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EVALUATION OF STEEL TIE PERFORMANCE AT THE FACILITY FOR ACCELERATED SERVICE TESTING

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FINAL REPORT

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16. Abstract The original construction of the FAST Track included a segment of steel ties, which remained in service from September to December 1976. A number of performance measurements were made during this period to determine the ability of the ties to maintain geometry, fastener strength, and lateral resistance. This report describes the performance of the steel ties in terms of these measurements. During the service period, problems developed with the steel ties, which included bending and cracking of the rail fastener tabs, rapid widening of track gage, and as much as six inches of lateral track shift.			
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PREFACE

This report was prepared by the Battelle-Columbus Laboratories under Contract DOT-TSC-1652 as part of the Improved Track Structures Research Program, which is managed by the Transportation Systems Center (TSC) of the Department of Transportation (DOT). This program is sponsored by the Office of Rail Safety Research, Improved Track Structures Research Division, of the Federal Railroad Administration (FRA), Washington, D.C.

This report summarizes data from the Steel Tie Performance Experiment, which was conducted at the Facility for Accelerated Service Testing (FAST) during the fall of 1976. FAST is located at the DOT Transportation Test Center (TTC) at Pueblo, Colorado.

Dr. Andrew Kish of TSC was the Contracting Officer's Technical Representative (COTR) for this work. His assistance is gratefully acknowledged. Mr. Howard Moody of the FRA, who succeeded Dr. Kish as COTR, was responsible for the final revisions to the report.

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ACRONYMS

AAR	Association of American Railroads
COTR	Contracting Officer's Technical Representative
DOT	Department of Transportation
FAST	Facility for Accelerated Service Testing
FRA	Federal Railroad Administration
MGT	Million gross tons
STB	Survey-to-benchmark
TSC	Transportation Systems Center
TTC	Transportation Test Center

ABBREVIATIONS AND METRIC CONVERSION FACTORS

°	(degree)	
1 ft	(foot)	= 0.3048 m
1 ",in	(inch)	= 25.4 mm
1 mi/h	(miles per hour)	= 1.6094 km/h
1 MGT	(million gross tons)	= 0.907 MGMg
1 ton		= 0.907 Mg

EXECUTIVE SUMMARY

The original construction of the FAST Track included a 300-ft segment of steel ties in a spiral transition (Section 06) leading to the 5° curve of Section 07. The steel ties remained in service for the first 29 million gross tons (MGT) of FAST operations, from September to December 1976. Problems experienced during this period included bending and cracking of the tabs that served as rail fasteners, and rapid widening of the track gage. In addition, the track shifted laterally by as much as 6". In late December the steel ties were removed and replaced with wood ties.

While the steel ties were in service, a number of performance measurements were taken to determine the ability of the ties to maintain geometry, fastener strength, and lateral resistance. Results of these measurements are summarized as follows:

- Rapid gage widening occurred in both the steel tie and adjacent wood tie segments. Gage widening was especially evident over the 9 MGT period immediately prior to removal of the steel ties. However, gage widening data were biased by the fact that gage bars were installed in the steel tie segment as fastener tabs began to crack, and by substantial gage face rail wear. As a result of sporadic rail lubrication during the first few months of operation, no judgment about tie/fastener construction could be made on the basis of the gage wear data.
- The lateral track shift also increased rapidly after track tamping at 20 MGT. Tamping practices and too much rail in 5° curve in spiral were possible causes of lateral track shift. The shift reached a peak of about 6" toward the outside of the track loop or toward the inside of the curve at the transition between the steel tie and wood tie sections. Owing to the design of the steel tie, it is necessary to fill and consolidate the ballast under the entire length of the tie prior to final surfacing. Measurements of lateral track resistance showed approximately equivalent performance between steel tie and wood tie track. No judgment about tie/fastener construction could be made on the basis of the track shift or lateral resistance data.
- The cracking of the fastener tabs indicated a clear lack of adequate fastener strength for the severe loading environment in which the ties were placed. Possible causes of the cracking include residual stresses from the original bending of the tabs, plastic deformation of the tabs in service, and fatigue bending stresses produced by combined vertical and lateral loads.

The need for redesign of the fastener system is clearly indicated by the fastener failures. The manufacturer has since performed additional tests in revenue service and, as of February 1978, planned to redesign the system.

1.0 INTRODUCTION

The Facility for Accelerated Service Testing (FAST) is located at the Transportation Test Center (TTC), Pueblo, Colorado. It is operated by the Federal Railroad Administration (FRA) of the U.S. Department of Transportation in cooperation with the Association of American Railroads (AAR) and the railroad companies and supply industry for the accelerated testing of track and mechanical components and systems.

The FAST Track (Figure 1-1) is a specially constructed 4.8-mi loop divided into 22 sections where specified combinations of track components and structures are installed for testing. It contains 2.2 mi of tangent, 0.4 mi of 3° curve, 0.3 mi of 4° curve, and 1.1 mi of 5° curve; the remaining 0.8 mi is in transitional spirals.

Mechanical components are tested in the FAST consist, which is made up of 4-axle locomotives normally hauling a 75-car, 9,500-ton train. Cars are available from a pool of about 90 cars assigned to FAST. The majority are 100-ton hopper or gondola cars, and the remainder are 100-ton capacity tank cars and laden trailer-on-flat-cars.

Each test run begins in the afternoon, continues all night, and ends the next morning, five days a week. Each run makes approximately 120 laps of the FAST loop and produces approximately 1 million gross tons (MGT) on the track and about 600 mi on the cars, an accelerated service of about 10 times normal revenue operations in any given period of time.

To ensure uniform wear potential on track and mechanical components, direction of running is reversed each day, the whole consist is turned end-for-end every two days. Blocks of cars are shifted systematically within the consist on a 22-day cycle.

The original construction of the FAST Track included a 300-ft segment of steel ties placed in a spiral transition (Section 06) leading to the 5° curve in Section 07. The steel ties remained in service for the first 29 MGT of FAST operations, from September to December 1976. Problems experienced during this service period included bending and cracking of the tabs that served as rail fasteners, and rapid widening of the track gage. In addition, the track shifted laterally by as much as 6". In late December the steel ties were removed and replaced with wood ties. A description of the ties and their installation and removal is given in the appendix.

After the ties were removed from service, the manufacturer conducted additional tests on revenue service track. Fasteners were strain-gaged to determine strength requirements. A redesign of the fastener system is planned.

