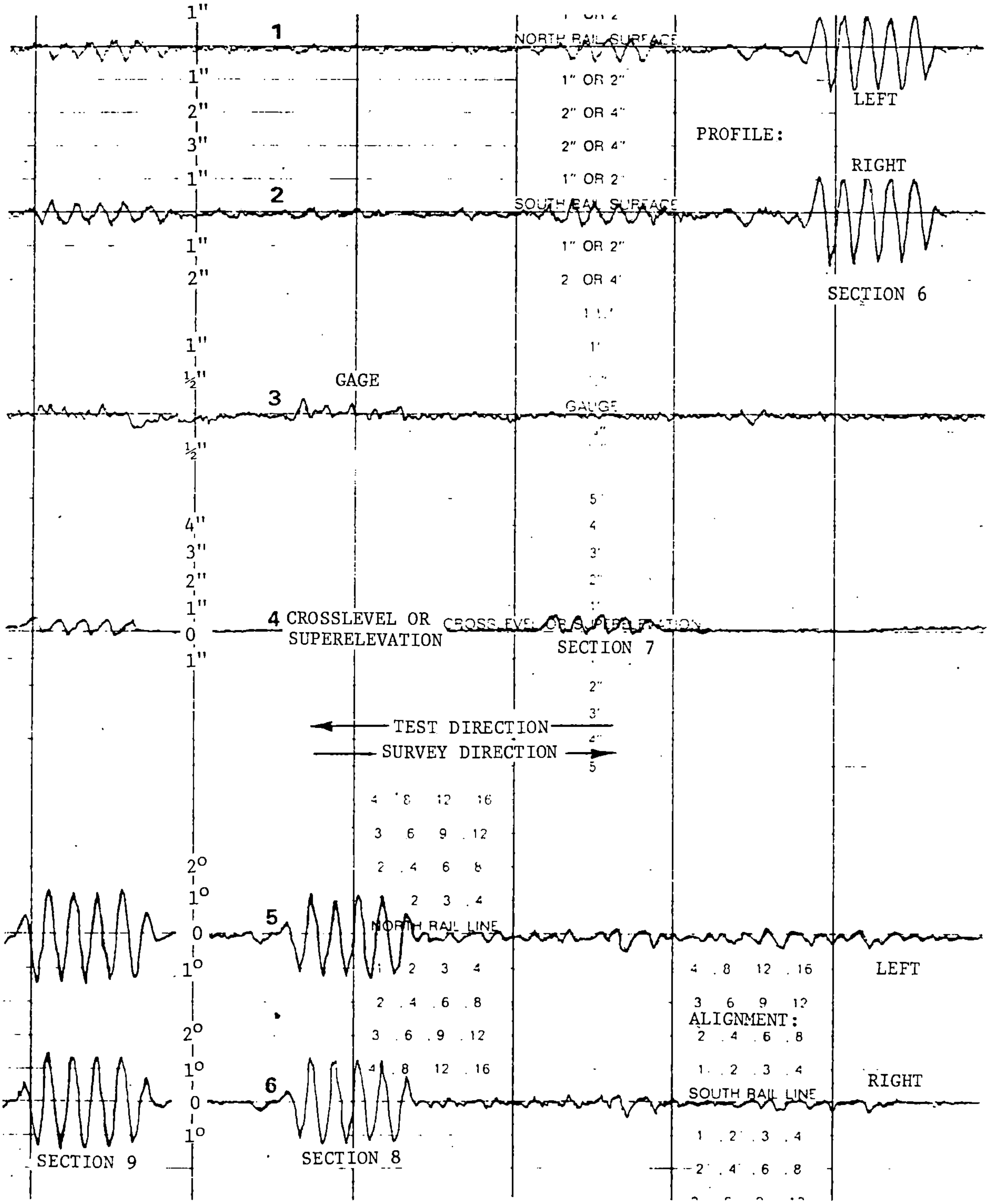


FIGURE 5-17. PLASSER CAR SURVEY CHART 12/19/78 TANGENT TEST ZONE AFTER MAIN TEST COMPLETION

located by using shaft encoder signals to reference wheel position.

Because both lateral and vertical signals are cyclical in form as they come from the wheels, they are "ac" coupled — because the signals oscillate, zero is always known — to the data acquisition system (after the signal conditioners) to eliminate quasi-static errors due to the effects of temperature variations and centrifugal force on the zero reference.

The lateral force signals are combined by taking the square root of the sum of the squares of the two instantaneous signals to produce a continous analog proportional to lateral force. The vertical force is essentially sampled four times per revolution.

SDP-40 Wheelsets

The three instrumented wheelsets for the SDP-40F were produced by the Allmanna Svenska Elektriska Aktiebolaget/ Svenskstatens Jarnvager (ASEA/SJ) consortium during 1978 for the AAR/FRA/AMTRAK. The wheels are strain-gaged to produce a continous analog of lateral force using a twelve-gage wheel plate bending bridge array.

The vertical signal is developed from the outputs of two strain gage bridges configured to produce a nearly triangular waveform, each with four peaks per revolution. These two signals are full-wave rectified and treated by an analog calculating network which includes a mean correction for lateral-to-vertical crosstalk and produces essentially a continous analog of vertical wheel force. Due to the cyclical nature of the vertical force signals, they were "ac" coupled by on-site modification of the ASEA/SJ analog calculator (Q Shaper) to eliminate zero reference errors due to the effect of temperature variations. Unfortunately, the lateral force signals could not be "ac" coupled. Because they did exhibit a nominal amount of temperature induced error, frequent manual zero adjustments of the signal conditioner outputs were required with the locomotive on tangent track.

Baggage Car Wheelset

This wheelset was produced for the Santa Fe Railroad by the AAR in 1975-1976 and was loaned for PTT use. Strain gage circuits are in fact very similar to those used on the

ASEA/SJ wheelsets, except only one vertical bridge is used with two peaks per revolution and no signal processing is provided. Because of the large errors induced in the lateral force signal by temperature variations and centrifugal forces, this wheelset has not been treated further in this chapter. In processing the data, the mean value of the lateral force signal is calculated and included in the tape header. Assuming a constant run speed and minute temperature variations, this mean value will be the steady state curving force, or zero, if on tangent track.

Wayside Rail Force Circuits

Rail forces are measured by strain gage bridges welded to the rail in each crib where a measurement is desired. Both the lateral and the vertical force circuits measure and sum those rail strain components proportional to the shear force developed during wheel passage. The vertical shear bridge is installed on the rail web, the lateral on the rail base flange. The principal difference between the two circuits is that the vertical circuit can be formed with back-to-back gages oriented to cancel the shear induced by rail torsion, while the lateral circuit cannot because in the general case gages cannot be installed and/or maintained on the underside of the rail.

Both circuits provide essentially a single point sample of the appropriate wheel force as a wheel passes the center on the instrumented crib. Hence, the sample rate is a function of crib length and train speed.

Location Correlation System

For the PTT, an extensive system of automatic location detector (ALD) targets was installed with the heaviest density in the areas containing rail instrumentation. This system used an inductive balance type metal detector mounted just ahead of the lead instrumented axle to sense the targets, 8" x 8" square metal plates. The electrical signal is similar to a half-sine pulse with an effective duration equivalent to about 14" of train travel. This signal is filtered at 85 Hz, as are wheel force signals, and digitized at a 256 Hz sample rate.

For the data comparisons in this report, playback oscillograms were used for onboard data (Brush charts). At ten chart division excursions, the Brush pen rise time will be about 2.5 milliseconds, or 2.6" at 60 mph, and 3.3" at 75 mph. This is a worst case condition because no phase lag of the wheel force data is considered; hence, in general, the error will be less, but should realistically include about ±1" target placement allowance.

5.3.2 Calibration Techniques

Figure 5-18 illustrates, in an oversimplified schematic representation, the various calibration methods employed for the PTT onboard and for wayside wheel-rail force instrumentation. The E-8 wheelset has been calibrated with the static-combined loading fixture and the portable lateral fixture, and was simultaneously calibrated with wayside lateral circuits at three instrumented cribs. The ASEA/SJ wheelsets were both statically and dynamically calibrated in Sweden, and one was also used in the joint calibration attempts with wayside (1 wheel).

There are significant, but often subtle, problems with all of the calibration methods illustrated, and these will be treated as each system is discussed in some detail below.

E-8 Wheelset

This wheelset has been calibrated several times in a static fixture wherein the wheelset sits on two rails and is loaded vertically through the journal boxes and laterally at one wheel rim with the reaction at the opposite wheel-rail interface. Difficulties arise when simultaneously loading both wheels because differences in the elastic deflections of the wheelset and the fixture result in the development of unknown lateral force components via friction coupling at the wheel-rail contacts. Also, to load one wheel laterally, the opposite wheel must be free of the rail. Hence, the exact vertical load on the measured wheel becomes the sum of the two journal box load cell signals plus the transfer of wheelset weight. In theory, this can be handled accurately; but in practice, when attemping to determine crosstalk characteristics within ±1/2 kip, such a procedure is undesirable at best. In fact, because the SJ people have developed sufficient reservations regarding results obtained in similar static fixtures, they now rely almost entirely on their dynamic calibrator for their final results.

Additionally, an independent lateral calibration for the E-8 wheelset is performed by spreading the wheels as illustrated.

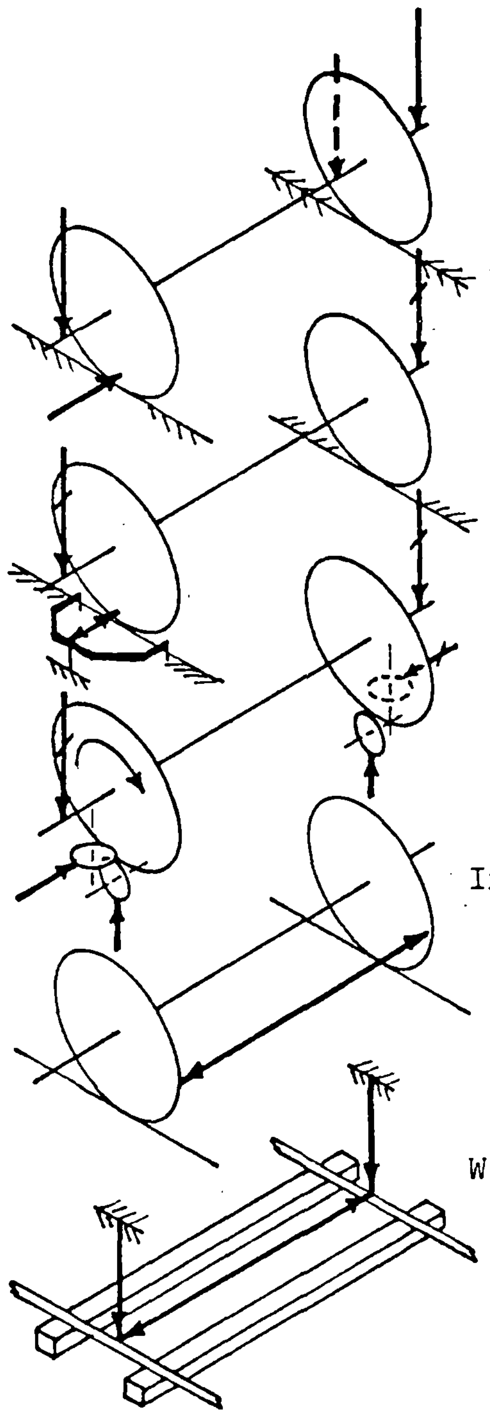


FIGURE 5-18. ONBOARD & WAYSIDE CALIBRATION METHODS

SDP-40F Wheelsets

These wheelsets were calibrated by SJ in Sweden. Some quick checks were performed here immediately prior to the PTT, but to date the Swedish results have been used for all the data analysis. SJ uses a static fixture for some of their work, but isolates one wheel at a time by dividing the vertical load as shown by the dashed line in Figure 5-18. All the final calibrations are based on the dynamic results, however.

The dynamic fixture rotates the wheelset and applies the loads at the wheel-rail interface through disc-shaped rollers. Most of the calibrations were performed at 54 rpm (6.4 mph), but centrifugal effects were investigated over a speed range to 500 rpm (59.4 mph). Parameters investigated were linearity, vertical-lateral crosstalk, lateral-vertical crosstalk, centrifugal effects, signal shape (i.e., ripple of composite signals and individual vertical bridge waveforms) and moment dependence of both lateral and vertical signals. Moment dependence was determined by observing the effect of the lateral position of the vertical load over a range of 2-1/2" (actually, 65 mm).

The dynamic calibration has the advantage over the previously described combined loading static fixture in that the applied forces are accurately known for the steady-state conditions simulated; however, the wheel force signals are recorded oscillographically, so some resolution is sacrificed in the data acquisition and analysis phase of the operation.

Wayside

Wayside circuits were calibrated for the PTT with an array of portable hardware assembled under a 100-ton hopper car. Loads are applied hydraulically and monitored with precision load cells. A rail head fixture was used which contacts the rail at the two nominal tangent points of wheel tread and wheel flange contact; the vertical load is therefore applied about 0.4" to the gage side of the rail centerline.

Vertical circuits were calibrated over a 30 kip range, lateral circuits were loaded to 30 kips vertically, and then calibrated over a range to 24-27 kips. The fixturing used for the PTT calibrations produced a relatively flexible vertical load path, but a relatively rigid lateral load path. As the rail head attempted to deflect laterally and hence rotate, a restoring moment of unknown magnitude developed as evidenced by the bending deflections imposed on the lateral load mechanism. The significance of calibrating the lateral circuits in this manner is not at all obvious. In the real rolling situation, as the rail head rotates, the point of application of the vertical load moves toward the flange corner, thus producing an increase in the rail head moment. With the calibration fixture, the vertical load application point was prevented from moving, but a rail head moment was indeed produced due to the rigidity of the lateral load path. The end result may well be similar to the real case.

The rail circuit properties measured in situ are vertical sensitivity, lateral sensitivity, and vertical-to-lateral crosstalk with 30 kips applied 0.4" to the gage side of the rail centerline. The calibration factor is based on the terminal slope, i.e., from no load to combined 30 kips vertical and approximately 25 kips lateral.

Table 5-4 presents the lateral transducer characteristics as best known at this time for both wheelsets and the rail circuit. The subsequent comparisons and error analyses presented here have been limited almost entirely to the lateral circuits.

The tabulated vertical-lateral wheelset crosstalk data at the nominal wheel-rail contact point is considered accurate. The effect of the lateral position of the vertical load, or the moment sensitivity, is not considered to be an accurate figure for either wheelset, however. Only one location on one wheel of the E-8 wheelset has been investigated, and the data for the SDP-40F wheelsets is inconsistent in that the effect does not appear to be a linear function of lateral position. The tabulated data is the most conservative interpretation of the available SJ test results. Basic linearity of all wheelset circuits is excellent.

The wayside lateral circuit characteristics presented in Table 5-4 are a mixture of published laboratory results developed by Battelle Columbus Laboratories (BCL) and some field data from the PTT calibrations. The PTT circuits are all installed in short cribs, a situation which can be expected to emphasize some of the undesirable characteristics, such as the effects of support. The linearity figure quoted is a typical average terminal linearity over a 30 kip lateral range and includes the crosstalk due to the 30 kip vertical calibration preload. It is taken from a typical X-Y calibration record.

TABLE 5-4. WHEELSET & WAYSIDE LATERAL FORCE CIRCUIT PROPERTIES

Characteristic	E-8	SDP-40	Wayside
Linearity, avg. terminal (0-30K lateral with 30K vertical)	-	-	-6.0%
Sensitivity (with 30K vertical)	-	-	-3.0%*
Vertical-Lateral Crosstalk			
@nominal contact	-5.7%	-4.0%	-6.7%
@flange corner	-	-	-5.6%*
Sensitivity to Lateral Position of Vertical (load moving to flange)	+6.0%	+1.3%	-4.0%
Sensitivity to Vertical Position of Lateral (load moving down)	+5.0%/in	+5.0%/in**	+21.6%/in*
Sensitivity to Rail Support	-	-	±10.0%*
Sensitivity to Rail Roll	-	-	+14.3%/in
Sensitivity to Angular Wheel Position	±7.0%	±2.0%	-

*BCL Laboratory Test Results

**Estimated as proportional to wheel radius (as E-8)

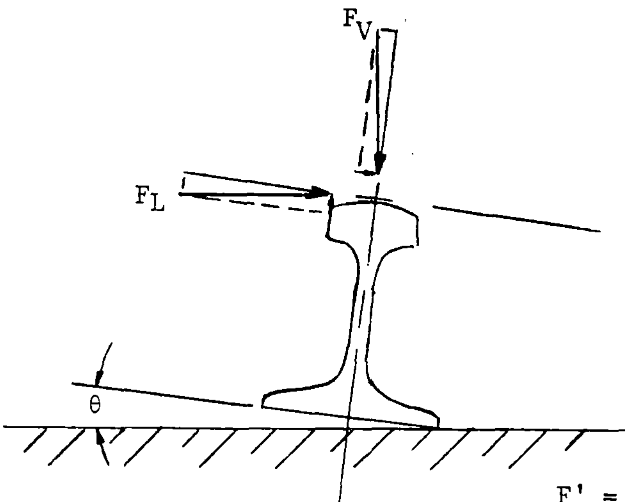
The average vertical-lateral crosstalk measured during seven calibration runs at three cribs was -2.0 kips, or 6.7%. If the zero crossing were at the rail centerline, this would project to about -7 kips, or 23.3%, at the gage corner. Most probably, the majority of the measured crosstalk results during initial rail seating under the vertical load, and the effect with additional vertical loading is a small proportion of the total. Unfortunately, the present field calibration procedures do not provide the data necessary to confirm this hypothesis. Hence, the -4.0%/inch sensitivity to the lateral position of the vertical load tabulated is computed from the laboratory results of -5.6% crosstalk with the vertical load at the flange corner and assumes a center zero crossing.

The effect of rail roll is calculated by summing force vectors based on a rigid body rotation, or tipping, of the entire rail section because the rail circuits sense force components in the two mutually perpendicular rail axes.

Unfortunately, the least understood property of all the lateral force circuits under consideration is the moment sensitivity, usually measured as the effect of the lateral position of the vertical load. Even if these characteristics were well documented, problems would still remain because the lateral position of the vertical load is seldom accurately known. This is coupled with the fact that in the general case of wheel flanging in curves, frictional forces develop at the rail head which are reacted at the flange contact point to produce an additional moment in both the rail head and the wheel rim. These considerations are illustrated in Figure 5-19.

Simultaneous Calibrations

Because of recent history regarding onboard/wayside lateral force correlations and a desire to further the understanding of the problem in general and enhance the evidence supporting the validity of the PTT data, a joint onboard/wayside calibration requirement was incorporated into the PTT test support requirements. The scheme selected was based on the use of a fixture conceived by R.A. Vanstone, designed by BCL to incorporate some of their existing hardware, and fabricated by the TTC. As illustrated in Figure 5-18, the fixture applies a lateral load to one wheel rim which is reacted by the rail immediately ahead of and behind the loaded wheel. The lateral force transmitted to the opposite wheel-rail



$$F_L' = F_L \cdot COS(\theta) + F_V \cdot SIN(\theta)$$

$$F_V' = F_V \cdot COS(\theta) - F_L \cdot SIN(\theta)$$

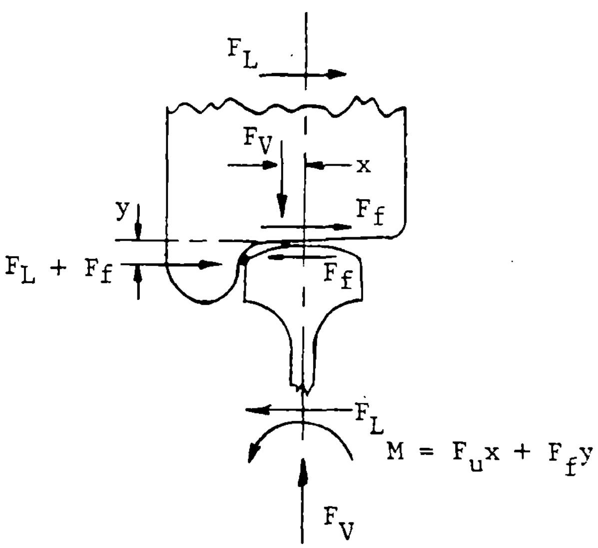


FIGURE 5-19. SKETCH OF POTENTIAL SOURCES OF CROSSTALK

interface, while unknown in absolute amplitude, has to be equal for both wheel and rail.

Joint tests were performed for one wheel of both the E-8 and the SDP-40F at three high rail crib locations in section 4.4. Loads of 20-25 kips were developed at the wheel-rail interface. The primary recorded data was an X-Y plot of wheel force signal versus rail circuit force signal. The three rail circuits used were recalibrated following the E-8 joint calibrations. Between the original and recalibrations, the rail perturbations had been rebuilt and then the panel had shifted. The SDP-40F joint calibrations were performed later, after the panel shift restoration.

Table 5-5 summarizes the results obtained. Figures 5-20 and 5-21 illustrate some typical results. In general, the joint calibration results are nonlinear and not readily reconcilable with either the static wayside calibrations or the subsequent dynamic comparisons (next section). Because wayside calibration constants are selected to compensate for vertical-lateral crosstalk at 25-30 kip lateral force levels, the joint calibration slopes would be expected to average about 1.08:1.

The most perplexing result is the E-8/wayside slope of 1.44:1 ±5 1/2% at wayside lateral Station L 4.4-7H. These data were recorded on two consecutive days at the lateral circuit which exhibited excellent static calibration repeatability. The variation of ±5-1/2% is certainly in agreement with wheelset calibrated ripple of ±7%. The amount of slope error measured is close to that required to explain the dynamic comparison results in the next section. Why, however, are the E-8 joint calibration slopes at the other two cribs tested similar to the SDP-40F results, and why doesn't the indicated variation between the three specific cribs show up in the dynamic comparison studies? Suspicion must be focused on the moment and/or point of load application sensitivities of both circuits and the differences between static and dynamic wheel flanging.

5.3.3 Dynamic Data Comparison

To evaluate the nature of the actual onboard/wayside correlation obtained during the PTT, some thirty-eight lateral force waveforms were plotted from oscillographic playbacks of onboard data and compared to simultaneously recorded wayside results as tabulated by BCL's micro-processor-based data reduction system.

TABLE 5-5. STATIC WAYSIDE AND JOINT WAYSIDE/ONBOARD CALIBRATIONS WAYSIDE STATIC CALIBRATION DATA

Station	Calibration	Calibration Constant* - Kips	
		Terminal Slope	Average Slope
L4.4-5H	Original	37.0	34.8
	1st Repeat	32.0	30.1
	2nd Repeat	31.5	29.6
L4.4-7H	Original	28.0	26.3
	Repeat	28.3	26.5
L4.4-8H	Original	26.2	23.3
	Repeat	24.5	22.2

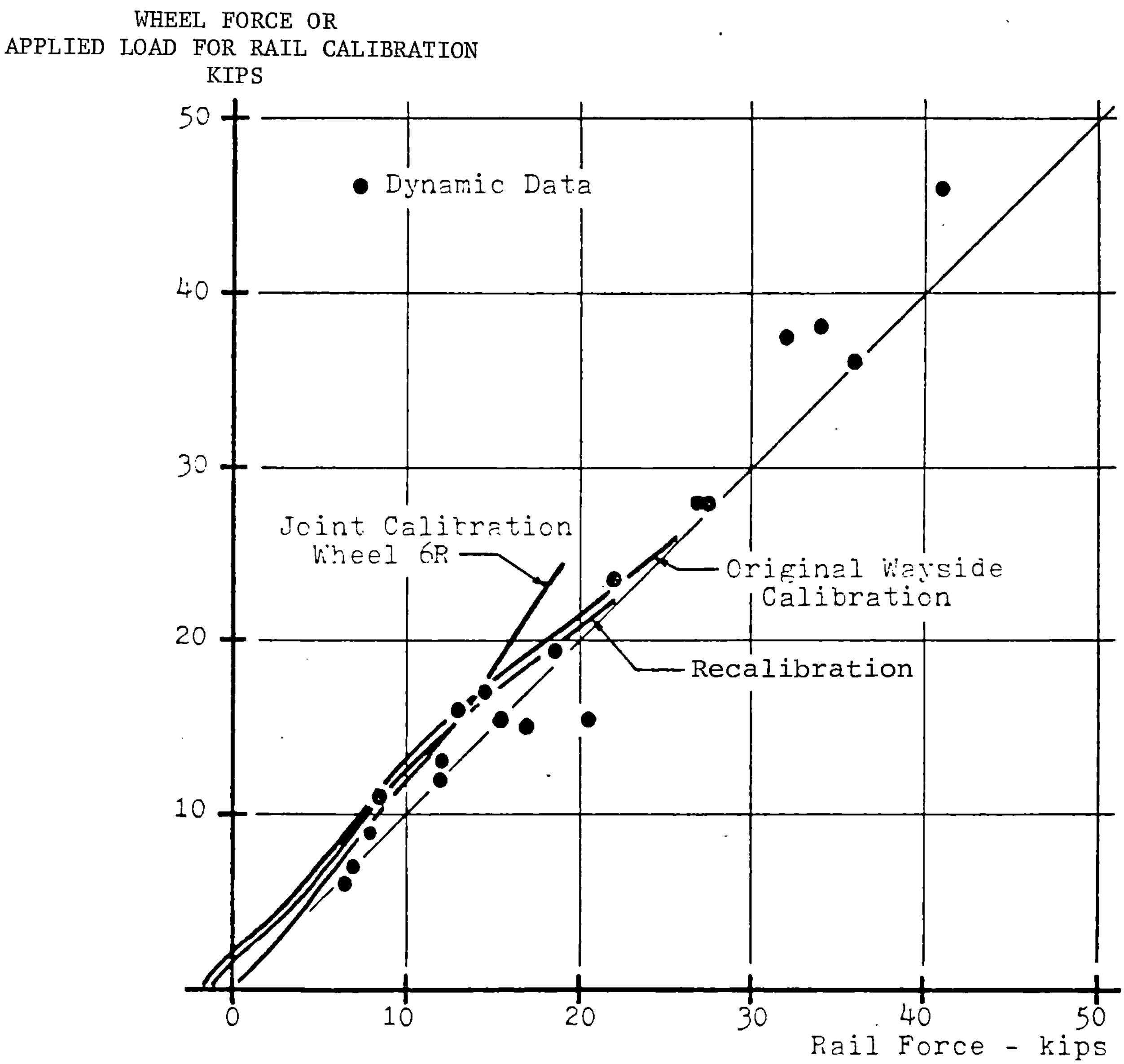
Notes: *1. Kips equivalent to 200K ohm shunt calibration
2. Repeat calibrations, 12/3/78
3. Average slope omits vertical cross-talk effect
4. Terminal slope used for recorded data

JOINT CALIBRATION DATA

Station	Wheel/Rail Slope	
	SDP-40*	E-8
L4.4-5H	1.107	1.280
	1.123	-
L4.4-7H	1.230	1.510**
	1.283	1.360
	-	1.440
	-	1.430
L4.4-8H	1.280	1.110
	1.273	-

NOTE: * SDP-40F CALIBRATIONS DONE IN "C" CONFIGURATION WITH AXLE 7 HIGH RAIL WHEEL. THIS CORRESPONDS TO THE RIGHT WHEEL OF AXLE 12 IN THE "A" CONFIGURATION

** E-8 CALIBRATIONS DONE WITH THE LEFT WHEEL OF AXLE 10, AT L4.4-7H FOUR WHEEL POSITIONS TESTED



* NOTE: TESTED IN "C" CONSIST CONFIGURATION.
WHEEL AT AXLE 7 ON HIGH RAIL.

FIGURE 5-20. WHEEL-RAIL LATERAL FORCE COMPARISONS
SDP-40F AT WAYSIDE STATION L4.4-7H

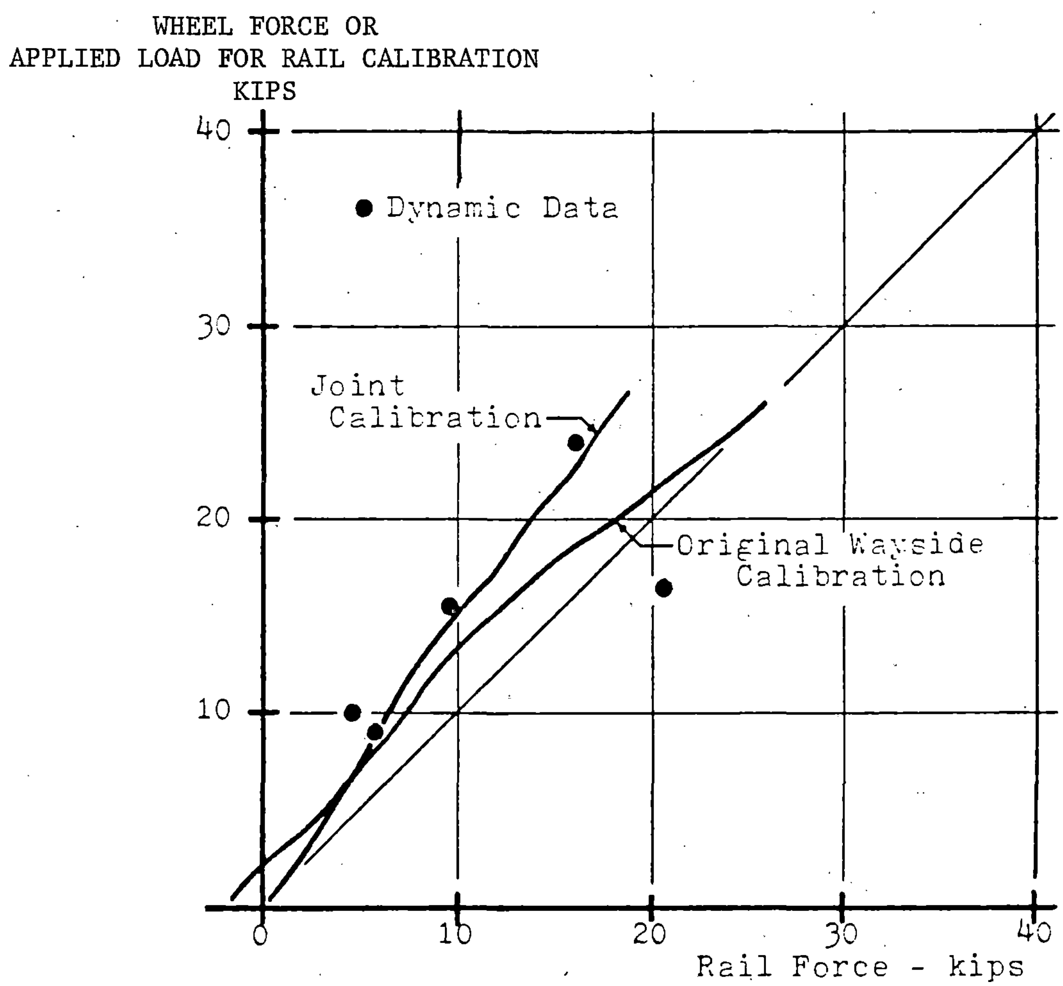


FIGURE 5-21. WHEEL-RAIL LATERAL FORCE COMPARISONS E-8 AT WAYSIDE STATION L4.4-7H

For the SDP-40F, 27 waveforms were constructed, 19 from section 4.4, and 8 from section 5.23. Some 227 data points were used in the analysis. Data was taken for all six wheels on track before, during, and after the panel shift, and after the panel shift restoration.

For the E-8, 11 waveforms were reconstructed, 5 from section 4.4, and 6 from section 5.23. Some 83 comparison data points from the left wheel were used. Data was taken on the original track geometry and after the panel shift, but prior to the restoration. Figures 5-22 and 5-23 illustrate two typical comparison waveforms.

To investigate the nature of the comparison results beyond a simple visual examination of the reconstructed time histories, some basic statistical analyses were undertaken. Table 5-6 summarizes the initial results. The data were treated in three groups; section 4.4 alone, section 5.23 alone, and the two sections taken together. The mean difference and the standard deviation of this mean were computed for both the absolute and the algebraic differences between the onboard and the wayside data. The tabulated results clearly indicate a mean, or bias, difference between E-8 and wayside results with a greater magnitude in section 4.4 than section 5.23.

The variance in the data as represented by the standard deviation is similar for both wheelsets, indicating that the spread of the computed mean differences is similar for both wheelsets. However, while the spreads are similar, the mean force amplitudes are not. A statistical analysis of wayside lateral force amplitude produced the following:

Locomotive	Section	Lateral Force - kips Mean	Std. Dev.
E-8	4.4	7.6	4.0
SDP-40F	4.4	18.6	10.9
E-8	5.23	8.3	5.7
SDP-40F	5.23	11.7	7.9

This analysis indicates that when compared to the mean force amplitudes, the proportionate data spread resulting from the SDP-40F wheelset would be less than that of the E-8. In addition, to investigate the possibility that vertical-lateral crosstalk was responsible for the difference in the E-8 lateral force correlation between sections 4.4 and 5.23,

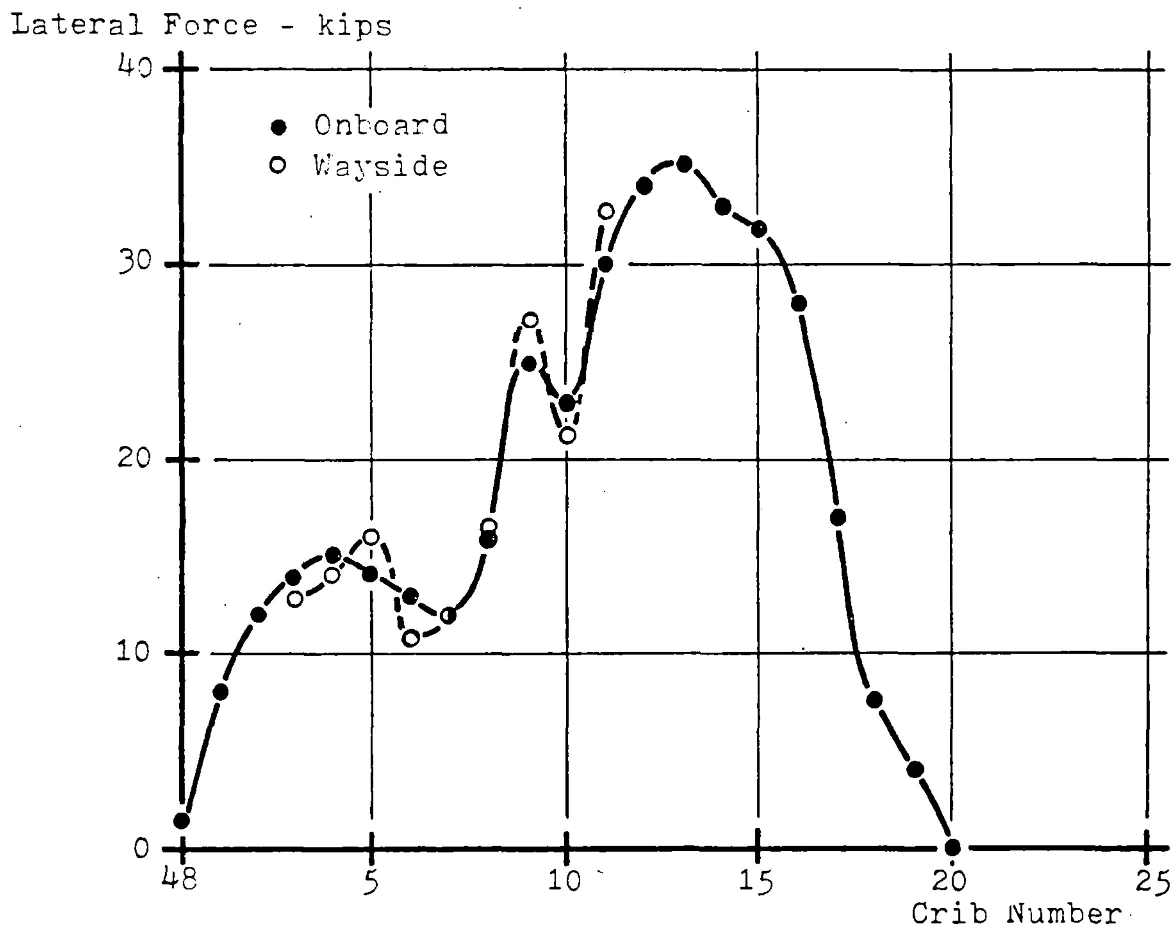


FIGURE 5-22. SDP-40F LEFT LATERAL WHEEL FORCE COMPARISON, SECTION 4.4, CONSIST C, AXLE 8, RUN 121311, 75 MPH

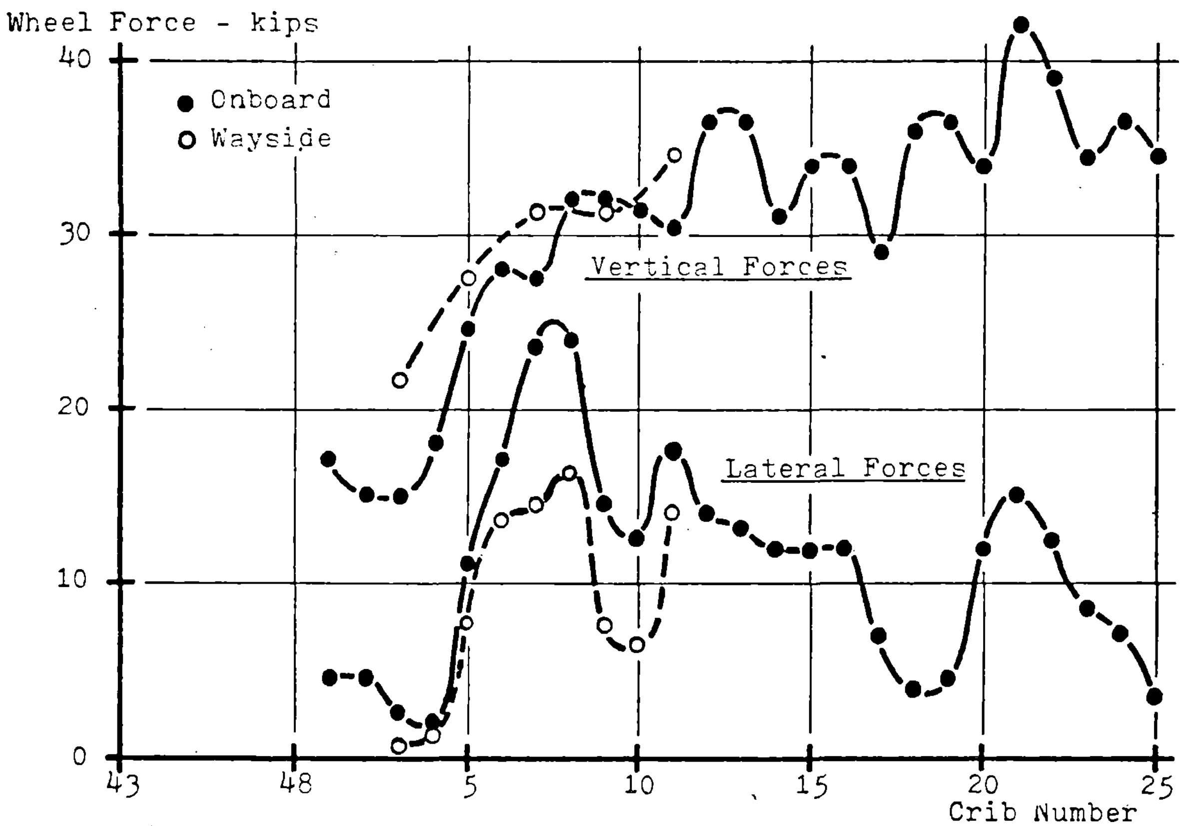


FIGURE 5-23. E-8 LEFT WHEEL FORCE COMPARISON, SECTION 4.4, LOCOMOTIVE & T-5 ONLY, AXLE 10, RUN 120407, 65 MPH

TABLE 5-6. SUMMARY OF RESULTS - STATISTICAL ANALYSIS

ABSOLUTE ANALYSIS

Data	E-8			SDP-40		
	N	$\bar{x}$	σ_{n-1}	N	$\bar{x}$	σ_{n-1}
Sec. 5.23	41	2.16	1.45	56	1.97	1.10
Sec. 4.4	42	4.49	2.31	171	2.35	2.09
All	83	3.34	2.25	227	2.25	1.90

ALGEBRAIC ANALYSIS

Data	N	$\bar{x}$	σ_{n-1}	N	$\bar{x}$	σ_{n-1}
Sec. 5.23	41	-1.72	1.96	56	-0.60	2.19
Sec. 4.4	42	-4.27	2.69	171	0.75	3.02
All	83	-3.01	2.67	227	0.42	2.90

Note: For Algebraic Analysis, positive data indicates wayside reading greater than onboard.

the measured high rail E-8 vertical forces were statistically treated with the following result:

Section	E-8 Vertical Force - kips Mean	Std. Dev.
4.4	32.6	3.9
5.23	36.7	4.8

While the maximum vertical force in the section 4.4 perturbations did, in fact, exceed the levels experienced in section 5.23, those higher levels occurred downstream from the area of the concentrated rail force instrumentation.

Accordingly, it appears that the most significant factor in the analysis, and the reason why Table 5-6 must be used very cautiously for wheelset performance comparisons, is that all E-8 lateral force data was centered around 8 kips with peaks rarely exceeding 20 kips while the mean lateral force experienced with the SDP-40F, in the instrumented zone, was nearly 19 kips with peaks to almost 50 kips.

To graphically illustrate the above, Figure 5-24 was prepared. Here the mean difference and standard deviation are plotted versus the mean lateral force. Also shown is a similar plot from an error analysis of the transducers properties discussed below. To supplement the Table 5-6 results, three additional points were computed from the SDP-40F data in section 4.4 and plotted. These three calculations treated data between 10 and 30 kips, 20 and 30 kips, and 30 and 50 kips. The trend illustrated is logical in that the mean difference is minimal in the 25-30 kip range as dictated by selection of the wayside calibration factors, and starts to go negative as the mean lateral falls below about 14 kips.

More important is the graphic illustration of the narrow-amplitude bandwidth of the E-8 data when compared to the SDP-40F and, hence, the danger inherent in reading too much into the significance of the statistical comparisons. In fact, were one to omit all E-8 data below 10 kips mean lateral, not an unreasonable approach in the real world, much of the E-8 data would be eliminated from consideration.

The statistical results could be used to improve the accuracy of the PTT data if one could determine which circuits to correct and by how much. As an arbitrary

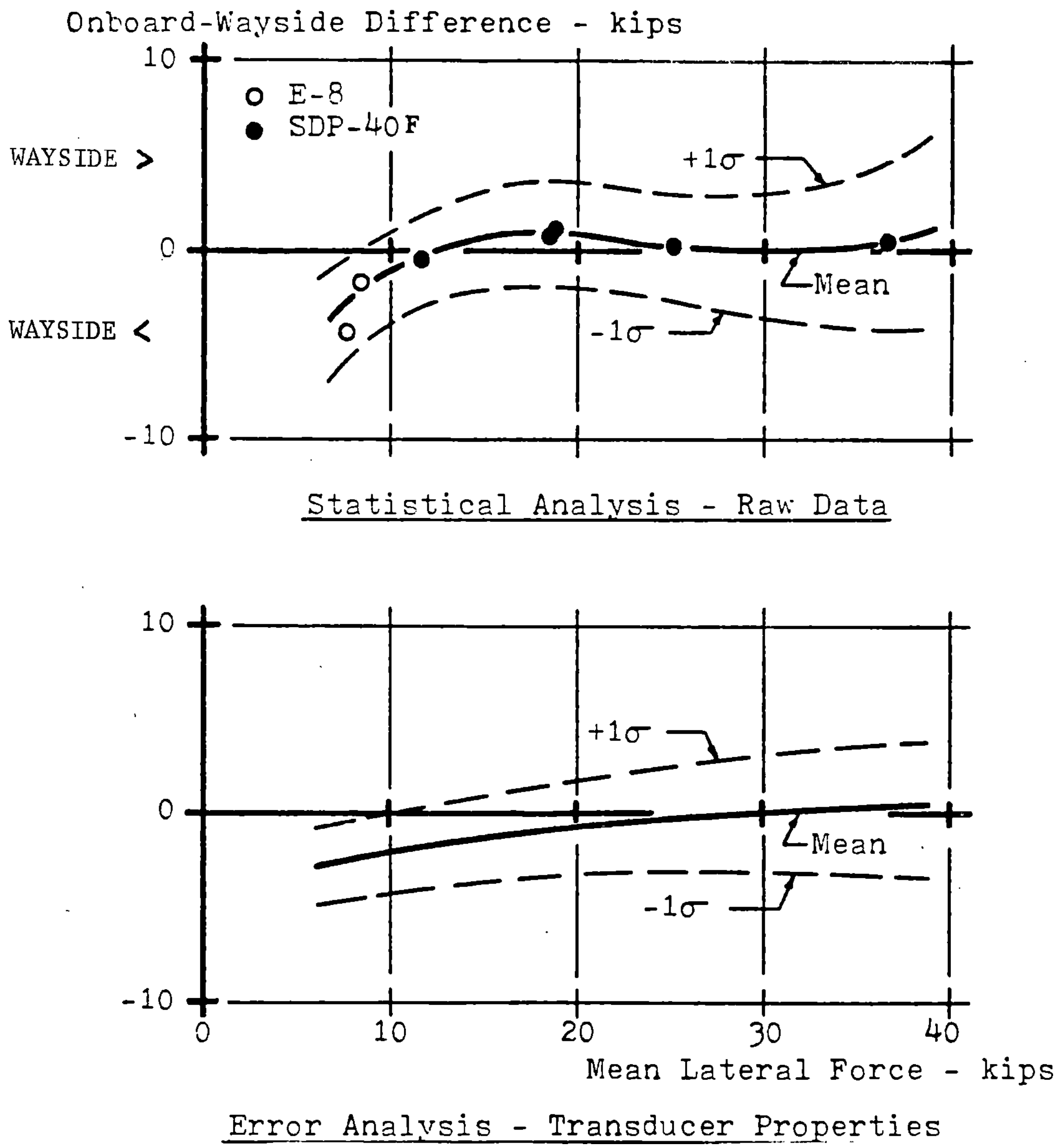


FIGURE 5-24. ONBOARD/WAYSIDE LATERAL FORCE COMPARISON, MEAN DIFFERENCE & STANDARD DEVIATION VERSUS MEAN LATERAL FORCE

example, Figure 5-25 illustrates three E-8 time histories adjusted by reducing the amplitude of the onboard data by the mean statistical difference.

Run 112113 is of particular significance because this record was used in some early attempts at comparisons analyses. As so often happens, it produced the worst of all the E-8 comparisons subsequently studied. The wayside data is shown to indicate a transient oscillation at about 23 Hz with an 8 kip amplitude. No indication of this apparent oscillation is observed in the onboard signal, although a similar oscillation of lower amplitude was observed on the low rail wheel. Because statistical analysis of the E-8 lateral forces in section 4.4 produced a standard deviation of 4.0 kips, the 8 kip amplitude is a two-sigma event and should not occur in greater than 5% of all data. This, therefore, is not a particularly common phenomenon, and Run 112113 is proven to have been an unfortunate choice for the initial comparisons.

The problem that still remains, however, is to resolve why the E-8 wheelset had such a better correlation in section 5. This problem is currently being investigated.

5.3.4 Error Analysis of Transducer Properties

In an attempt to isolate potential contributions to the onboard/wayside comparison discrepancies observed, the transducer characteristics previously presented in Table 5-4 have been used to predict anticipated errors. Three such analyses were attempted; the E-8 with a 30 kip vertical and an 8 kip lateral, the SDP-40 with a 30 kip vertical and a 20 kip lateral, and the SDP-40 with a 40 kip vertical and a 36 kip lateral. The results are shown in Tables 5-7, 5-8 and 5-9, and compared to the raw data statistics in Figure 5-24.

These error analyses consider the wheels hard-flanged in each case so that the vertical load is transferred to the flange corner. The variance is computed by taking the square root of the sum of the squares of the individual error sources.

Much of such an error analysis must be arbitrary in nature. This presentation is made to provide some insight into the problems associated with wheel-rail force measurement and is not intended to produce highly quantitative results. Taken in that spirit, the tables can be surveyed to indicate the source(s) of the errors indicated in the E-8 comparisons. It is obvious that the

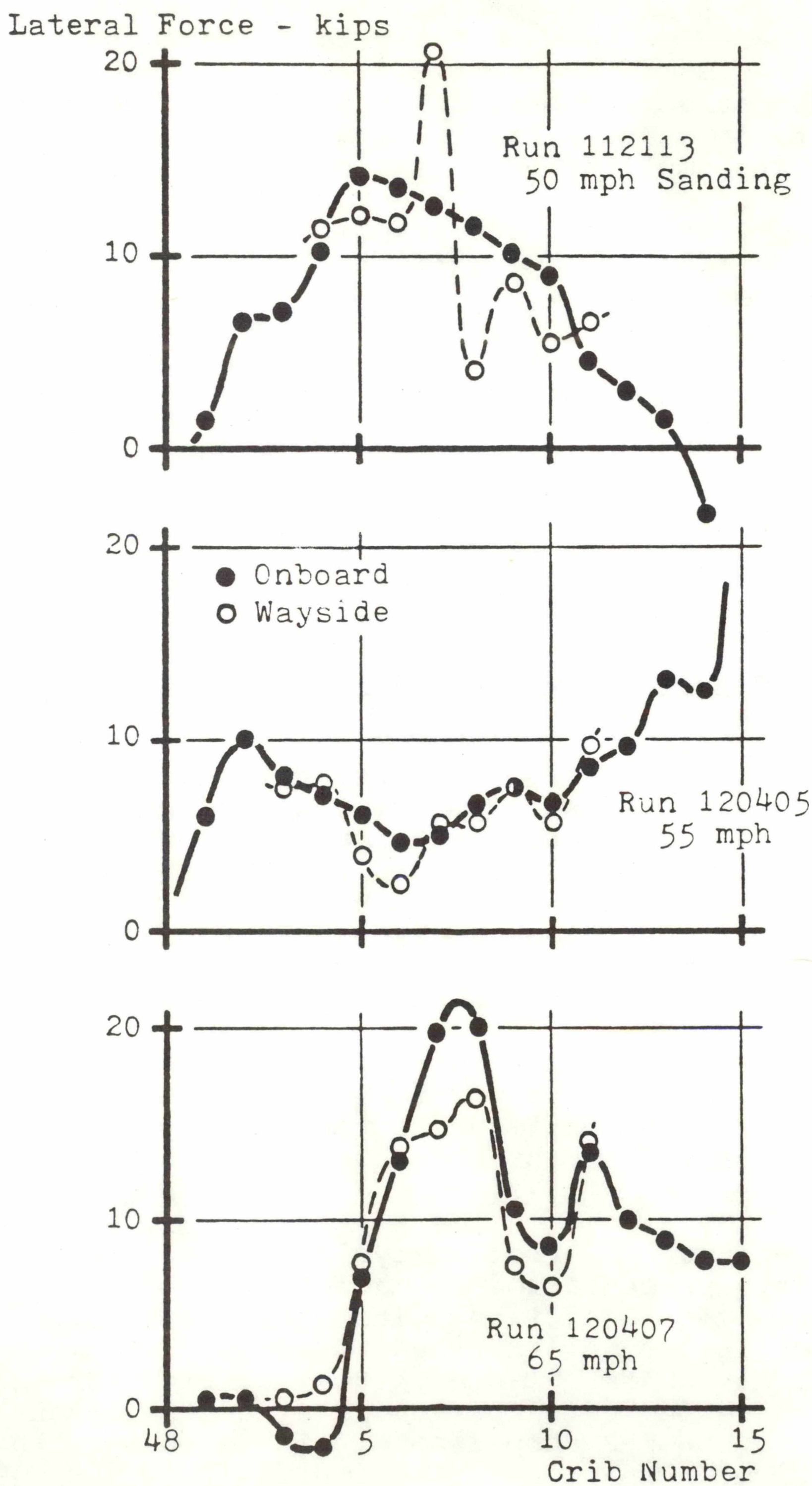


FIGURE 5-25. E-8 LEFT LATERAL WHEEL FORCE COMPARISONS, SECTION 4.4
ONBOARD DATA REDUCED 4 KIPS PER STATISTICAL ANALYSIS

TABLE 5-7. ERROR ANALYSIS: E-8 LATERAL VERSUS WAYSIDE LATERAL 30 ±10 KIPS VERTICAL, 8 KIPS LATERAL

Transducer	E-8	Wayside
Characteristic	Error - Kips	
Vertical-Lateral Crosstalk		
Nominal	-1.7	-1.5
±10 Kips	±0.6	±0.7
±1/2"	±0.9	±0.6
@ Flange Corner	+1.8	-1.2
Vertical Position of Lateral		
+1/4"	±0.1	±0.4
-1/4"	+0.1	+0.4
Wheel Ripple	±0.6	-
Rail Support (±5%)	-	±0.4
Instrumentation/Reading	±1.0	±1.0
Summation*	+0.2±1.6	-2.3±1.5
Wayside - E-8	-2.5±2.2	
Raw Data Statistics**	-3.0±2.7	

*Variance calculated by square root of sum of squares

**Table 5-6

TABLE 5-8. ERROR ANALYSIS: SDP-40 LATERAL VERSUS WAYSIDE LATERAL 30 ± 10 KIPS VERTICAL, 20 KIPS LATERAL

Transducer	SDP-40	Wayside
Characteristic	Error - Kips	
Vertical-Lateral Crosstalk		
Nominal	0**	0
±10 Kips	±0.4	±0.7
±1/2"	±0.2	±0.6
@ Flange Corner	+0.4	-1.2
Vertical Position of Lateral		
+1/4"	±0.3	±1.1
-1/4"	+0.3	+1.1
Wheel Ripple	±0.4	-
Rail Support (±5%)	-	±1.0
Instrumentation/Reading	±1.0	±1.0
Summation*	+0.7±1.2	-0.1±2.0
Wayside - SDP-40	-0.8±2.3	
Raw Data Statistics***	+0.4±2.9	

*Variance calculated by square root of sum of squares
**Zeroed electrically with instrumentation
***Table 5-6

TABLE 5-9. ERROR ANALYSIS: SDP-40 LATERAL VERSUS WAYSIDE LATERAL 40 ±10 KIPS VERTICAL, 36 KIPS LATERAL

Transducer	SDP-40	Wayside
Characteristic	Error - Kips	
Vertical-Lateral Crosstalk		
Nominal	+0.4**	+0.7
±10 Kips	±0.4	±0.7
±1/2"	±0.3	±0.8
@ Flange Corner	+0.5	-1.6
Vertical Position of Lateral		
±1/4"	±0.5	±1.9
-1/4"	+0.5	+1.9
Wheel Ripple	±0.7	-
Rail Support (±5%)	-	±1.8
Instrumentation/Reading	±1.0	±1.0
Summation*	+1.4±1.4	+1.0±3.0
Wayside - SDP-40	-0.4±3.3	
Raw Data Statistics***	+0.3±4.5	

*Variance calculated by square root of sum of squares

**Assumes instrument zero reference set at 30 Kips

***30 - 50 Kip mean lateral population only vertical position of the lateral load and the lateral position of the vertical load are the principal contributors. Moment sensitivity of both wheelset and rail circuits appears as a potential problem area.

Before any data corrections can be applied, the locations of the load points must be determined. Since this information is unknown in the general case, accurate results can only be assured by the use of transducers with negligible moment sensitivity, and the most accurate wheelsets and rail circuits will be those which best minimize that characteristic.

