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# Field Testing of High Degree Revenue Service Track for Buckling Safety Assessment

Office of Research
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Washington, DC 20590

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This report presents the results of a field study of high degree curves in continuous welded rail (CWR) territory. This program was conducted at two test sites: a 10 degree curve on the Atchison, Topeka, and Santa Fe (ATSF) Railroad near Sante Fe, NM, and a 12 degree curve on the Norfolk Southern (NS) Railroad near Bluefield, WV. The work presented here is part of a major investigation carried out by the Volpe National Transportation Systems Center, for the Federal Railroad Administration (FRA), on thermal buckling of CWR track, with the objective of developing guidelines and recommendations for buckling prevention.

The field data collected included rail strain and temperature, rail radial movement, and tie lateral resistance in winter, spring, and summer conditions. Based on strain and temperature data, variations in rail neutral (zero force) temperatures are calculated. Seasonal neutral temperature shifts on the order of 20°F and diurnal shifts on the order of 5°F were typically recorded. The neutral temperature variations due to the rail radial movement (radial breathing) are evaluated. The lateral resistance test results indicated an increase in resistance as a function of traffic volume.

Using the neutral temperature data and the track lateral resistance measured in the field tests as inputs, the track buckling potential has been evaluated using the Volpe Center's computer model. The predicted buckling response has been correlated with the observed buckling incidents on some of the track sections.

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# PREFACE

This report presents the results of field tests on 10 and 12 degree curved continuous welded rail (CWR) track, conducted on the Atchison, Topeka, and Santa Fe (ATSF) railroad in Sante Fe, NM, and the Norfolk Southern (NS) railroad in Bluefield, WV. The work is a part of the Volpe National Transportation Systems Center's track stability research program being conducted for the Federal Railroad Administration for the purpose of developing safety guidelines and specifications for the prevention of track buckling-induced derailments.

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## METRIC/ENGLISH CONVERSION FACTORS

### ENGLISH TO METRIC

**LENGTH (APPROXIMATE)**

1 inch (in) = 2.5 centimeters (cm)
1 foot (ft) = 30 centimeters (cm)
1 yard (yd) = 0.9 meter (m)
1 mile (mi) = 1.6 kilometers (km)

**AREA (APPROXIMATE)**

1 square inch (sq in, in$^2$ = 6.5 square centimeters (cm$^2$)
1 square foot (sq ft, ft$^2$ = 0.09 square meter (m$_2$)
1 square yard (sq yd, yd$^2$) = 0.8 square meter (m$^2$)
1 square mile (sq mi, mi$^2$) = 2.6 square kilometers (km$^2$)
1 acre = 0.4 hectares (he) = 4,000 square meters (m$^2$)

**MASS - WEIGHT (APPROXIMATE)**

1 ounce (oz) = 28 grams (gr)
1 pound (lb) = .45 kilogram (kg)
1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)

**VOLUME (APPROXIMATE)**

1 teaspoon (tsp) = 5 milliliters (ml)
1 tablespoon (tbsp) = 15 milliliters (ml)
1 fluid ounce (fl oz) = 30 milliliters (ml)
1 cup (c) = 0.24 liter (l)
1 pint (pt) = 0.47 liter (l)
1 quart (qt) = 0.96 liter (l)
1 gallon (gal) = 3.8 liters (l)
1 cubic foot (cu ft, ft$^3$) = 0.03 cubic meter (m$^3$)
1 cubic yard (cu yd, yd$^3$) = 0.76 cubic meter (m$^3$)

**TEMPERATURE (EXACT)**

[(x-32)(5/9)] $^{o}$F = y $^{o}$C

### METRIC TO ENGLISH

**LENGTH (APPROXIMATE)**

1 millimeter (mm) = 0.04 inch (in)
1 centimeter (cm) = 0.4 inch (in)
1 meter (m) = 3.3 feet (ft)
1 meter (m) = 1.1 yards (yd)
1 kilometer (km) = 0.6 mile (mi)

**AREA (APPROXIMATE)**

1 square centimeter (cm$^2$) = 0.16 square inch (sq in, in$^2$)
1 square meter (m$^2$) = 1.2 square yeards (sq yd, yd$^2$)
1 square kilometer (km$^2$) = 0.4 square mile (sq mi, mi$^2$)
1 hectare (he) = 10,000 square meters (m$^2$) = 2.5 acres

**MASS - WEIGHT (APPROXIMATE)**

1 gram (gr) = 0.036 ounce (oz)
1 kilogram (kg) = 2.2 pounds (lb)
1 tonne (t) = 1,000 kilograms (kg) = 1.1 short tons

**VOLUME (APPROXIMATE)**

1 milliliters (ml) = 0.03 fluid ounce (fl oz)
1 liter (l) = 2.1 pints (pt)
1 liter (l) = 1.06 quarts (qt)
1 liter (l) = 0.26 gallon (gal)
1 cubic meter (m$^3$) = 36 cubic feet (cu ft, ft$^3$)
1 cubic meter (m$^3$) = 1.3 cubic yards (cu yd, yd$^3$)

**TEMPERATURE (EXACT)**

[(9/5) y + 32] $^{o}$C = x $^{o}$F

### QUICK INCH-LENTIMETER LENGTH CONVERSION

| INCHES | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|

CENTIMETERS 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 25.40

### QUICK FAHRENHEIT-CELSIUS TEMPERATURE CONVERSION

| $^{o}$F | -40$^{o}$ | -22$^{o}$ | -4$^{o}$ | 14$^{o}$ | 32$^{o}$ | 50$^{o}$ | 68$^{o}$ | 86$^{o}$ | 104$^{o}$ | 122$^{o}$ | 140$^{o}$ | 158$^{o}$ | 176$^{o}$ | 194$^{o}$ | 212$^{o}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $^{o}$C | -40$^{o}$ | -30$^{o}$ | -20$^{o}$ | -10$^{o}$ | 0$^{o}$ | 10$^{o}$ | 20$^{o}$ | 30$^{o}$ | 40$^{o}$ | 50$^{o}$ | 60$^{o}$ | 70$^{o}$ | 80$^{o}$ | 90$^{o}$ | 100$^{o}$ |

For more exact and or other conversion factors, see NBS Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50. SD Catalog No. C13 10286.

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# LIST OF SYMBOLS AND ABBREVIATIONS

| | |
|---|---|
| $\alpha$ | Coefficient of Linear Thermal Expansion (6.4 μin/in/°F for Rail) |
| A | Rail Cross Section Area |
| ATSF | Atchison, Topeka, and Sante Fe |
| C | Track Curvature in Degrees |
| CWR | Continuous Welded Rail |
| $\Delta R$ | Radial Movement in Inches |
| $\Delta T_N$ | Change in Neutral Temperature |
| E | Modulus of Elasticity (30E6 psi for Rail) |
| $\varepsilon_c$ | Current Rail Strain |
| $\varepsilon_i$ | Indicated Strain |
| $\varepsilon_{mi}$ | Indicated Strain due to Radial Movement |
| $\varepsilon_{mt}$ | True Strain due to Radial Movement |
| $\varepsilon_o$ | Reference Strain at Zero Rail Force |
| $\varepsilon_t$ | True Strain |
| EOTA | Every Other Tie Anchored |
| ETA | Every Tie Anchored |
| $F_L$ | Limit Lateral Resistance of a Tie |
| $F_P$ | Peak Lateral Resistance of a Tie |
| $\mu$ | Poisson's Ratio (0.3 for Rail) |
| MGT | Million Gross Tons |
| NS | Norfolk Southern |
| $P_{rail}$ | Rail Force |
| R | Curve Radius in Inches |
| SG | Rail Force Strain Gauge |
| STPT | Single Tie Push Test |
| $T_c$ | Current Rail Temperature |
| $T_N$ | Neutral Temperature |
| TS | Test Section |
| $W_L$ | Tie Lateral Deflection at Limit Resistance |
| $W_P$ | Tie Lateral Deflection at Peak Resistance |

# EXECUTIVE SUMMARY


During the periods of February to August 1990 and January to August 1991, field testing and data analyses were performed to evaluate the track buckling potential of typical continuous welded rail (CWR) high degree curve revenue service track. Field testing was performed near Santa Fe, NM, and Bluefield, WV, to monitor changes in rail neutral temperature and rail radial movement and to evaluate track lateral resistance. These data were correlated with known track work and damage to explain changes in neutral temperature. Analysis was done with the dynamic buckling model to compare model predictions with observed field behavior.

The neutral temperature, defined as the temperature at which the net longitudinal force in the rail is zero, was directly determined from rail mounted strain gauges and temperature probe data. These results were correlated with measurements of the rail radial displacement, which is a contributing parameter of neutral temperature variation of high degree curves. These measurements were made during winter, spring, and summer to evaluate seasonal factors.

Track lateral resistance was measured at both sites using a single tie push test (STPT) device. The test sites were each subdivided into three test sections for comparison of lateral resistance under either recently tamped or consolidated conditions. Data was collected during spring and summer both to monitor increasing lateral resistance as a function of tonnage and to evaluate seasonal variation influences.

Buckling predictions were made using the Volpe Center's dynamic buckling model and the neutral temperature and track lateral resistance. These predictions were correlated with field results and observations of track condition. In the one case where a buckling incident occurred, the model predictions correlated well with the recorded incident.

# 1. INTRODUCTION

Continuous welded rail (CWR) track buckling potential is essentially governed by rail longitudinal force, track lateral resistance, rail size, track curvature, and track misalignments. The compressive rail force is primarily due to rail temperature increase over its neutral temperature.

The rail neutral temperature can shift from the installation temperature due to rail vertical, longitudinal, and lateral displacements caused by vehicle and thermal loads, and maintenance operations. Previous field tests on revenue service track and at the U.S. DOT Transportation Test Center (TTC) in Pueblo, CO, which is operated by the Association of American Railroads (AAR) under contract to DOT, have measured neutral temperature shifts on tangent and low degree curves (≤7.5 deg). Buckling potential on these tracks has been evaluated by direct buckling tests at TTC, and the test data have been correlated with the theoretical model predictions.

No significant data exist for evaluation of the buckling potential on high degree (>7.5 deg) CWR track. Unlike in the foreign railroads, particularly the European, where the maximum curvature of CWR is restricted to 5 degrees, high degree CWR curves do exist on U.S. railroads. High degree curve CWR track apparently experiences significant maintenance problems due to the rail radial breathing in and out of the curves as the temperature changes. Theoretically, uniform outward movements could be beneficial to the track, as they tend to reduce the rail compressive force at high temperatures. In practice, these movements are not uniform and induce alignment defects, which may lead to eventual buckles. Furthermore, large radial movements due to seasonal changes can reduce the track lateral resistance itself. Prevention of track movement would require unduly large lateral and longitudinal resistance. Thus, the high degree CWR track is subject to complex parameter variations; buckling predictions need to include these parameters and influences.

## 1.1 Objectives of the Field Tests

- To study and compare the behavior of two high degree curves in different geographical locations (hence, different peak rail temperatures), at different annual traffic volumes measured in million gross tons (MGT) (hence, presumably operated at different lateral resistance levels)

- To monitor the rail force over a period covering winter, spring, and summer conditions, and thus determine the rail neutral temperature shifts on a diurnal/seasonal basis

- To monitor rail radial movements and evaluate the rail breathing influence on the neutral temperature shifts

- To determine the lateral resistance under tamped, "as-is," and consolidated conditions, and also to monitor changes in the lateral resistance over time

- To estimate the buckling potential on the basis of the measured parameters, using the Volpe Center's theoretical dynamic buckling model.

# 2. FIELD TESTS

## 2.1 Test Sites

Based on the forgoing objectives, two test sites, one near Santa Fe, NM, and another near Bluefield, WV, were selected. The Santa Fe site is about 7,000 ft above sea level, and its ambient temperatures range from 0° to 110°F, whereas in Bluefield, the range is typically 10° to 100°F, approximately. Further, the Santa Fe site has a low annual traffic volume of 9 MGT, while the Bluefield site has 68 MGT annually. The sites have some history of track buckles.

### 2.1.1 Santa Fe, NM - ATSF Railroad

This site was located on the Atchison, Topeka, and Santa Fe (ASTF) Railroad, east of Santa Fe, NM, near I-25 between Sands and Blanchard, at mile posts 796 to 797. Track characteristics were:

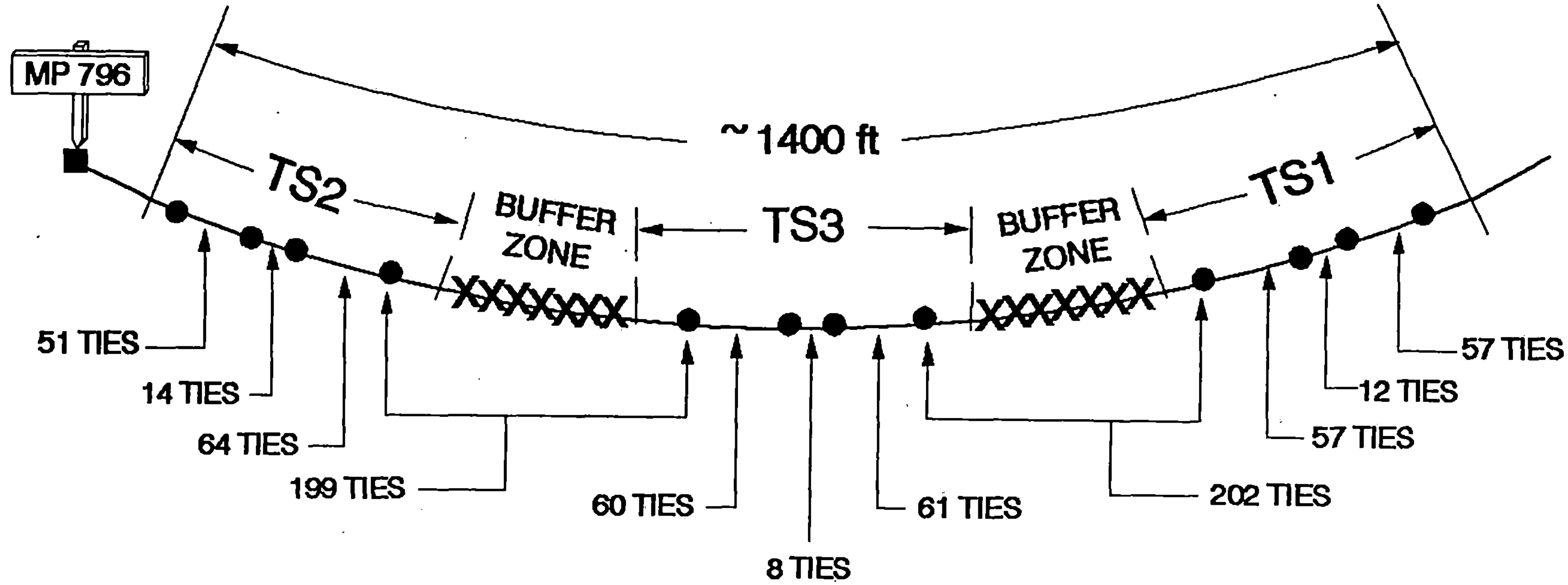
- Rail: 132 lb CWR
- Curvature: 10 degrees
- Ballast: Mix of hard rock and Pueblo slag
- Ballast shoulder: 14 to 16 in.
- Crib: Full
- Ties: Wood, approximate spacing 20 in., average condition
- Anchoring: Every other tie (EOTA)
- Speed: 20 mph freight, 25 mph Amtrak
- Tonnage: 9 MGT
- Curve length: $\simeq$ 1,300 ft
- Single track territory
- Superelevation: 2.5 in.

Three test sections (TS) were partitioned at this site as shown in Figure 2-1, which also gives the strain gauge and rail movement benchmark locations.

### 2.1.2 Bluefield, WV - NS Railroad

This site was located on the Norfolk Southern (NS) Railroad, northwest of Bluefield, WV, near Rte. 52 between Keystone and Vivian, at mile posts 390.2 and 390.6. Track characteristics were:

- Rail: 136 lb CWR
- Curvature: 12 degrees
- Ballast: Granite
- Ballast shoulder: 10 to 16 in. high rail; 4 to 12 in. low rail
- Crib: Full




• *STRAIN GAUGE AND SURVEY LOCATIONS ON HIGH AND LOW RAILS*

**Figure 2-1. ATSF - Santa Fe Test Zone Layout**

- Ties: Wood, approximate spacing 20 in., good condition
- Anchoring: Every tie (ETA)
- Speed: 25 mph freight
- Tonnage: 68 MGT
- Curve length: $\simeq$ 2,000 ft
- Double track territory
- Superelevation: 3.5 in.

The three test sections selected at this site are shown in Figure 2-2.

## 2.2 Test Measurements and Instrumentation

### 2.2.1 Rail Force

Longitudinal force in the rail was monitored using full (4-arm) strain gauge bridges welded to the rail web at the neutral axis. Rail temperature readings were taken, using a portable rail thermometer, at a total of 24 gauge locations at each site. Strains were monitored with a Vishay P-3500 portable strain indicator. Using the strain and temperature of the rail, the change in rail longitudinal force can be calculated against zero force readings obtained by cutting the rail.

Note: All strain values shown in this report and used in equations are full bridge indicated microstrain ($\varepsilon_i$). The true microstrain ($\varepsilon_t$) may be determined as follows:

$$\varepsilon_t = \frac{\varepsilon_i}{2(1+\mu)} \qquad (2\text{-}1)$$

where

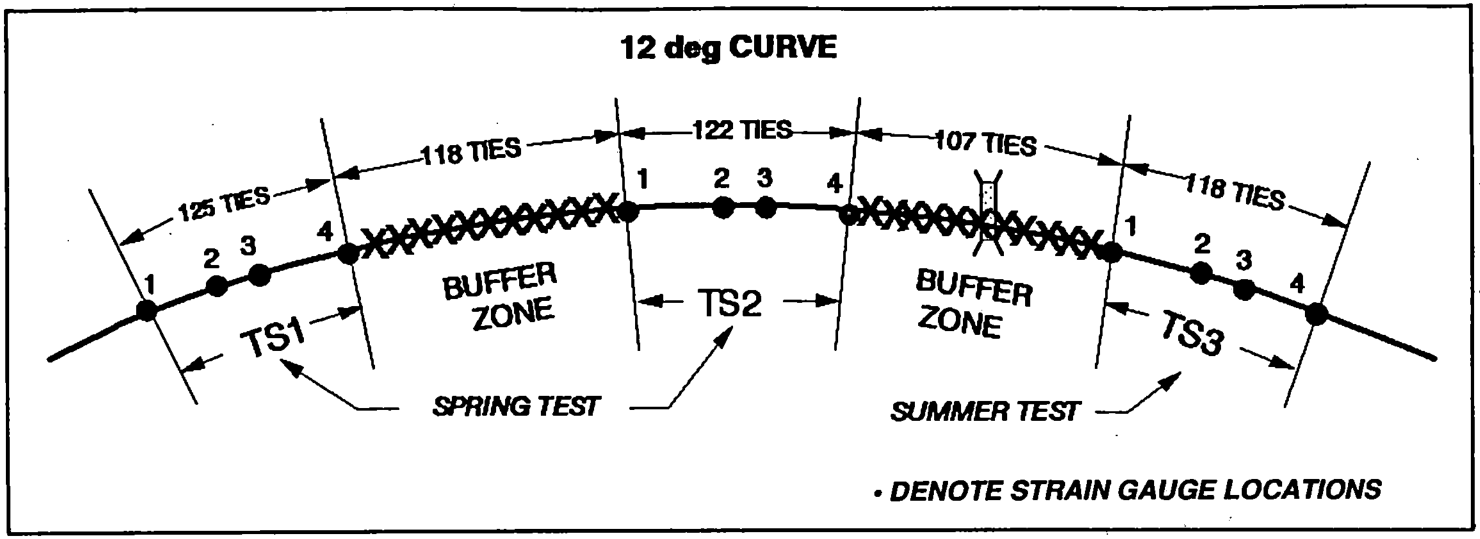
$\mu$ = Poisson's Ratio (0.3 for rail)

### 2.2.2 Rail Movement

Movement of the rail in the radial direction was measured using a special device designed for this purpose (Figure 2-3). Benchmark posts were cemented in the ground near the track. The radial movement of an etched point in the rail was measured directly from the benchmark to the rail.

### 2.2.3 Track Lateral Resistance

The single tie push test (STPT) device includes instrumentation for measuring the lateral resistance of the ties. The load applied is measured by a pressure transducer, which monitors the hydraulic pressure. The movement of the tie is measured with a linear potentiometer-type transducer attached to the rail. These two measurements are plotted against each other




**TEST SECTION (TS1)**
- *SG 1-2 (58 ties)*
- *SG 2-3 (8 ties)*
- *SG 3-4 (59 ties)*

**TEST SECTION (TS2)**
- *SG 1-2 (56 ties)*
- *SG 2-3 (9 ties)*
- *SG 3-4 (57 ties)*

**TEST SECTION (TS3)**
- *SG 1-2 (48 ties)*
- *SG 2-3 (8 ties)*
- *SG 3-4 (62 ties)*

**BUFFER ZONE**
(BETWEEN TS1 and TS2)
- *118 ties*

**BUFFER ZONE**
(BETWEEN TS2 and TS3)
- *107 ties*

**Figure 2-2. NS - Bluefield Test Zone Layout**

**Figure 2-3. Radial Measurement Device**

during the test using a portable x-y plotter. The STPT device is shown moving a tie in Figure 2-4.

## 2.3 Field Work

### 2.3.1 Phase I: 1990

Initial test site visits were made to Santa Fe on 12 February 1990 and to Bluefield on 5 March 1990. During these visits, the strain gauges were applied to the rail. Steel posts were cemented into the ground to serve as rail movement benchmarks. Initial strain readings and rail location measurements were recorded.

Second test site visits were made to Santa Fe on 2 April 1990 and to Bluefield on 23 April 1990. During these visits, strain readings and rail movements were recorded over a three-day period. The rails were cut in TS1 and 2 to obtain the strain readings for zero stress. STPTs were conducted in TS1 and 2. TS1 was tamped prior to these tests to provide a comparison between tamped and "as-is" lateral tie resistance.

Third test site visits were made to Santa Fe on 25 June 1990 and to Bluefield on 6 June 1990. These additional visits were made primarily to replace the steel cover plates which protect the strain gauges. At this time, rail strain and radial movement data were recorded.

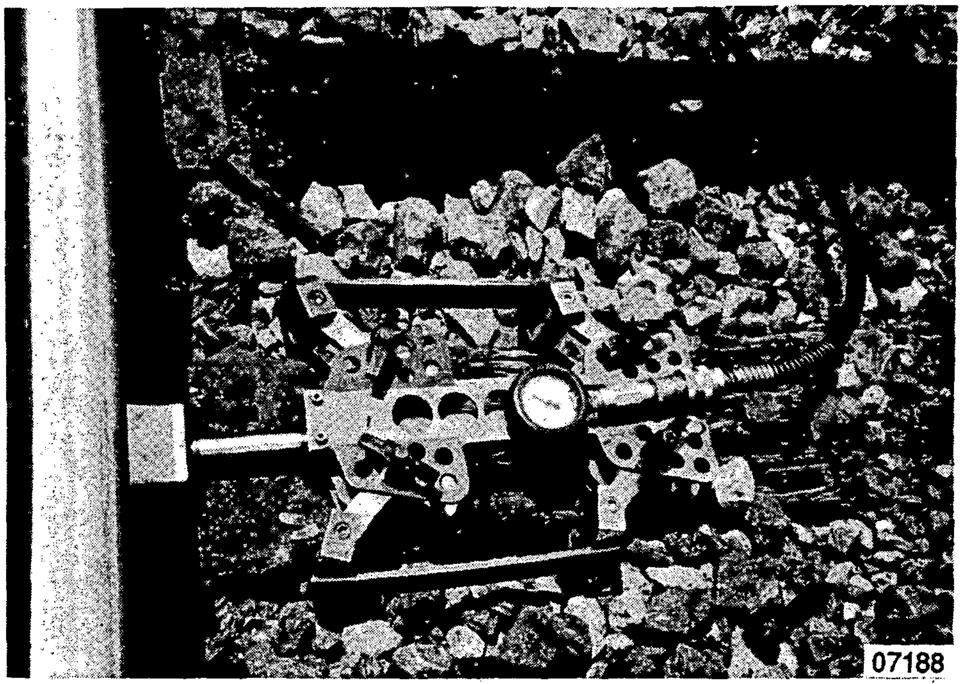



**Figure 2-4. STPT Device**

Fourth test site visits were made to Santa Fe on 23 July 1990 and to Bluefield on 30 July 1990. During these visits, rail strain and radial movement data were recorded. The rails were cut in TS3 to obtain initial readings for zero stress. STPTs were conducted in TS1 and 3. TS1 was tested to provide a comparison between its tamped condition in the spring and its consolidated condition in the summer.

### 2.3.2 Phase II: 1991

The first on-site data collections of 1991 were made in Santa Fe on 29 January and in Bluefield on 4 February. During each of these visits strain readings and rail movements were recorded over a two-day period.

The next on-site visits were made to Bluefield on 1 April 1991 and to Santa Fe on 3 April 1991. Both rails had been replaced in Bluefield due to substantial wear; a final strain reading was taken to check zeros and the test was terminated. Strain and rail movement data were collected in Santa Fe over a two-day period.

Subsequent Sante Fe site visits and measurements were made on 21 May, 16 July, and 13 August 1991. On the final visit on 13 August 1991, track lateral resistance was measured using the STPT device. A total of 29 STPTs were conducted throughout the three test sections, for comparison to data from the previous year. Strain and rail movement data were also recorded over a three-day period.

A summary of field work is shown in Table 2-1.

**Table 2-1. Summary of Field Work**

| Visit | Date | ATSF - Santa Fe, NM | NS - Bluefield, WV |
|---|---|---|---|
| 1 | 2/12/90 - ATSF<br>3/5/90 - NS | - Strain gauges applied<br>- Steel benchmarks cemented into ground<br>- Initial rail location measurements taken | Same as ATSF |
| 2 | 4/2/90 - ATSF<br>4/23/90 - NS | - Rail strain and temperature recorded<br>- Rail movement recorded<br>- Rails cut and zero strains recorded in TS1 and TS2<br>- TS1 tamped prior to STPTs<br>- STPTs conducted in TS1 and TS2 | Same as ATSF |
| 3 | 6/6/90 - NS<br>6/23/90 - ATSF | - Rail strain and temperature recorded<br>- Rail movement recorded<br>- New cover plates installed | Same as ATSF |
| 4 | 7/23/90 - ATSF<br>7/30/90 - NS | - Rail strain and temperature recorded<br>- Rail movement recorded<br>- Rails cut and zero strains recorded in TS3<br>- STPTs conducted in TS1 and TS3 | Same as ATSF |
| 5 | 1/29/91 - ATSF<br>2/4/91 - NS | - Rail strain and temperature recorded<br>- Rail movement recorded using new radial measurement device | Same as ATSF |
| 6 | 4/1/91 - NS<br>4/3/91 - ATSF | - Rail strain and temperature recorded<br>- Rail movement recorded | - Zero strains taken on rail after removal for replacement<br>- Test teminated |
| 7 | 5/22/91 - ATSF | - Rail strain and temperature recorded<br>- Rail movement recorded | |
| 8 | 7/16/91 - ATSF | - Rail strain and temperature recorded<br>- Rail movement recorded | |
| 9 | 8/13/91 - ATSF | - Rail strain and temperature recorded<br>- Rail movement recorded<br>- STPTs conducted in all three test sections<br>- Test terminated | |

## 2.4 Related Information

### 2.4.1 Instrumentation Damage

Two instrumentation problems partially affected the execution of this test program. The most significant of these was the extensive strain gauge damage that occurred at the Bluefield site between the first and second visits. Due to apparent vandalism, all of the gauges in TS3, and three of the gauges in TS2 had their wires cut. Of these 11 gauges, three were damaged permanently and the other eight had to be directly wired to the indicator box for reading. A second problem developed with the steel cover plates that protected the strain gauges. Track vibration proved to be too great for the clamps to hold the plates in place. Thus, a new cover plate attachment was designed and installed during the third site visits. This new cover plate assembly, shown in Figure 2-5, performed very well.

### 2.4.2 Track Work Problems

During this five-month testing period of Phase II, maintenance work was performed on the rails at both test sites. This work affected rail force and movement, and caused significant abrupt changes in the test data.

**Figure 2-5. New Cover Plate Assembly**

### 2.4.3 Santa Fe

During the second visit to Santa Fe, rail work was performed for our tests. Both rails were cut in TS1 and 2 to obtain the strain at zero stress. These rails were then rewelded. In addition, TS1 was tamped as per the test requirements. Between the third and fourth visits, a significant increase in the ambient temperature caused several rail kinks. Both rails were cut at 200 ft to the east of TS2 to relieve minor kinks. These rails were then welded. Likewise, both rails were cut at 400 ft to the west of TS1 to relieve many minor kinks, two major kinks in TS1, and a major kink to the west of the cuts near a bridge. Rail jacks were used to line up the track at the major kinks. Six inches of the high rail and 5 in. of the low rail were removed before the rails were rewelded. In September 1990, the railroad crew installed Pandrol clips between TS3, strain gauge (SG) 4 and TS1 SG 2 on the high rail; this installation was not part of the test requirement. In June 1991, defective welds were found in TS1 and TS3. Sections of rail were removed and secured with bolted joints. Rail work at the ATSF site is summarized in Figure 2-6.

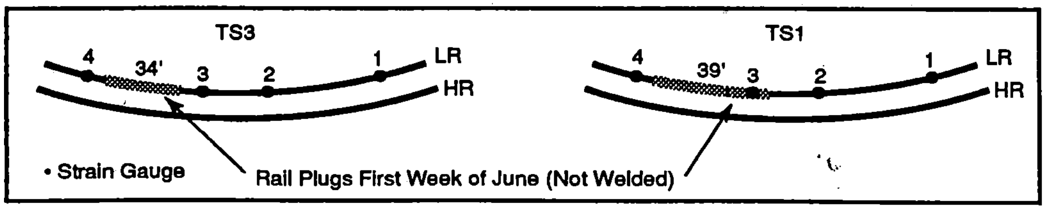
### 2.4.4 Bluefield

During the second visit to Bluefield, rail work was performed both for and in addition to our tests. Both rails were cut in TS1 and 2 to obtain the strain at zero stress. These rails were then welded. In addition, TS1 was tamped, lined, lifted, and given additional ballast.

Between the third and fourth visits, a significant increase in the ambient temperature caused several problems, primarily during the last week in June. In TS1, the tie plates were repositioned 1 in. outward for alignment. In TS2, the low rail broke and a 41-ft section was cut out and replaced but not welded. Since it remained a bolted joint, the neutral temperature was no longer an appropriate measure for this section. In addition, tie plates on the low rail were moved to tighten the gauge from 57-1/2 in. to 56-1/2 in. (Figure 2-7). Between TS2 and 3, the rail broke at midnight and again, a 41-ft section was replaced and secured with bolted joints. In TS3, a crack in a high rail weld (Figure 2-8) was discovered and a 37-ft section, between strain gauges 3 and 4, was replaced and secured with bolted joints. This work is pictorially summarized in Figure 2-9.

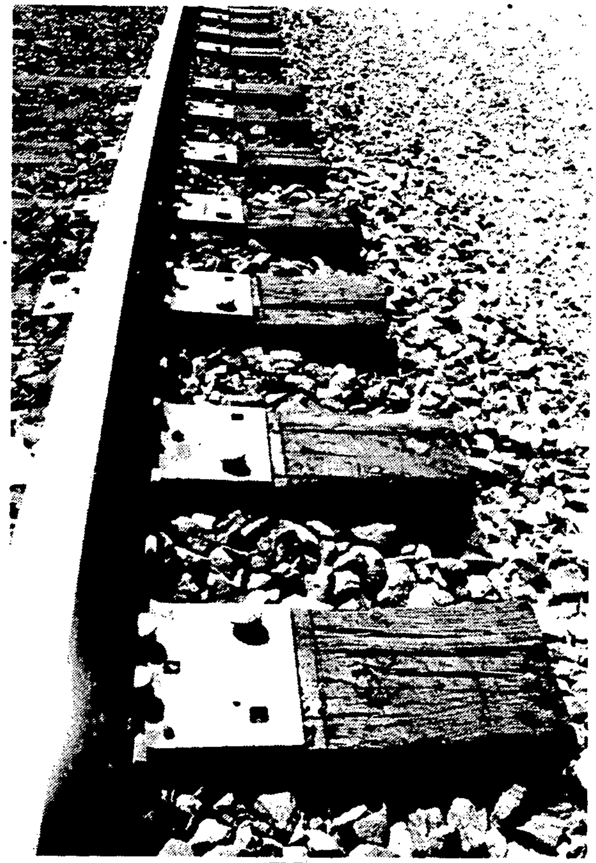
Testing at this site was terminated when the rail section, which was originally installed in 1981, was replaced in 1991. As a result of the high degree of curvature, the high rail was significantly worn after 700 MGT of traffic. As shown in Figure 2-10, the low rail maintained its width at 3 in. while the high rail was worn to a substantially reduced width of 2-1/4 in. This curve's stability was also potentially affected by the fact that typically only a 6-in. ballast shoulder on the inside and a 12-in. ballast shoulder on the outside of the curve are permitted, to facilitate drainage and prevent rain water flooding.

| | | |
|---|---|---|
| 1990 | ***FEBRUARY*** | Strain Gauge Installation at ATSF Test Site (Total of 24) |
| | ***APRIL*** | • Rails cut and rewelded at TS1 and TS2 (as part of test) |
| | | • Tamped track at TS1 |
| | ***JUNE*** | • Buckle occurrences at TS1 |
| | ***JUNE*** | Post Buckled Maintenance |
| | | • Rail cut (6" from HR), (5" from LR) - both cuts about 400' away from TS1 |
| | | • Rail jacks used to line the track back at TS1 buckles |
| | ***JULY*** | • Rails cut and rewelded at TS3 (as part of test) |
| | ***SEPTEMBER*** | • Pandrol clips installed in late Sept 1990 from TS3-s.g.4 to TS1-s.g.2 on high rail |
| 1991 | ***JUNE*** | • Rail plug installed (bolted in only) at TS3 low rail between s.g.3 and s.g.4 (34' long) |
| | | • Rail plug installed (bolted in only) at TS1 low rail at s.g.3 and before s.g.4 (39' long) (See below) |
| 1992 | ***JUNE*** | • Tie replacement activity |

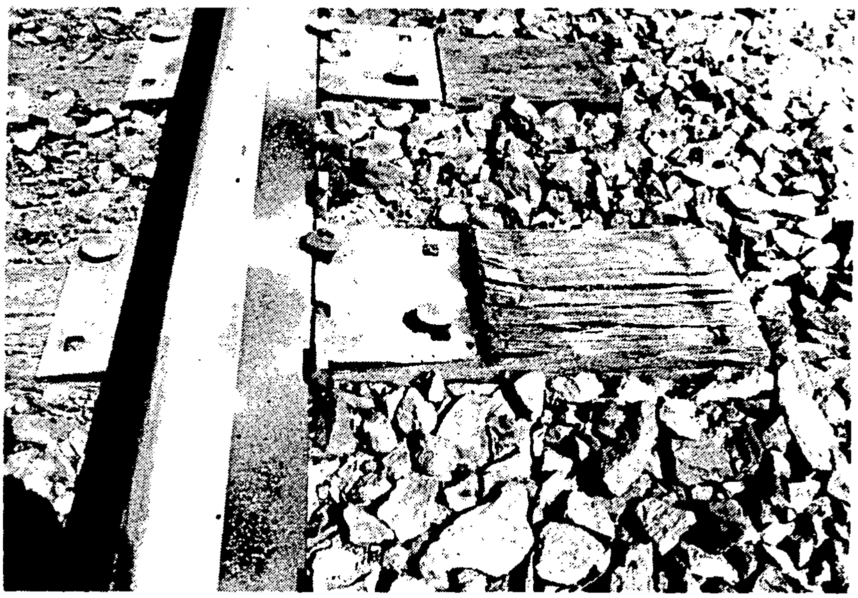



307-DTS-95190-1

**Figure 2-6. Track Work in Santa Fe, NM**



a) LOW RAIL



b) HIGH RAIL

**Figure 2-7. Rail Gauge Adjustment - Bluefield, WV**

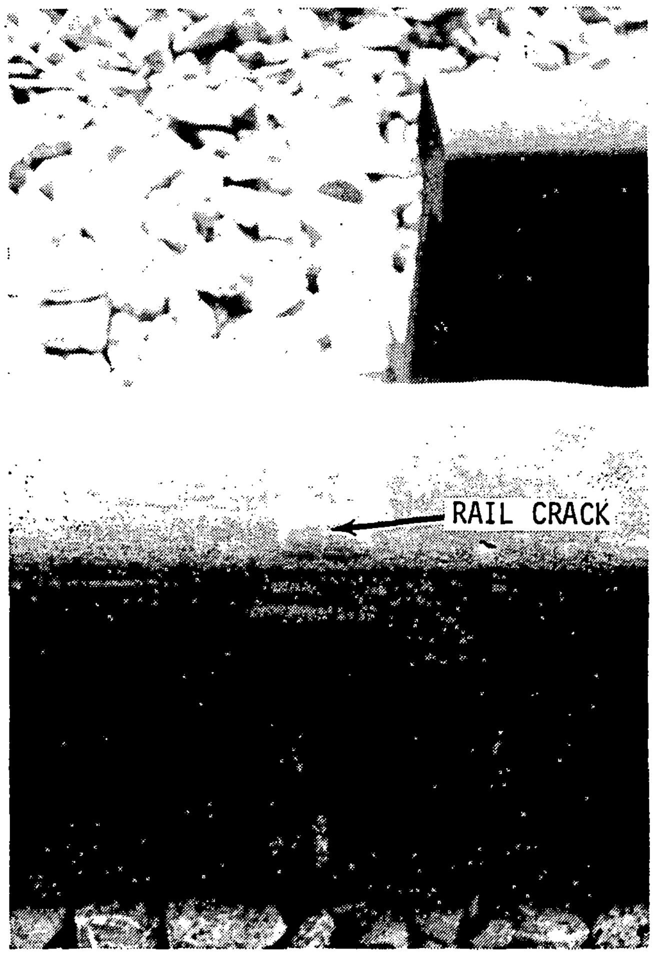



**Figure 2-8. Crack in High Rail in Test Section 3 - Bluefield, WV**

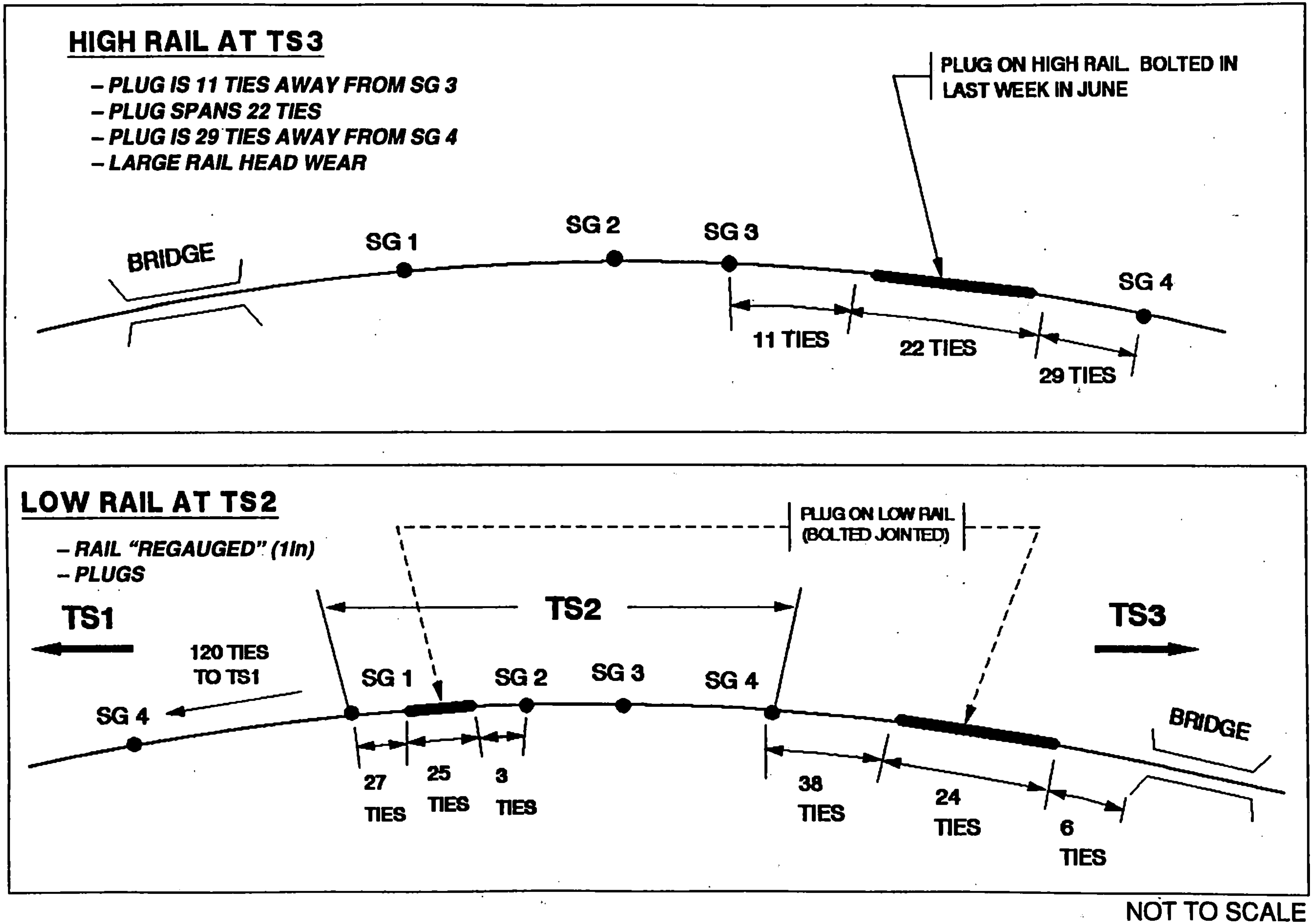



**Figure 2-9. Track Work in Bluefield, WV**


a) HIGH RAIL WORN (2-1/4 in.)

b) LOW RAIL (3 in.)