While the steel ties were in service, a number of performance measurements were taken to determine the ability of the ties to maintain geometry, fastener strength, and lateral resistance. This report describes the performance of the steel ties in terms of these measurements. It is concluded that the only clear deficiency of the tie design was inadequate fastener strength. Possible causes of fastener failures are discussed.

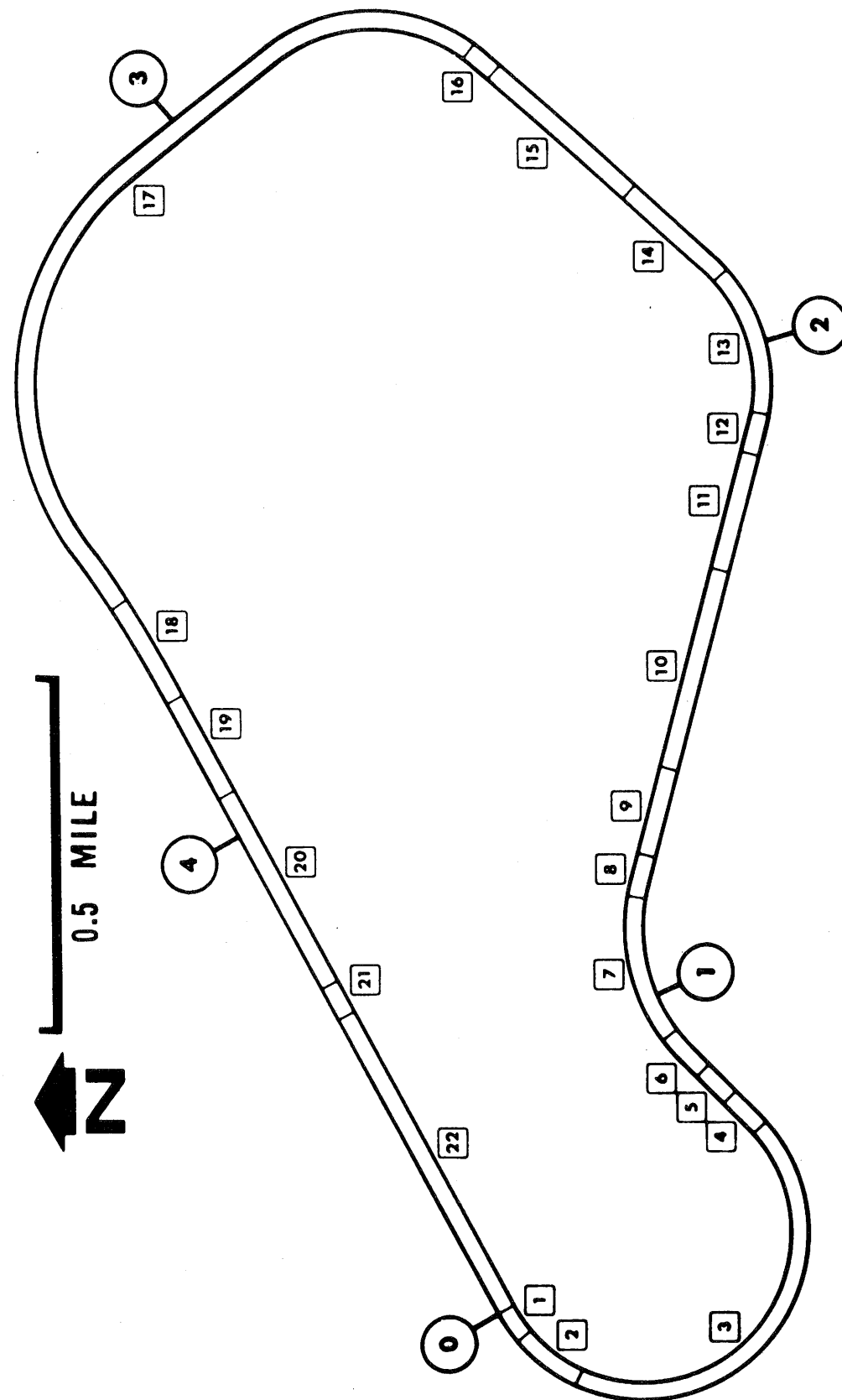


FIGURE 1-1. THE FAST TRACK.

2.0 PERFORMANCE MEASUREMENTS

Performance measurements were centered around 12 benchmarks specially installed for this experiment between the two rails and spaced over Section 06 and a portion of Section 07 (figure 2-1). Measurements of lateral and longitudinal shift were taken relative to the benchmarks. Gage widening and crosslevel were measured on groups of ties centered on the benchmarks. Additional survey-to-benchmark (STB) measurements were taken at regular STB sites in the two sections. One measurement of horizontal track stiffness was taken at 20 MGT. The significant results of these measurements are summarized below.

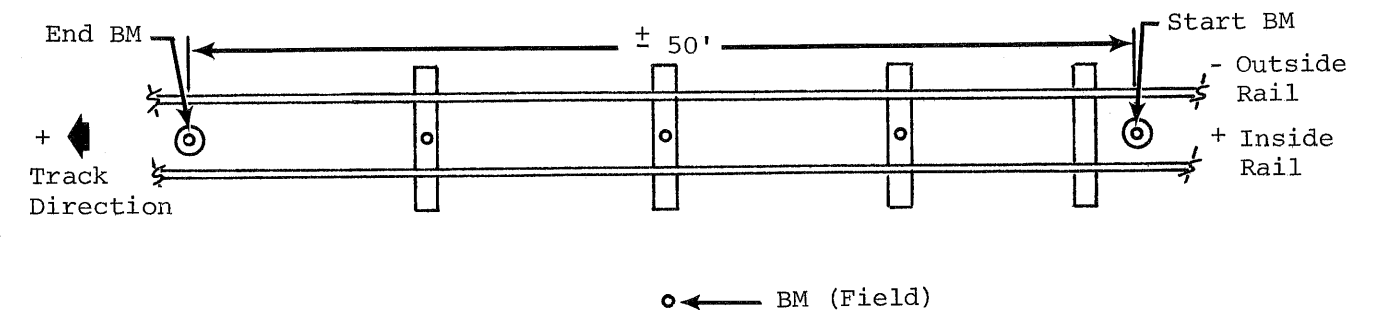


FIGURE 2-1. TYPICAL STEEL TIE PERFORMANCE MEASUREMENT ZONE AND BENCHMARKS.