6. SAMPLE TEST DATA

The intent of this chapter is to provide a sample of the data collected during the PTT so as to illustrate the types of data that are available. Selected onboard instrumentation time histories of the dynamic responses of the E-8 and SDP-40F locomotives are presented in the form of Brush charts. These are shown to provide a feel for the form of this type of data, as well as its variability and magnitude. Also presented are selected wayside instrumentation spatial force histories to show the type of data available for noninstrumented axles. Finally, some typical curves such as lateral force versus speed and axle lateral force versus truck lateral force are shown. No conclusions are drawn from the graphs since the intent is to demonstrate the type of data collected rather than attempt a detailed analysis. Further, caution must be used when comparing any of the results presented here, since the changes in track geometry discussed in Chapter 5 of this report and the variations in perturbation shapes as constructed complicate the evaluation of the differences in the dynamic response of the two locomotives.

Throughout this chapter, a consistent axle numbering system has been used (described in Chapter 3.1). Briefly, the locomotive axles are always numbered sequentially from 1 to 12 for the Main Test, as if there were always a two-locomotive consist, and from 1 to 16 for the Freight Test. For the remaining vehicles, the axles of each car are numbered from 1 to 4 from the leading end and are referenced to the car number for the freight vehicles, or to the car type for the baggage and instrumentation cars.

Much of the data presented here is shown relative to the Automatic Location Detector (ALD) trace. A complete description of these traces is presented in Chapter 3.5. Finally, for a complete description of the track geometry, refer to Chapter 3.2.

6.1 DYNAMIC RESPONSE OF THE E-8 LOCOMOTIVE

Figures 6-1 through 6-4 show examples of the dynamic response of the E-8 locomotive, as recorded, with onboard instrumentation.

Figure 6-1 shows data for section 5, where the superelevation changes from one subsection to another. The specific test run shown had the following test conditions:

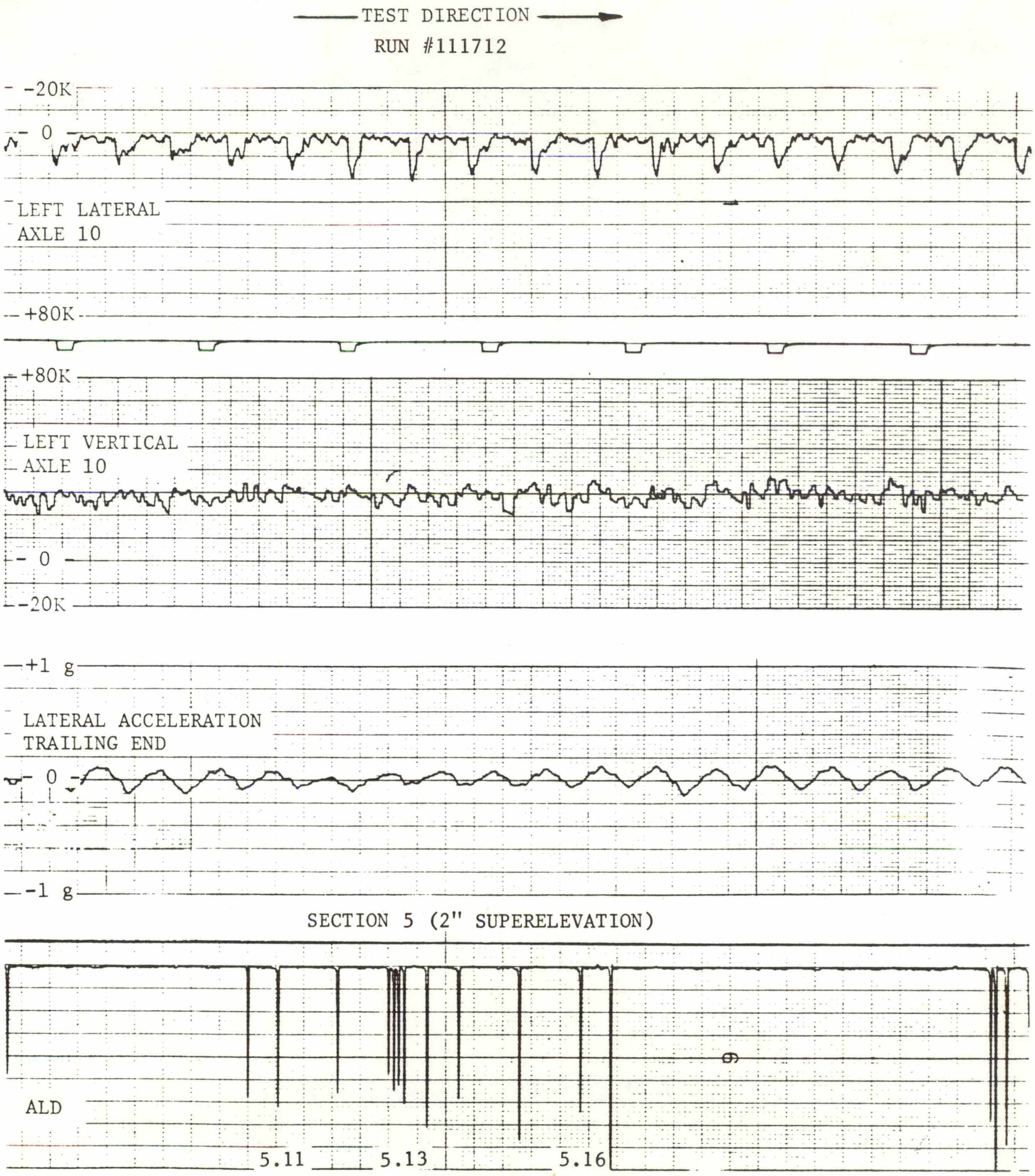


FIGURE 6-1. E-8 RESPONSE IN SECTION 5 AT 65 MPH - "A" CONSIST LEFT LATERAL, LEFT VERTICAL - AXLE 10, LATERAL CARBODY ACCELERATION - TRAILING END

Speed	:	65 mph
Configuration	:	A (Nominal)
Rail Condition	:	Dry

The four data channels shown are: top - the high rail lateral wheel force for the instrumented axle; second - the vertical wheel force for the same wheel; third - the lateral acceleration level of the trailing end of the trailing locomotive. The last channel trace is of the ALD. The total length of track for which data is shown in Figure 6-1 is approximately 500 feet and encompasses the second subsection of superelevation (2") in section 5, sections 5.11 to 5.16.

Figure 6-2 compares the high rail lateral wheel forces for the lead instrumented axle in sections 3 and 4. The speed in both instances is 65 mph. It may be recalled that section 3 has a rectified sine alignment perturbation with a wavelength of 39 feet, while section 4 has piecewise linear crosslevel and alignment perturbations with a wavelength of 78 feet. Of interest in this figure is the fourth peak in lateral wheel force in section 4, which is smaller than either the third or the fifth peak. This difference is even worse than shown in that the peak forces fall outside the region of the extensive rail instrumentation. This is the result of inherent construction errors using the techniques discussed in Chapter 4, which generated an unfortunately small perturbation amplitude. As this was the site of the most extensive deployment of wayside instrumentation, this perturbation cycle was rebuilt after the E-8 test series.

Figure 6-3 provides a more detailed picture of the dynamic response of the E-8 in section 4 while traveling at 65 mph. Shown are the lateral and vertical high rail wheel forces, as well as the L/V ratio for the lead instrumented axle.

Figure 6-4 is identical to Figure 6-3 except that the speed in Figure 6-4 is 40 mph. Thus, a comparison of Figures 6-3 and 6-4 provides a feeling for the effects of speed.

Figures 6-5 and 6-6 show examples of the lateral force data processed from the wayside instrumentation. These plots are spatial histories in that the lateral force is plotted as a function of location and crib number of the perturbed section. This is because the wayside instrumentation records data as the wheels pass over a specific gage; no data is inferred by the lines connecting the data points.

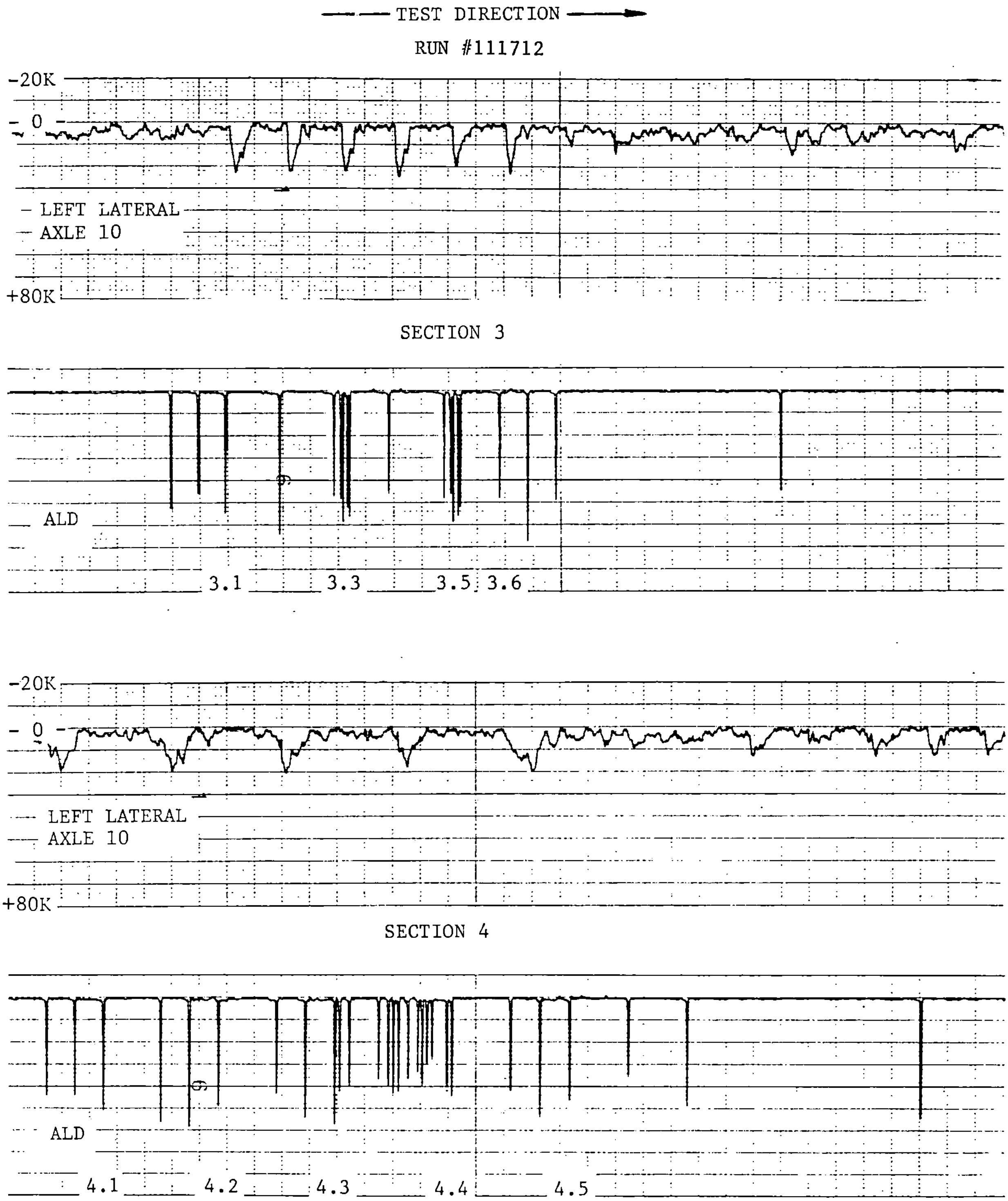


FIGURE 6-2. E-8 RESPONSE IN SECTIONS 3 AND 4 AT 65 MPH - "A" CONSIST - LEFT LATERAL AXLE 10

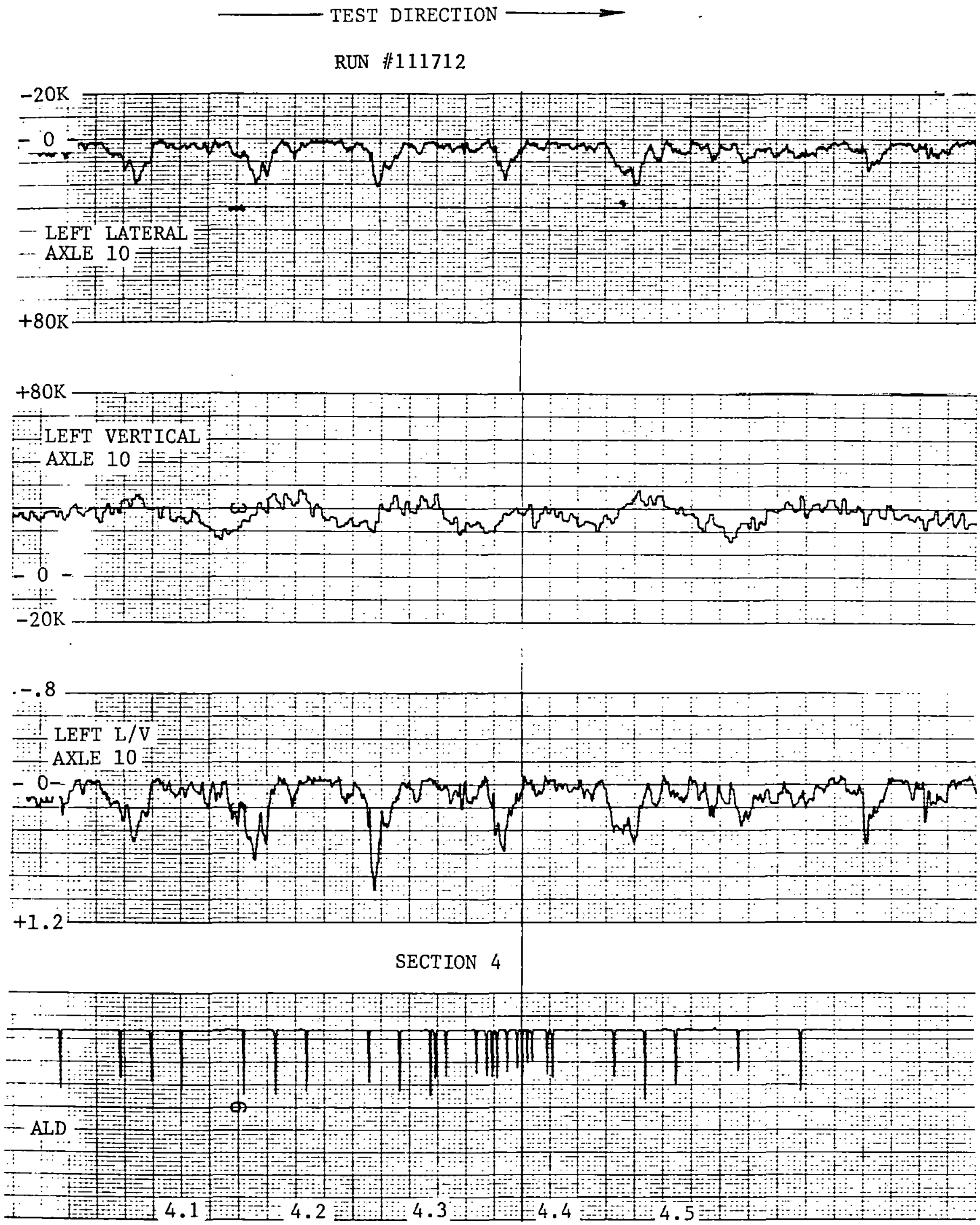


FIGURE 6-3. E-8 RESPONSE IN SECTION 4 AT 65 MPH - "A" CONSIST LEFT LATERAL, LEFT VERTICAL, LEFT L/V - AXLE 10

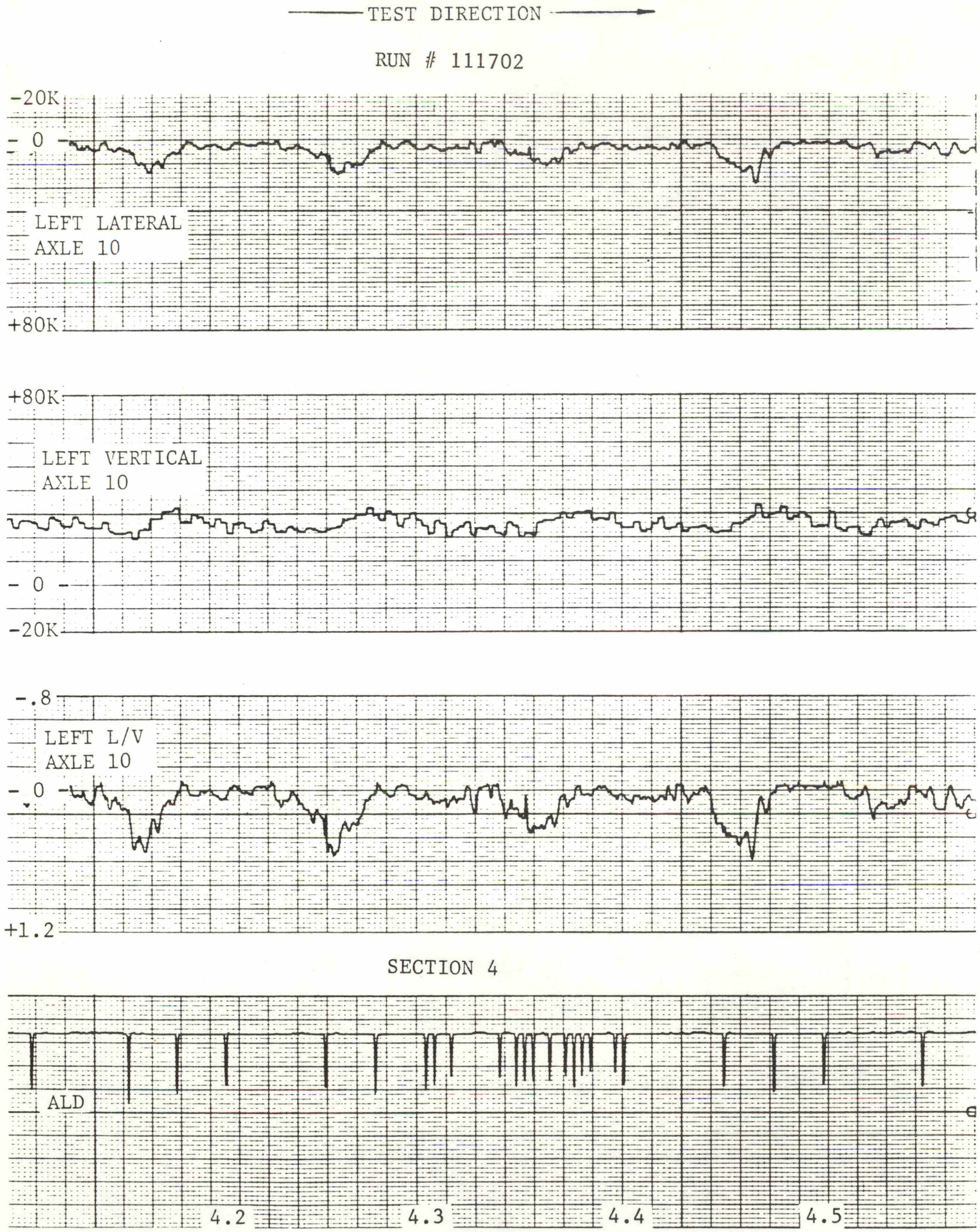


FIGURE 6-4. DYNAMIC RESPONSE OF E-8 IN SECTION 4 AT 40 MPH

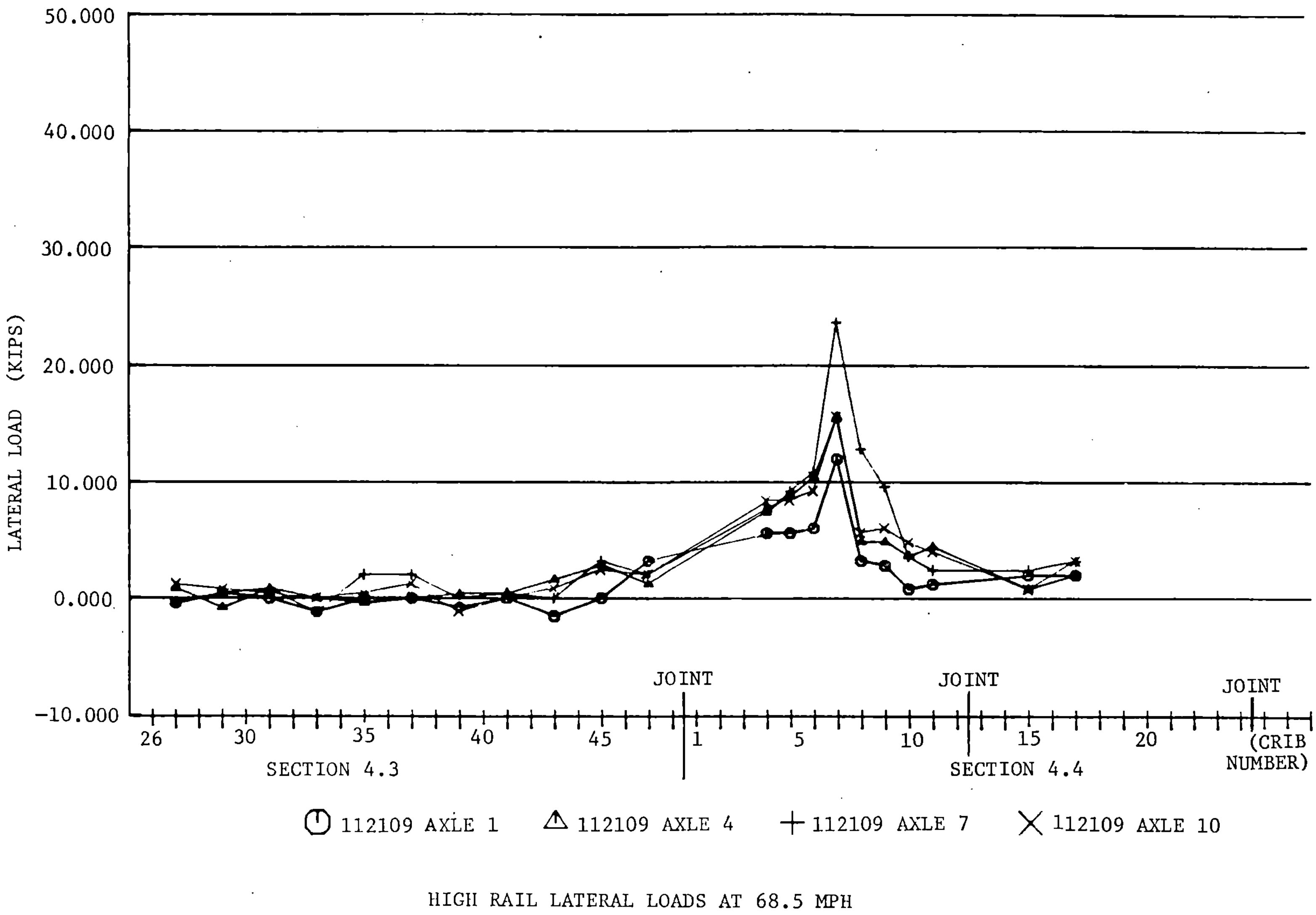
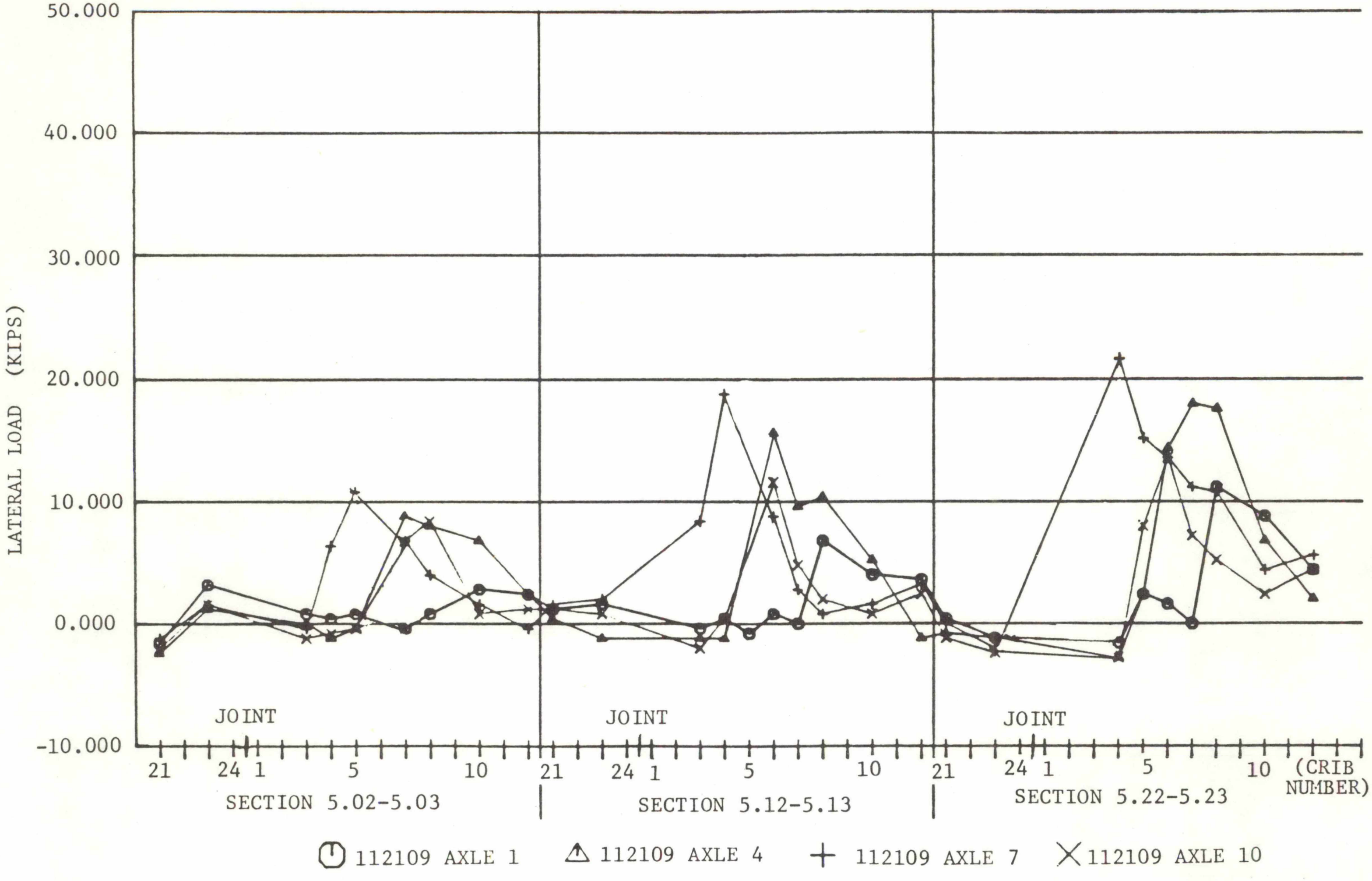


FIGURE 6-5. E-8 "D" CONSIST FROM BCL WAYSIDE INSTRUMENTATION SECTION 4 - ALL LEAD AXLES



HIGH RAIL LATERAL LOADS AT 68.5 MPH

FIGURE 6-6. E-8 "D" CONSIST FROM BCL WAYSIDE INSTRUMENTATION SECTION 5 - ALL LEAD AXLES

Figure 6-5 shows the high rail lateral loads of the leading axles of each truck of the two E-8 locomotives in sections 4.3 and 4.4. The data is from a 68 mph run with the "D" consist on dry rail.

Figure 6-6 shows the high rail lateral loads for the same axles and run in the three subsections of section 5.

Finally, Figures 6-7 and 6-8 show typical response trends for the E-8 locomotive from onboard data.

Figure 6-7 shows the high rail lateral force in section 4 of the E-8's instrumented axle as a function of speed for the three two-locomotive consists. In the "A" consist, the axle is the leading axle of the trailing truck of the trailing locomotive, axle 10. In the "C" consist, it is the trailing axle of the leading truck of the trailing locomotive, axle 9. For the "D" consist, it is the leading axle of the trailing truck of the leading locomotive, axle 4.

Figure 6-8 shows the high rail lateral force in section 4 of the E-8's instrumented axle as a function of the lateral carbody acceleration measured over this axle.

6.2 DYNAMIC RESPONSE OF THE SDP-40F

Figures 6-9 through 6-12 show examples of typical Brush chart data for the SDP-40F locomotive.

Figure 6-9 shows the lateral and vertical high rail forces and the L/V ratio for the lead axle of the instrumented truck of the SDP-40F in its nominal 'A' configuration while traveling at 65 mph through section 4.

Figure 6-10 shows the same variables as Figure 6-9, except that the data is now from section 9, which has perturbations similar to those of section 4. Section 9 is located on tangent track, however, while section 4 is on the curve. Thus, a comparison of Figures 6-9 and 6-10 provides an indication of the effects of curvature and superelevation. Caution must be used when comparing these figures, however, as the scales for all traces in Figure 6-9 are twice those of Figure 6-10. Of interest is a comparison in magnitude of the peak forces. The maximum lateral force is larger with each successive perturbation cycle in section 9 of the tangent zone, while no buildup is seen in section 4 of the curved zone.

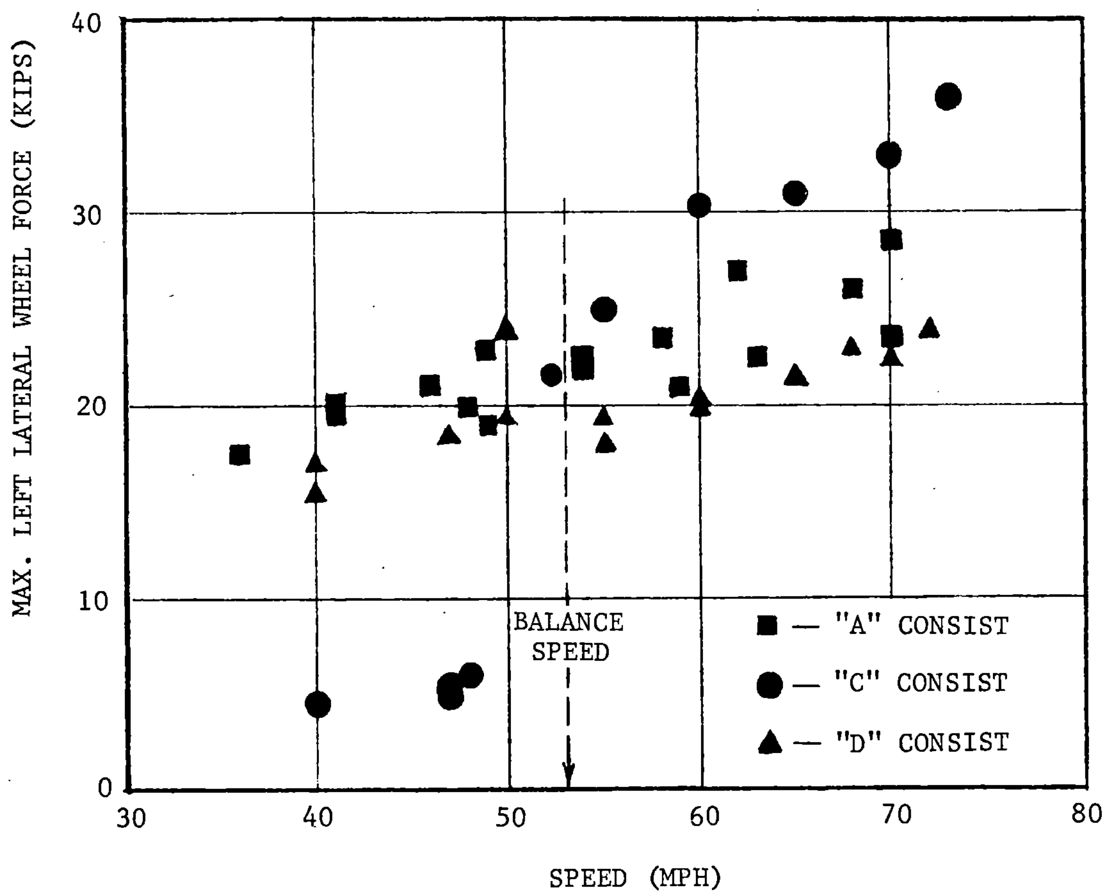


FIGURE 6-7. E-8 HIGH RAIL LATERAL RESPONSE OF INSTRUMENTED AXLE FOR CONSISTS A, C, AND D IN SECTION 4, ONBOARD DATA. NOTE THAT FOR "C" CONSIST INSTRUMENTED AXLE IS TRAILING AXLE IN LEAD TRUCK OF TRAILING LOCOMOTIVE

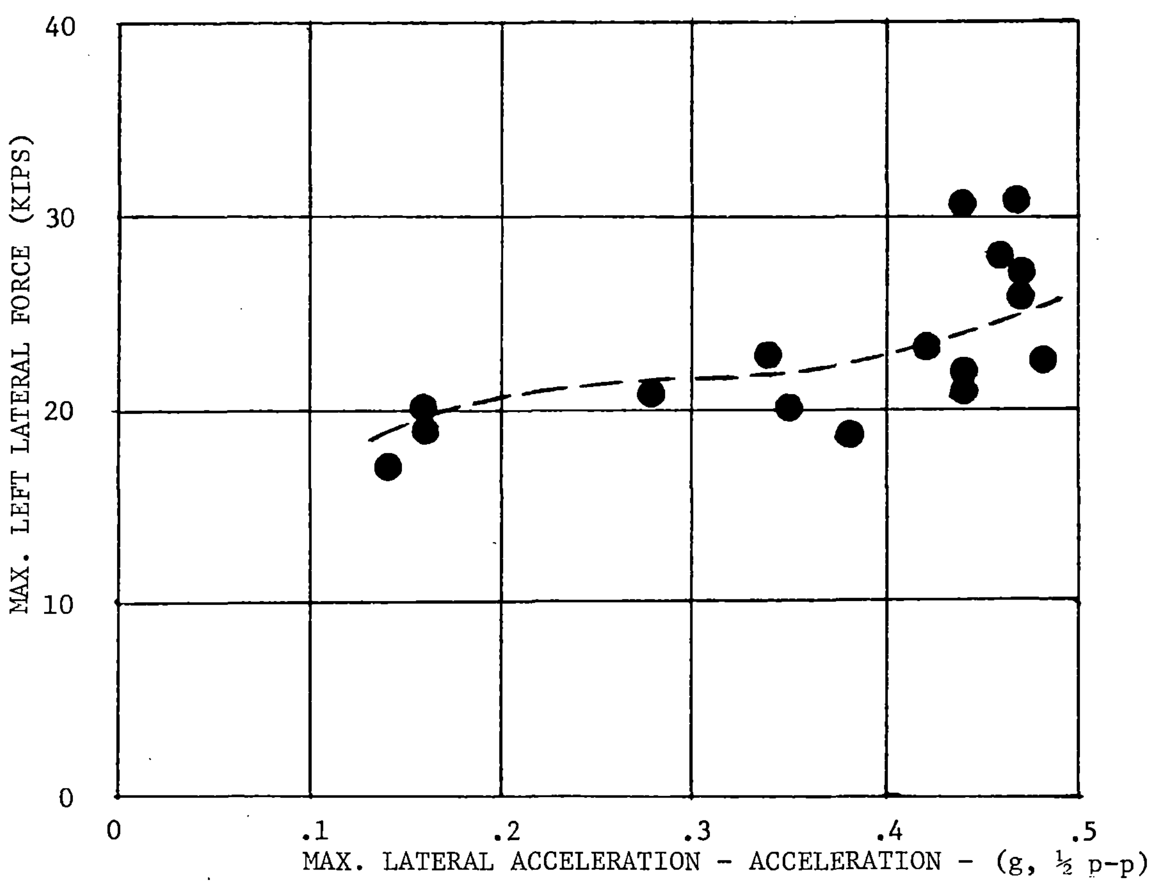


FIGURE 6-8. E-8 LEAD INSTRUMENTED AXLE RESPONSE VERSUS LATERAL CARBODY ACCELERATION, SECTION 4 - ONBOARD DATA FROM 11/17/78

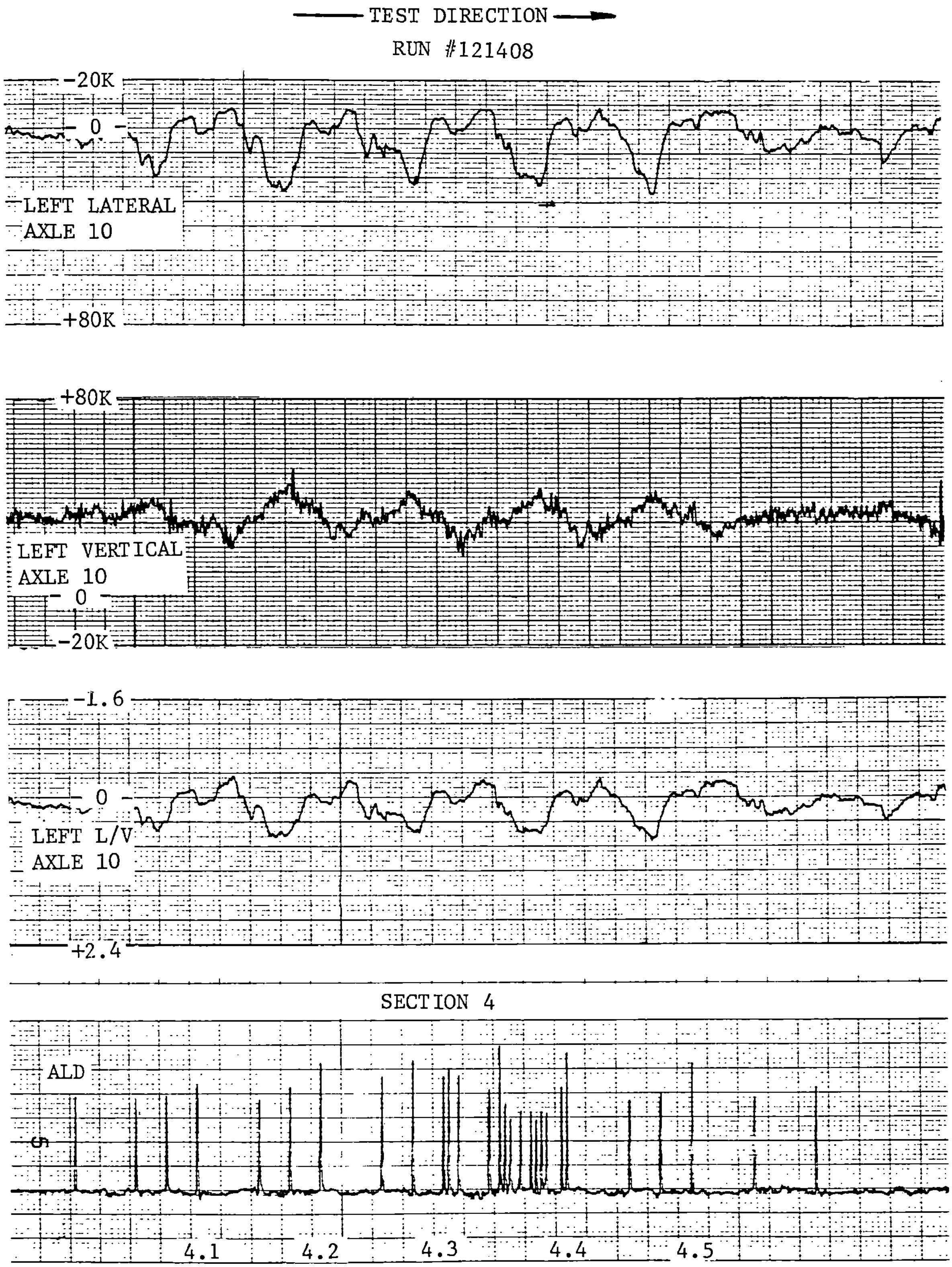


FIGURE 6-9. SDP-40F RESPONSE IN SECTION 4 AT 65 MPH - "A" CONSIST - LEFT LATERAL, LEFT VERTICAL, AND L/V - AXLE 10

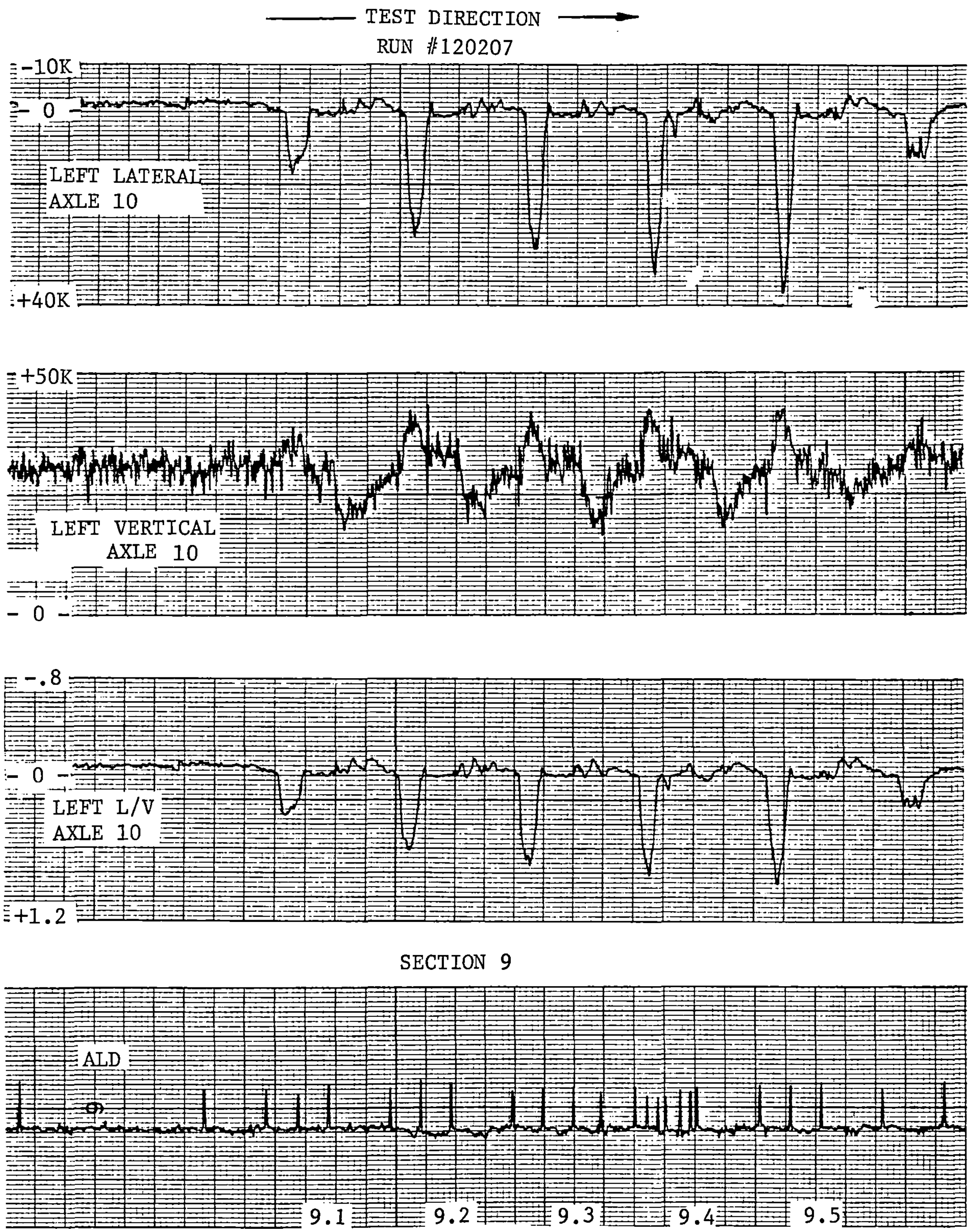


FIGURE 6-10. SDP-40F RESPONSE IN SECTION 9 AT 65 MPH "A" CONSIST - LEFT LATERAL, LEFT VERTICAL, AND LEFT L/V - AXLE 10

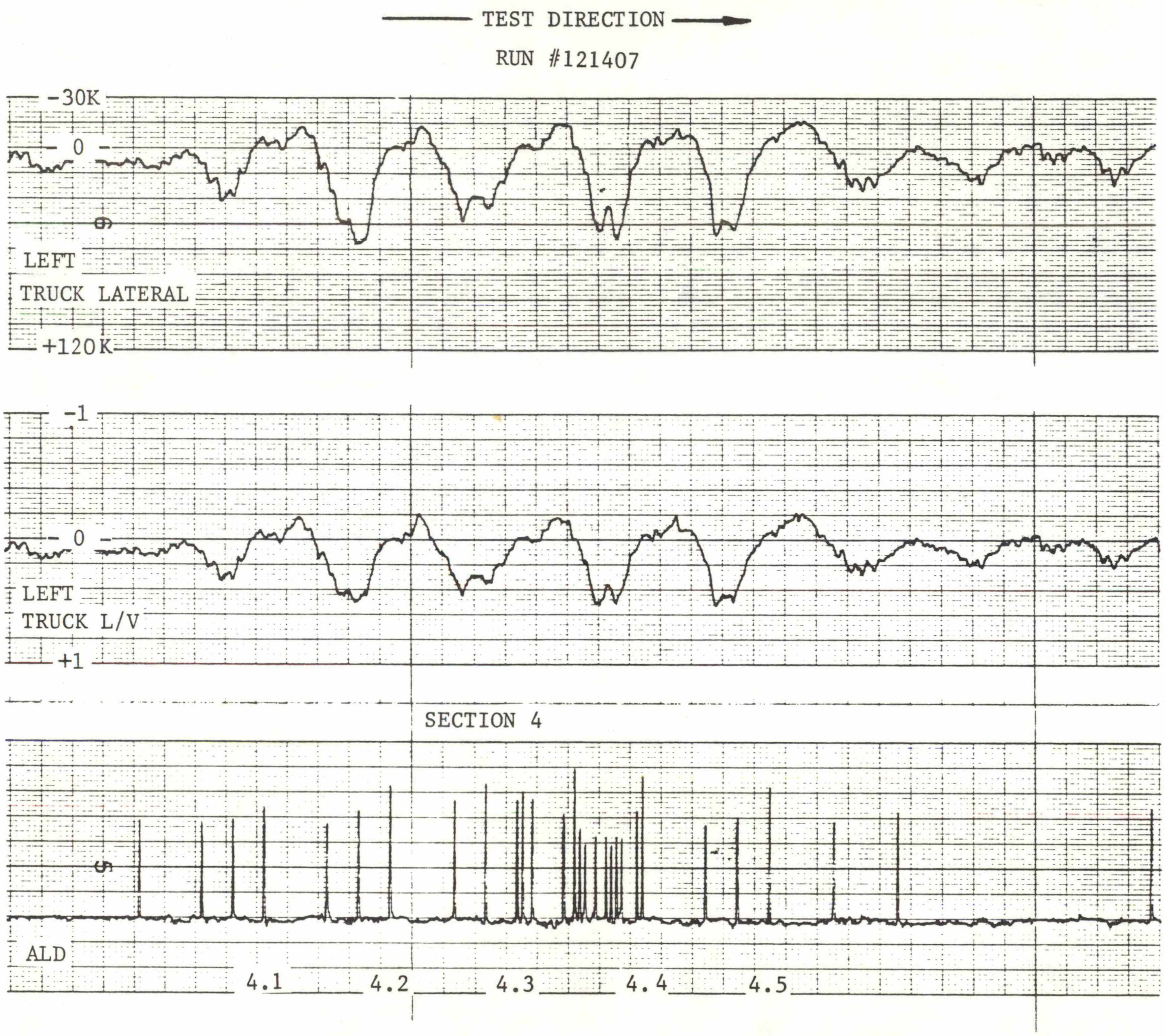


FIGURE 6-11. SDP-40F RESPONSE IN SECTION 4 AT 65 MPH - "A" CONSIST - LEFT TRUCK LATERAL AND L/V

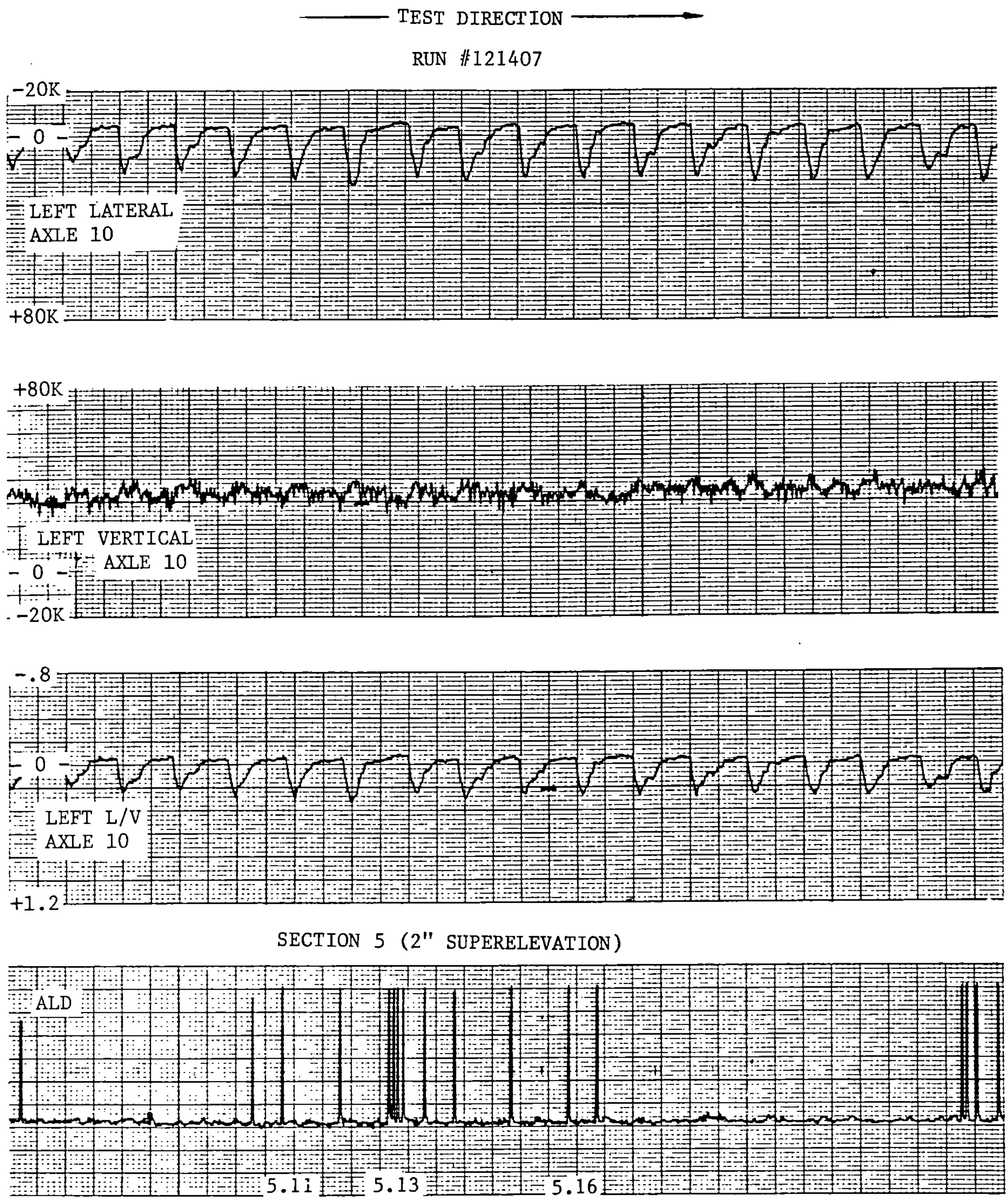


FIGURE 6-12. SDP-40F RESPONSE IN SECTION 5 AT 65 MPH - "A" CONSIST - LEFT LATERAL, LEFT VERTICAL, AND LEFT L/V - AXLE 10

Figure 6-11 shows the lateral force and L/V ratio for the entire side of the instrumented truck that is on the high rail in section 4 at 65 mph. A comparison of high rail axle and truck responses may be made by contrasting Figure 6-11 with Figure 6-9 which shows the descriptors for axle 10, the leading instrumented axle.

Figure 6-12 shows the lateral and vertical high rail forces and L/V ratio in the second subsection of superelevation in section 5 for the lead instrumented axle of the SDP-40F while traveling at 65 mph.

Figure 6-13 shows the simultaneous (at any instant in time) high rail lateral response of all three of the instrumented axles in section 4 at 65 mph. The ALD trace, of course, is referenced to the location of the lead axle, number 10.

Figure 6-14 compares the low and high rail lateral forces for the lead instrumented axle of the SDP-40F in section 4 at 65 mph. On the Brush chart, inward forces on the wheel flanges are positive for both right and left wheels. For the raw and processed data tapes, inward forces are negative as discussed in Chapter 3.3.

Figures 6-15 and 6-16 compare the high rail lead instrumented axle response between the individual perturbations in sections 1 and 2 and the combined perturbations in section 4. Figure 6-15 compares the vertical response in sections 1 and 4 at 65 mph. Section 1 contains a pure crosslevel perturbation, while section 4 contains nominally the same crosslevel perturbation superimposed on an alignment perturbation. Figure 6-16 compares the lateral response for the same run in sections 2 and 4. Section 2 contains an alignment perturbation only, which is similar to the alignment perturbation in section 4.

Figures 6-17 and 6-18 show the high rail lateral forces for the lead axle of each truck of the SDP-40F locomotive consist as measured by the wayside instrumentation in section 4. All of the following wayside plots are spatial histories, plotting lateral force versus location as described by crib number.

The first figure is for a 65 mph run prior to the panel shift which occurred on the first day of the SDP-40F test series. Figure 6-18 is for a 65 mph run after the panel shift. By comparing the two figures, the significant change in response is readily seen.