**Figure 2-10. Rail Wear in Test Section 2, 136 lb Rail Installed in 1981 - Bluefield, WV**

# 3. TEST DATA

This section presents summaries of the data collected at the test sites. Rail force and neutral temperature are calculated from the rail strain and temperature raw data to provide information of practical interest. All the raw data on strain, temperature, and radial movement, are presented in Appendix A. STPT data from three separate site visits are also summarized in this section.

## 3.1 Rail Force

The rail strain and temperature were recorded to monitor the rail force and, consequently, the neutral temperature of the rail ($T_N$), which is the rail temperature at which the net longitudinal force in the rail is zero. The greater the difference is between $T_N$ and the actual rail temperature, the greater the force will be in a fully constrained rail. Since the rail temperature will go through a daily cycle, the rail force will exhibit a similar progression in CWR.

Figures 3-1 through 3-3 show this force cycle for several full days in each of the three ATSF tes sections during 1991 (Phase II). When force was calculated as an average of the high and low rails a solid data point is shown, with an open point indicating data from only one rail. These figures provide a large amount of supporting information in addition to the variation of rail force, which is calculated using equation 3-1, shown below. The data collection time is also shown, which indicates that rail force typically peaked between 1:00 pm and 2:00 pm each day. The average rail temperature for each point is provided for reference along the x-axis, however, the data is actually plotted at data collection intervals along the date scale shown above the x-axis. Also shown is the variance of neutral temperature ($\Delta T_N$) within each data collection day.

The plot for TS1 (Figure 3-1) shows an average force for both rails from January to May 1991, and for the high rail only from July and August (the low rail contained a bolted joint during those two months). Figure 3-2 shows the data from TS2 as an average of both rails throughout. The plot for TS3 (Figure 3-3) is similar to that for TS1 in that the low rail contained a bolted joint during July and August. The bolted joints permit rail thermal expansion and thus serve to relieve the force buildup. During the testing, gaps on the order of 1/4 in. in the rail bolted joints were observed to close due to thermal expansion during the day. It should be noted that plots were not made of the NS data as several bolted joints were used at this site and the test was terminated early in 1991.

The rail force ($P_{rail}$) is calculated by measuring the current rail strain ($\varepsilon_C$). The rail force in pounds is then calculated from the following equation:

$$P_{rail} = \frac{(\varepsilon_c - \varepsilon_o)AE}{2(1+\mu)} \qquad (3\text{-}1)$$

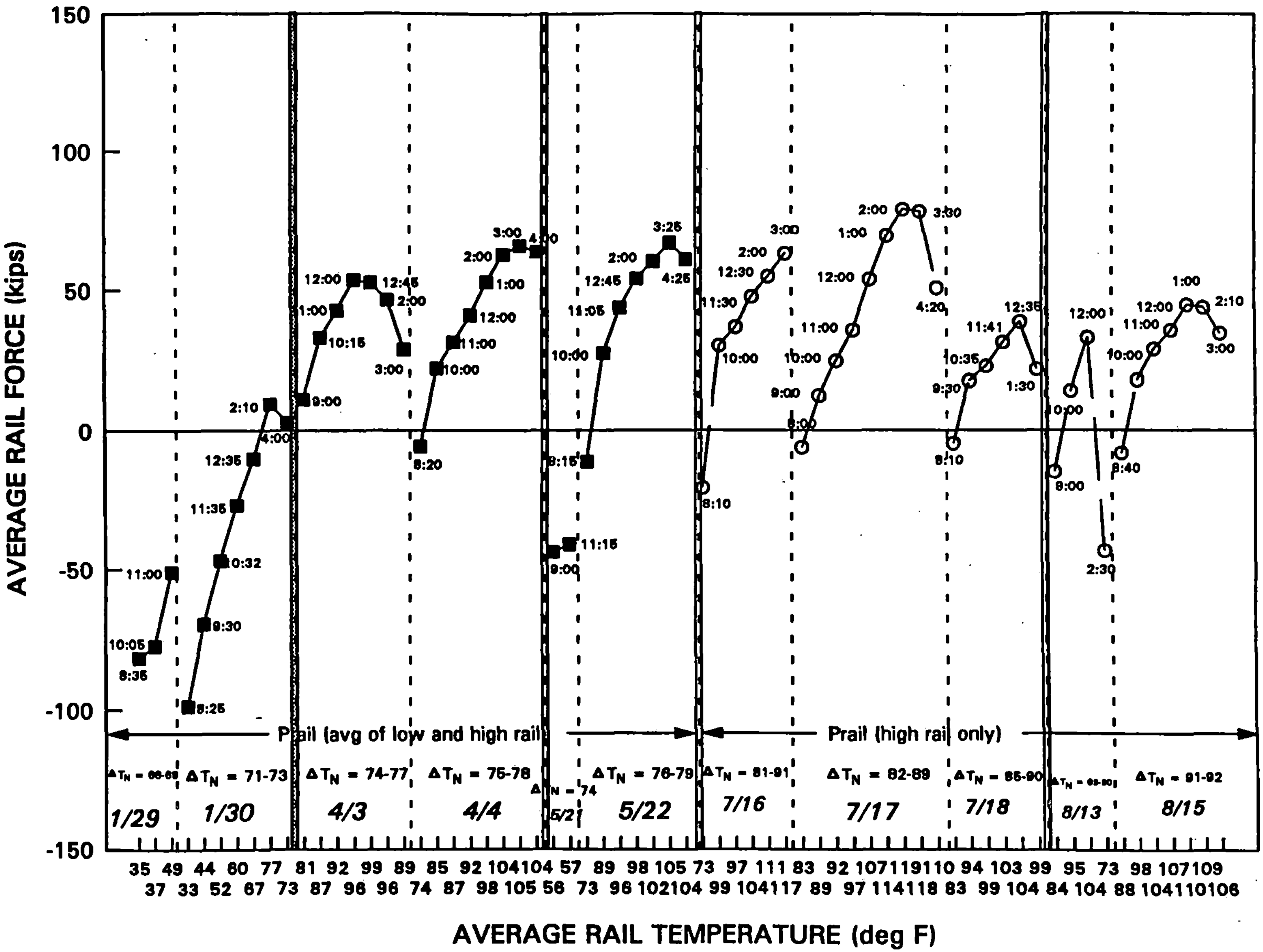



**Figure 3-1. ATSF - Santa Fe, NM: Rail Force versus Rail Temperature at TS1 During 1991 (Phase II)**

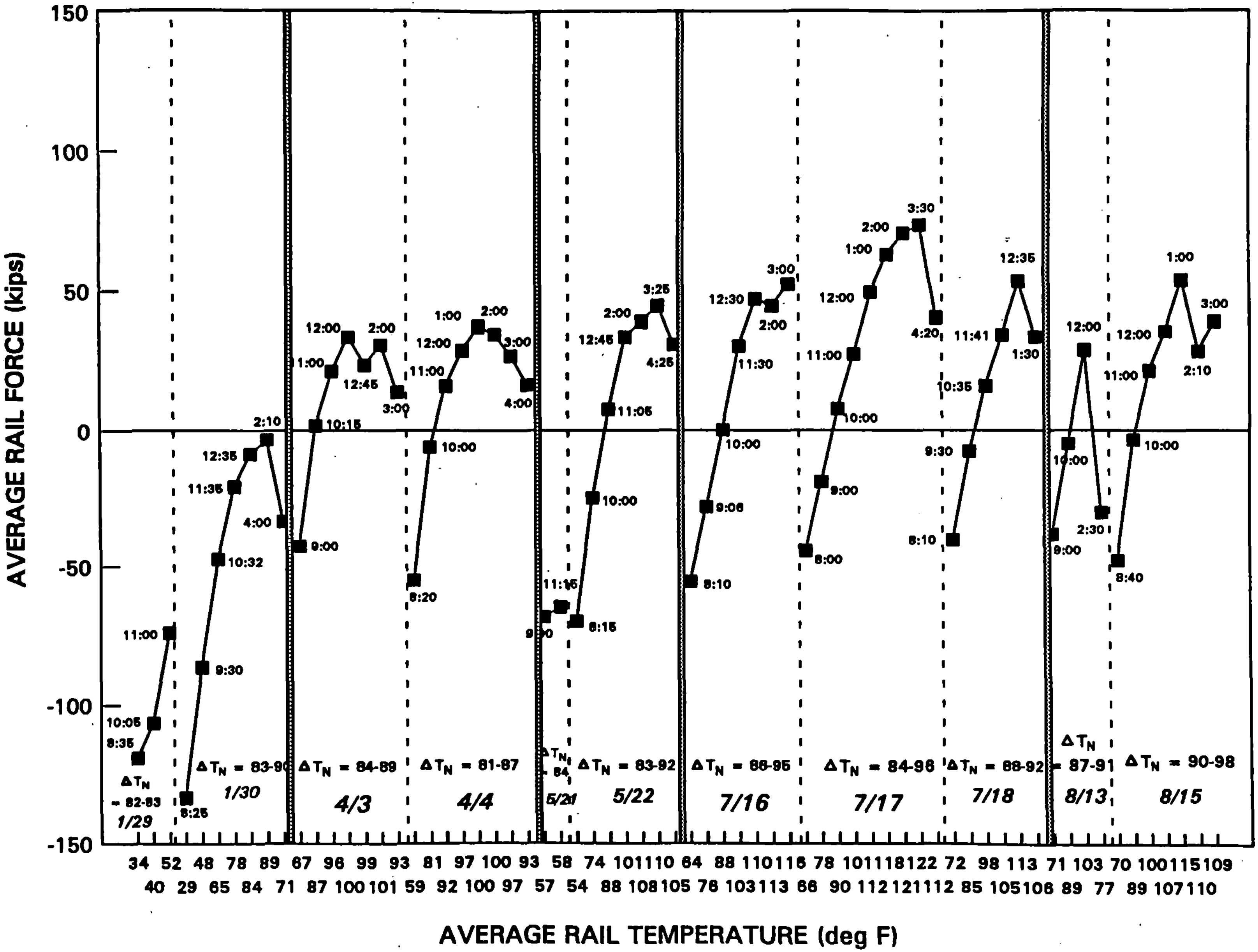



**Figure 3-2. ATSF - Santa Fe, NM: Rail Force versus Rail Temperature at TS2 During 1991 (Phase II)**

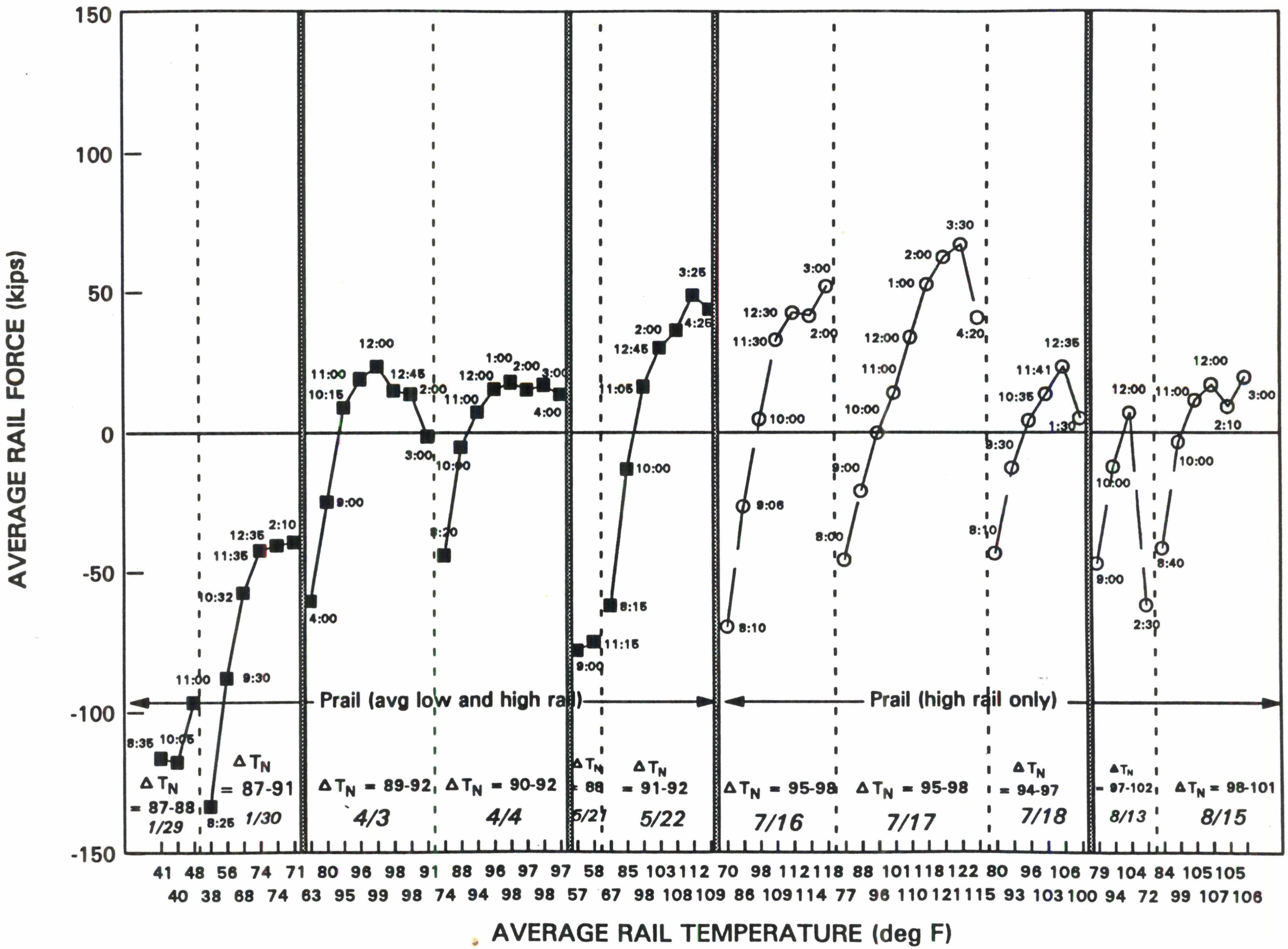



**Figure 3-3. ATSF - Santa Fe, NM: Rail Force versus Rail Temperature at TS3 During 1991 (Phase II)**

where

$\mu$ = Poisson's ratio (0.3 for rail)

$\varepsilon_o$ = Reference strain at zero rail force (recorded when rail was cut)

A = Rail cross section area (12.95 in.$^2$ for 132 lb rail, 13.35 in.$^2$ for 136 lb rail)

E = Modulus of elasticity (30E6 psi for rail)

The peak rail force, which is critical for track buckling, was captured on all data collection days shown in Figures 3-1 through 3-3. Since all data was taken after dawn, the full range of rail force was not recorded. However, it can be seen that the range of rail force is typically at least 100 kips on a sunny day. Further, this large range is found under winter, spring, and summer conditions, independent of the absolute rail temperature. Therefore, it is preferable for the neutral temperature to be near the middle of the daily range in all seasons to minimize the likelihood of track buckling and tension failure.

### 3.2 Rail Neutral Temperature

The neutral temperature can be calculated by measuring the current rail strain and rail temperature ($T_c$). These are then compared to the zero force strain using the following equation:

$$T_N = T_C - \frac{(\varepsilon_C - \varepsilon_O)}{2(1+\mu)\alpha} \qquad (3\text{-}2)$$

where $\alpha$ = Coefficient of linear thermal expansion (6.4 $\mu$in./in./°F for rail).

The variation of the neutral temperature over time is shown in Figures 3-4 through 3-6 for the three NS test sections and Figures 3-7 through 3-9 for the three ATSF test sections. On all plots, the high rail is designated by solid data points and a solid line and the low rail is designated by open data points and a dashed line. A dotted line is used to indicate the presence of bolted rail joints. The test implementation activity, when the rail was cut to establish the zero force reference strain readings, is indicated by a shaded section. Further shaded lines provide a break between Phase I (1990) and Phase II (1991) as well as between each site visit on the ATSF data plots. The rail temperature for each point is provided for reference along the x-axis, however, the data is actually plotted at data collection intervals along the date scale shown below the temperatures. Major testing and maintenance activities are also noted on the figures.

#### 3.2.1 NS Railroad

In all of the test sections, major changes in neutral temperature could be attributed to maintenance or seasonal changes. Due to the limited data set, most notably on the damaged TS3 section, daily variations at the NS sites were more difficult to evaluate.