2.1 GAGE WIDENING

The gage widening data shown in figure 2-2 are biased by the fact that after the fastener tabs began to bend and crack, gage bars were installed to prevent track failure. The dates of installation and the distribution of gage bars are not known. However, a possible effect of the gage bars can be seen in the figure 2-2 plots of gage widening vs. track distance for each of the seven measurement cycles conducted over the steel tie service period. The plots "dip" over about the latter third of Section 06, in contrast to a general trend of increase in gage with increasing track curvature. Maximum gage widening was actually reached in the wood tie Section 07, but it was not accompanied by failure of the wood tie fasteners. (There were four cut spikes per rail in the measurement zone of Section 07). It should also be noted that much of the gage widening in Section 07 and in the higher-curvature portion of Section 06 was caused by rail wear.

2.2 LATERAL SHIFT OF THE TRACK

Figure 2-3 shows the lateral shift of the track plotted vs. track distance for each of the seven measurement cycles. It can be seen that a slight bulge

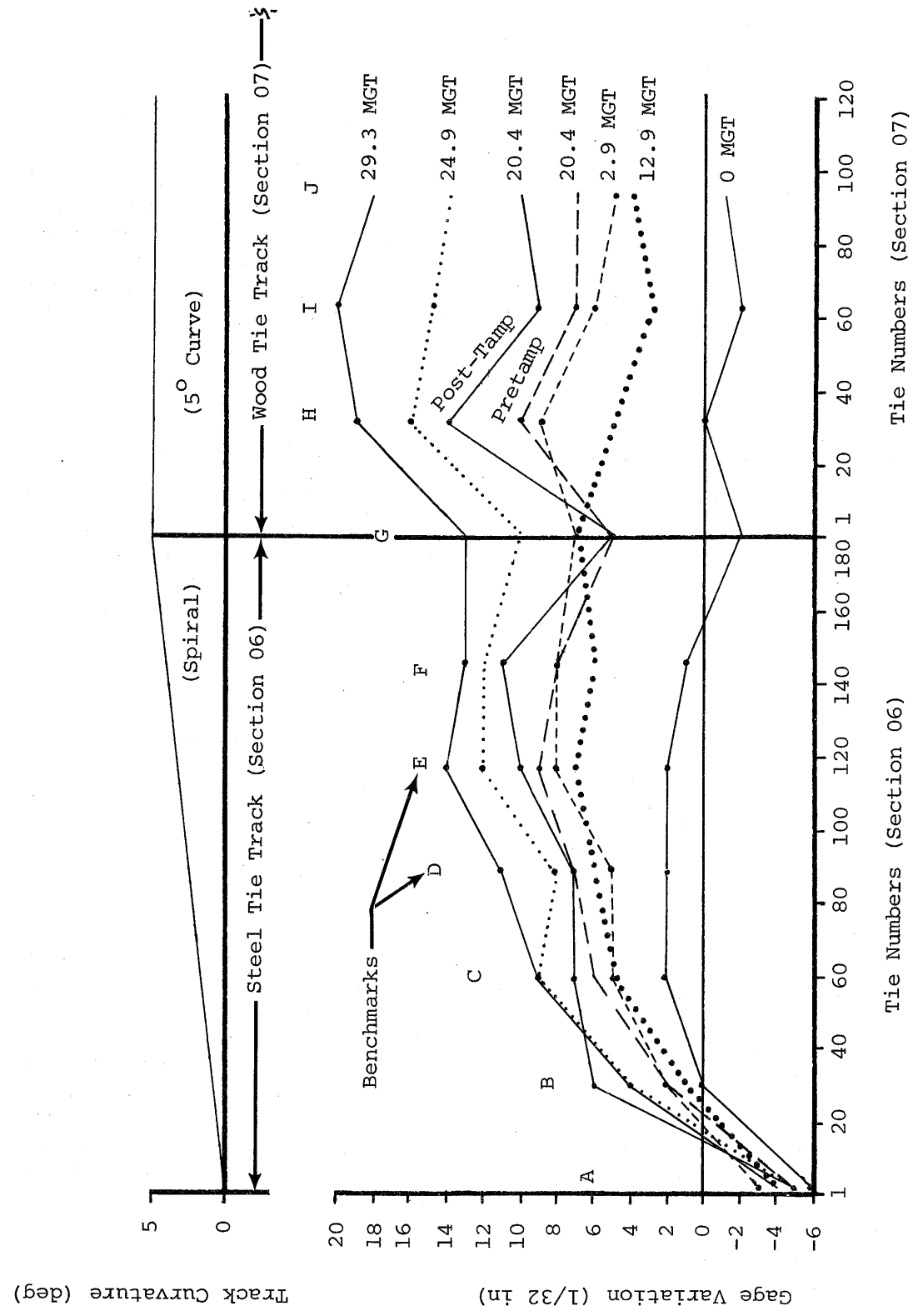


FIGURE 2-2. GAGE VARIATION VS. DISTANCE ALONG TRACK.