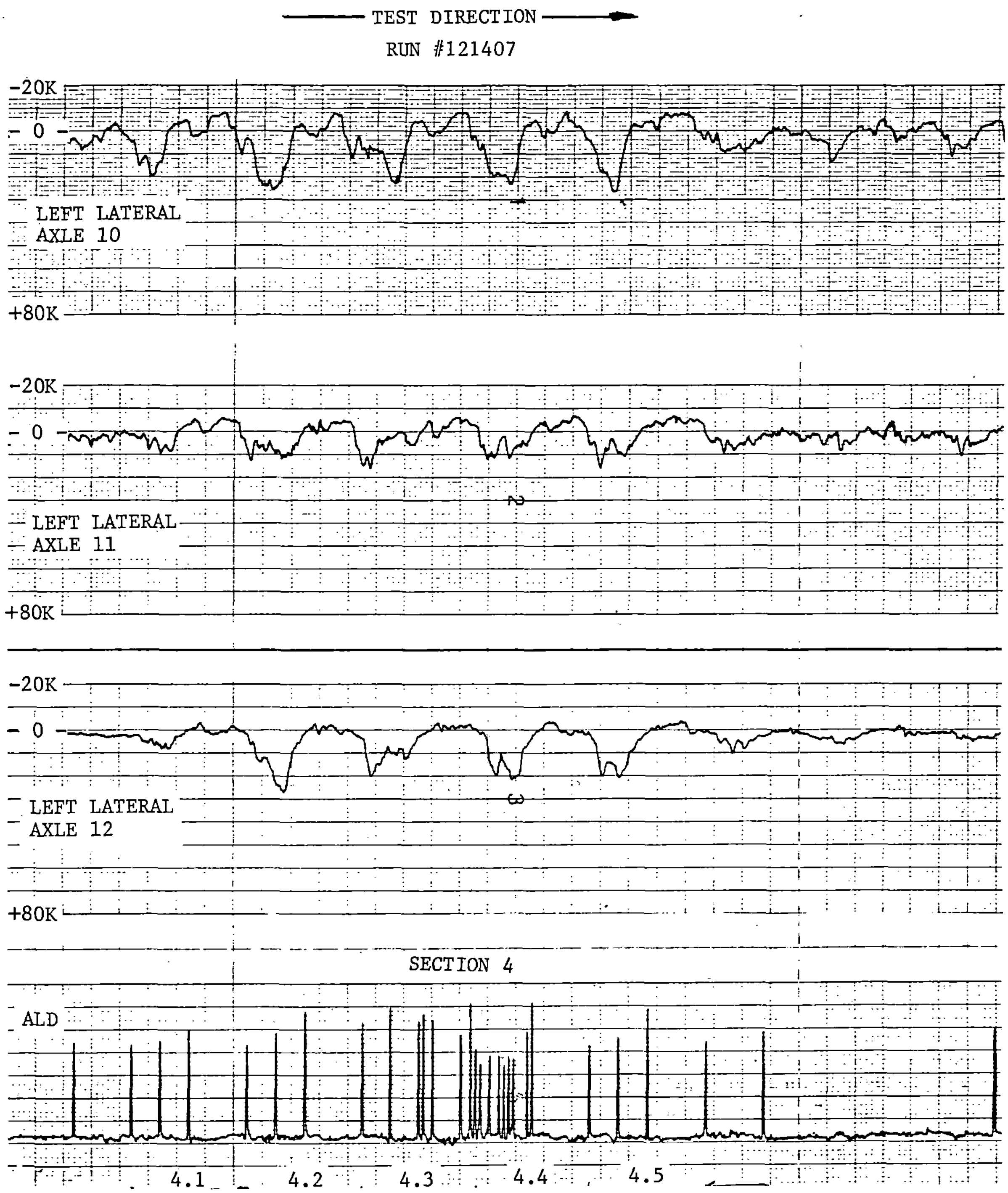


FIGURE 6-13. SDP-40F RESPONSE IN SECTION 4 AT 65 MPH - "A" CONSIST - LEFT LATERAL ALL INSTRUMENTED AXLES

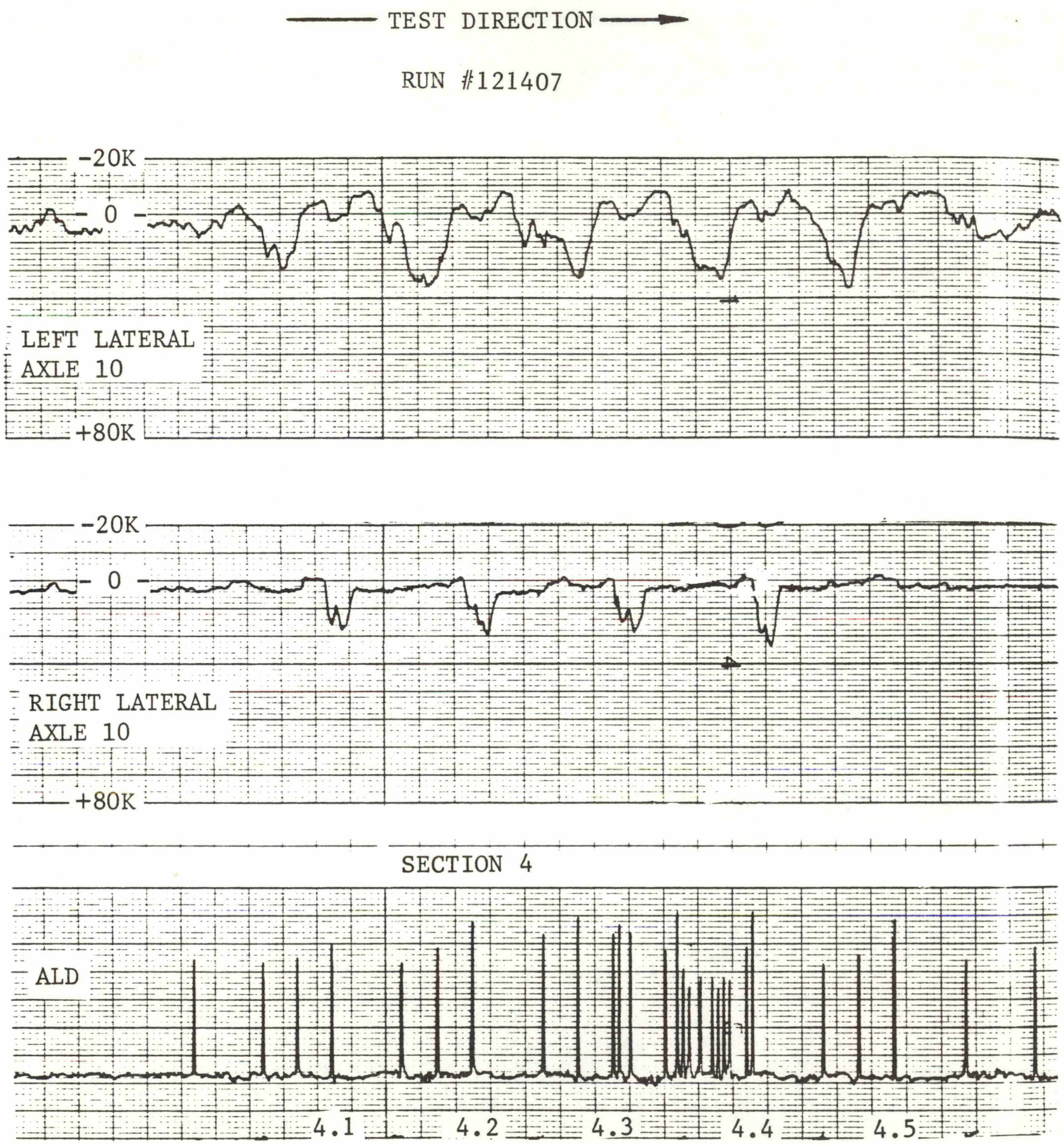


FIGURE 6-14. SDP-40F RESPONSE IN SECTION 4 AT 65 MPH - "A" CONSIST - LEFT AND RIGHT LATERAL FORCE AXLE 10

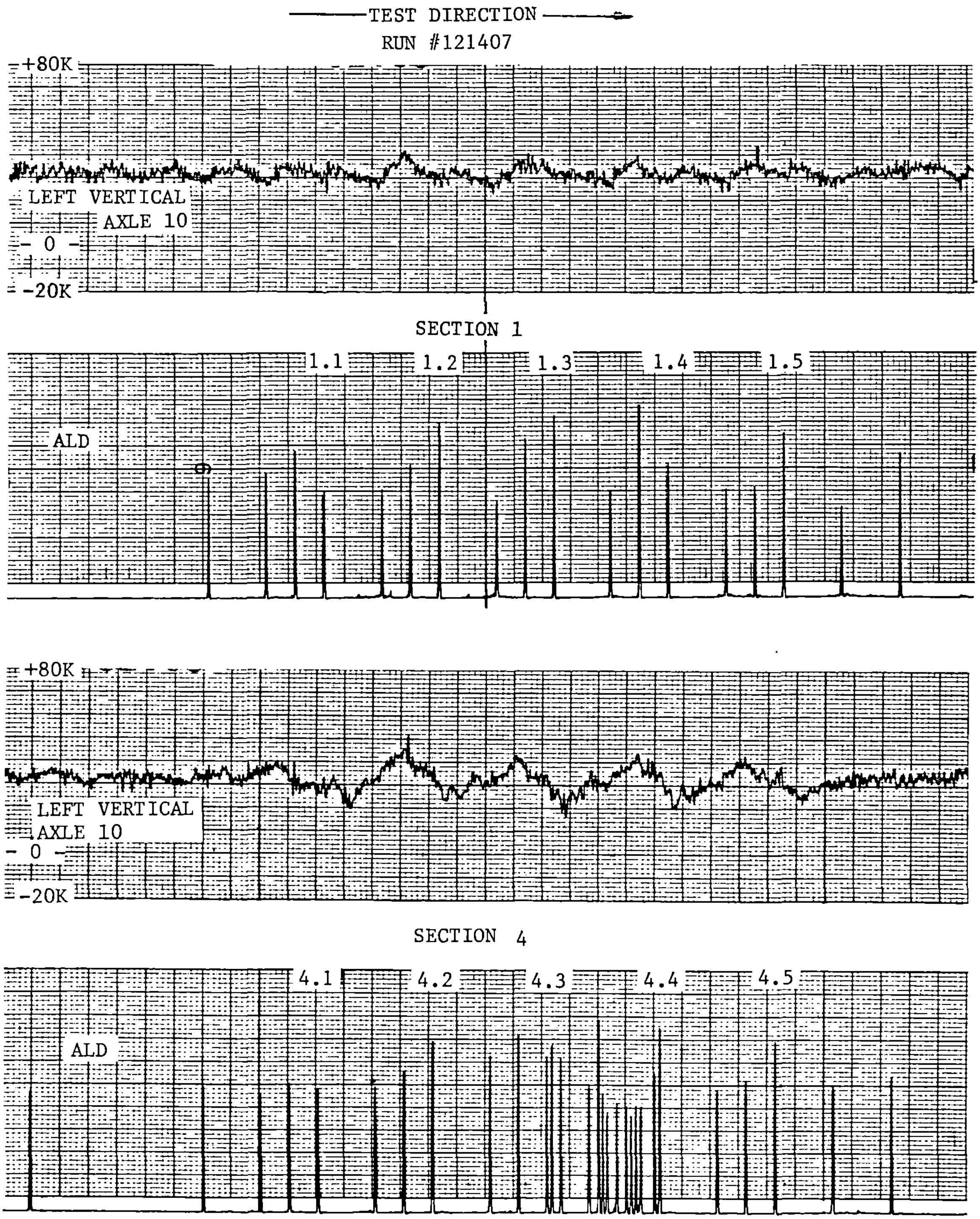


FIgure 6-15. SDP-40F RESPONSE IN SECTIONS 1 AND 4 AT 65 MPH "A" CONSIST - LEFT VERTICAL FORCES AXLE 10

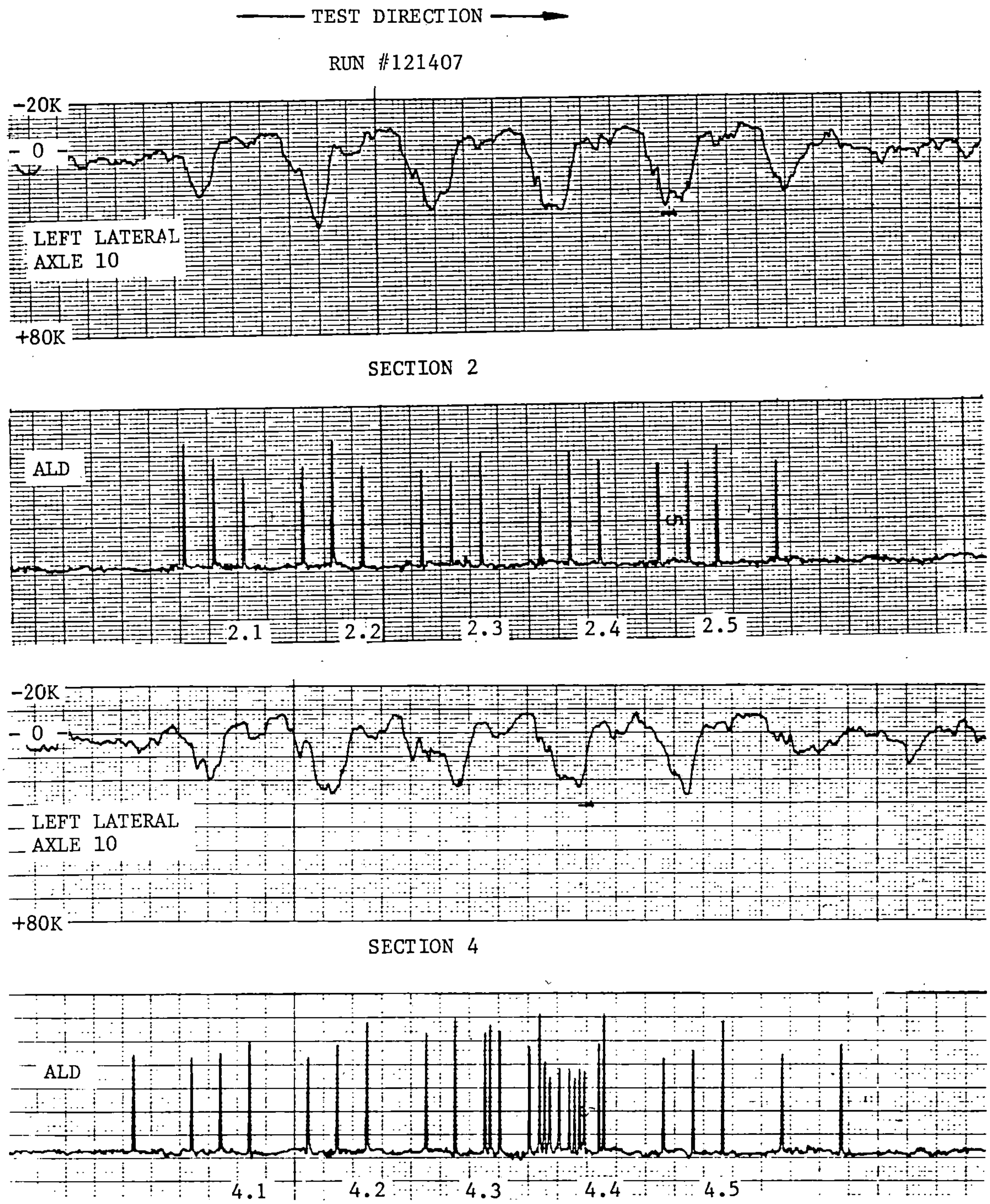
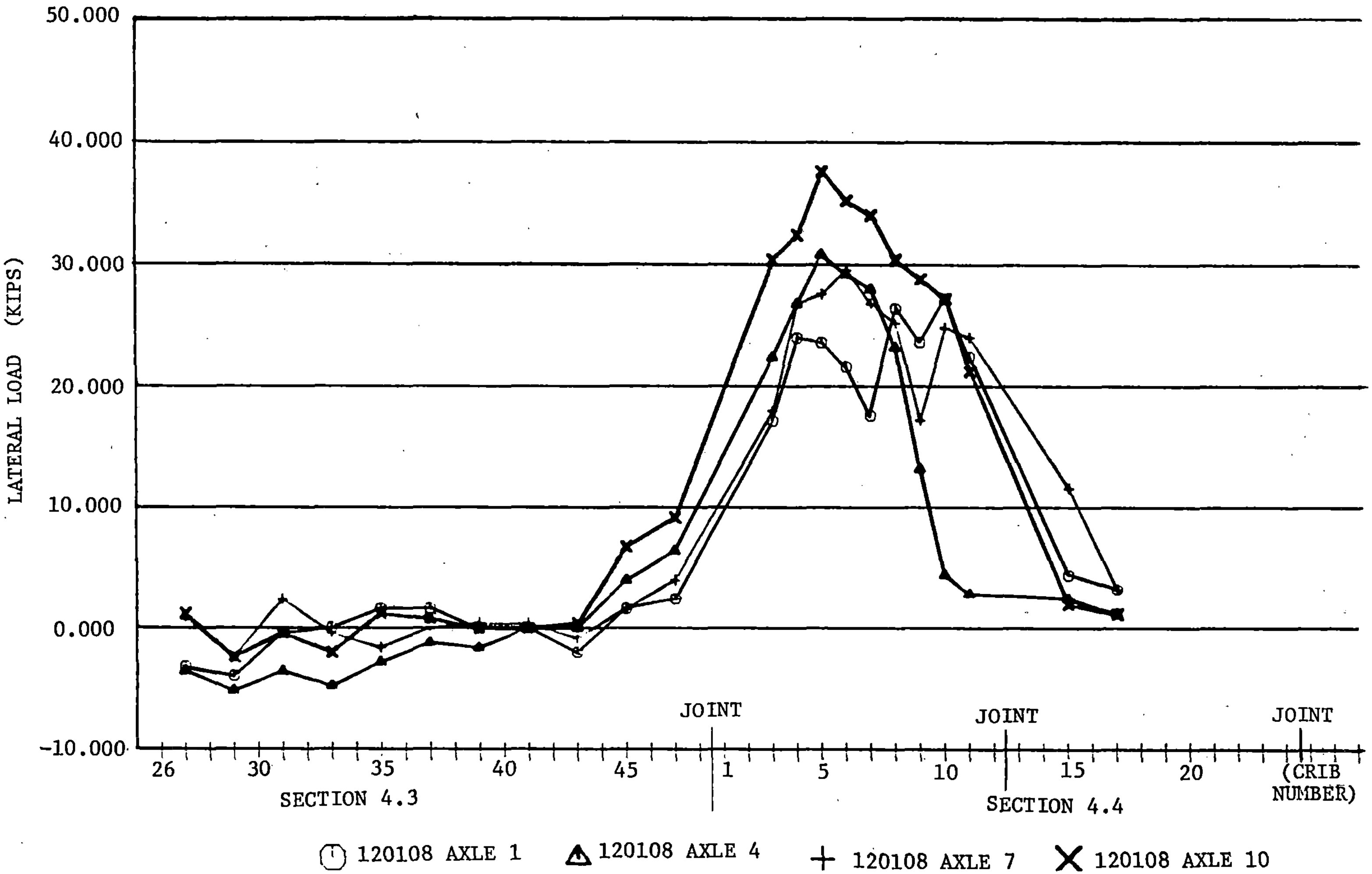
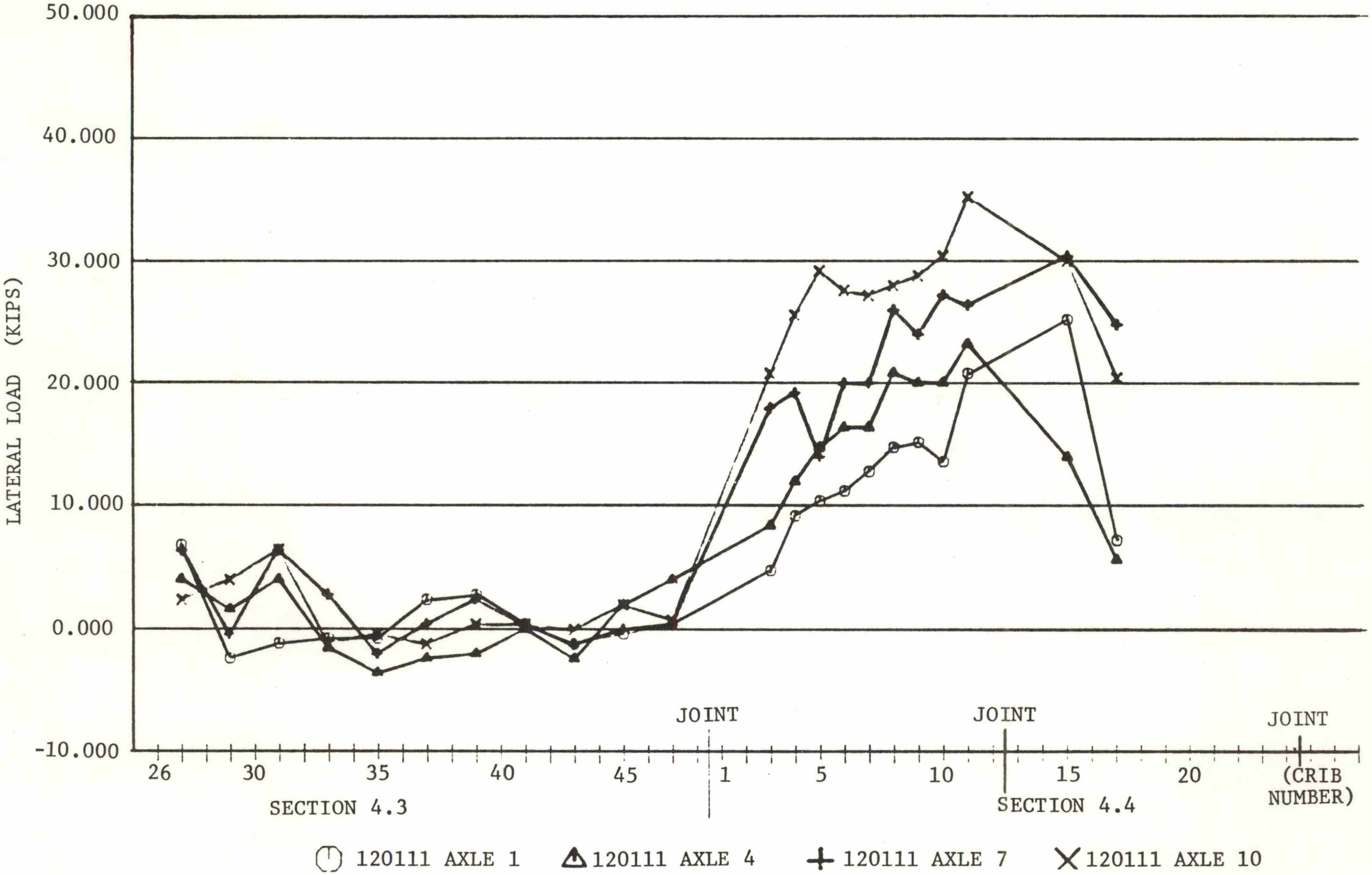


FIGURE 6-16. SDP-40F COMPARISON OF AXLE 10 LEFT LATERAL RESPONSE IN SECTIONS 2 AND 4 AT 65 MPH - "A CONSIST



HIGH RAIL LATERAL LOADS AT 65 MPH

FIGURE 6-17. SDP-40F "A" CONSIST FROM BCL WAYSIDE INSTRUMENTATION, SECTION 4 - ALL LEAD AXLES (BEFORE PANEL SHIFT)



HIGH RAIL LATERAL LOADS AT 65 MPH

FIGURE 6-18. SDP-40F "A" CONSIST FROM BCL WAYSIDE INSTRUMENTATION, SECTION 4 - ALL LEAD AXLES (AFTER PANEL SHIFT)

Figures 6-19 and 6-20, respectively, show the response of the middle and trailing axles of each truck for the 65 mph run prior to the panel shift. The lead axle responses for the same run in section 5, where there are three subsections of decreasing superelevation, are shown in Figure 6-21.

Figures 6-22 through 6-24 show some typical maximum force or acceleration data in sections 2 and 4, as measured by onboard instrumentation.

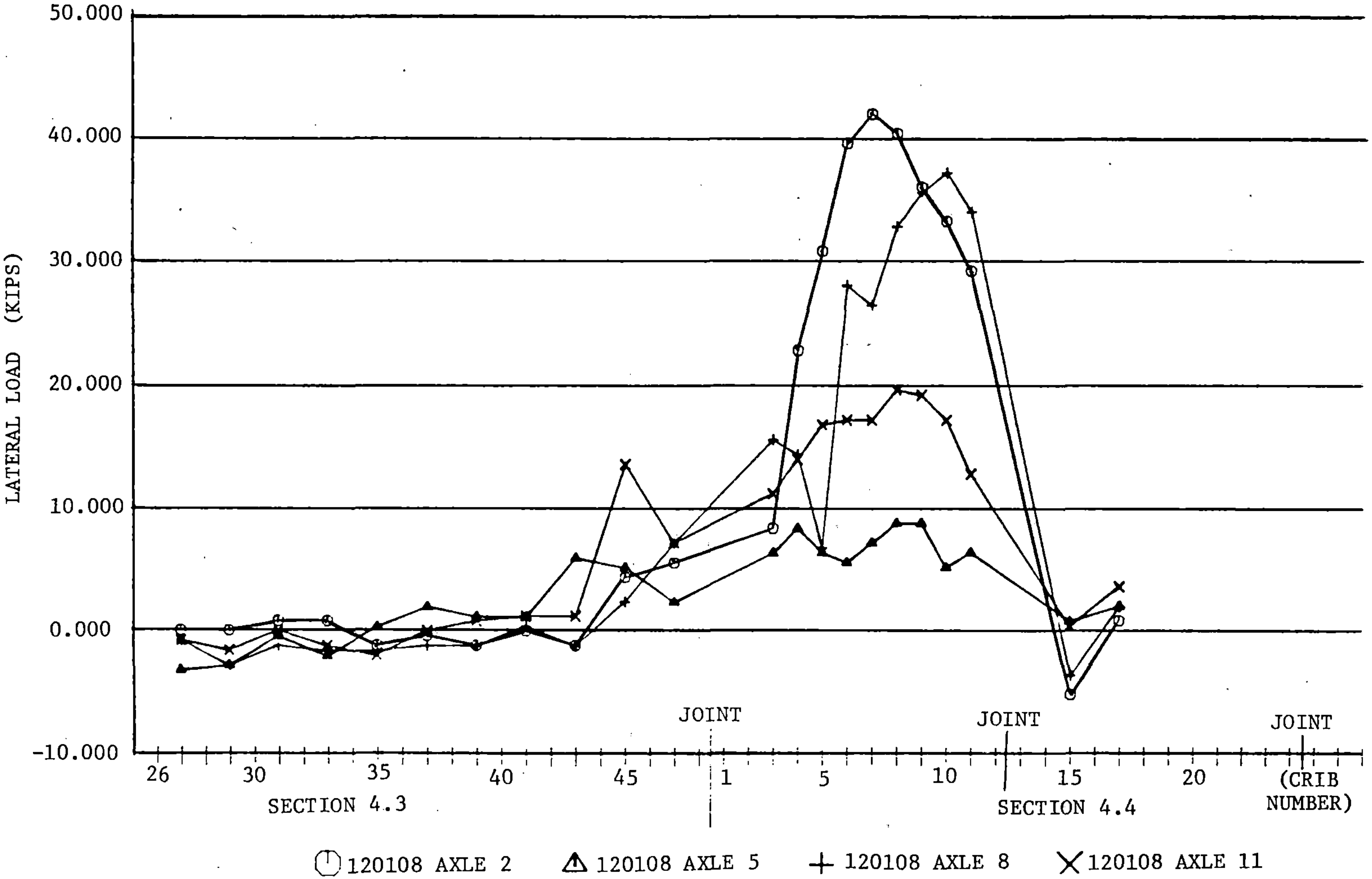
In Figure 6-22, the peak high rail lateral forces for all three instrumented axles of the SDP-40F "A" consist are plotted versus speed. Next, the peak high rail lateral force for the leading instrumented axle is plotted versus the total high rail truck lateral force and is shown in Figure 6-23. Figure 6-24 shows the leading instrumented axle peak high rail lateral force as a function of the lateral acceleration of the SDP-40F carbody over the trailing truck.

Finally, Figure 6-25 shows the peak vertical acceleration of the trailing end of the trailing locomotive in section 6 of the tangent test zone as a function of speed for the nominal (1800/1800) shock absorber configuration, and for the case where the primary vertical shock absorbers were removed.

6.3 FREIGHT TEST DATA

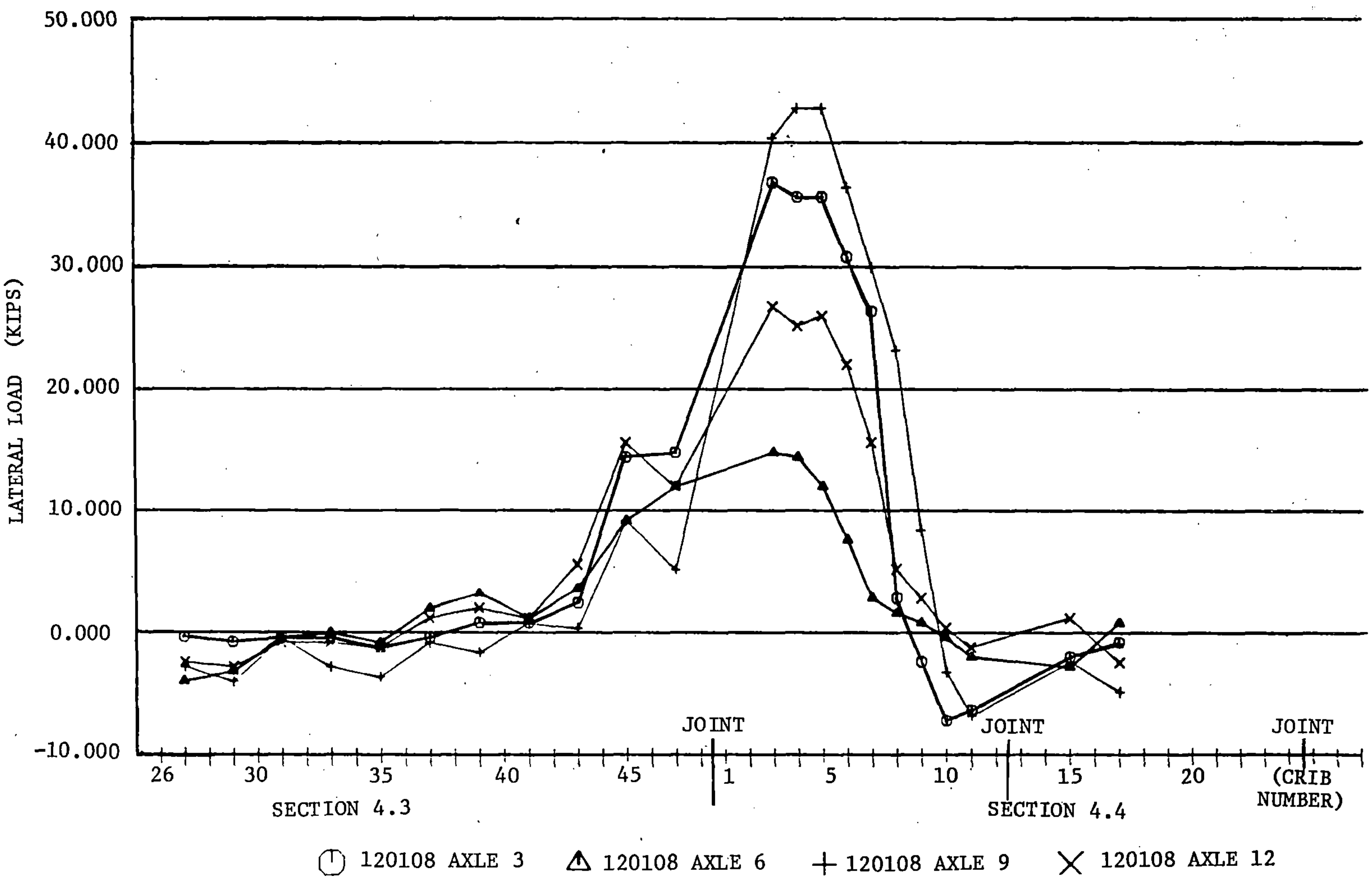
During the follow-up Freight Test, only wayside instrumentation was used. In the following four Figures, 6-26 through 6-29, spatial force histories from the first day of the Freight Test are presented. In Figure 6-26, the lateral force for the lead axles of both trucks of the first two locomotives in the consist are shown. Only data from gages directly after the main cusp is shown.

The remaining figures are for the freight vehicles. In Figure 6-27, the spatial force histories for the leading axle of the leading truck of cars 1, 8, and 10 (the leading loaded car of each type, hopper, tank, and TOFC) are shown. The force histories for the same axles for the leading unloaded vehicles, cars 6, 9, and 11, are shown in Figure 6-28. Finally, the spatial force histories for all the axles, 1 through 4, of the leading loaded hopper car (number 1) are shown in Figure 6-29.



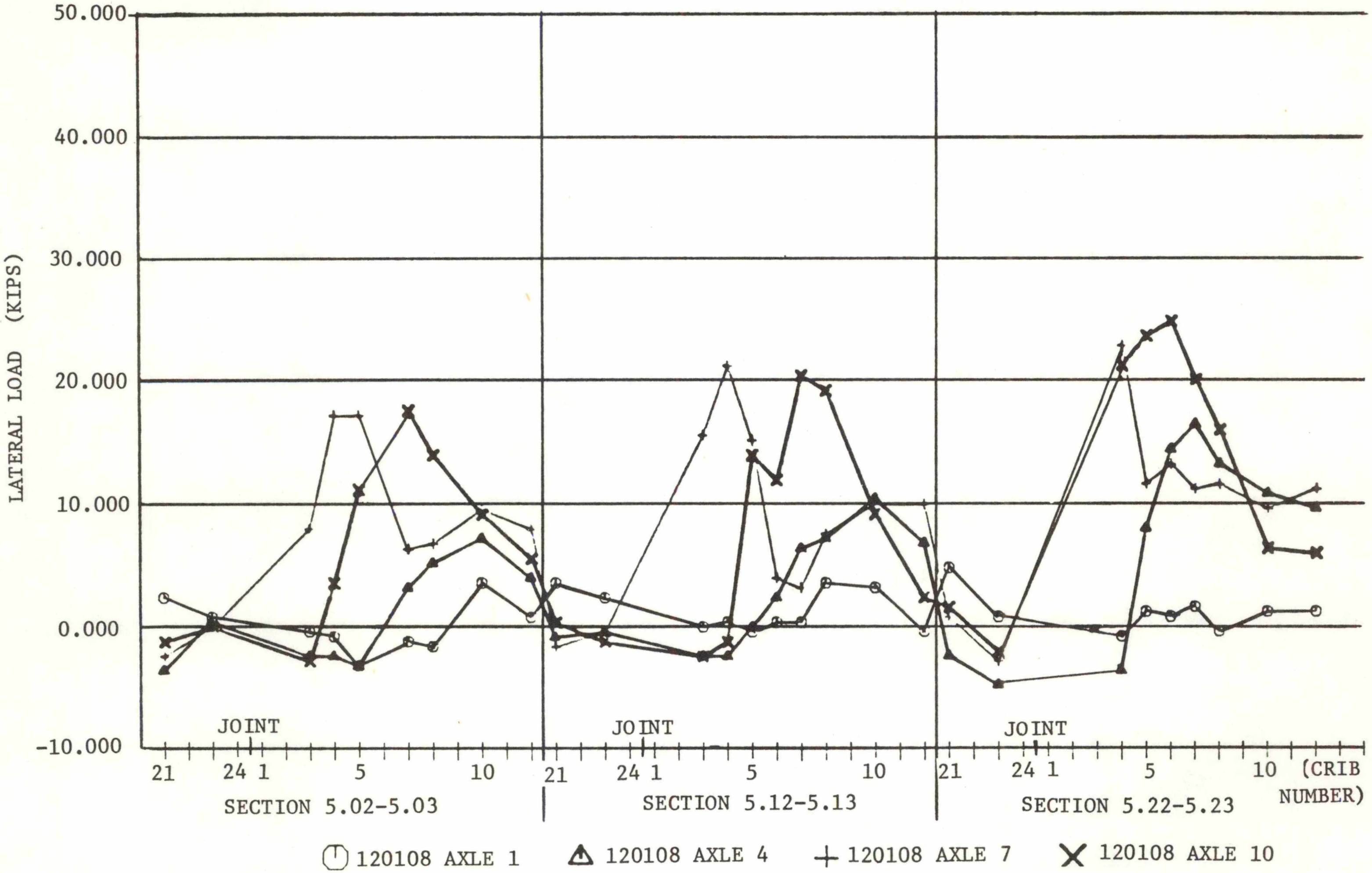
HIGH RAIL LATERAL LOADS AT 65.MPH

FIGURE 6-19. SDP-40F "A" CONSIST FROM BCL WAYSIDE INSTRUMENTATION, SECTION 4 - ALL MIDDLE AXLES (BEFORE PANEL SHIFT)



HIGH RAIL LATERAL LOADS AT 65 MPH

FIGURE 6-20. SDP-40F "A" CONSIST FROM BCL WAYSIDE INSTRUMENTATION, SECTION 4 - ALL TRAIL AXLES (BEFORE PANEL SHIFT)



HIGH RAIL LATERAL LOADS AT 65 MPH

FIGURE 6-21. SDP-40F "A" CONSIST FROM BCL WAYSIDE INSTRUMENTATION, SECTION 5 - ALL LEAD AXLES

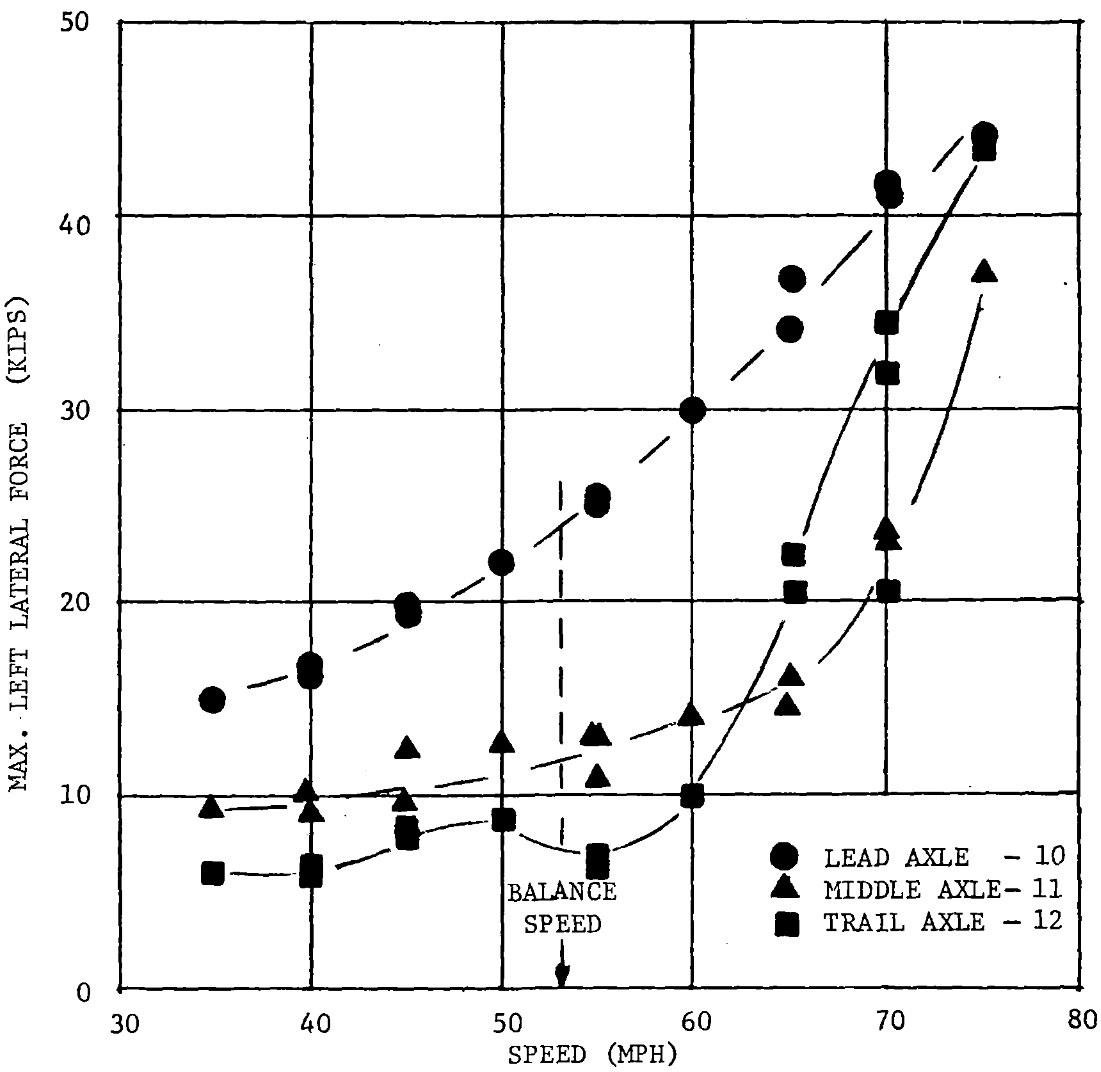


FIGURE 6-22. SDP-40F INSTRUMENTED AXLES RESPONSE VERSUS SPEED IN SECTION 4.2 - LEFT LATERAL FORCE (MAX. VALUES) CONSIST A - ONBOARD DATA FROM 12/14/78

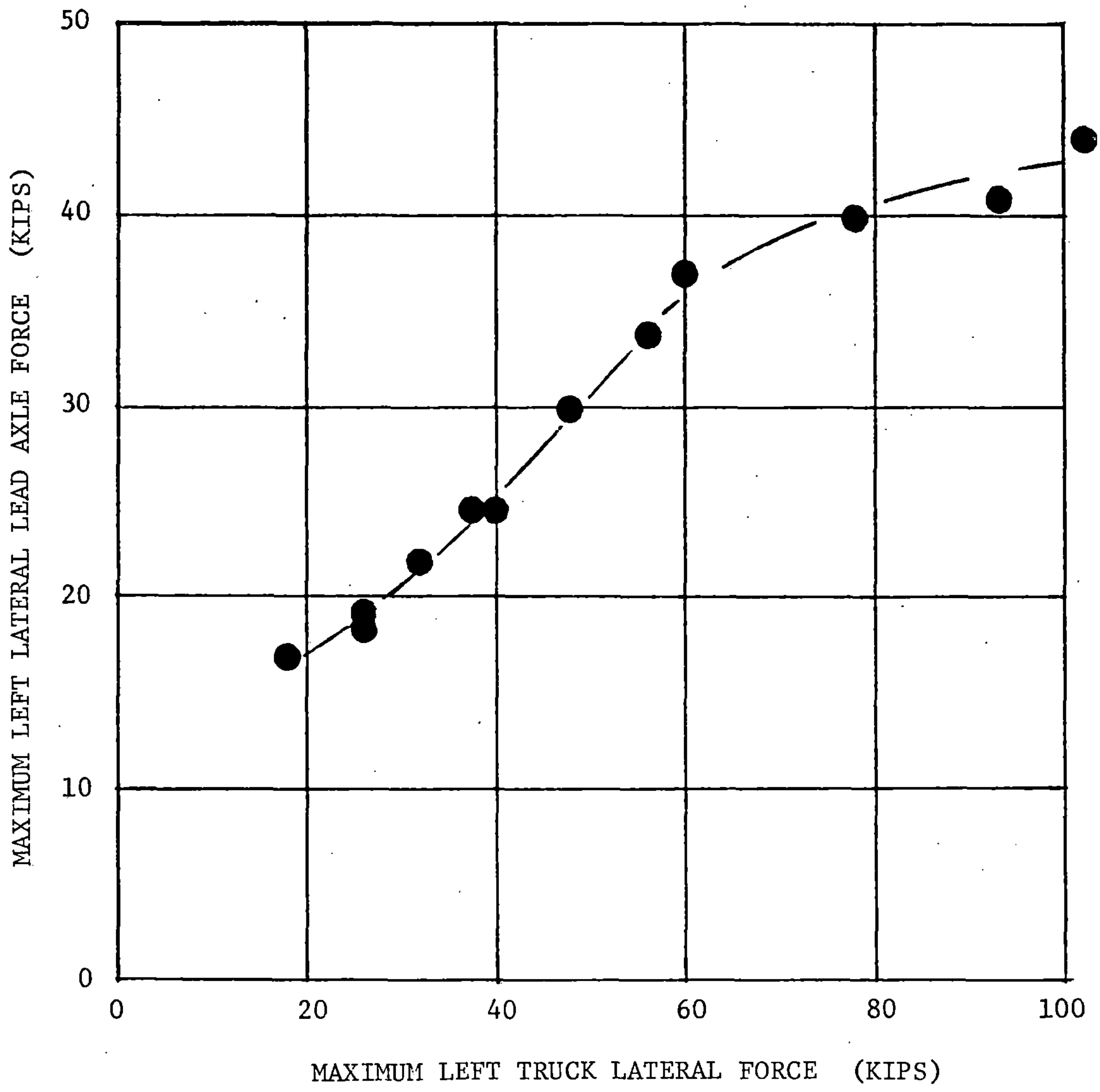


FIGURE 6-23. SDP-40F LEAD AXLE VERSUS TRUCK LEFT LATERAL RESPONSE SECTION 2 - "A" CONSIST (ONBOARD DATA)

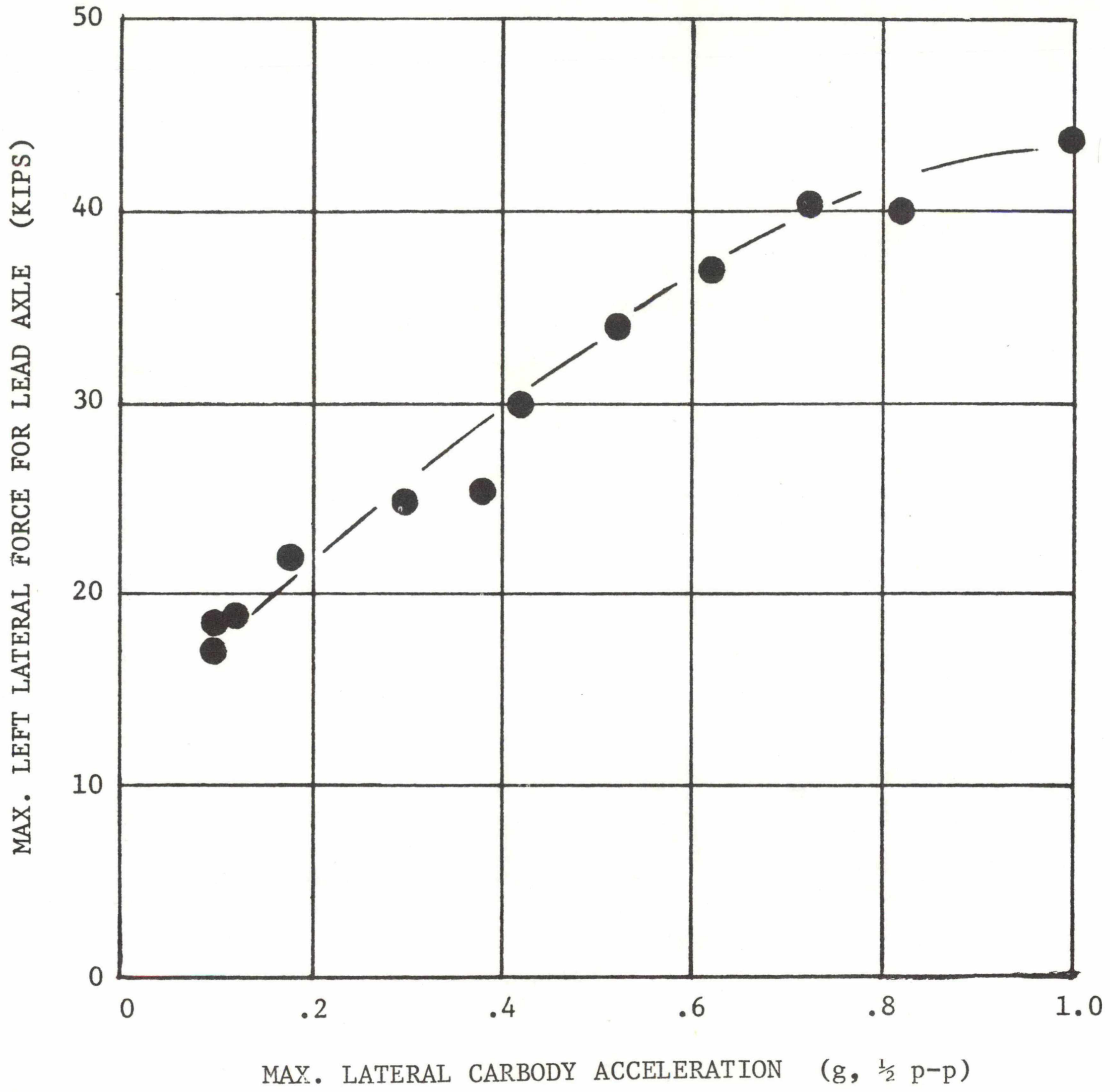


FIGURE 6-24. SDP-40F LEAD AXLE LEFT LATERAL RESPONSE VERSUS LATERAL CARBODY ACCELERATION IN SECTION 2 "A" CONSIST (ONBOARD DATA)

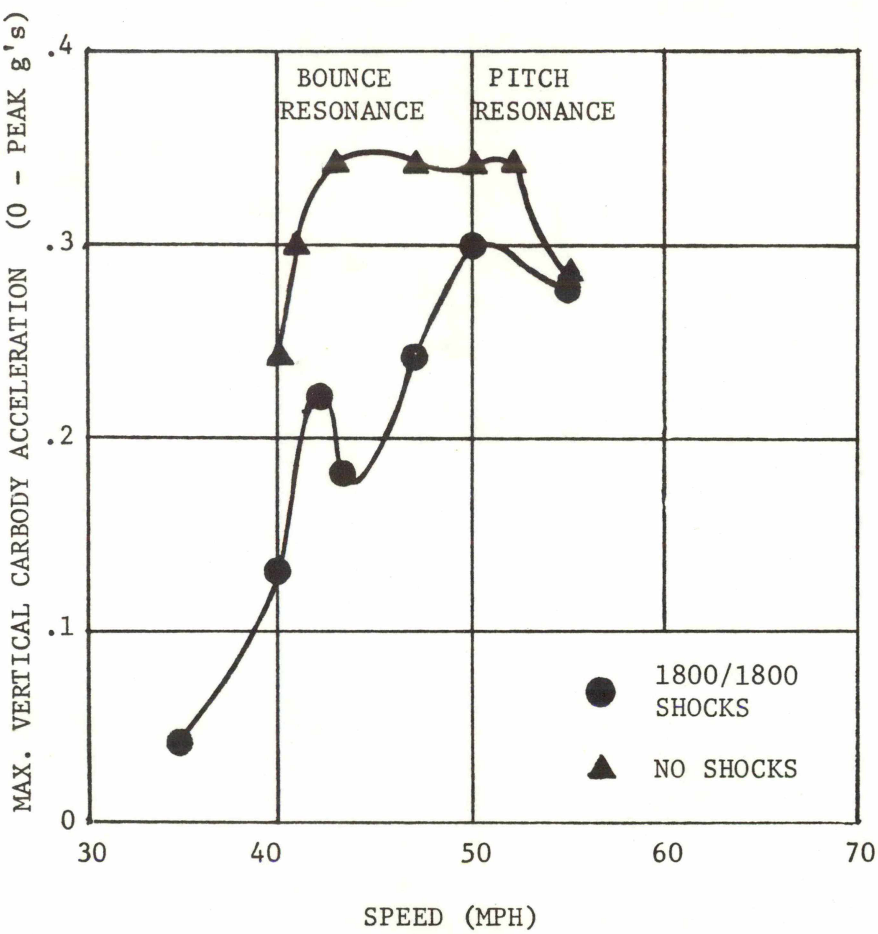


FIGURE 6-25. SDP-40F VERTICAL CARBODY ACCELERATION VERSUS SPEED IN SECTION 6 (ONBOARD DATA)

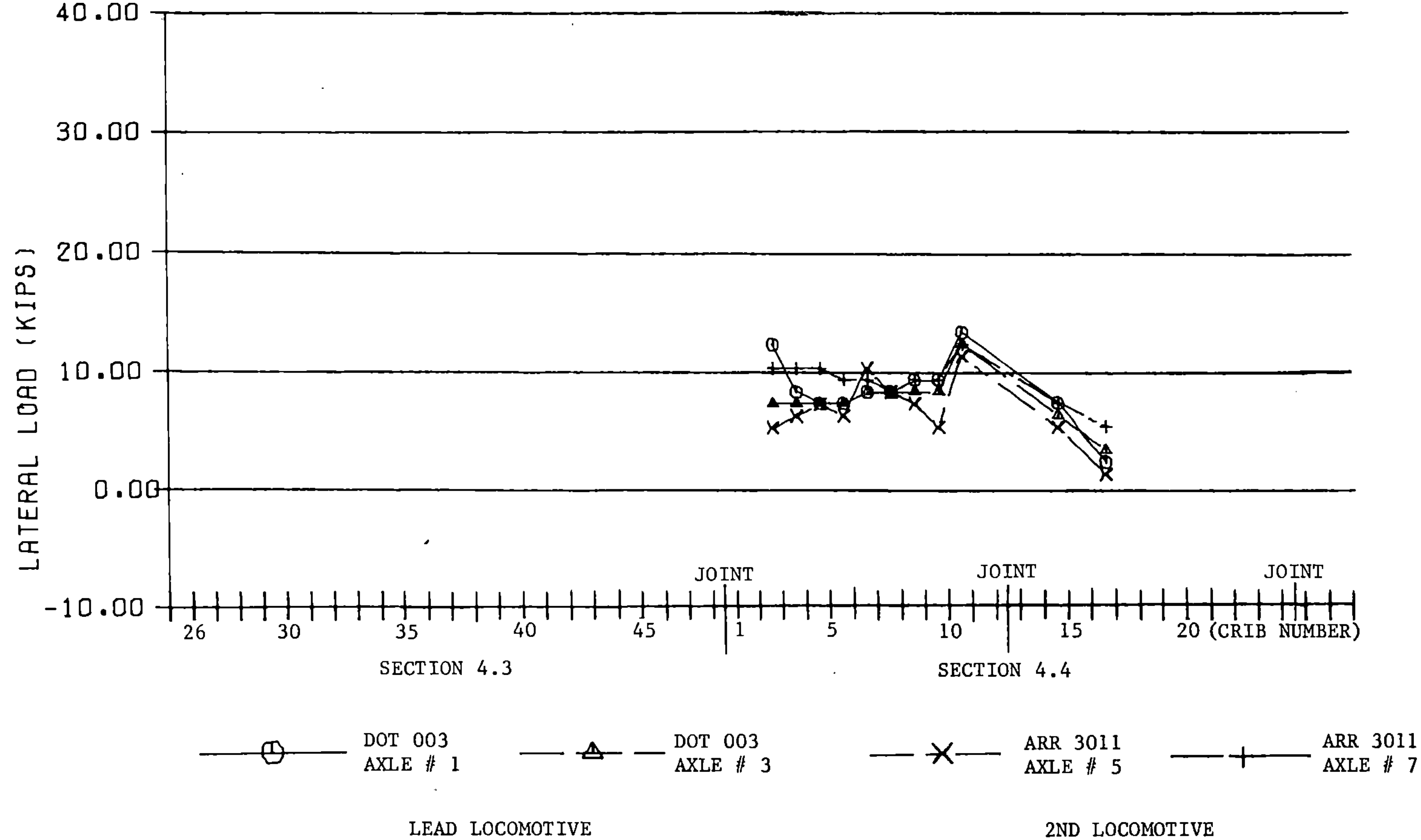


FIGURE 6-26. 11-CAR FREIGHT CONSIST (2/3/79) FROM BCL WAYSIDE INSTRUMENTATION, SECTION 4 - LEAD AXLES OF BOTH TRUCKS FOR DOT 003 AND ARR 3011 - SPEED 60 MPH