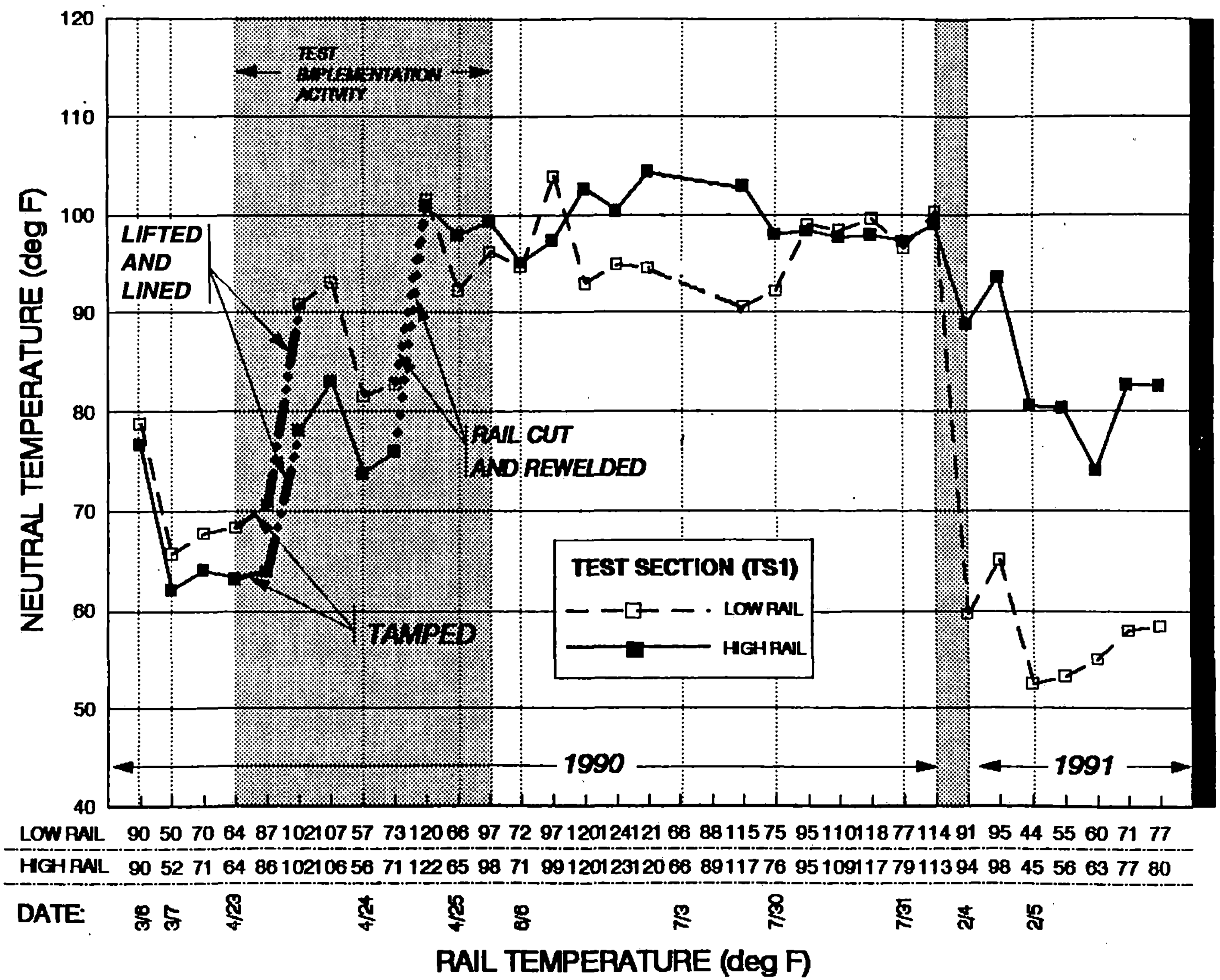



**Figure 3-4. NS - Bluefield, WV: Neutral Temperature at TS1**

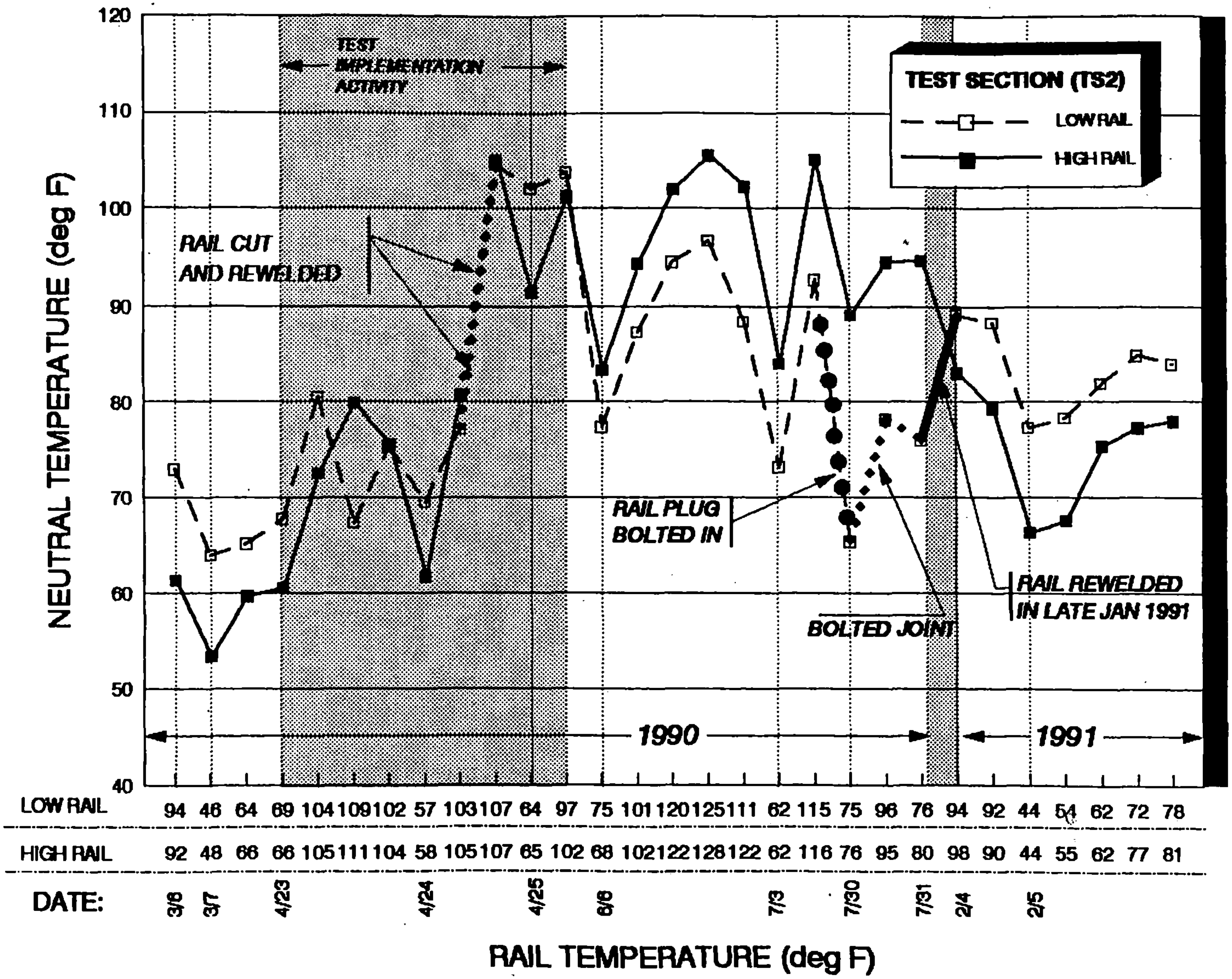



**Figure 3-5. NS - Bluefield, WV: Neutral Temperature at TS2**

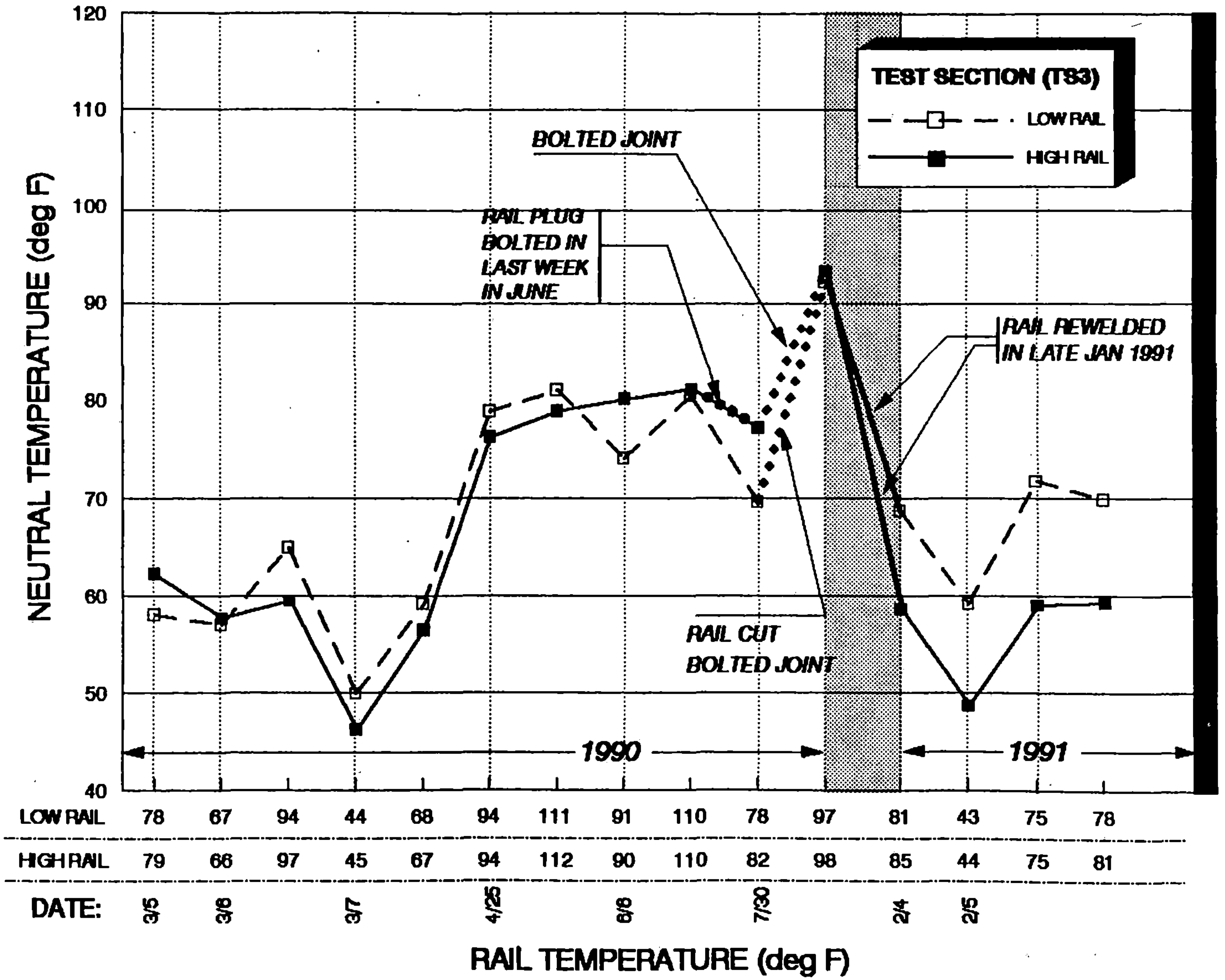



**Figure 3-6. NS - Bluefield, WV: Neutral Temperature at TS3**

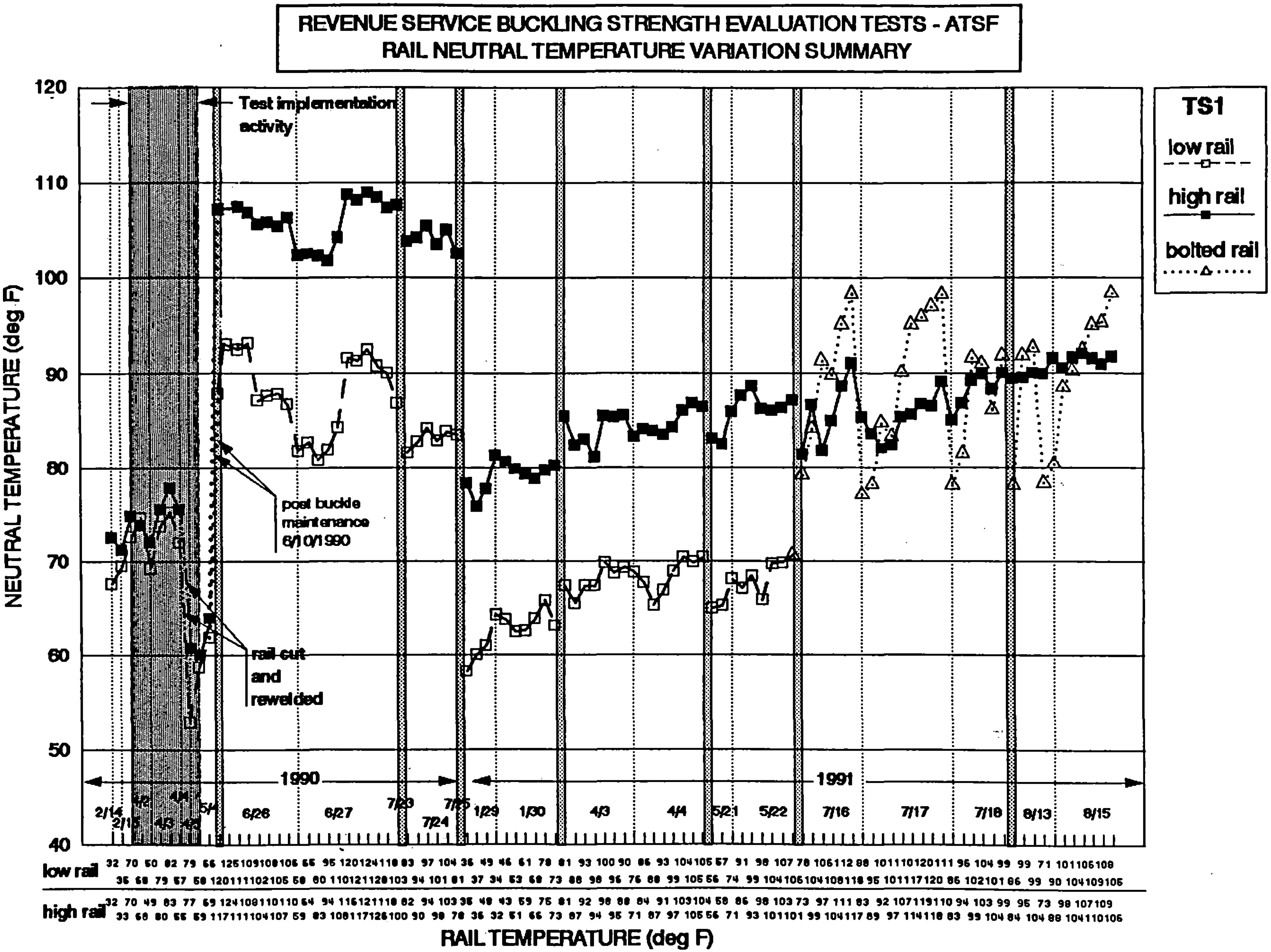



Figure 3-7. ATSF - Santa Fe, NM: Neutral Temperature at TS1

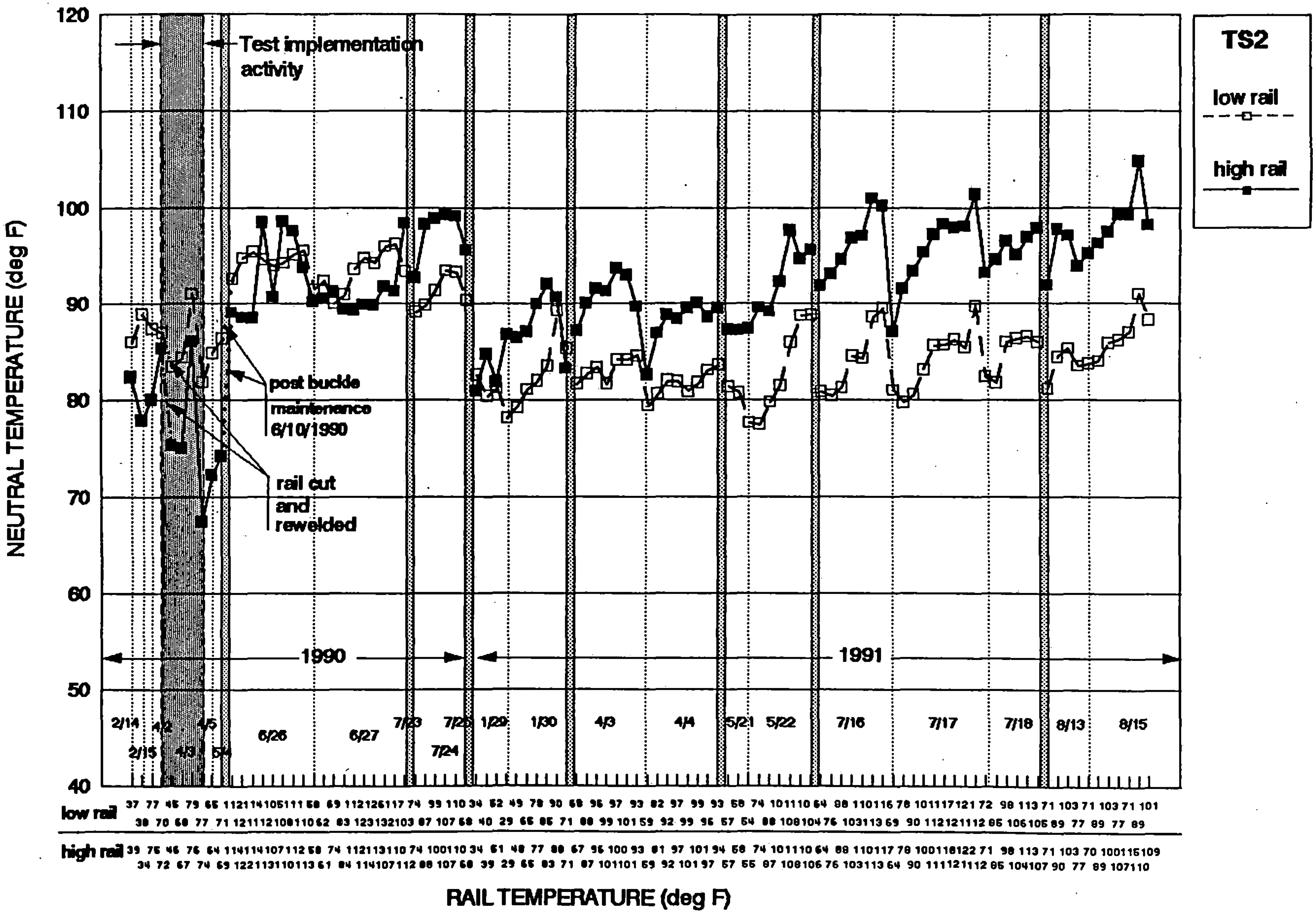



**Figure 3-8. ATSF - Santa Fe, NM: Neutral Temperature at TS2**

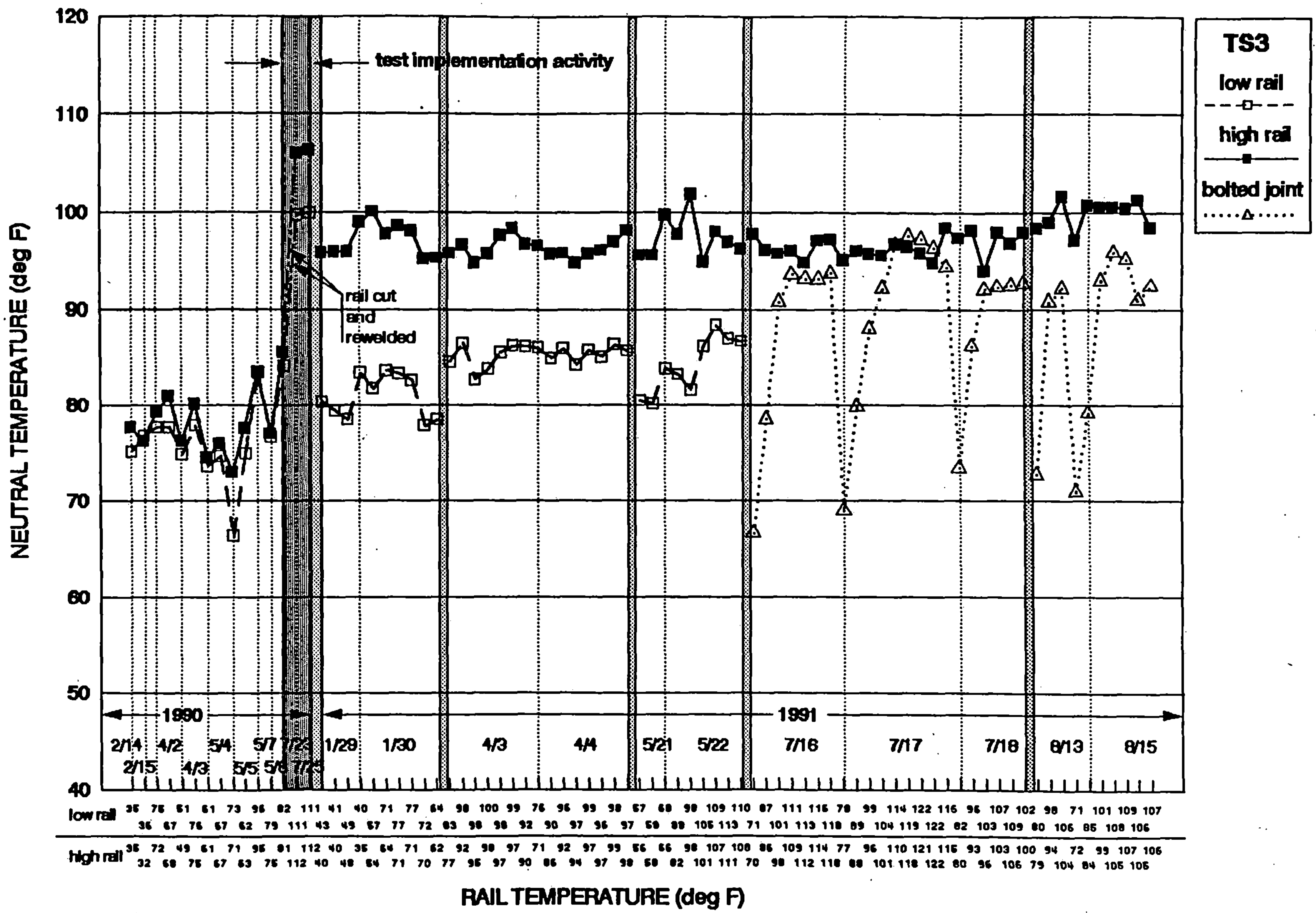



Figure 3-9. ATSF - Santa Fe, NM: Neutral Temperature at TS3

The neutral temperature variation for TS1 at the NS site is shown in Figure 3-4. During the test implementation period, the track was tamped, lifted, and lined, thus the neutral temperature was raised as the rail moved radially outward. The rails were then cut to obtain the zero force reference strain. Following rewelding of the rails, which set the neutral temperature at approximately 100°F, the neutral temperature remained fairly constant throughout the remainder of the Phase I (1990) testing, with typical daily variations of less than 5°F, while the rail temperature range was as much as 50°F. Track lateral resistance measurements, which are discussed in subsection 3.4, indicate that a high level of ballast consolidation was achieved by July 1990 in this section, which was tamped in April. This consolidation would support the constant neutral temperature, which was observed in June and July.

Between July 1990 and February 1991, there was, as would be expected, a substantial decrease in the average ambient temperature. This decrease would result in a high tensile force in the rail, especially at night, and apparently caused the track to shift radially inward. Such movement is the most likely explanation for the observed decrease in neutral temperature over this period. It is not inherently obvious why the low rail neutral temperature decreased substantially more than the high rail neutral temperature. The test in this section was terminated in March 1991 with the replacement of the rail.

The neutral temperature variation for TS2 at the NS site is shown in Figure 3-5. During the test implementation period, the rails were cut to obtain the zero force reference strain. The rewelding of the rails on the same day as the rewelding of the TS1 rails set the neutral temperature at approximately 105°F. However, unlike TS1, the neutral temperature in TS2 varied substantially over the remainder of 1990, with daily variation of as much as 20°F.

As was the case with TS1, the ambient temperature decrease between July 1990 and February 1991 led to a reduction in the neutral temperature in the continuous high rail. It appears in the figure that the low rail neutral temperature actually increased during this same period, however, the rail contained a bolted joint prior to rewelding in January 1991. Thus, the comparable neutral temperature in July 1990 is not a meaningful parameter. The test in this section was terminated in March 1991 with the replacement of the rail.

The neutral temperature variation for TS3 at the NS site is shown in Figure 3-6. The rails were not cut in this section to obtain the zero force reference strain until July 1990. After some substantial daily variance in March, the rail neutral temperature remained fairly constant from April to June prior to the rail cutting and the addition of bolted joints on both rails during late June 1990. The zero reference strains were recorded in July 1990 but the rails were not rewelded in January 1991. The February 1991 data shows a 10°F variation in neutral temperature as the rail temperature changes by 30°F. This variation is similar to that recorded in TS2 during the same period and in TS3 during March 1990, and may be caused by decreased track lateral resistance due to ballast thawing. The testing in this section was terminated in March 1991 with the replacement of the rail.

### 3.2.2 ATSF Railroad

The large data set from the ATSF test site permits a reasonable evaluation of both daily and seasonal neutral temperature variations, as well as changes due to maintenance activities. Comparisons of the same seasons from successive years are also made.

The neutral temperature variation for TS1 at the ATSF site is shown in Figure 3-7. During the test implementation period of April 1990, the section was tamped and then the rails were cut to obtain the zero force reference strain. The rails were rewelded on a cool morning and the neutral temperature was set at approximately 60°F. High ambient temperatures in June 1990 resulted in high compressive forces in the rails with low neutral temperatures. These forces, combined with the low lateral resistance due to recent tamping, resulted in buckling of the track in this section. Maintenance procedures subsequently increased the neutral temperature of both rails. Daily neutral temperature variations of 5° to 10°F were recorded through June and July 1990 while the track lateral resistance was still relatively low.

During the period of July 1990 to January 1991, when no data was collected, there was a substantial decrease in the average ambient temperature. As was the case at the NS test sites, this temperature change led to high tension forces in the rails and likely resulted in radially inward movement of the track. Consequently, a substantial decrease in the neutral temperature was recorded in both rails. It is interesting to note that the change in neutral temperature was similar (~25°F) in both rails, with the low rail neutral temperature remaining approximately 15°F lower than that of the high rail. This is to be expected, since the cross ties maintain a constant gauge between the rails; thus, any radial movement should be the same in both rails. Therefore, the change in neutral temperature, not the neutral temperature itself, should be the same for both rails, providing that no other maintenance activities are performed.

For all of the Phase II (1991) test dates, the neutral temperature showed minimal daily variations of less than 5°F. Over the entire test period from January to August 1991, the total gradual increase of the neutral temperature was less than 15°F. This slow increase was likely due to ambient temperature increases, which resulted in high compressive forces in the rails. These forces, combined with the lateral forces due to train passage, likely led to some radially outward movement of the track and, subsequently, to increases in the neutral temperature. Replacement of a section of the low rail in June 1991, due to a defective weld, ended the relevant neutral temperature monitoring of this rail because bolted joints were used. As can be seen in the figure, the neutral temperature increased along with the rail temperature and maintained a nearly zero force condition in this rail.

The neutral temperature variation for TS2 at the ATSF test site is shown in Figure 3-8. During the test implementation period of April 1990, the rails were cut to obtain the zero force reference strain. These rails were rewelded with higher neutral temperatures than TS1 (approximately 70°F for the high rail and 80°F for the low rail). The high June temperatures, which led to the buckling in TS1, also caused some minor sunkinks to the east of TS2. To relieve these kinks, both rails were cut and rewelded and the TS2 neutral temperature was reset to approximately 95°F in both rails. This neutral temperature remained fairly constant, with typical daily variations of less than 10°F, for the remainder of the Phase I testing.

During the period of July 1990 to January 1991, the neutral temperature decreased in both rails in the same manner as was discussed for TS1. Since the summer of 1990, neutral temperature was not as high in TS2 as it was in TS1, the reduction in TS2 neutral temperature was only 10°F.

For the Phase II (1991) testing period, the daily variation of neutral temperature was substantially greater in TS2 than it was in either TS1 or TS3. While the increase in average neutral temperature over the period was less than 15°F and similar to TS1, the typical daily variations were 10° to 15°F. This variation is particularly pronounced in the high rail, which is subjected to the lateral forces due to train passage as well as the thermal forces. It is possible that Pandrol fasteners used in TS1 and TS3 in 1991 could have constrained the rail more effectively than the wood tie anchors in TS2.

The neutral temperature variation in TS3 at the ATSF site is shown in Figure 3-9. The rails were not cut in this section to obtain the zero force reference strain until July 1990, when cutting and rewelding resulted in neutral temperatures above 100°F in both rails.

No data was taken following the rewelding of TS3 in July 1990, until January 1991, when the neutral temperature had decreased in both rails in the same manner as was discussed for TS1. While the neutral temperature decreased for both rails, it is not obvious why the low rail decreased by 20°F while the high rail only decreased by 10°F. Both rails exhibited very small daily variations (typically 2° to 3°F) in neutral temperature for the entire Phase II (1991) test period. As with TS1, replacement of a section of the low rail in June 1991, due to a defective weld, ended the neutral temperature monitoring of this rail.

## 3.3 Track Radial Movement

Rail longitudinal force is affected not only by the change in rail temperature, but also by the movement of the rail as a result of the thermal or train passage forces. As the force increases, the track tends to move to relieve the force. As mentioned previously, radially outward movement will relieve force throughout a section and consequently raise the neutral temperature of the rails. This movement can be assisted by train passage. Longitudinal movement of the rail along the track may also occur influencing the rail force distribution.

Limited Phase I test data of the radial movement at the NS test sites are shown in Figures 3-10 through 3-12. The high scatter of this data is due to the inaccuracy of the original measurement system, as discussed in the analysis to follow in subsection 4.2. The data from the ATSF test sites are shown in Figures 3-13 through 3-15. The Phase II (1991) data shows

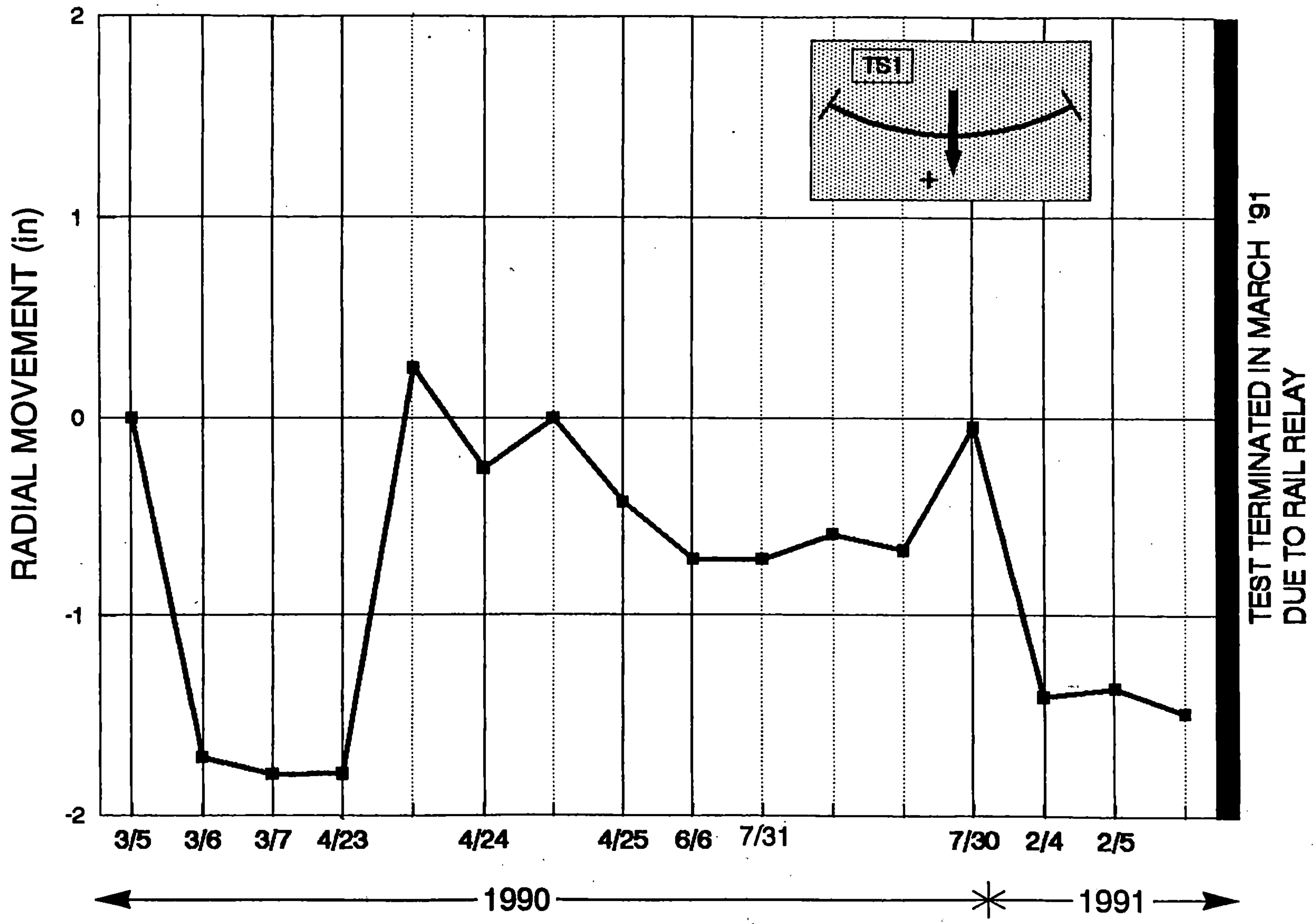



**Figure 3-10. NS Rail Radial Movement Variation Summary (TS1)**

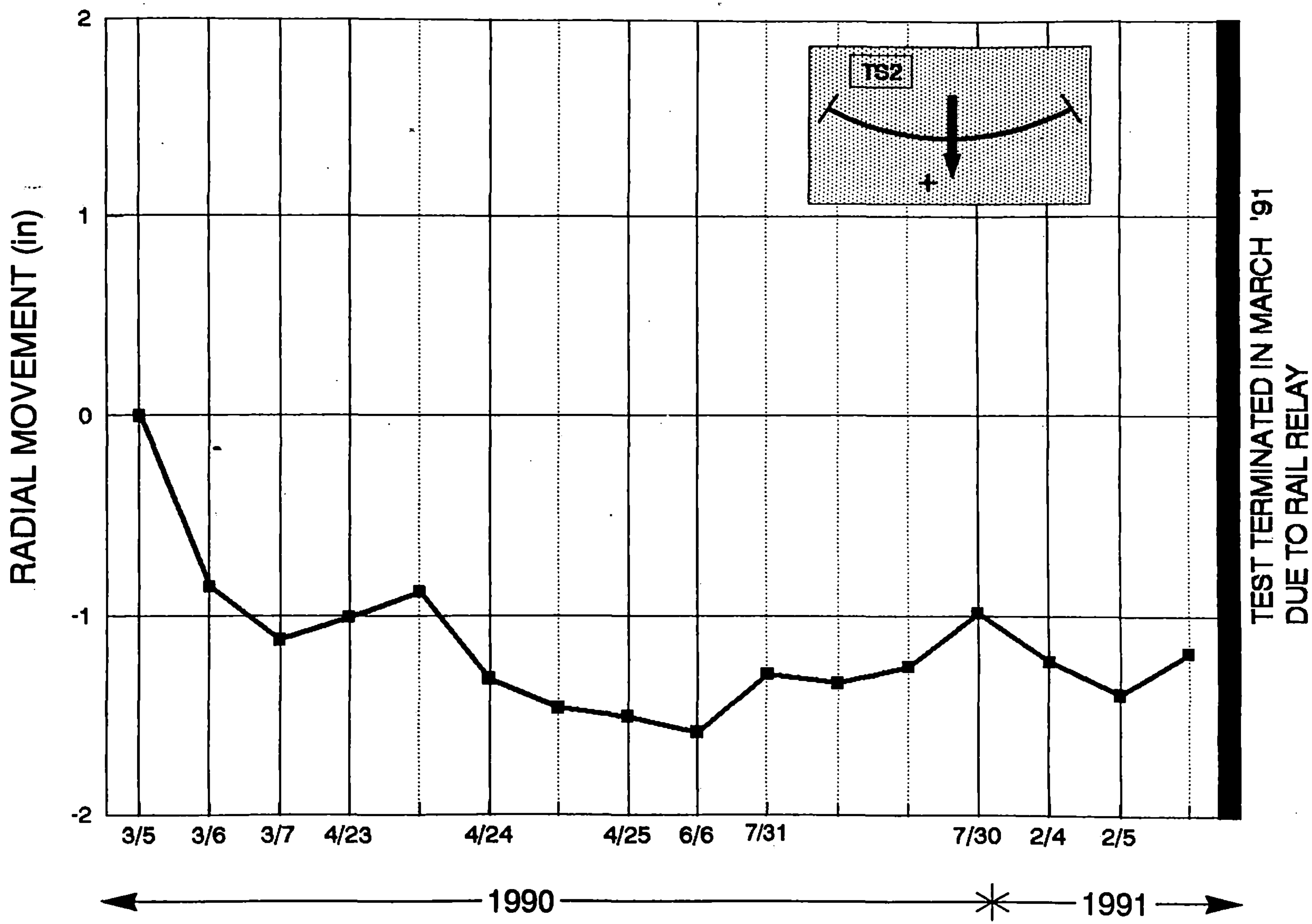



**Figure 3-11. NS Rail Radial Movement Variation Summary (TS2)**

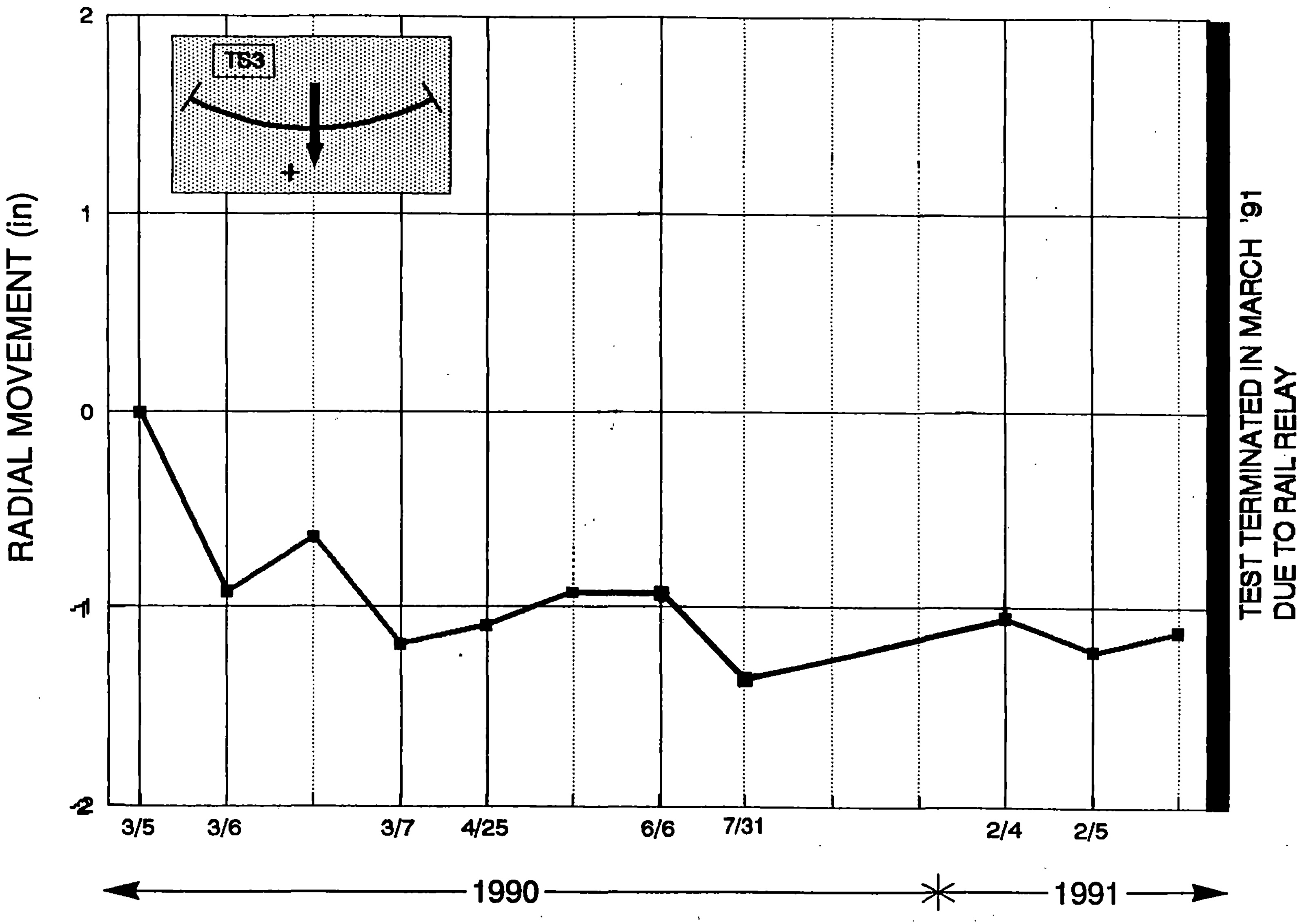



**Figure 3-12. NS Rail Radial Movement Variation Summary (TS3)**

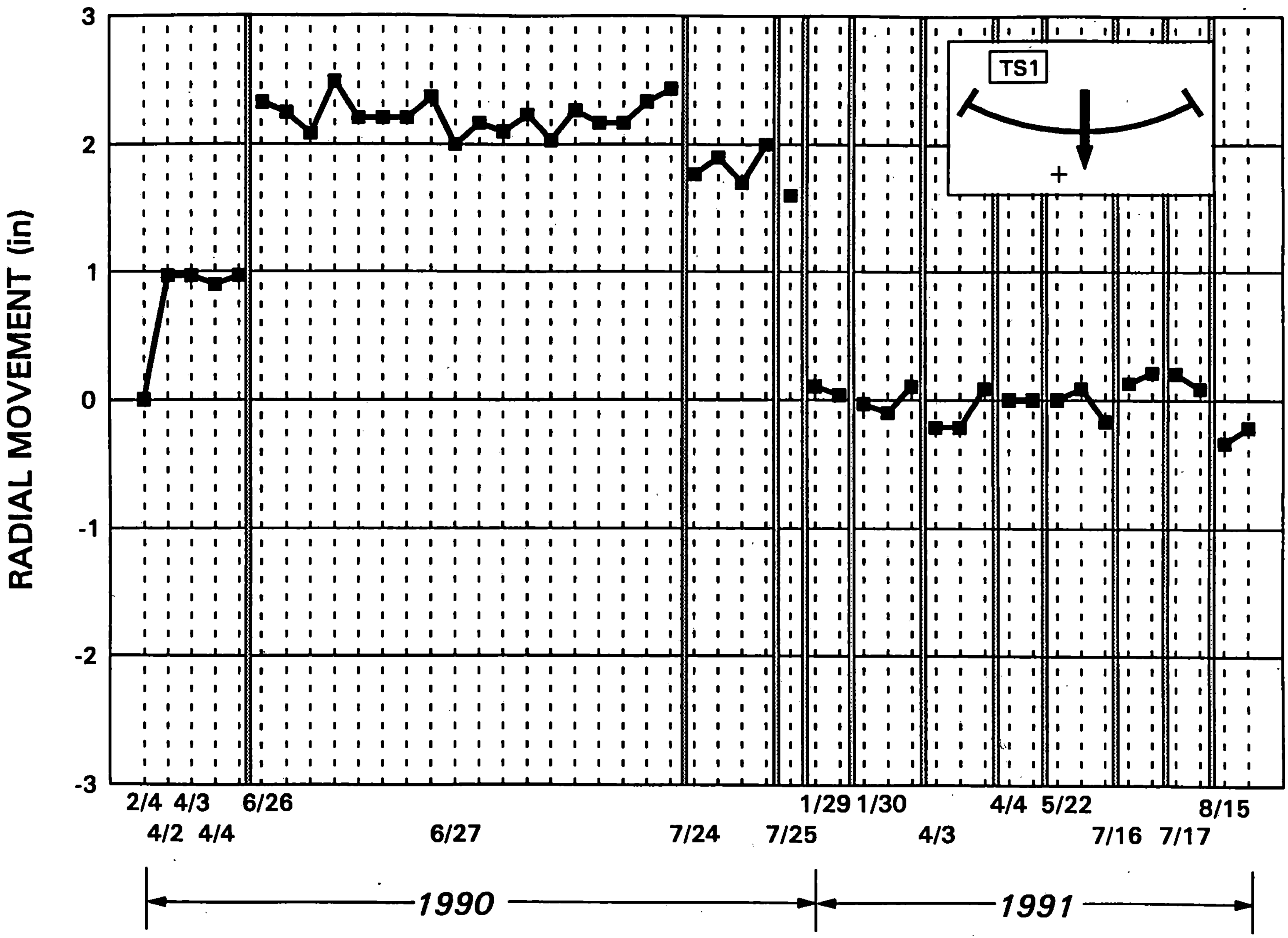



**Figure 3-13. ATSF Rail Radial Movement Variation Summary (TS1)**

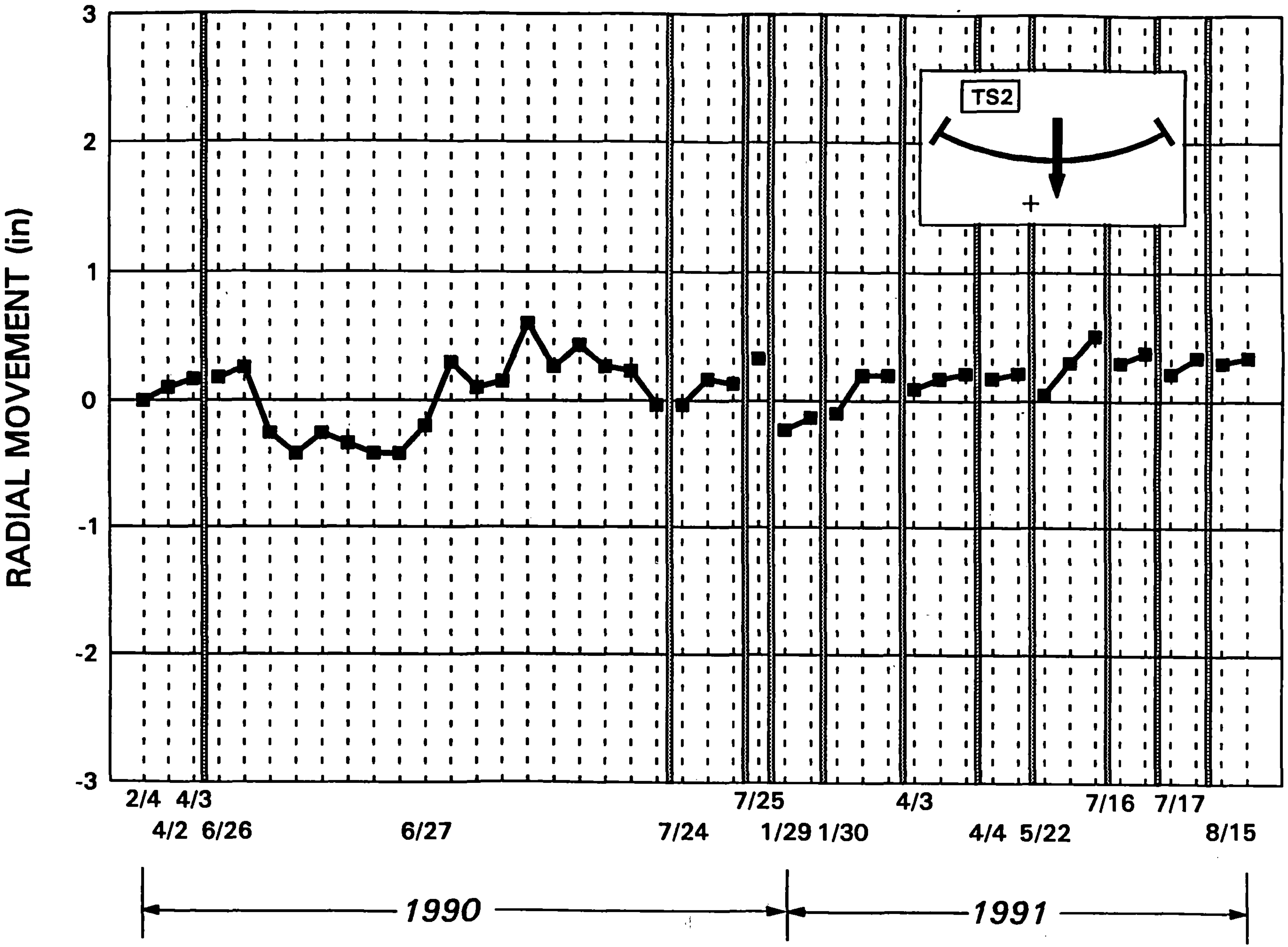



**Figure 3-14. ATSF Rail Radial Movement Variation Summary (TS2)**

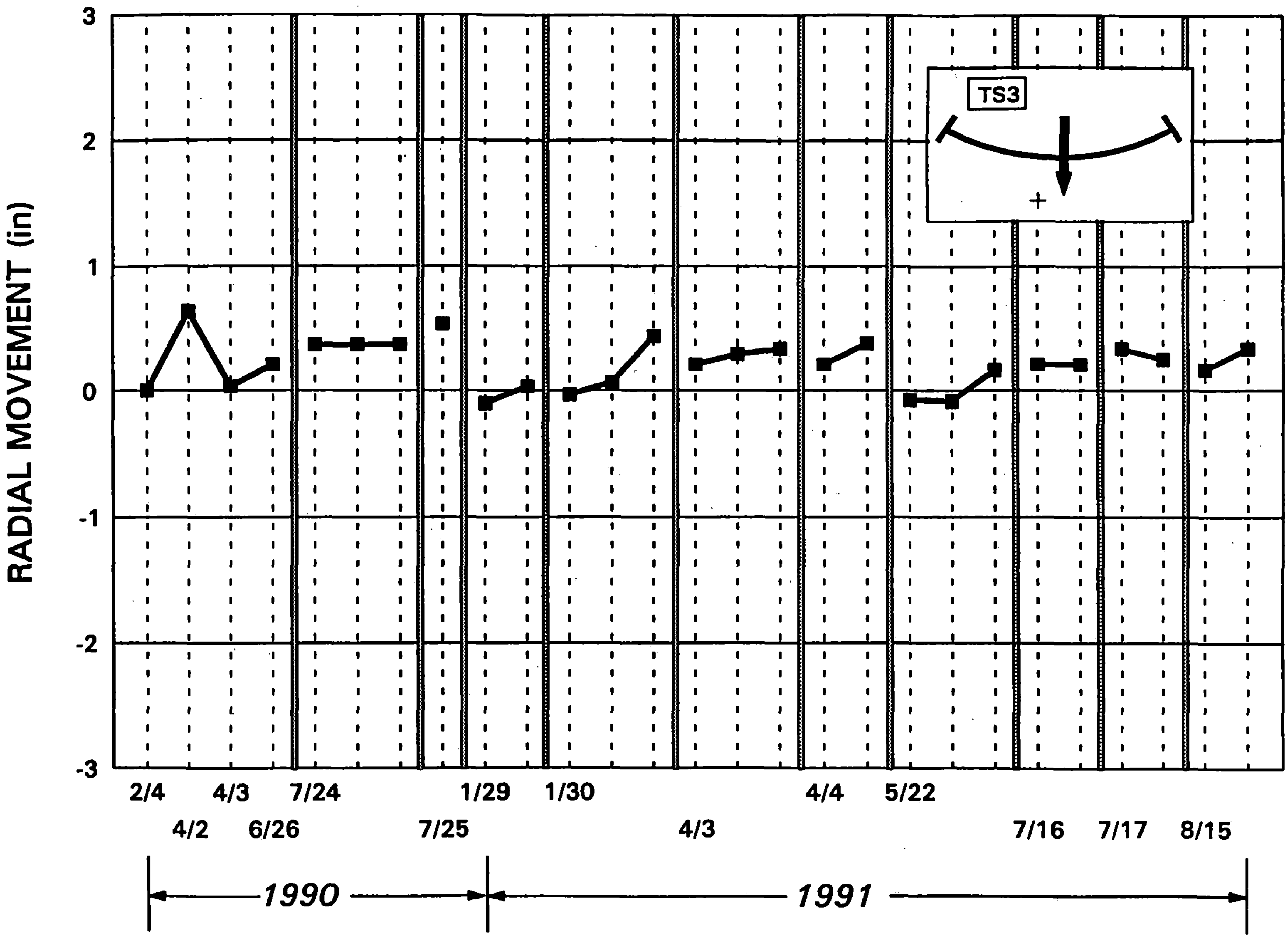



Figure 3-15. ATSF Rail Radial Movement Variation Summary (TS3)

substantially less scatter than the Phase I data and correlates reasonably well with the strain gauge data within the accuracy of the measurement system, as discussed later.

The relationship between radial movement of the track and the force in the rails can be expressed in terms of the rail strain. Since all strain data recorded in this test program is expressed as indicated strain, as discussed in subsection 2.2, the *indicated* strain due to track radial movement $\left(\varepsilon_{m_i}\right)$ is calculated as follows.

The *true* strain due to track radial movement $\left(\varepsilon_{m_t}\right)$ is expressed as:

$$\varepsilon_{m_t} = \Delta R / R \tag{3-3}$$

and,

$$R = [12 \text{ in. x } 100 \text{ ft x } 360°/C]/2\pi \tag{3-4}$$

where:

| | | |
|---|---|---|
| C | = | Track curvature in degrees |
| $\Delta R$ | = | Radial movement in inches |
| R | = | Curve radius in inches |

combining,

$$\varepsilon_{m_t} = \frac{2\pi C \Delta R(1E6\mu\varepsilon / \varepsilon)}{360 \times 100 \times 12} \approx 4.63C\pi\Delta R \tag{3-5}$$

from equation 2-1,

$$\varepsilon_{m_i} = 2(1+\mu)(4.63C\pi\Delta R) \approx 12C\pi\Delta R \tag{3-6}$$

where $\varepsilon_{m_i}$ is expressed in microstrain

Thus, the radial movement data can provide a comparison to the recorded strain data and may be able to explain shifts in the neutral temperature. Complete tables of the rail movement data are given in Appendix A.

### 3.4 Track Lateral Resistance

Track lateral resistance is defined as the load required to move the tie in the ballast, in the lateral direction. This lateral resistance, determined by performing the STPT, is one of the fundamental parameters controlling track lateral stability under thermal and vehicle loads. This parameter is one of the inputs for the Volpe Center's computer model, used here to predict the CWR buckling strength.

Using the procedure defined previously in subsection 2.2, applied load versus tie displacement, plots were generated for each tested tie. As shown in the typical plots in Appendix B, a maximum "peak" load ($F_P$) will be reached, usually after 0.25 to 0.50 in. of tie displacement. The load will then drop to a constant "limit" load ($F_L$), usually after 3 to 6 in. of tie displacement. The peak and limit loads are nearly equal in low resistance ties, but the peak can be 2 to 3 times greater than the limit in high resistance ties. A summary of the STPT results is given in Table 3-1. For each site, test section, and ballast condition tested, the average peak and limit loads and the tie displacements at these loads are shown. The standard deviation of each data set and the number of ties in the data set are also provided. Figures 3-16 and 3-17 summarize the data pictorially to more clearly show the lateral resistance distributions of both test sites.