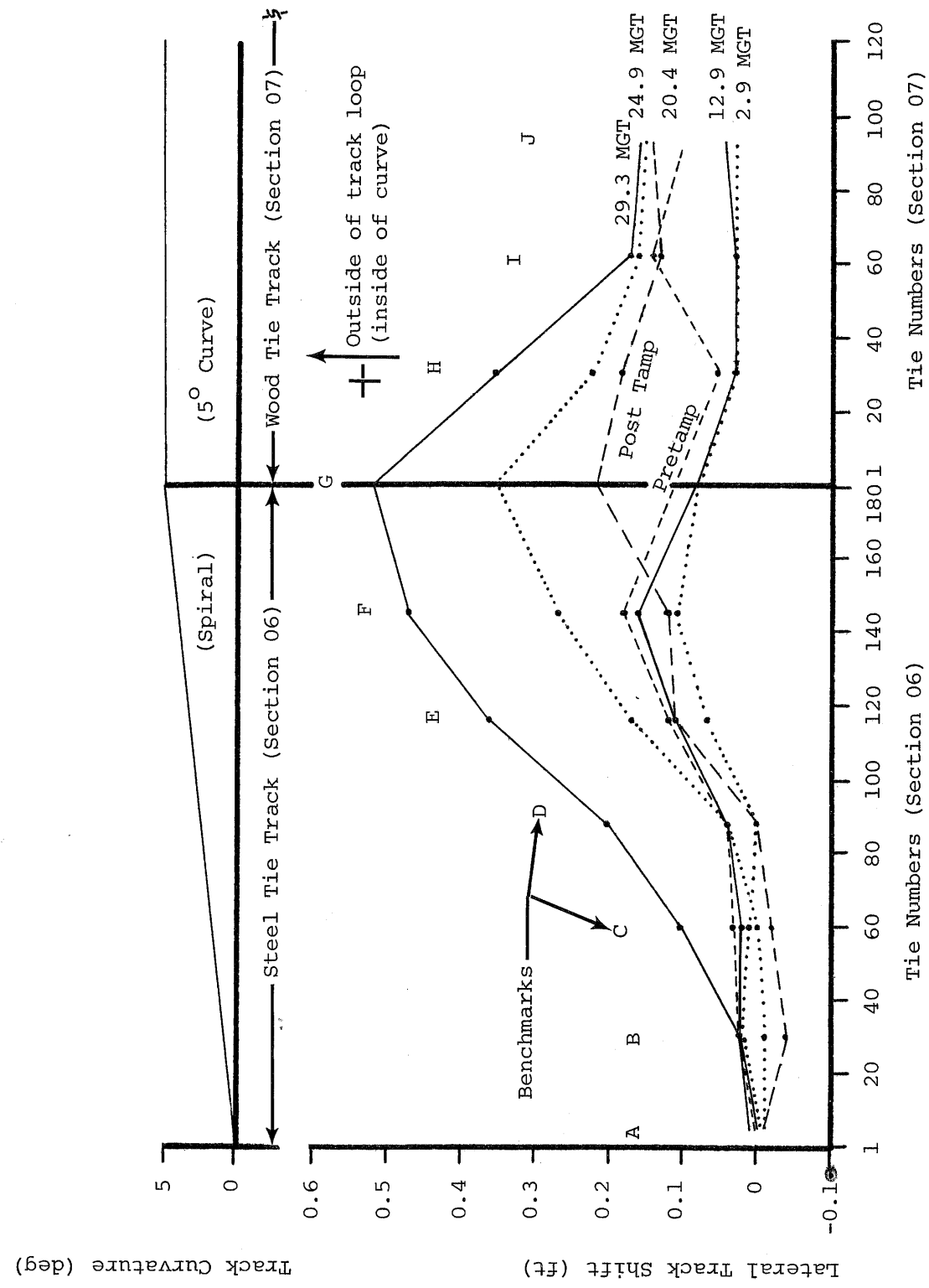


FIGURE 2-3. LATERAL TRACK SHIFT VS. DISTANCE ALONG TRACK.

had begun to develop in Section 06 near tie 06-0145 before the tamping at 20.4 MGT. The shift generally increased with curvature, reaching a maximum of 0.5 ft at the boundary of Sections 06 and 07 just before the ties were removed at 29 MGT. The lateral shift in the wood tie section dropped rapidly from this peak. It can also be seen that the rate of shift increased dramatically during the final 9 MGT of service after the tamping.

The direction of the lateral shift was to the outside of the loop, or to the inside of the 5° concave curve of Section 07. This occurrence was opposite from the direction which would normally be expected in a region of significant curvature where the train runs in an overbalanced condition. With 4" of nominal superelevation in the curve, the top speed of 45 mi/h represents 3" of overbalance.

An examination of unpublished instrumented wheelset loads data from June 1979 tests shows the expected result that lateral loads generally increase with curvature for well-aligned track. Peak loads on the high (inside) rail had approximately twice the values of those on the low (outside) rail. Thus, the train loads acted to oppose the track shift. Further, when the steel tie track began to shift, the misalignment should have acted to increase the lateral loads opposing the shift. Therefore, the shift was probably not caused by train loads. It is possible that the tension in the rail during the cool months of November and December could have contributed to the shift to the inside of the curve. Replacement of defective rail without proper temperature adjustment may have been a contributing factor. High draft loads in the train could also have caused such a shift. Finally, it should be noted that the natural ground slope in the Section 06/07 region of the FAST Track is downward to the outside of the loop.

In any case, the data convincingly demonstrate that the steel tie track experienced a major track shift problem. The design of the steel tie with open ends may have less resistance to lateral shift of track than a wood tie. However, it should be pointed out that in subsequent FAST operations, both the wood and concrete tie track have experienced track buckles (in the transitions of Sections 03/04 and 05/06 for wood ties and in the 5° curve of Section 17 for concrete ties). All of these shifts may be attributed as much to inadequate ballast resistance as to any feature of the tie and fastener construction. In none of these cases was the actual cause of the shift proved.

2.3 HORIZONTAL TRACK STIFFNESS

Tests of horizontal track stiffness at FAST consist of applying a lateral load through a yoke to one rail at two points 60" apart. Lateral displacements were measured at 11 locations along the track, 10 ties apart. Two such measurements were taken on the steel tie section at 20.4 MGT, just before and after the tamping operation. In figure 2-4, the force-deflection results were compared with a summary of results from measurements on wood and concrete ties. In comparison to results from wood ties, the steel tie lateral strength before tamping was about the same as the average strength of the wood tie track at very small deflections, and approximated the upper range of wood tie strength at larger deflections (up to 0.2"). Tamping reduced the steel tie