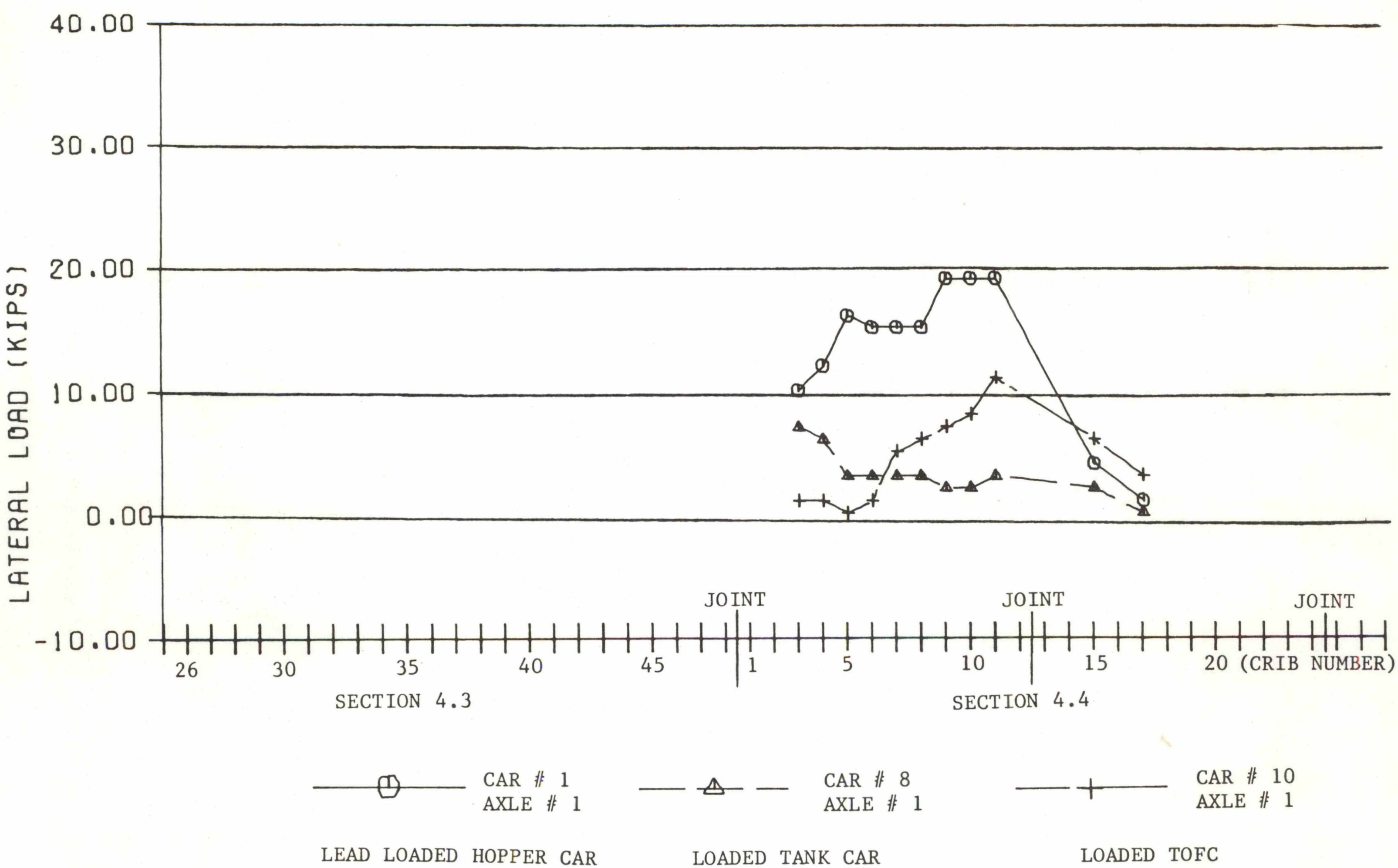


FIGURE 6-27. 11-CAR FREIGHT CONSIST (2/3/79) FROM BCL WAYSIDE INSTRUMENTATION, SECTION 4 - LEAD AXLES OF LEADING LOADED HOPPER, TANK, AND TOFC - SPEED 60 MPH

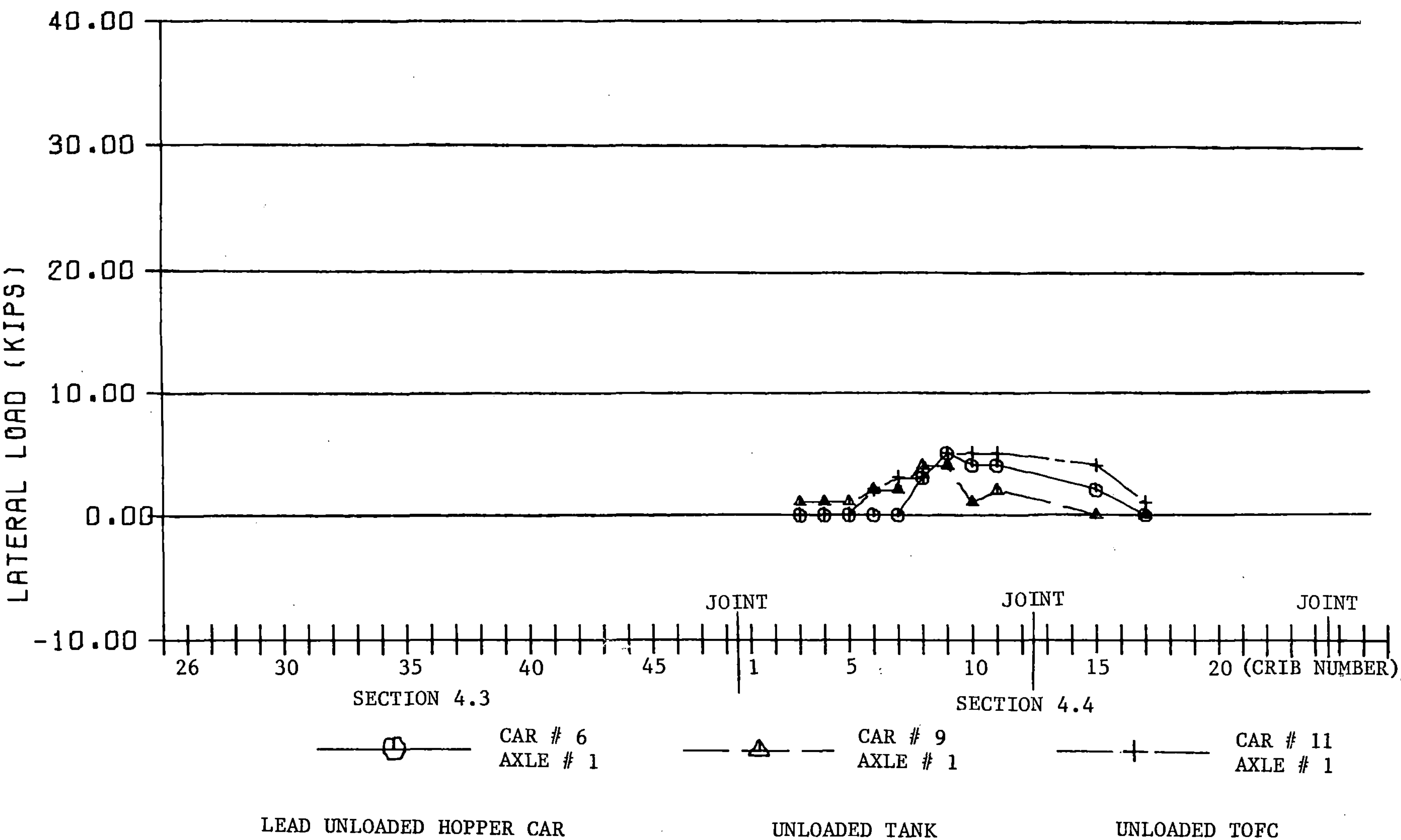


FIGURE 6-28. 11-CAR FREIGHT CONSIST (2/3/79) FROM BCL WAYSIDE INSTRUMENTATION, SECTION 4 - LEAD AXLES OF LEADING UNLOADED HOPPER, TANK, AND TOFC - SPEED 60 MPH

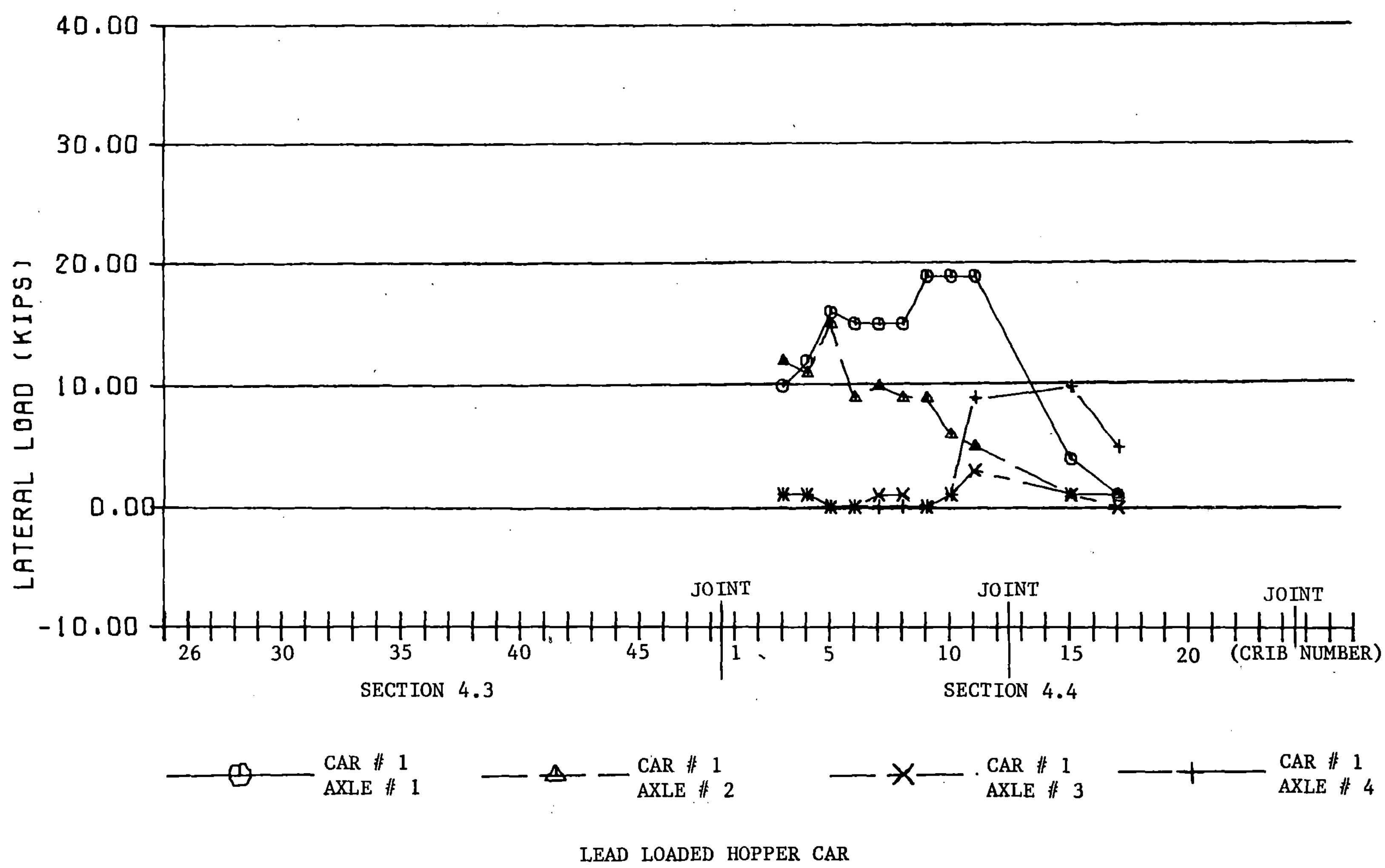


FIGURE 6-29. 11-CAR FREIGHT CONSIST (2/3/79) FROM BCL WAYSIDE INSTRUMENTATION, SECTION 4 - ALL AXLES FOR LEADING LOADED HOPPER CAR SPEED 60 MPH

7. POTENTIAL DATA APPLICATIONS

As has been indicated, the Perturbed Track Test has been designed to address the broad objectives of the FRA's Track Research Program and the Vehicle/Track Interaction Subtask of the Track Train Dynamics (TTD) Program. These objectives include: design data for a Safety Assessment Facility for Equipment (SAFE); establishing methods for characterizing track, equipment, and operational parameters; and providing data for dynamic model validation and for the confirmation of parametric studies of derailment tendencies. Accordingly, the PTT data base has the potential for many varied applications.

The following is a description of the types of information that the PTT data base can provide. Processed data tapes are now currently available. However, a complete, integrated and documented operational data base is being compiled and will be available in December for general use by the railroad community. Although selected analyses will be performed in many of the areas described below, they will be oriented towards specific issues such as specifying design requirements for SAFE. Accordingly, the purpose of this chapter is not to describe the specific analyses that will be performed, but rather to illustrate the wide spectrum of issues that could be investigated using the PTT data base.

7.1 SAFE DESIGN

Clearly, a prerequisite to developing a design for SAFE is to establish the feasibility of assessing the safety of a rail vehicle's dynamic performance using a fixed facility with standardized testing procedures. The first step in this design procedure is to define the objectives of such a facility and then to establish potential approaches which would meet these objectives. Each approach would, in general, have different facility and data requirements; however, each must be capable of predicting the potential for undesirable dynamic performance in revenue service. The PTT data, in conjunction with the Chessie Test data,[3] provides the principal source for assessing the feasibility and requirements of each approach. In particular, the PTT data will be the primary source of information needed to identify the following requirements:

- Critical dynamic processes (e.g., underbalanced curve negotiation)

- Corresponding fundamental track processes (e.g., alignment wave length)

- Critical vehicle parameters

- Methodologies for vehicle assessment

- Data measurement requirements

- Key track input and vehicle response output descriptors.

Further, the PTT data could identify the important vehicle characteristics that should be determined prior to, or independent of, controlled track testing through the use of equipment such as a shaker or roller rig.

Some of the more important analyses to be conducted would address the following issues:

- Significance of perturbation frequency content and phasing

- The number of cycles required to approach maximum response

- The effect of superelevation

- The effect of combined perturbations

- The difference between vehicle dynamic response on tangent and curved track

- The effects of rail surface condition

- The variability in response between vehicles nominally the same.

7.2 INSTRUMENTATION CAPABILITIES

Another important analysis is the investigation into alternative wheel/rail force measuring systems. A common hypothesis is that given the carbody and suspension displacement and acceleration data, along with the component masses, an accurate estimate of the wheel/rail forces can be developed using a "sum of forces" approach. The ability to use this approach independently or in conjunction with wayside force transducers would eliminate the need for specially instrumented wheelsets. The adequacy of the wayside force measuring system alone for each potential approach to SAFE could also be investigated.

Further, the effectiveness of the instrumentation used could be investigated, providing information useful to the design and deployment of instrumentation for field testing. The PTT used three different types of wheelsets, various accelerometers and displacement transducers, analog and digital recording techniques, wayside lateral and vertical force measuring systems, rail deflection measuring systems, and real-time data processing systems. By comparing the techniques for consistency, durability, and accuracy over the wide range of response seen during the PTT, the systems used in future field tests may be made more effective.

7.3 TRACK CHARACTERIZATION

An important potential use of the PTT data is an assessment of the present parameters used to classify track for the Track Safety Standards. The perturbations used for PTT met at least Class 4 standards for the most part; however, severe responses were generated. These responses included panel shift, large rail roll, high lateral forces and L/V ratios, and high carbody accelerations. Investigations correlating vehicle response with detailed track geometry using statistical descriptors and frequency power spectral densities should help to identify critical track geometry deviations. The dynamic response to the isolated perturbations and to the combined alignment and crosslevel perturbations could be used to investigate the significance of combined descriptors.

Track lateral strength and its significance to vehicle safety is another area where the PTT data could provide valuable insight. The experiments with the spiking pattern, the dynamic displacement measurements, and the data associated with the track panel shift could be used to assess the importance of lateral track compliance to vehicle safety and to provide the data required for the validation of dynamic lateral rail stiffness models.

Finally, the track geometry was measured using several distinct methods, providing data to assess the accuracy and limitations of the commonly used track geometry survey cars. This could provide further information pertaining to the validity of the present descriptors used in the Track Safety Standards.

7.4 MODEL VALIDATION

A principal objective of the PTT was to supply data for the validation of the various dynamic models of locomotives. The data could be used to refine the models and to determine the regimes for which each is adequate.

The limitations of linearization procedures and the refinements which may be made might be investigated by comparing the model's predicted response with the actual response. The relative importance of lateral rail stiffness and of detailed vehicle component modeling could be identified.

The process by which these models are validated would be an important result of the PTT alone. If any modeling is used for SAFE, a standardized procedure for validating and refining computer models from test data is essential.

7.5 VEHICLE PARAMETER SENSITIVITY

During the PTT, a tremendous amount of data was collected addressing relatively specific objectives. These include the experiments to determine the effect of locomotive position and orientation, sand, grease, various shock absorber configurations, and restricted coupler freedom. With the extensive truck component instrumentation on the SDP-40F, the data is available to investigate what modal elements most contribute to vehicle response in different operating regimes. Such information can help in understanding the mechanics of truck curving and dynamic response, contributing to future improvements in locomotive design.

7.6 COMPARISONS OF VEHICLE PERFORMANCE

Finally, the data could be used to compare a wide variety of vehicle and truck designs. Some of the more interesting comparisons which might be made are:

- E-8 versus SDP-40F locomotives.
- Four-axle versus six-axle locomotives.
- 100 ton hopper cars versus tank cars versus TOFC.
- Loaded versus unloaded characteristics of the above freight vehicles.

- Statistical characterizations of the range of performance to be expected from nominally similar freight vehicles.
- Effect of different trucks, suspensions, or wheel profiles on otherwise similar freight vehicles.
- T-5 versus T-7 versus baggage car to investigate passenger-type vehicles.
- Performance comparison of above passenger-type vehicles versus the different freight vehicles.
- Sensitivity of above vehicles to various operating conditions and track parameters.

There are, obviously, radical differences in the above vehicle designs and responses. Assessing these differences should be of considerable use to future truck and vehicle designers. In addition, the measurements taken periodically of the freight vehicles will be useful in defining the validity and usefulness of routine inspections.

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3. ENSCO, Inc., "SDP-40F Test Series Conducted Between March 16 and April 13, 1976, on the ICG Railroad: Summary of Comments and Conclusions," prepared for AMTRAK (May 1976).

4. Southern Pacific Transportation Company, Technical Research and Development Department, "Dynamic Performance of the HTC Suspension System Under 6-Axle Locomotives," (July 1977).

5. R.T. Yoshino and K.R. Smith, "AMTRAK SDP-40F Derailment Tests on the Burlington Northern Railroad," General Motors Corporation, Electro-Motive Division, Report No. 898-77-200 (December 1977).

6. P. Tong, R. Brantman, R. Greif, and J. Mirabella, "Tests of the AMTRAK SDP-40F Train Consist Conducted on Chessie System Track," U.S. Department of Transportation, prepared by the Transportation Systems Center for the Federal Railroad Administration, Report No. DOT-TSC-FRA-79/14, FRA/ORD-79/19 (May 1979).

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9. ENSCO, Inc., "Operations Plan for TSD Survey in Support of the Perturbed Track Test at TTC," prepared for FRA (November 1978).

10. Car and Locomotive Cyclopedia, ed.: G.R. Cockle (New York, Simmons-Boardman, 1974), Third Edition, 1012p.

*On file at Structures and Mechanics Branch, Vehicles and Engineering Division, Transportation Systems Center, Cambridge, MA.

11. P.W. Abbott, "Track/Train Dynamics Test Results: HTC Truck Static Test," Vol. I, Martin Marietta Corporation, Denver Division, MRC-77-100 (March 1977).

12. P.W. Abbott, "Track/Train Dynamics Test Results: Swing Hanger Truck," Martin Marietta Corporation, Denver Division (Report in Progress).

13. R.A. Vanstone, "Perturbed Track Test Data Acquisition Instrumentation Systems Handbook," available at DOT/TSC (December 1978).

14. R.A. Vanstone, "Perturbed Track Test Onboard Wayside Wheel-Rail Force Measurement Systems Comparison and Evaluation," available at DOT/TSC (February 1979).

APPENDIX A

PHOTOGRAPHIC RECORDS

An important aspect of the Perturbed Track Test was the use of motion pictures and video and still photography to document the conduct of the test. The motion picture coverage included sequences of the consists traversing all the test sections, selected sequences of the wayside and onboard data collection and analysis operations, and sequences of the consist taken with a camera mounted at rail height on the data acquisition vehicle.

The video coverage was intended to record, through the use of split screen techniques, the lead instrumented axle motion on the rail with a view of the simultaneously recorded lateral force as displayed on a brush chart. Due to many problems, including power requirements and the severe dynamic environment, very few clear, usable sequences have been retrieved.

Finally, still photography was used extensively to visually record the principal aspects of the PTT. The following pages present a selection of the pictures.

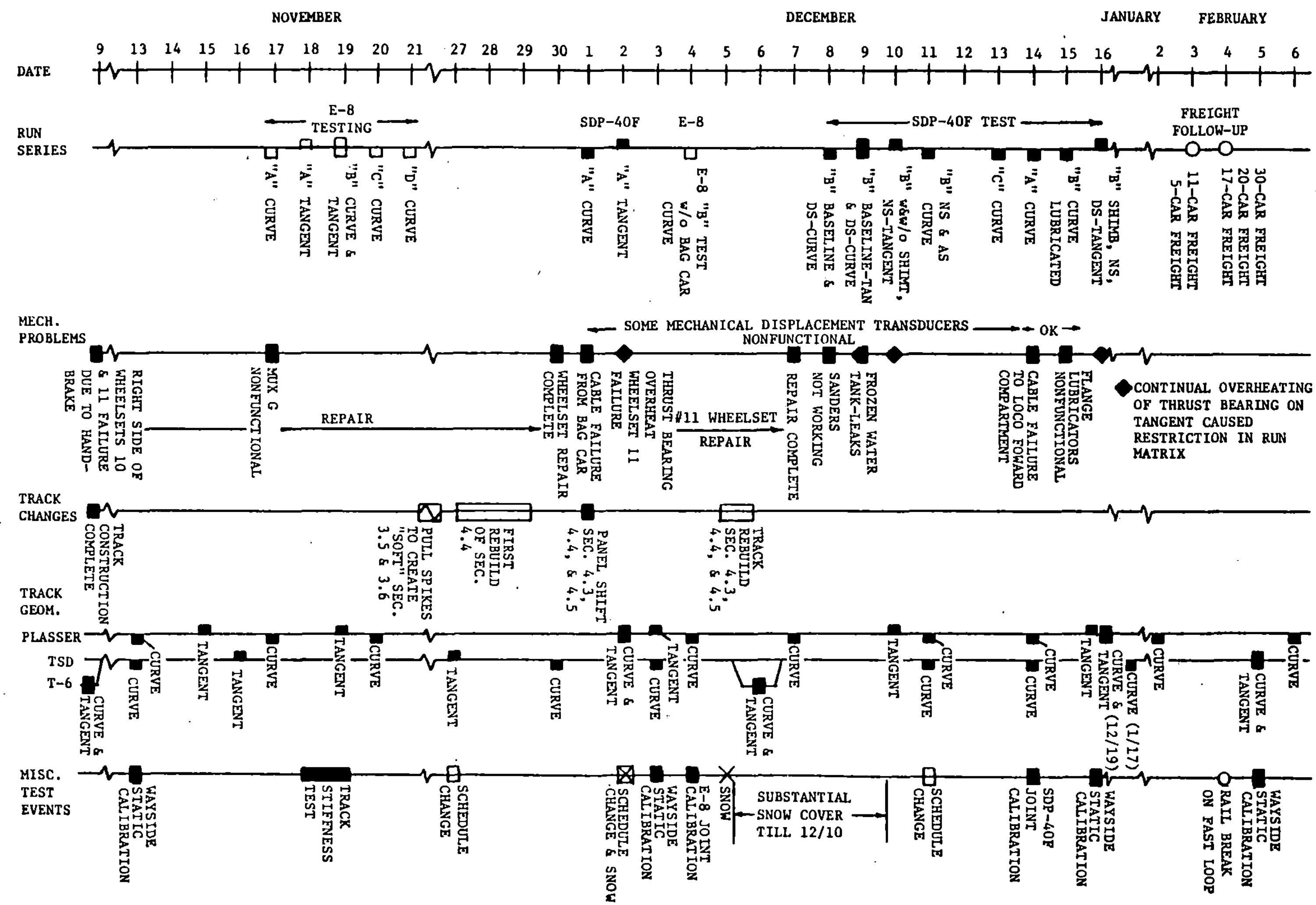
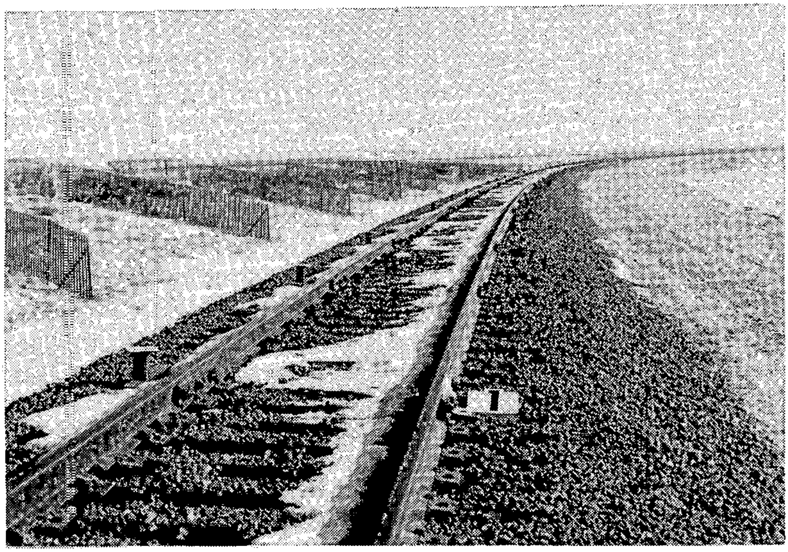
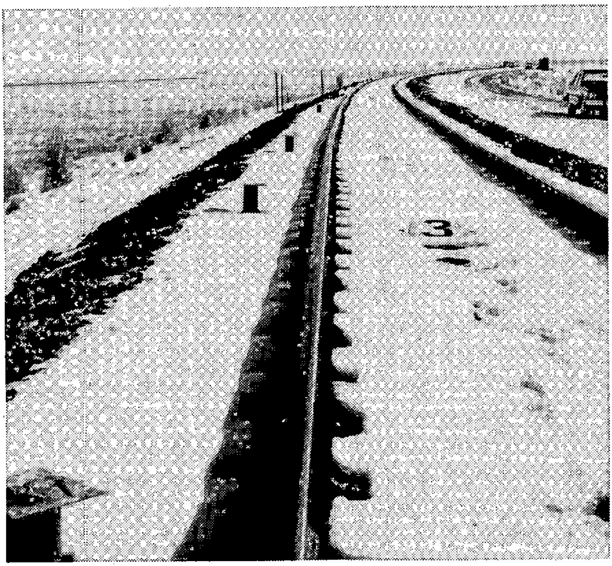


FIGURE A-1. DATELINE OF TEST EVENTS

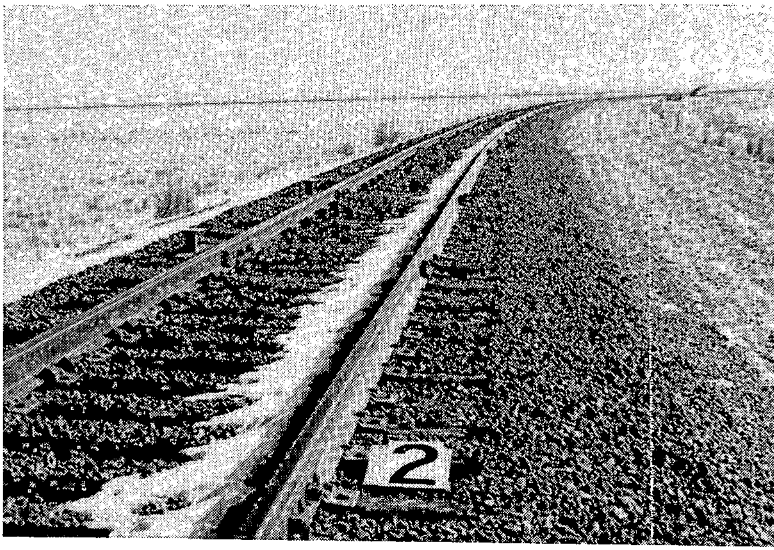
I. TRACK LAYOUT



1. SECTION 1 - PIECEWISE LINEAR CROSSLEVEL PERTURBATION ON CURVE

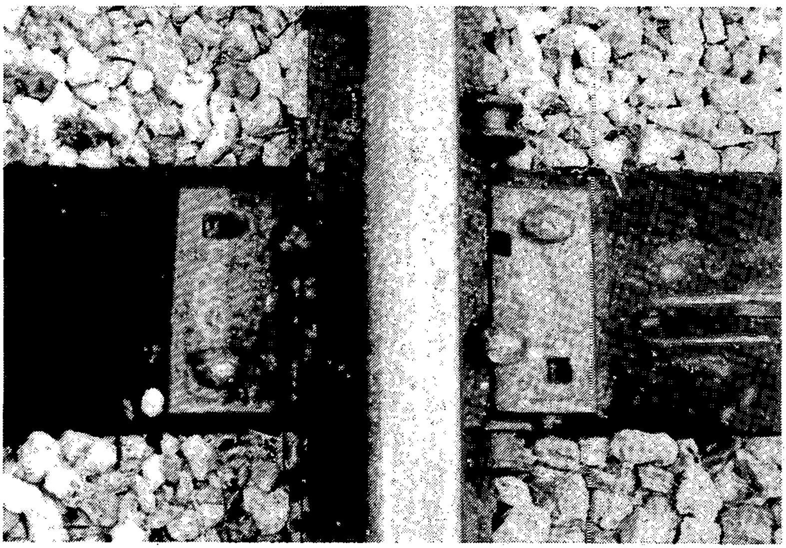


3. SECTION 3 - RECTIFIED SINE ALIGNMENT PERTURBATION ON CURVE

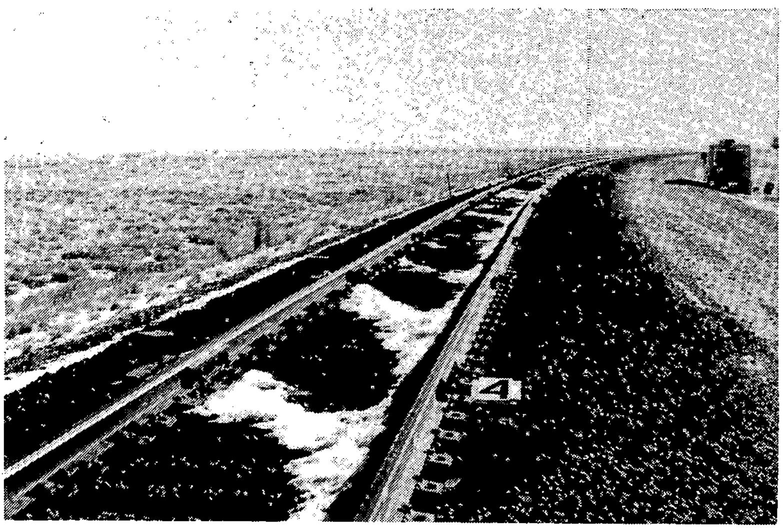


2. SECTION 2 - PIECEWISE LINEAR ALIGNMENT PERTURBATION ON CURVE

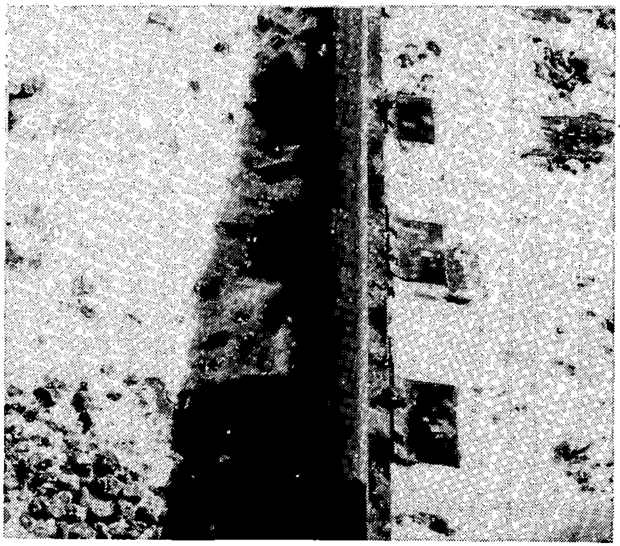
4. TELEPHOTO VIEW OF SECTION 3



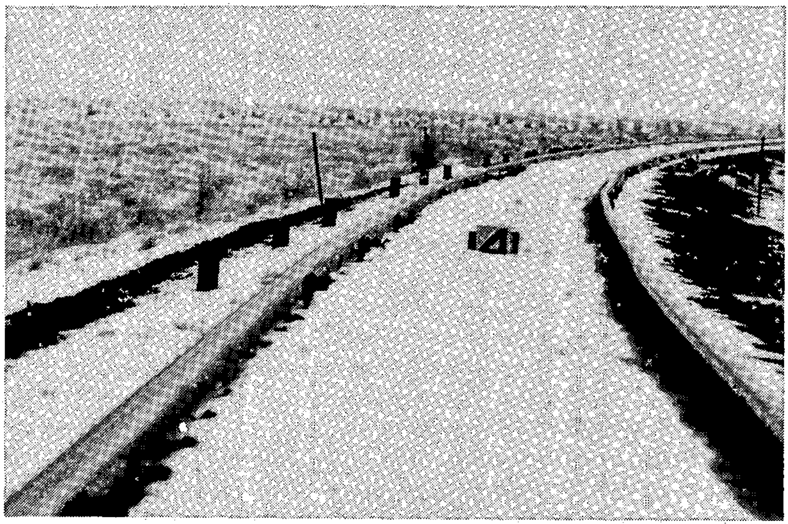
5. NORMAL SPIKING PATTERN FOR "STIFF" TRACK



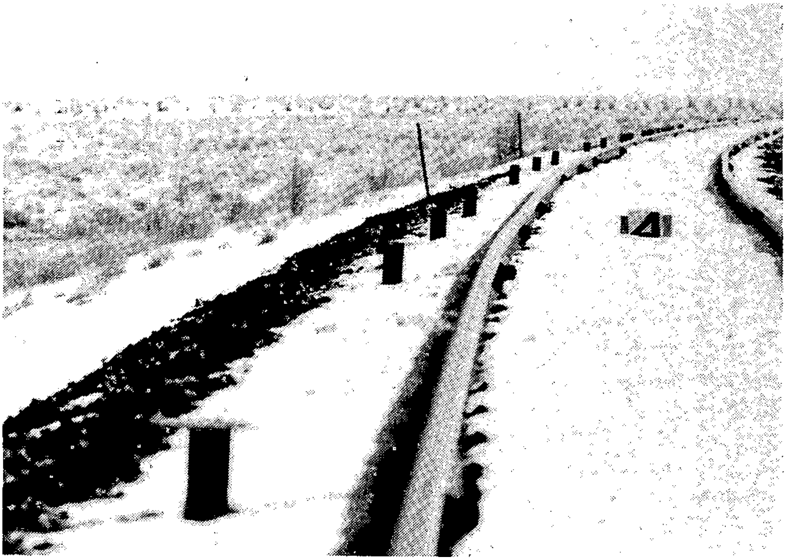
7. SECTION 4 - COMBINED PIECEWISE LINEAR CROSSLEVEL AND ALIGNMENT PERTURBATION ON CURVE



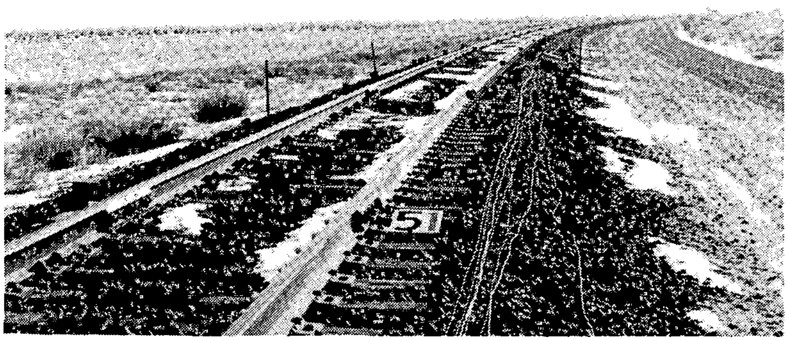
6. SPIKING PATTERN FOR "SOFT" TRACK SECTION 3



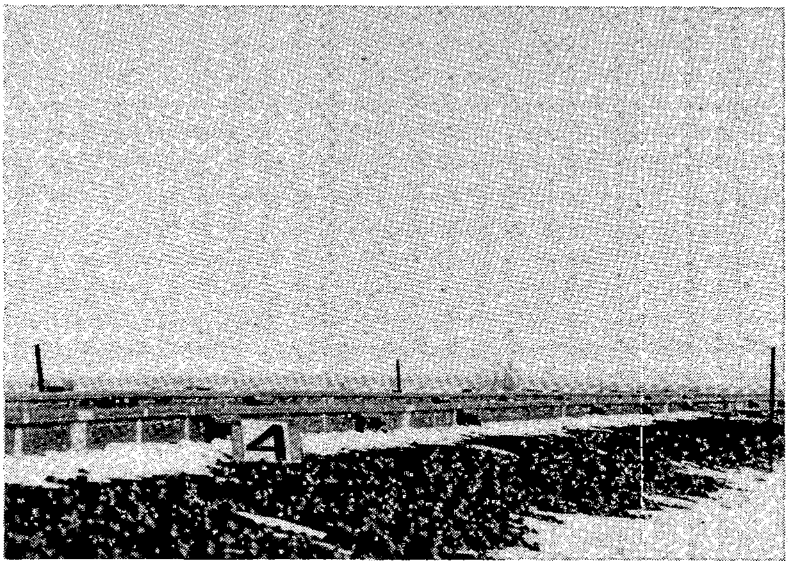
8. TELEPHOTO VIEW OF SECTION 4 SHOWING ALIGNMENT PERTURBATION



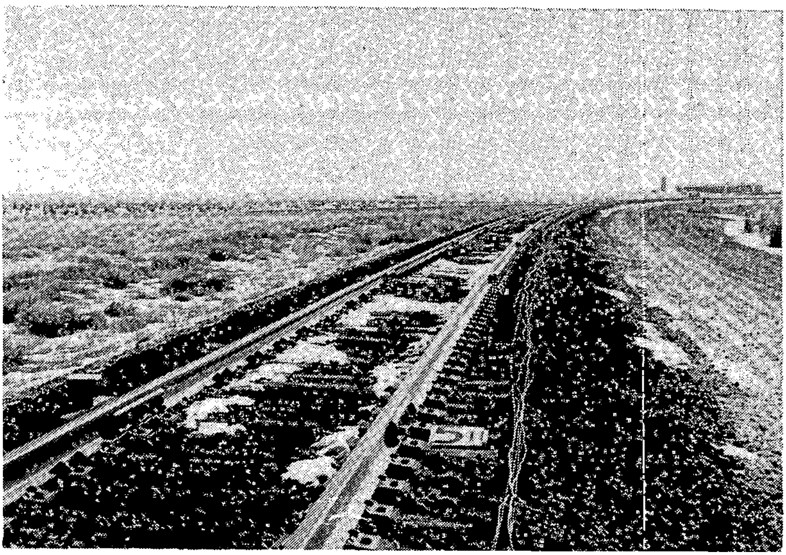
9. TELEPHOTO VIEW OF SECTION 4 SHOWING HIGH RAIL ALIGNMENT PERTURBATION



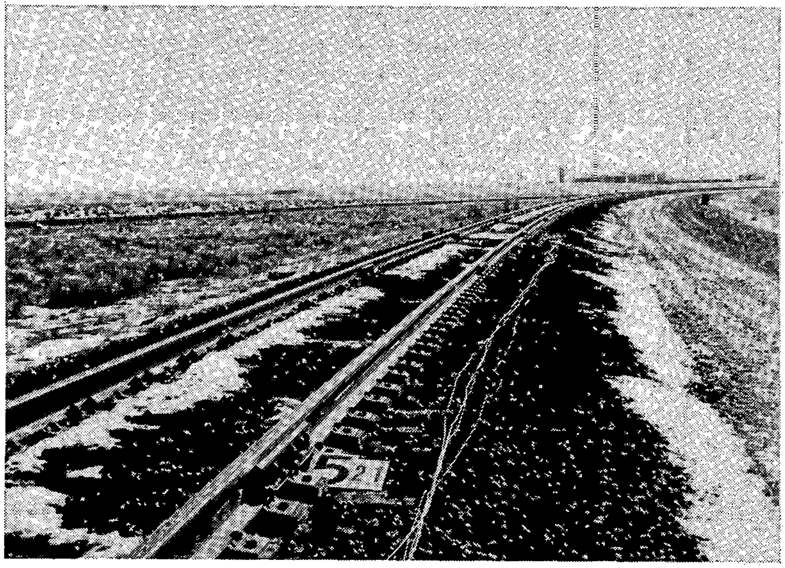
11. SECTION 5.1 - RECTIFIED SINE HIGH RAIL MISALIGNMENT PERTUBATION WITH NOMINAL 3" SUPERELEVATION ON CURVE



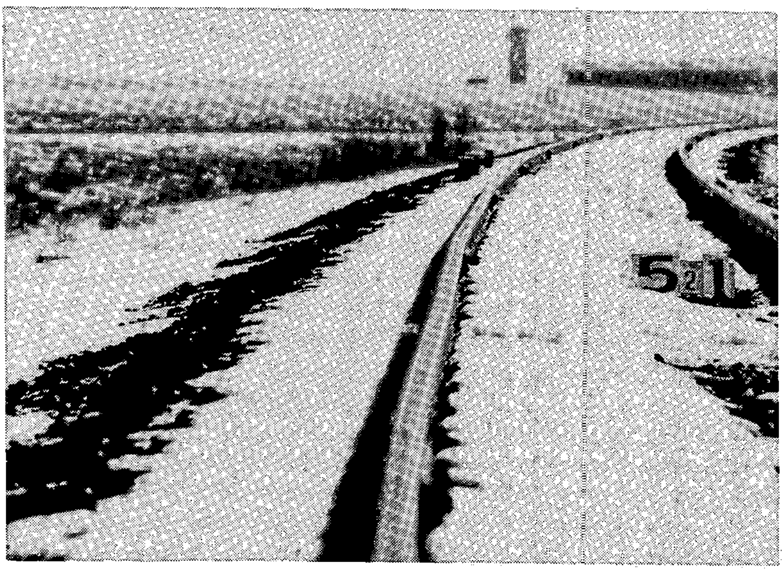
10. TELEPHOTO VIEW OF SECTION 4 SHOWING CROSSLEVEL PERTURBATION



12. SECTION 5.11 - RECTIFIED SINE HIGH RAIL MISALIGNMENT PERTURBATION WITH 2" SUPERELEVATION ON CURVE



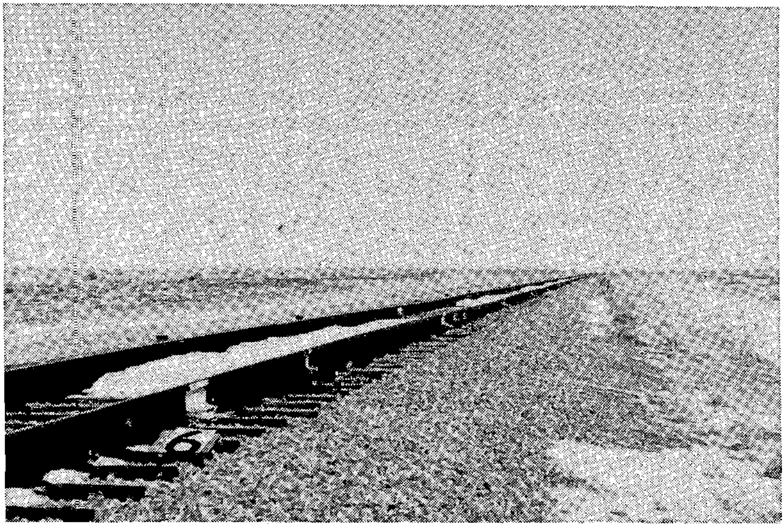
13. SECTION 5.21 - RECTIFIED SINE HIGH RAIL MISALIGNMENT PERTURBATION WITH 1" SUPERELEVATION ON CURVE



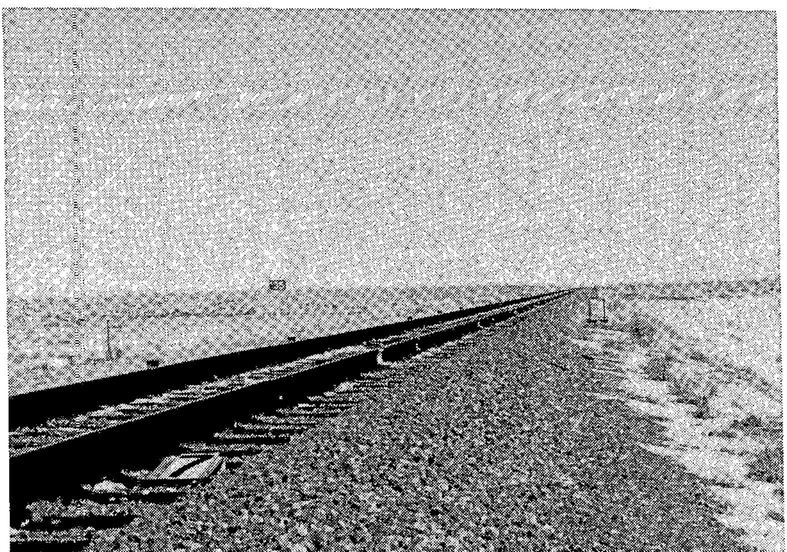
15. TELEPHOTO VIEW OF SECTION 5.21 HIGH RAIL SHOWING ALIGNMENT PERTURBATION

14. SECTION 5.21 - VIEW OF HIGH RAIL ALIGNMENT PERTURBATION, LOW RAIL UNPERTURBED IN ALIGNMENT

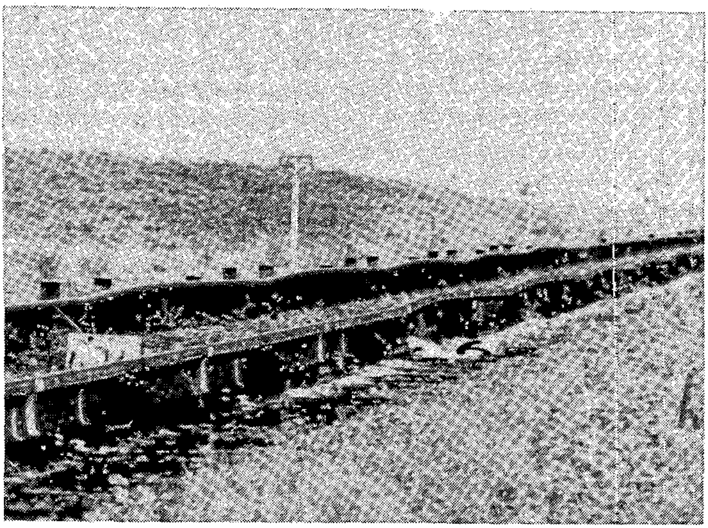
16. SECTION 5.23 - SHOWING 2" SHIMS USED ON LOW RAIL TO REDUCE NOMINAL SUPERELEVATION TO 1"



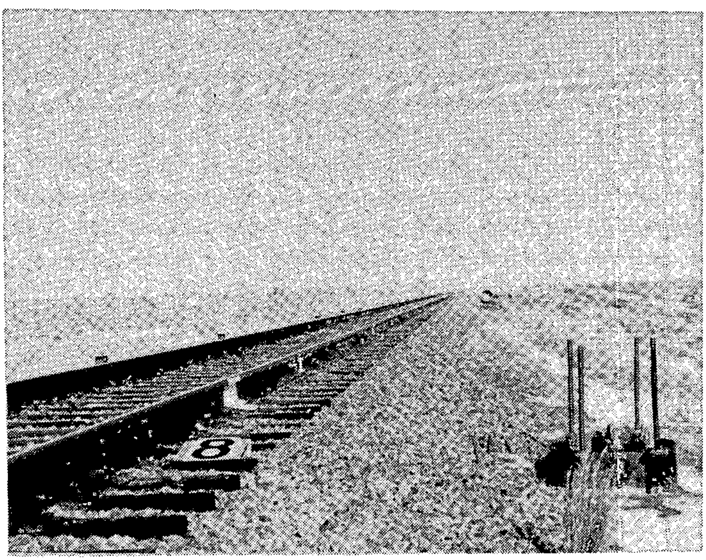
17. SECTION 6 - PIECEWISE LINEAR PROFILE PERTURBATION ON TANGENT



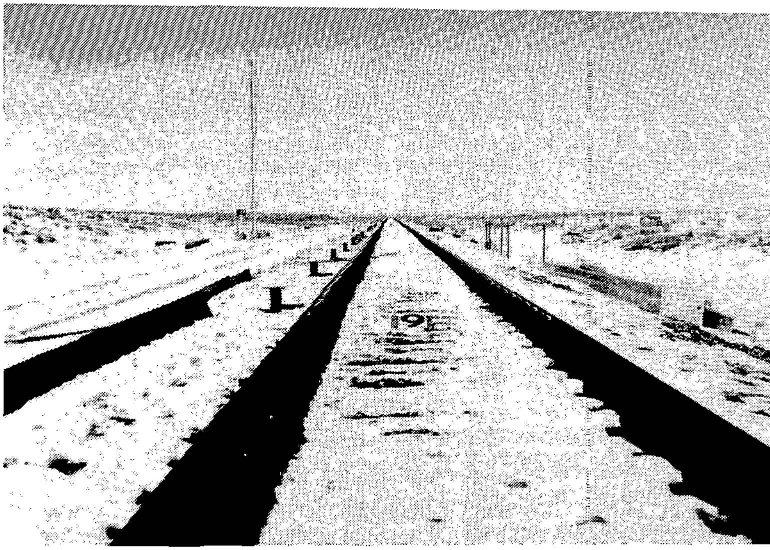
19. SECTION 7 - PIECEWISE LINEAR CROSSLEVEL PERTURBATION ON TANGENT



18. TELEPHOTO VIEW OF SECTION 6 SHOWING PROFILE PERTURBATION

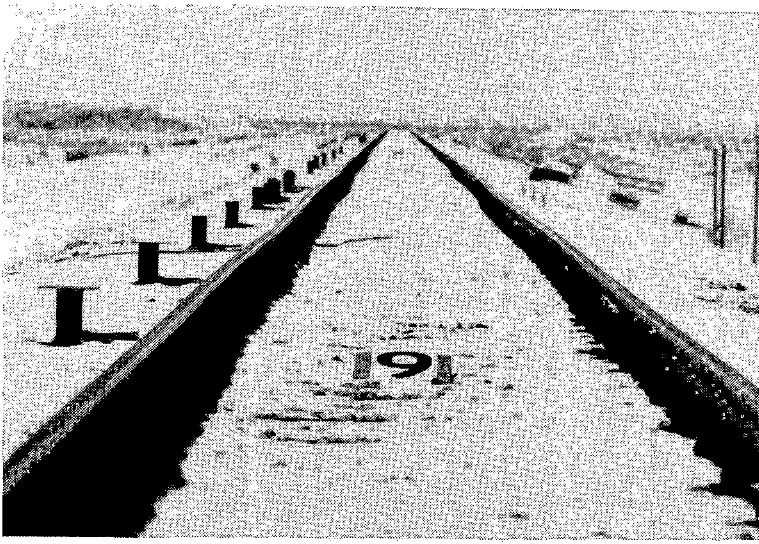


20. SECTION 8 - PIECEWISE LINEAR ALIGNMENT PERTURBATION ON TANGENT

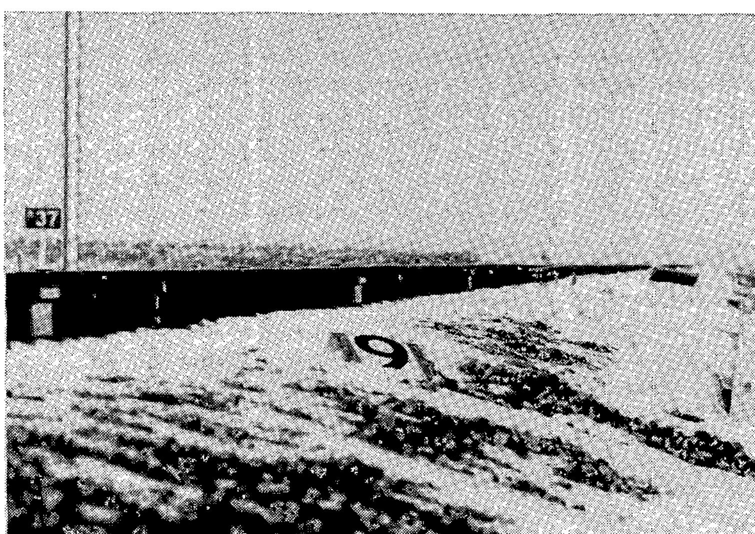


21. SECTION 9 - COMBINED PIECEWISE LINEAR CROSSLEVEL AND ALIGNMENT PERTURBATION ON TANGENT

23. TELEPHOTO VIEW OF SECTION 9 SHOWING RIGHT RAIL ALIGNMENT PERTURBATION



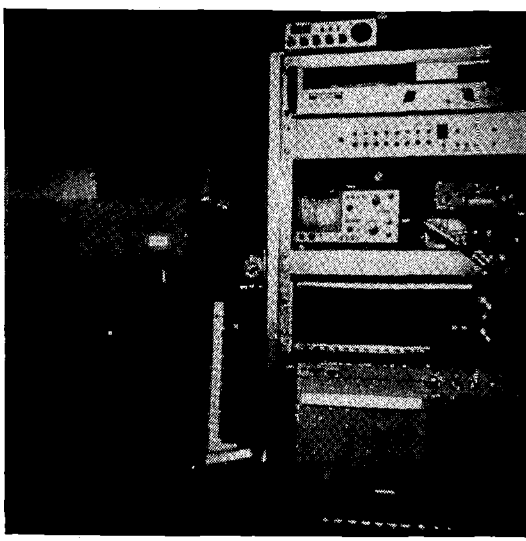
22. TELEPHOTO VIEW OF SECTION 9 SHOWING ALIGNMENT PERTURBATION



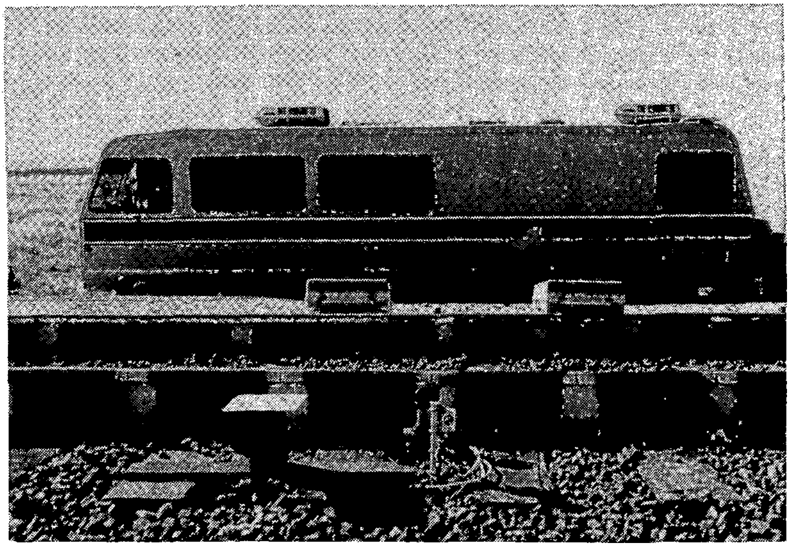
24. TELEPHOTO VIEW OF SECTION 9 SHOWING CROSSLEVEL PERTURBATION

II. WAYSIDE INSTRUMENTATION - OVERVIEW

25. BATTELLE WAYSIDE DATA COLLECTION AND PROCESSING MOBILE UNIT



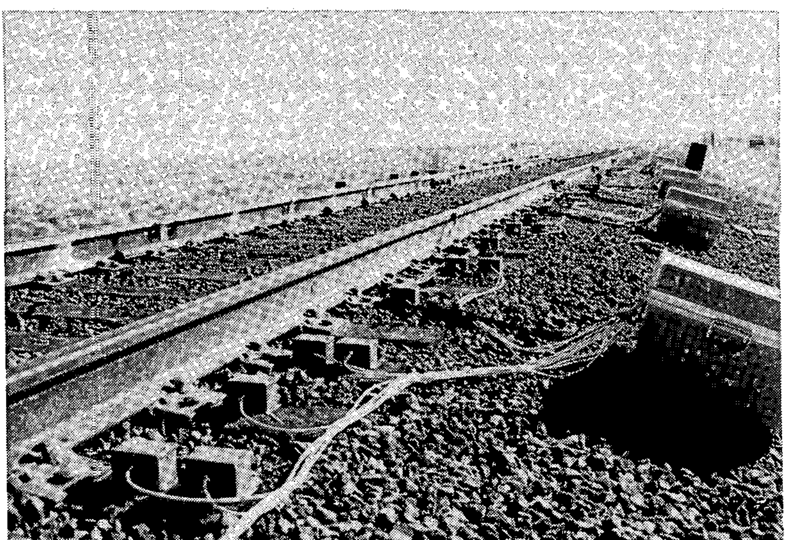
27. PROCESSOR INSIDE BATTELLE MOBILE UNIT



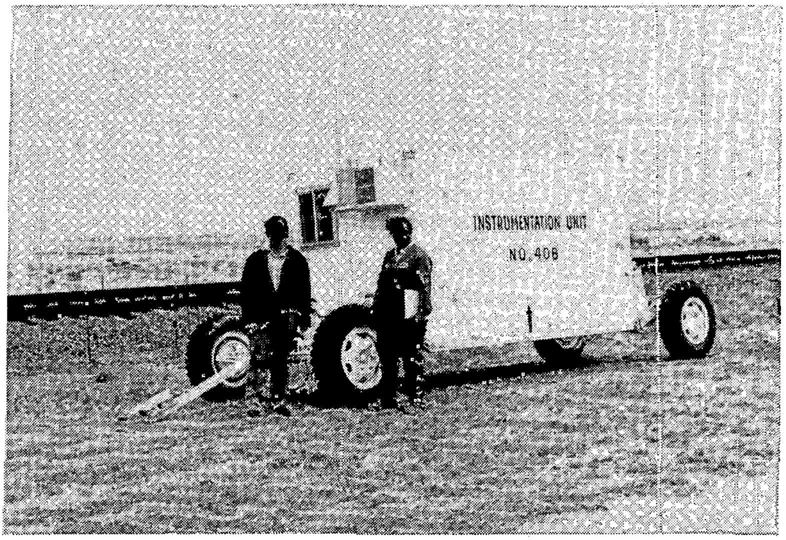
26. LOCATION OF BATTELLE MOBILE UNIT OPPOSITE RAIL DEFLECTION TRANSDUCER IN SECTION 4