The lateral resistance increased at different rates at the two sites as a function of traffic volume. Correlation of this data with the track tonnage is discussed in subsection 4.3.

**Table 3-1. Summary of STPT Results from Both Test Sites**

| Site | TS | Condition | $F_P$ Peak (lb) | Std. Dev. (lb) | $W_P$ Displacement (in.) | No. of Ties | $F_L$ Limit (lb) | Std. Dev. (lb) | $W_P$ Displacement (in.) | No. of Ties |
|---|---|---|---|---|---|---|---|---|---|---|
| Santa Fe, NM | 1 | Tamped-Spring | 1,477 | 214 | 0.52 | 11 | 1,032 | 200 | 4.2 | 11 |
| | | Summer | 1,966 | 292 | 0.81 | 9 | 1,361 | 140 | 4.4 | 9 |
| | | Summer-Inward | 1,512 | 270 | 0.23 | 4 | 987 | 163 | 4.17 | 4 |
| | 2 | Spring | 2,834 | 409 | 0.41 | 16 | 1,575 | 198 | 4.8 | 16 |
| | | Summer | 3,038 | 330 | 0.4 | 4 | 1,900 | 374 | 4.9 | 4 |
| | 3 | Summer | 2,420 | 301 | 0.35 | 9 | 1,585 | 195 | 4.4 | 9 |
| | 1-3 | Spring | 1,833 | 125 | 0.37 | 3 | 1,467 | 170 | 4.6 | 3 |
| Bluefield, WV | 1 | Tamped-Spring | 2,610 | 530 | 0.58 | 10 | 1,538 | 308 | 4.5 | 8 |
| | | | 4,207 | 410 | 0.52 | 7 | 1,729 | 262 | 4.5 | 7 |
| | | Summer | 4,025 | 75 | 0.9 | 2 | 1,900 | - | - | - |
| | | Summer-Inward | | | | | | | | |
| | 2 | Spring | 3,688 | 463 | 0.34 | 8 | 1,613 | 322 | 3.58 | 8 |
| | 3 | Summer | 3,833 | 672 | 0.28 | 6 | 1,285 | 235 | 4.18 | 6 |
| Santa Fe, NM | 1 | Summer '91 | 2,686 | 899 | 0.6 | 9 | 1,278 | 322 | 4 | 9 |
| | 2 | | 4,030 | 874 | 0.4 | 11 | 1,688 | 232 | 4 | 8 |
| | 3 | | 3,356 | 903 | 0.5 | 8 | 1,857 | 256 | 3 | 7 |

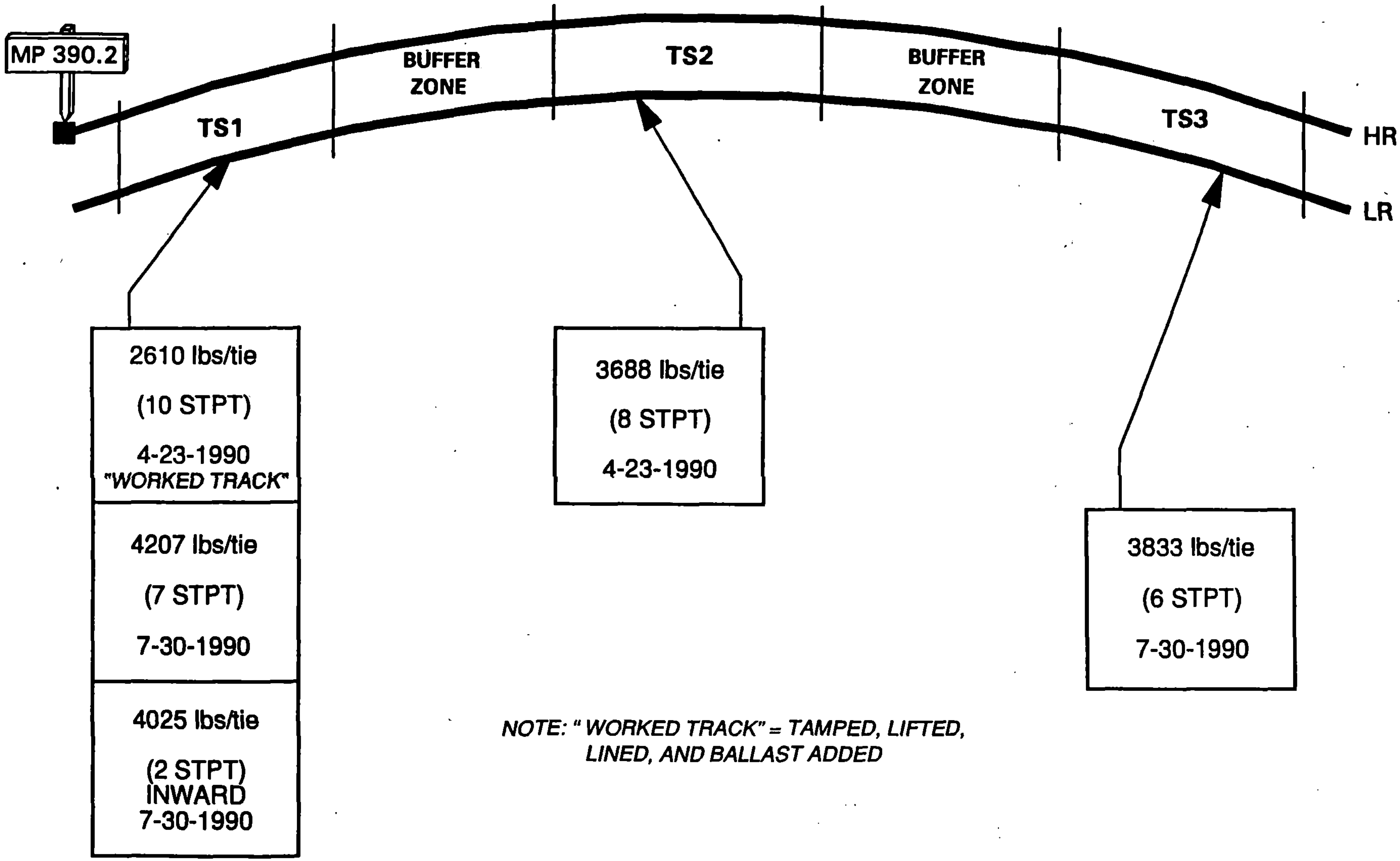



**Figure 3-16. NS Track Lateral Resistance (STPT) Summary**

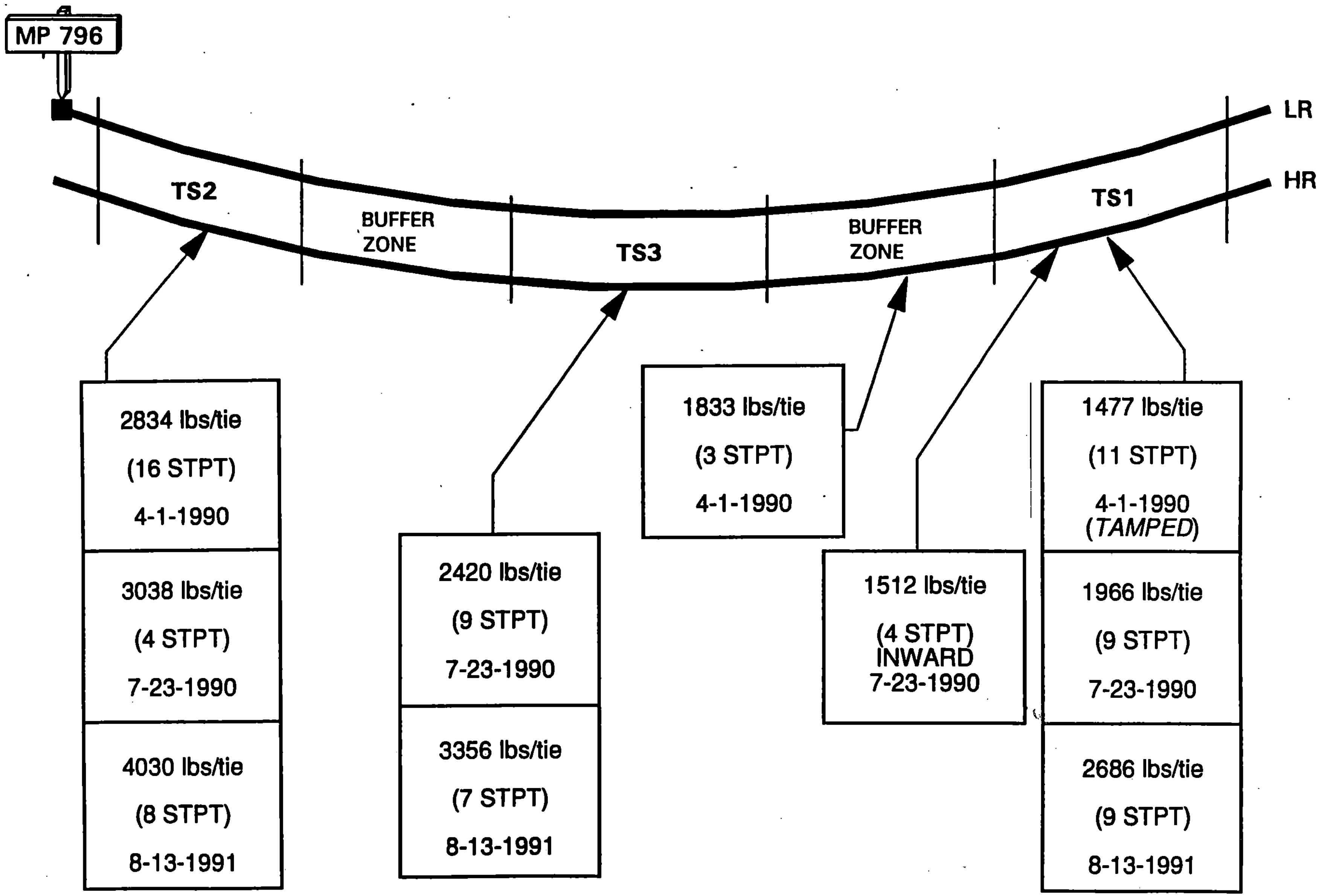



**Figure 3-17. ATSF Track Lateral Resistance (STPT) Summary**

# 4. DATA ANALYSIS

This section presents an evaluation of the results of the field test program. The data collected, namely (1) rail strain and temperature, (2) track radial movement, and (3) track lateral resistance, are utilized to characterize the following four primary aspects of track performance.

1. Rail neutral temperature, which was calculated from the rail strain and temperature data and presented previously in Section 3, is evaluated to assess daily, seasonal, and abrupt changes.

2. Radial breathing, which affects changes in rail neutral temperature, is compared with the evaluation from 1 to quantify the contribution of this movement to the recorded neutral temperature shifts.

3. Track lateral resistance is evaluated to compare the ballast consolidation rates at the two test sites and to provide input to the analysis in 4.

4. Track buckling potential is analyzed using the Volpe Center's dynamic buckling computer model with the above data, and the resulting predictions are compared with field observations.

As noted in Section 3, the complete strain, temperature, and movement raw data are presented in Appendix A.

## 4.1 Rail Neutral Temperature

Changes in the rail neutral temperature were observed throughout the test program and were shown previously in Figures 3-4 through 3-9. While most daily variations were typically on the order of 5°F, large daily variations on the order of 20°F were recorded in TS2 at the NS site. Primarily, the large shifts in neutral temperature were due to either seasonal temperature changes or track maintenance work. Table 4-1 provides a summary of the typical daily and seasonal variations in neutral temperatures recorded at each test site. These changes are most clearly evident at the ATSF site due to the substantially greater amount of data collected. However, summer-to-winter neutral temperature decreases are also found in the NS data, most notably in TS1.

The significant reductions in neutral temperature from summer to winter were partly due to the high neutral temperatures set by cutting and welding the rails in the late spring or summer of 1990. The data from the extended testing at the ATSF site indicate that an uncut rail will maintain a neutral temperature on the order of 85°F with seasonal fluctuations of less than 10°F. This is indicated by the data from 1991 and the data from April 1990 prior to rail cutting.

**Table 4-1. Daily and Seasonal Neutral Temperature Variations**

| Norfolk Southern (NS) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Average Neutral Temperature (F) | | | | | Daily Variation (F) | |
| Test Site | Mar 90 | Apr 90 | Jun/Jul 90 | Feb 91 | | 1990 | 1991 |
| TS1 | 65 | 65/100* | 85 | 90 | | 5 | <10 |
| TS2 | 65 | 75/105 | 95** | 80 | | 20 | 10 |
| TS3 | 60 | 80 | 80/*** | 60 | | 5 | 10 |
| Atchison, Topeka, and Sante Fe (ATSF) | | | | | | | |
| | Average Neutral Temperature (F) | | | | | Daily Variation (F) | |
| Test Site | Apr 90 | Jun/Jul 90 | Jan 91 | Apr 91 | Jul/Aug 91 | 1990 | 1991 |
| TS1 | 75/60 | 105 | 80 | 85 | 90 | 5-10 | 5 |
| TS2 | 85/75 | 95 | 85 | 85 | 90 | <10 | 10-15 |
| TS3 | 75 | 80/105 | 95 | 95 | 100 | 5 | <5 |

* The two Tn values represent before and after cut and weld

** The neutral temperature at NS-TS2 varied greatly

*** Rail not welded after cutting

A summary of the shifts in neutral temperature due to track maintenance operations is provided in Table 4-2. In each test section, the rails were cut to obtain the zero force reference for the strain gauges. Due to low temperatures at rail welds in TS1 and TS2 at the ATSF site and high ambient temperatures in June 1990, a few buckles occurred in these test sections and substantial post-buckle maintenance was performed to realign the track radically outward and thus raise the neutral temperature in these sections. Unfortunately, the track crew's decision to use bolted joints in the rails at both sites prevented continuous tracking of seasonal changes. Since the bolted joints permit free expansion and contraction of the rail at the joints, the concept of neutral temperature is not applicable. Although these joints potentially reduce the likelihood of track buckling, the advantages of CWR are no longer realized.

## 4.2 Radial Breathing Contribution to Neutral Temperature Shift

The significant neutral temperature shifts observed in subsection 4.1 can be attributed in part to radial movement of the rail. Recall equation 3-6,

$$\varepsilon_{m_i} \approx 12C\pi\Delta R$$

where C is the curvature in degrees, $\Delta R$ is the radial movement in inches, and $\varepsilon_{mi}$ is the change in indicated microstrain. Further, recall equation 3-2,

$$T_N = T_c - \frac{(\varepsilon_c - \varepsilon_o)}{2(1+\mu)\alpha}$$

which may be rewritten as,

$$\Delta T_N = \frac{\Delta\varepsilon}{16.64} \qquad (4\text{-}1)$$

where $\Delta\varepsilon = \varepsilon_c - \varepsilon_o$

using the rail properties of $\mu = 0.3$ and $\alpha = 6.4 \times 10$ µin./in./°F.

Thus, the change in neutral temperature ($\Delta T_N = T_C - T_N$) due to radial movement ($\Delta R$) may be directly expressed as follows:

$$\Delta T_N \approx \frac{12C\pi\Delta R}{16.64}$$

$$\approx 0.723\, C\pi\Delta R \qquad (4\text{-}2)$$

**Table 4-2. Neutral Temperature Variations due to Maintenance Procedures**

| | | | | |
|---|---|---|---|---|
| Norfolk Southern (NS) | | | | |
| | | | | |
| | | Neutral Temp. (F) | | |
| Test Site | Date | Before | After | Maintenance Action |
| | | | | |
| TS1 | Apr-90 | 65 | 85 | Track lifted and lined |
| | Apr-90 | 80 | 100 | Rails cut and welded for zero force measurement |
| | | | | |
| TS2 | Apr-90 | 75 | 105 | Rails cut and welded for zero force measurement |
| | Jul-90 | 95 | N/A* | Bolted joint installed in the low rail |
| | Jan-91 | N/A | 80 | Low rail welded |
| | | | | |
| TS3 | Jun-90 | 80 | N/A | Bolted joint installed in the high rail |
| | Jul-90 | 80 | N/A | Bolted joint installed in the low rail |
| | Jan-91 | N/A | 60 | Both rails welded |
| | | | | |
| Atchison, Topeka, and Sante Fe (ATSF) | | | | |
| | | | | |
| TS1 | Apr-90 | 75 | 60 | Rails cut and welded for zero force measurement |
| | Jun-90 | 60 | 105 | Post-buckle maintenance |
| | Jul-91 | 70 | N/A | Bolted joint installed in the low rail |
| | | | | |
| TS2 | Apr-90 | 85 | 75 | Rails cut and welded for zero force measurement |
| | Jun-90 | 75 | 95 | Post-buckle maintenance |
| | | | | |
| TS3 | Jul-90 | 80 | 105 | Rails cut and welded for zero force measurement |
| | Jul-91 | 85 | N/A | Bolted joint installed in the low rail |
| | | | | |
| | | | | |
| *N/A - Neutral temperature is not an applicable concept due to the bolted joint | | | | |

Figures 4-1 through 4-3 show the total neutral temperature shift, as indicated by the strain gauges, and the contribution of radial movement toward the neutral temperature shift, as calculated above, for the test data from the ATSF site. Within the limited movement data, it can be seen that the radial movement typically accounts for the majority of the neutral temperature shift.

The Phase I data collected in 1990 was simply measured using a tape measure and plumb bob. Analysis of this data indicated that this measurement technique was not sufficiently accurate. The Phase II data collected in 1991 was measured with the new device shown in Figure 2-3. The improved accuracy of this measurement system yielded data that was typically in agreement with the strain gauge data. Thus, the NS data is not shown, as no Phase II measurements were made on radial movement at this site.

While radial movement is usually the most significant factor contributing to rail force relief, some of the data indicates the presence of other contributing factors. Most significantly,

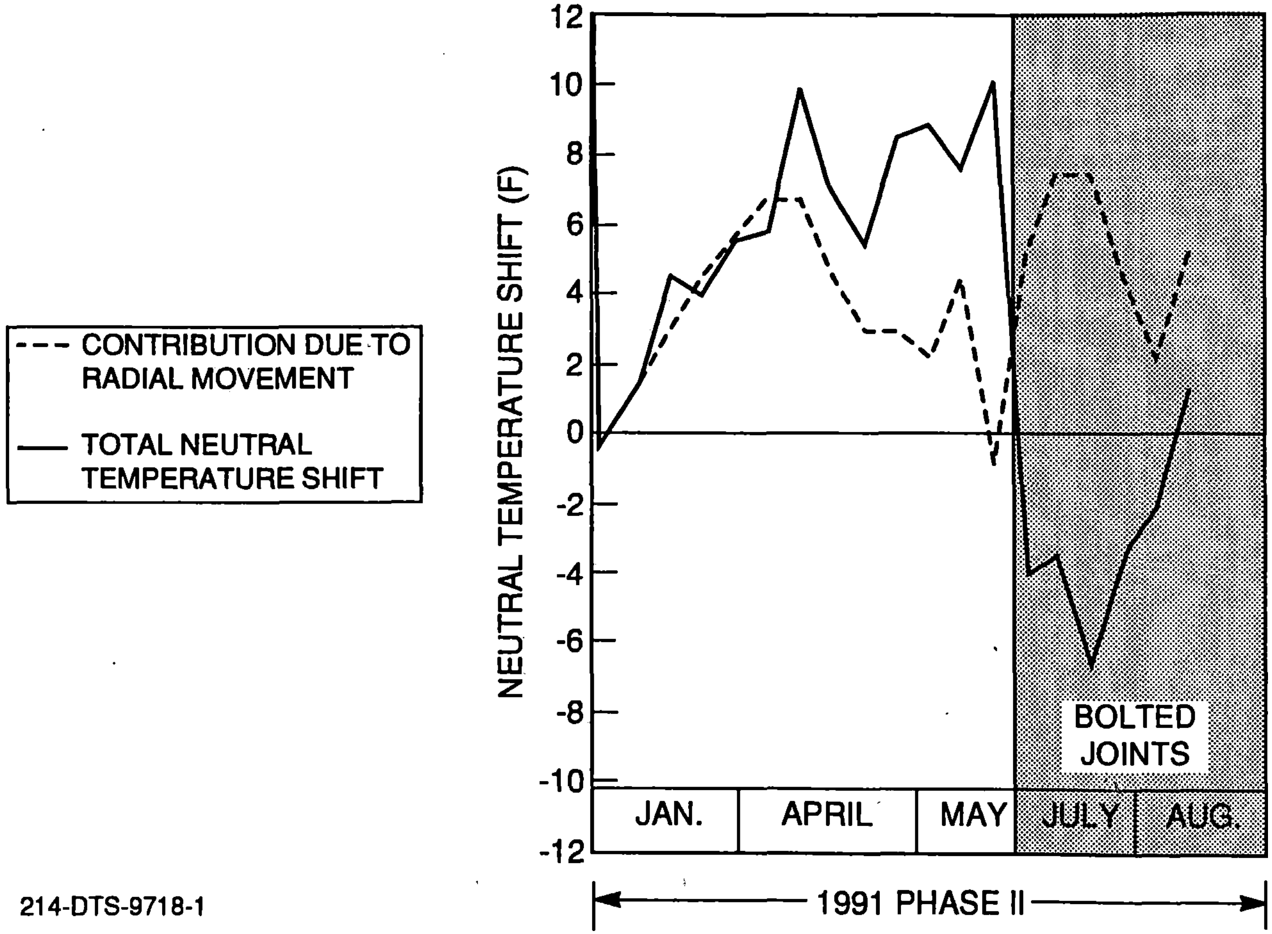
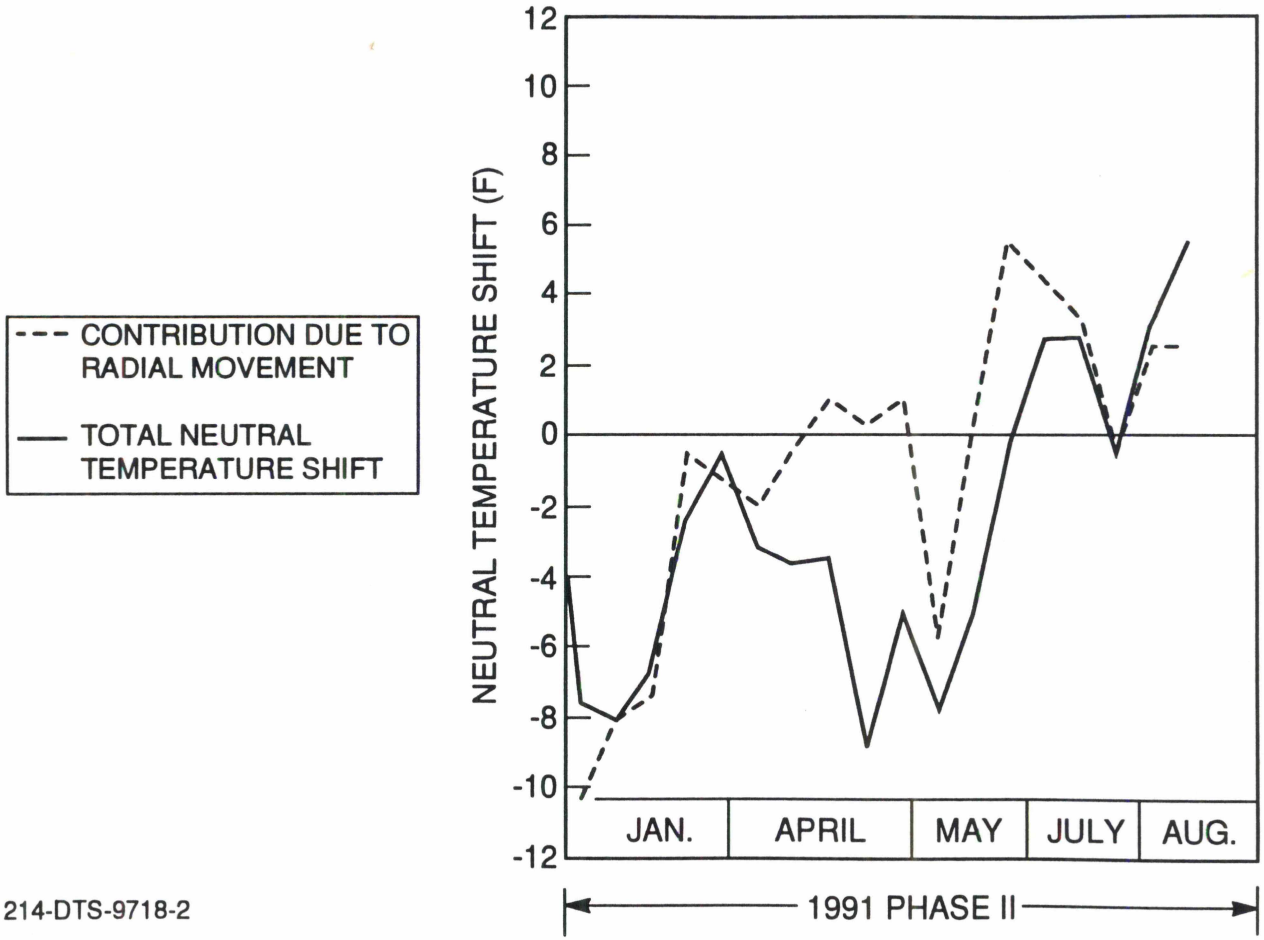



**Figure 4-1. ATSF TS1 Rail Movement Correlation**




214-DTS-9718-2

**Figure 4-2. ATSF TS2 Rail Movement Correlation**

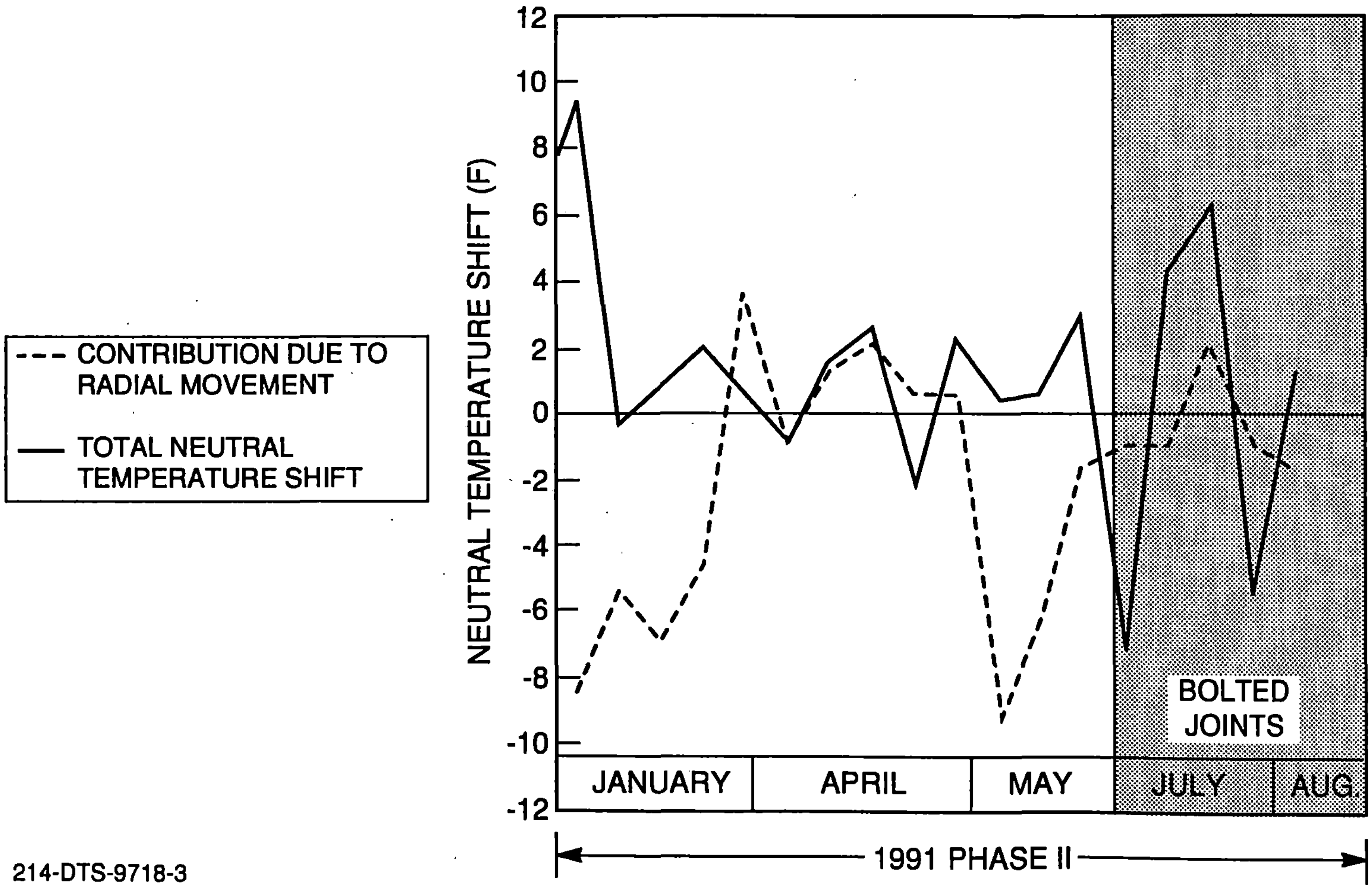



**Figure 4-3. ATSF TS3 Rail Movement Correlation**

neutral temperature would also be influenced by rail longitudinal movement, which was not recorded in the tests. Table 4-3 summarizes the contribution of the radial movement and provides a physical explanation when it is evident from the test data and observations.

## 4.3 Track Lateral Resistance

The STPT data was shown previously in Table 3-1. The average rate of increase of lateral resistance over the entire test period was found to be 90 lb/MGT for ATSF and 120 lb/MGT for NS, although data was not taken at fine intervals of MGT to truly characterize the nonlinear increase in resistance. This is in agreement with the fact that the overall resistance at NS was consistently larger than that at ATSF. A significant amount of coal dust was also visible in the ballast at the NS site, which may provide a more binding formation.

The results of the STPTs are discussed below for each test site.

**Table 4-3. Summary of Rail Radial Movement Contribution to Neutral Temperature Shift at ATSF**

| Test Section | Dates | Comments |
|---|---|---|
| TS1 | All 1990 | Poor correlation due to measurement device. |
| | 1/29/91 to 4/4/91 | Radial movement within 1/8 in. of total $T_N$ shift. |
| | 5/21/91 to 5/22/91 | Radial movement within 1/4 in. of total $T_N$ shift. |
| | 7/16/91 to 8/15/91 | No correlation due to bolted joints. |
| TS2 | All 1990 | Poor correlation due to measurement device. |
| | 1/29/91 to 4/3/91 | Radial movement within 1/8 in. of total $T_N$ shift. |
| | 4/3/91 to 4/4/91 | Shift apparently not related to radial movement. |
| | 5/21/91 to 5/22/91 | Radial movement within 1/4 in. of total $T_N$ shift. |
| | 7/16/91 to 8/15/91 | Radial movement within 1/8 in. of total $T_N$ shift. |
| TS3 | All 1990 | Poor correlation due to measurement device. |
| | 1/29/91 to 1/30/91 | Shift apparently not related to radial movement. |
| | 4/3/91 to 4/4/91 | Radial movement within 1/4 in. of total $T_N$ shift. |
| | 5/21/91 to 5/22/91 | Shift apparently not related to radial movement. |
| | 7/16/91 to 8/15/91 | No correlation due to bolted joints. |

### 4.3.1 ATSF Railroad

In the spring of 1990, TS1 was tamped and subsequent STPTs indicated that the average lateral resistance peak was reduced to 1477 lbs/tie. The tests performed in TS1 indicate that from spring to summer 1990, the resistance had not increased dramatically. This is due to the low rail tonnage and may also be due to the lining of the track in late June 1990. The tests in TS2 and TS3 indicate a higher resistance than TS1 since no track work was performed in these test sections. The test results from August 1991 indicate that the lateral resistance has increased in all sections at a similar rate. However, as mentioned previously, the low tonnage is unable to consolidate the ballast sufficiently to provide high lateral resistance. The following subsection (4.4) will discuss the effects of this lower lateral resistance on track buckling.

### 4.3.2 NS Railroad

In the spring of 1990, TS1 was also tamped, lined, and lifted, and subsequent STPTs indicated that the lateral resistance average peak was reduced to 2610 lbs/tie. This resistance is substantially higher than that recorded at the tamped ATSF site. This difference may be due to several factors, including ballast type, shoulder width, and variables in the tamping operation.

The tests performed in TS1 in 1990 indicate that from spring to summer, the ballast cosolidated back to the pre-tamping state. The resistance may also have increased in other sections. The increase, between spring and summer 1990, of the track lateral resistance at NS, in the tamped section (TS1), was three times greater than the increase rate measured at ATSF TS1, primarily due to the higher traffic volume at the NS site.

## 4.4 Buckling Potential Evaluation

The Volpe Center's dynamic buckling model was utilized to evaluate all six test sections at the two test sites using track lateral resistance data from the STPTs, neutral temperature data from the strain gauges, and an assumed misalignment amplitude of 1.5 in. The model predicts $T_{B,MIN}$, the lower critical buckling temperature increase at which buckling can occur with sufficient external energy input, and $T_{B,MAX}$, the upper critical buckling temperature increase at which buckling will occur with zero external energy input. Thus, the potential for buckling exists when the sum of $T_{B,MIN}$ and the rail neutral temperature ($T_N$) exceeds the temperature of the rail ($T_{rail}$).

The evaluation of each test site is summarized in Table 4-4. The minimum margin of safety for the three ATSF test sites occurred in June 1990. The three NS test sites were evaluated for the same time period for comparison. Additionally, TS1 and TS2 and the NS sites were evaluated for April 1990 when the minimum margin of safety existed for these sections.

The low neutral temperature at ATSF TS1, combined with the low lateral resistance due to recent tamping and low traffic, resulted in a low maximum allowable temperature of 117°F

**Table 4-4. Safety Margin at Each Test Section**

| Site | ATSF | | | NS | | | | |
|---|---|---|---|---|---|---|---|---|
| Section | TS1 | TS2 | TS3 | TS1 | TS1 | TS2 | TS2 | TS3 |
| Date | Jun-90 | Jun-90 | Jun-90 | Apr-90 | Jun-90 | Apr-90 | Jun-90 | Jun-90 |
| Min Lateral Resistance (lbs/in) | 90 | 150 | 120 | 130 | 180 | 180 | 190 | 170 |
| Min Buckling Temperature (Tbmin) | 54 | 64 | 60 | 67 | 79 | 79 | 81 | 76 |
| Neutral Temperature (Tn) | 63 | 74 | 82 | 75 | 95 | 70 | 95 | 80 |
| Max Temp Allowable (Tbmin + Tn) | 117 | 138 | 142 | 142 | 174 | 149 | 176 | 156 |
| Max Rail Temperature (Trmax) | 135 | 135 | 135 | 115 | 128 | 115 | 128 | 128 |
| Margin of Safety | -18 | 3 | 7 | 27 | 46 | 34 | 48 | 28 |
| Notes: | 1. Buckling occurred at ATSF TS1 on 10 June 1990 | | | | | | | |
| | 2. Minimum margin of safety occurred at NS on 23 April 1990 | | | | | | | |
| | 3. All temperatures are in deg F | | | | | | | |
| | 4. Tbmin is calculated from the computer program | | | | | | | |

during June 1990. Rail temperatures during June at this site were measured as high as 135°F on a day in which the ambient temperature reached 105°F. Consequently, the track buckled in this test site on 10 June 1990. Following this event, the rail was cut, destressed, and rewelded at a sufficiently higher neutral temperature.

TS2 and TS3 at the ATSF site also experienced the high rail temperatures of TS1. However, due to higher lateral resistance and higher neutral temperature, a slight margin of safety was maintained and buckling did not occur within these sections. The effect of lateral resistance is particularly evident in TS2, where there would have been a negative margin of safety and buckling would have been likely to occur had the section been tamped to the same low resistance as TS1. The effect of neutral temperature is evident in TS3, which was not cut and rewelded in April 1990 and thus had a higher $T_N$ than the other two sections. If this section had the same low neutral temperature of TS1, buckling would have been likely despite the higher lateral resistance.

The high lateral resistance of the NS track typically resulted in a much lower buckling potential (much higher margin of safety). The lowest margin of safety apparent during the test period occurred in April 1990 at TS1, after tamping but prior to destressing of the rails. However, even after tamping, STPTs indicated a lateral resistance of 130 lb/in. Thus, a margin of safety of more than 25°F was maintained. By June 1990, when the highest rail temperatures were recorded at the site, the high traffic had consolidated the ballast and substantially increased the minimum buckling strength. Further, the rail destressing in April increased the neutral temperature and thus a large margin of safety is apparent. The high lateral resistance and moderate neutral temperatures in the other test sections also consistently resulted in high margins of safety throughout the test program.

# 5. CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations can be drawn on the basis of the field test data and analysis presented in the previous sections.

## 5.1 Conclusions

1. Rail neutral temperature shifts in high degree curved tracks can be significant. Shifts due to seasonal effects are typically on the order of 20°F and in one extreme case a shift of 40°F was recorded. Shifts on the order of 5°F typically occur daily due to diurnal changes in rail temperature. However, in one test section, diurnal changes of 20°F were recorded.

2. Due to drainage requirements, adequate ballast shoulder was not always provided on the inside of some curved portions to prevent rail pulling in due to tensile loads. To increase the neutral temperature and reduce the misalignments, the track was realigned outward (larger radius) at some sites. The nighttime cooling of rails, together with general low resistance in the radially inwards direction, due to the minimal ballast shoulder, did occasionally offset the advantage of this outward realignment and the misalignments reappeared in the track.

3. Likewise, adequate ballast shoulder could not be maintained on the outside of some superelevated curved sections. These curved portions moved outward radially on hot summer days, and occasionally problems arose in the form of unacceptably large lateral misalignments at hard spots such as bridge abutments.