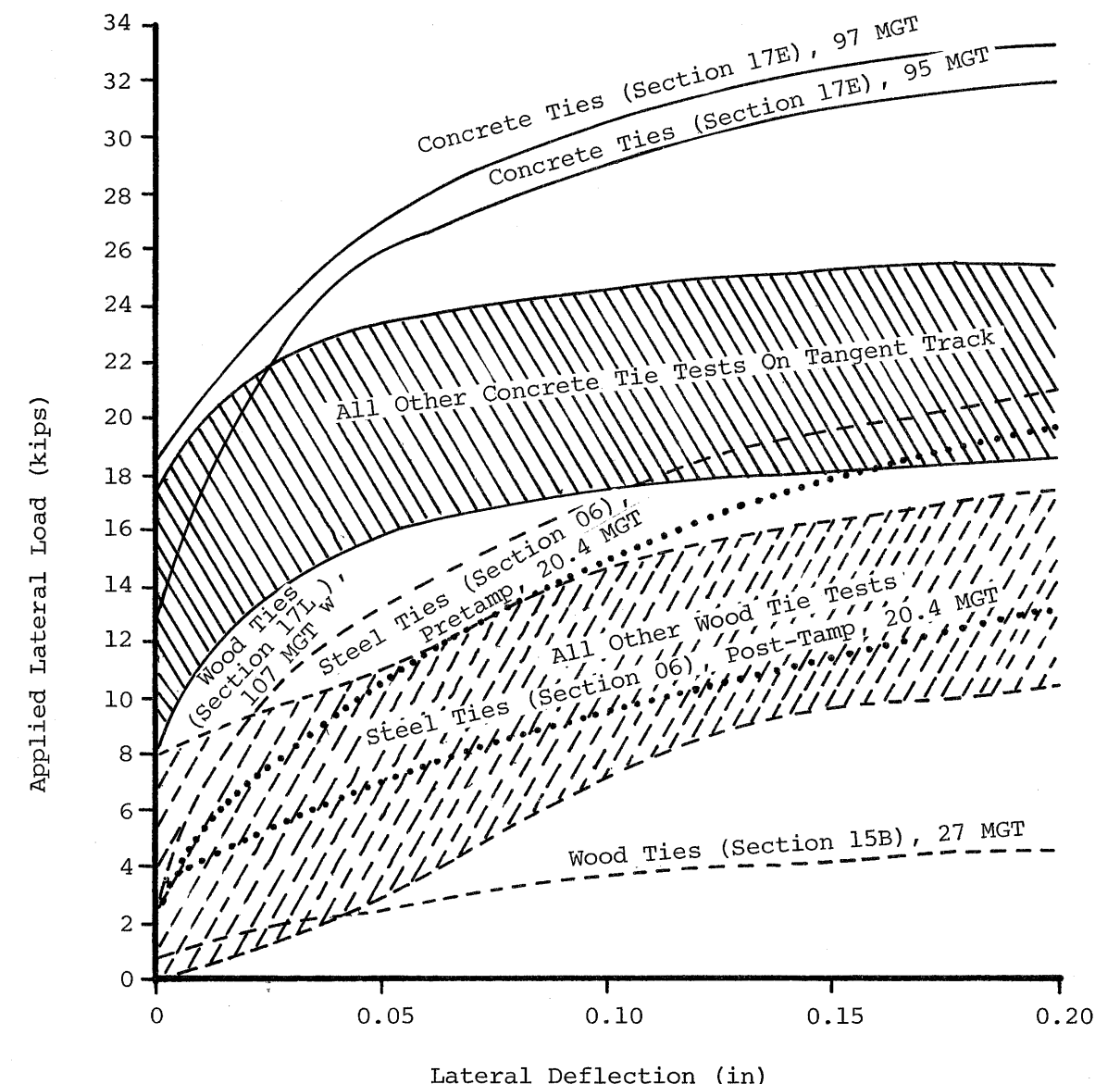


FIGURE 2-4. FORCE-DEFLECTION CURVES FROM HORIZONTAL TRACK STIFFNESS TESTS ON WOOD, CONCRETE, AND STEEL TIES.

lateral strength to slightly less than the average of the wood tie strength. These tests indicate that the steel ties should perform about as well as wood ties with regard to resistance to lateral movement.

2.4 RAIL CREEP

Rail creep data are plotted vs. MGT for the inside and outside rails in figures 2-5 and 2-6, respectively. The loss of fastener strength in the higher-curvature end of the steel tie section is definitely indicated by figure 2-5.

2.5 SURVEY-TO-BENCHMARK DATA

In addition to the steel tie performance experiment, regular measurements were taken at STB locations in the two test sections. Longitudinal rail movement, gage reduction, and crosslevel variation are plotted vs. MGT in figure 2-7. Each of these measurements shows approximately equivalent performance for the wood tie and steel tie track. However, the highest curvature for the steel tie track, among the data locations represented in figure 2-7, is 3.5°. All wood tie track has 5° curvature.