28. MONITORING DATA COLLECTION INSIDE BATTELLE MOBILE UNIT

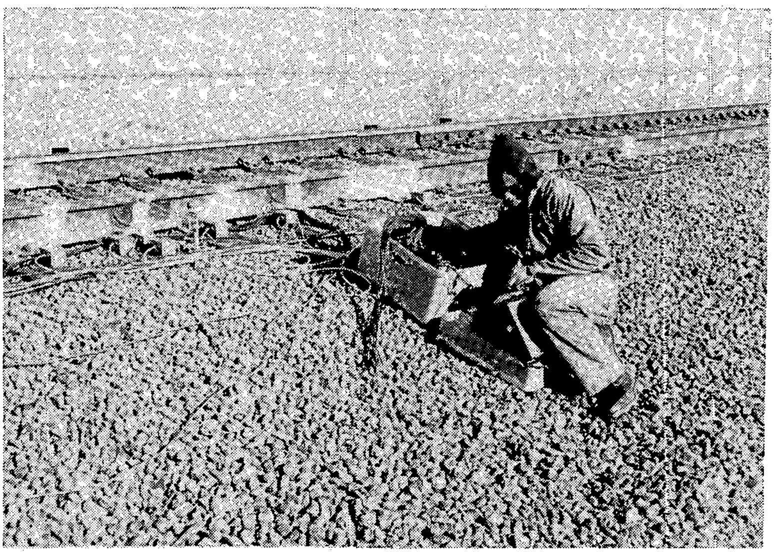
29. DATA REDUCTION INSIDE BATTELLE MOBILE UNIT



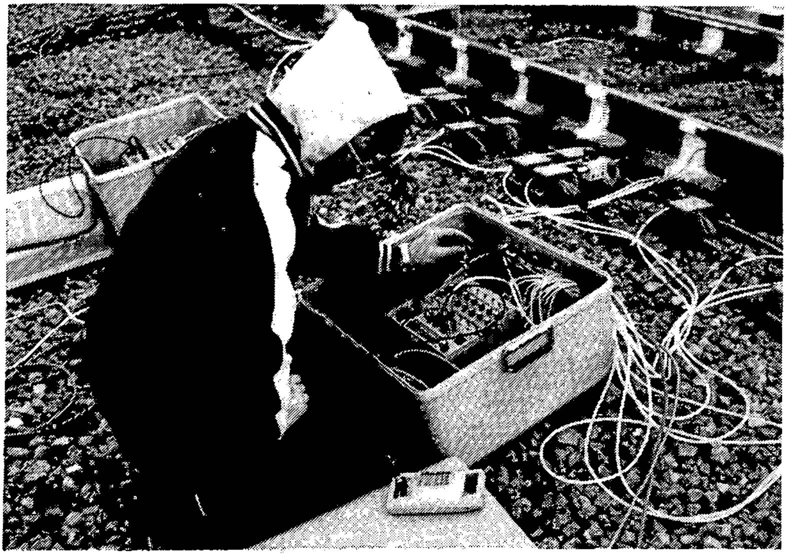
31. OVERVIEW OF WAYSIDE INSTRUMENTATION IN SECTION 4 SHOWING J. BOXES AND MULTIPLEXES (MUX)



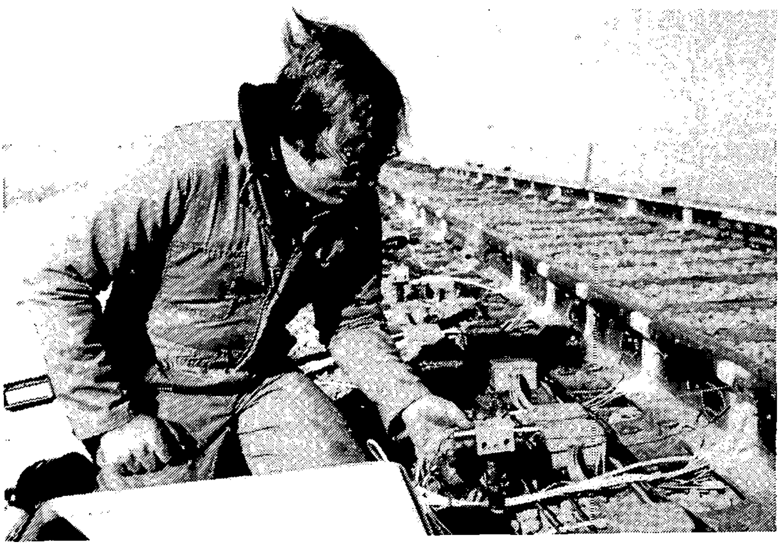
30. TTC DATA COLLECTION UNIT USED IN SECTION 3 FOR MONITORING RAIL DEFLECTIONS



32. CALIBRATING MUX IN SECTION 4



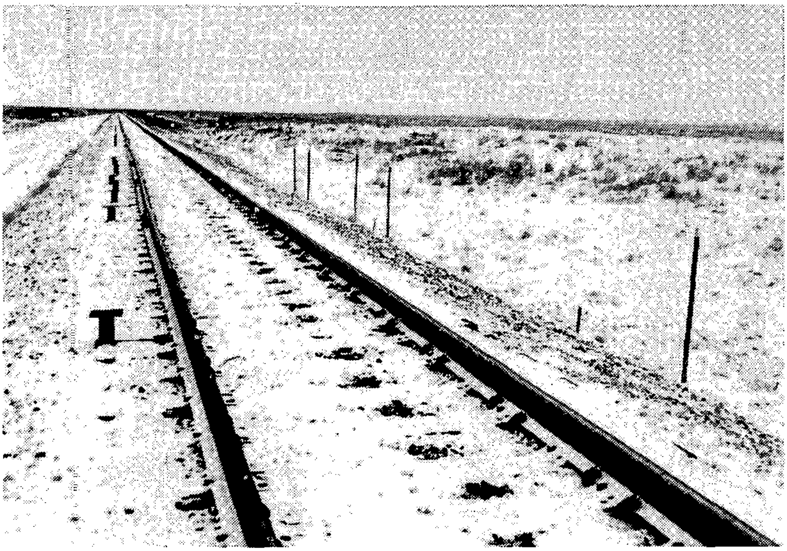
33. DETAIL OF MUX - ELECTRICAL CALIBRATION



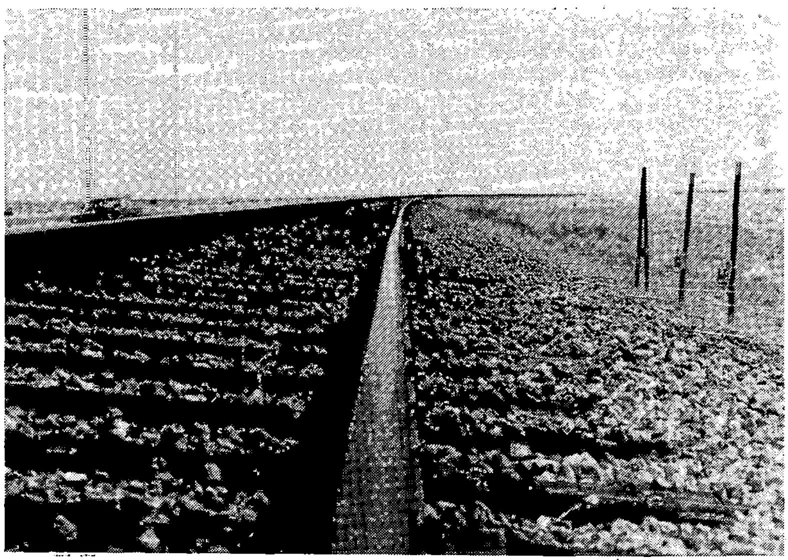
35. ZEROING ELECTRONIC DEFLECTION TRANSDUCER

34. SETTING UP ELECTRONIC RAIL DEFLECTION TRANSDUCER

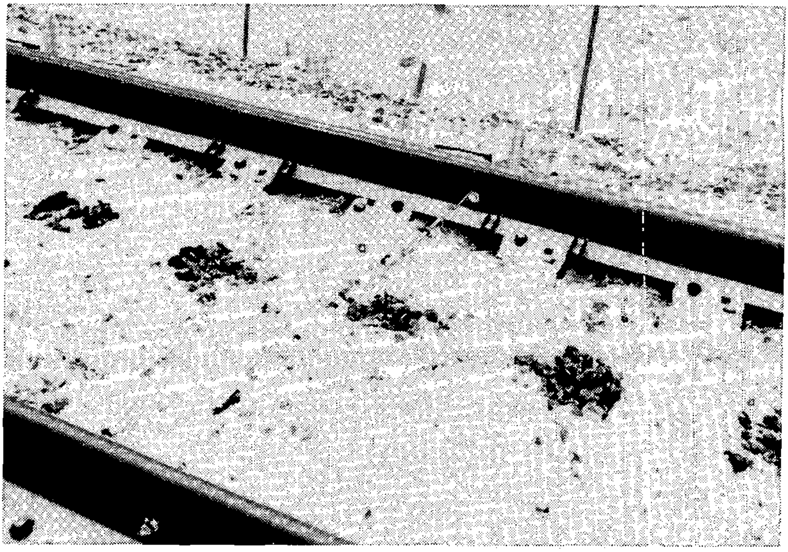
36. SECTION 4 INSTRUMENTATION - MUX, ELECTRONIC DEFLECTION TRANSDUCERS, J. BOXES, FISHSCALES, AND ALD's



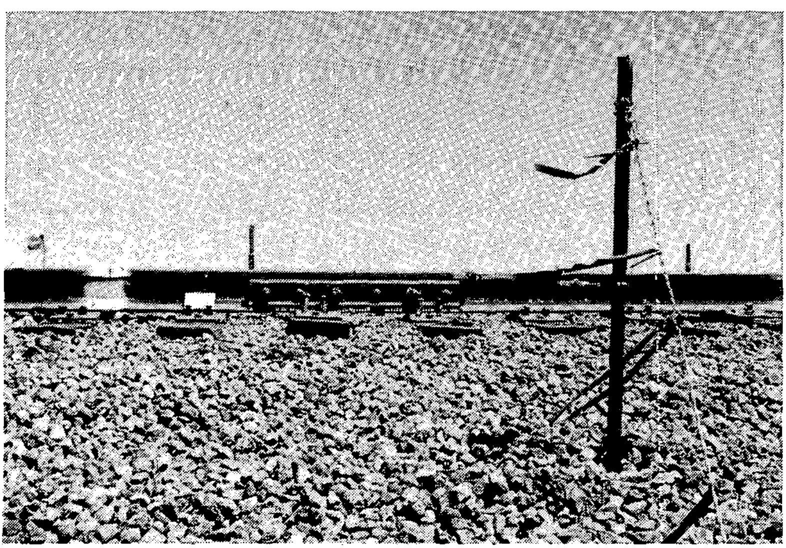
37. SECTION 9 - ALD's AND FISHSCALES



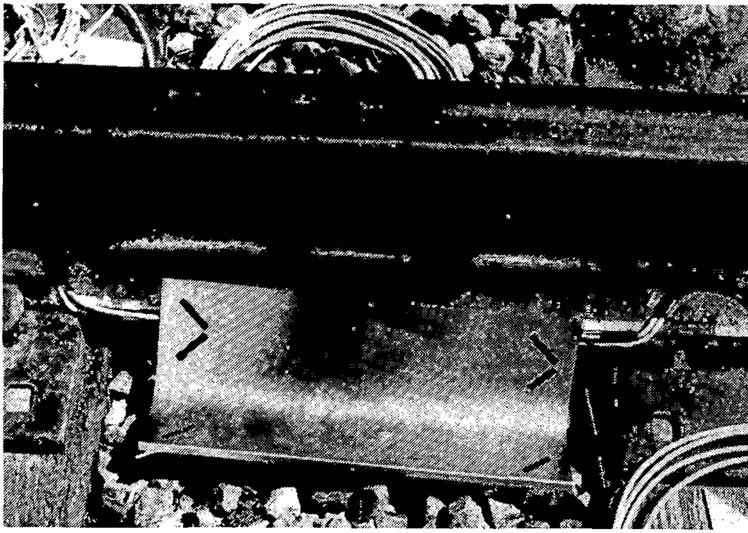
39. FISHSCALE ARRANGEMENT FOR MEASURING TIE SHIFT



38. DETAIL OF FISHSCALE ATTACHMENT FOR MEASURING MAXIMUM DYNAMIC GAGE



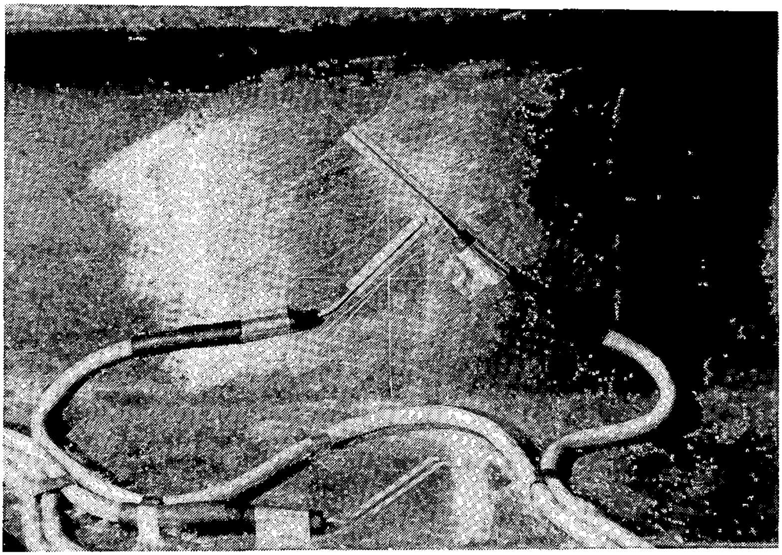
40. FISHSCALE ARRANGEMENT FOR MEASURING RAIL HEAD LATERAL DEFLECTION (USED ON PILOT TEST ONLY)



45. STRAIN GAGE TEMPLATE

47. TACK WELDING STRAIN GAGE TO RAIL BASE

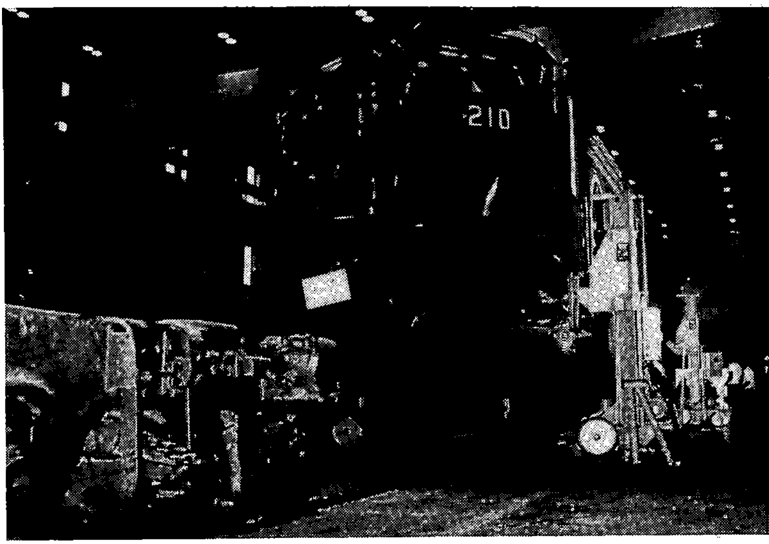
46. ETCHING STRAIN GAGE PATTERN WITH TEMPLATE



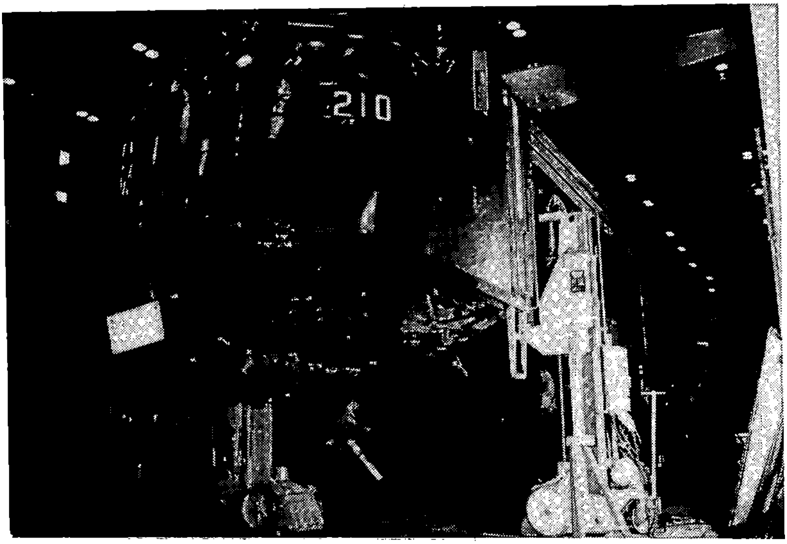
48. DETAIL OF STRAIN GAGES AS INSTALLED

IV. E-8 LOCOMOTIVE AND WHEELSET PREPARATION

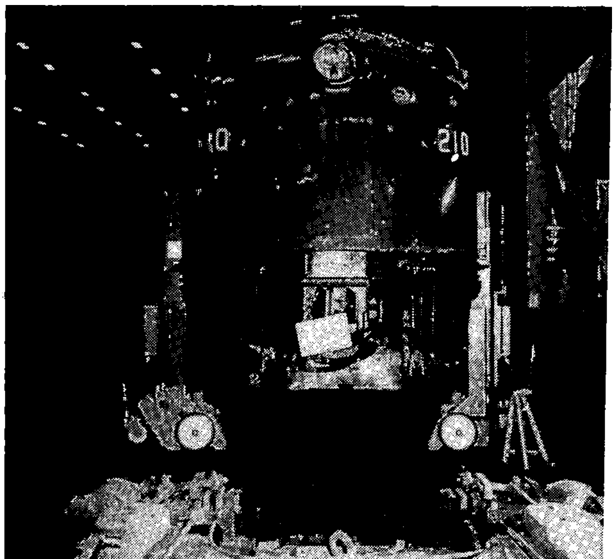
49. E-8 LOCOMOTIVE



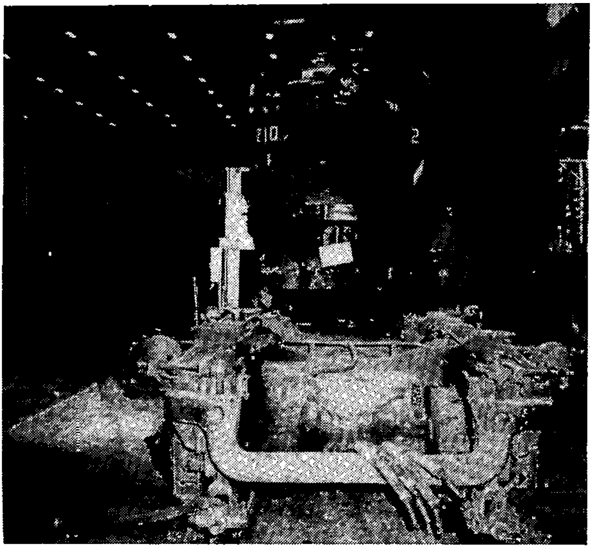
51. E-8 LOCOMOTIVE DETRUCKED



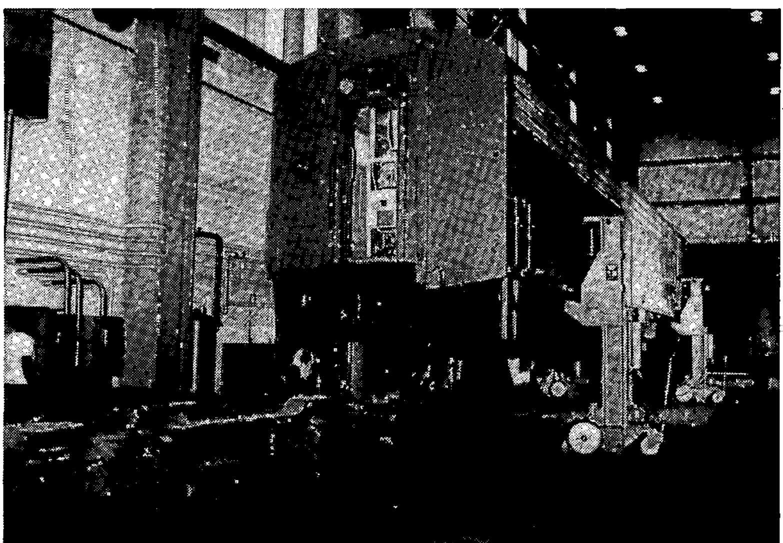
50. DETRUCKING E-8 LOCOMOTIVE FOR INSPECTION AND INSTRUMENTATION PREPARATION



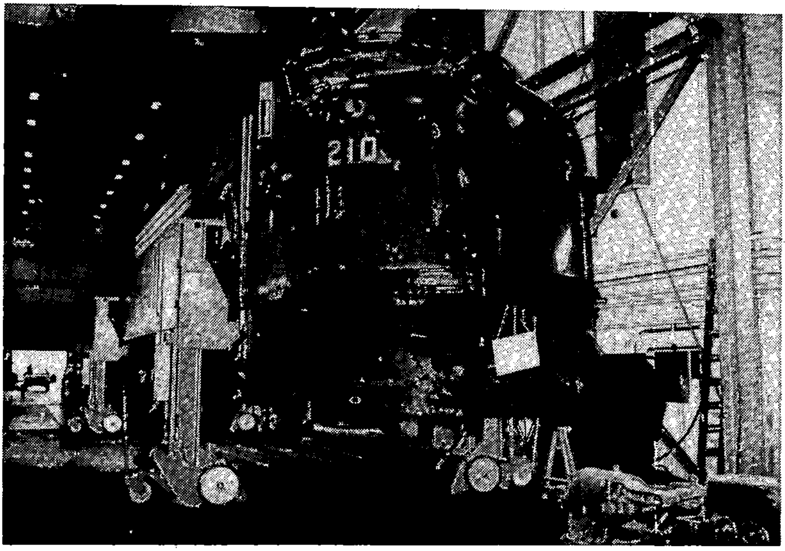
52. FRONT VIEW OF DETRUCKED E-8 LOCOMOTIVE



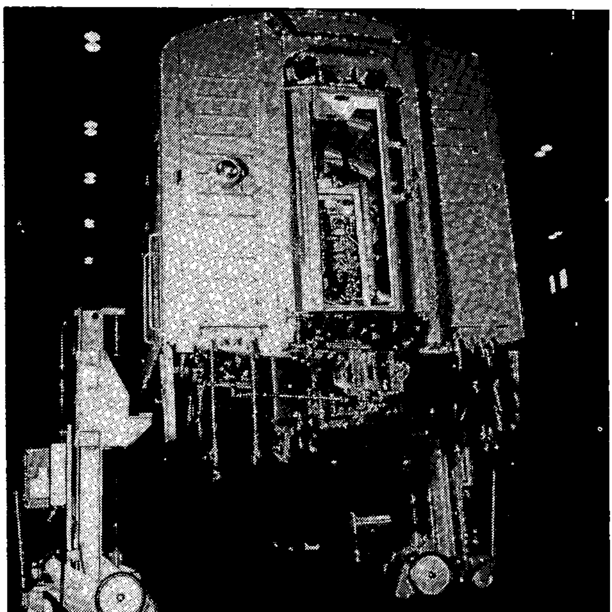
53. INSPECTING E-8 TRUCK



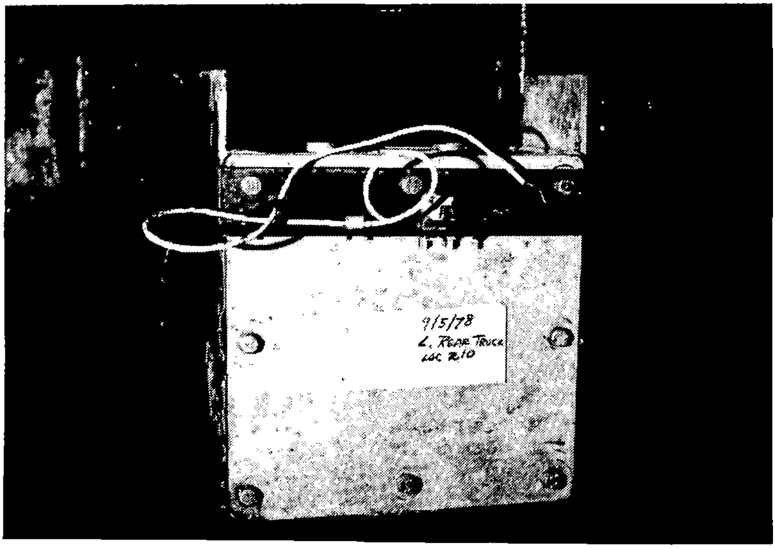
55. DETRUCKING REAR TRUCK OF E-8 LOCOMOTIVE



54. INSPECTING AND PREPARING E-8 LOCOMOTIVE

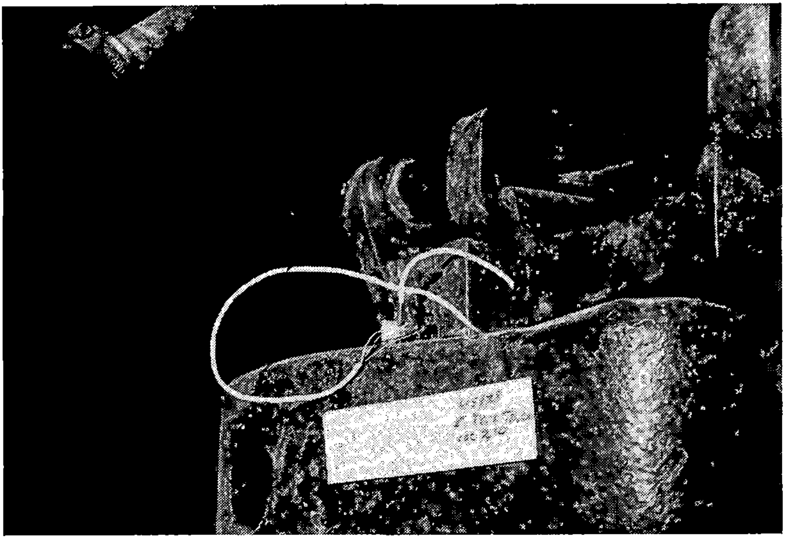


56. REAR VIEW OF DETRUCKED
E-8 LOCOMOTIVE

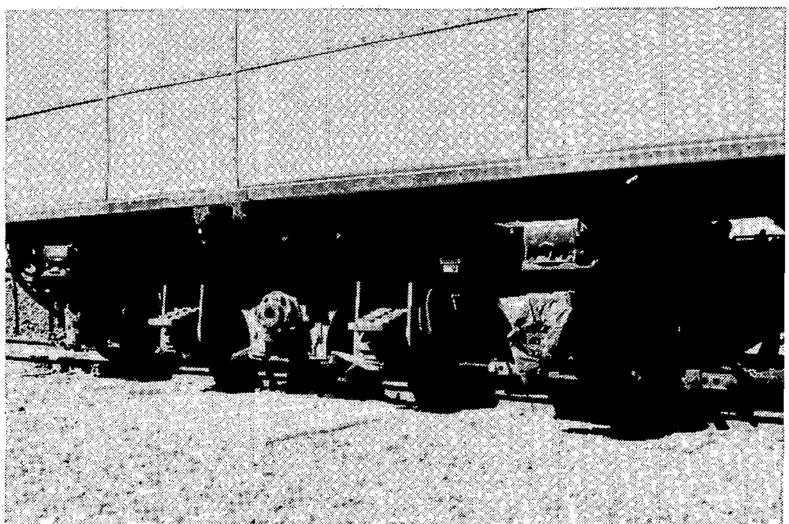


57. E-8 INSTRUMENTED AXLE 10 JUNCTION

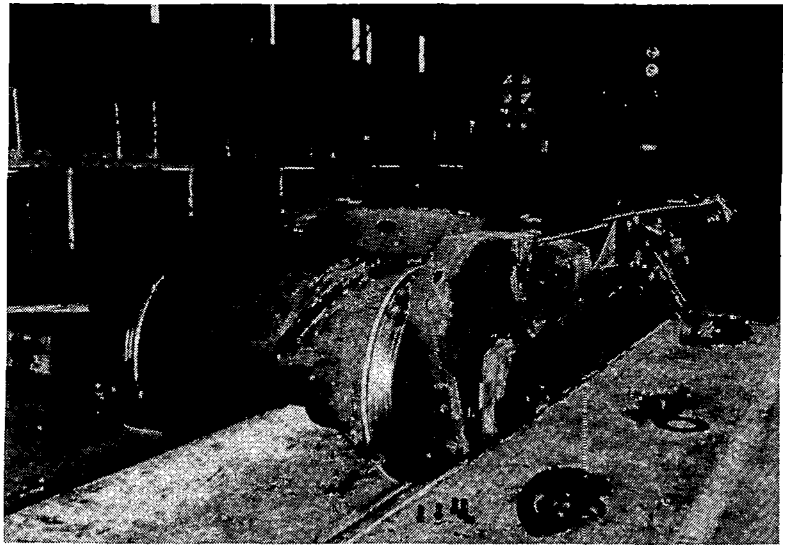
59. E-8 TRUCK YAW STRING POT



58. E-8 TRUCK FRAME INSTRUMENTATION

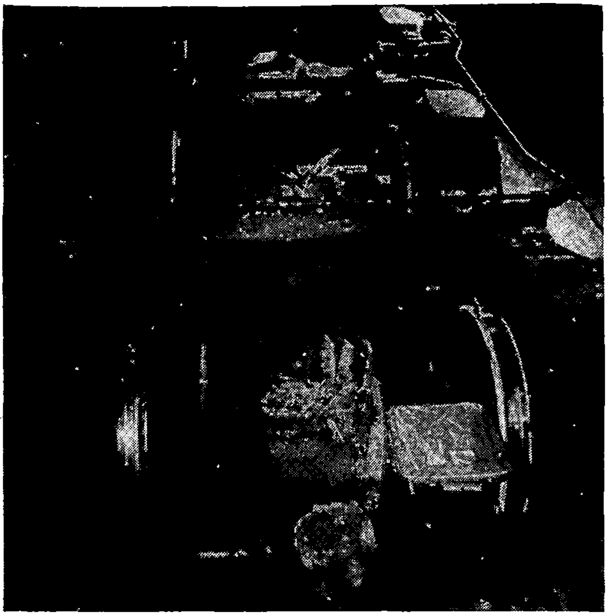


60. E-8 INSTRUMENTED TRUCK SHOWING AXLE 10



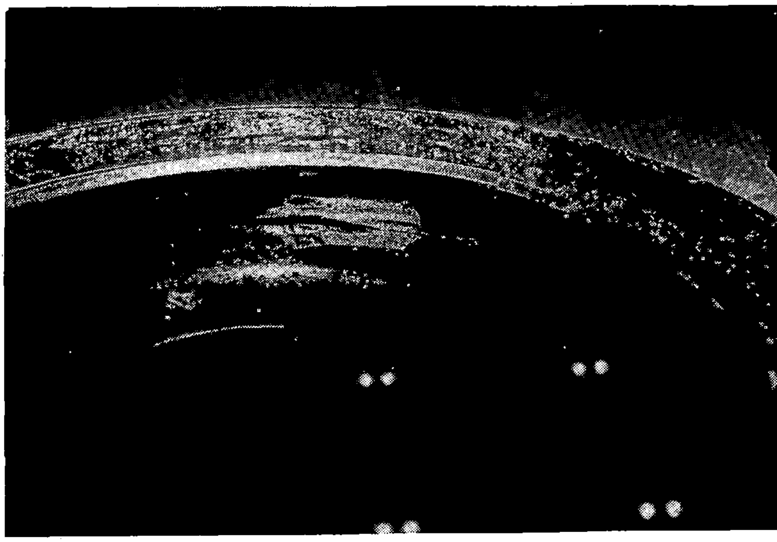
61. SDP-40F TRUCK/LOCOMOTIVE PREPARATION

63. SDP-40F TRUCK BOLSTER

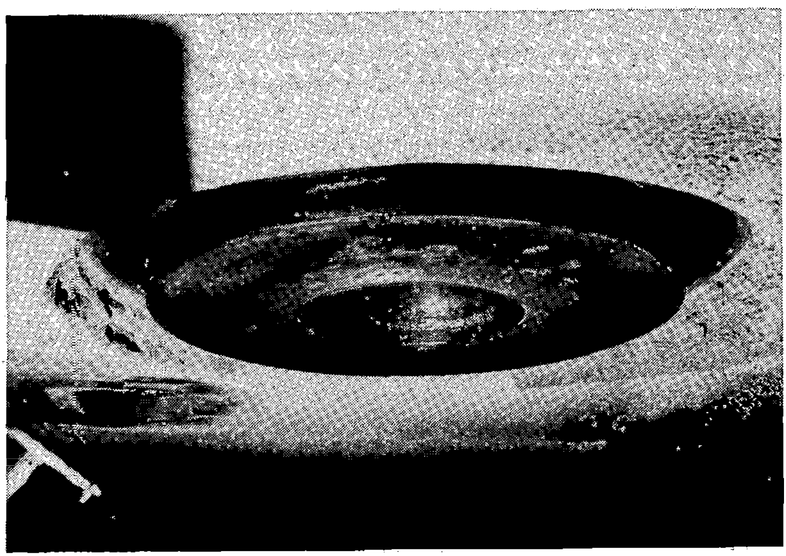


62. SDP-40F TRUCK WITHOUT BOLSTER

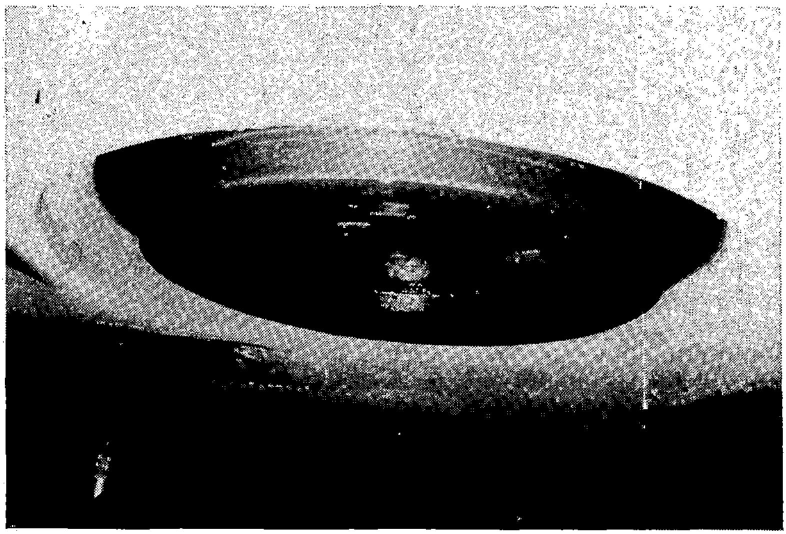
64. SDP-40F BOLSTER CENTER PLATE



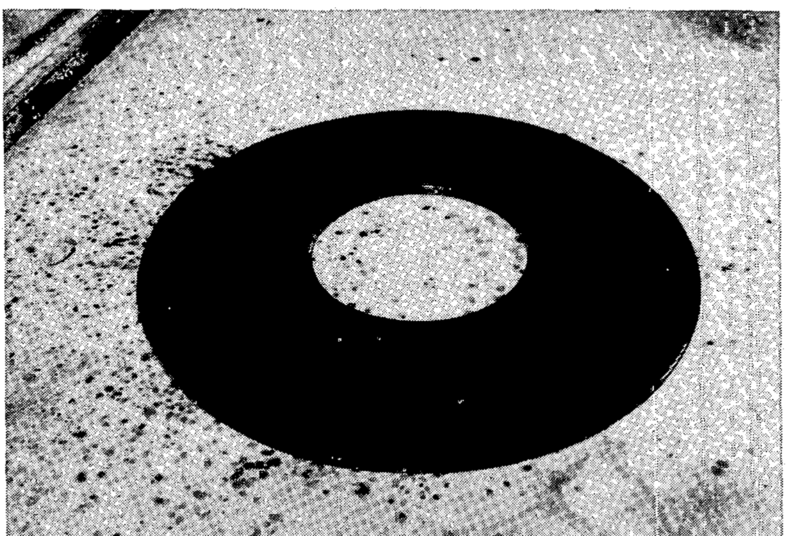
65. DETAIL OF BOLSTER CENTER PLATE



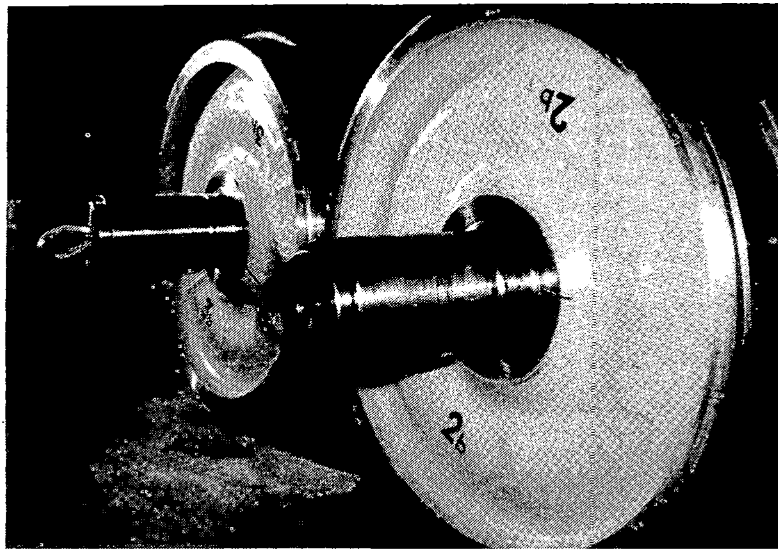
67. CARBODY CENTER PLATE TRAIL END



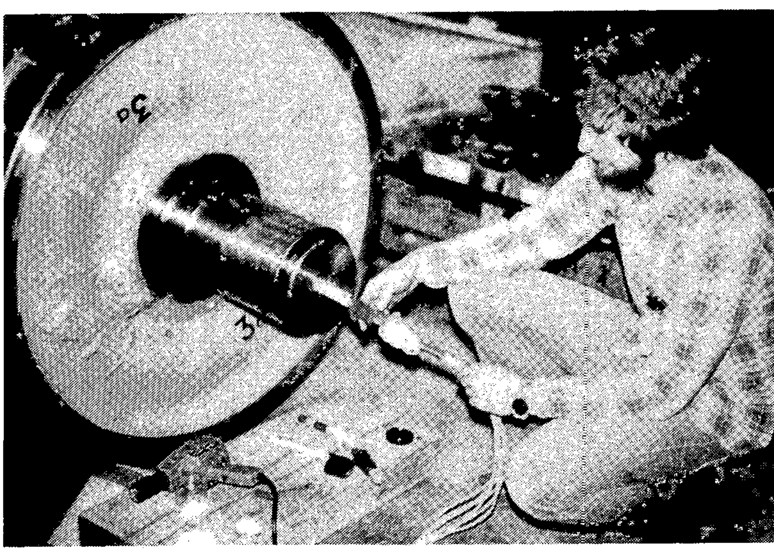
66. CARBODY CENTER PLATE LEAD END



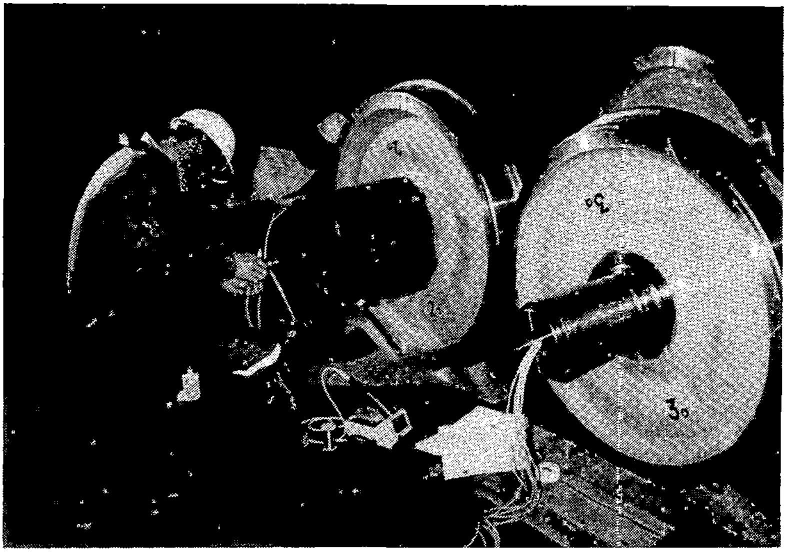
68. CENTER PLATE LINER



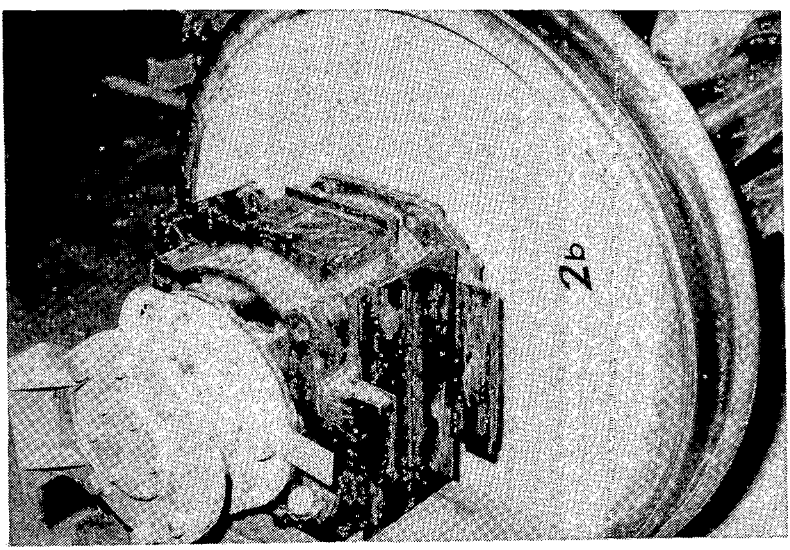
69. ASEA/SJ INSTRUMENTED WHEELSETS 11 AND 12
LEFT SIDE



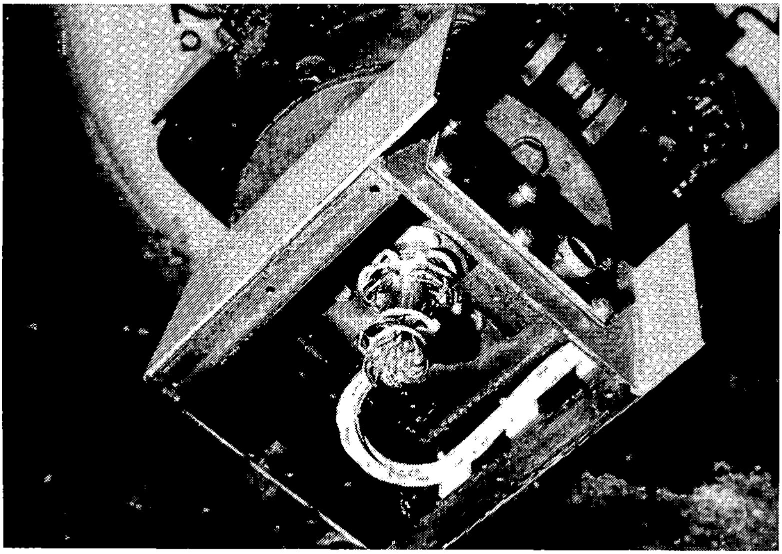
71. INSTRUMENTED WHEELSET 12 SLIP RING
PREPARATION



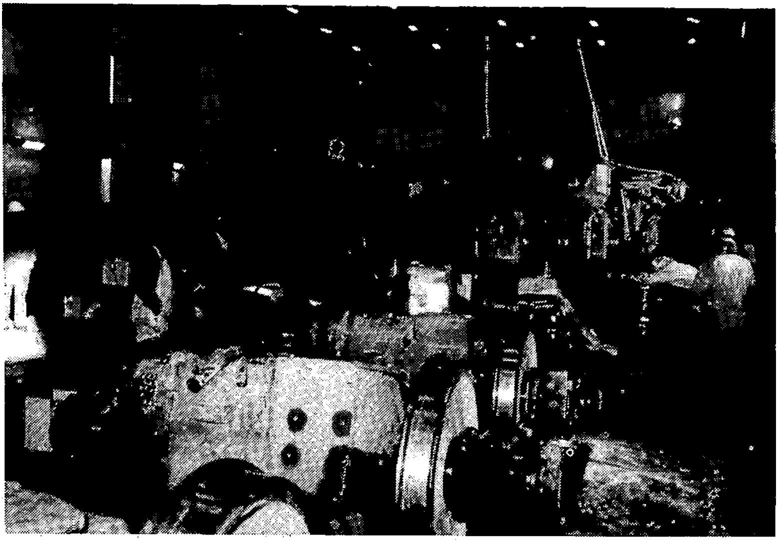
70. ASEA/SJ INSTRUMENTED WHEELSETS 11 & 12
SLIP RING SIDE (RIGHT)