4. Radial movement of rails contributed to shifts in the neutral temperature and were measurable in the field. In one extreme case, a seasonal shift of 1.1 in. was recorded. One inch of radial movement theoretically corresponds to a neutral temperature change of 22°F on 10 degree track.

5. Tamping of the tracks dropped the lateral resistance to about 55 percent of the untamped value in the curve. Whereas at one site the resistance was quickly recovered due to the high traffic volume (5.7 MGT/month) of traffic, at another site the resistance rose to only about 65 percent of the untamped resistance after three months. The low traffic volume (0.8 MGT/month) at the second site could keep the tamped track under low resistance over a long period in some sections.

6. Track lateral resistance measured by STPT at both sites showed a drooping softening characteristic for consolidated ballast, similar to those observed previously at TTC. For tamped tracks, the peak and limiting values approach one another at values of about 1000 lb/tie. For consolidated track, the ratio of peak to limiting values can reach two or higher, depending on the level of consolidation.

7. By early spring, the CWR track does not seem to regain the neutral temperature lost during the winter due to inward radial movement. The rail temperatures reach significantly high values, increasing the buckling potential in the spring.

8. The combination of low neutral temperature and reduced lateral resistance after tamping could precipitate buckling on a hot day. Such buckling incidents did occur at some of the tested sites. A neutral temperature of 60°F was obtained after cutting and welding at one site. The rail temperature was anticipated to be low for subsequent weeks. Rail temperatures over 125°F were in fact reached, and these exceeded the theoretically allowable temperature, resulting in a few buckling incidents. Rail distressing, which raised the neutral temperature to greater than 90°F, reduced the problem significantly at this site.

## 5.2 Recommendations

1. The industry should be encouraged to utilize the following available instrumentation and hardware for improved monitoring of the safety of CWR track: (a) The STPT fixture should be simplified for rapid evaluation of resistance and spot checking of the ballast consolidation. The simplified STPT will have a green and red indicator for a minimum level of specified resistance; (b) At spots where the rails are cut for destressing, etc., the neutral temperature can be monitored using the strain gauge and portable strain indicator system; (c) Using reference pegs and a measuring tape, the radial movements of high degree curves can be monitored at selected locations.

2. The rail temperature should be regularly measured so that seasonal records of the typical local maximum temperatures can be developed. These records could be used by the track crew to properly select a rail temperature for welding after a rail has been cut.

3. Additional field tests should be conducted on high degree curve CWR, where maintenance operations can be restricted. The program presented in this report was hampered to some extent by the numerous maintenance operations, conducted at both sites, not related to buckling situations.

4. A similar field test program should be conducted on curved, CWR, concrete tie track to characterize track performance with these ties. The rail strain and temperature should be recorded periodically to quantify diurnal and seasonal neutral temperature variations. Further, the track lateral resistance and radial movement should be measured to fully assess the track performance.

# APPENDIX A
## Test Data

| RAIL STRAIN DATA FROM SANTE FE, NM | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | |
| SECTION 1 | | | | | | | High Rail | | | | | | | | |
| Date | Amb | Time | | 1 | Neut | | 2 | Neut | | 3 | Neut | | 4 | Neut | |
| | Temp | | Strain | Temp | Temp | Strain | Temp | Temp | Strain | Temp | Temp | Strain | Temp | Temp | Comments |
| 2/14/90 | 37 | | 1316 | 37.3 | 67.4 | 315 | 32.4 | 72.5 | -44 | 32.5 | 72.4 | 414 | 33.1 | 74.8 | |
| 2/15/90 | 20 | | 1229 | 33.2 | 68.5 | 358 | 31.5 | 69.1 | -10 | 35.4 | 73.3 | 431 | 31.5 | 72.2 | |
| 4/02/90 | 56 | | 1730 | 69.8 | 75.0 | 895 | 70.6 | 75.9 | 540 | 69.1 | 73.9 | 1024 | 73.5 | 78.5 | |
| 4/02/90 | | 4:00 | 1759 | 68.0 | 71.5 | 881 | 67.1 | 73.2 | 513 | 68.1 | 74.5 | 963 | 69.9 | 78.6 | |
| 4/03/90 | 45 | 9:00 | 1454 | 47.8 | 69.6 | 590 | 48.0 | 71.6 | 242 | 49.7 | 72.4 | 687 | 48.7 | 74.0 | |
| 4/03/90 | | | 1921 | 80.9 | 74.7 | 1062 | 80.0 | 75.3 | 692 | 80.2 | 75.9 | 1142 | 77.9 | 75.9 | |
| 4/03/90 | | 4:15 | 1953 | 83.7 | 75.5 | 1072 | 85.0 | 79.7 | 702 | 81.0 | 76.1 | 1159 | 80.5 | 77.4 | After Tamping |
| 4/04/90 | | 8:15 | 1496 | 54.3 | 73.6 | 644 | 54.4 | 74.8 | 283 | 56.0 | 76.3 | 743 | 55.3 | 77.2 | Before High Rail Cut |
| 4/04/90 | | | 1817 | 75.7 | | 983 | 75.5 | | 620 | 74.6 | | 1108 | 81.5 | | Zero, after Cut |
| 4/05/90 | | | 1859 | 60.3 | 57.8 | 1261 | 77.6 | 60.9 | 888 | 76.8 | 60.7 | 1142 | 64.3 | 62.3 | After Welding |
| 5/04/90 | 48 | 11:30 | 1787 | 57.2 | 59.0 | 933 | 58.3 | 61.3 | 640 | 59.9 | 58.7 | 1050 | 59.8 | 63.3 | Jon's Data |
| 5/04/90 | 55 | 3:00 | 1925 | 67.0 | 60.5 | 1049 | 68.0 | 64.0 | 504 | 69.0 | 76.0 | 1153 | 68.4 | 65.7 | Jon's Data |
| 6/26/90 | 95 | 10:25 | 1924 | 111.8 | 105.4 | 1161 | 117.2 | 106.5 | 783 | 117.5 | 107.7 | 1300 | 117.9 | 106.4 | |
| 6/26/90 | 92 | 5:35 | 1816 | 106.1 | 106.2 | 1048 | 108.4 | 104.5 | 680 | 111.8 | 108.2 | 1203 | 112.9 | 107.2 | |
| 6/27/90 | 60 | 5:40am | 1072 | 58.9 | 103.7 | 269 | 59.4 | 102.3 | -110 | 58.5 | 102.4 | 359 | 58.0 | 103.0 | Begin Full Day Test |
| 6/27/90 | 65 | 6:40 | 1144 | 62.5 | 102.9 | 351 | 63.9 | 101.9 | -19 | 64.8 | 103.2 | 458 | 64.8 | 103.9 | |
| 6/27/90 | 68 | 7:18 | 1481 | 85.5 | 105.7 | 672 | 83.7 | 102.4 | 278 | 81.7 | 102.3 | 723 | 81.1 | 104.2 | |
| 6/27/90 | 84 | 8:25 | 1644 | 92.5 | 102.9 | 857 | 93.4 | 101.0 | 471 | 93.8 | 102.8 | 940 | 95.3 | 105.4 | |
| 6/27/90 | 89 | 9:29 | 1840 | 106.8 | 105.4 | 1058 | 108.5 | 104.0 | 665 | 107.2 | 104.5 | | | | Train Prevented #4 |
| 6/27/90 | 92 | 10:45 | 1888 | 111.7 | 107.4 | 1109 | 115.7 | 108.1 | 732 | 116.1 | 109.4 | 1245 | 118.1 | 109.9 | |
| 6/27/90 | 95 | 12:00 | 1920 | 115.8 | 109.6 | 1137 | 116.3 | 107.0 | 755 | 117.3 | 109.2 | 1270 | 119.8 | 110.1 | |
| 6/27/90 | 98 | 1:00 | 1997 | 120.1 | 109.3 | 1200 | 121.4 | 108.4 | 815 | 121.2 | 109.5 | 1321 | 122.8 | 110.0 | |
| 6/27/90 | 105 | 2:00 | 2093 | 128.2 | 111.6 | 1292 | 126.5 | 107.9 | 896 | 125.6 | 109.0 | 1396 | 128.3 | 111.0 | |
| 6/27/90 | 95 | 2:57 | 2012 | 121.9 | 110.2 | 1188 | 118.7 | 106.4 | 778 | 117.8 | 108.3 | 1264 | 118.7 | 109.3 | End Full Day Test |
| 7/23/90 | 66 | 9:20am | 1449 | 83.2 | 105.3 | 680 | 84.5 | 102.7 | 289 | 84.4 | 104.3 | 790 | 85.4 | 104.5 | |
| 7/23/90 | 82.8 | 12:08 | 1654 | 97.8 | 107.6 | 879 | 100.0 | 106.3 | 485 | 100.8 | 108.9 | 990 | 102.4 | 109.5 | |
| 7/24/90 | 73 | 9:00 | 1409 | 79.3 | 103.8 | | | | 251 | 81.6 | 103.8 | 767 | 83.0 | 103.5 | |
| 7/24/90 | 81 | 10:00 | 1582 | 91.9 | 106.0 | | | | 387 | 90.2 | 104.2 | 897 | 91.8 | 104.5 | |
| 7/24/90 | 78 | 11:00 | 1599 | 93.3 | 106.4 | | | | 422 | 93.5 | 105.4 | 938 | 95.7 | 105.9 | |
| 7/24/90 | 83 | 12:00 | 1689 | 99.1 | 106.8 | | | | 522 | 97.6 | 103.5 | 1018 | 98.9 | 104.3 | |
| 7/24/90 | 82 | 1:00 | 1756 | 102.3 | 106.0 | | | | 578 | 102.5 | 105.0 | 1079 | 104.8 | 106.5 | |
| 7/25/90 | 73 | 8:00am | 1355 | 80.5 | 108.3 | | | | 215 | 78.2 | 102.5 | 717 | 80.8 | 104.3 | |
| 1/29/91 | 35 | 8:35 | 980 | 34.0 | 84.3 | | | | -101 | 34.9 | 78.2 | 391 | 35.7 | 78.8 | |
| 1/29/91 | 30 | 10:05 | 1046 | 36.4 | 82.7 | | | | -37 | 36.3 | 75.8 | 457 | 37.6 | 76.7 | |
| 1/29/91 | 38 | 1:00 | 1260 | 50.5 | 84.0 | | | | 132 | 48.4 | 77.7 | 597 | 48.4 | 79.1 | |
| 1/30/91 | 38 | 8:25 | 844 | 30.6 | 89.1 | | | | -195 | 32.3 | 81.3 | 321 | 34.9 | 82.2 | |
| 1/30/91 | 39 | 9:30 | 1032 | 41.3 | 88.5 | | | | -10 | 42.8 | 80.7 | 526 | 46.1 | 81.1 | |
| 1/30/91 | 40 | 10:32 | 1222 | 51.7 | 87.5 | | | | 145 | 51.3 | 79.8 | 675 | 53.3 | 79.3 | |
| 1/30/91 | 45 | 11:35 | 1411 | 62.4 | 86.8 | | | | 289 | 59.4 | 79.3 | 786 | 58.9 | 78.3 | |
| 1/30/91 | 49 | 12:35 | 1535 | 70.9 | 87.8 | | | | 409 | 66.2 | 78.9 | 880 | 65.5 | 79.2 | |
| 1/30/91 | 55 | 2:10 | 1688 | 81.4 | 89.2 | | | | 542 | 75.1 | 79.8 | 984 | 75.6 | 83.1 | |
| 1/30/91 | 49 | 4:00 | 1647 | 77.8 | 88.0 | | | | 491 | 72.5 | 80.3 | 914 | 69.2 | 80.9 | |
| 4/03/91 | 60 | 9:00 | 1642 | 79.6 | 90.1 | | | | 543 | 80.9 | 85.5 | 1058 | 87.2 | 90.2 | Begin Full Day Test |
| 4/03/91 | 73 | 10:15 | 1787 | 86.6 | 88.4 | | | | 692 | 86.8 | 82.5 | 1224 | 89.4 | 82.4 | |
| 4/03/91 | 72 | 11:00 | 1870 | 93.5 | 90.3 | | | | 760 | 91.5 | 83.1 | 1284 | 92.6 | 82.0 | |
| 4/03/91 | 73 | 12:00 | 1950 | 98.0 | 90.0 | | | | 840 | 94.4 | 81.2 | 1359 | 98.2 | 83.1 | |
| 4/03/91 | 77 | 12:45 | 1932 | 100.3 | 93.4 | | | | 832 | 98.3 | 85.6 | 1339 | 101.0 | 87.1 | |
| 4/03/91 | 69 | 2:00 | 1893 | 97.2 | 92.6 | | | | 784 | 95.3 | 85.4 | 1301 | 98.3 | 86.7 | |
| 4/03/91 | 69 | 3:00 | 1785 | 84.9 | 86.8 | | | | 662 | 88.2 | 85.7 | 1161 | 89.9 | 86.7 | End Full Day Test |
| 4/04/91 | 51 | 8:20 | 1519 | 61.2 | 79.1 | | | | 422 | 71.4 | 83.3 | 933 | 73.8 | 84.3 | Begin Full Day Test |
| 4/04/91 | 63 | 10:00 | 1709 | 82.2 | 88.7 | | | | 618 | 84.0 | 84.1 | 1116 | 84.6 | 84.1 | |
| 4/04/91 | 64 | 11:00 | 1787 | 86.9 | 88.7 | | | | 668 | 86.8 | 83.9 | 1191 | 89.2 | 84.2 | |
| 4/04/91 | 69 | 10:00 | 1857 | 92.4 | 90.0 | | | | 739 | 90.7 | 83.5 | 1242 | 93.4 | 85.3 | |
| 4/04/91 | 73 | 1:00 | 1957 | 98.8 | 90.4 | | | | 831 | 97.1 | 84.4 | 1315 | 98.5 | 86.1 | |
| 4/04/91 | 75 | 2:00 | 2034 | 105.2 | 92.2 | | | | 902 | 103.1 | 86.2 | 1378 | 103.6 | 87.4 | |
| 4/04/91 | 72 | 3:00 | 2050 | 103.4 | 89.4 | | | | 914 | 104.6 | 86.9 | 1402 | 104.9 | 87.2 | |
| 4/04/91 | 72 | 4:00 | 2008 | 104.5 | 93.0 | | | | 906 | 103.8 | 86.6 | 1408 | 103.7 | 85.7 | End Full Day Test |
| 5/21/91 | 59 | 9:00 | 1293 | 56.7 | 88.2 | | | | 176 | 56.4 | 83.1 | 674 | 56.4 | 82.5 | |
| 5/21/91 | 61 | 11:15 | 1299 | 57.4 | 88.5 | | | | 204 | 57.5 | 82.5 | 691 | 57.6 | 82.7 | |

| RAIL STRAIN DATA FROM SANTE FE, NM | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
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| SECTION 1 | | | | | | | High Rail | | | | | | | | |
| Date | Amb | Time | | 1 | Neut | | 2 | Neut | | 3 | Neut | | 4 | Neut | |
| | Temp | | Strain | Temp | Temp | Strain | Temp | Temp | Strain | Temp | Temp | Strain | Temp | Temp | Comments |
| 5/22/91 | 56 | 8:15 | 1420 | 72.5 | 96.4 | | | | 366 | 70.8 | 86.1 | 887 | 70.9 | 84.2 | |
| 5/22/91 | 64 | 10:00 | 1738 | 87.4 | 92.1 | | | | 591 | 86.0 | 87.7 | 1161 | 86.9 | 83.7 | |
| 5/22/91 | 70 | 11:05 | 1856 | 94.4 | 92.1 | | | | 693 | 93.1 | 88.7 | 1298 | 95.5 | 84.1 | |
| 5/22/91 | 74 | 12:45 | 1945 | 98.2 | 90.5 | | | | 805 | 97.5 | 86.4 | 1359 | 100.4 | 85.3 | |
| 5/22/91 | 75 | 2:00 | 1968 | 103.1 | 94.0 | | | | 863 | 100.8 | 86.2 | 1406 | 104.1 | 86.2 | |
| 5/22/91 | 74 | 3:25 | 2030 | 106.3 | 93.5 | | | | 902 | 103.4 | 86.5 | 1431 | 106.3 | 86.9 | |
| 5/22/91 | 76 | 4:25 | 1979 | 102.4 | 92.7 | | | | 854 | 101.3 | 87.2 | 1368 | 104.5 | 88.9 | |
| 7/16/91 | 64 | 8:10 | 1571 | 75.9 | 90.7 | | | | 482 | 73.1 | 81.4 | 926 | 75.1 | 86.0 | |
| 7/16/91 | 75 | 9:06 | | | | | | | | | | | | | |
| 7/16/91 | 79 | 10:00 | 1950 | 99.3 | 91.3 | | | | 823 | 99.0 | 86.8 | 1367 | 102.0 | 86.4 | |
| 7/16/91 | 84 | 11:30 | 1990 | 101.0 | 90.6 | | | | 868 | 96.8 | 81.9 | 1433 | 105.0 | 85.5 | |
| 7/16/91 | 83 | 12:30 | 2079 | 105.7 | 90.0 | | | | 940 | 104.3 | 85.1 | 1493 | 107.3 | 84.2 | |
| 7/16/91 | 85 | 2:00 | 2100 | 110.9 | 93.9 | | | | 989 | 110.9 | 88.7 | 1551 | 113.5 | 86.9 | |
| 7/16/91 | 87 | 3:00 | 2226 | 118.2 | 93.6 | | | | 1043 | 116.6 | 91.2 | 1608 | 118.1 | 88.1 | |
| 7/17/91 | 70 | 8:00 | 1764 | 84.6 | 87.8 | | | | 580 | 83.0 | 85.4 | 1098 | 80.9 | 81.5 | |
| 7/17/91 | 75 | 9:00 | 1861 | 92.6 | 90.0 | | | | 703 | 88.6 | 83.6 | 1230 | 91.5 | 84.2 | |
| 7/17/91 | 78 | 10:00 | 1938 | 98.1 | 90.8 | | | | 786 | 92.1 | 82.1 | 1324 | 98.1 | 85.1 | |
| 7/17/91 | 84 | 11:00 | 2013 | 102.2 | 90.4 | | | | 860 | 96.9 | 82.5 | 1390 | 102.2 | 85.3 | |
| 7/17/91 | 88 | 12:00 | 2130 | 108.4 | 89.6 | | | | 981 | 107.2 | 85.5 | 1510 | 110.3 | 86.1 | |
| 7/17/91 | 92 | 1:00 | 2238 | 115.2 | 89.9 | | | | 1086 | 113.8 | 85.8 | 1614 | 116.3 | 85.9 | |
| 7/17/91 | 89 | 2:00 | 2309 | 118.3 | 88.7 | | | | 1150 | 118.7 | 86.8 | 1677 | 120.5 | 86.3 | |
| 7/17/91 | 87 | 3:30 | 2284 | 117.3 | 89.2 | | | | 1145 | 118.3 | 86.7 | 1685 | 120.5 | 85.8 | |
| 7/17/91 | 86 | 4:20 | 2084 | 107.8 | 91.8 | | | | 961 | 109.8 | 89.3 | 1534 | 110.5 | 84.9 | |
| 7/18/91 | 76 | 8:10 | 1730 | 86.7 | 91.9 | | | | 589 | 83.3 | 85.2 | 1134 | 83.8 | 82.2 | |
| 7/18/91 | 80 | 9:30 | 1866 | 95.4 | 92.5 | | | | 739 | 94.1 | 86.9 | 1292 | 94.9 | 83.8 | |
| 7/18/91 | 84 | 10:35 | 1916 | 99.6 | 93.7 | | | | 774 | 98.6 | 89.3 | 1316 | 100.2 | 87.7 | |
| 7/18/91 | 87 | 11:41 | 1987 | 104.0 | 93.8 | | | | 832 | 102.8 | 90.1 | 1368 | 104.0 | 88.4 | |
| 7/18/91 | 89 | 12:35 | 2035 | 106.6 | 93.5 | | | | 880 | 104.1 | 88.5 | 1419 | 106.4 | 87.7 | |
| 7/18/91 | 88 | 1:30 | 1966 | 99.1 | 90.1 | | | | 766 | 98.9 | 90.1 | 1305 | 99.8 | 88.0 | |
| 8/13/91 | 72 | 9:00 | 1670 | 85.4 | 94.2 | | | | 521 | 83.6 | 89.5 | 1084 | 82.1 | 83.5 | |
| 8/13/91 | 81 | 10:00 | 1827 | 98.8 | 98.2 | | | | 715 | 95.4 | 89.7 | 1325 | 96.5 | 83.5 | |
| 8/13/91 | 82 | 12:00 | 1948 | 105.1 | 97.2 | | | | 842 | 103.5 | 90.2 | 1446 | 104.3 | 84.0 | |
| 8/13/91 | 69 | 2:30 | 1478 | 73.9 | 94.3 | | | | 330 | 72.6 | 90.0 | 910 | 72.6 | 84.5 | |
| 8/15/91 | 70 | 8:40 | 1659 | 88.9 | 98.4 | | | | 565 | 88.3 | 91.6 | 1172 | 88.3 | 84.5 | |
| 8/15/91 | 80 | 10:00 | 1808 | 98.1 | 98.6 | | | | 740 | 97.9 | 90.7 | 1366 | 100.9 | 85.4 | |
| 8/15/91 | 86 | 11:00 | 1879 | 101.2 | 97.5 | | | | 815 | 103.5 | 91.8 | 1445 | 106.2 | 85.9 | |
| 8/15/91 | 85 | 12:00 | 1940 | 105.3 | 97.9 | | | | 859 | 106.5 | 92.1 | 1480 | 108.5 | 86.1 | |
| 8/15/91 | 90 | 1:00 | 2000 | 108.4 | 97.4 | | | | 920 | 109.7 | 91.7 | 1544 | 111.3 | 85.1 | |
| 8/15/91 | 85 | 2:10 | 1991 | 108.3 | 97.8 | | | | 914 | 107.2 | 89.5 | 1508 | 108.7 | 84.7 | |
| 8/15/91 | 84 | 3:00 | 1940 | 102.2 | 94.8 | | | | 853 | 105.9 | 91.9 | 1468 | 106.6 | 85.0 | |

| RAIL STRAIN DATA FROM SANTE FE, NM | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
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| SECTION 1 | | | | | | | | | | | | | | | |
| | | | | | | | Low Rail | | | | | | | | |
| Date | Amb | Time | | 1 | Neut | | 2 | Neut | | 3 | Neut | | 4 | Neut | |
| | Temp | | Strain | Temp | Temp | Strain | Temp | Temp | Strain | Temp | Temp | Strain | Temp | Temp | Comments |
| 2/14/90 | 37 | | -85 | 38.5 | 77.8 | 373 | 32.5 | 68.4 | 557 | 32.1 | 66.8 | -351 | 32.5 | 74.5 | |
| 2/15/90 | 20 | | -172 | 34.1 | 78.6 | 373 | 35.4 | 71.3 | 569 | 33.6 | 67.6 | -344 | 35.1 | 76.7 | |
| 4/02/90 | 56 | | 382 | 68.4 | 79.6 | 917 | 69.1 | 72.3 | 1087 | 70.0 | 72.9 | 235 | 71.8 | 78.6 | |
| 4/02/90 | | 4:00 | 189 | 67.6 | 90.4 | 862 | 68.1 | 74.6 | 1033 | 68.5 | 74.6 | 165 | 67.3 | 78.3 | |
| 4/03/90 | 45 | 9:00 | 63 | 49.1 | 79.5 | 632 | 49.7 | 70.0 | 835 | 50.4 | 68.4 | -36 | 51.5 | 74.6 | |
| 4/03/90 | | | 617 | 80.0 | 77.1 | 1072 | 80.2 | 74.1 | 1220 | 78.4 | 73.3 | 348 | 78.1 | 78.1 | |
| 4/03/90 | | 4:15 | 607 | 79.8 | 77.5 | 1094 | 83.2 | 75.7 | 1239 | 81.0 | 74.8 | 394 | 80.5 | 77.7 | After Tamping |
| 4/04/90 | | 8:15 | 240 | 57.0 | 76.8 | 714 | 57.5 | 72.9 | 888 | 56.2 | 71.0 | 24 | 57.6 | 77.1 | Before Low Rail Cut |
| 4/04/90 | | | 569 | 80.9 | | 970 | 82.6 | | 1135 | 83.5 | | 348 | 84.8 | | Zero, after Cut |
| 4/05/90 | | 11:30 | 569 | 63.1 | 63.1 | 1418 | 79.7 | 52.8 | 1563 | 78.9 | 53.2 | 460 | 66.0 | 59.3 | After Welding |
| 5/04/90 | 48 | 11:30 | 350 | 57.7 | 70.9 | 948 | 58.3 | 59.6 | 1132 | 57.8 | 58.0 | 123 | 59.9 | 73.4 | Jon's Data |
| 5/04/90 | 55 | 3:00 | 442 | 66.1 | 73.7 | 1043 | 66.7 | 62.3 | 1209 | 66.1 | 61.7 | 206 | 66.8 | 75.3 | Jon's Data |
| 6/26/90 | 95 | 10:25 | 835 | 115.2 | 99.2 | 1499 | 119.0 | 87.2 | 1654 | 120.0 | 88.8 | 821 | 119.8 | 91.4 | |
| 6/26/90 | 92 | 5:35 | 645 | 105.7 | 101.1 | 1296 | 106.5 | 86.9 | 1463 | 106.4 | 86.7 | 627 | 109.7 | 92.9 | |
| 6/27/90 | 60 | 5:40am | -67 | 59.2 | 97.4 | 553 | 58.5 | 83.6 | 770 | 58.1 | 80.0 | -140 | 58.3 | 87.6 | Begin Full Day Test |
| 6/27/90 | 65 | 6:40 | 15 | 63.5 | 96.8 | 646 | 64.8 | 84.3 | 862 | 64.7 | 81.1 | -35 | 65.5 | 88.5 | |
| 6/27/90 | 68 | 7:18 | 300 | 80.3 | 96.5 | 940 | 79.9 | 81.7 | 1135 | 80.0 | 80.0 | 228 | 79.3 | 86.5 | |
| 6/27/90 | 84 | 8:25 | 520 | 91.5 | 94.4 | 1180 | 94.4 | 81.8 | 1359 | 95.6 | 82.1 | 479 | 97.1 | 89.2 | |
| 6/27/90 | 89 | 9:29 | 740 | 107.5 | 97.2 | 1400 | 109.8 | 84.0 | 1561 | 110.4 | 84.8 | | | | Train Prevented #4 |
| 6/27/90 | 92 | 10:45 | 811 | 117.1 | 102.6 | 1450 | 120.2 | 91.4 | 1603 | 120.2 | 92.1 | 767 | 122.4 | 97.2 | |
| 6/27/90 | 95 | 12:00 | 830 | 118.1 | 102.4 | 1614 | 122.0 | 83.3 | 1614 | 122.0 | 93.2 | 779 | 122.2 | 96.3 | |
| 6/27/90 | 98 | 1:00 | 888 | 120.6 | 101.4 | 1652 | 125.2 | 84.2 | 1652 | 125.2 | 94.1 | 815 | 124.8 | 96.7 | |
| 6/27/90 | 105 | 2:00 | 981 | 129.6 | 104.8 | 1593 | 126.1 | 88.7 | 1730 | 128.9 | 93.1 | 889 | 128.7 | 96.2 | |
| 6/27/90 | 95 | 2:57 | 866 | 120.1 | 102.3 | 1447 | 118.3 | 89.6 | 1585 | 117.6 | 90.6 | 710 | 116.9 | 95.1 | End Full Day Test |
| 7/23/90 | 66 | 9:20am | 356 | 83.5 | 96.3 | 1007 | 83.7 | 81.5 | 1192 | 85.4 | 82.0 | 329 | 87.2 | 88.3 | |
| 7/23/90 | 82.8 | 12.08 | 620 | 101.3 | 98.2 | 1241 | 102.9 | 86.6 | 1400 | 103.2 | 87.3 | 558 | 103.7 | 91.1 | 12:02; Eastbound Train |
| 7/24/90 | 73 | 9:00 | 311 | 79.8 | 95.3 | 982 | 82.8 | 82.1 | 1172 | 83.4 | 81.2 | | | | |
| 7/24/90 | 81 | 10:00 | 497 | 92.6 | 96.9 | 1149 | 93.6 | 82.8 | 1320 | 93.9 | 82.8 | | | | |
| 7/24/90 | 78 | 11:00 | 522 | 95.4 | 98.2 | 1182 | 96.7 | 84.0 | 1353 | 97.7 | 84.6 | | | | |
| 7/24/90 | 83 | 12:00 | 618 | 101.2 | 98.3 | 1270 | 101.0 | 83.0 | 1431 | 100.7 | 82.9 | | | | |
| 7/24/90 | 82 | 1:00 | 677 | 103.5 | 97.0 | 1317 | 103.4 | 82.5 | 1465 | 105.1 | 85.3 | | | | |
| 7/25/90 | 73 | 8:00am | 273 | 79.0 | 96.8 | 918 | 80.6 | 83.7 | 1102 | 81.3 | 83.3 | | | | |
| 1/29/91 | 35 | 8:35am | -138 | 34.1 | 76.6 | 591 | 35.7 | 58.5 | 773 | 36.3 | 58.1 | -89 | 37.8 | 64.1 | |
| 1/29/91 | 30 | 10:05 | -93 | 37.8 | 77.6 | 586 | 36.8 | 59.9 | 760 | 37.5 | 60.0 | -112 | 38.3 | 65.9 | |
| 1/29/91 | 38 | 1:00 | 115 | 52.5 | 79.8 | 780 | 49.8 | 61.2 | 938 | 49.0 | 60.8 | 71 | 48.1 | 64.7 | |
| 1/30/91 | 38 | 8:25 | -276 | 30.6 | 81.4 | 453 | 34.1 | 65.2 | 643 | 33.9 | 63.5 | -202 | 36.2 | 69.3 | |
| 1/30/91 | 39 | 9:30 | -86 | 40.9 | 80.3 | 665 | 46.4 | 64.7 | 842 | 45.2 | 62.8 | 32 | 48.1 | 67.1 | |
| 1/30/91 | 40 | 10:32 | 94 | 50.9 | 79.4 | 820 | 53.3 | 62.3 | 980 | 53.4 | 62.7 | 175 | 56.0 | 66.4 | |
| 1/30/91 | 45 | 11:35 | 267 | 61.2 | 79.3 | 950 | 60.1 | 61.3 | 1095 | 61.6 | 64.0 | 269 | 62.2 | 66.9 | |
| 1/30/91 | 49 | 12:35 | 401 | 71.1 | 81.2 | 1058 | 68.4 | 63.1 | 1196 | 68.4 | 64.7 | 346 | 67.2 | 67.3 | |
| 1/30/91 | 55 | 2:10 | 541 | 83.0 | 84.7 | 1191 | 78.2 | 64.9 | 1323 | 78.2 | 66.9 | 468 | 76.9 | 69.7 | |
| 1/30/91 | 49 | 4:00 | 517 | 78.6 | 81.7 | 1152 | 73.3 | 62.4 | 1287 | 73.2 | 64.1 | 407 | 71.6 | 68.1 | |
| 4/03/91 | 60 | 9:00 | 508 | 79.5 | 83.2 | 1211 | 81.7 | 67.2 | 1345 | 80.2 | 67.6 | 541 | 84.0 | 72.4 | |
| 4/03/91 | 73 | 10:15 | 663 | 85.9 | 80.3 | 1364 | 87.6 | 63.9 | 1487 | 88.4 | 67.2 | 703 | 92.9 | 71.6 | |
| 4/03/91 | 72 | 11:00 | 736 | 91.6 | 81.6 | 1425 | 92.6 | 65.3 | 1545 | 94.3 | 69.7 | 739 | 93.3 | 69.8 | |
| 4/03/91 | 73 | 12:00 | 806 | 98.5 | 84.3 | 1495 | 97.1 | 65.5 | 1609 | 97.9 | 69.4 | 808 | 99.5 | 71.9 | |
| 4/03/91 | 77 | 12:45 | 823 | 101.4 | 86.1 | 1487 | 99.6 | 68.5 | 1605 | 99.5 | 71.3 | 794 | 100.3 | 73.5 | |
| 4/03/91 | 69 | 2:00 | 793 | 98.2 | 84.7 | 1454 | 95.8 | 66.7 | 1571 | 97.1 | 70.9 | 757 | 98.4 | 73.8 | |
| 4/03/91 | 69 | 3:00 | 668 | 91.7 | 85.8 | 1330 | 84.3 | 62.7 | 1462 | 90.7 | 71.0 | 649 | 91.7 | 73.6 | |
| 4/04/91 | 51 | 8:20 | 390 | 73.2 | 84.0 | 1096 | 75.9 | 68.3 | 1249 | 76.2 | 69.3 | 410 | 77.1 | 73.4 | |
| 4/04/91 | 63 | 10:00 | 599 | 82.9 | 81.1 | 1282 | 85.0 | 66.3 | 1416 | 86.1 | 69.2 | 608 | 87.7 | 72.1 | |
| 4/04/91 | 64 | 11:00 | 676 | 87.7 | 81.3 | 1354 | 87.1 | 64.0 | 1491 | 88.4 | 67.0 | 665 | 91.0 | 71.9 | |
| 4/04/91 | 69 | 10:00 | 747 | 92.6 | 81.9 | 1421 | 92.7 | 65.6 | 1543 | 92.1 | 67.6 | 712 | 95.0 | 73.1 | |
| 4/04/91 | 73 | 1:00 | 833 | 99.1 | 83.2 | 1490 | 98.2 | 67.0 | 1607 | 99.4 | 71.0 | 772 | 99.4 | 73.9 | |
| 4/04/91 | 75 | 2:00 | 897 | 105.3 | 85.6 | 1556 | 103.6 | 68.4 | 1662 | 104.3 | 72.6 | 837 | 104.5 | 75.1 | |
| 4/04/91 | 72 | 3:00 | 908 | 104.9 | 84.5 | 1580 | 105.5 | 68.8 | 1703 | 105.2 | 71.1 | 861 | 107.0 | 76.2 | |
| 4/04/91 | 72 | 4:00 | 897 | 104.5 | 84.8 | 1556 | 104.5 | 69.3 | 1684 | 104.6 | 71.6 | 847 | 104.9 | 74.9 | |
| 5/21/91 | 59 | 9:00 | 152 | 56.6 | 81.7 | 811 | 56.4 | 66.0 | 1008 | 56.5 | 64.1 | 74 | 56.0 | 72.5 | |