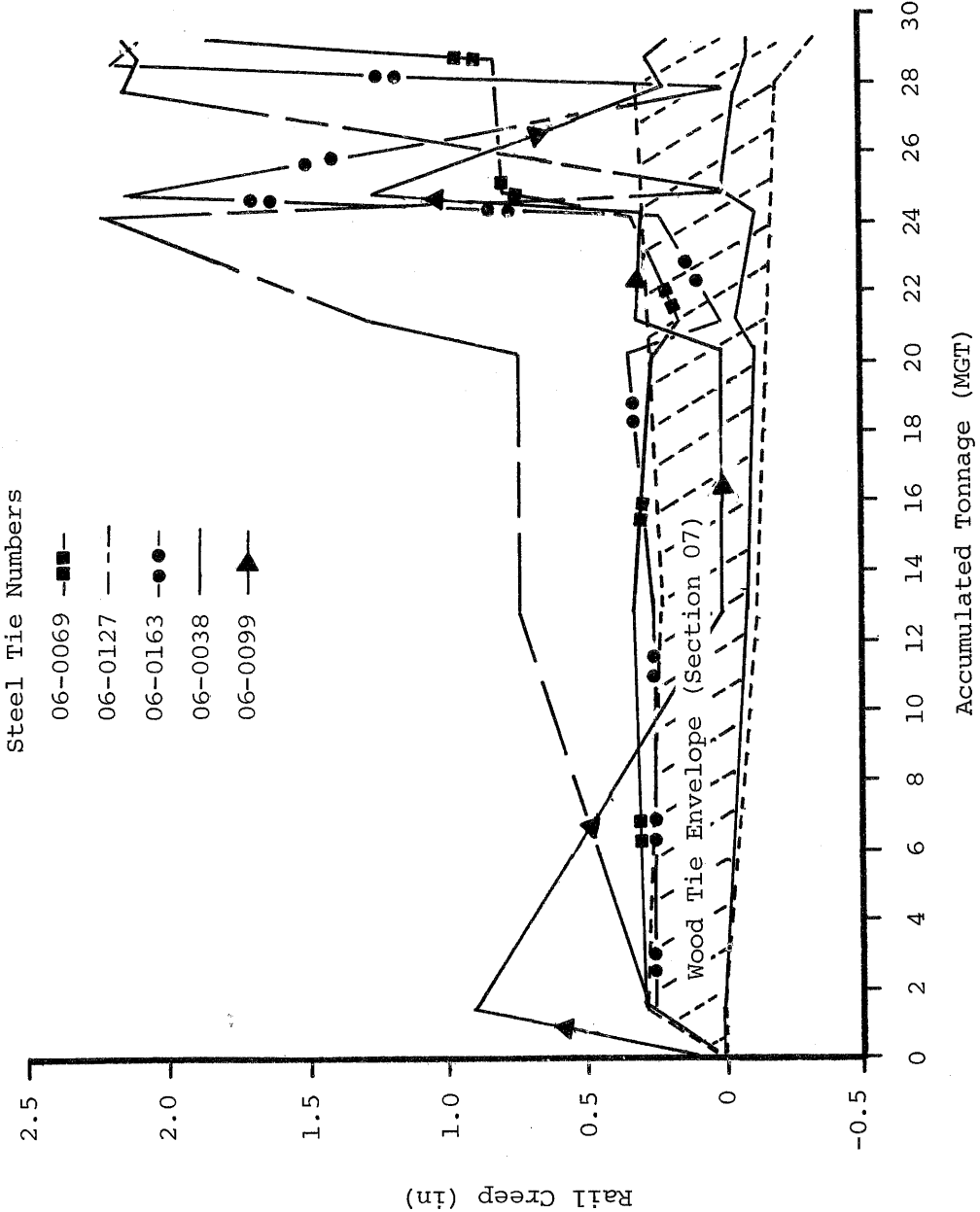


FIGURE 2-5. RAIL CREEP VS. MGT FOR INSIDE RAIL OF SECTIONS 06 (STEEL TIES) AND 07 (WOOD TIES).

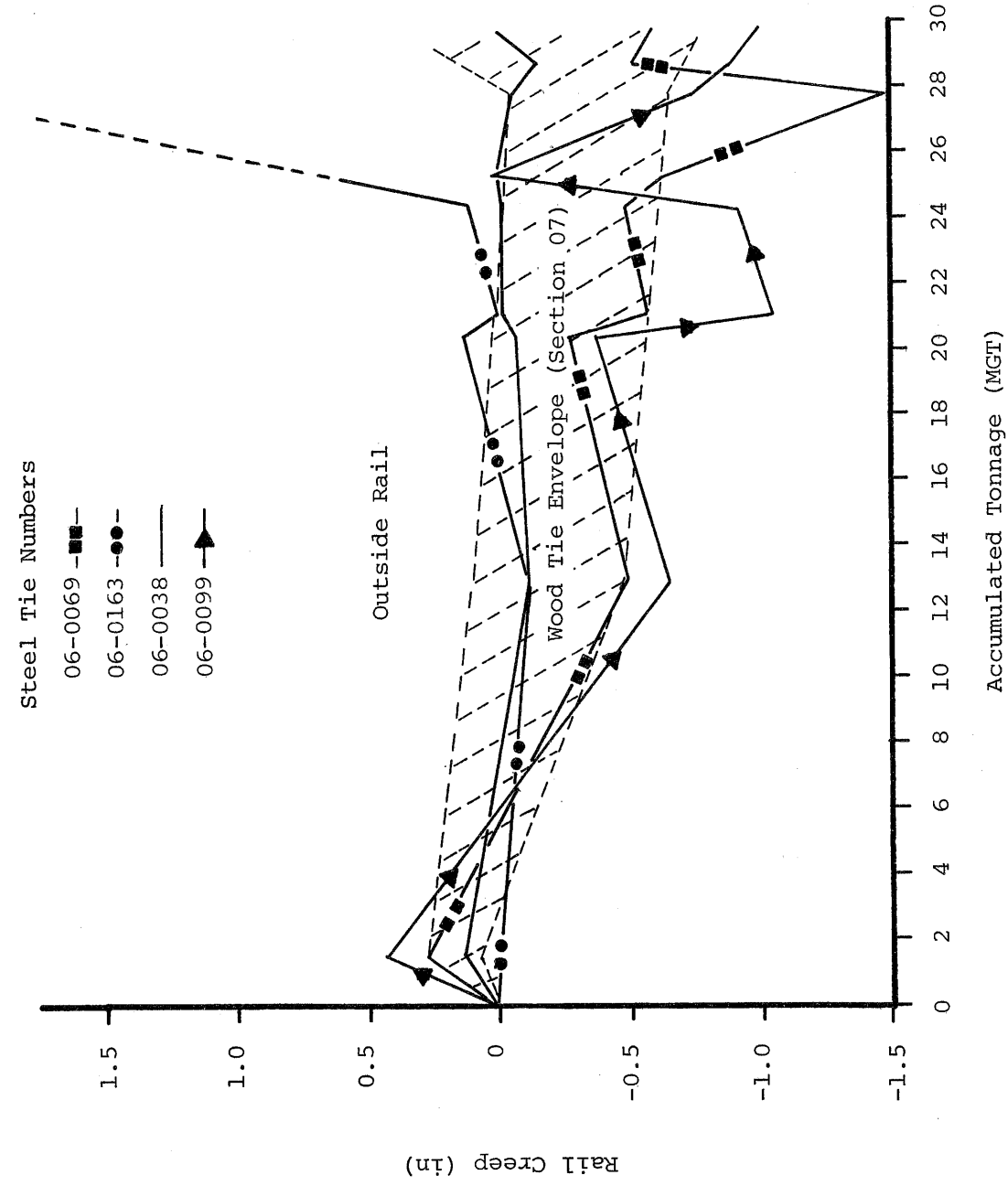


FIGURE 2-6. RAIL CREEP VS. MGT FOR OUTSIDE RAIL OF SECTIONS 06 (STEEL TIES) AND 07 (WOOD TIES).