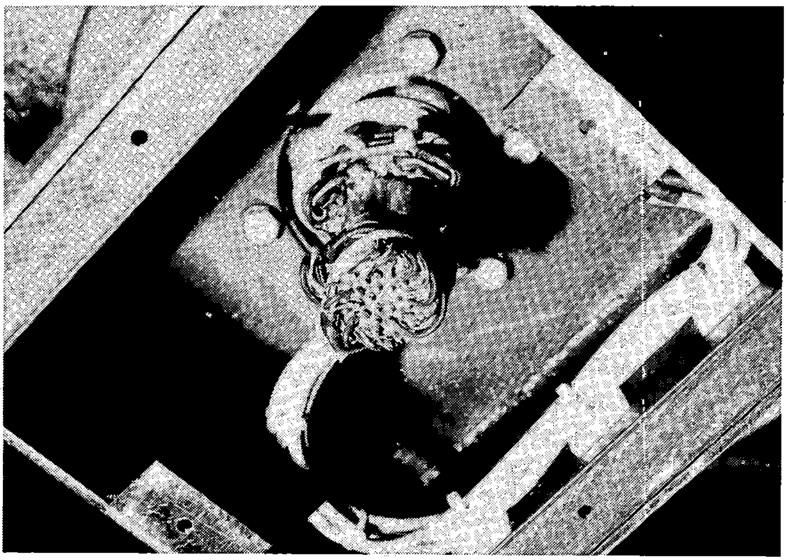
72. INSTRUMENTED WHEELSET 11 WITH JOURNAL
BOX REINSTALLED



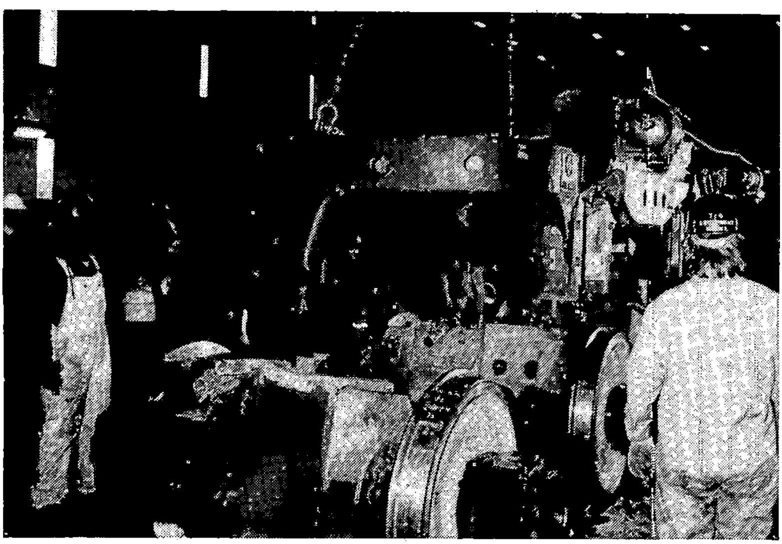
73. SLIP RING ON INSTRUMENTED AXLE



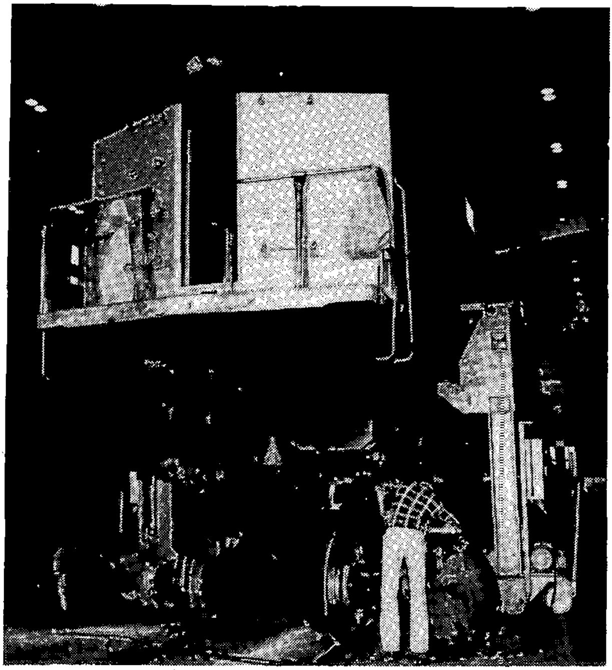
75. POSITIONING SDP-40F TRUCK FRAME PRIOR TO REASSEMBLY



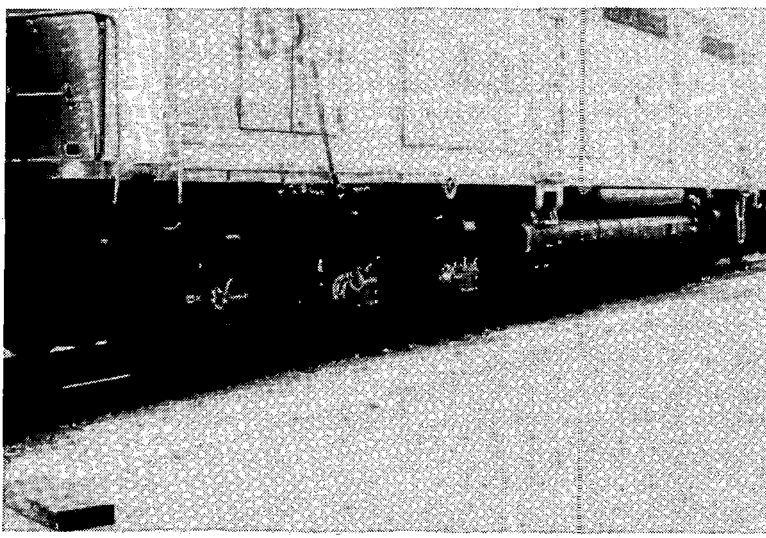
74. DETAIL OF SLIP RING



76. REASSEMBLING SDP-40F INSTRUMENTED TRUCK



77. POSITIONING INSTRUMENTED TRUCK PRIOR TO RETRUCKING



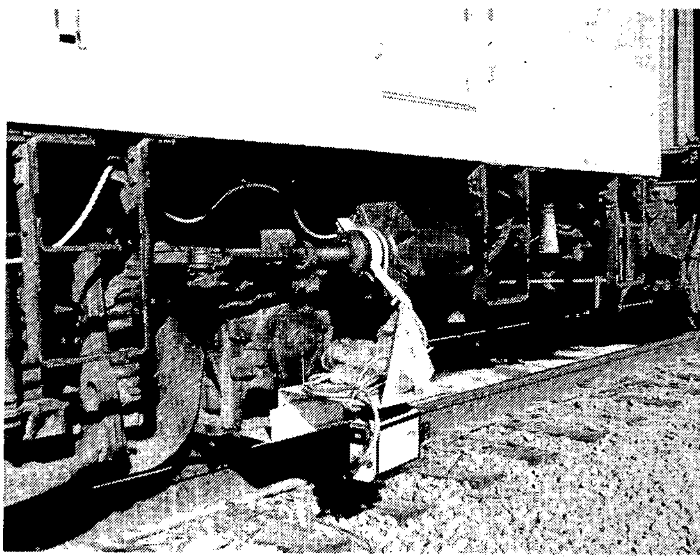
79. SDP-40F LOCOMOTIVE 620 WITH INSTRUMENTED TRUCK - RIGHT SIDE

78. RETRUCKING INSTRUMENTED TRUCK

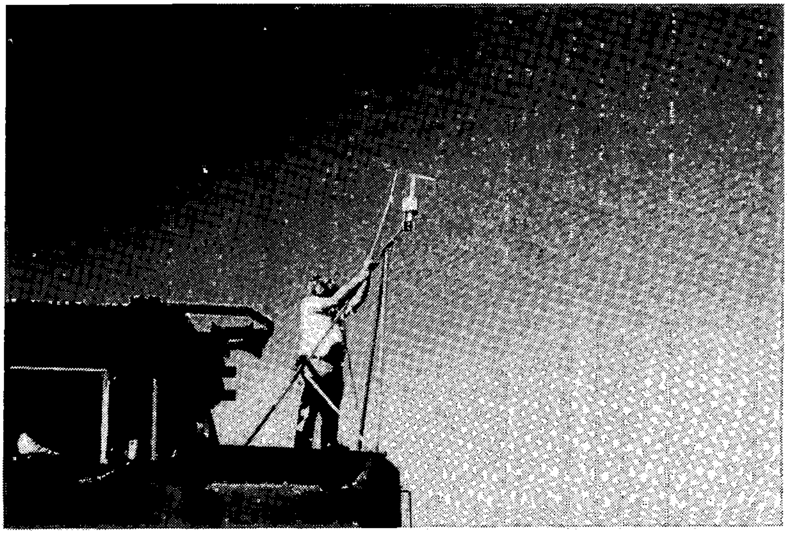
80. ELECTRICAL CALIBRATION OF INSTRUMENTED TRUCK

VI. ONBOARD INSTRUMENTATION (SDP-40F)

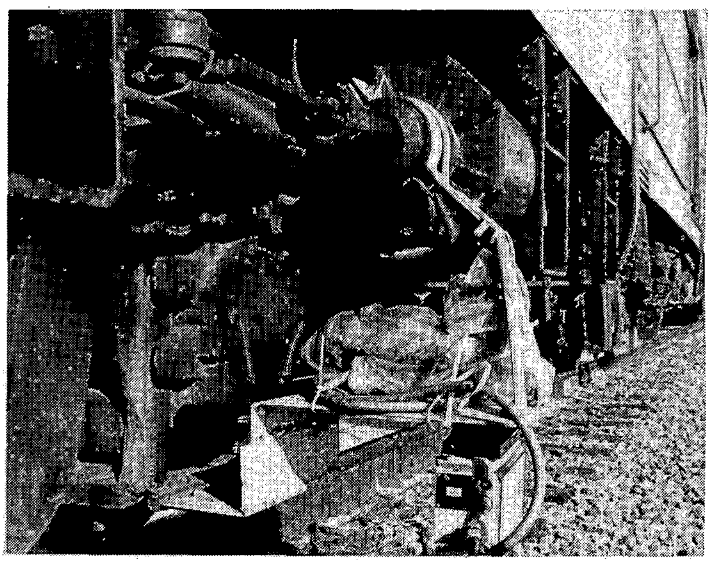
81. SDP-40F SHOWING WIND BOOM AND RIGHT SIDE OF LOCOMOTIVE



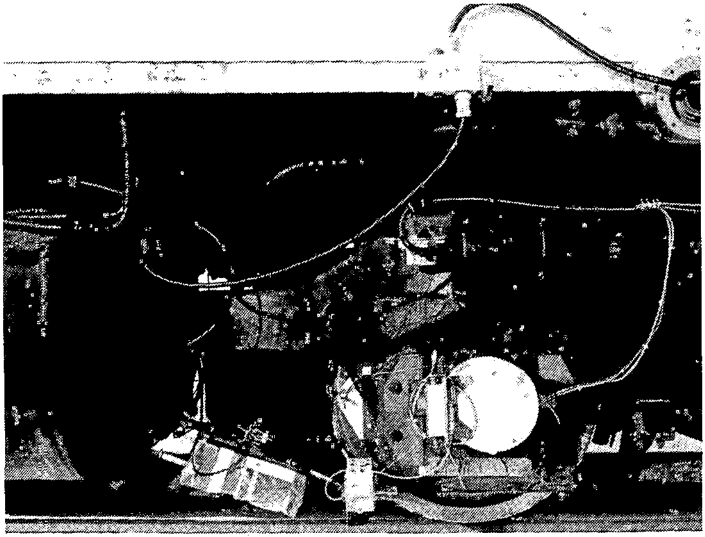
83. CAMERA MOUNTED ON T-7 USED TO VIEW LATERAL MOTION OF CONSIST



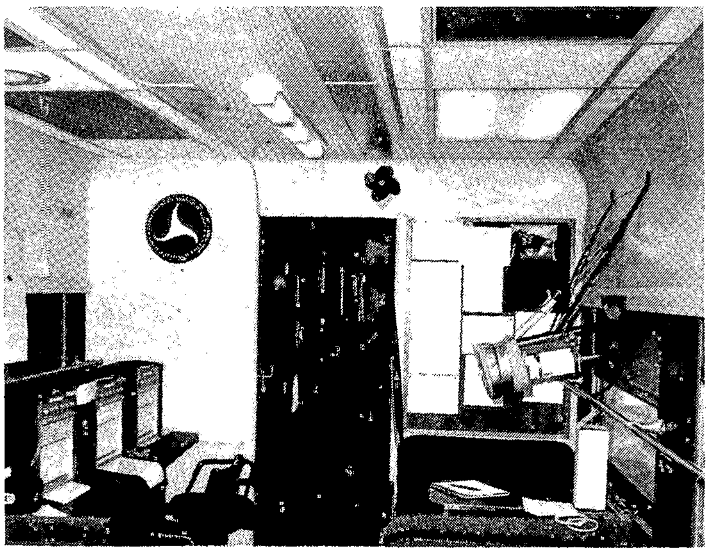
82. DETAIL OF WIND BOOM



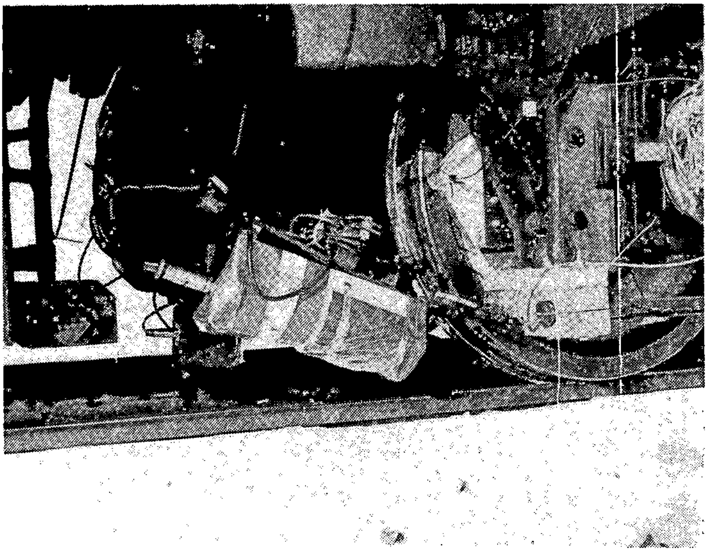
84. VIEW AS SEEN BY CAMERA MOUNTED ON T-7



85. VIDEO CAMERA USED TO RECORD AXLE 10 WHEEL CLIMB - ALSO SHOWN: LOCATION OF ALD TRANSDUCER

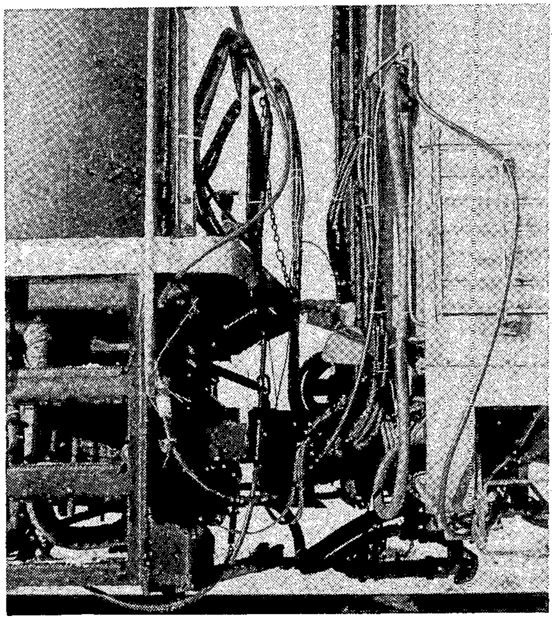


87. VIDEO CAMERA RECORDING BRUSH CHART OF AXLE 10 LATERAL FORCE IN T-7 CAR

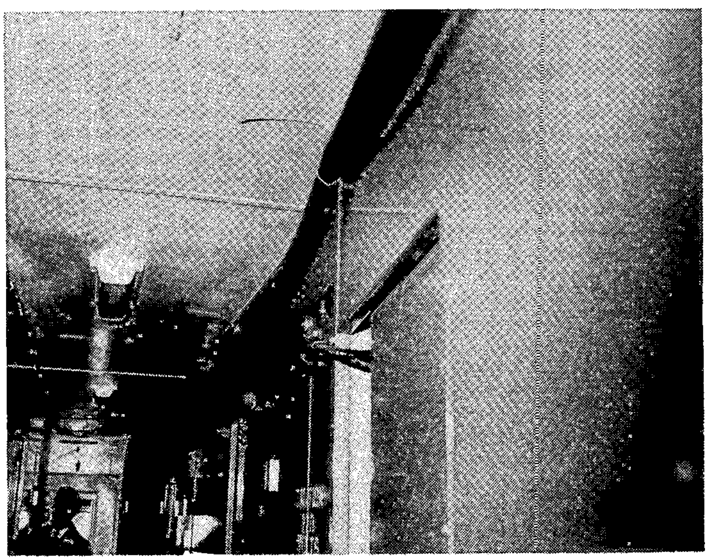


86. CLOSE-UP VIEW OF AXLE 10 VIDEO CAMERA

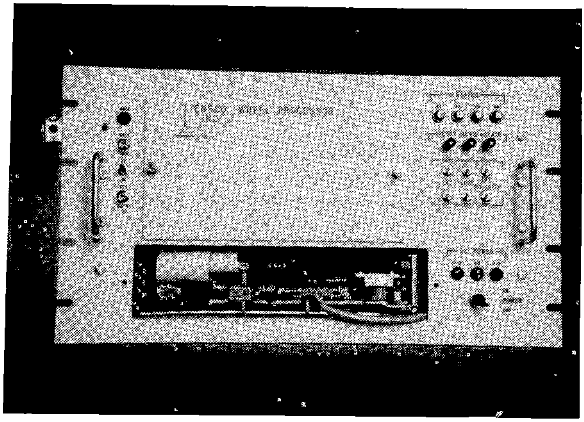
88. VIDEO/FILM CONTROL CONSOLE WITH SPLIT SCREEN PROCESSOR



89. SDP-40F AND BAGGAGE CAR INSTRUMENTED COUPLERS AND CABLING OF INSTRUMENTATION



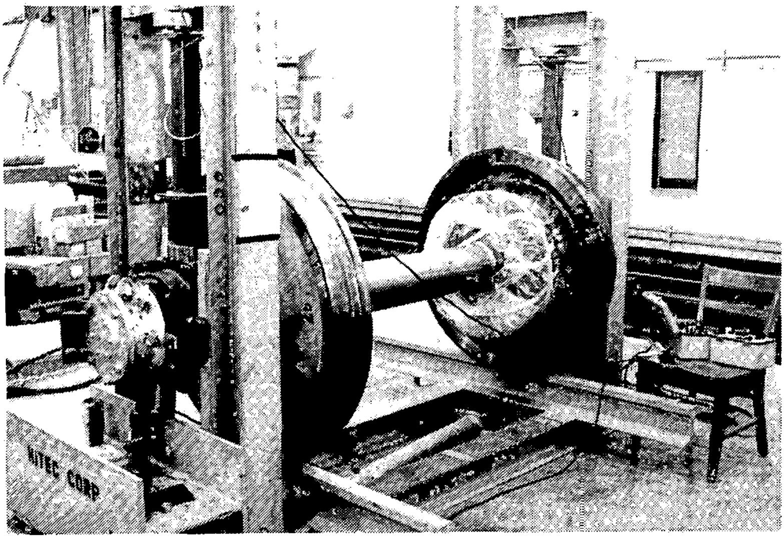
91. INSTRUMENTATION CABLING IN T-7



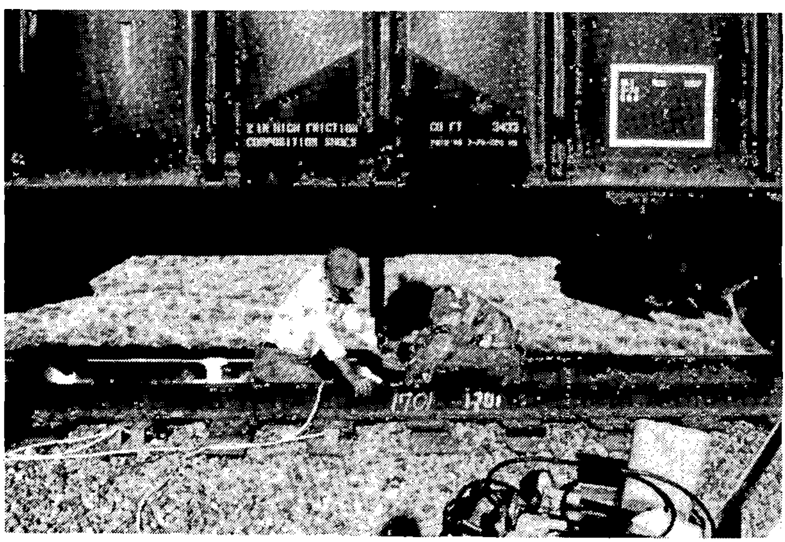
90. WHEEL SET PROCESSOR

92. SDP-40F FLANGE LUBRICATOR AND TREAD SANDER

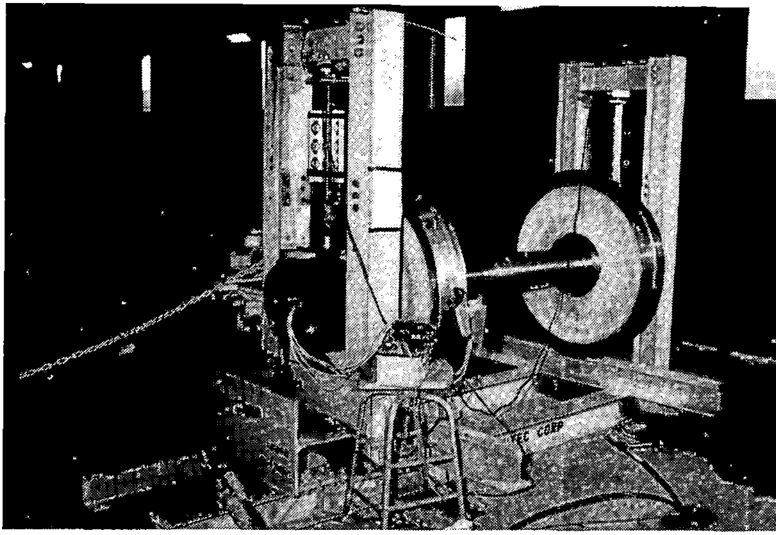
VII. CALIBRATIONS (WHEELSET/WAYSIDE)



93. WHEELSET STATIC CALIBRATION FIXTURE

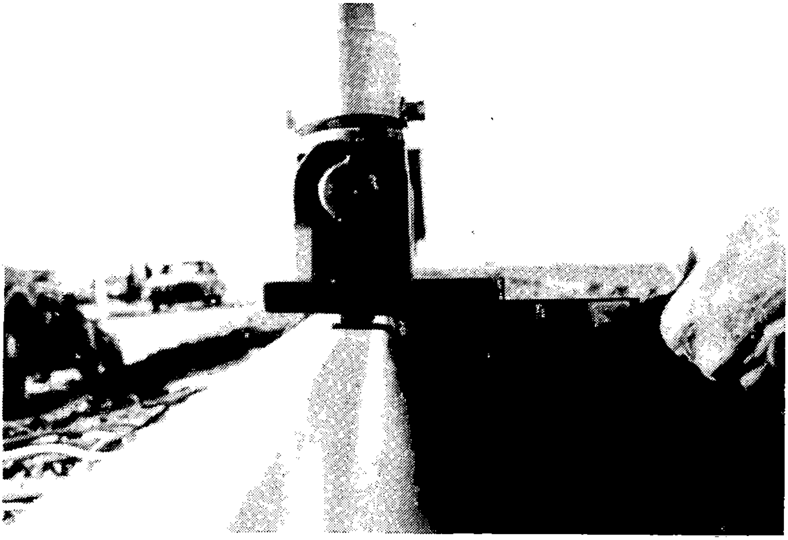


95. POSITIONING VERTICAL AND LATERAL JACKS FOR WAYSIDE STRAIN GAGE CALIBRATION

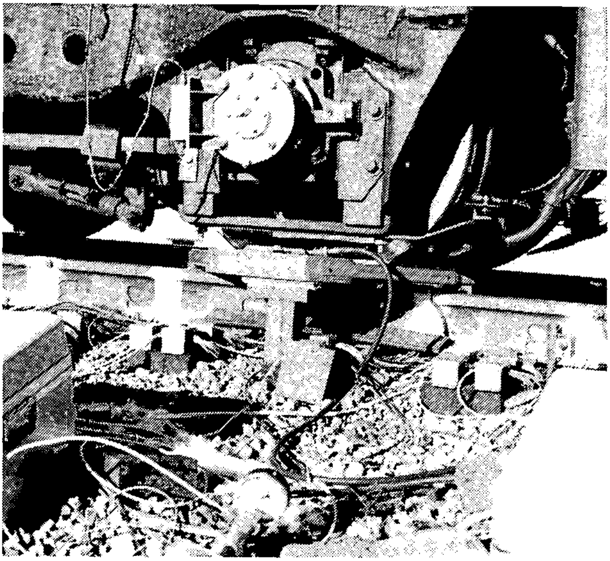


94. WHEELSET CALIBRATION AT TTC

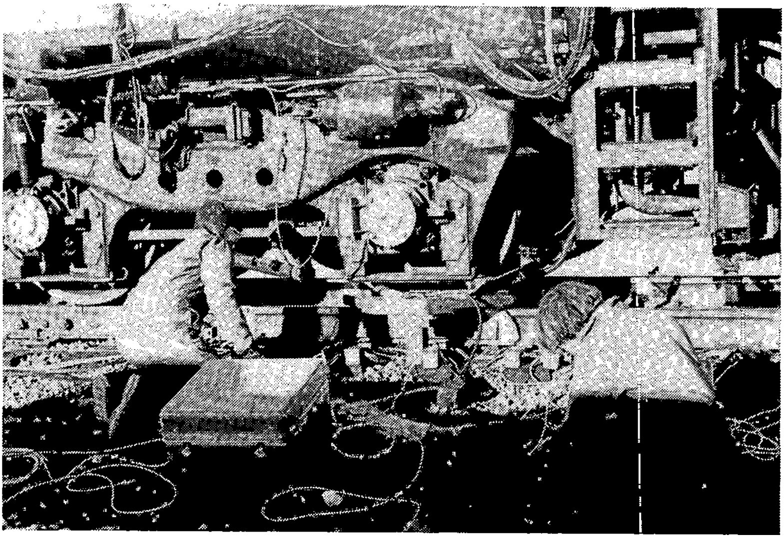
96. WAYSIDE CALIBRATION



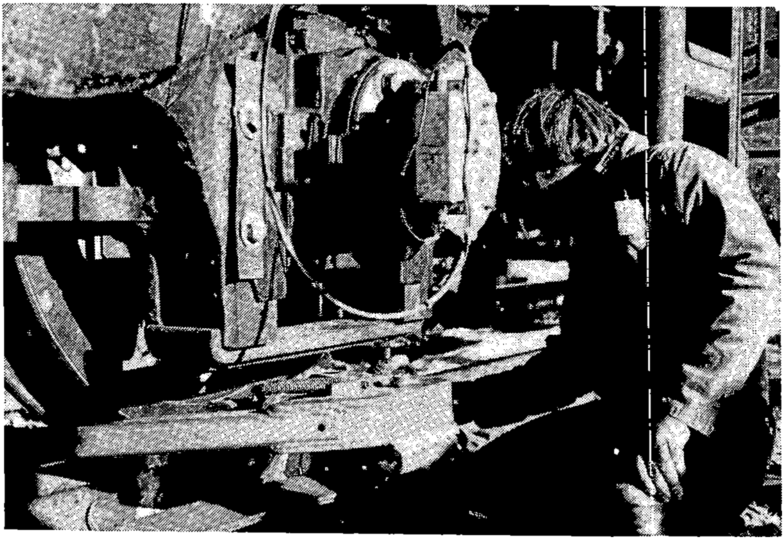
97. HEAD DETAIL OF VERTICAL AND LATERAL CALIBRATION JACKS UNDER COMBINED LOADING



99. CALIBRATION JACK FORCES WHEELSET AGAINST OUTER RAIL TO OBTAIN SIMULTANEOUS WHEELSET AND WAYSIDE LATERAL FORCE MEASUREMENTS



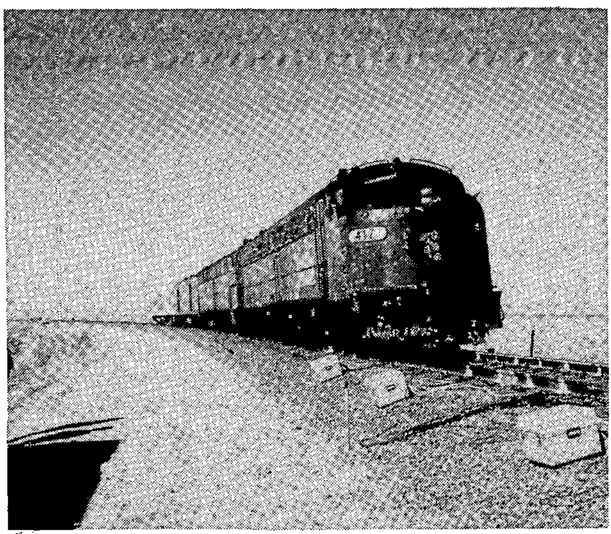
98. WHEELSET/WAYSIDE JOINT CALIBRATION



100. DETAIL OF WHEELSET/WAYSIDE JOINT CALIBRATION JACK

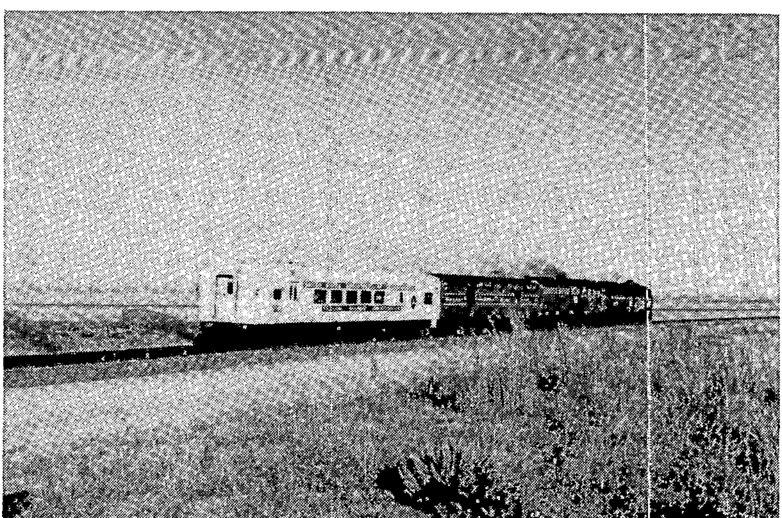
VIII. E-8 TESTING

101. BRIEFING BEFORE TEST RUNS

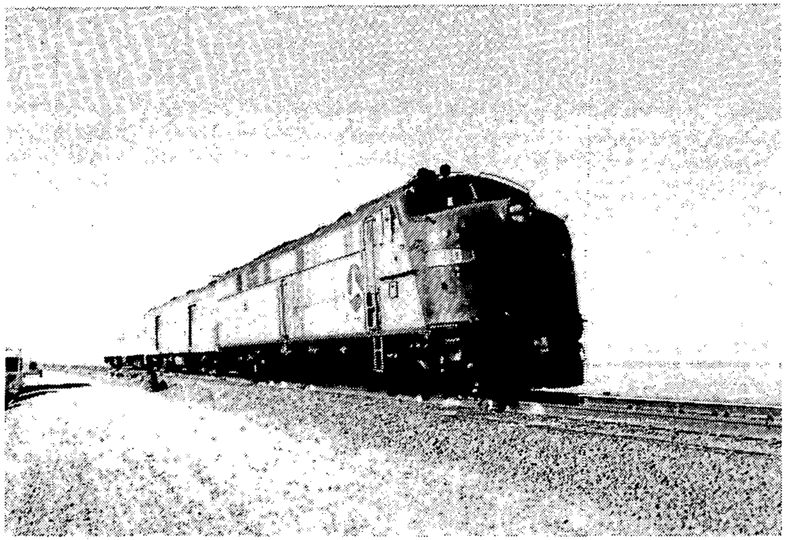


103. E-8 CONFIGURATION "A"

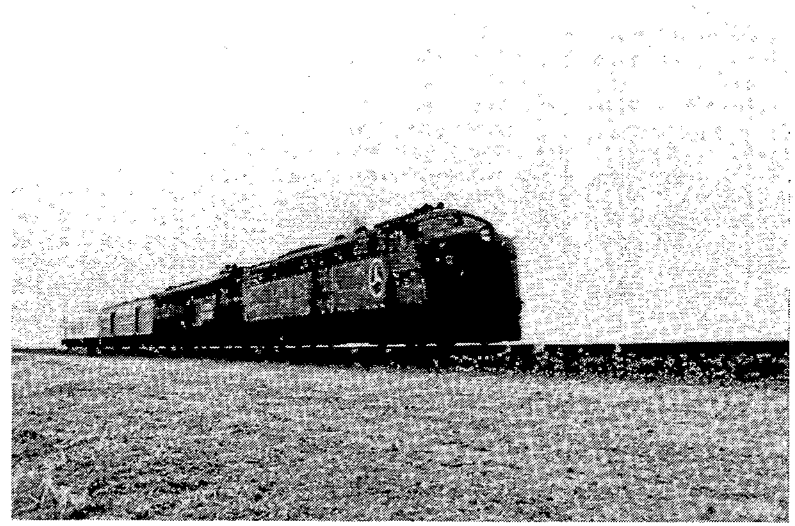
102. FILMING OF TEST RUN



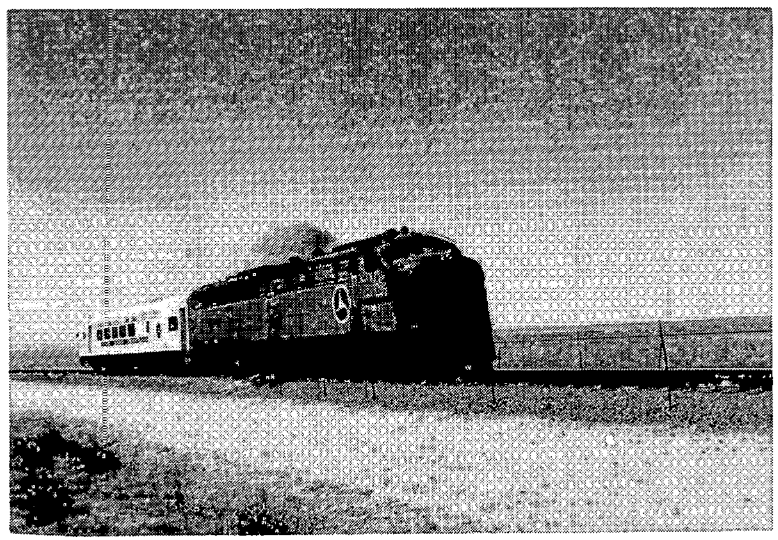
104. E-8 CONFIGURATION "A" ACCELERATING TOWARD TEST ZONE



105. E-8 CONFIGURATION "B"

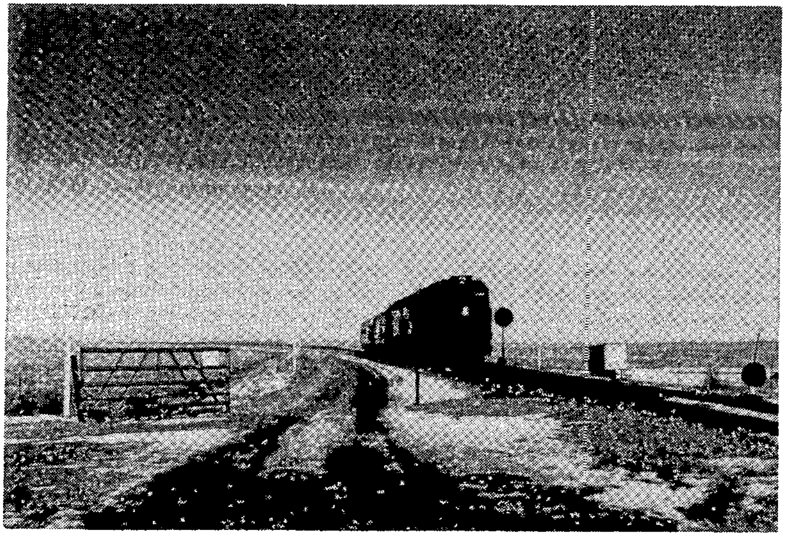


106. E-8 CONFIGURATION "D"

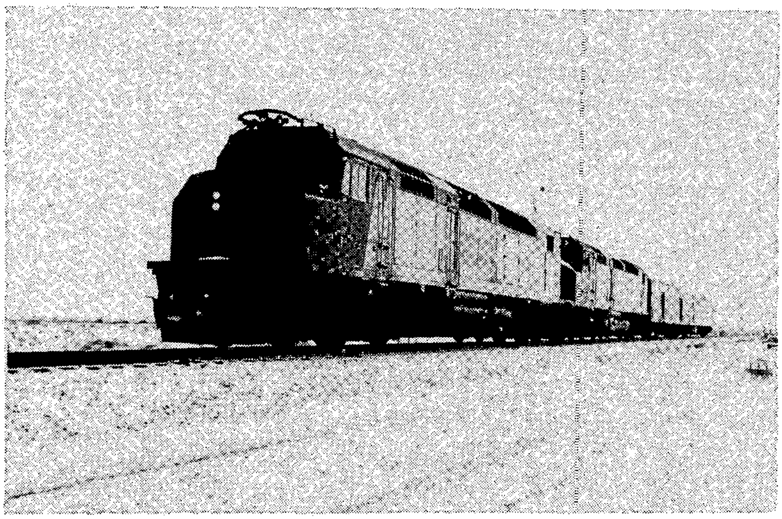


107. E-8 CONFIGURATION "B*" (AFTER SDP-40F TRACK SHIFT)

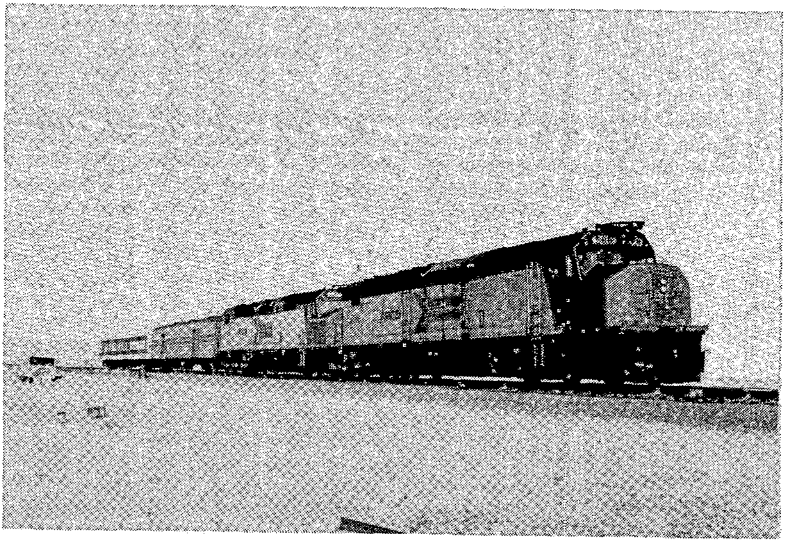
IX. SDP-40F TESTING



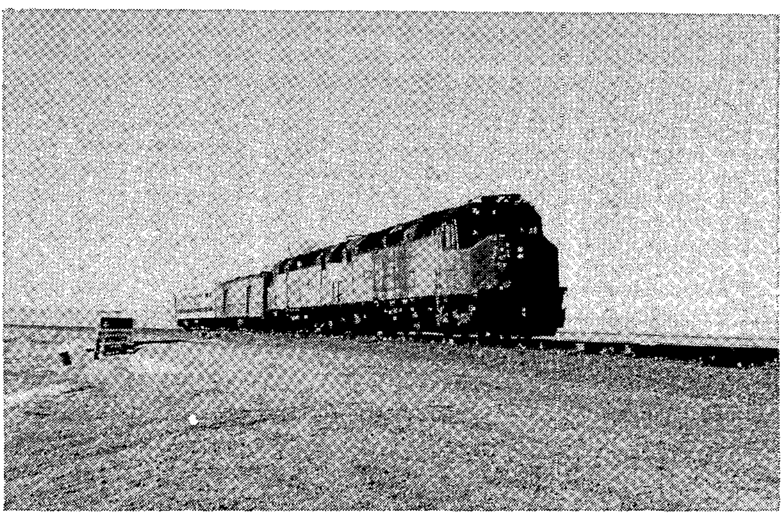
108. SDP-40F CONFIGURATION "A" LEAVING EAST TDT



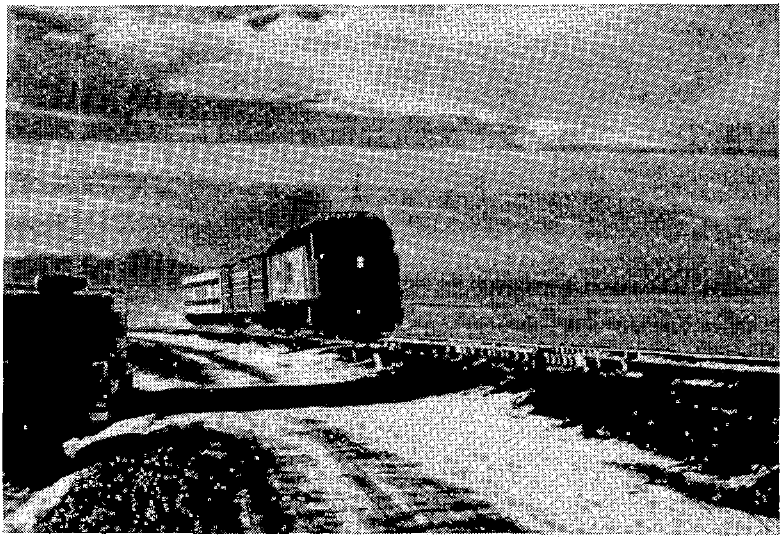
110. SDP-40F CONFIGURATION "A" IN TANGENT TEST ZONE



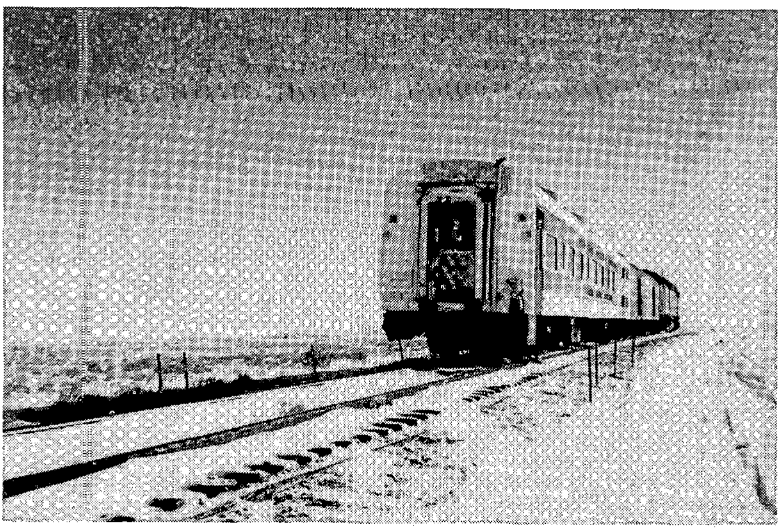
109. SDP-40F CONFIGURATION "A"



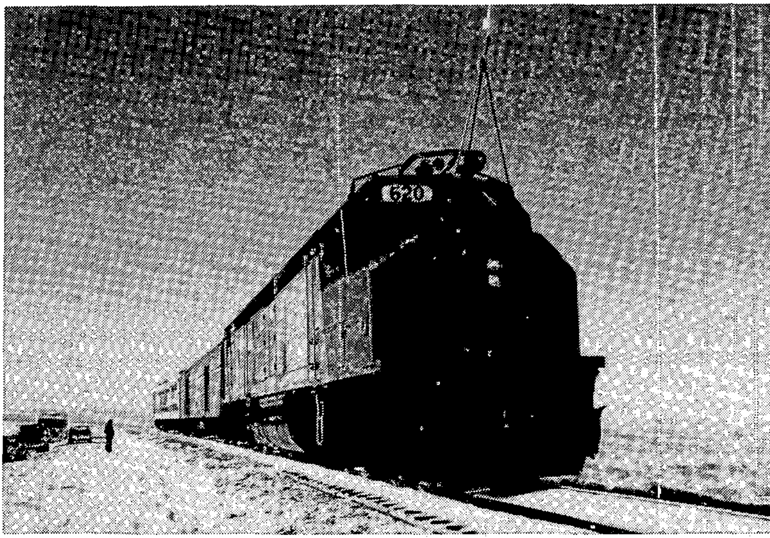
111. SDP-40F CONFIGURATION "C"



112. SDP-40F CONFIGURATION "B" ENTERING SECTION 4

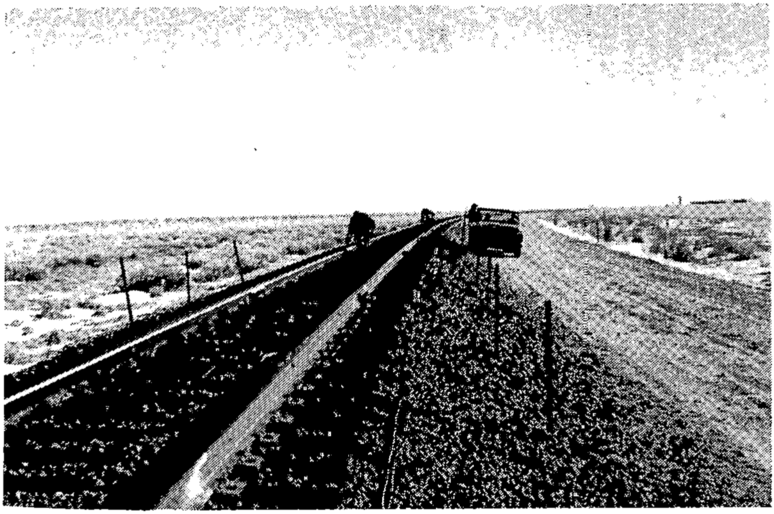


114. STATIONARY REAR VIEW OF SDP-40F CONFIGURATION "B"



113. CLOSE-UP OF SDP-40F CONFIGURATION "B"

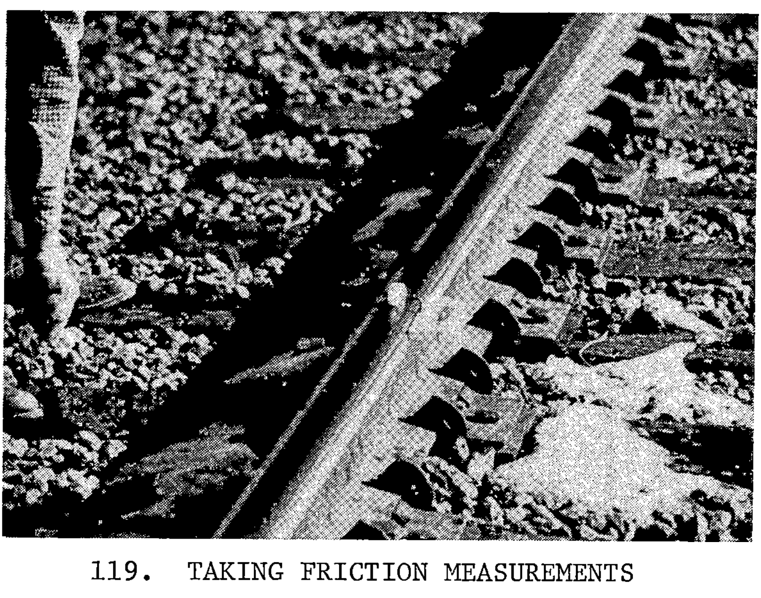
115. STOP-ACTION REAR VIEW OF SDP-40F CONFIGURATION "B" SHOWING BLOWING SNOW KICKED-UP IN PASSAGE



116. MANUALLY LUBRICATING THE HIGH RAIL

118. APPLYING THE GREASE

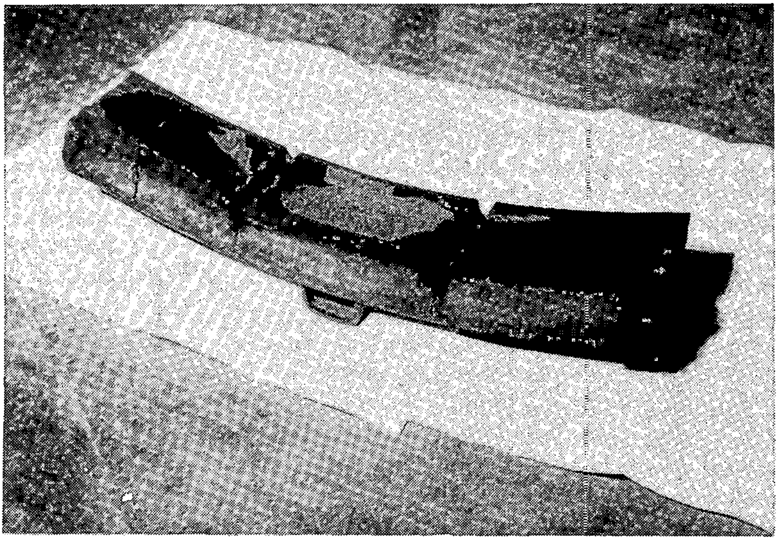
117. CLOSE-UP OF GREASED RAIL



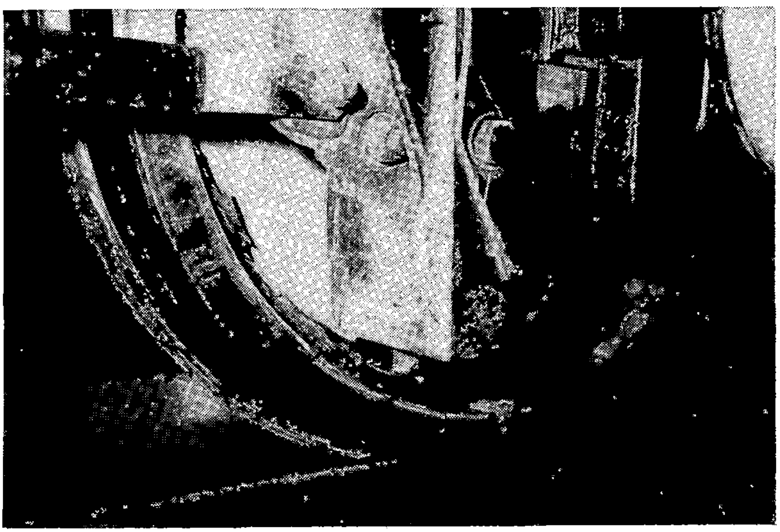
119. TAKING FRICTION MEASUREMENTS

X. PROBLEMS

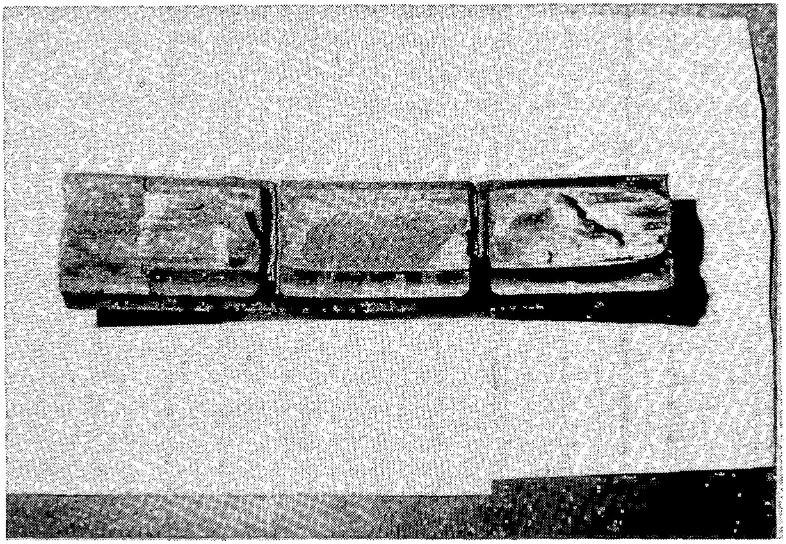
(OVERHEATED WHEELS DUE TO ENGAGED HAND BRAKE)



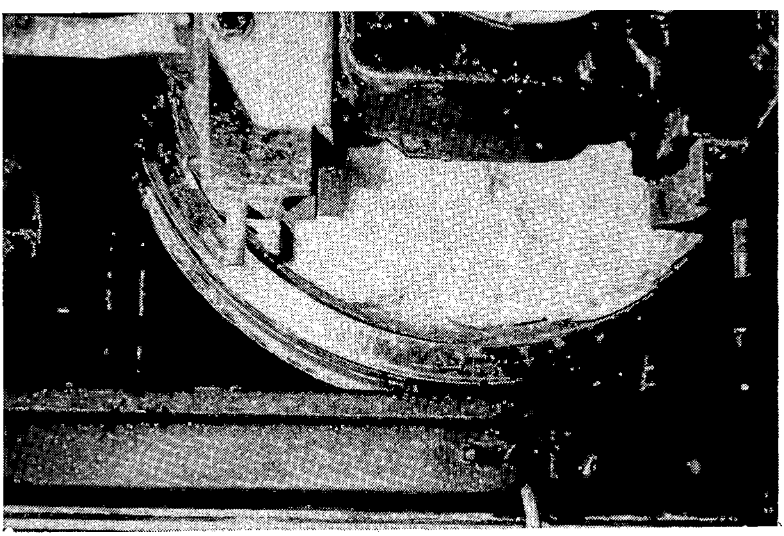
120. HEAT DAMAGED BRAKE SHOE OF AXLE 10 RIGHT WHEEL



122. OVERHEATED WHEEL CAUSED BY ENGAGED HAND BRAKE

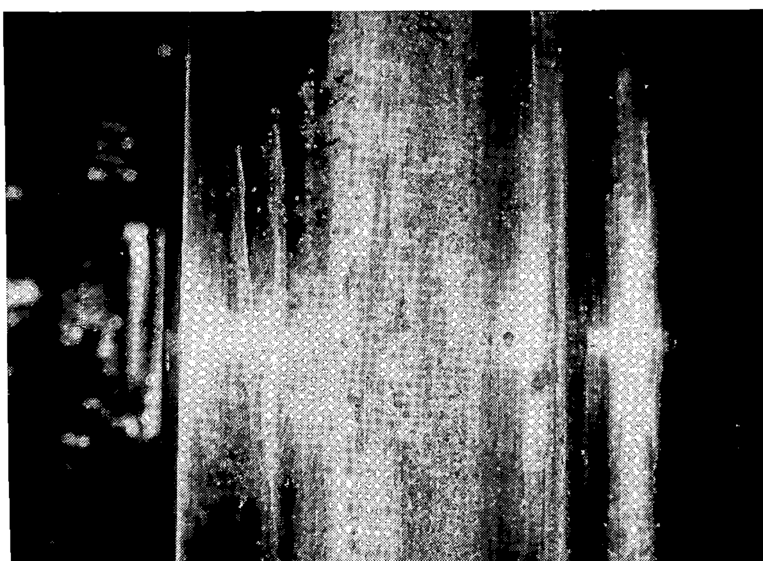


121. HEAT DAMAGED BRAKE SHOE OF AXLE 11
RIGHT WHEEL

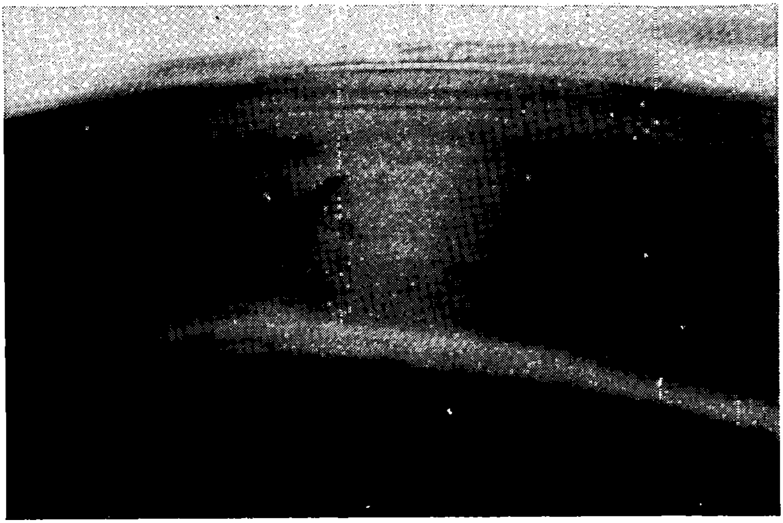


123. OVERHEATED WHEEL SHOWING PEALED PAINT
AS RESULT OF THE HEAT

124. TREAD DISCOLORATION CAUSED BY THE HEAT



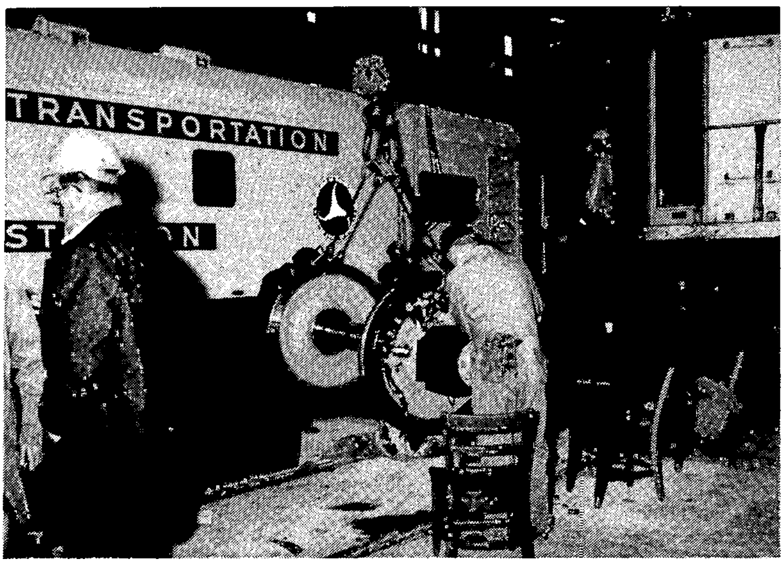
126. SCARRING OF WHEEL TREAD SURFACE



125. CLOSE-UP OF TREAD AND FLANGE DISCOLORATION

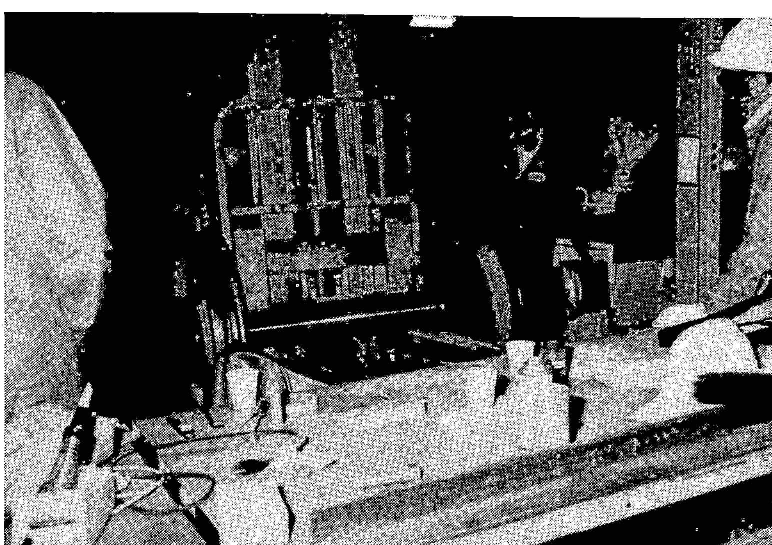
127. REMOVING WATERPROOF/PROTECTIVE COATING TO EXPOSE STRAIN GAGES ALSO SHOWING TRACTION MOTOR