| RAIL STRAIN DATA FROM SANTE FE, NM | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
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| SECTION 1 | | | | | | | | | | | | | | | |
| | | | | | | | Low Rail | | | | | | | | |
| Date | Amb | Time | | 1 | Neut | | 2 | Neut | | 3 | Neut | | 4 | Neut | |
| | Temp | | Strain | Temp | Temp | Strain | Temp | Temp | Strain | Temp | Temp | Strain | Temp | Temp | Comments |
| 5/21/91 | 61 | 11:15 | 172 | 57.3 | 81.2 | 819 | 57.1 | 66.2 | 1018 | 57.4 | 64.4 | 58 | 57.5 | 74.9 | |
| 5/22/91 | 56 | 8:15 | 403 | 72.5 | 82.5 | 1069 | 73.4 | 67.5 | 1243 | 75.3 | 68.8 | 345 | 73.9 | 74.1 | |
| 5/22/91 | 64 | 10:00 | 663 | 89.4 | 83.8 | 1394 | 89.7 | 64.2 | 1506 | 92.4 | 70.1 | 655 | 92.1 | 73.7 | |
| 5/22/91 | 70 | 11:05 | 783 | 96.0 | 83.1 | 1489 | 98.2 | 67.0 | 1637 | 100.2 | 70.0 | 747 | 100.7 | 76.7 | |
| 5/22/91 | 74 | 12:45 | 843 | 100.6 | 84.1 | 1514 | 100.7 | 68.0 | 1669 | 96.0 | 63.9 | 809 | 104.0 | 76.3 | |
| 5/22/91 | 75 | 2:00 | 869 | 103.1 | 85.1 | 1542 | 102.7 | 68.3 | 1691 | 104.7 | 71.3 | 831 | 106.5 | 77.5 | |
| 5/22/91 | 74 | 3:25 | 924 | 105.2 | 83.9 | 1597 | 106.5 | 68.8 | 1737 | 107.1 | 70.9 | 876 | 109.8 | 78.1 | |
| 5/22/91 | 76 | 4:25 | 893 | 104.2 | 84.7 | 1568 | 104.9 | 69.0 | 1702 | 106.5 | 72.4 | 842 | 109.3 | 79.6 | |
| 7/16/91 | 64 | 8:10 | 333 | 76.2 | 90.4 | 952 | 78.1 | 79.2 | | | | 286 | 76.6 | 80.3 | |
| 7/16/91 | 75 | 9:06 | | | | | | | | | | | | | |
| 7/16/91 | 79 | 10:00 | 704 | 102.0 | 93.9 | 1303 | 104.2 | 84.2 | | | | 645 | 104.8 | 87.0 | |
| 7/16/91 | 84 | 11:30 | 624 | 102.5 | 99.2 | 1214 | 106.1 | 91.4 | | | | 598 | 106.8 | 91.8 | |
| 7/16/91 | 83 | 12:30 | 681 | 106.7 | 100.0 | 1267 | 107.7 | 89.9 | | | | 634 | 108.6 | 91.4 | |
| 7/16/91 | 85 | 2:00 | 674 | 111.1 | 104.8 | 1251 | 112.1 | 95.2 | | | | 611 | 113.3 | 97.5 | |
| 7/16/91 | 87 | 3:00 | 743 | 117.3 | 106.8 | 1289 | 117.6 | 98.4 | | | | 642 | 119.0 | 101.3 | |
| 7/17/91 | 70 | 8:00 | 529 | 84.6 | 87.0 | 1145 | 87.6 | 77.1 | | | | 460 | 84.4 | 77.7 | |
| 7/17/91 | 75 | 9:00 | 641 | 93.0 | 88.7 | 1245 | 94.7 | 78.2 | | | | 577 | 94.9 | 81.1 | |
| 7/17/91 | 78 | 10:00 | 658 | 99.4 | 94.1 | 1239 | 101.0 | 84.8 | | | | 583 | 100.8 | 86.7 | |
| 7/17/91 | 84 | 11:00 | 683 | 103.4 | 96.5 | 1262 | 100.9 | 83.4 | | | | 619 | 104.2 | 87.9 | |
| 7/17/91 | 88 | 12:00 | 735 | 108.9 | 98.9 | 1293 | 109.6 | 90.2 | | | | 669 | 111.3 | 92.0 | |
| 7/17/91 | 92 | 1:00 | 772 | 115.9 | 103.7 | 1331 | 116.9 | 95.2 | | | | 708 | 117.6 | 96.0 | |
| 7/17/91 | 89 | 2:00 | 816 | 118.9 | 104.1 | 1364 | 119.7 | 96.0 | | | | 759 | 121.0 | 96.3 | |
| 7/17/91 | 87 | 3:30 | 795 | 118.3 | 104.7 | 1356 | 120.3 | 97.1 | | | | 760 | 121.9 | 97.1 | |
| 7/17/91 | 86 | 4:20 | 604 | 108.3 | 106.2 | 1179 | 110.9 | 98.3 | | | | 595 | 113.3 | 98.5 | |
| 7/18/91 | 76 | 8:10 | 477 | 85.3 | 90.8 | 1100 | 85.9 | 78.1 | | | | 461 | 87.2 | 80.4 | |
| 7/18/91 | 80 | 9:30 | 605 | 96.8 | 94.6 | 1215 | 96.3 | 81.6 | | | | 580 | 98.3 | 84.4 | |
| 7/18/91 | 84 | 10:35 | 536 | 100.3 | 102.3 | 1135 | 101.6 | 91.7 | | | | 478 | 102.8 | 95.0 | |
| 7/18/91 | 87 | 11:41 | 581 | 104.5 | 103.8 | 1182 | 103.8 | 91.1 | | | | 509 | 104.7 | 95.0 | |
| 7/18/91 | 89 | 12:35 | 612 | 107.2 | 104.6 | 1210 | 106.0 | 91.6 | | | | 539 | 106.0 | 94.5 | |
| 7/18/91 | 88 | 1:30 | 499 | 99.6 | 103.8 | 1088 | 99.0 | 91.9 | | | | 426 | 100.1 | 95.4 | |
| 8/13/91 | 72 | 9:00 | 496 | 85.9 | 90.3 | 1100 | 85.9 | 78.1 | | | | 696 | 83.8 | 62.9 | |
| 8/13/91 | 81 | 10:00 | 513 | 99.2 | 102.6 | 1093 | 99.3 | 91.9 | | | | 680 | 100.6 | 80.6 | |
| 8/13/91 | 82 | 12:00 | 593 | 104.5 | 103.1 | 1154 | 103.8 | 92.7 | | | | 720 | 106.0 | 83.6 | |
| 8/13/91 | 69 | 2:30 | 252 | 71.4 | 90.5 | 845 | 70.8 | 78.3 | | | | 432 | 72.7 | 67.7 | |
| 8/15/91 | 70 | 8:40 | 475 | 88.5 | 94.1 | 1132 | 90.1 | 80.4 | | | | 815 | 91.3 | 63.2 | |
| 8/15/91 | 80 | 10:00 | 589 | 99.1 | 97.9 | 1177 | 101.0 | 88.6 | | | | 805 | 103.4 | 75.9 | |
| 8/15/91 | 86 | 11:00 | 626 | 102.5 | 99.1 | 1194 | 103.8 | 90.3 | | | | 855 | 106.5 | 76.0 | |
| 8/15/91 | 85 | 12:00 | 640 | 105.6 | 101.3 | 1191 | 105.8 | 92.5 | | | | 876 | 107.4 | 75.7 | |
| 8/15/91 | 90 | 1:00 | 663 | 108.9 | 103.3 | 1198 | 108.8 | 95.1 | | | | 949 | 110.6 | 74.5 | |
| 8/15/91 | 85 | 2:10 | 654 | 110.4 | 105.3 | 1184 | 108.3 | 95.4 | | | | 910 | 109.7 | 75.9 | |
| 8/15/91 | 84 | 3:00 | 549 | 104.7 | 105.9 | 1074 | 104.7 | 98.5 | | | | 809 | 106.9 | 79.2 | |

| RAIL STRAIN DATA FROM SANTE FE, NM | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | |
| SECTION 2 | | | | | | | High Rail | | | | | | | | |
| Date | Amb | Time | | 1 | Neut | | 2 | Neut | | 3 | Neut | | 4 | Neut | |
| | Temp | | Strain | Temp | Temp | Strain | Temp | Temp | Strain | Temp | Temp | Strain | Temp | Temp | Comments |
| 2/14/90 | 37 | | 249 | 40.7 | 83.5 | 356 | 39.5 | 83.6 | -94 | 39.0 | 81.3 | 2 | 39.6 | 81.2 | |
| 2/15/90 | 20 | | 215 | 31.6 | 76.4 | 344 | 31.7 | 76.5 | -116 | 35.7 | 79.3 | -22 | 35.7 | 78.8 | |
| 4/02/90 | 56 | | 888 | 75.4 | 79.8 | 1004 | 74.9 | 80.0 | 535 | 75.8 | 80.3 | 605 | 75.2 | 80.6 | |
| 4/02/90 | | 4:00 | 750 | 70.0 | 82.7 | 857 | 72.1 | 86.0 | 397 | 72.0 | 84.8 | 513 | 73.9 | 84.8 | |
| 4/03/90 | 45 | 9:00 | 462 | 46.5 | 76.5 | 595 | 45.6 | 75.3 | 116 | 45.8 | 75.5 | 182 | 44.5 | 75.3 | |
| 4/03/90 | | | 845 | 66.3 | 73.3 | 961 | 67.2 | 74.9 | 477 | 67.4 | 75.4 | 525 | 64.1 | 74.3 | |
| 4/03/90 | | 8.0 | 784 | 75.2 | 85.8 | 917 | 76.0 | 86.3 | 448 | 76.3 | 86.0 | 535 | 75.8 | 85.4 | Before Low Rail Cut |
| 4/03/90 | | 1:47 | 961 | 84.0 | | 1089 | 86.7 | | 610 | 86.6 | | 695 | 87.8 | | Zero, after Cut |
| 4/05/90 | | 11:56 | 1043 | 79.7 | 74.8 | 1191 | 76.5 | 70.4 | 721 | 71.5 | 64.8 | 796 | 74.3 | 68.2 | After Welding |
| 5/04/90 | 48 | 11:30 | 807 | 65.0 | 74.3 | 931 | 64.0 | 73.5 | 490 | 64.0 | 71.2 | 565 | 65.0 | 72.8 | Jon's Data |
| 5/04/90 | 55 | 3:00 | 891 | 69.2 | 73.4 | 972 | 69.0 | 76.0 | 551 | 69.0 | 72.5 | 646 | 71.2 | 74.1 | Jon's Data |
| 6/26/90 | 95 | 10:25 | 1444 | 113.5 | 84.5 | 1509 | 114.0 | 88.8 | 1012 | 113.9 | 89.7 | 986 | 113.6 | 96.1 | |
| 6/26/90 | 92 | 5:35 | 1400 | 113.5 | 87.1 | 1424 | 113.6 | 93.5 | 918 | 113.0 | 94.5 | 865 | 108.1 | 97.9 | |
| 6/27/90 | 60 | 5:40am | 489 | 58.8 | 87.2 | 562 | 58.2 | 89.9 | 72 | 58.3 | 90.6 | 73 | 58.0 | 95.4 | Begin Full Day Test |
| 6/27/90 | 65 | 6:40 | 512 | 60.5 | 87.5 | 597 | 61.1 | 90.7 | | | | | | | Train Prevented #3&4 |
| 6/27/90 | 68 | 7:18 | 772 | 73.2 | 84.6 | 804 | 75.5 | 92.6 | 311 | 72.1 | 90.1 | 306 | 75.1 | 98.5 | |
| 6/27/90 | 84 | 8:25 | 961 | 84.2 | 84.2 | 1011 | 84.7 | 89.4 | 517 | 84.1 | 89.7 | 554 | 85.8 | 94.3 | |
| 6/27/90 | 89 | 9:29 | | | | | | | | | | | | | Temp Probe Failed |
| 6/27/90 | 92 | 10:45 | 1140 | 113.8 | 103.0 | 1474 | 111.8 | 88.7 | 967 | 111.7 | 90.2 | 944 | 111.5 | 96.5 | Temp Probe Repaired |
| 6/27/90 | 95 | 12:00 | 1607 | 124.1 | 85.3 | 1649 | 122.6 | 88.9 | 1138 | 122.9 | 91.2 | 1105 | 120.3 | 95.7 | |
| 6/27/90 | 98 | 1:00 | 1680 | 131.0 | 87.8 | 1723 | 127.3 | 89.2 | 1208 | 126.7 | 90.8 | 1187 | 126.2 | 96.6 | |
| 6/27/90 | 105 | 2:00 | 1753 | 135.2 | 87.6 | 1807 | 134.4 | 91.3 | 1291 | 133.6 | 92.7 | 1267 | 131.3 | 96.9 | |
| 6/27/90 | 95 | 2:57 | 1526 | 120.5 | 86.5 | 1547 | 118.2 | 90.7 | 1026 | 117.3 | 92.3 | 959 | 111.8 | 95.9 | End Full Day Test |
| 7/23/90 | 66 | 9:20am | 832 | 76.7 | 84.5 | 876 | 75.5 | 88.3 | 345 | 75.8 | 91.7 | 400 | 76.0 | 93.7 | |
| 7/23/90 | 82.8 | 12:08 | 1129 | 104.8 | 94.7 | 1191 | 104.7 | 98.6 | 655 | 101.3 | 98.6 | 715 | 101.1 | 99.9 | 12.02; Eastbound Trai |
| 7/24/90 | 73 | 9:00am | 747 | 75.6 | 88.5 | 804 | 74.3 | 91.4 | 278 | 74.2 | 94.2 | 297 | 75.1 | 99.0 | |
| 7/24/90 | 81 | 10:00 | 920 | 88.4 | 90.9 | 894 | 88.1 | 99.8 | 449 | 87.3 | 97.0 | 524 | 87.8 | 98.1 | |
| 7/24/90 | 78 | 11:00 | 1060 | 99.0 | 93.1 | 1129 | 99.2 | 96.8 | 593 | 100.2 | 101.2 | 678 | 99.1 | 100.1 | |
| 7/24/90 | 83 | 12:00 | 1171 | 105.7 | 93.1 | 1238 | 106.1 | 97.1 | 701 | 107.2 | 101.7 | 778 | 106.8 | 101.8 | |
| 7/24/90 | 82 | 1:00 | 1227 | 109.3 | 93.3 | 1294 | 110.5 | 98.2 | 751 | 108.9 | 100.4 | 829 | 108.9 | 100.8 | |
| 7/25/90 | 73 | 8:00am | 558 | 68.1 | 92.3 | 652 | 68.0 | 94.3 | 133 | 68.4 | 97.1 | 251 | 70.0 | 96.7 | |
| 1/29/91 | 35 | 8:35 | 192 | 36.1 | 82.3 | 347 | 34.4 | 79.0 | -221 | 33.1 | 83.0 | -118 | 30.3 | 79.2 | |
| 1/29/91 | 30 | 10:05 | 229 | 40.7 | 84.7 | 372 | 39.5 | 82.6 | -183 | 39.3 | 87.0 | 16 | 39.3 | 80.1 | |
| 1/29/91 | 38 | 1:00 | 464 | 52.6 | 82.5 | 619 | 51.4 | 79.6 | 60 | 51.1 | 84.2 | 215 | 51.2 | 80.0 | |
| 1/30/91 | 38 | 8:25 | 4 | 31.7 | 89.2 | 166 | 29.0 | 84.5 | -402 | 28.3 | 89.1 | -223 | 24.8 | 80.0 | |
| 1/30/91 | 39 | 9:30 | 344 | 52.1 | 89.2 | 483 | 47.9 | 84.3 | -78 | 47.4 | 88.7 | 84 | 44.0 | 80.7 | |
| 1/30/91 | 40 | 10:32 | 634 | 69.1 | 88.8 | 759 | 65.5 | 85.3 | 200 | 64.4 | 89.0 | 363 | 62.4 | 82.4 | |
| 1/30/91 | 45 | 11:35 | 782 | 76.1 | 86.9 | 916 | 77.5 | 87.9 | 358 | 77.1 | 92.2 | 530 | 74.9 | 84.8 | |
| 1/30/91 | 49 | 12:35 | 836 | 82.6 | 90.1 | 979 | 83.1 | 89.7 | 428 | 83.7 | 94.6 | 617 | 82.6 | 87.3 | |
| 1/30/91 | 55 | 2:10 | 920 | 84.1 | 86.6 | 1082 | 87.2 | 87.6 | 525 | 88.9 | 94.0 | 683 | 84.7 | 85.4 | |
| 1/30/91 | 49 | 4:00 | 716 | 69.1 | 83.8 | 909 | 70.8 | 81.6 | 366 | 70.4 | 85.1 | 534 | 74.2 | 83.9 | |
| 4/03/91 | 60 | 9:00 | 702 | 71.3 | 86.9 | 972 | 66.9 | 73.9 | 217 | 66.2 | 89.8 | 380 | 63.5 | 82.4 | |
| 4/03/91 | 73 | 10:15 | 997 | 92.2 | 90.0 | 1079 | 86.9 | 87.5 | 502 | 85.9 | 92.4 | 676 | 84.2 | 85.3 | |
| 4/03/91 | 72 | 11:00 | 1115 | 99.6 | 90.3 | 1205 | 96.3 | 89.3 | 641 | 95.9 | 94.0 | 808 | 93.3 | 86.5 | |
| 4/03/91 | 73 | 12:00 | 1190 | 102.6 | 88.8 | 1295 | 101.1 | 88.7 | 728 | 101.3 | 94.2 | 906 | 98.1 | 85.4 | |
| 4/03/91 | 77 | 12:45 | 1111 | 102.6 | 93.6 | 1225 | 100.2 | 92.0 | 669 | 99.2 | 95.7 | 859 | 96.7 | 86.8 | |
| 4/03/91 | 69 | 2:00 | 1137 | 101.5 | 90.9 | 1262 | 101.4 | 91.0 | 711 | 101.4 | 95.3 | 905 | 99.8 | 87.2 | |
| 4/03/91 | 69 | 3:00 | 1068 | 92.8 | 86.4 | 1184 | 93.7 | 88.0 | 629 | 92.8 | 91.7 | 794 | 92.5 | 86.6 | |
| 4/04/91 | 51 | 8:20am | 632 | 62.9 | 82.7 | 733 | 59.6 | 81.0 | 164 | 57.5 | 84.3 | 312 | 66.3 | 89.3 | |
| 4/04/91 | 63 | 10:00 | 943 | 83.7 | 84.8 | 1037 | 81.5 | 84.6 | 468 | 80.9 | 89.4 | 623 | 78.6 | 82.9 | |
| 4/04/91 | 64 | 11:00 | 1083 | 93.1 | 85.8 | 1184 | 92.0 | 86.3 | 617 | 91.9 | 91.5 | 777 | 91.2 | 86.3 | |
| 4/04/91 | 69 | 12:00 | 1174 | 97.7 | 84.9 | 1272 | 96.8 | 85.8 | 704 | 96.9 | 91.3 | 866 | 96.7 | 86.4 | |
| 4/04/91 | 73 | 1:00 | 1224 | 103.0 | 87.2 | 1325 | 101.1 | 86.9 | 764 | 101.6 | 92.3 | 932 | 100.3 | 86.1 | |
| 4/04/91 | 75 | 2:00 | 1202 | 99.2 | 84.7 | 1314 | 100.1 | 86.6 | 755 | 101.3 | 92.6 | 934 | 100.2 | 85.8 | |
| 4/04/91 | 72 | 3:00 | 1158 | 97.2 | 85.4 | 1272 | 97.5 | 86.5 | 712 | 97.3 | 91.2 | 874 | 97.3 | 86.5 | |
| 4/04/91 | 72 | 4:00 | 1097 | 94.0 | 85.8 | 1202 | 94.3 | 87.5 | 644 | 93.8 | 91.8 | 805 | 93.1 | 86.5 | |
| 5/21/91 | 59 | 9:00 | 528 | 57.0 | 83.0 | | | | 102 | 56.8 | 87.3 | | | | |
| 5/21/91 | 61 | 11:15 | 548 | 57.9 | 82.7 | | | | 124 | 58.1 | 87.3 | | | | |
| 5/22/91 | 56 | 8:15 | 514 | 56.4 | 83.3 | | | | 62 | 54.5 | 87.4 | | | | |

| RAIL STRAIN DATA FROM SANTE FE, NM | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
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| SECTION 2 | | | | | | | High Rail | | | | | | | | |
| Date | Amb | Time | | 1 | Neut | | 2 | Neut | | 3 | Neut | | 4 | Neut | |
| | Temp | | Strain | Temp | Temp | Strain | Temp | Temp | Strain | Temp | Temp | Strain | Temp | Temp | Comments |
| 5/22/91 | 64 | 10:00 | 816 | 76.4 | 85.1 | | | | 343 | 73.6 | 89.6 | | | | |
| 5/22/91 | 70 | 11:05 | 1039 | 90.3 | 85.6 | | | | 579 | 87.4 | 89.3 | | | | |
| 5/22/91 | 74 | 12:45 | 1244 | 102.0 | 85.0 | | | | 745 | 100.5 | 92.4 | | | | |
| 5/22/91 | 75 | 2:00 | 1277 | 109.2 | 90.2 | | | | 779 | 108.0 | 97.8 | | | | |
| 5/22/91 | 74 | 3:25 | 1363 | 111.1 | 86.9 | | | | 857 | 109.7 | 94.9 | | | | |
| 5/22/91 | 76 | 4:25 | 1281 | 106.8 | 87.6 | | | | 772 | 105.5 | 95.8 | | | | |
| 7/16/91 | 64 | 8:10 | 620 | 64.5 | 85.0 | | | | 148 | 64.2 | 92.0 | | | | |
| 7/16/91 | 75 | 9:06 | 832 | 77.0 | 84.8 | | | | 317 | 75.6 | 93.2 | | | | |
| 7/16/91 | 79 | 10:00 | 1032 | 89.7 | 85.4 | | | | 503 | 88.3 | 94.7 | | | | |
| 7/16/91 | 84 | 11:30 | 1256 | 107.0 | 89.3 | | | | 706 | 102.8 | 97.0 | | | | |
| 7/16/91 | 83 | 12:30 | 1368 | 113.4 | 88.9 | | | | 817 | 109.7 | 97.3 | | | | |
| 7/16/91 | 85 | 2:00 | 1347 | 114.6 | 91.4 | | | | 804 | 112.8 | 101.1 | | | | |
| 7/16/91 | 87 | 3:00 | 1427 | 118.4 | 90.4 | | | | 880 | 116.6 | 100.4 | | | | |
| 7/17/91 | 70 | 8:00 | 705 | 70.1 | 85.5 | | | | 225 | 69.0 | 92.1 | | | | |
| 7/17/91 | 75 | 9:00 | 888 | 81.3 | 85.7 | | | | 386 | 78.2 | 91.7 | | | | |
| 7/17/91 | 78 | 10:00 | 1063 | 91.8 | 85.7 | | | | 555 | 90.2 | 93.5 | | | | |
| 7/17/91 | 84 | 11:00 | 1202 | 101.9 | 87.4 | | | | 689 | 100.3 | 95.6 | | | | |
| 7/17/91 | 88 | 12:00 | 1355 | 112.9 | 89.2 | | | | 832 | 110.8 | 97.5 | | | | |
| 7/17/91 | 92 | 1:00 | 1471 | 120.4 | 89.8 | | | | 929 | 117.7 | 98.5 | | | | |
| 7/17/91 | 89 | 2:00 | 1534 | 125.4 | 91.0 | | | | 983 | 120.6 | 98.2 | | | | |
| 7/17/91 | 87 | 3:30 | 1547 | 125.6 | 90.4 | | | | 1006 | 122.1 | 98.3 | | | | |
| 7/17/91 | 86 | 4:20 | 1336 | 115.4 | 92.9 | | | | 790 | 112.4 | 101.6 | | | | |
| 7/18/91 | 76 | 8:10 | 741 | 73.2 | 86.4 | | | | 245 | 71.4 | 93.3 | | | | |
| 7/18/91 | 80 | 9:30 | 965 | 88.3 | 88.1 | | | | 453 | 85.3 | 94.7 | | | | |
| 7/18/91 | 84 | 10:35 | 1136 | 99.1 | 88.6 | | | | 630 | 97.9 | 96.7 | | | | |
| 7/18/91 | 87 | 11:41 | 1260 | 107.3 | 89.3 | | | | 754 | 103.9 | 95.2 | | | | |
| 7/18/91 | 89 | 12:35 | 1377 | 114.2 | 89.2 | | | | 881 | 113.4 | 97.1 | | | | |
| 7/18/91 | 88 | 1:30 | 1240 | 106.2 | 89.4 | | | | 751 | 106.5 | 98.0 | | | | |
| 8/13/91 | 72 | 9:00 | 718 | 72.8 | 87.4 | | | | 262 | 71.1 | 92.0 | | | | |
| 8/13/91 | 81 | 10:00 | 960 | 91.2 | 91.3 | | | | 472 | 89.6 | 97.9 | | | | |
| 8/13/91 | 82 | 12:00 | 1167 | 149.2 | 136.8 | | | | 699 | 102.6 | 97.3 | | | | |
| 8/13/91 | 69 | 2:30 | 765 | 73.5 | 85.3 | | | | 322 | 76.7 | 94.0 | | | | |
| 8/15/91 | 70 | 8:40 | 683 | 74.5 | 91.2 | | | | 190 | 70.1 | 95.3 | | | | |
| 8/15/91 | 80 | 10:00 | 973 | 91.7 | 91.0 | | | | 485 | 88.9 | 96.4 | | | | |
| 8/15/91 | 86 | 11:00 | 1141 | 102.8 | 92.0 | | | | 651 | 100.1 | 97.6 | | | | |
| 8/15/91 | 85 | 12:00 | 1230 | 109.3 | 93.1 | | | | 742 | 107.4 | 99.5 | | | | |
| 8/15/91 | 90 | 1:00 | 1346 | 115.3 | 92.2 | | | | 867 | 114.9 | 99.5 | | | | |
| 8/15/91 | 85 | 2:10 | 1164 | 109.8 | 97.6 | | | | 685 | 109.5 | 105.0 | | | | |
| 8/15/91 | 84 | 3:00 | 1274 | 108.5 | 89.7 | | | | 790 | 109.2 | 98.4 | | | | |

| RAIL STRAIN DATA FROM SANTE FE, NM | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
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| SECTION 2 | | | | | | | | | | | | | | | |
| | | | | | | | Low Rail | | | | | | | | |
| Date | Amb | Time | | 1 | Neut | | 2 | Neut | | 3 | Neut | | 4 | Neut | |
| | Temp | | Strain | Temp | Temp | Strain | Temp | Temp | Strain | Temp | Temp | Strain | Temp | Temp | Comments |
| 2/14/90 | 37 | | 85 | 37.4 | 86.7 | 472 | 37.2 | 86.5 | 68 | 36.7 | 85.4 | -179 | 36.7 | 86.6 | |
| 2/15/90 | 20 | | 290 | 31.4 | 68.4 | 440 | 36.9 | 88.1 | 39 | 39.2 | 89.6 | -186 | 31.3 | 81.6 | |
| 4/02/90 | 56 | | 743 | 76.7 | 86.4 | 1118 | 76.9 | 87.4 | 699 | 76.7 | 87.5 | 465 | 76.7 | 87.9 | |
| 4/02/90 | | 4:00 | 627 | 70.2 | 86.9 | 1014 | 69.9 | 86.6 | 598 | 70.4 | 87.2 | 387 | 71.3 | 87.2 | |
| 4/03/90 | 45 | 9:00 | 281 | 47.1 | 84.6 | 658 | 45.0 | 83.1 | 244 | 45.5 | 83.6 | 15 | 44.8 | 83.0 | |
| 4/03/90 | | | 656 | 68.7 | 83.7 | 1024 | 69.6 | 85.7 | 607 | 66.7 | 83.0 | 363 | 65.8 | 83.1 | |
| 4/03/90 | | 11:37 | 658 | 76.3 | 91.1 | 1094 | 78.9 | 90.8 | 663 | 78.3 | 91.2 | 443 | 77.3 | 89.8 | Before Low Rail Cut |
| 4/03/90 | | 2:48 | 905 | 85.2 | | 1292 | 88.1 | | 878 | 86.0 | | 651 | 91.4 | | Zero, after Cut |
| 4/05/90 | | 11:56 | 912 | 82.7 | 82.3 | 1212 | 79.4 | 78.5 | 782 | 73.7 | 79.5 | 617 | 81.5 | 83.5 | After Welding |
| 5/04/90 | 48 | 11:30 | 638 | 65.0 | 81.0 | 951 | 65.0 | 85.5 | 559 | 65.0 | 84.2 | 366 | 65.0 | 82.1 | Jon's Data |
| 5/04/90 | 55 | 3:00 | 747 | 68.6 | 78.1 | 1020 | 71.0 | 87.3 | 640 | 71.0 | 85.3 | 480 | 71.8 | 82.1 | Jon's Data |
| 6/26/90 | 95 | 10:25 | 1302 | 113.1 | 89.2 | 1612 | 110.8 | 91.6 | 1195 | 112.7 | 93.6 | 915 | 112.3 | 96.4 | |
| 6/26/90 | 92 | 5:35 | 1248 | 113.6 | 93.0 | 1552 | 110.4 | 94.8 | 1111 | 110.5 | 96.5 | 827 | 108.2 | 97.6 | |
| 6/27/90 | 60 | 5:40am | 391 | 58.5 | 89.4 | 747 | 58.2 | 91.0 | 314 | 58.1 | 92.0 | 55 | 58.2 | 94.0 | Begin Full Day Test |
| 6/27/90 | 65 | 6:40 | 415 | 60.5 | 89.9 | 781 | 61.7 | 92.4 | | | | | | | Train Prevented #3&4 |
| 6/27/90 | 68 | 7:18 | 594 | 70.7 | 89.4 | 950 | 69.4 | 90.0 | 521 | 68.6 | 90.1 | 243 | 67.6 | 92.1 | |
| 6/27/90 | 84 | 8:25 | 824 | 84.2 | 89.1 | 1163 | 82.8 | 90.6 | 741 | 83.1 | 91.3 | 484 | 84.0 | 94.0 | |
| 6/27/90 | 89 | 9:29 | | | | | | | | | | | | | Temp Probe Failed |
| 6/27/90 | 92 | 10:45 | 1302 | 113.0 | 89.1 | 1602 | 111.6 | 93.0 | 1168 | 111.8 | 94.4 | 885 | 110.7 | 96.6 | Temp Probe Repaired |
| 6/27/90 | 95 | 12:00 | 1455 | 124.4 | 91.3 | 1762 | 123.2 | 95.0 | 1330 | 121.9 | 94.7 | 1038 | 119.4 | 96.1 | |
| 6/27/90 | 98 | 1:00 | 1516 | 129.3 | 92.6 | 1829 | 125.9 | 93.6 | 1390 | 125.7 | 94.9 | 1114 | 125.0 | 97.2 | |
| 6/27/90 | 105 | 2:00 | 1583 | 132.4 | 91.7 | 1906 | 132.8 | 95.9 | 1473 | 132.0 | 96.2 | 1192 | 129.5 | 97.0 | |
| 6/27/90 | 95 | 2:57 | 1360 | 118.4 | 91.1 | 1651 | 116.8 | 95.2 | 1202 | 116.8 | 97.3 | 905 | 112.9 | 97.6 | End Full Day Test |
| 7/23/90 | 66 | 9:20am | 704 | 77.4 | 89.5 | 1062 | 75.4 | 89.2 | 620 | 76.3 | 91.8 | 360 | 76.0 | 93.5 | |
| 7/23/90 | 82.8 | 12:08 | 1119 | 105.8 | 92.9 | 1474 | 104.1 | 93.2 | 1020 | 102.3 | 93.8 | 734 | 99.6 | 94.6 | 12.02; Eastbound Trai |
| 7/24/90 | 73 | 9:00am | 697 | 76.6 | 89.1 | 1059 | 74.5 | 88.5 | 618 | 74.1 | 89.7 | 362 | 74.1 | 91.5 | |
| 7/24/90 | 81 | 10:00 | 890 | 88.4 | 89.3 | 1259 | 86.8 | 88.8 | 812 | 86.9 | 90.9 | 540 | 86.9 | 93.6 | |
| 7/24/90 | 78 | 11:00 | 1047 | 99.1 | 90.6 | 1430 | 99.4 | 91.1 | 981 | 97.9 | 91.7 | 712 | 98.0 | 94.3 | |
| 7/24/90 | 83 | 12:00 | 1161 | 105.2 | 89.8 | 1536 | 106.8 | 92.1 | 1090 | 107.6 | 94.9 | 816 | 107.9 | 98.0 | |
| 7/24/90 | 82 | 1:00 | 1186 | 109.9 | 93.0 | 1578 | 109.9 | 92.7 | 1135 | 109.4 | 94.0 | 863 | 107.1 | 94.4 | |
| 7/25/90 | 73 | 8:00am | 563 | 68.5 | 89.1 | 936 | 68.0 | 89.4 | 499 | 68.4 | 91.2 | 255 | 69.6 | 93.4 | |
| 1/29/91 | 35 | 8:35 | 76 | 37.6 | 87.4 | 490 | 34.9 | 83.1 | 69 | 33.3 | 81.9 | -172 | 31.3 | 80.8 | |
| 1/29/91 | 30 | 10:05 | 236 | 41.1 | 81.3 | 642 | 40.2 | 79.3 | 223 | 40.3 | 79.7 | 8 | 40.3 | 78.9 | |
| 1/29/91 | 38 | 1:00 | 393 | 52.9 | 83.7 | 814 | 52.2 | 80.9 | 393 | 52.3 | 81.4 | 172 | 53.3 | 82.1 | |
| 1/30/91 | 38 | 8:25 | 22 | 32.1 | 85.2 | 489 | 29.3 | 77.6 | 47 | 28.7 | 78.6 | -210 | 25.2 | 76.9 | |
| 1/30/91 | 39 | 9:30 | 362 | 54.1 | 86.7 | 792 | 49.1 | 79.1 | 363 | 48.3 | 79.2 | 103 | 46.4 | 79.3 | |
| 1/30/91 | 40 | 10:32 | 622 | 70.4 | 87.4 | 1044 | 65.3 | 80.2 | 605 | 65.6 | 82.0 | 348 | 64.1 | 82.3 | |
| 1/30/91 | 45 | 11:35 | 814 | 80.1 | 85.6 | 1234 | 78.6 | 82.1 | 810 | 77.7 | 81.8 | 558 | 76.4 | 82.0 | |
| 1/30/91 | 49 | 12:35 | 900 | 83.1 | 83.4 | 1330 | 85.3 | 83.0 | 901 | 85.4 | 84.0 | 667 | 83.9 | 82.9 | |
| 1/30/91 | 55 | 2:10 | 861 | 85.3 | 87.9 | 1302 | 88.7 | 88.1 | 875 | 90.3 | 90.5 | 674 | 90.1 | 88.7 | |
| 1/30/91 | 49 | 4:00 | 620 | 69.1 | 86.2 | 1058 | 71.6 | 85.7 | 645 | 71.0 | 85.0 | 470 | 74.9 | 85.8 | |
| 4/03/91 | 60 | 9:00 | 695 | 72.5 | 85.1 | 1085 | 68.6 | 81.0 | 640 | 67.9 | 82.2 | 378 | 63.3 | 79.7 | |
| 4/03/91 | 73 | 10:15 | 972 | 90.8 | 86.8 | 1389 | 89.4 | 83.6 | 946 | 86.3 | 82.2 | 701 | 85.2 | 82.2 | |
| 4/03/91 | 72 | 11:00 | 1135 | 100.1 | 86.3 | 1520 | 98.1 | 84.4 | 1081 | 94.5 | 82.3 | 836 | 92.6 | 81.5 | |
| 4/03/91 | 73 | 12:00 | 1209 | 103.7 | 85.4 | 1597 | 100.7 | 82.4 | 1158 | 97.8 | 81.0 | 922 | 98.7 | 82.4 | |
| 4/03/91 | 77 | 12:45 | 1135 | 103.0 | 89.2 | 1524 | 97.4 | 83.5 | 1088 | 97.5 | 84.9 | 868 | 94.5 | 81.5 | |
| 4/03/91 | 69 | 2:00 | 1148 | 101.2 | 86.6 | 1580 | 101.3 | 84.0 | 1143 | 100.3 | 84.4 | 931 | 96.7 | 79.9 | |
| 4/03/91 | 69 | 3:00 | 1012 | 92.2 | 85.8 | 1429 | 92.9 | 84.7 | 1004 | 92.1 | 84.5 | 792 | 90.9 | 82.4 | |
| 4/04/91 | 51 | 8:20am | 591 | 65.8 | 84.7 | 972 | 60.6 | 79.8 | 533 | 58.2 | 78.9 | 291 | 57.3 | 78.9 | |
| 4/04/91 | 63 | 10:00 | 934 | 85.9 | 84.2 | 1322 | 83.3 | 81.5 | 882 | 80.0 | 79.8 | 632 | 78.8 | 79.9 | |
| 4/04/91 | 64 | 11:00 | 1082 | 95.1 | 84.5 | 1470 | 93.2 | 82.5 | 1034 | 90.9 | 81.5 | 795 | 92.0 | 83.3 | |
| 4/04/91 | 69 | 12:00 | 1169 | 100.3 | 84.4 | 1554 | 97.5 | 81.8 | 1116 | 96.4 | 82.1 | 879 | 95.1 | 81.4 | |
| 4/04/91 | 73 | 1:00 | 1210 | 102.9 | 84.6 | 1607 | 101.3 | 82.4 | 1175 | 97.3 | 79.5 | 946 | 96.4 | 78.7 | |
| 4/04/91 | 75 | 2:00 | 1117 | 99.2 | 86.5 | 1582 | 98.1 | 80.7 | 1151 | 99.3 | 82.9 | 935 | 96.0 | 78.9 | |
| 4/04/91 | 72 | 3:00 | 1102 | 97.1 | 85.3 | 1519 | 96.2 | 82.6 | 1093 | 96.5 | 83.6 | 883 | 94.1 | 80.2 | |
| 4/04/91 | 72 | 4:00 | 1036 | 93.4 | 85.5 | 1452 | 92.6 | 83.0 | 1081 | 92.6 | 80.4 | 803 | 92.0 | 82.9 | |
| 5/21/91 | 59 | 9:00 | 486 | 57.0 | 82.2 | 885 | 57.1 | 81.6 | 473 | 56.8 | 81.1 | 252 | 56.8 | 80.8 | |
| 5/21/91 | 61 | 11:15 | 516 | 57.7 | 81.1 | 914 | 58.0 | 80.7 | 496 | 57.8 | 80.8 | 275 | 57.8 | 80.4 | |