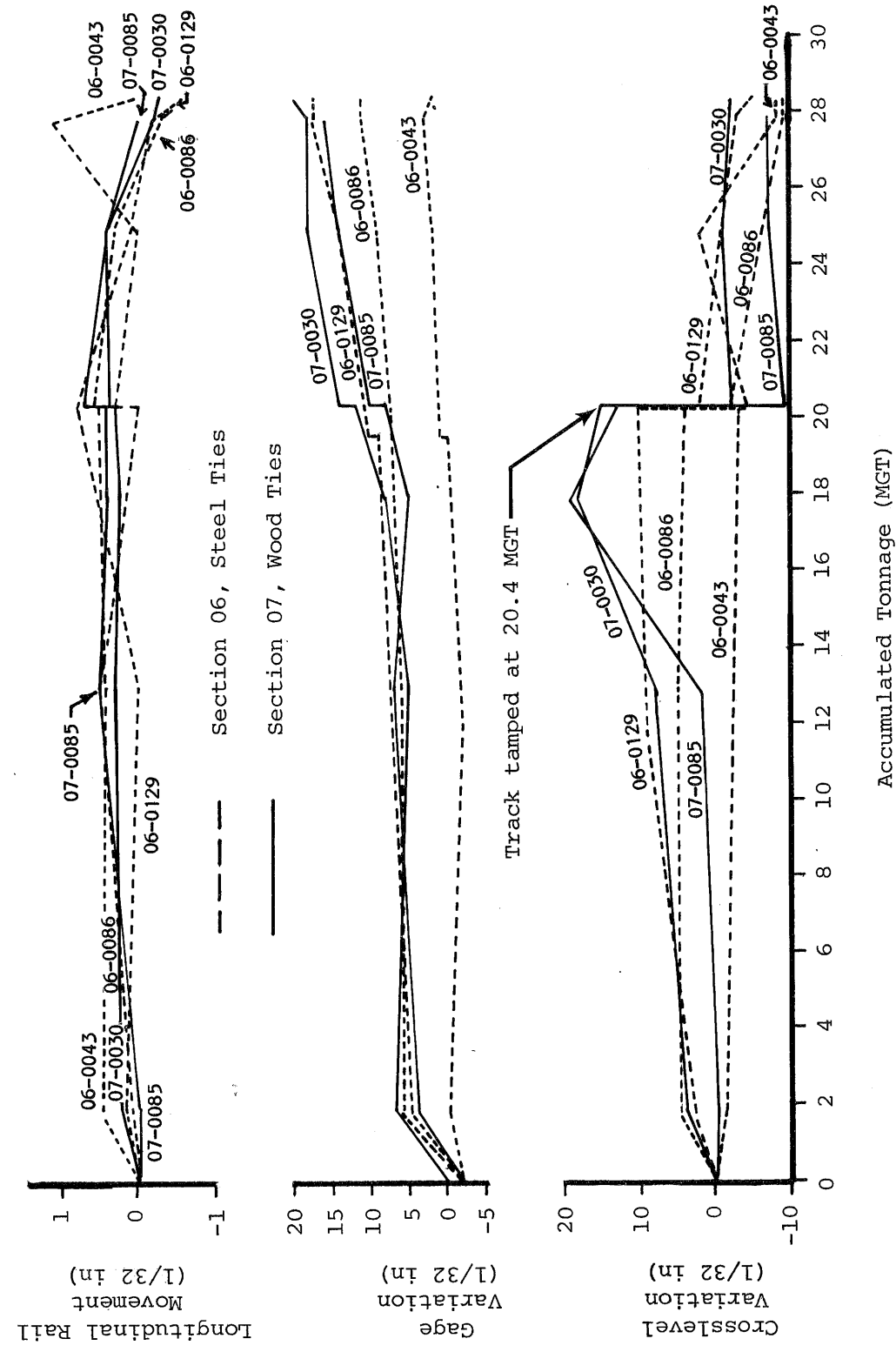


FIGURE 2-7. SUMMARY OF SURVEY-TO-BENCHMARK MEASUREMENTS VS. MGT.

3.0 SUMMARY OF RESULTS AND CONCLUSIONS

3.1 FASTENER STRENGTH

The only clear performance deficiency of the steel ties was the cracking of the fastener tabs, which developed toward the end of the service period. While gage widening was substantial, its magnitude was actually less than that which developed in the adjacent 5° curve on wood ties. This result was, in part, due to the use of an unspecified number of gage bars in the steel tie section.

3.2 POSSIBLE CAUSES OF FASTENER FAILURE

The exact cause of the cracks in the fasteners can only be determined by metallurgical examination. However, since they occurred in the rail seat region of the tie, it is possible that all of the following effects could have contributed to the failures:

- Residual stresses resulting from the original bending of the tabs to fasten the rail,
- Plastic deformation of the tabs in service, and
- Cyclic stresses at the base of the tab produced by lateral loads on the tab and by vertical loads, which can produce bending stresses in the top surface of the tie. Such bending stresses are normally maximum in the rail seat region.

It is recommended that the redesign of the fastener system take into account the existence of this combination of effects. The redesign should also consider the necessity of fastener reopenings or removal to transpose or replace rail.

3.3 LATERAL RESISTANCE

A second major element of tie performance is the resistance offered by the ties to lateral track misalignment or shift. Although a large track shift developed in the steel tie section, the data strongly indicate that the principal cause of this shift was the tamping operation at 20.4 MGT. The two lateral resistance tests on steel ties indicate that steel tie lateral resistance compares favorably with that of wood ties.

APPENDIX

BASIC FEATURES, INSTALLATION, AND REMOVAL OF THE STEEL TIES

The basic features of the steel ties are illustrated in figure A-1. The tie cross section is formed from flat steel plate, with eight tabs cut to provide either rail fastening or lateral resistance. The finished tie is 8.5 ft long and 11-3/8" wide. Tie spacing was 19.5", the same as for FAST wood ties.

Figures A-2 through A-5 illustrate the tie installation, which took place in June 1976. High-density polyethylene pads were placed over the rail seat and the partially bent fastener tabs (figure A-2). After placement of the rail, the fastener tabs were bent by hand tools (figure A-3) while the gage was controlled with jacks and gage bars. Figure A-4 shows the ties in place before track raising. Figure A-5 shows the completed section just before the beginning of operations in September 1976. Figure A-6 shows the section on November 22, with gage rods and broken tabs evident. Figure A-7 shows an example of a tab with a lateral crack.

Figure A-8 illustrates the cutting of the fastener tabs required for removal in late December 1976. After the rail was jacked, the ties were removed in conventional fashion, as shown in figure A-9.



FIGURE A-1. STEEL TIES BEFORE INSTALLATION.



FIGURE A-2. TIE RAIL SEAT WITH PAD IN PLACE.



FIGURE A-3. BENDING THE FASTENER TABS.



FIGURE A-4. TIES IN PLACE BEFORE TRACK RAISING (JUNE 1976).