128. DETAIL OF REMOVING PROTECTIVE COATING TO EXPOSE STRAIN GAGES



130. HOISTING DAMAGED WHEELSET TO NEW WORKING LOCATION

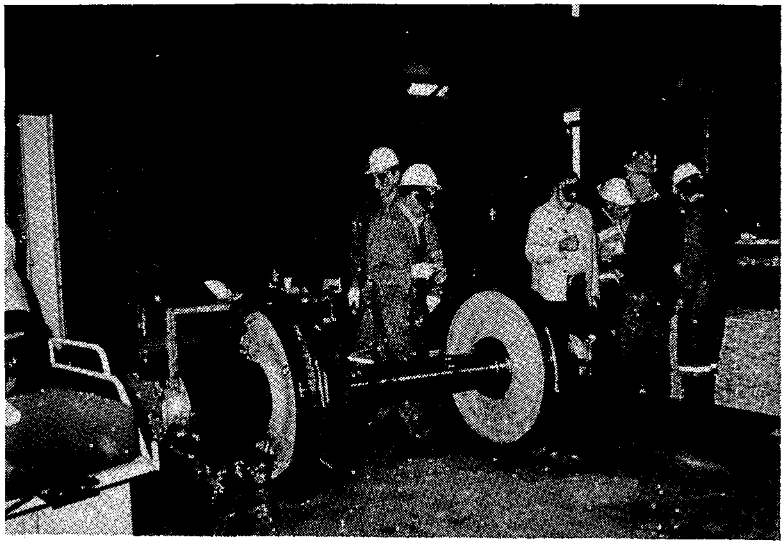
129. TESTING STRAIN GAGES



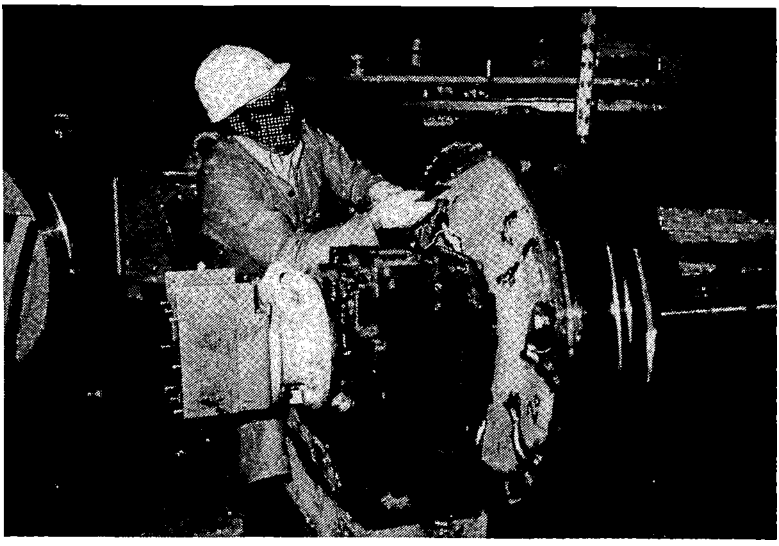
131. MOVING DAMAGED WHEELSET TO FINAL REPAIR AREA

132. WHEELSET REPAIR CREW AND ASEA REPRESENTATIVES

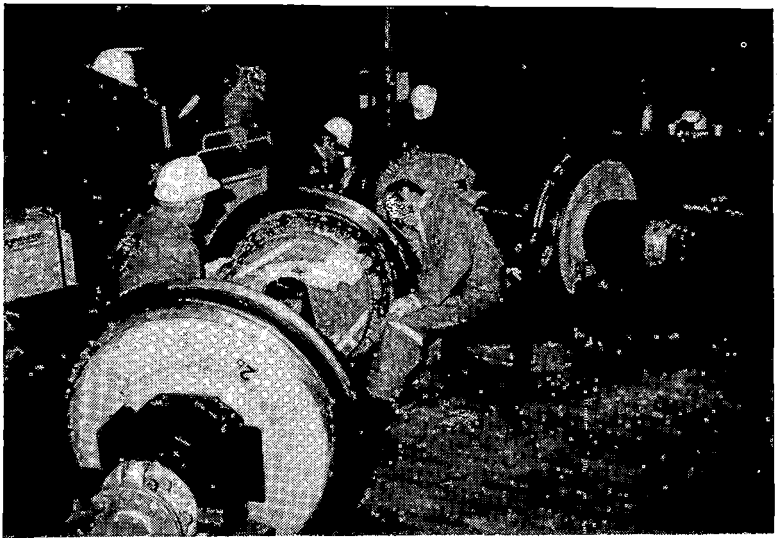
134. SETTING UP WHEELSET



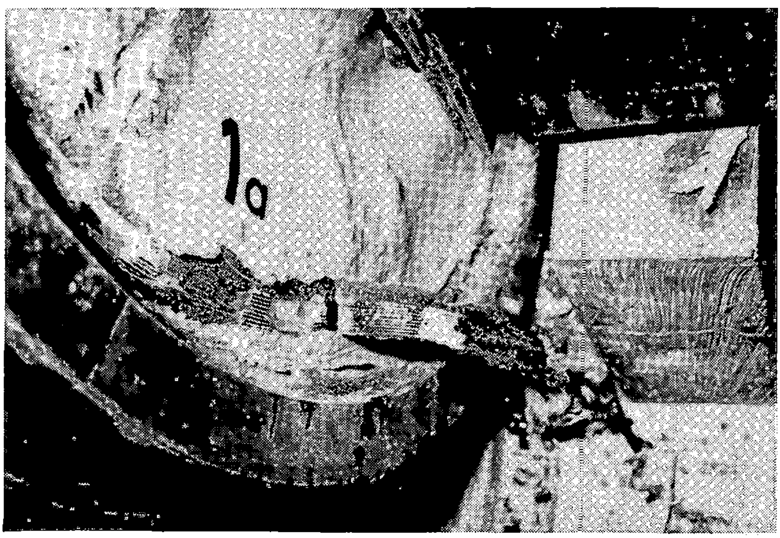
133. GENERAL WHEELSET REPAIR AREA



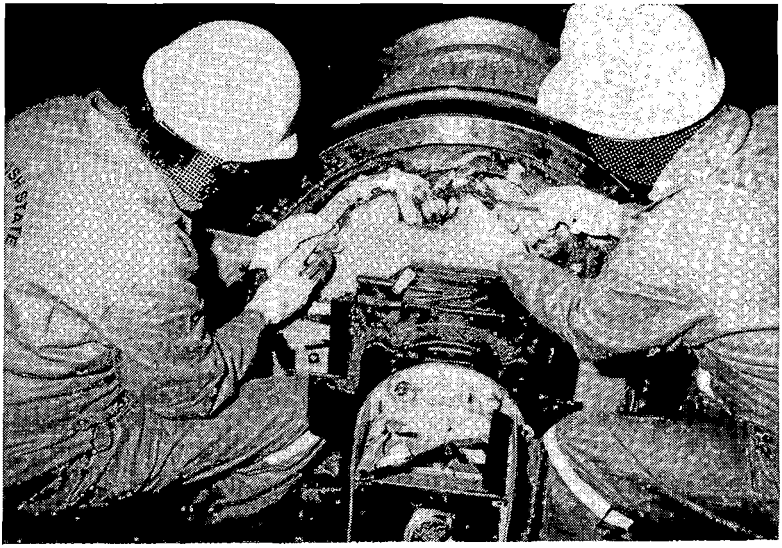
135. REMOVING PROTECTIVE COATING TO EXPOSE DAMAGED STRAIN GAGES AND WIRING



136. REMOVING PROTECTIVE COATING ON AXLE 11 RIGHT WHEEL

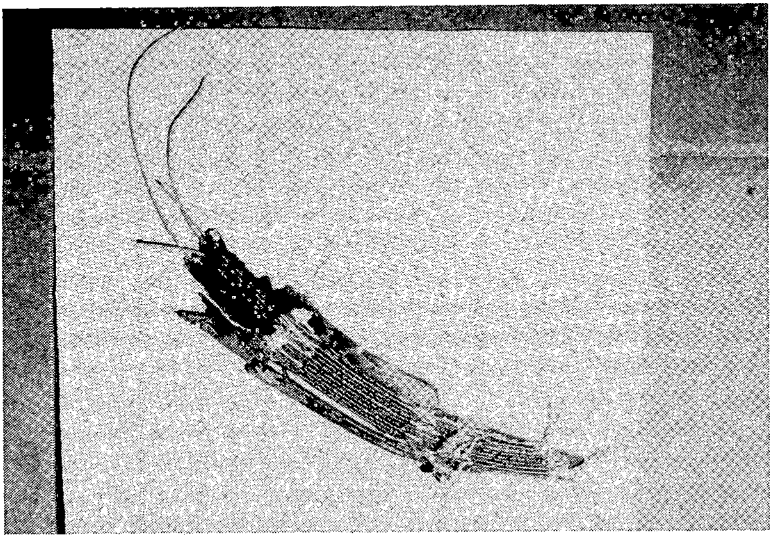


138. EXPOSING THE DAMAGED WIRING

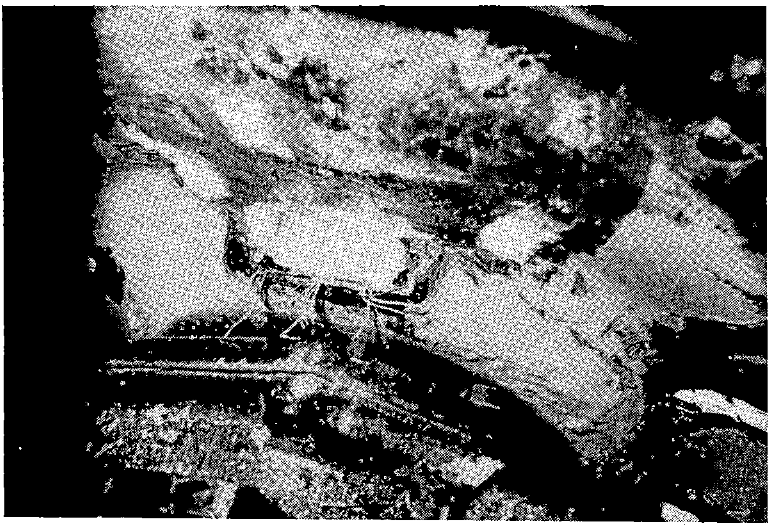


137. REMOVING PROTECTIVE COATING ON AXLE 10
RIGHT WHEEL

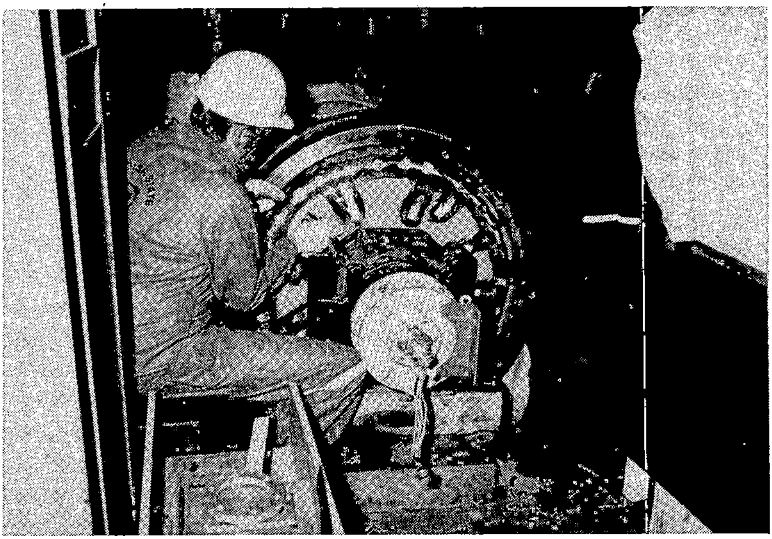
139. REMOVING THE WIRING



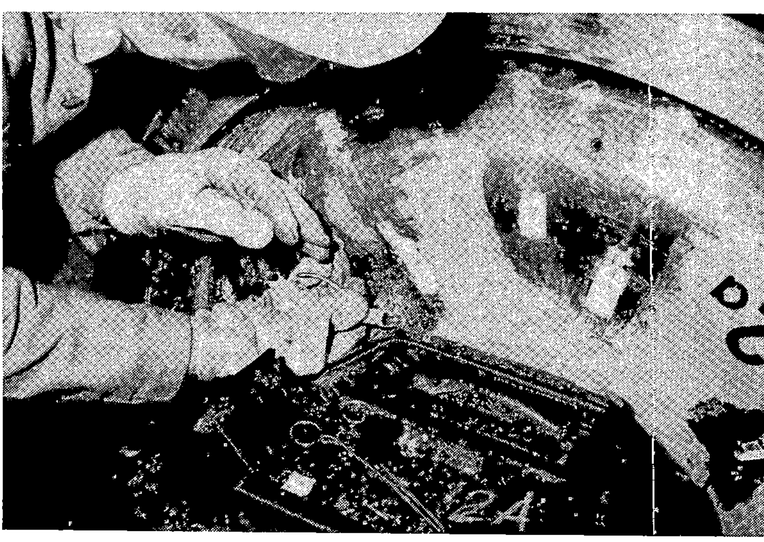
140. DETAIL OF DAMAGED WIRES



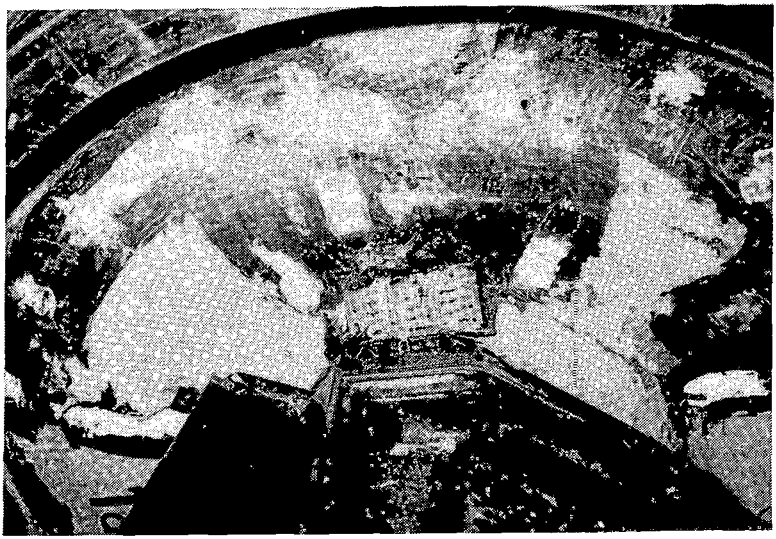
142. EXPOSING DAMAGED JUNCTION BOARD



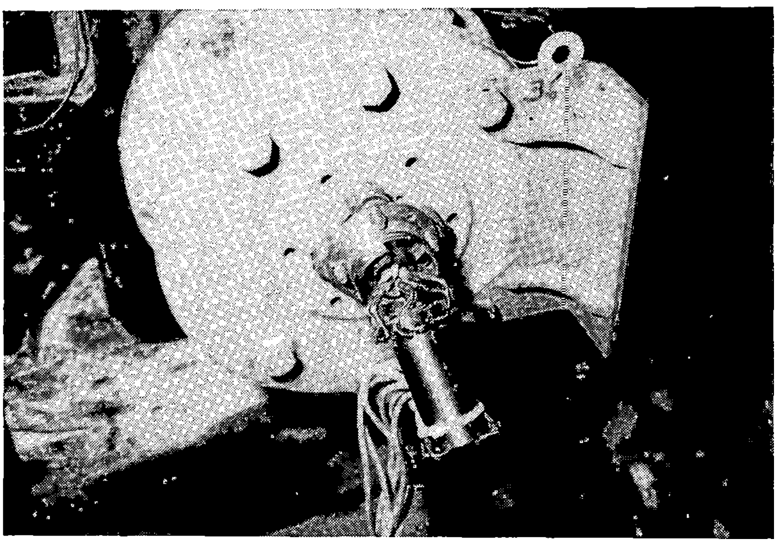
141. REMOVING PROTECTIVE COATING TO EXPOSE JUNCTION BOARD



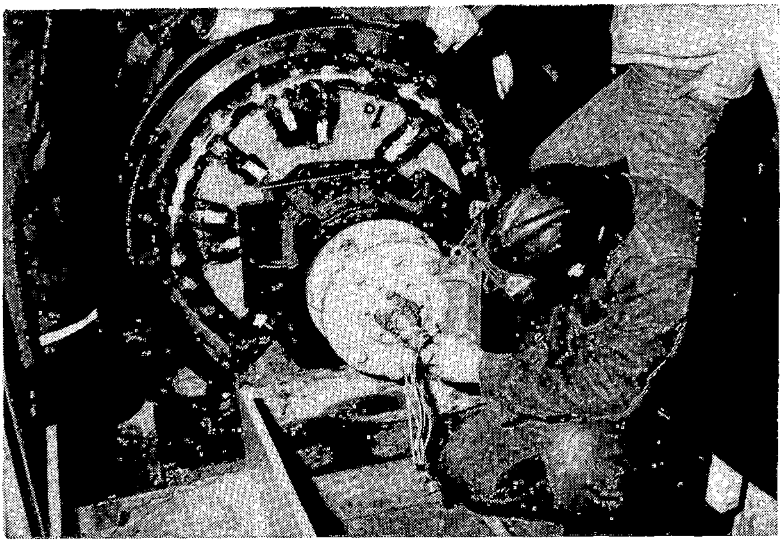
143. REMOVING JUNCTION BOARD



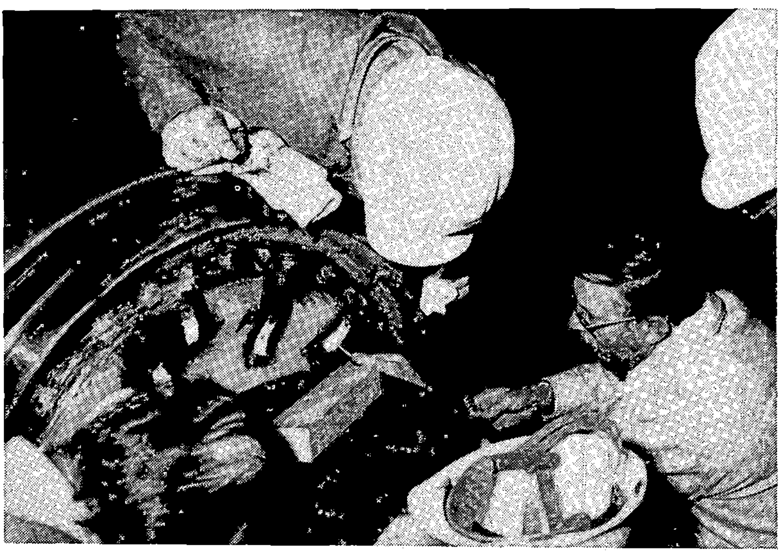
144. CLOSE-UP OF JUNCTION BOARD



146. DETAIL OF SLIP RING



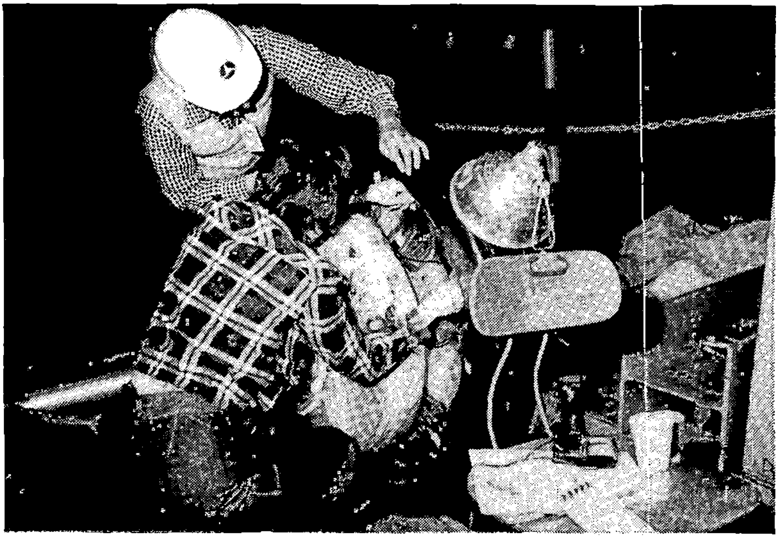
145. REMOVING SLIP RING



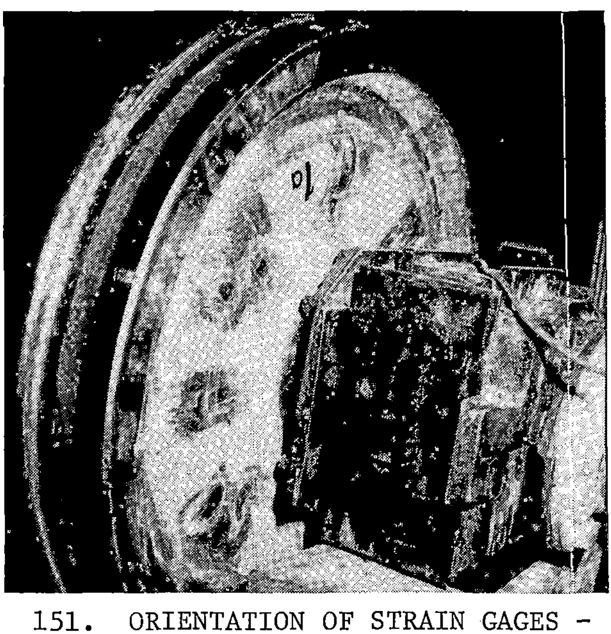
147. REMOVING DAMAGED STRAIN GAGES

148. DETAIL OF WHEEL WITH STRAIN GAGES REMOVED AND REPAIR PREPARATION

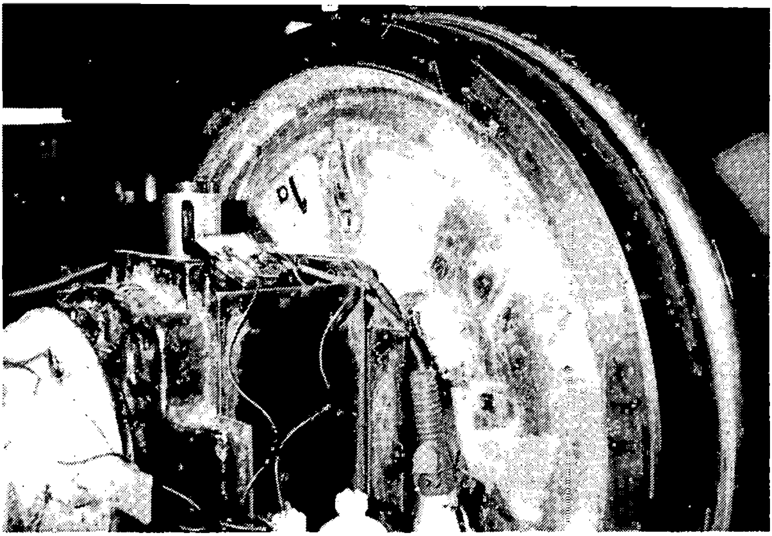
150. SOLDERING NEW STRAIN GAGE LEADS



149. INSTALLING NEW WIRES

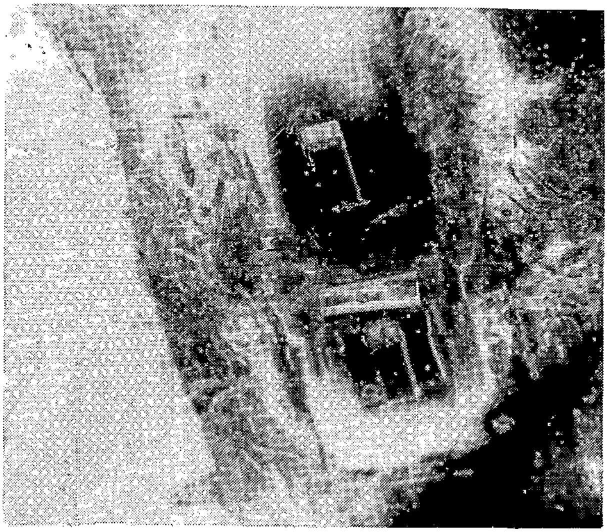


151. ORIENTATION OF STRAIN GAGES - LEFT VIEW

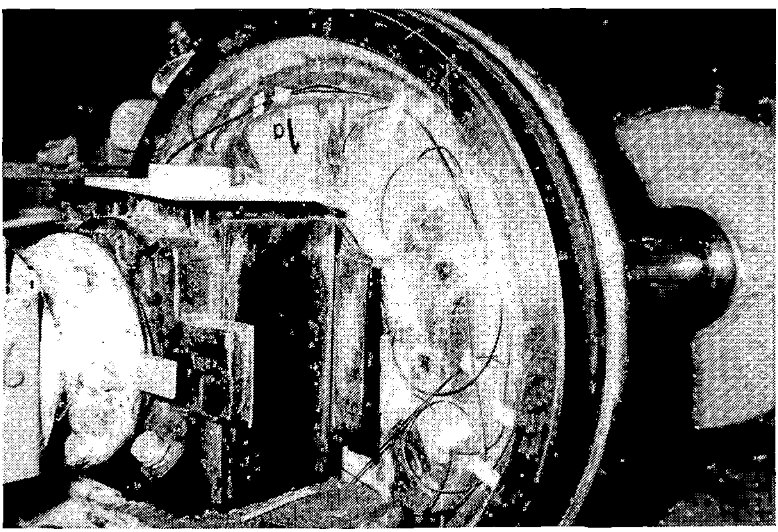


152. ORIENTATION OF STRAIN GAGES - RIGHT VIEW

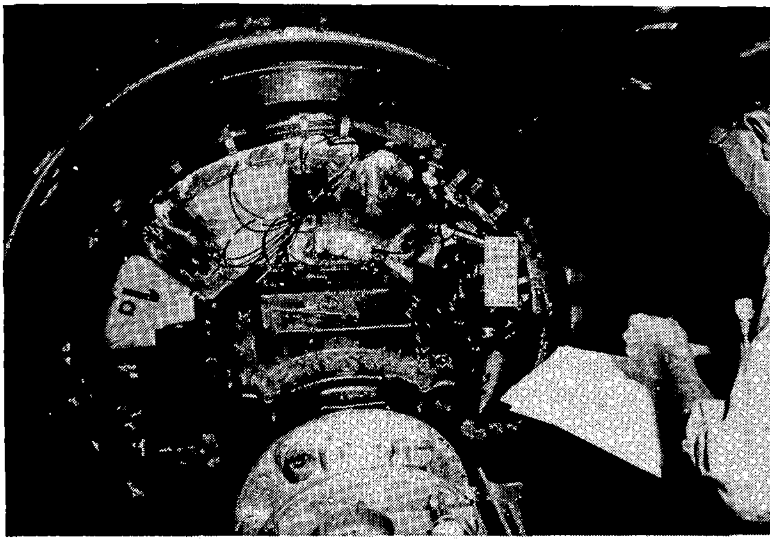
154. WIRING FOR STRAIN GAGES AXLE 11 RIGHT WHEEL



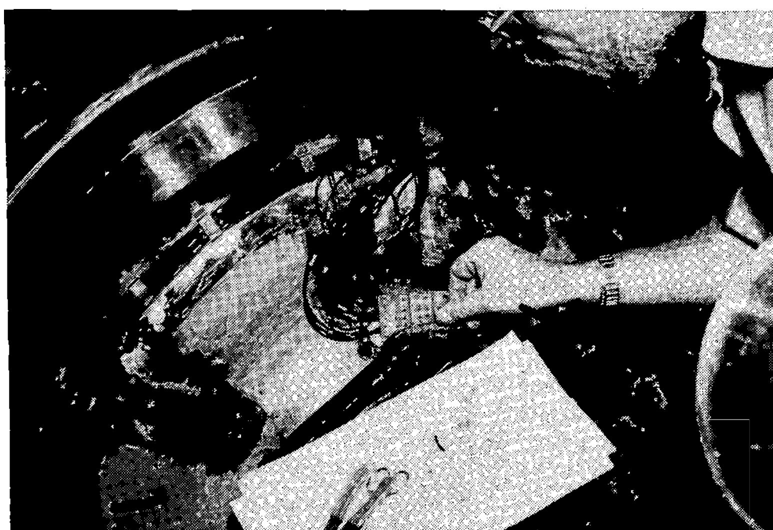
153. DETAIL OF STRAIN GAGES AS INSTALLED



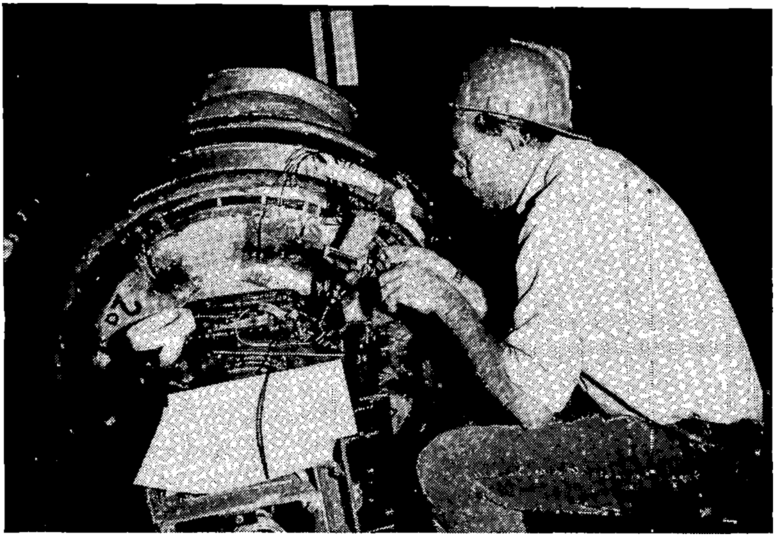
155. WIRING FOR STRAIN GAGES AXLE 10 RIGHT WHEEL



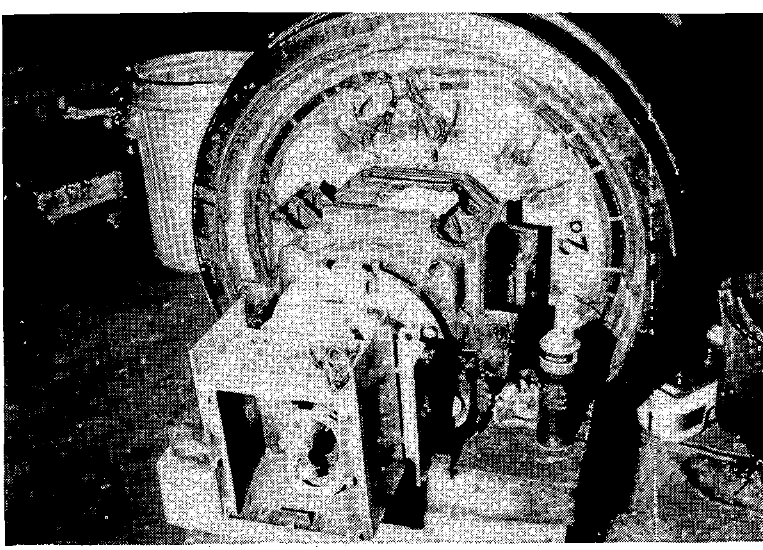
156. PREPARING NEW LEADS FOR JUNCTION BOARD



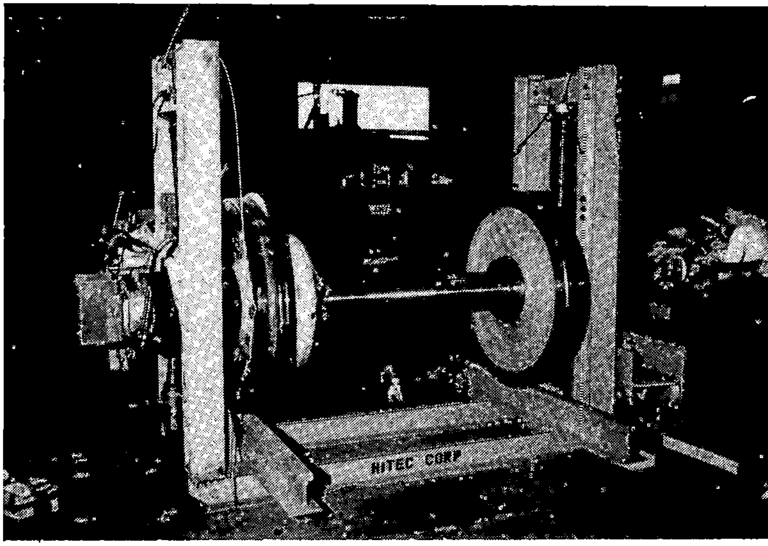
158. POSITIONING JUNCTION BOARD



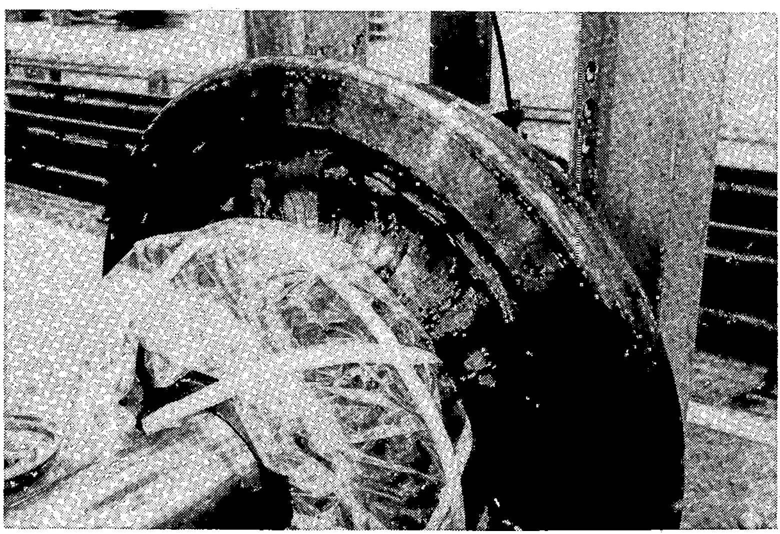
157. WIRING THE JUNCTION BOARD



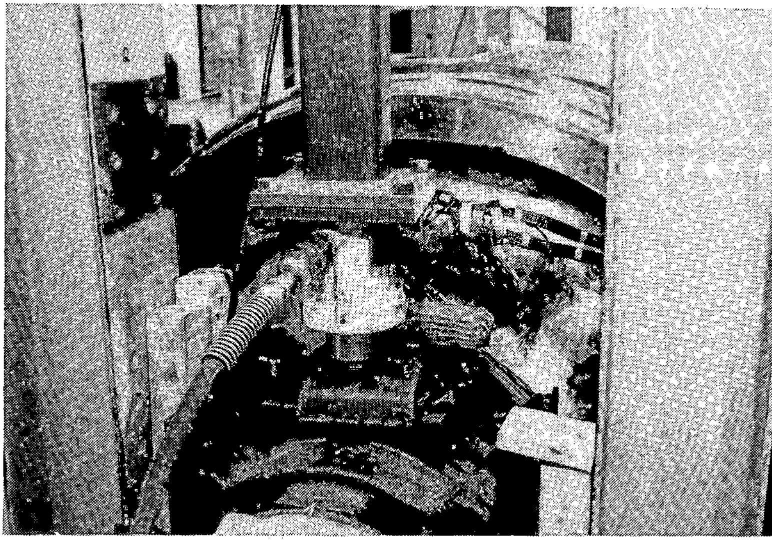
159. OVERVIEW OF WIRING FOR STRAIN GAGES AND JUNCTION BOARD



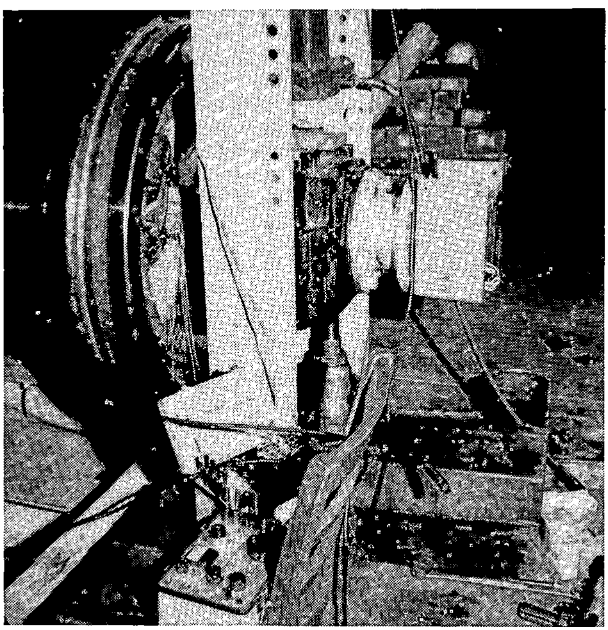
160. CALIBRATING REPAIRED WHEELSET FOR AXLE 10



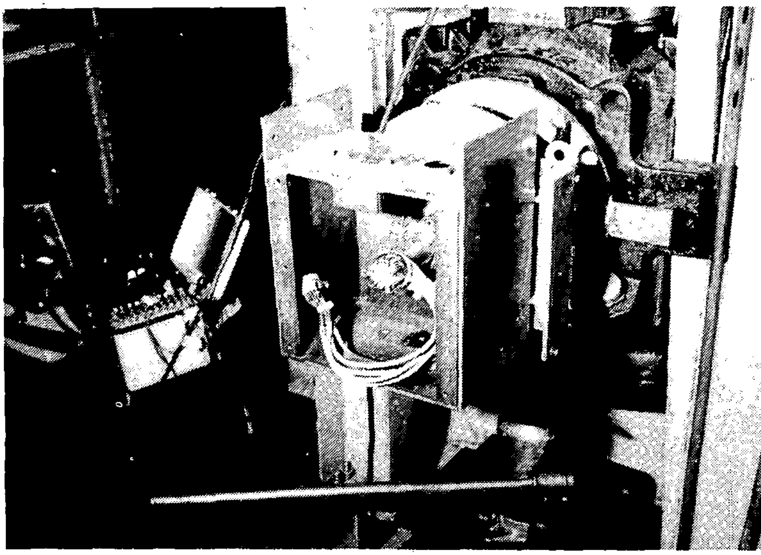
162. CALIBRATING REPAIRED WHEELSET ALSO SHOWS AXLE GEARING



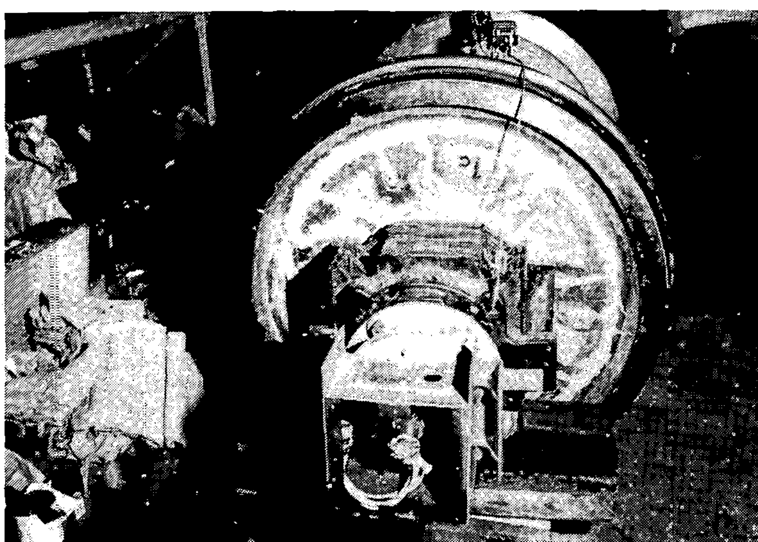
161. DETAIL OF CALIBRATION LOAD CELL



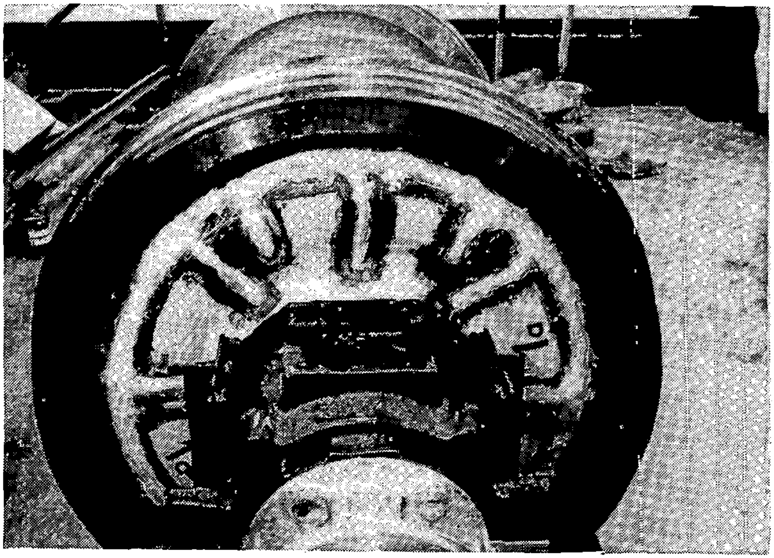
163. CALIBRATING REPAIRED WHEELSET FOR AXLE 11



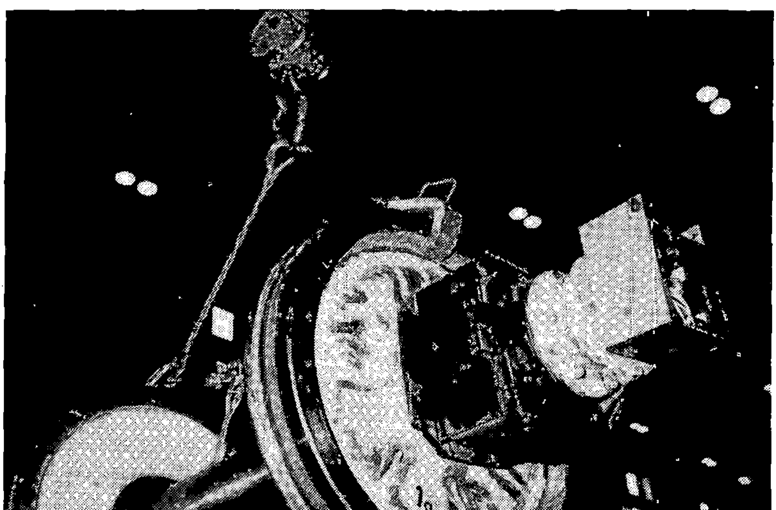
164. CALIBRATING REPAIRED WHEELSET
SHOWING SLIP RING ASSEMBLY



166. WHEELSETS READY FOR REINSTALLATION



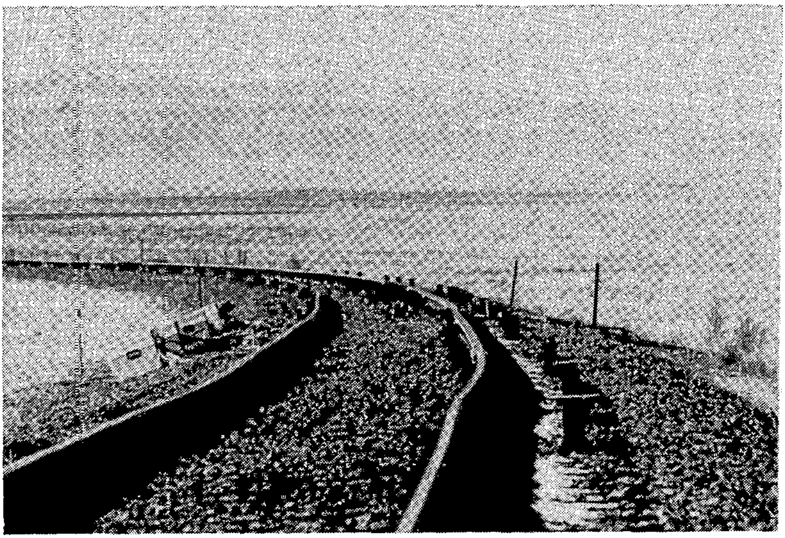
165. PROTECTIVE COATING APPLIED TO GAGES AND WIRING



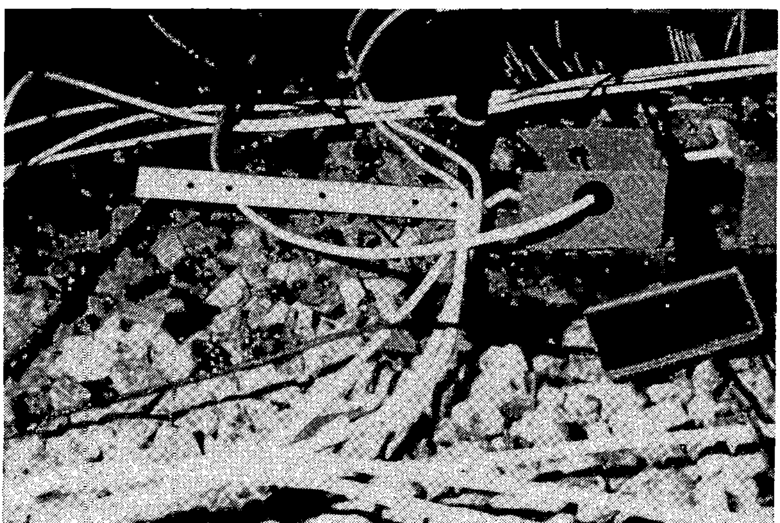
167. HOISTING REPAIRED WHEELSETS BACK TO LOCOMOTIVE

X. PROBLEMS

(PANEL SHIFT)

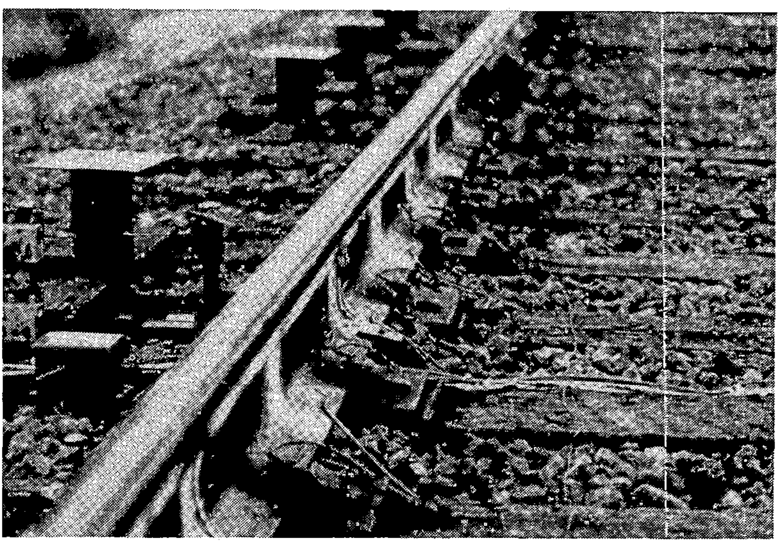


168. OVERVIEW OF PANEL SHIFT IN SECTION 4
SHOWING BOWED PERTURBATION

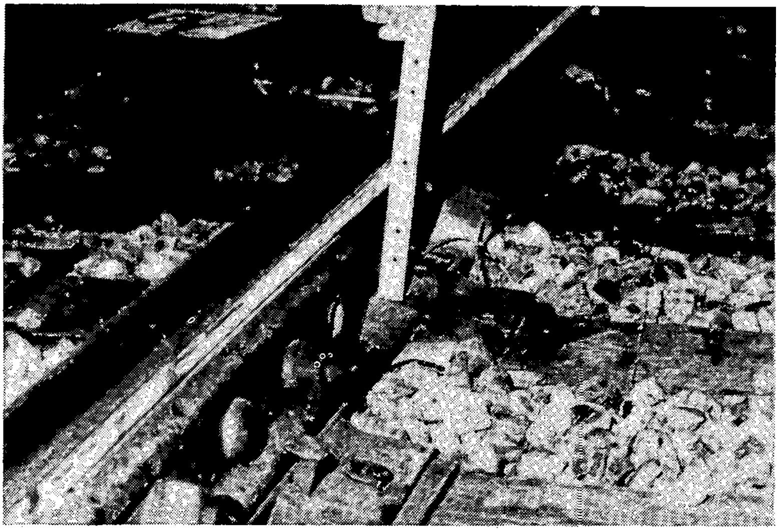


170. DETAIL OF 1.6" TIE SHIFT IN SECTION 4.4

169. 3" TIE SHIFT IN SECTION 4.5



171. SPIKES PULLED DUE TO RAIL ROLL IN SECTION 4



172. DETAIL OF 1.5" SPIKE PULL

174. CHECKING GAGE

173. TRACK REBUILD - ALIGNING HIGH RAIL BY JACKING AGAINST LOW RAIL AND MEASURING HIGH RAIL OFFSETS FROM 78' STRINGLINE

175. TRACK REBUILD - SETTING LOW RAIL TO GAGE USING A COME-ALONG WINCH

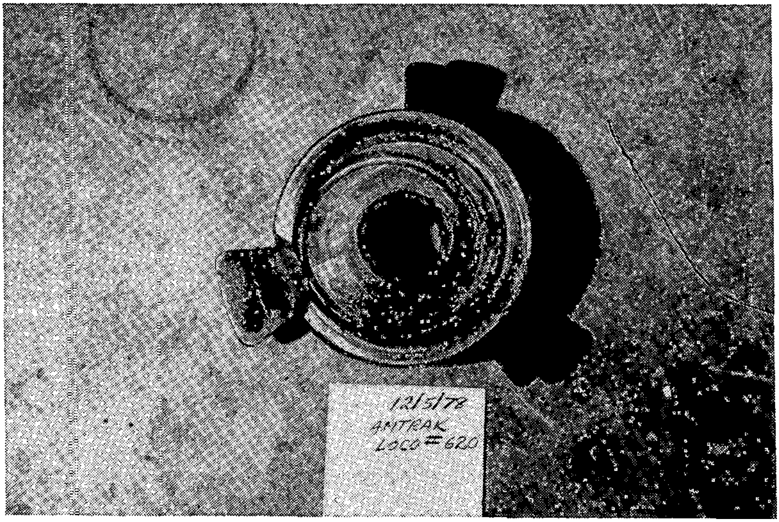
176. TRACK REBUILD - RESPIKING LOW RAIL

177. TRACK REBUILD - FINAL ADJUSTMENTS

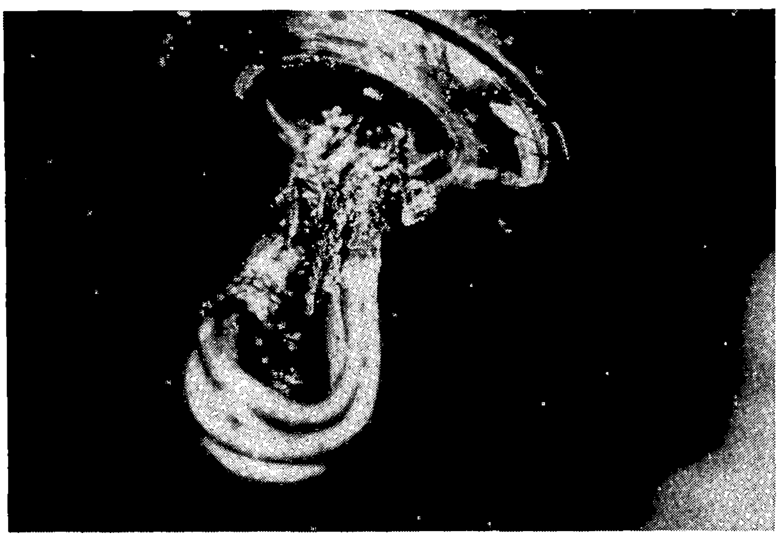
178. RECALIBRATING WAYSIDE INSTRUMENTATION AT 10° UNDER BLOWING SNOW

X. PROBLEMS

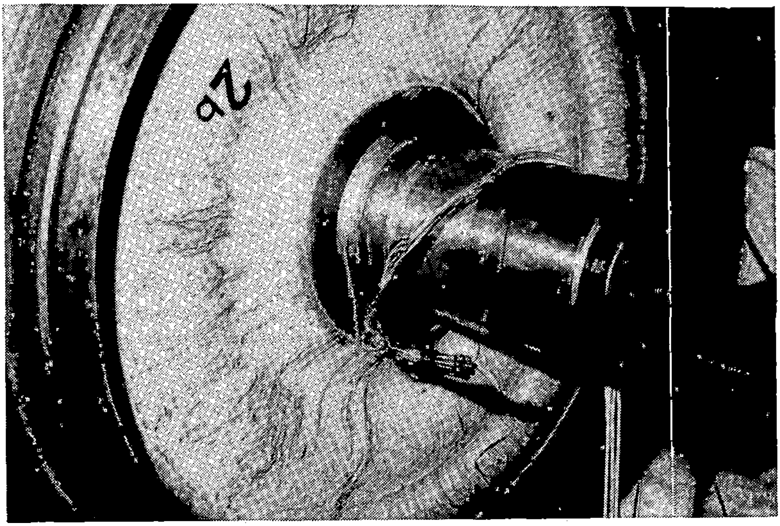
(OVERHEATED THRUST BEARING)



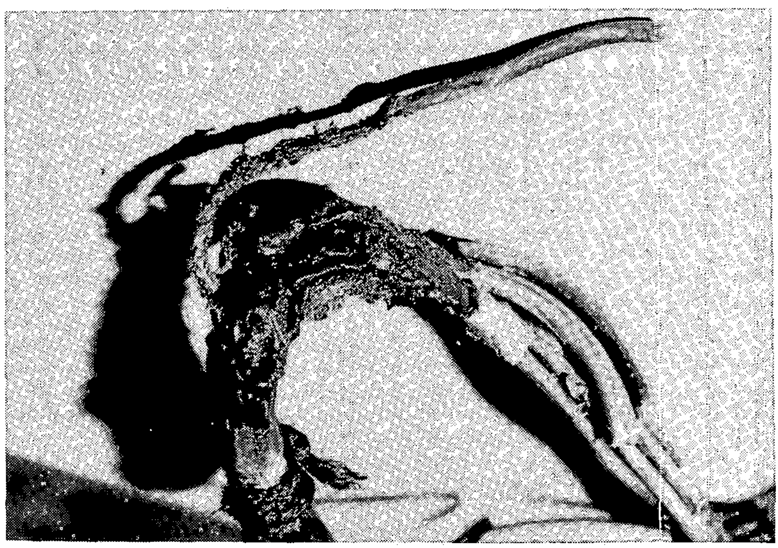
179. BURNT OUT THRUST BEARING - AXLE 11
ALSO SHOWING SCORING PROBABLY DUE TO
UNSTAKED BEARING BLOCK SCREWS