| RAIL STRAIN DATA FROM SANTE FE, NM | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
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| SECTION 2 | | | | | | | | | | | | | | | |
| | | | | | | | Low Rail | | | | | | | | |
| Date | Amb | Time | | 1 | Neut | | 2 | Neut | | 3 | Neut | | 4 | Neut | |
| | Temp | | Strain | Temp | Temp | Strain | Temp | Temp | Strain | Temp | Temp | Strain | Temp | Temp | Comments |
| 5/22/91 | 56 | 8:15 | 515 | 55.8 | 79.2 | 905 | 54.6 | 77.9 | 487 | 53.8 | 77.3 | 214 | 55.1 | 81.4 | |
| 5/22/91 | 64 | 10:00 | 863 | 76.3 | 78.8 | 1240 | 74.2 | 77.3 | 801 | 73.0 | 77.6 | 503 | 73.1 | 82.0 | |
| 5/22/91 | 70 | 11:05 | 1085 | 91.5 | 80.7 | 1440 | 89.2 | 80.3 | 999 | 86.6 | 79.3 | 742 | 85.5 | 80.0 | |
| 5/22/91 | 74 | 12:45 | 1252 | 102.5 | 81.6 | 1618 | 101.6 | 82.0 | 1191 | 99.8 | 81.0 | 936 | 97.2 | 80.1 | |
| 5/22/91 | 75 | 2:00 | 1266 | 109.1 | 87.4 | 1650 | 108.2 | 86.7 | 1235 | 106.8 | 85.3 | 991 | 103.9 | 83.5 | |
| 5/22/91 | 74 | 3:25 | 1280 | 110.2 | 87.7 | 1651 | 111.1 | 89.5 | 1227 | 109.1 | 88.1 | 987 | 106.3 | 86.1 | |
| 5/22/91 | 76 | 4:25 | 1182 | 106.2 | 89.6 | 1553 | 104.7 | 89.0 | 1125 | 103.6 | 88.8 | 882 | 99.3 | 85.4 | |
| 7/16/91 | 64 | 8:10 | 570 | 64.7 | 84.8 | 1008 | 64.0 | 81.1 | 604 | 64.1 | 80.6 | 379 | 64.6 | 80.9 | |
| 7/16/91 | 75 | 9:06 | 792 | 76.8 | 83.6 | 1210 | 75.7 | 80.6 | 799 | 75.5 | 80.2 | 559 | 77.7 | 83.2 | |
| 7/16/91 | 79 | 10:00 | 988 | 89.7 | 84.7 | 1404 | 88.8 | 82.1 | 985 | 86.9 | 80.5 | 734 | 87.2 | 82.2 | |
| 7/16/91 | 84 | 11:30 | 1196 | 106.5 | 89.0 | 1612 | 104.4 | 85.2 | 1185 | 102.4 | 84.0 | 909 | 98.3 | 82.8 | |
| 7/16/91 | 83 | 12:30 | 1300 | 113.0 | 89.3 | 1725 | 112.2 | 86.2 | 1297 | 107.6 | 82.4 | 1020 | 105.1 | 82.9 | |
| 7/16/91 | 85 | 2:00 | 1255 | 114.8 | 93.8 | 1706 | 114.4 | 89.5 | 1275 | 111.6 | 87.7 | 1020 | 107.3 | 85.1 | |
| 7/16/91 | 87 | 3:00 | 1282 | 117.1 | 94.4 | 1730 | 116.6 | 90.3 | 1306 | 114.6 | 88.9 | 1055 | 110.1 | 85.8 | |
| 7/17/91 | 70 | 8:00 | 659 | 70.1 | 84.9 | 1086 | 68.6 | 81.0 | 673 | 68.7 | 81.0 | 457 | 69.6 | 81.3 | |
| 7/17/91 | 75 | 9:00 | 851 | 80.8 | 84.0 | 1265 | 78.1 | 79.7 | 850 | 78.1 | 79.8 | 618 | 79.0 | 81.0 | |
| 7/17/91 | 78 | 10:00 | 1020 | 91.8 | 84.9 | 1454 | 90.3 | 80.6 | 1037 | 90.1 | 80.5 | 791 | 89.6 | 81.2 | |
| 7/17/91 | 84 | 11:00 | 1140 | 102.0 | 87.9 | 1589 | 101.3 | 83.5 | 1166 | 100.2 | 82.9 | 918 | 100.1 | 84.1 | |
| 7/17/91 | 88 | 12:00 | 1287 | 112.8 | 89.8 | 1740 | 112.6 | 85.7 | 1318 | 112.1 | 85.7 | 1064 | 108.1 | 83.3 | |
| 7/17/91 | 92 | 1:00 | 1393 | 120.4 | 91.1 | 1825 | 118.3 | 86.3 | 1395 | 116.3 | 85.2 | 1134 | 112.2 | 83.2 | |
| 7/17/91 | 89 | 2:00 | 1446 | 124.1 | 91.6 | 1876 | 121.6 | 86.5 | 1444 | 120.1 | 86.1 | 1193 | 115.8 | 83.2 | |
| 7/17/91 | 87 | 3:30 | 1450 | 123.9 | 91.1 | 1889 | 121.6 | 85.7 | 1464 | 120.5 | 85.3 | 1200 | 115.4 | 82.4 | |
| 7/17/91 | 86 | 4:20 | 1217 | 113.8 | 95.1 | 1665 | 111.9 | 89.5 | 1235 | 111.6 | 90.1 | 989 | 106.0 | 85.7 | |
| 7/18/91 | 76 | 8:10 | 703 | 73.7 | 85.8 | 1124 | 72.2 | 82.3 | 705 | 72.2 | 82.6 | 479 | 72.7 | 83.0 | |
| 7/18/91 | 80 | 9:30 | 949 | 88.1 | 85.5 | 1354 | 85.6 | 81.9 | 929 | 84.8 | 81.7 | 683 | 84.9 | 83.0 | |
| 7/18/91 | 84 | 10:35 | 1026 | 99.3 | 92.0 | 1495 | 98.5 | 86.3 | 1072 | 97.4 | 85.7 | 833 | 96.1 | 85.2 | |
| 7/18/91 | 87 | 11:41 | 1146 | 108.0 | 93.5 | 1616 | 106.1 | 86.6 | 1194 | 105.1 | 86.1 | 952 | 104.0 | 85.9 | |
| 7/18/91 | 89 | 12:35 | 1261 | 114.5 | 93.1 | 1741 | 113.5 | 86.5 | 1319 | 113.2 | 86.7 | 1077 | 112.2 | 86.6 | |
| 7/18/91 | 88 | 1:30 | 1115 | 105.5 | 92.9 | 1606 | 104.2 | 85.3 | 1190 | 105.4 | 86.7 | 959 | 104.8 | 86.3 | |
| 8/13/91 | 72 | 9:00 | 618 | 72.7 | 89.9 | 1130 | 71.5 | 81.2 | 714 | 71.3 | 81.2 | 477 | 70.8 | 81.3 | |
| 8/13/91 | 81 | 10:00 | 844 | 89.8 | 93.5 | 1370 | 89.1 | 84.4 | 948 | 86.7 | 82.5 | 697 | 88.5 | 85.7 | |
| 8/13/91 | 82 | 12:00 | 1069 | 105.1 | 95.2 | 1591 | 103.1 | 85.1 | 1181 | 103.7 | 85.5 | 936 | 103.2 | 86.1 | |
| 8/13/91 | 69 | 2:30 | 600 | 72.3 | 90.6 | 1180 | 76.3 | 83.0 | 760 | 76.8 | 83.9 | 536 | 77.3 | 84.2 | |
| 8/15/91 | 70 | 8:40 | 557 | 74.1 | 95.0 | 1078 | 70.5 | 83.4 | 655 | 70.6 | 84.0 | 413 | 70.2 | 84.5 | |
| 8/15/91 | 80 | 10:00 | 861 | 92.4 | 95.0 | 1375 | 89.6 | 84.6 | 954 | 87.9 | 83.3 | 694 | 87.2 | 84.6 | |
| 8/15/91 | 86 | 11:00 | 1020 | 103.8 | 96.9 | 1545 | 102.0 | 86.8 | 1122 | 99.7 | 85.0 | 862 | 98.3 | 85.6 | |
| 8/15/91 | 85 | 12:00 | 1099 | 110.1 | 98.4 | 1640 | 108.3 | 87.4 | 1229 | 106.2 | 85.1 | 967 | 106.2 | 87.2 | |
| 8/15/91 | 90 | 1:00 | 1205 | 114.9 | 96.9 | 1759 | 115.3 | 87.2 | 1342 | 114.7 | 86.8 | 1090 | 114.3 | 87.9 | |
| 8/15/91 | 85 | 2:10 | 1052 | 110.3 | 101.5 | 1606 | 109.1 | 90.2 | 1180 | 110.0 | 91.9 | 937 | 109.2 | 92.0 | |
| 8/15/91 | 84 | 3:00 | 1071 | 108.6 | 98.6 | 1636 | 109.7 | 89.0 | 1224 | 108.5 | 87.7 | 986 | 108.5 | 88.4 | |

| RAIL STRAIN DATA FROM SANTE FE, NM | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
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| SECTION 3 | | | | | | | High Rail | | | | | | | | |
| Date | Amb | Time | | 1 | Neut | | 2 | Neut | | 3 | Neut | | 4 | Neut | |
| | Temp | | Strain | Temp | Temp | Strain | Temp | Temp | Strain | Temp | Temp | Strain | Temp | Temp | Comments |
| 2/14/90 | 37 | | 593 | 34.2 | 79.6 | 467 | 34.6 | 79.3 | 0 | 35.1 | 76.0 | 416 | 43.3 | 81.0 | |
| 2/15/90 | 20 | | 581 | 31.1 | 77.2 | 443 | 31.6 | 77.7 | -31 | 32.0 | 74.7 | 237 | 31.8 | 80.3 | |
| 4/02/90 | 56 | | 1215 | 73.7 | 81.7 | 1096 | 73.0 | 79.9 | 566 | 71.8 | 78.7 | 874 | 75.1 | 85.3 | |
| 4/02/90 | | 4:00 | 1133 | 66.0 | 78.9 | 987 | 68.3 | 81.7 | 465 | 67.3 | 80.2 | 779 | 68.0 | 83.9 | |
| 4/03/90 | 45 | 9:00 | 849 | 48.2 | 78.2 | 733 | 48.4 | 77.1 | 235 | 48.6 | 75.3 | 501 | 48.0 | 80.6 | |
| 4/03/90 | | | 1261 | 77.0 | 82.2 | 1133 | 75.5 | 80.1 | 598 | 75.3 | 80.2 | 934 | 75.5 | 82.1 | |
| 7/23/90 | 66 | 9:20am | 1189 | 81.6 | 91.2 | 1130 | 81.0 | 85.8 | 617 | 81.5 | 85.3 | 922 | 81.0 | 88.3 | |
| 7/23/90 | | 10:42 | | | | 1285 | 92.4 | 87.9 | 763 | 91.6 | 86.6 | | | | Before Rail Cut |
| 7/23/90 | | 11:19 | 1348 | 101.3 | | 1210 | 100.9 | | 680 | 100.3 | | 1044 | 99.4 | | Zero |
| 7/23/90 | | 12:08 | 1303 | 102.7 | 105.4 | 1216 | 104.6 | 104.2 | 691 | 107.5 | 106.8 | 1061 | 105.2 | 104.2 | 12:02;Eastbound Train |
| 7/24/90 | 73 | 9:00am | 1099 | 80.9 | 95.9 | 949 | 79.1 | 94.8 | 472 | 81.9 | 94.4 | 741 | 79.4 | 97.6 | Rail Not Welded |
| 7/24/90 | 81 | 10:00 | 1190 | 89.1 | 98.6 | 1118 | 88.2 | 93.7 | 590 | 91.2 | 96.6 | 884 | 88.5 | 98.1 | |
| 7/24/90 | 78 | 11:00 | 1268 | 95.1 | 99.9 | 1220 | 96.2 | 95.6 | 695 | 99.0 | 98.1 | 1016 | 96.5 | 98.2 | |
| 7/24/90 | 83 | 12:00 | 1548 | 100.5 | 88.5 | 1299 | 100.9 | 95.6 | 763 | 101.8 | 96.8 | 1105 | 102.9 | 99.2 | |
| 7/24/90 | 82 | 1:00 | 1406 | 101.9 | 98.4 | 1348 | 104.4 | 96.1 | 804 | 106.4 | 98.9 | 1154 | 105.7 | 99.1 | |
| 7/25/90 | 73 | 8:00am | 967 | 76.4 | 99.3 | 851 | 73.5 | 95.1 | 346 | 75.1 | 95.2 | 609 | 73.6 | 99.7 | |
| 7/25/90 | | 11:15 | 1322 | 102.3 | 103.9 | 1200 | 111.1 | 111.7 | 661 | 107.0 | 108.1 | 1010 | 101.6 | 103.6 | Pre-weld |
| 7/25/90 | | 12:14 | 1347 | 101.8 | 101.9 | 1205 | 115.5 | 115.8 | 672 | 108.6 | 109.1 | 1026 | 103.8 | 104.9 | Right after Weld |
| 7/25/90 | 89 | 3:26 | 1418 | 105.4 | 101.2 | 1320 | 112.7 | 106.1 | 777 | 111.8 | 106.0 | 1132 | 108.7 | 103.4 | 3 hrs. after Welding |
| 7/25/90 | 85 | 4:01 | 1414 | 109.1 | 105.1 | 1305 | 111.5 | 105.8 | 765 | 112.0 | 106.9 | 1118 | 107.7 | 103.3 | |
| 1/29/91 | 35 | 8:35 | 429 | 38.8 | 94.0 | 255 | 39.9 | 97.3 | -219 | 40.1 | 94.1 | 43 | 37.1 | 97.3 | |
| 1/29/91 | 30 | 10:05 | 432 | 39.5 | 94.5 | 246 | 39.3 | 97.2 | -223 | 40.2 | 94.5 | 28 | 39.0 | 100.1 | |
| 1/29/91 | 38 | 1:00 | 558 | 46.5 | 94.0 | 383 | 47.2 | 96.9 | -89 | 48.6 | 94.8 | 214 | 48.5 | 98.4 | |
| 1/30/91 | 38 | 8:25 | 315 | 35.5 | 97.6 | 120 | 35.6 | 101.1 | -341 | 35.2 | 96.6 | -133 | 34.5 | 105.2 | |
| 1/30/91 | 39 | 9:30 | 594 | 50.8 | 96.1 | 419 | 55.0 | 102.5 | -55 | 53.2 | 97.4 | 212 | 51.6 | 101.6 | |
| 1/30/91 | 40 | 10:32 | 785 | 62.6 | 96.4 | 629 | 63.7 | 98.6 | 153 | 65.1 | 96.8 | 470 | 64.3 | 98.8 | |
| 1/30/91 | 45 | 11:35 | 879 | 67.2 | 95.4 | 734 | 69.3 | 97.9 | 245 | 73.0 | 99.1 | 604 | 73.2 | 99.6 | |
| 1/30/91 | 49 | 12:35 | 896 | 67.7 | 94.9 | 748 | 70.3 | 98.1 | 257 | 72.5 | 97.9 | 641 | 74.1 | 98.3 | |
| 1/30/91 | 55 | 2:10 | 934 | 69.7 | 94.6 | 765 | 68.1 | 94.8 | 273 | 71.0 | 95.5 | 620 | 71.3 | 96.8 | |
| 1/30/91 | 49 | 4:00 | 815 | 62.7 | 94.7 | 628 | 61.1 | 96.1 | 145 | 62.2 | 94.4 | 422 | 60.2 | 97.6 | |
| 4/03/91 | 60 | 9:00 | 1091 | 79.1 | 94.5 | 891 | 78.8 | 98.0 | 383 | 75.6 | 93.4 | 667 | 74.2 | 96.9 | |
| 4/03/91 | 73 | 10:15 | 1308 | 90.9 | 93.3 | 1134 | 92.7 | 97.3 | 606 | 91.6 | 96.0 | 933 | 92.9 | 99.6 | |
| 4/03/91 | 72 | 11:00 | 1363 | 93.8 | 92.9 | 1206 | 93.5 | 93.7 | 677 | 95.6 | 95.8 | 1028 | 98.2 | 99.2 | |
| 4/03/91 | 73 | 12:00 | 1417 | 96.7 | 92.6 | 1252 | 97.8 | 95.3 | 716 | 98.3 | 96.1 | 1071 | 99.1 | 97.5 | |
| 4/03/91 | 77 | 12:45 | 1393 | 96.8 | 94.1 | 1205 | 96.7 | 97.0 | 670 | 97.6 | 98.2 | 989 | 97.7 | 101.0 | |
| 4/03/91 | 69 | 2:00 | 1366 | 96.3 | 95.2 | 1188 | 96.1 | 97.4 | 659 | 98.0 | 99.3 | 997 | 96.8 | 99.6 | |
| 4/03/91 | 69 | 3:00 | 1251 | 89.4 | 95.2 | 1094 | 89.3 | 96.3 | 572 | 90.7 | 97.2 | 918 | 90.5 | 98.1 | |
| 4/04/91 | 51 | 8:20am | 965 | 71.8 | 94.8 | 773 | 71.7 | 98.0 | 277 | 70.9 | 95.1 | 569 | 70.1 | 98.6 | |
| 4/04/91 | 63 | 10:00 | 1218 | 85.6 | 93.4 | 1046 | 86.1 | 96.0 | 529 | 86.4 | 95.5 | 856 | 84.1 | 95.4 | |
| 4/04/91 | 64 | 11:00 | 1299 | 90.3 | 93.2 | 1138 | 92.5 | 96.8 | 612 | 90.6 | 94.7 | 966 | 92.7 | 97.4 | |
| 4/04/91 | 69 | 12:00 | 1356 | 91.0 | 90.5 | 1203 | 94.1 | 94.5 | 672 | 94.6 | 95.1 | 1040 | 96.9 | 97.1 | |
| 4/04/91 | 73 | 1:00 | 1398 | 96.4 | 93.4 | 1236 | 97.0 | 95.4 | 699 | 97.1 | 96.0 | 1063 | 96.9 | 95.8 | |
| 4/04/91 | 75 | 2:00 | 1403 | 96.2 | 92.9 | 1231 | 96.3 | 95.0 | 689 | 97.6 | 97.1 | 1027 | 96.0 | 97.0 | |
| 4/04/91 | 72 | 3:00 | 1433 | 99.5 | 94.4 | 1238 | 98.4 | 96.7 | 706 | 98.8 | 97.2 | 1026 | 95.8 | 96.9 | |
| 4/04/91 | 72 | 4:00 | 1405 | 97.4 | 94.0 | 1189 | 97.3 | 98.6 | 688 | 98.1 | 97.6 | 997 | 95.0 | 97.8 | |
| 5/21/91 | 59 | 9:00 | 707 | 56.6 | 95.1 | 536 | 56.2 | 96.7 | 54 | 56.7 | 94.3 | 366 | 56.7 | 97.4 | |
| 5/21/91 | 61 | 11:15 | 722 | 57.3 | 94.9 | 560 | 57.3 | 96.4 | 65 | 57.7 | 94.7 | 394 | 57.5 | 96.6 | |
| 5/22/91 | 56 | 8:15 | 874 | 68.2 | 96.7 | 660 | 65.6 | 98.7 | 100 | 65.8 | 100.7 | 363 | 61.7 | 102.6 | |
| 5/22/91 | 64 | 10:00 | 1197 | 85.1 | 94.2 | 1001 | 82.4 | 95.0 | 381 | 82.5 | 100.5 | 689 | 81.8 | 103.1 | |
| 5/22/91 | 70 | 11:05 | 1387 | 96.5 | 94.2 | 1180 | 95.8 | 97.6 | 594 | 100.9 | 106.1 | 901 | 93.4 | 102.0 | |
| 5/22/91 | 74 | 12:45 | 1469 | 100.6 | 93.3 | 1310 | 101.6 | 95.6 | 772 | 99.7 | 94.2 | 1081 | 100.8 | 98.6 | |
| 5/22/91 | 75 | 2:00 | 1519 | 104.7 | 94.4 | 1358 | 106.5 | 97.6 | 818 | 106.7 | 98.4 | 1144 | 106.5 | 100.5 | |
| 5/22/91 | 74 | 3:25 | 1594 | 109.1 | 94.3 | 1447 | 109.8 | 95.6 | 894 | 111.2 | 98.3 | 1229 | 110.6 | 99.5 | |
| 5/22/91 | 76 | 4:25 | 1570 | 106.8 | 93.5 | 1413 | 108.4 | 96.2 | 866 | 107.4 | 96.2 | 1197 | 106.8 | 97.6 | |
| 7/16/91 | 64 | 8:10 | 920 | 70.3 | 96.0 | 736 | 70.0 | 98.5 | 222 | 69.4 | 96.9 | 486 | 66.9 | 100.4 | |
| 7/16/91 | 75 | 9:06 | 1207 | 86.0 | 94.5 | 1029 | 85.2 | 96.1 | 508 | 85.8 | 96.1 | 767 | 82.9 | 99.5 | |
| 7/16/91 | 79 | 10:00 | 1406 | 99.1 | 95.6 | 1248 | 97.6 | 95.3 | 708 | 97.9 | 96.2 | 993 | 96.2 | 99.3 | |
| 7/16/91 | 84 | 11:30 | 1597 | 110.8 | 95.8 | 1448 | 109.2 | 94.9 | 883 | 109.4 | 97.2 | 1200 | 105.9 | 96.5 | |
| 7/16/91 | 83 | 12:30 | 1647 | 109.9 | 91.9 | 1516 | 112.2 | 93.8 | 944 | 111.8 | 95.9 | 1295 | 111.2 | 96.1 | |

| RAIL STRAIN DATA FROM SANTE FE, NM | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | |
| SECTION 3 | | | | | | | High Rail | | | | | | | | |
| Date | Amb | Time | | 1 | Neut | | 2 | Neut | | 3 | Neut | | 4 | Neut | |
| | Temp | | Strain | Temp | Temp | Strain | Temp | Temp | Strain | Temp | Temp | Strain | Temp | Temp | Comments |
| 7/16/91 | 85 | 2:00 | 1655 | 113.1 | 94.7 | 1510 | 113.4 | 95.4 | 935 | 114.2 | 98.9 | 1278 | 114.4 | 100.3 | |
| 7/16/91 | 87 | 3:00 | 1732 | 117.2 | 94.1 | 1589 | 117.9 | 95.1 | 999 | 118.5 | 99.3 | 1347 | 115.9 | 97.7 | |
| 7/17/91 | 70 | 8:00 | 1078 | 80.9 | 97.1 | 898 | 78.0 | 96.8 | 383 | 75.6 | 93.4 | 623 | 74.3 | 99.6 | |
| 7/17/91 | 75 | 9:00 | 1233 | 89.1 | 96.0 | 1068 | 88.0 | 96.5 | 544 | 87.2 | 95.4 | 803 | 86.5 | 101.0 | |
| 7/17/91 | 78 | 10:00 | 1365 | 97.2 | 96.2 | 1209 | 96.0 | 96.1 | 680 | 95.4 | 95.4 | 969 | 94.9 | 99.4 | |
| 7/17/91 | 84 | 11:00 | 1456 | 102.2 | 95.7 | 1310 | 101.5 | 95.5 | 770 | 101.1 | 95.7 | 1079 | 101.2 | 99.1 | |
| 7/17/91 | 88 | 12:00 | 1587 | 110.2 | 95.8 | 1454 | 110.3 | 95.6 | 889 | 110.4 | 97.8 | 1227 | 110.2 | 99.2 | |
| 7/17/91 | 92 | 1:00 | 1729 | 117.8 | 94.9 | 1589 | 117.2 | 94.4 | 1008 | 118.2 | 98.5 | 1351 | 117.2 | 98.8 | |
| 7/17/91 | 89 | 2:00 | 1792 | 120.1 | 93.4 | 1657 | 120.6 | 93.7 | 1074 | 121.7 | 98.0 | 1424 | 120.9 | 98.1 | |
| 7/17/91 | 87 | 3:30 | 1817 | 120.9 | 92.7 | 1688 | 121.1 | 92.4 | 1103 | 122.7 | 97.3 | 1452 | 123.2 | 98.7 | |
| 7/17/91 | 86 | 4:20 | 1652 | 113.2 | 94.9 | 1505 | 113.5 | 95.8 | 933 | 116.3 | 101.1 | 1262 | 116.3 | 103.2 | |
| 7/18/91 | 76 | 8:10 | 1100 | 81.6 | 96.5 | 914 | 80.2 | 98.0 | 397 | 79.7 | 96.7 | 643 | 77.4 | 101.5 | |
| 7/18/91 | 80 | 9:30 | 1304 | 94.3 | 96.9 | 1126 | 93.1 | 98.1 | 596 | 93.1 | 98.1 | 873 | 92.1 | 102.4 | |
| 7/18/91 | 84 | 10:35 | 1397 | 98.6 | 95.7 | 1248 | 99.2 | 96.9 | 701 | 98.4 | 97.1 | 1013 | 98.2 | 100.1 | |
| 7/18/91 | 87 | 11:41 | 1451 | 102.5 | 96.3 | 1315 | 103.3 | 97.0 | 758 | 103.6 | 98.9 | 1092 | 103.5 | 100.6 | |
| 7/18/91 | 89 | 12:35 | 1506 | 105.0 | 95.5 | 1381 | 106.1 | 95.8 | 821 | 106.9 | 98.4 | 1181 | 107.4 | 99.2 | |
| 7/18/91 | 88 | 1:30 | 1383 | 98.9 | 96.8 | 1254 | 99.7 | 97.1 | 705 | 100.4 | 98.9 | 1042 | 100.2 | 100.3 | |
| 8/13/91 | 72 | 9:00 | 1074 | 81.1 | 97.6 | 900 | 80.0 | 98.6 | 362 | 78.9 | 98.0 | 638 | 77.9 | 102.3 | |
| 8/13/91 | 81 | 10:00 | 1308 | 96.8 | 99.2 | 1129 | 93.2 | 98.1 | 598 | 94.9 | 99.8 | 883 | 94.6 | 104.3 | |
| 8/13/91 | 82 | 12:00 | 1465 | 105.2 | 98.2 | 1274 | 104.5 | 100.7 | 710 | 104.4 | 102.6 | 1049 | 104.4 | 104.1 | |
| 8/13/91 | 69 | 2:30 | 948 | 72.7 | 96.7 | 792 | 71.2 | 96.3 | 271 | 73.3 | 97.9 | 582 | 73.4 | 101.2 | |
| 8/15/91 | 70 | 8:40 | 1149 | 85.0 | 97.0 | 938 | 83.2 | 99.5 | 399 | 85.0 | 101.9 | 668 | 79.4 | 102.0 | |
| 8/15/91 | 80 | 10:00 | 1386 | 98.9 | 96.6 | 1202 | 99.2 | 99.7 | 644 | 99.2 | 101.4 | 944 | 95.3 | 101.3 | |
| 8/15/91 | 86 | 11:00 | 1478 | 104.5 | 96.7 | 1305 | 105.2 | 99.5 | 740 | 105.2 | 101.6 | 1072 | 103.2 | 101.5 | |
| 8/15/91 | 85 | 12:00 | 1508 | 106.3 | 96.7 | 1343 | 106.9 | 98.9 | 775 | 107.7 | 102.0 | 1121 | 105.7 | 101.1 | |
| 8/15/91 | 90 | 1:00 | 1576 | 109.9 | 96.2 | 1124 | 110.4 | 115.6 | 852 | 111.4 | 101.1 | 1225 | 110.2 | 99.3 | |
| 8/15/91 | 85 | 2:10 | 1478 | 106.2 | 98.4 | 1296 | 104.2 | 99.0 | 719 | 105.8 | 103.5 | 1049 | 104.5 | 104.2 | |
| 8/15/91 | 84 | 3:00 | 1508 | 106.1 | 96.5 | 1360 | 106.1 | 97.1 | 791 | 106.5 | 99.8 | 1153 | 106.2 | 99.6 | |

| RAIL STRAIN DATA FROM SANTE FE, NM | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | |
| SECTION 3 | | | | | | | Low Rail | | | | | | | | |
| Date | Amb | Time | | 1 | Neut | | 2 | Neut | | 3 | Neut | | 4 | Neut | |
| | Temp | | Strain | Temp | Temp | Strain | Temp | Temp | Strain | Temp | Temp | Strain | Temp | Temp | Comments |
| 2/14/90 | 37 | | | | | 898 | 34.7 | 75.6 | -312 | 34.8 | 74.6 | -162 | 35.6 | 75.7 | |
| 2/15/90 | 20 | | | | | 915 | 36.4 | 78.3 | -322 | 34.7 | 75.1 | -196 | 36.6 | 78.8 | |
| 4/02/90 | 56 | | | | | 254 | 74.8 | 77.0 | 298 | 75.3 | 78.5 | 450 | 76.7 | 80.1 | |
| 4/02/90 | | 4:00 | | | | 387 | 66.7 | 76.9 | 172 | 67.7 | 78.5 | 327 | 68.9 | 79.7 | |
| 4/03/90 | 45 | 9:00 | | | | 610 | 51.2 | 74.8 | -44 | 51.2 | 74.9 | 102 | 49.7 | 74.0 | |
| 4/03/90 | | | | | | 240 | 76.4 | 77.8 | 319 | 76.1 | 78.0 | 467 | 79.8 | 82.1 | |
| 7/23/90 | 66 | 9:20am | -407 | 84.1 | 87.3 | 250 | 82.5 | 84.5 | 318 | 81.8 | 83.8 | 434 | 81.4 | 85.7 | |
| 7/23/90 | | 9:55 | | | | 221 | 86.3 | 86.5 | 346 | 86.3 | 86.6 | | | | Before Rail Cut |
| 7/23/90 | | 10:10 | | | | 213 | 88.3 | 88.1 | 350 | 87.0 | 87.1 | | | | After Cut, Anchors on |
| 7/23/90 | | 10.22 | -354 | 92.4 | | 217 | 88.4 | | 351 | 87.5 | | 506 | 89.6 | | Zero |
| 7/23/90 | 82.8 | 12:08 | -133 | 104.4 | 91.1 | -30 | 107.1 | 92.3 | 574 | 106.4 | 93.0 | 746 | 106.8 | 92.4 | 2:02; Eastbound Train |
| 7/24/90 | 73 | 9:00 | -328 | 80.6 | 79.0 | 124 | 82.7 | 77.1 | 438 | 81.4 | 76.2 | 516 | 80.8 | 80.2 | |
| 7/24/90 | 81 | 10:00 | -236 | 91.7 | 84.6 | 82 | 92.9 | 84.8 | 470 | 92.2 | 85.0 | 586 | 89.8 | 85.0 | |
| 7/24/90 | 78 | 11:00 | -182 | 97.9 | 87.6 | 35 | 99.9 | 89.0 | 519 | 100.3 | 90.2 | 658 | 99.1 | 90.0 | |
| 7/24/90 | 83 | 12:00 | -134 | 103.5 | 90.3 | -10 | 103.3 | 89.7 | 556 | 103.4 | 91.1 | 703 | 104.9 | 93.1 | |
| 7/24/90 | 82 | 1:00 | -113 | 104.1 | 89.6 | -25 | 105.7 | 91.2 | 572 | 107.5 | 94.2 | 760 | 107.5 | 92.2 | |
| 7/25/90 | 73 | 8:00am | -410 | 76.7 | 80.1 | 208 | 75.3 | 74.8 | 352 | 75.5 | 75.4 | 411 | 73.5 | 79.2 | Rail Bolt-joined |
| 7/25/90 | | 10.20 | -289 | 96.9 | 93.0 | 197 | 100.2 | 99.0 | 354 | 99.1 | 98.9 | 543 | 97.7 | 95.5 | 1" of Rail Cut Out |
| 7/25/90 | | 11:22 | -221 | 102.4 | 94.4 | 140 | 111.0 | 106.4 | 400 | 105.3 | 102.4 | 626 | 104.2 | 97.0 | Right after Weld |
| 7/25/90 | | 12:14 | -210 | 102.8 | 94.1 | 150 | 120.1 | 116.1 | 391 | 109.8 | 107.4 | 657 | 106.4 | 97.3 | Grinding on Low Rail |
| 7/25/90 | 89 | 3:26 | -137 | 108.8 | 95.8 | 21 | 111.4 | 99.6 | 527 | 110.5 | 99.9 | 720 | 110.5 | 97.6 | 4 hrs. after Welding |
| 7/25/90 | 85 | 4:01 | -133 | 109.3 | 96.0 | 22 | 110.6 | 98.9 | 515 | 110.8 | 100.9 | 701 | 109.5 | 97.8 | |
| 1/29/91 | 35 | 8:35 | -927 | 41.8 | 76.2 | 870 | 42.2 | 81.4 | -251 | 43.0 | 79.2 | -125 | 40.9 | 78.8 | |
| 1/29/91 | 30 | 10:05 | -927 | 39.5 | 73.9 | 886 | 40.9 | 81.1 | -255 | 41.3 | 77.7 | -100 | 40.9 | 77.3 | |
| 1/29/91 | 38 | 1:00 | -814 | 46.4 | 74.0 | 743 | 48.5 | 80.1 | -108 | 49.2 | 76.8 | 37 | 48.9 | 77.1 | |
| 1/30/91 | 38 | 8:25 | -1041 | 39.1 | 80.4 | 979 | 40.1 | 85.9 | -342 | 39.1 | 80.7 | -208 | 36.0 | 78.9 | |
| 1/30/91 | 39 | 9:30 | -739 | 57.0 | 80.1 | 658 | 56.6 | 83.1 | -32 | 57.3 | 80.3 | 105 | 56.5 | 80.6 | |
| 1/30/91 | 40 | 10:32 | -547 | 66.9 | 78.5 | 459 | 71.0 | 85.5 | 167 | 70.7 | 81.8 | 323 | 70.3 | 81.3 | |
| 1/30/91 | 45 | 11:35 | -470 | 71.3 | 78.3 | 352 | 76.1 | 84.2 | 268 | 77.5 | 82.5 | 436 | 77.9 | 82.1 | |
| 1/30/91 | 49 | 12:35 | -476 | 69.8 | 77.1 | 346 | 76.0 | 83.8 | 286 | 77.5 | 81.4 | 458 | 78.4 | 81.3 | |
| 1/30/91 | 55 | 2:10 | -424 | 71.8 | 76.0 | 340 | 71.6 | 79.0 | 276 | 72.3 | 76.8 | 431 | 73.5 | 78.0 | |
| 1/30/91 | 49 | 4:00 | -544 | 64.9 | 76.3 | 480 | 63.7 | 79.5 | 117 | 63.4 | 77.5 | 241 | 61.5 | 77.4 | |
| 4/03/91 | 60 | 9:00 | -296 | 84.0 | 80.5 | 249 | 84.4 | 86.3 | 337 | 82.0 | 82.8 | 470 | 78.8 | 81.0 | |
| 4/03/91 | 73 | 10:15 | -95 | 96.2 | 80.6 | 31 | 99.0 | 87.8 | 557 | 97.6 | 85.2 | 716 | 95.6 | 83.0 | |
| 4/03/91 | 72 | 11:00 | -63 | 95.8 | 78.3 | -30 | 98.3 | 83.5 | 619 | 98.1 | 82.0 | 798 | 98.7 | 81.2 | |
| 4/03/91 | 73 | 12:00 | -45 | 97.5 | 78.9 | -44 | 100.5 | 84.8 | 634 | 99.9 | 82.9 | 820 | 101.3 | 82.4 | |
| 4/03/91 | 77 | 12:45 | -87 | 97.6 | 81.6 | 17 | 96.5 | 84.5 | 565 | 99.6 | 86.7 | 732 | 98.1 | 84.5 | |
| 4/03/91 | 69 | 2:00 | -112 | 96.1 | 81.6 | 26 | 98.2 | 86.7 | 569 | 98.9 | 85.8 | 733 | 98.1 | 84.5 | |
| 4/03/91 | 69 | 3:00 | -206 | 91.1 | 82.2 | 131 | 92.5 | 87.3 | 454 | 91.3 | 85.1 | 618 | 91.6 | 84.9 | |
| 4/04/91 | 51 | 8:20am | -451 | 76.6 | 82.4 | 395 | 75.7 | 86.4 | 192 | 76.1 | 85.7 | 325 | 72.4 | 83.3 | |
| 4/04/91 | 63 | 10:00 | -206 | 89.0 | 80.1 | 138 | 90.4 | 85.7 | 448 | 90.3 | 84.5 | 595 | 88.3 | 83.0 | |
| 4/04/91 | 64 | 11:00 | -140 | 93.4 | 80.5 | 60 | 96.5 | 87.1 | 529 | 95.5 | 84.8 | 691 | 94.3 | 83.2 | |
| 4/04/91 | 69 | 12:00 | -102 | 95.2 | 80.1 | 46 | 97.0 | 86.7 | 579 | 97.3 | 83.6 | 758 | 98.9 | 83.8 | |
| 4/04/91 | 73 | 1:00 | -84 | 97.8 | 81.6 | 9 | 98.9 | 86.4 | 577 | 98.9 | 85.3 | 752 | 98.3 | 83.5 | |
| 4/04/91 | 75 | 2:00 | -96 | 94.5 | 79.0 | 37 | 95.4 | 84.6 | 549 | 97.5 | 85.6 | 712 | 96.5 | 84.1 | |
| 4/04/91 | 72 | 3:00 | -57 | 98.5 | 80.7 | 30 | 98.1 | 86.9 | 561 | 98.5 | 85.9 | 708 | 96.2 | 84.1 | |
| 4/04/91 | 72 | 4:00 | -84 | 96.2 | 80.0 | 33 | 97.4 | 86.3 | 545 | 96.8 | 85.1 | 687 | 94.7 | 83.8 | |
| 5/21/91 | 59 | 9:00 | -706 | 56.3 | 77.5 | 643 | 56.4 | 82.0 | -16 | 56.9 | 79.0 | 147 | 56.6 | 78.2 | |
| 5/21/91 | 61 | 11:15 | -688 | 57.4 | 77.5 | 615 | 57.7 | 81.6 | 2 | 57.7 | 78.7 | 156 | 57.9 | 78.9 | |
| 5/22/91 | 56 | 8:15 | -539 | 70.6 | 81.7 | 507 | 69.2 | 86.6 | 109 | 66.5 | 81.0 | 237 | 65.9 | 82.1 | |
| 5/22/91 | 64 | 10:00 | -206 | 89.1 | 80.2 | 165 | 89.3 | 86.2 | 459 | 86.9 | 80.4 | 588 | 84.4 | 79.5 | |
| 5/22/91 | 70 | 11:05 | -28 | 101.2 | 81.6 | -3 | 101.3 | 88.1 | 680 | 95.0 | 75.2 | 771 | 97.5 | 81.6 | |
| 5/22/91 | 74 | 12:45 | 24 | 101.5 | 78.8 | -73 | 105.0 | 87.6 | 671 | 104.1 | 84.9 | 853 | 104.2 | 83.3 | |
| 5/22/91 | 75 | 2:00 | 51 | 107.0 | 82.7 | -111 | 108.7 | 89.0 | 707 | 109.3 | 87.9 | 886 | 106.5 | 83.7 | |
| 5/22/91 | 74 | 3:25 | 136 | 111.3 | 81.9 | -197 | 113.1 | 88.2 | 789 | 112.1 | 85.8 | 938 | 111.3 | 85.3 | |
| 5/22/91 | 76 | 4:25 | 118 | 109.9 | 81.5 | -161 | 110.9 | 88.2 | 754 | 109.6 | 85.4 | 889 | 109.3 | 86.3 | |
| 7/16/91 | 64 | 8:10 | -338 | 72.7 | 71.7 | 189 | 70.9 | 69.2 | 452 | 70.2 | 64.1 | 558 | 67.5 | 64.4 | |
| 7/16/91 | 75 | 9:06 | -163 | 88.9 | 77.4 | 104 | 88.3 | 81.5 | 519 | 85.7 | 75.6 | 669 | 82.5 | 72.7 | |
| 7/16/91 | 79 | 10:00 | -102 | 99.1 | 84.0 | 61 | 103.0 | 93.6 | 542 | 99.5 | 88.0 | 696 | 96.0 | 84.6 | |