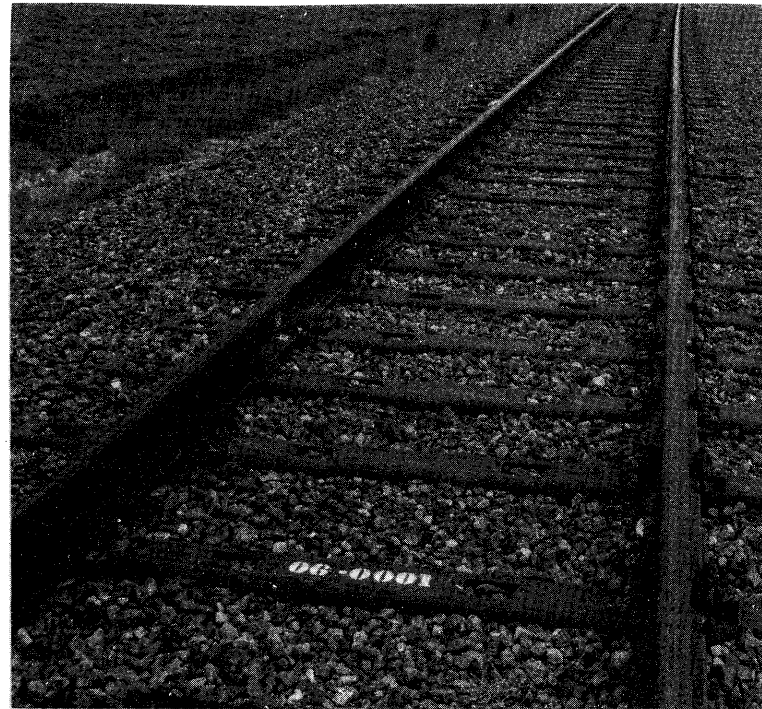


FIGURE A-5. COMPLETED STEEL TIE SECTION BEFORE BEGINNING OF OPERATIONS, SEPTEMBER 1976.



FIGURE A-6. STEEL TIE TEST SECTION (NOVEMBER 22, 1976) SHOWING GAGE RODS INSTALLED AND FAILURE OF FASTENING TABS, HIGH RAIL, FIELD SIDE.

A-4

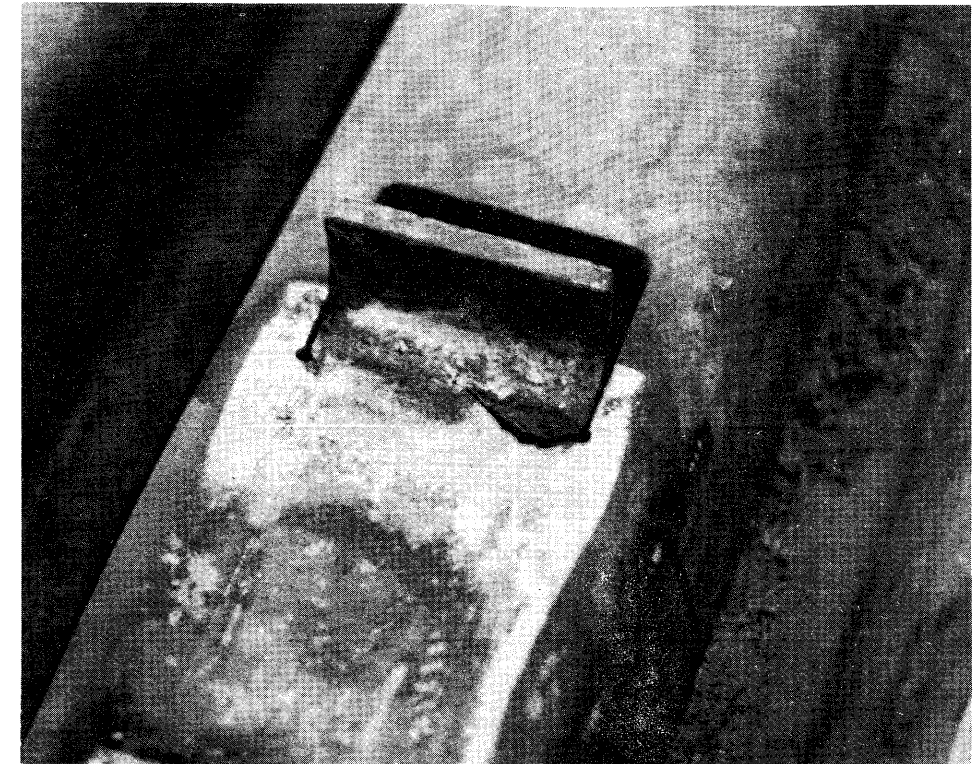


FIGURE A-7. EXAMPLE OF TAB WITH A LATERAL CRACK.



FIGURE A-8. CUTTING THE FASTENER TABS BEFORE REMOVING TIES.

A-5

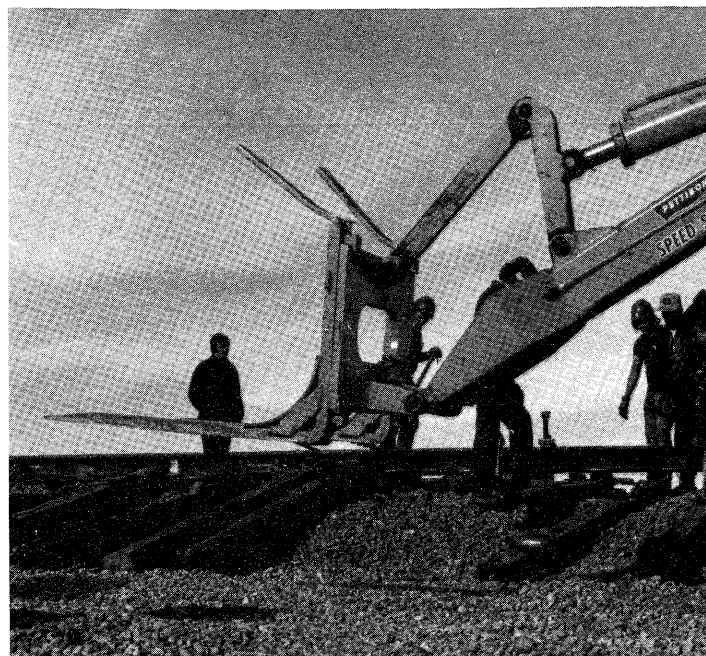


FIGURE A-9. TIE REMOVAL, DECEMBER 1976.