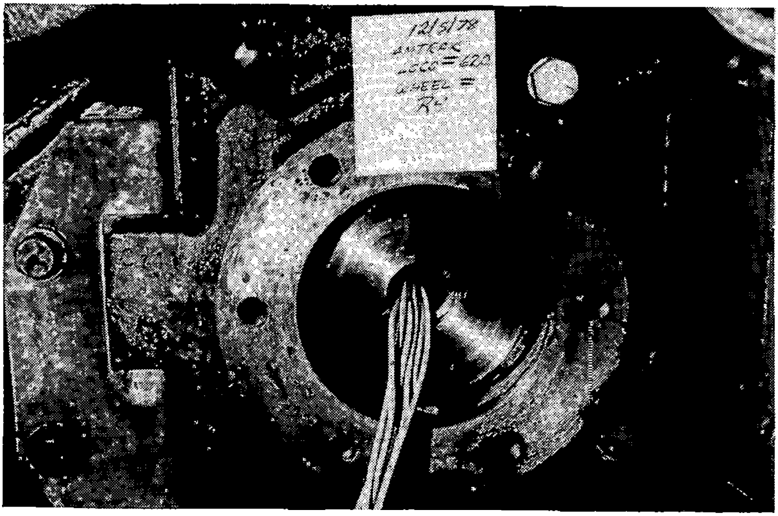
181. DETAIL OF DAMAGED WIRING PROTRUDING FROM
AXLE BEARING BLOCK



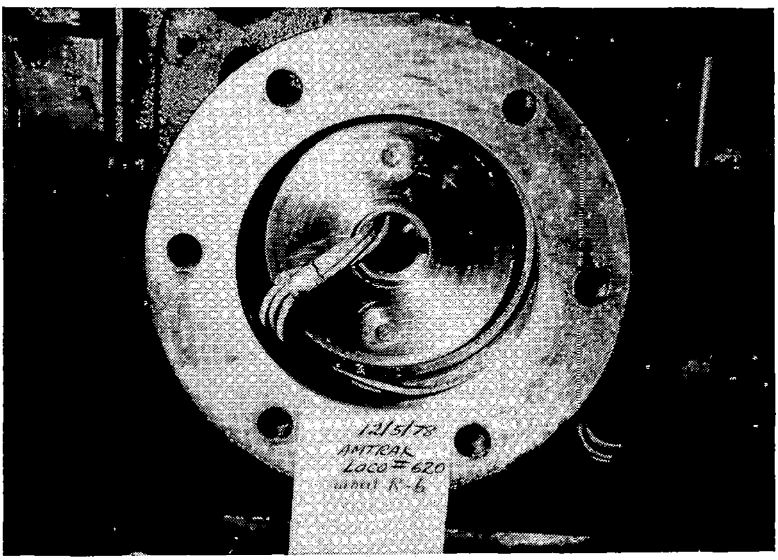
180. DAMAGED WIRING DUE TO OVERHEATED THRUST BEARING



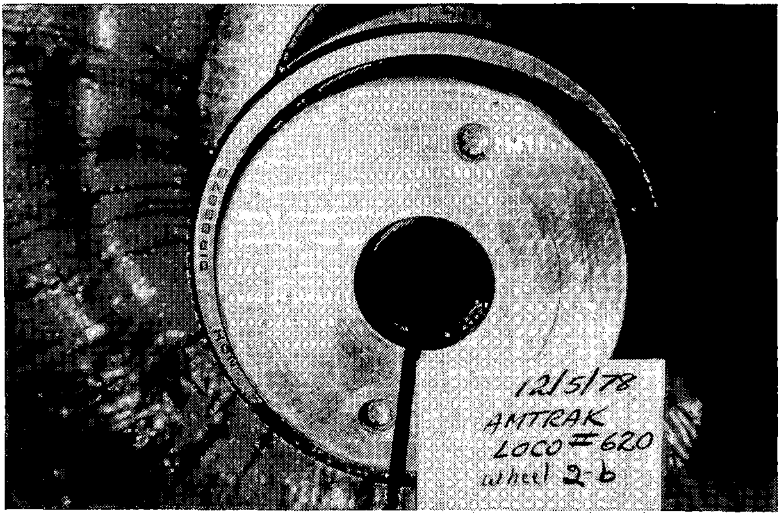
182. DETAIL OF DAMAGED WIRING AFTER REMOVAL



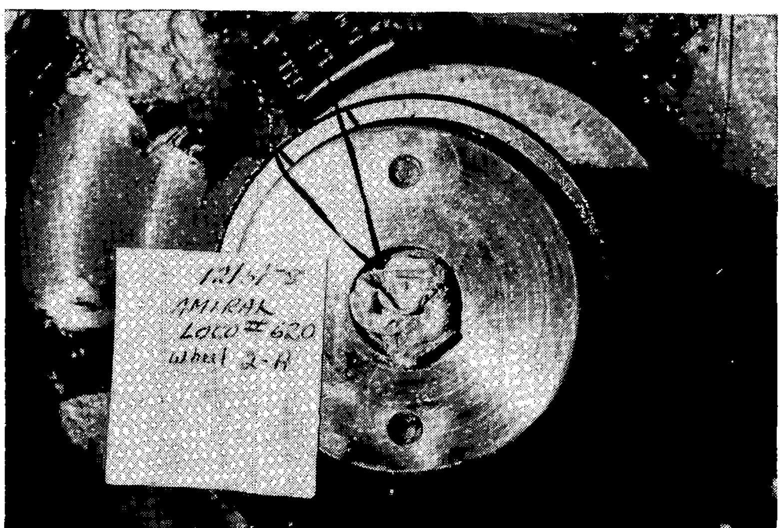
183. DETAIL OF AXLE 10 THRUST BEARING



185. DETAIL OF AXLE 12 THRUST BEARING SHOWING COUNTERSUNK AND STAKED SET SCREWS AFTER REPAIR

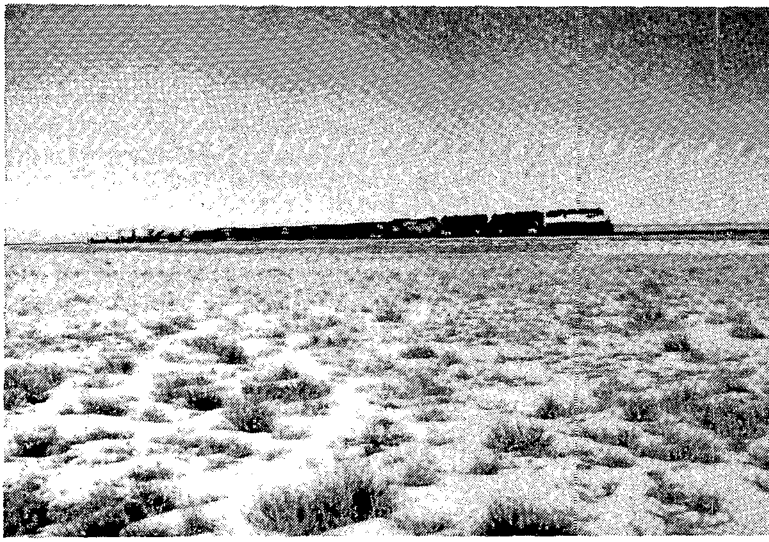


184. AXLE 11 THRUST BEARING SHOWING COUNTERSUNK AND STAKED SET SCREWS AFTER REPAIR - LEFT SIDE



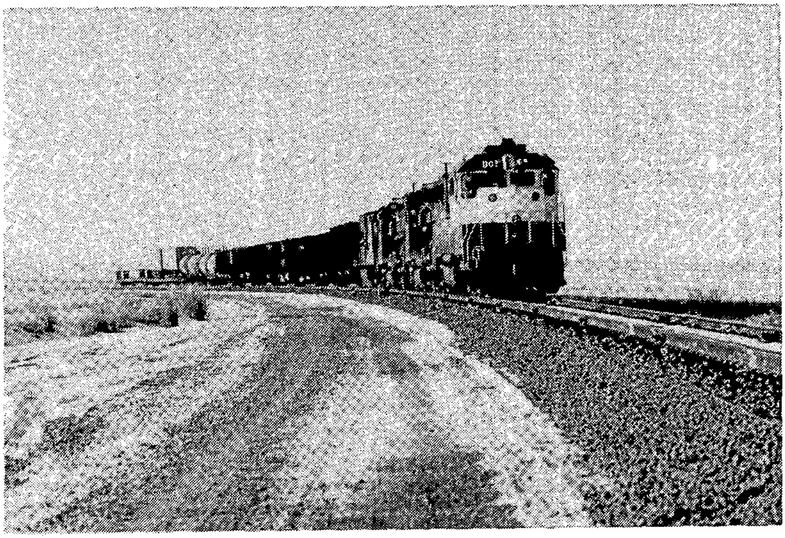
186. AXLE 11 THRUST BEARING SLIP RING SIDE

XI. FREIGHT TEST



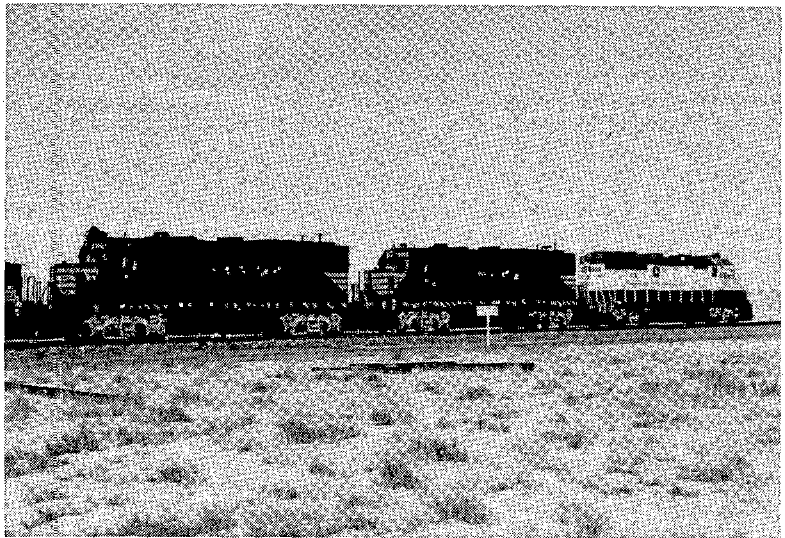
187. 11 - CAR FREIGHT CONSIST - SIDE VIEW

189. 11 - CAR FREIGHT CONSIST IN SECTION 4



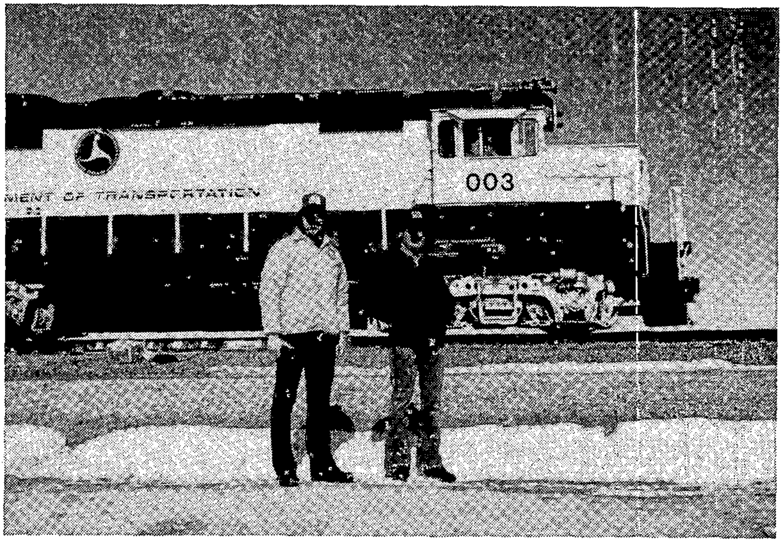
188. 11 - CAR FREIGHT CONSIST ACCELERATING
TOWARD TEST ZONE

190. CLOSE-UP OF CONSIST



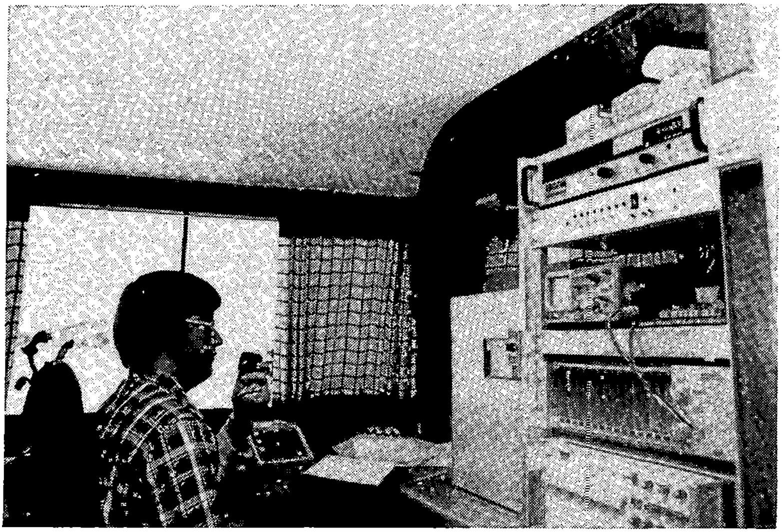
191. 3 OF THE LOCOMOTIVES USED IN FREIGHT TESTING

193. TRACK INSTRUMENTATION FOR FREIGHT TEST



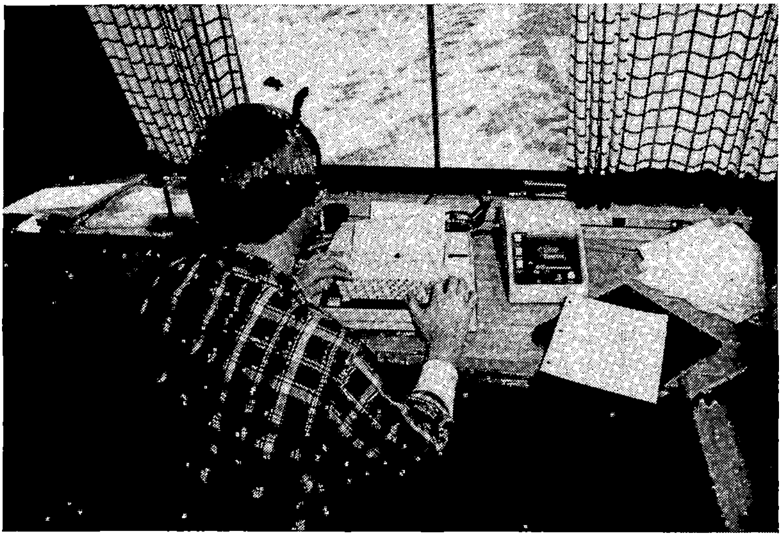
192. GP-40-2 4-AXLE LOCOMOTIVE

194. BATTELLE WAYSIDE DATA COLLECTION AND PROCESSING MOBILE UNIT



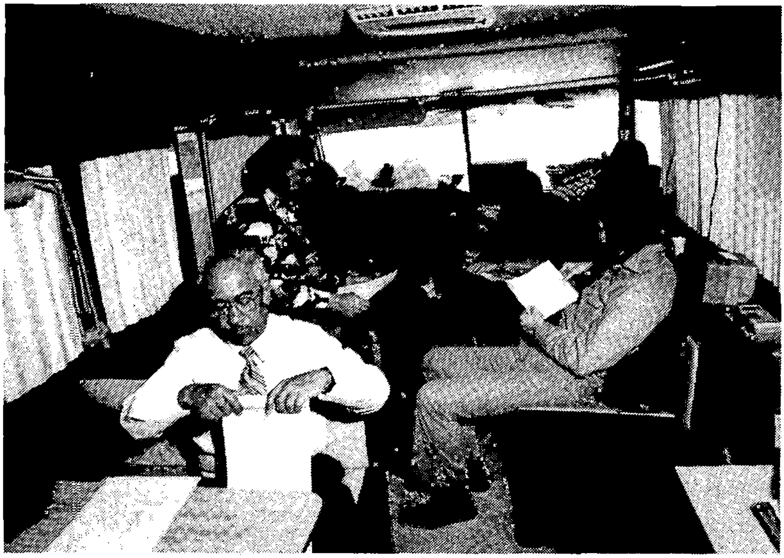
195. DATA PROCESSING IN BCL MOBILE UNIT FOR FREIGHT TEST

197. OUTPUT FROM PROCESSOR FOR REAL TIME ANALYSIS



196. DATA VERIFICATION

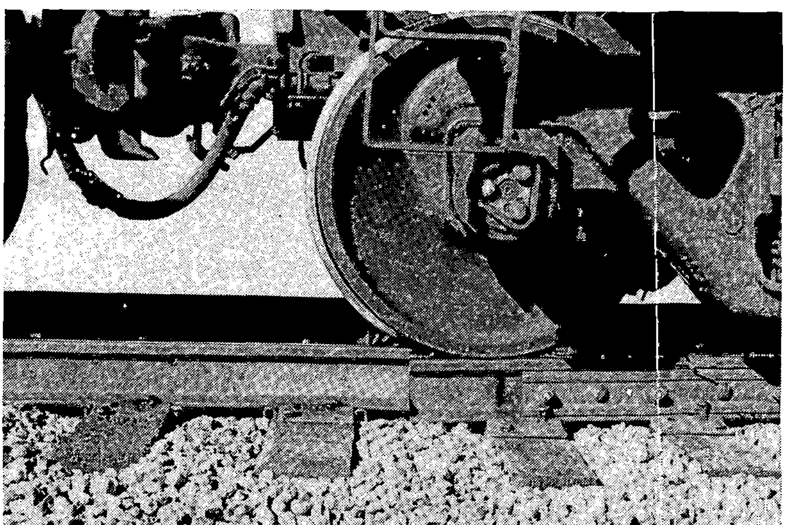
198. REAL TIME DATA ANALYSIS OF O - GRAPH



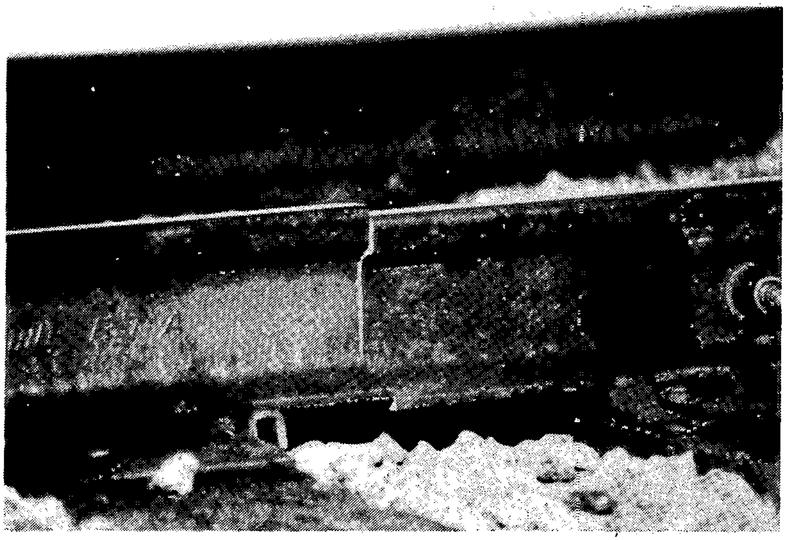
199. CHECKING DATA AGAINST SAFETY CRITERIA

201. 30-CAR FREIGHT CONSIST

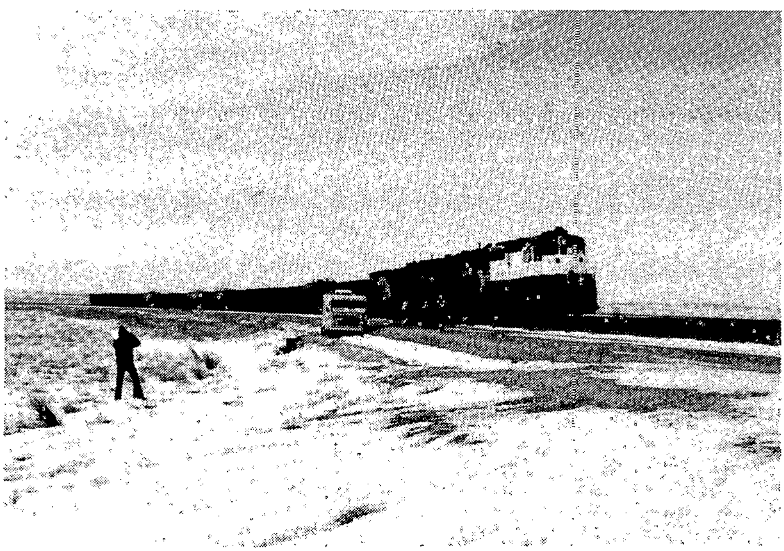
200. CLOSE-UP OF O - GRAPH



202. "WALKING" TRAIN OVER FAST RAIL BREAK

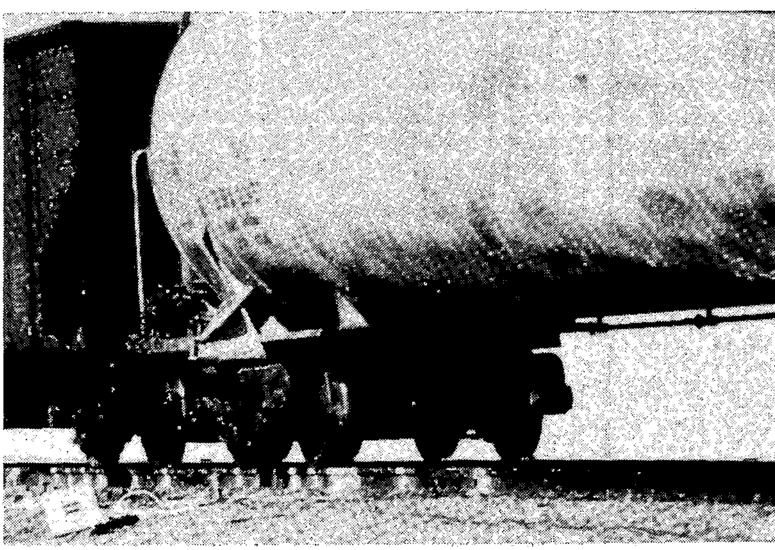


203. FAST RAIL BREAK



205. 20-CAR FREIGHT CONSIST - CARS DROPPED FROM LEAD END DUE TO FAST RAILBREAK

204. DETAIL OF RAIL BREAK



206. WHEEL LIFT ON HIGH RAIL IN SECTION 4

APPENDIX B

TEST MATRIX AND OBJECTIVES

The Perturbed Track Test was designed to address a broad spectrum of hypotheses within the general objectives stated in Chapter 1. Included here is a compilation of the test matrices as planned and as run with the specific objectives of each test series singled out for reference.

TEST MATRIX

AND

OBJECTIVES

(PTT MAIN TEST PROGRAM)

PROGRAM OBJECTIVES

(1) TO PROVIDE DATA FOR THE DESIGN AND USE OF SAFE

(2) TO DELINEATE SAFE OPERATING BOUNDARIES FOR THE SDP-40F AND SIMILAR 6-AXLE LOCOMOTIVES

(3) TO PROVIDE DATA FOR LOCOMOTIVE MODEL VALIDATION

(4) TO OBTAIN CORRELATIONS BETWEEN LOCOMOTIVE RESPONSE, OPERATING CONDITIONS, AND TRACK GEOMETRY

TRACK VARIABLES

TEST CURVE (1.5°, 3" SUPERELEVATION)

PL Cross Level (± .5")	N	PL Alignment (1.5")	N	RS Alignment (1")	N	PL Combined Crosslevel + Alignment (±.5" C, 1.5" A)	N	RS Continuous High Rail Alignment (1")
				4 cycles "Stiff" | 2 cycles "Soft"				Superelevation: 3" | T | 2" | T | 1"

THESE SECTIONS UNIQUELY EXCITE THE LATERAL AND ROLL MODES AND ENABLE THE FOLLOWING COMPARISONS:

A. Superposition of crosslevel and alignment (on a curve)

B. Importance of waveform (PL and RS)

C. Alignment and high rail only alignment (which includes gage variation)

D. Effect of different input frequencies (on a curve)

E. Effect of balance speed

F. Effect of track lateral compliance

PL = Piecewise Linear
RS = Rectified Sine
N = Nominal

TRACK VARIABLES

TEST TANGENT

PL Profile (1.5")	N	PL Crosslevel ($\pm$ .5")	N	PL Alignment (1.5")	N	PL Combined Crosslevel + Alignment ($\pm$ .5"C, 1.5"A)

THESE SECTIONS UNIQUELY EXCITE THE LATERAL, ROLL, AND VERTICAL MODES AND ENABLE THE FOLLOWING COMPARISONS:

A. Superposition of crosslevel and alignment (on tangent track)

B. Tangent and curved track response (for the same perturbations)

C. Wheel unloading from profile and twist

D. All response modes and their natural decay rates

E. Effect of different input frequencies (on tangent track)

PL = Piecewise Linear
N = Nominal

TEST VARIABLES

SPEED (RANGE 35 - 75 mph)

Primary independent variable, all response variables hypothesized to be strong function of speed or underbalance on curve.

LOCOMOTIVE DESIGN (SDP-40F and E-8)

To assess variations in dynamic response between two widely used 6-axle locomotives with significant differences in truck and vehicle design.

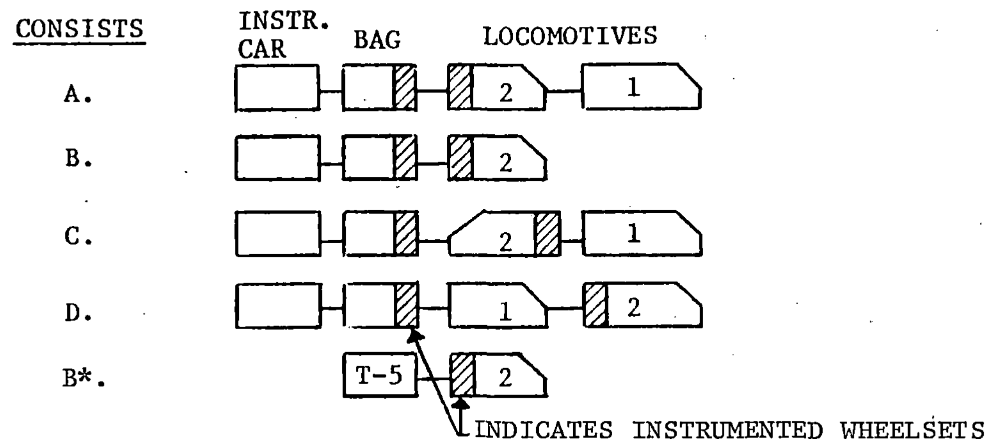
To clarify the differences in response shown in Chessie tests.

CONTROL VARIABLES

0. Baseline Dual Locomotives
1. Baseline Single Locomotive
2. Locomotive Orientation
3. Rail Surface Condition
4. Primary Suspension Damping
5. Coupler Vertical Misalignment

NOTATION USED IN MATRIX

LOCOMOTIVE ORIENTATION



RAIL SURFACE CONDITION

D - DRY
DS - DRY SAND
RL - RAIL LUBRICANT (MANUALLY APPLIED TO HIGH RAIL)

SUSPENSION DAMPING (VERTICAL PRIMARY)

NOM - 1800/1800 SHOCK ABSORBERS
NS - NO SHOCK ABSORBERS
AS - ASYMMETRIC SHOCK ABSORBERS (NO SHOCKS ON LEFT SIDE)

COUPLER MISALIGNMENT (RESTRICTED VERTICAL COUPLER FREEDOM)

NOM - STANDARD ALIGNMENT
SHIMT - SHIMMING OF TOP OF COUPLER HOUSING REDUCING FREE CLEARANCE BY - .75"
SHIMB - SHIMMING OF BOTTOM OF COUPLER HOUSING REDUCING FREE CLEARANCE BY - 1.5"
B* - SPECIAL E-8 CONSIST. RUN AFTER SDP-40F PANEL SHIFT

SDP-40F: AS PLANNED TEST MATRIX

TOTAL RUNS= 167

			PRIORITY	SPEED									LOCOMOTIVE ORIENTATION				RAIL SURFACE CONDITION				SUSPENSION DAMPING			COUPLER ALIGNMENT		# OF RUNS
				35-40	40-43	43-47	47-50	50-55	55-60	60-65	65-70	70-75	A	B	C	D	D	DS	RL	FL	NOM.	NS	AS	NOM	SHIM	
CURVE		BASELINE DUAL	1	1	2	1	2	2	2	1	2	2	X				X				X					15
CURVE		LOCOMOTIVE ORIENTATION											X				X				X					--
														X			X				X					--
			5		2		1	2		1		2			X		X				X					8
			6		2		1	2		1		2				X	X				X					8
CURVE	SINGLE LOCOMOTIVE	BASELINE SINGLE	3	1	4	1	2	4	2	1	4			X			X				X					19
		RAIL SURFACE CONDITION												X			X				X					--
			7	1	2		1	2		1	2			X				X			X					9
			8	1	2		1	2		1	2			X					X		X					9
			15	1	2		1	2		1	2			X						X	X					9
		SUSPENSION DAMPING												X			X				X					--
			11	1	2	1	2	1	2		1			X			X					X				10
			12	1	2	1	2	1	2		1			X			X						X			10
																										97
TANGENT		BASELINE DUAL	2	1	2	1	2	2	2	1	2	2	X				X				X			X		15
TANGENT	SINGLE LOCOMOTIVE	BASELINE SINGLE	4	1	4	1	2	4	2	1	4	2		X			X				X			X		21
		RAIL SURFACE CONDITION												X			X				X			X		--
			9		2			2			2			X				X			X			X		6
			16		2			2			2			X						X	X			X		6
		SUSPENSION DAMPING												X			X				X			X		--
			10	1	2	1	2	1	2		1			X			X					X		X		10
		COUPLER MIS-ALIGNMENT												X			X				X			X		--
														X			X					X		X		--
			13		2		2		2					X			X				X				X	6
			14		2		2		2					X			X					X			X	6
																										70

SDP-40F: AS RUN TEST MATRIX

TOTAL RUNS = 159

			SPEED										LOCOMOTIVE ORIENTATION			RAIL SURFACE CONDITION			SUSPENSION DAMPING			COUPLER ALIGNMENT			# OF RUNS
			35-40	40-43	43-47	47-50	50-55	55-60	60-65	65-70	70-75	75-80	A	B	C	D	DS	RL	NOM	NS	AS	NOM	SHIMT	SHIMB	
CURVE		BASELINE DUAL 12/1/78	1	1	1	1	1	1	2	3	1	1	X			X			X			X			13
CURVE		BASELINE DUAL 12/14/78	1	2	2		1	2	1	2	2	1	X			X			X			X			14
CURVE		LOCOMOTIVE ORIENTATION	2	2	2		2	1	2	1	1	1			X	X			X			X			14
CURVE	SINGLE LOCOMOTIVE	BASELINE SINGLE	4	2	1	2	2	1	1	1	2	1		X		X			X			X			17
CURVE	SINGLE LOCOMOTIVE	RAIL SURFACE CONDITION	2	2	1		1	1		1				X			X		X			X			8
CURVE	SINGLE LOCOMOTIVE	RAIL SURFACE CONDITION **	1	2	2		1	1	1	1				X			X		X			X			9
CURVE	SINGLE LOCOMOTIVE	RAIL SURFACE CONDITION ***		3	1		2	1	2	1	1			X				X	X			X			11
CURVE	SINGLE LOCOMOTIVE	SUSPENSION DAMPING	2	1	2	1		1	1	1	1			X		X				X		X			10
CURVE	SINGLE LOCOMOTIVE	SUSPENSION DAMPING	1	2	1	2		1	2	1	1			X		X					X	X			11
																									107
TANGENT		BASELINE DUAL	1	1	2	1	1	1	1	2	1	2	X			X			X			X			13
TANGENT	SINGLE LOCOMOTIVE	BASELINE SINGLE	2	1	1		1	1	1	1	1	2		X		X			X			X			11
TANGENT	SINGLE LOCOMOTIVE	RAIL SURFACE CONDITION		1				1		1				X		X				X				X	3
TANGENT	SINGLE LOCOMOTIVE	RAIL SURFACE CONDITION		1	1	1	1	1	2	1				X			X			X				X	8
TANGENT	SINGLE LOCOMOTIVE	SUSPENSION DAMPING		2	1	1	2	2	1	1	1			X		X				X		X			11
TANGENT	SINGLE LOCOMOTIVE	COUPLER MISALIGNMENT	1	1	2		1		1					X		X				X			X	*	6
																									52

* SEE "RAIL SURFACE CONDITION"
** SECOND DAY OF RAIL SURFACE 12/9/75, NO WAYSIDE INSTRUMENTATION
*** FIRST RUN AT 40 MPH, ATTEMPT AT FLANGE LUBRICATION TEST - NOT FUNCTIONING

E-8: AS PLANNED TEST MATRIX

TOTAL RUNS = 63

		PRIORITY	SPEED									LOCOMOTIVE ORIENTATION				RAIL SURFACE CONDITION				SUSPENSION DAMPING			COUPLER ALIGNMENT		# OF RUNS
			35-40	40-43	43-47	47-50	50-55	55-60	60-65	65-70	70-75	A	B	C	D	D	DS	RL	FL	NOM.	NS	AS	NOM	SHIM	RUNS
CURVE	BASELINE DUAL	1	1	2	1	2	2	2	1	2	2	X													15
CURVE	LOCOMOTIVE ORIENTATION											X													--
													X												--
		5		2		1	2		1		2			X											8
		6		2		1	2		1		2				X										8
CURVE	BASELINE SINGLE	3		2		1	2		1	2			X												8
																									39

		PRIORITY	35-40	40-43	43-47	47-50	50-55	55-60	60-65	65-70	70-75	A	B	C	D	D	DS	RL	FL	NOM.	NS	AS	NOM	SHIM	# OF RUNS
TANGENT	BASELINE DUAL	2	1	2	1	2	2	2	1	2	2	X													15
TANGENT	BASELINE SINGLE	4		2		1	2		1	1	2		X												9
																									24

E-8: AS RUN TEST MATRIX

TOTAL RUNS = 89

		SPEED										LOCOMOTIVE ORIENTATION				RAIL SURFACE CONDITION			SUSPENSION DAMPING			COUPLER ALIGNMENT			# OF RUNS
		35-40	40-43	43-47	47-50	50-55	55-60	60-65	65-70	70-75	75-80	A	B	C	D	D	DS	RL	NOM	NS	AS	NOM	SHIMT	SHIMB	
CURVE	BASELINE DUAL	1	1	1	3	1	2	2	2	2	1	X				X			X			X			16
CURVE	LOCOMOTIVE ORIENTATION	1	1	1		1	1	1	1				X*			X			X			X			7
			1		2	2	2	2	1	1	1			X		X			X			X			12
			2		1	2o	2	2	1	2	1				Xo	X			X			X			13
CURVE	BASELINE SINGLE		1	1	2	1	3	2					X			X			X			X			10
																									58
TANGENT	BASELINE DUAL	1	2	1	2	2	3	3	2	1	2	X				X			X			X			19
TANGENT	BASELINE SINGLE	1	1		1	2	1	3	1	2			X			X			X			X			12
																									31

* CONSIST "B*" w/o BAGGAGE CAR

o LAST RUN DONE w/SAND AT 50 MPH

Objectives of Each Test Series

SDP-40F
ON
CURVE

SDP-40F CURVE

	PRIORITY	SPEED									LOCOMOTIVE ORIENTATION				RAIL SURFACE CONDITION				SUSPENSION DAMPING			COUPLER ALIGNMENT		# OF
		35-40	40-43	43-47	47-50	50-55	55-60	60-65	65-70	70-75	A	B	C	D	D	DS	RL	FL	NOM.	NS	AS	NOM	SHIM	RUNS
0. BASELINE DUAL LOCOMOTIVES	1	1	2	1	2	2	2	1	2	2	X				X				X					15

PURPOSE

1. BASELINE REFERENCE FOR PTT AND CHESSIE (Requires covering all speeds)

2. ESTABLISH STATISTICAL REPEATABILITY (Requires repeat runs)

IMPORTANCE TO SAFE

1. ABILITY TO EXTRAPOLATE FROM CONTROLLED TESTS TO REVENUE SERVICE (using PTT and Chessie tests)

2. IDENTIFICATION OF CRITICAL TRACK PERTURBATIONS (on curve)

IMPORTANCE TO OPERATING GUIDELINES

1. CONFIRMATION AND EXTENSION OF CHESSIE TEST UNDERBALANCE SPEED RESULTS

2. IMPORTANCE OF DIFFERENT TRACK PERTURBATIONS FOR TRACK SAFETY STANDARDS

SDP-40F CURVE

	PRIORITY	SPEED									LOCOMOTIVE ORIENTATION				RAIL SURFACE CONDITION				SUSPENSION DAMPING			COUPLER ALIGNMENT		# OF RUNS
		35-40	40-43	43-47	47-50	50-55	55-60	60-65	65-70	70-75	A	B	C	D	D	DS	RL	FL	NOM.	NS	AS	NOM	SHIM	
1. BASELINE SINGLE LOCOMOTIVE	3	1	4	1	2	4	2	1	4			X			X				X					19

PURPOSE

1. REFERENCE FOR ALL OTHER TEST CONDITIONS (Requires covering all speeds)
2. OVER WHAT REGIME ARE LOCOMOTIVES DYNAMICALLY UNCOUPLED, AND WHEN IS A SINGLE LOCOMOTIVE MODEL ADEQUATE (On curve)
3. CURVING MODEL VALIDATION (Requires multiple runs at several speeds)

IMPORTANCE TO SAFE

1. ABILITY TO USE MODELS TO EXTRAPOLATE BEYOND TEST CONDITIONS

IMPORTANCE TO OPERATING GUIDELINES

1. ABILITY TO USE MODELS TO DEVELOP OPERATING GUIDELINES

SDP-40F CURVE

	PRIORITY	SPEED 35-40	40-43	43-47	47-50	50-55	55-60	60-65	65-70	70-75	LOCOMOTIVE ORIENTATION A	B	C	D	RAIL SURFACE CONDITION D	DS	RL	FL	SUSPENSION DAMPING NOM.	NS	AS	COUPLER ALIGNMENT NOM	SHIM	# OF RUNS
2. LOCOMOTIVE ORIENTATION	5 6		2 2		1 1	2 2		1 1		2 2	X	X	X	X	X X X X				X X X X			X	X	-- -- 8 8

PURPOSE

A. REFERENCE

B. COUPLING BETWEEN LOCOMOTIVES ON CURVE

C. TRUCK TO TRUCK VARIATIONS AND COUPLING BETWEEN LEADING AND TRAILING TRUCK

D. LOCOMOTIVE-TO-LOCOMOTIVE VARIATIONS AND COUPLING BETWEEN BAGGAGE CAR AND TRAILING LOCOMOTIVE

IMPORTANCE TO SAFE

1. HOW REPRESENTATIVE IS ONE VEHICLE OF ITS TYPE?
2. ESTIMATE OF DYNAMIC RESPONSE SPREAD INHERENT BETWEEN TRUCKS AND VEHICLES OF SAME DESIGN IN NOMINAL CONDITION OF MAINTENANCE

IMPORTANCE TO OPERATING GUIDELINES

1. IMPORTANCE OF NOMINAL VARIATIONS IN TRUCKS AND VEHICLES OF THE SAME TYPE
2. IMPORTANCE OF LOCOMOTIVE AND BAGGAGE CAR COUPLING
3. IMPORTANCE OF TRUCK POSITION

SDP-40F CURVE

	PRIORITY	SPEED									LOCOMOTIVE ORIENTATION				RAIL SURFACE CONDITION				SUSPENSION DAMPING			COUPLER ALIGNMENT		# OF
		35-40	40-43	43-47	47-50	50-55	55-60	60-65	65-70	70-75	A	B	C	D	D	DS	RL	FL	NOM.	NS	AS	NOM	SHIM	RUNS
3. RAIL SURFACE CONDITION												X			X				X					--
	7	1	2		1	2		1	2			X				X			X					9
	8	1	2		1	2		1	2			X					X		X					9
	15	1	2		1	2		1	2			X						X	X					9

PURPOSE

1. EFFECT OF RAIL SURFACE CONDITION AS A FUNCTION OF SPEED, ON CURVE
2. EFFECT ON DIFFERENT VEHICLES (Locomotive, Baggage Car, and T-7)
3. CURVING MODEL VALIDATION: EXTRACT CREEP COEFFICIENTS AND BOUND REGIME (RL, D, DS)
4. USEFULNESS OF FLANGE LUBRICATOR AND IMPORTANCE OF CREEP VS. IMPACT FORCES (RL, FL)

IMPORTANCE TO SAFE

1. IMPORTANCE OF TESTING UNDER DS RELATIVE TO D
2. IMPORTANCE OF ENVIRONMENTAL CONDITIONS ON SAFE TESTING (RL, D, DS)

IMPORTANCE TO OPERATING GUIDELINES

1. GUIDELINES ON USE OF SAND
2. SIGNIFICANCE OF RAIL LUBRICATION FOR ENTIRE CONSIST
3. USEFULNESS OF FLANGE LUBRICATOR

SDP-40F CURVE

	PRIORITY	SPEED									LOCOMOTIVE ORIENTATION				RAIL SURFACE CONDITION				SUSPENSION DAMPING			COUPLER ALIGNMENT		# OF
		35-40	40-43	43-47	47-50	50-55	55-60	60-65	65-70	70-75	A	B	C	D	D	DS	RL	FL	NOM.	NS	AS	NOM	SHIM	RUNS
4. PRIMARY SUSPENSION DAMPING												X			X				X					--
	11	1	2	1	2	1	2		1			X			X					X				10
	12	1	2	1	2	1	2		1			X			X						X			10

PURPOSE

1. IMPORTANCE OF PRIMARY VERTICAL DAMPING ON WHEEL UNLOADING
2. IMPORTANCE OF SHOCK MAINTENANCE AND IDENTIFICATION OF WHETHER ESPECIALLY CRITICAL CONDITIONS EXIST (NS, AS)
3. IDENTIFICATION OF ROLL COUPLING BETWEEN BAGGAGE CAR AND TRAILING LOCOMOTIVE (HS, NS)
4. CURVING MODEL VALIDATION: ASSESS MODEL CAPABILITY TO PREDICT SUSPENSION CHANGE (NS)

IMPORTANCE TO SAFE

1. IDENTIFICATION OF ESPECIALLY CRITICAL SNUBBER TEST CONDITIONS (Curving truck yaw and roll modes)

IMPORTANCE TO OPERATING GUIDELINES

1. IMPORTANCE OF SNUBBER MAINTENANCE ON VEHICLE SAFETY AND IDENTIFICATION OF ESPECIALLY CRITICAL CONDITIONS

Objectives of Each Test Series

E-8

ON

CURVE

E-8 CURVE

	PRIORITY	SPEED 35-40	40-43	43-47	47-50	50-55	55-60	60-65	65-70	70-75	LOCOMOTIVE ORIENTATION A	B	C	D	RAIL SURFACE CONDITION D	DS	RL	FL	SUSPENSION DAMPING NOM.	NS	AS	COUPLER ALIGNMENT NOM	SHIM	# OF RUNS
0. BASELINE DUAL LOCOMOTIVES	1	1	2	1	2	2	2	1	2	2	X													15

PURPOSE

1. COMPARISON OF E-8 AND SDP-40F AND BAGGAGE CAR RESPONSE (Requires covering all speeds)
2. ESTABLISH STATISTICAL REPEATABILITY (Requires repeat runs)
3. IDENTIFICATION OF RELATIVE LATERAL COUPLING BETWEEN BAGGAGE CAR AND SDP-40F AND BAGGAGE CAR AND E-8

IMPORTANCE TO SAFE

PROVIDES DATA ON 2nd LOCOMOTIVE TYPE TO ESTABLISH CONFIDENCE LEVEL IN:

1. ABILITY TO EXTRAPOLATE FROM CONTROLLED TESTS TO REVENUE SERVICE (Using PTT and Chessie tests)
2. IDENTIFICATION OF CRITICAL TRACK PERTURBATIONS (On curve)

IMPORTANCE TO OPERATING GUIDELINES

1. PROVIDES BASELINE AGAINST WHICH TO JUDGE RELATIVE ACCEPTABILITY OF SDP-40F RESPONSE, AND PROVIDES 2nd LOCOMOTIVE TYPE TO ESTABLISH CONFIDENCE LEVEL IN:
   - A. CONFIRMATION AND EXTENSION OF CHESSIE TESTS UNDERBALANCE SPEED RESULTS
   - B. IMPORTANCE OF DIFFERENT TRACK PERTURBATIONS FOR TRACK SAFETY STANDARDS
2. UNIQUELY ESTABLISHES:
   1. WHETHER SDP-40F (Under nominal coupler forces) CAUSES BAGGAGE CAR TO HAVE HIGHER LATERAL WHEEL FORCES

E-8 CURVE

	PRIORITY	SPEED									LOCOMOTIVE ORIENTATION				RAIL SURFACE CONDITION				SUSPENSION DAMPING			COUPLER ALIGNMENT		# OF RUNS
		35-40	40-43	43-47	47-50	50-55	55-60	60-65	65-70	70-75	A	B	C	D	D	DS	RL	FL	NOM.	NS	AS	NOM	SHIM	RUNS
1. BASELINE SINGLE LOCOMOTIVE	3		2		1	2		1	2			X												8

<u>PURPOSE</u>

PROVIDES DATA ON 2nd LOCOMOTIVE TYPE TO ESTABLISH CONFIDENCE LEVEL IN:

1. OVER WHAT REGIME ARE LOCOMOTIVES DYNAMICALLY UNCOUPLED, AND WHEN IS A SINGLE LOCOMOTIVE MODEL ADEQUATE (On curve)

2. CURVING MODEL VALIDATION

<u>IMPORTANCE TO SAFE</u>

PROVIDES DATA ON 2nd LOCOMOTIVE TYPE TO ESTABLISH CONFIDENCE LEVEL IN:

1. ABILITY TO USE MODELS TO EXTRAPOLATE BEYOND TEST CONDITIONS.

<u>IMPORTANCE TO OPERATING GUIDELINES</u>

PROVIDES BASELINE AGAINST WHICH TO JUDGE RELATIVE ACCEPTABILITY OF SDP-40F RESPONSE AND PROVIDES 2nd LOCOMOTIVE TYPE TO ESTABLISH CONFIDENCE LEVEL IN:

1. ABILITY TO USE MODELS TO DEVELOP OPERATING GUIDELINES.

B-21

E-8 CURVE

	PRIORITY	SPEED 35-40	40-43	43-47	47-50	50-55	55-60	60-65	65-70	70-75	LOCOMOTIVE ORIENTATION A	B	C	D	RAIL SURFACE CONDITION D	DS	RL	FL	SUSPENSION DAMPING NOM.	NS	AS	COUPLER ALIGNMENT NOM	SHIM	# OF RUNS
2. LOCOMOTIVE ORIENTATION											X													--
												X												--
	5		2		1	2		1		2			X											8
	6		2		1	2		1		2				X										8

PURPOSE

PROVIDES DATA FOR A LOCOMOTIVE OF DIFFERENT DESIGN FROM SDP-40F TO COMPARE:

A. REFERENCE

B. COUPLING BETWEEN LOCOMOTIVES ON CURVE

C. TRUCK-TO-TRUCK VARIATIONS AND COUPLING BETWEEN LEADING AND TRAILING TRUCKS

D. LOCOMOTIVE-TO-LOCOMOTIVE VARIATIONS AND COUPLING BETWEEN BAGGAGE CAR AND TRAILING LOCOMOTIVE

IMPORTANCE TO SAFE

PROVIDES DATA ON 2nd LOCOMOTIVE TYPE TO ESTABLISH CONFIDENCE LEVEL IN:

1. HOW REPRESENTATIVE ONE VEHICLE IS OF IT TYPE
2. ESTIMATE OF DYNAMIC RESPONSE SPREAD INHERENT BETWEEN TRUCKS OF SAME DESIGN IN NOMINAL CONDITION OF MAINTENANCE

IMPORTANCE TO OPERATING GUIDELINES

PROVIDES BASELINE AGAINST WHICH TO JUDGE RELATIVE ACCEPTABILITY OF SDP-40F RESPONSE, AND PROVIDES 2ND LOCOMOTIVE TYPE TO ESTABLISH CONFIDENCE LEVEL IN:

1. IMPORTANCE OF NOMINAL VARIATIONS IN TRUCKS AND VEHICLES OF THE SAME TYPE
2. IMPORTANCE OF LOCOMOTIVE AND BAGGAGE CAR COUPLING
3. IMPORTANCE OF TRUCK POSITION

Objectives of Each Test Series

SDP-40F

ON

TANGENT

SDP-40F TANGENT

	PRIORITY	SPEED 35-40	40-43	43-47	47-50	50-55	55-60	60-65	65-70	70-75	LOCOMOTIVE ORIENTATION A	B	C	D	RAIL SURFACE CONDITION D	DS	RL	FL	SUSPENSION DAMPING NOM.	NS	AS	COUPLER ALIGNMENT NOM	SHIM	# OF RUNS
0. BASELINE DUAL LOCOMOTIVES	2	1	2	1	2	2	2	1	2	2	X				X				X			X		15

PURPOSE

1. BASELINE REFERENCE FOR PTT AND CHESSIE (Requires covering all speeds)
2. ESTABLISH STATISTICAL REPEATABILITY (Requires repeat runs)
3. COMPARISON OF CURVE AND TANGENT RESPONSE
4. COMPARISON OF WHEEL UNLOADING DUE TO PROFILE AND CROSSLEVEL

IMPORTANCE TO SAFE

1. ABILITY TO EXTRAPOLATE FROM CONTROLLED TESTS TO REVENUE SERVICE (Using PTT and Chessie tests)
2. IDENTIFICATION OF CRITICAL TRACK PERTURBATIONS (On tangent)
3. IMPORTANCE OF TANGENT TESTING

IMPORTANCE TO OPERATING GUIDELINES

1. FOR EQUIVALENT PERTURBATIONS, IDENTIFICATION OF RELATIVE SEVERITY OF TANGENT AND CURVED TRACK RESPONSE AS A FUNCTION OF SPEED
2. IMPORTANCE OF DIFFERENT TRACK PERTURBATIONS FOR TRACK SAFETY STANDARDS (Tangent vs. curve)

SDP-40F TANGENT

	PRIORITY	SPEED									LOCOMOTIVE ORIENTATION				RAIL SURFACE CONDITION				SUSPENSION DAMPING			COUPLER ALIGNMENT		# OF RUNS
		35-40	40-43	43-47	47-50	50-55	55-60	60-65	65-70	70-75	A	B	C	D	D	DS	RL	FL	NOM.	NS	AS	NOM	SHIM	RUNS
1. BASELINE SINGLE LOCOMOTIVE	4	1	4	1	2	4	2	1	4	2		X			X				X			X		21

PURPOSE

1. REFERENCE FOR ALL OTHER TEST CONDITIONS (Requires covering all speeds)
2. OVER WHAT REGIME ARE LOCOMOTIVES DYNAMICALLY UNCOUPLED, AND WHEN IS SINGLE LOCOMOTIVE MODEL ADEQUATE (On tangent)
3. TANGENT MODEL VALIDATION (Requires multiple runs at several speeds)

IMPORTANCE TO SAFE

1. ABILITY TO USE MODELS TO EXTRAPOLATE BEYOND TEST CONDITIONS

IMPORTANCE TO OPERATING GUIDELINES

1. ABILITY TO USE MODELS TO DEVELOP OPERATING GUIDELINES

SDP-40F TANGENT

	PRIORITY	SPEED 35-40	40-43	43-47	47-50	50-55	55-60	60-65	65-70	70-75	LOCOMOTIVE ORIENTATION A	B	C	D	RAIL SURFACE CONDITION D	DS	RL	FL	SUSPENSION DAMPING NOM.	NS	AS	COUPLER ALIGNMENT NOM	SHIM	# OF RUNS
3. RAIL SURFACE CONDITION												X			X				X			X		--
	9		2			2			2			X				X			X			X		6
	16		2			2			2			X						X	X			X		6

PURPOSE

1. EFFECT OF RAIL SURFACE CONDITION AS A FUNCTION OF SPEED, ON TANGENT
2. COMPARISON OF EFFECTS OF RAIL SURFACE CONDITION FOR TANGENT AND CURVE
3. TANGENT MODEL VALIDATION: EXTRACT CREEP COEFFICIENTS (D, DS)
4. USEFULNESS OF FLANGE LUBRICATOR ON TANGENT TRACK (FL)

IMPORTANCE TO SAFE

1. IMPORTANCE OF TANGENT TESTING UNDER DS RELATIVE TO D

IMPORTANCE TO OPERATING GUIDELINES

1. GUIDELINES ON USE OF SAND
2. USEFULNESS OF FLANGE LUBRICATOR ON TANGENT

SDP-40F TANGENT

	PRIORITY	SPEED									LOCOMOTIVE ORIENTATION				RAIL SURFACE CONDITION				SUSPENSION DAMPING			COUPLER ALIGNMENT		# OF
		35-40	40-43	43-47	47-50	50-55	55-60	60-65	65-70	70-75	A	B	C	D	D	DS	RL	FL	NOM.	NS	AS	NOM	SHIM	RUNS
4. PRIMARY SUSPENSION DAMPING	10	1	2	1	2	1	2		1			X X			X X				X	X		X X		-- 10

PURPOSE

1. IMPORTANCE OF PRIMARY VERTICAL DAMPING ON WHEEL UNLOADING AND VERTICAL CARBODY ACCELERATIONS
2. IMPORTANCE OF SHOCK MAINTENANCE
3. IDENTIFICATION OF VERTICAL COUPLING BETWEEN BAGGAGE CAR AND TRAILING LOCOMOTIVE (HS, NS)
4. TANGENT MODEL VALIDATION: ASSESS MODEL CAPABILITY TO PREDICT SUSPENSION CHANGE (NS)

IMPORTANCE TO SAFE

1. IMPORTANCE OF SNUBBER CONDITION AS A TEST PARAMETER (Tangent vertical and roll modes)

IMPORTANCE TO OPERATING GUIDELINES

1. EFFECT OF SNUBBER MAINTENANCE

SDP-40F TANGENT

	PRIORITY	SPEED									LOCOMOTIVE ORIENTATION				RAIL SURFACE CONDITION				SUSPENSION DAMPING			COUPLER ALIGNMENT		# OF
		35-40	40-43	43-47	47-50	50-55	55-60	60-65	65-70	70-75	A	B	C	D	D	DS	RL	FL	NOM.	NS	AS	NOM	SHIM	RUNS
5. COUPLER												X			X				X			X		--
VERTICAL												X			X					X		X		--
MISALIGNMENT	13		2		2		2					X			X				X				X	6
	14		2		2		2					X			X					X			X	6

PURPOSE

1. IMPORTANCE OF COUPLER VERTICAL ALIGNMENT AND IDENTIFICATION OF WHETHER CRITICAL CONDITIONS EXIST (HS, NS, SHIMS)
2. IDENTIFICATION OF VERTICAL COUPLING BETWEEN BAGGAGE CAR AND TRAILING LOCOMOTIVE
3. VALIDATE CHESSIE TRUCK SHIMMING HYPOTHESIS.

IMPORTANCE TO SAFE

1. IMPORTANCE OF COUPLER VERTICAL ALIGNMENT AS A TEST PARAMETER
2. IDENTIFICATION OF ESPECIALLY CRITICAL TEST CONDITION (Failed shocks and coupler misalignment)

IMPORTANCE TO OPERATING GUIDELINES

1. GUIDELINES ON ALLOWABLE COUPLER VERTICAL MISALIGNMENT
2. IDENTIFICATION OF ESPECIALLY CRITICAL CONDITIONS FOR BAGGAGE CAR

Objectives of Each Test Series

E-8

ON

TANGENT

E-8 TANGENT

	PRIORITY	SPEED									LOCOMOTIVE ORIENTATION				RAIL SURFACE CONDITION				SUSPENSION DAMPING			COUPLER ALIGNMENT		# OF RUNS
		35-40	40-43	43-47	47-50	50-55	55-60	60-65	65-70	70-75	A	B	C	D	D	DS	RL	FL	NOM.	NS	AS	NOM	SHIM	
0. BASELINE DUAL LOCOMOTIVES	2	1	2	1	2	2	2	1	2	2	X													15

PURPOSE

1. COMPARISON OF E-8 AND SDP-40F AND BAGGAGE CAR RESPONSE (Requires covering all speeds)
2. ESTABLISH STATISTICAL REPEATABILITY (Requires repeat runs)
3. COMPARISON OF CURVE AND TANGENT RESPONSE FOR A LOCOMOTIVE OF DIFFERENT DESIGN FROM SDP-40F
4. IDENTIFICATION OF RELATIVE VERTICAL COUPLING BETWEEN BAGGAGE CAR AND SDP-40F AND BAGGAGE CAR AND E-8

IMPORTANCE TO SAFE

PROVIDES DATA ON 2nd LOCOMOTIVE TYPE TO ESTABLISH CONFIDENCE LEVEL IN:

1. ABILITY TO EXTRAPOLATE FROM CONTROLLED TESTS TO REVENUE SERVICE (Using PTT and Chessie tests)
2. IDENTIFICATION OF CRITICAL TRACK PERTURBATIONS (On tangent)
3. IMPORTANCE OF TANGENT TESTING

IMPORTANCE OF OPERATING GUIDELINES

1. PROVIDES BASELINE AGAINST WHICH TO JUDGE RELATIVE ACCEPTABILITY OF SDP-40F RESPONSE, AND PROVIDES 2nd LOCOMOTIVE TYPE TO ESTABLISH CONFIDENCE LEVEL IN:
   A. FOR EQUIVALENT PERTURBATIONS, IDENTIFICATION OF RELATIVE SEVERITY OF TANGENT AND CURVED-TRACK RESPONSE AS A FUNCTION OF SPEED
   B. IMPORTANCE OF DIFFERENT TRACK PERTURBATIONS FOR TRACK SAFETY STANDARDS (Tangent vs. curve)
2. UNIQUELY ESTABLISHES:
   A. WHETHER HIGH CARBODY ACCELERATIONS ARE INHERENT TO BAGGAGE CAR

E-8 TANGENT

	PRIORITY	SPEED									LOCOMOTIVE ORIENTATION				RAIL SURFACE CONDITION				SUSPENSION DAMPING			COUPLER ALIGNMENT		# OF RUNS
		35-40	40-43	43-47	47-50	50-55	55-60	60-65	65-70	70-75	A	B	C	D	D	DS	RL	FL	NOM.	NS	AS	NOM	SHIM	RUNS
1. BASELINE SINGLE LOCOMOTIVE	4		2		1	2		1	1	2		X												9

PURPOSE

PROVIDES DATA ON 2nd LOCOMOTIVE TYPE TO ESTABLISH CONFIDENCE LEVEL IN:

1. OVER WHAT REGIME ~~ARE~~ LOCOMOTIVES DYNAMICALLY UNCOUPLED, AND WHEN ~~IS~~ A SINGLE LOCOMOTIVE MODEL ADEQUATE (On tangent)
2. TANGENT MODEL VALIDATION

IMPORTANCE TO SAFE

PROVIDES DATA ON 2nd LOCOMOTIVE TYPE TO ESTABLISH CONFIDENCE LEVEL IN:

1. ABILITY TO USE MODELS TO EXTRAPOLATE BEYOND TEST CONDITIONS

IMPORTANCE TO OPERATING GUIDELINES

PROVIDES BASELINE AGAINST WHICH TO JUDGE RELATIVE ACCEPTABILITY OF SDP-40F RESPONSE, AND PROVIDES 2nd LOCOMOTIVE TYPE TO ESTABLISH CONFIDENCE LEVEL IN:

1. ABILITY TO USE MODELS TO DEVELOP OPERATING GUIDELINES

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