| RAIL STRAIN DATA FROM SANTE FE, NM | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | |
| SECTION 3 | | | | | | | Low Rail | | | | | | | | |
| Date | Amb | Time | | 1 | Neut | | 2 | Neut | | 3 | Neut | | 4 | Neut | |
| | Temp | | Strain | Temp | Temp | Strain | Temp | Temp | Strain | Temp | Temp | Strain | Temp | Temp | Comments |
| 7/16/91 | 84 | 11:30 | 35 | 114.6 | 91.2 | | 111.5 | 98.5 | 648 | 109.8 | 92.0 | 815 | 107.5 | 88.9 | |
| 7/16/91 | 83 | 12:30 | 66 | 109.4 | 84.2 | -101 | 113.7 | 94.6 | 697 | 112.6 | 91.8 | 884 | 112.2 | 89.5 | |
| 7/16/91 | 85 | 2:00 | 50 | 114.2 | 89.9 | -142 | 115.5 | 93.9 | 758 | 116.8 | 92.3 | 927 | 115.9 | 90.6 | |
| 7/16/91 | 87 | 3:00 | 99 | 118.0 | 90.8 | -165 | 118.6 | 95.6 | 783 | 117.8 | 91.8 | 958 | 116.5 | 89.3 | |
| 7/17/91 | 70 | 8:00 | -207 | 81.1 | 72.3 | 97 | 80.1 | 72.9 | 534 | 78.2 | 67.2 | 662 | 75.8 | 66.4 | |
| 7/17/91 | 75 | 9:00 | -139 | 91.4 | 78.5 | 89 | 89.2 | 81.5 | 538 | 89.4 | 78.2 | 709 | 87.5 | 75.3 | |
| 7/17/91 | 78 | 10:00 | -120 | 99.2 | 85.1 | 62 | 99.8 | 90.5 | 555 | 97.8 | 85.5 | 730 | 97.3 | 83.8 | |
| 7/17/91 | 84 | 11:00 | -67 | 104.7 | 87.5 | 44 | 104.6 | 94.2 | 567 | 103.1 | 90.1 | 769 | 104.2 | 88.4 | |
| 7/17/91 | 88 | 12:00 | 30 | 112.1 | 89.0 | -47 | 114.4 | 98.5 | 656 | 113.2 | 94.9 | 851 | 112.4 | 91.7 | |
| 7/17/91 | 92 | 1:00 | 112 | 118.2 | 90.2 | -120 | 119.5 | 99.2 | 736 | 119.1 | 96.0 | 936 | 118.7 | 92.9 | |
| 7/17/91 | 89 | 2:00 | 166 | 121.4 | 90.2 | -177 | 122.2 | 98.5 | 794 | 122.7 | 96.1 | 993 | 122.3 | 93.0 | |
| 7/17/91 | 87 | 3:30 | 179 | 122.6 | 90.6 | -192 | 121.6 | 97.0 | 809 | 123.3 | 95.8 | 1004 | 122.4 | 92.5 | |
| 7/17/91 | 86 | 4:20 | 42 | 115.1 | 91.3 | -118 | 116.0 | 95.9 | 748 | 116.8 | 92.9 | 913 | 117.2 | 92.7 | |
| 7/18/91 | 76 | 8:10 | -175 | 82.9 | 72.1 | 104 | 82.4 | 75.6 | 514 | 81.1 | 71.3 | 674 | 78.8 | 68.7 | |
| 7/18/91 | 80 | 9:30 | -139 | 96.4 | 83.5 | 85 | 97.1 | 89.2 | 530 | 94.0 | 83.2 | 683 | 94.0 | 83.4 | |
| 7/18/91 | 84 | 10:35 | -147 | 101.9 | 89.5 | 54 | 104.0 | 94.2 | 563 | 102.7 | 90.0 | 726 | 102.0 | 88.8 | |
| 7/18/91 | 87 | 11:41 | -100 | 103.6 | 88.3 | 5 | 107.2 | 94.5 | 616 | 106.2 | 90.3 | 795 | 106.8 | 89.4 | |
| 7/18/91 | 89 | 12:35 | -75 | 107.1 | 90.3 | -34 | 108.4 | 93.3 | 657 | 110.1 | 91.7 | 854 | 110.4 | 89.5 | |
| 7/18/91 | 88 | 1:30 | -193 | 99.2 | 89.5 | 93 | 101.6 | 94.1 | 537 | 102.4 | 91.2 | 716 | 102.8 | 90.2 | |
| 8/13/91 | 72 | 9:00 | -232 | 81.7 | 74.4 | 132 | 80.0 | 74.9 | 495 | 79.3 | 70.6 | 647 | 78.7 | 70.2 | |
| 8/13/91 | 81 | 10:00 | -199 | 99.4 | 90.1 | 138 | 97.9 | 93.2 | 495 | 97.2 | 88.5 | 662 | 91.2 | 81.8 | |
| 8/13/91 | 82 | 12:00 | -73 | 106.5 | 89.6 | 8 | 106.6 | 94.0 | 605 | 106.1 | 90.8 | 766 | 105.8 | 90.2 | |
| 8/13/91 | 69 | 2:30 | -362 | 70.3 | 70.8 | 270 | 70.2 | 73.4 | 390 | 70.9 | 68.6 | 501 | 71.4 | 71.7 | |
| 8/15/91 | 70 | 8:40 | -200 | 86.5 | 77.2 | 144 | 86.2 | 81.8 | 484 | 84.6 | 76.6 | 653 | 82.8 | 74.0 | |
| 8/15/91 | 80 | 10:00 | -140 | 102.5 | 89.6 | 96 | 102.8 | 95.5 | 510 | 100.0 | 90.4 | 683 | 99.0 | 88.4 | |
| 8/15/91 | 86 | 11:00 | -80 | 106.1 | 89.6 | 43 | 108.2 | 97.7 | 564 | 106.9 | 94.1 | 729 | 106.0 | 92.6 | |
| 8/15/91 | 85 | 12:00 | -63 | 107.4 | 89.9 | 13 | 108.6 | 96.3 | 593 | 108.6 | 94.1 | 769 | 107.5 | 91.7 | |
| 8/15/91 | 90 | 1:00 | -23 | 109.5 | 89.6 | -40 | 112.0 | 96.6 | 650 | 112.5 | 94.5 | 842 | 111.8 | 91.6 | |
| 8/15/91 | 85 | 2:10 | -77 | 105.1 | 88.5 | -7 | 106.9 | 93.4 | 612 | 104.3 | 88.6 | 780 | 106.4 | 89.9 | |
| 8/15/91 | 84 | 3:00 | -89 | 105.8 | 89.9 | -10 | 107.4 | 93.8 | 623 | 107.5 | 91.2 | 806 | 106.9 | 88.9 | |

| RAIL STRAIN DATA FROM BLUEFIELD, WV | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | |
| SECTION 1 | | | | | | | High Rail | | | | | | | | |
| Date | Amb | Time | | 1 | Neut | | 2 | Neut | | 3 | Neut | | 4 | Neut | |
| | Temp | | Strain | Temp | Temp | Strain | Temp | Temp | Strain | Temp | Temp | Strain | Temp | Temp | Comments |
| 3/06/90 | | 4:30 | 182 | 82.1 | 75.9 | 922 | 89.2 | 74.8 | 390 | 91.3 | 78.9 | 1021 | 104.2 | 80.6 | Old Ind. Box (x2.42) |
| 3/07/90 | | 9:40 | -198 | 52.4 | 69.0 | 513 | 51.6 | 61.8 | 5 | 52.0 | 62.7 | 378 | 50.4 | 65.5 | Old Ind. Box (x2.42) |
| 3/07/90 | | 12:15 | 51 | 68.8 | 70.5 | 830 | 70.8 | 61.9 | 252 | 70.6 | 66.5 | 627 | 69.2 | 69.3 | Old Ind. Box (x2.42) |
| 4/23/90 | 60 | 9:20 | 32 | 66.6 | 69.4 | 675 | 64.5 | 64.9 | 216 | 63.7 | 61.7 | 607 | 60.9 | 62.2 | |
| 4/23/90 | 79 | 11:30 | 402 | 93.6 | 74.2 | 1045 | 85.3 | 63.5 | 560 | 87.3 | 64.6 | 982 | 89.0 | 67.8 | After One Pass of Liner |
| 4/23/90 | 88 | 12:36 | 380 | 105.4 | 87.3 | 957 | 100.1 | 83.6 | 689 | 103.4 | 73.0 | | | | After Line,Tamp,Bal. Reg |
| 4/23/90 | 85 | 4:21 | 416 | 105.4 | 85.1 | 1058 | 105.6 | 83.0 | 567 | 106.6 | 83.5 | 974 | 106.4 | 85.7 | |
| 4/24/90 | 56 | 8:48 | -281 | 56.8 | 78.4 | 375 | 55.4 | 73.8 | -118 | 55.9 | 74.0 | 312 | 57.0 | 76.1 | |
| 4/24/90 | 75 | 10:05 | | | | 604 | 71.9 | 76.6 | 103 | 70.8 | 75.6 | | | | Pre LR Cut, Anch Part Out |
| 4/24/90 | 76 | 10:29 | | | | 716 | 79.1 | | 211 | 78.2 | | | | | After LR Cut |
| 4/24/90 | 80 | 10:44 | 79 | 86.0 | | 682 | 82.4 | | 183 | 83.0 | | 629 | 81.1 | | After HR Cut |
| 4/24/90 | 90 | 2:20 | 399 | 119.9 | 100.7 | 1026 | 119.5 | 98.8 | 519 | 123.6 | 103.4 | 861 | 121.4 | 107.5 | After Welding,Anchors On |
| 4/25/90 | 64 | 9:30 | -481 | 68.4 | 102.1 | 129 | 65.4 | 98.6 | -355 | 65.1 | 97.4 | 5 | 64.2 | 101.7 | |
| 4/25/90 | 85 | 11:30 | -23 | 96.8 | 102.9 | 657 | 97.5 | 99.0 | 169 | 99.2 | 100.0 | 575 | 97.6 | 100.8 | |
| 6/06/90 | 74 | 10:10 | -302 | 77.5 | 100.4 | 274 | 72.8 | 97.3 | -211 | 69.5 | 93.2 | 167 | 69.1 | 96.9 | Rec. by J. Pietrak (TSC) |
| 6/06/90 | 84 | 11:40 | 62 | 101.1 | 102.1 | 687 | 98.6 | 98.3 | 212 | 98.5 | 96.8 | 645 | 92.6 | 91.6 | Rec. by J. Pietrak (TSC) |
| 6/06/90 | 92 | 2:25 | 349 | 121.0 | 104.8 | 959 | 119.5 | 102.9 | 479 | 120.6 | 102.8 | 890 | 121.5 | 105.8 | Rec. by J. Pietrak (TSC) |
| 6/06/90 | 89 | 3:30 | 446 | 123.1 | 101.0 | 1046 | 122.3 | 100.4 | 571 | 124.1 | 100.8 | 964.0 | 125.6 | 105.5 | Rec. by J. Pietrak (TSC) |
| 6/06/90 | 90 | 4:45 | 323 | 119.8 | 105.1 | 937 | 119.9 | 104.6 | 453 | 120.8 | 104.6 | 866.0 | 122.4 | 108.2 | Rec. by J. Pietrak (TSC) |
| 7/03/90 | 65 | 9:30 | -298 | 75.8 | 98.5 | 205 | 68.2 | 96.9 | -270 | 64.7 | 91.9 | 104.0 | 63.9 | 95.5 | Rec. by D. Cregger (NS) |
| 7/03/90 | 82 | 11:15 | -10 | 92.1 | 97.4 | 530 | 89.4 | 98.5 | 60 | 87.6 | 95.0 | 180.0 | 81.5 | 108.5 | Rec. by D. Cregger (NS) |
| 7/03/90 | 90 | 12:55 | 284 | 115.5 | 103.2 | 894 | 115.6 | 102.9 | 418 | 117.5 | 103.4 | 778.0 | 115.8 | 106.8 | Rec. by D. Cregger (NS) |
| 7/30/90 | | 9:44am | -216 | 78.7 | 96.4 | 332 | 76.2 | 97.2 | -196 | 76.2 | 99.0 | 292.0 | 76.3 | 96.6 | |
| 7/30/90 | 87 | 11:41 | 80 | 98.1 | 98.0 | 616 | 94.5 | 98.5 | | | 11.0 | 572.0 | 87.2 | 90.6 | |
| 7/30/90 | 96 | 12:15 | 290 | 112.7 | 100.0 | 842 | 108.7 | 99.1 | 398 | 109.6 | 96.7 | 796.0 | 104.7 | 94.7 | |
| 7/30/90 | 89 | | 394 | 120.0 | 101.1 | 970 | 117.8 | 100.5 | 520 | 116.0 | 95.7 | 948.0 | 115.7 | 96.5 | |
| 7/31/90 | 72 | 8:05am | -241 | 77.9 | 97.1 | 341 | 78.5 | 99.0 | -92 | 79.4 | 95.9 | 334.0 | 79.6 | 97.3 | |
| 7/31/90 | 92 | 1:41 | 316 | 113.3 | 99.1 | 889 | 113.0 | 100.6 | 448 | 113.8 | 97.9 | 866.0 | 112.6 | 98.4 | |
| 2/04/91 | 70 | 1:50 | 208 | 98.6 | 90.8 | 739 | 92.5 | 89.1 | 288 | 95.2 | 88.9 | 794.0 | 102.9 | 93.0 | |
| 2/04/91 | 65 | 4:05 | 185 | 92.2 | 85.8 | 707 | 97.2 | 95.7 | 282 | 97.8 | 91.9 | 745.0 | 92.8 | 85.8 | |
| 2/05/91 | 45 | 8:20 | -482 | 44.6 | 78.3 | 47 | 44.6 | 82.8 | -376 | 44.9 | 78.5 | 125.0 | 45.9 | 76.2 | |
| 2/05/91 | 54 | 10:00 | -284 | 56.1 | 77.9 | 246 | 54.2 | 80.4 | -178 | 58.7 | 80.4 | 175.0 | 54.8 | 82.1 | |
| 2/05/91 | 58 | 11:35 | -20 | 62.1 | 68.0 | 460 | 61.2 | 74.5 | 19 | 63.9 | 73.8 | 454.0 | 63.5 | 74.0 | |
| 2/05/91 | 65 | 12:55 | 40 | 74.5 | 76.8 | 551 | 75.1 | 83.0 | 121 | 77.9 | 81.6 | 587.0 | 76.7 | 79.2 | |
| 2/05/91 | 69 | 2:30 | 81 | 78.4 | 78.3 | 596 | 79.1 | 84.3 | 164 | 80.0 | 81.1 | 630.0 | 80.5 | 80.4 | |

| RAIL STRAIN DATA FROM BLUEFIELD, WV | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | |
| SECTION 1 | | | | | | | Low Rail | | | | | | | | |
| Date | Amb | Time | | 1 | Neut | | 2 | Neut | | 3 | Neut | | 4 | Neut | |
| | Temp | | Strain | Temp | Temp | Strain | Temp | Temp | Strain | Temp | Temp | Strain | Temp | Temp | Comments |
| 3/06/90 | | 4:30 | -397 | 80.4 | 76.8 | 499 | 89.7 | 82.8 | 1079 | 90.3 | 74.8 | 525 | 103.8 | 84.6 | Old Ind. Box (x2.42) |
| 3/07/90 | | 9:40 | -777 | 50.6 | 69.8 | 63 | 50.7 | 70.1 | 627 | 49.7 | 61.4 | -184 | 47.8 | 71.2 | Old Ind. Box (x2.42) |
| 3/07/90 | | 12:15 | -496 | 69.7 | 72.0 | 358 | 69.3 | 70.9 | 929 | 71.2 | 64.7 | 148 | 68.4 | 71.9 | Old Ind. Box (x2.42) |
| 4/23/90 | 60 | 9:20 | -229 | 66.6 | 52.9 | 260 | 64.0 | 71.5 | 797 | 63.8 | 65.2 | 43 | 61.2 | 71.0 | |
| 4/23/90 | 79 | 11:30 | -160 | 93.2 | 75.4 | 614 | 86.3 | 72.5 | 1130 | 87.3 | 68.7 | 430 | 89.0 | 75.5 | After One Pass of Liner |
| 4/23/90 | 88 | 12:36 | -110 | 108.0 | 87.1 | 533 | 100.3 | 91.4 | 1035 | 103.3 | 90.4 | 260 | 99.8 | 96.6 | After Line,Tamp, Bal. Reg |
| 4/23/90 | 85 | 4:21 | -216 | 105.7 | 91.2 | 607 | 105.8 | 92.5 | 1053 | 107.7 | 93.8 | 420 | 109.1 | 96.2 | |
| 4/24/90 | 56 | 8:48 | -832 | 58.7 | 81.2 | -51 | 57.2 | 83.4 | 452 | 57.4 | 79.6 | -275 | 57.0 | 85.9 | |
| 4/24/90 | 75 | 10:05 | | | | 214 | 71.9 | 82.2 | 673 | 71.6 | 80.5 | | | | Pre LR Cut, Anch Part Out |
| 4/24/90 | 76 | 10:29 | -492 | 76.4 | | 381 | 76.9 | | 842 | 75.7 | | 150 | 76.2 | | After LR Cut |
| 4/24/90 | 80 | 10:44 | -457 | 86.8 | | 385 | 82.5 | | 821 | 86.0 | | 206 | 80.6 | | After HR Cut |
| 4/24/90 | 90 | 2:20 | -163 | 119.6 | 101.9 | 687 | 119.7 | 101.6 | 1120 | 119.6 | 101.6 | 485 | 120.0 | 103.2 | After Welding, Anchors On |
| 4/25/90 | 64 | 9:30 | -885 | 69.3 | 95.0 | -80 | 66.8 | 94.7 | 424 | 65.9 | 89.8 | -322 | 63.8 | 95.5 | |
| 4/25/90 | 85 | 11:30 | -472 | 96.5 | 97.4 | 405 | 96.3 | 95.1 | 840 | 98.5 | 97.4 | 218 | 97.2 | 96.5 | |
| 6/06/90 | 74 | 10:10 | -682 | 76.3 | 89.8 | 135 | 72.8 | 87.8 | 306 | 70.5 | 101.4 | -95 | 69.8 | 87.9 | Rec. by J. Pietrak (TSC) |
| 6/06/90 | 84 | 11:40 | -372 | 99.8 | 94.7 | 489 | 96.5 | 90.3 | 470 | 96.5 | 117.6 | 288 | 91.4 | 86.5 | Rec. by J. Pietrak (TSC) |
| 6/06/90 | 92 | 2:25 | -62 | 120.2 | 96.5 | 808 | 119.0 | 93.6 | 1281 | 120.1 | 92.5 | 609 | 119.9 | 95.7 | Rec. by J. Pietrak (TSC) |
| 6/06/90 | 89 | 3:30 | -40 | 123.3 | 98.2 | 831 | 123.6 | 96.8 | 1325 | 123.5 | 93.2 | 652 | 124.2 | 97.4 | Rec. by J. Pietrak (TSC) |
| 6/06/90 | 90 | 4:45 | -73 | 112.3 | 89.2 | 798 | 122.7 | 97.9 | 1300 | 120.2 | 91.4 | 597 | 121.6 | 98.1 | Rec. by J. Pietrak (TSC) |
| 7/03/90 | 65 | 9:30 | -682 | 77.0 | 90.5 | 76 | 67.8 | 86.4 | 777 | 64.2 | 66.8 | -155 | 64.0 | 85.7 | Rec. by D. Cregger (NS) |
| 7/03/90 | 82 | 11:15 | -435 | 91.5 | 90.2 | 398 | 88.9 | 88.1 | 966 | 87.5 | 78.8 | 438 | 79.7 | 65.8 | Rec. by D. Cregger (NS) |
| 7/03/90 | 90 | 12:55 | -170 | 114.5 | 97.3 | 712 | 114.6 | 94.9 | 1294 | 114.8 | 86.4 | 510 | 111.7 | 93.4 | Rec. by D. Cregger (NS) |
| 7/30/90 | | 9:44am | -772 | 80.6 | 99.5 | 32 | 75.3 | 96.5 | 604 | 74.9 | 87.9 | -132 | 74.7 | 95.0 | |
| 7/30/90 | 87 | 11:14 | -492 | 98.5 | 100.6 | 320 | 95.1 | 99.0 | | | | 146 | 89.9 | 93.5 | |
| 7/30/90 | 96 | 12:15 | -288 | 113.8 | 103.6 | 538 | 110.7 | 101.5 | 1056 | 109.5 | 95.4 | 364 | 105.2 | 95.7 | |
| 7/30/90 | 90 | 1:15 | -234 | 116.3 | 102.9 | 608 | 114.0 | 100.6 | 1126 | 114.6 | 96.3 | 448 | 112.1 | 97.6 | |
| 7/30/90 | 89 | | -196 | 119.5 | 103.8 | 654 | 118.5 | 102.3 | 1174 | 118.3 | 97.1 | 502 | 117.9 | 100.1 | |
| 7/31/90 | 72 | 8:05am | -857 | 76.1 | 100.1 | 0 | 76.8 | 99.9 | 540 | 76.4 | 93.3 | -124 | 76.2 | 96.0 | |
| 7/31/90 | 92 | 1:41 | -296 | 114.0 | 104.3 | 564 | 113.3 | 102.5 | 1086 | 114.1 | 98.2 | 403 | 112.8 | 101.0 | |
| 2/04/91 | 70 | 1:50 | | | | 849 | 87.8 | 59.9 | 1389 | 93.5 | 59.4 | 679 | 93.3 | 64.9 | |
| 2/04/91 | 65 | 4:05 | | | | 831 | 95.7 | 68.9 | 1380 | 94.9 | 61.3 | 643 | 91.8 | 65.5 | |
| 2/05/91 | 45 | 8:20 | | | | 191 | 43.8 | 55.5 | 726 | 43.8 | 49.5 | 21 | 43.7 | 54.8 | |
| 2/05/91 | 54 | 10:00 | | | | 350 | 54.6 | 56.7 | 900 | 54.6 | 49.9 | 320 | 58.7 | 51.8 | |
| 2/05/91 | 58 | 11:35 | | | | 416 | 60.0 | 58.1 | 952 | 59.7 | 51.8 | 245 | 61.4 | 59.1 | |
| 2/05/91 | 65 | 12:55 | | | | 539 | 70.5 | 61.2 | 1089 | 70.7 | 54.6 | 355 | 70.2 | 61.2 | |
| 2/05/91 | 69 | 2:30 | | | | 632 | 77.1 | 62.3 | 1185 | 76.4 | 54.5 | 454 | 76.3 | 61.4 | |
| | | | | | | | | | | | | | | | |

| RAIL STRAIN DATA FROM BLUEFIELD, WV | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | |
| NEW SECTION 2 | (Middle Section) | | | | | | High Rail | | | | | | | | |
| Date | Amb | Time | | 1 | Neut | | 2 | Neut | | 3 | Neut | | 4 | Neut | |
| | Temp | | Strain | Temp | Temp | Strain | Temp | Temp | Strain | Temp | Temp | Strain | Temp | Temp | Comments |
| 3/06/90 | | 2:50 | 428 | 99.3 | 71.0 | 404 | 92.2 | 61.3 | 1089 | 98.4 | 43.2 | 828 | 104.0 | | Old Ind. Box (x2.42) |
| 3/07/90 | | 9:30 | -213 | 48.5 | 58.7 | -206 | 47.5 | 53.3 | 503 | 48.8 | 28.8 | 182 | 48.0 | | Old Ind. Box (x2.42) |
| 3/07/90 | | 11:50 | -10 | 66.1 | 64.1 | 0 | 66.2 | 59.6 | 695 | 65.4 | 33.9 | 375 | 66.6 | | Old Ind. Box (x2.42) |
| 4/23/90 | 69 | 10:05 | 2 | 65.3 | 62.6 | 2 | 66.4 | 59.7 | 242 | 65.5 | 61.2 | | | | |
| 4/23/90 | 85 | 12:58 | 562 | 104.4 | 68.0 | 409 | 105.4 | 74.2 | 741 | 105.1 | 70.8 | | | | |
| 4/23/90 | 86 | 2:46 | 480 | 111.6 | 80.2 | 504 | 110.4 | 73.5 | 604 | 112.3 | 86.3 | | | | After STPT's |
| 4/23/90 | 85 | 4:39 | 472 | 113.0 | 82.1 | 406 | 104.4 | 73.4 | 591 | 102.9 | 77.7 | | | | |
| 4/24/90 | 56 | 8:30 | -251 | 57.2 | 69.7 | -207 | 56.8 | 62.6 | 136 | 58.4 | 60.5 | | | | |
| 4/24/90 | 88 | 12:45 | 307 | 104.5 | 83.5 | 362 | 105.0 | 76.6 | 502 | 104.8 | 84.9 | | | | Pre LR Cut |
| 4/24/90 | 87 | 1:15 | 377 | 109.4 | 84.2 | 419 | 109.0 | 77.2 | 573 | 109.8 | 85.6 | | | | After LR Cut |
| 4/24/90 | 87 | 1:35 | -43 | 114.3 | | -110 | 113.7 | | 171 | 112.8 | | | | | After HR Cut |
| 4/24/90 | 85 | 4:25 | -63 | 121.7 | 122.9 | -61 | 104.1 | 101.2 | 207 | 110.8 | 108.6 | | | | After Weld, 2 & 3 Shaded |
| 4/25/90 | 64 | 9:20 | -678 | 64.0 | 102.2 | -655 | 65.0 | 97.8 | -153 | 65.3 | 84.8 | | | | |
| 4/25/90 | 84 | 11:30 | 146 | 98.4 | 87.0 | -125 | 101.6 | 102.5 | 210 | 102.2 | 99.9 | | | | |
| 6/06/90 | 74 | 10:10 | -402 | 66.9 | 88.5 | -360 | 68.2 | 83.2 | | | | | | | Rec. by J. Pietrak (TSC) |
| 6/06/90 | 84 | 11:40 | -15 | 96.7 | 95.0 | 18 | 102.0 | 94.3 | | | | | | | Rec. by J. Pietrak (TSC) |
| 6/06/90 | 92 | 2:25 | 205 | 119.9 | 105.0 | 230 | 122.4 | 102.0 | | | | | | | Rec. by J. Pietrak (TSC) |
| 6/06/90 | 89 | 3:30 | 253 | 126.1 | 108.3 | 261 | 127.7 | 105.4 | | | | | | | Rec. by J. Pietrak (TSC) |
| 6/06/90 | 90 | 5:07 | 179 | 123.4 | 110.1 | 211 | 121.5 | 102.2 | | | | | | | Rec. by J. Pietrak (TSC) |
| 7/03/90 | 65 | 9:30 | -468 | 62.8 | 88.3 | -480 | 61.7 | 83.9 | | | | | | | Rec. by D. Cregger (NS) |
| 7/03/90 | 90 | 12:55 | 80 | 116.4 | 109.0 | | | | | | | | | | Rec. by D. Cregger (NS) |
| 7/30/90 | | 9:44 | -310 | 75.5 | 91.5 | -325 | 76.1 | 89.0 | | | | | | | |
| 7/30/90 | 87 | 11:14 | -74 | 86.5 | 88.4 | -104 | 94.8 | 94.4 | | | | | | | |
| 7/30/90 | 96 | 12:15 | 76 | 103.3 | 96.1 | 2 | 102.7 | 96.0 | | | | | | | |
| 7/30/90 | 90 | 1:15 | 168 | 111.0 | 98.3 | 118 | 113.3 | 99.6 | | | | | | | |
| 7/30/90 | 89 | | 216 | 116.8 | 101.2 | 161 | 117.9 | 101.6 | | | | | | | |
| 7/31/90 | 72 | 8:05am | -327 | 80.5 | 97.6 | -359 | 79.6 | 94.6 | | | | | | | |
| 7/31/90 | 92 | 1:41 | 162 | 112.8 | 100.5 | 131 | 113.9 | 99.4 | | | | | | | |
| 2/04/91 | 70 | 1:50 | | | | 136 | 97.8 | 83.0 | | | | | | | |
| 2/04/91 | 65 | 4:05 | | | | 64 | 89.7 | 79.2 | | | | | | | |
| 2/05/91 | 45 | 8:20 | | | | -480 | 44.0 | 66.2 | | | | | | | |
| 2/05/91 | 54 | 10:00 | | | | -342 | 54.6 | 68.5 | | | | | | | |
| 2/05/91 | 58 | 11:35 | | | | -330 | 62.0 | 75.2 | | | | | | | |
| 2/05/91 | 65 | 12:55 | | | | -115 | 76.9 | 77.2 | | | | | | | |
| 2/05/91 | 69 | 2:30 | | | | -63 | 80.7 | 77.9 | | | | | | | |

| RAIL STRAIN DATA FROM BLUEFIELD, WV | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | |
| NEW SECTION 2 | (Middle Section) | | | | | | Low Rail | | | | | | | | |
| Date | Amb | Time | | 1 | Neut | | 2 | Neut | | 3 | Neut | | 4 | Neut | |
| | Temp | | Strain | Temp | Temp | Strain | Temp | Temp | Strain | Temp | Temp | Strain | Temp | Temp | Comments |
| 3/06/90 | | 2:50 | 411 | 96.0 | 74.9 | 443 | 90.2 | 69.6 | 956 | 97.5 | 76.4 | 278 | 102.0 | 78.4 | Old Ind. Box (x2.42) |
| 3/07/90 | | 9:30 | -244 | 45.6 | 63.9 | -232 | 46.1 | 66.1 | 336 | 45.7 | 61.9 | -387 | 45.0 | 61.3 | Old Ind. Box (x2.42) |
| 3/07/90 | | 11:50 | 39 | 64.5 | 65.8 | 56 | 64.2 | 66.9 | 615 | 64.1 | 63.5 | -123 | 65.5 | 66.0 | Old Ind. Box (x2.42) |
| 4/23/90 | 69 | 10:05 | 63 | 67.8 | 67.6 | 117 | 68.8 | 67.8 | | | | | | | |
| 4/23/90 | 85 | 12:58 | 557 | 102.7 | 72.8 | 494 | 104.4 | 80.7 | | | | | | | |
| 4/23/90 | 86 | 2:46 | 523 | 109.3 | 81.5 | 792 | 109.0 | 67.4 | | | | 372 | 109.8 | 80.5 | After STPT's |
| 4/23/90 | 85 | 4:39 | 502 | 111.3 | 84.7 | 560 | 104.8 | 77.2 | 1043 | 100.0 | 73.7 | 368 | 108.0 | 79.0 | |
| 4/24/90 | 56 | 8:30 | -199 | 57.7 | 73.3 | -125 | 56.4 | 69.9 | 421 | 58.0 | 69.1 | -283 | 56.6 | 66.7 | |
| 4/24/90 | 88 | 12:45 | 431 | 103.0 | 80.7 | 542 | 103.3 | 76.7 | 1026 | 103.2 | 77.9 | 349 | 99.0 | 71.1 | Pre LR Cut, New Plug #4 |
| 4/24/90 | 87 | 1:15 | 60 | 107.5 | | 100 | 107.8 | | 605 | 106.8 | | -115 | 105.7 | | After LR Cut |
| 4/24/90 | 85 | 4:25 | 109 | 117.3 | 114.4 | 145 | 105.7 | 103.0 | 640 | 108.4 | 106.3 | -78 | 115.3 | 113.1 | After Weld, 2 & 3 Shaded |
| 4/25/90 | 64 | 9:20 | -570 | 63.7 | 101.6 | -537 | 64.0 | 102.3 | -14 | 64.7 | 101.9 | -662 | 66.3 | 99.2 | |
| 4/25/90 | 84 | 11:30 | -34 | 97.8 | 103.4 | 26 | 99.5 | 103.9 | 443 | 93.8 | 103.5 | -147 | 100.3 | 102.2 | |
| 6/06/90 | 74 | 10:10 | -82 | 69.9 | 78.4 | 35 | 72.6 | 76.5 | 594 | 77.7 | 78.4 | -71 | 69.4 | 66.8 | Rec. by J. Pietrak (TSC) |
| 6/06/90 | 84 | 11:40 | 227 | 98.4 | 88.4 | 318 | 100.6 | 87.5 | 854 | 102.2 | 87.2 | 136 | 96.8 | 81.7 | Rec. by J. Pietrak (TSC) |
| 6/06/90 | 92 | 2:25 | 428 | 119.0 | 96.9 | 528 | 119.6 | 93.9 | 1017 | 120.1 | 95.3 | 318 | 117.7 | 91.7 | Rec. by J. Pietrak (TSC) |
| 6/06/90 | 89 | 3:30 | 473 | 125.1 | 100.3 | 581 | 125.8 | 96.9 | 1065 | 124.4 | 96.8 | 383 | 125.3 | 95.4 | Rec. by J. Pietrak (TSC) |
| 6/06/90 | 90 | 5:07 | 379 | 121.5 | 102.3 | 481 | 110.4 | 87.5 | 956 | 110.7 | 89.6 | 271 | 108.7 | 85.5 | Rec. by J. Pietrak (TSC) |
| 7/03/90 | 65 | 9:30 | -190 | 62.7 | 77.7 | -108 | 62.2 | 74.7 | 442 | 61.9 | 71.7 | -250 | 61.4 | 69.5 | Rec. by D. Cregger (NS) |
| 7/03/90 | 90 | 12:55 | 356 | 116.9 | 99.1 | 476 | 115.4 | 92.8 | | | | 310 | 114.7 | 89.2 | Rec. by D. Cregger (NS) |
| 7/30/90 | | 9:44am | -5 | 74.0 | 77.9 | 140 | 75.2 | 72.8 | 890 | 75.2 | 58.1 | -22 | 75.1 | 69.5 | Bolted Joint |
| 7/30/90 | 87 | 11:14 | 190 | 89.7 | 81.9 | 274 | 95.4 | 84.9 | 1026 | 96.8 | 71.5 | 50 | 83.3 | 73.4 | Bolted Joint |
| 7/31/90 | 72 | 8:24am | 25 | 76.1 | 78.2 | 103 | 76.2 | 76.0 | | | | -111 | 76.9 | 76.7 | Bolted Joint |
| 2/04/91 | 70 | 1:50 | 582 | 90.6 | 59.2 | | | | | | | 297 | 98.3 | 73.5 | |
| 2/04/91 | 65 | 4:05 | 551 | 90.8 | 61.3 | | | | | | | 290 | 94.1 | 69.8 | |
| 2/05/91 | 45 | 8:20 | -77 | 43.3 | 51.5 | | | | | | | -343 | 43.7 | 57.4 | |
| 2/05/91 | 54 | 10:00 | 73 | 53.1 | 52.3 | | | | | | | -190 | 54.2 | 58.7 | |
| 2/05/91 | 58 | 11:35 | 153 | 60.5 | 54.9 | | | | | | | -102 | 62.2 | 61.4 | |
| 2/05/91 | 65 | 12:55 | 265 | 71.8 | 59.5 | | | | | | | 18 | 72.6 | 64.6 | |
| 2/05/91 | 69 | 2:30 | 372 | 76.7 | 58.0 | | | | | | | 119 | 78.4 | 64.3 | |
| 4/01/91 | 60 | 3:45 | 127 | | | | | | | | | -140 | | | Rail Replaced |
| 4/01/91 | | 4:00 | 129 | | | | | | | | | -141 | | | |

| RAIL STRAIN DATA FROM BLUEFIELD, WV | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | |
| NEW SECTION 3 | | (End Section) | | | | | High Rail | | | | | | | | |
| Date | Amb | Time | | 1 | Neut | | 2 | Neut | | 3 | Neut | | 4 | Neut | |
| | Temp | | Strain | Temp | Temp | Strain | Temp | Temp | Strain | Temp | Temp | Strain | Temp | Temp | Comments |
| 3/05/90 | | 12:30 | 0 | 84.7 | | 31 | 78.5 | 68.2 | 995 | 79.1 | 56.5 | 281 | 78.1 | 52.3 | (x2.42), #1 Taken @ 1:30 |
| 3/06/90 | | 11:00 | -327 | 66.8 | | 29 | 65.2 | 55.0 | 733 | 67.3 | 60.4 | -29 | 60.8 | 53.6 | Old Ind. Box (x2.42) |
| 3/06/90 | | 2:30 | 167 | 97.5 | | 511 | 98.8 | 59.6 | 1227 | 96.1 | 59.6 | 477 | 97.7 | 60.1 | Old Ind. Box (x2.42) |
| 3/07/90 | | 9:00 | -368 | 44.9 | | -121 | 45.5 | 44.3 | 568 | 45.2 | 48.3 | -206 | 45.6 | 49.0 | Old Ind. Box (x2.42) |
| 3/07/90 | | 11:30 | -322 | 67.8 | | 58 | 66.2 | 54.2 | 772 | 68.0 | 58.8 | 34 | 68.4 | 57.4 | Old Ind. Box (x2.42) |
| 4/25/90 | 80 | 10:30 | | | | 157 | 92.3 | 74.4 | 910 | 95.8 | 78.3 | 247 | 98.3 | 74.5 | Wired Direct to Ind. Box |
| 4/25/90 | 88 | 1:24 | 470 | 110.5 | 82.3 | 409 | 111.7 | 78.6 | 1160 | 111.8 | 79.3 | 533 | 113.0 | 72.0 | Wired Direct to Ind. Box |
| 6/06/90 | 74 | 10:10 | 152 | 90.3, | 81.2 | 42 | 96.1 | 85.1 | 775 | 84.7 | 75.3 | 81 | 92.3 | 78.5 | Rec. by J. Pietrak (TSC) |
| 6/06/90 | 84 | 11:40 | 434 | 108.7 | 82.6 | 341 | 110.1 | 81.1 | 1088 | 109.4 | 81.2 | 431 | 111.8 | 76.9 | Rec. by J. Pietrak (TSC) |
| 7/30/90 | | 9:44am | 98 | 78.0 | 72.1 | -52 | 85.7 | 80.4 | 685 | 78.1 | 74.1 | -42 | 83.4 | 77.0 | Bolted Joint |
| 7/30/90 | 87 | 11:14 | 242 | 101.2 | 86.7 | -12 | 99.7 | 91.9 | 636 | 95.8 | 94.8 | -28 | 102.4 | 95.1 | Bolted Joint |
| 7/31/90 | 72 | 8:40 | 0 | 80.1 | | -141 | 81.8 | | 619 | 80.9 | | -149 | 81.2 | | Zero, Joint Unbolted |
| 2/04/91 | 70 | 1:50 | 570 | 92.3 | 58.0 | 455 | 93.3 | 57.5 | 1115 | 90.6 | 60.8 | 351 | 89.8 | 59.8 | |
| 2/04/91 | 65 | 4:05 | 467 | 86.1 | 58.0 | 352 | 85.8 | 56.2 | 1008 | 84.6 | 61.2 | 287 | 85.0 | 58.8 | |
| 2/05/91 | 45 | 8:20 | -81 | 43.4 | 48.3 | -185 | 43.7 | 46.3 | 494 | 43.6 | 51.1 | -280 | 44.1 | 52.0 | |
| 2/05/91 | 65 | 12:55 | 283 | 76.7 | 59.7 | 172 | 77.8 | 59.0 | 833 | 72.1 | 59.2 | 104 | 77.6 | 62.4 | |
| 2/05/91 | 69 | 2:30 | 367 | 80.0 | 57.9 | 266 | 82.1 | 57.6 | 929 | 79.7 | 61.1 | 205 | 81.0 | 59.7 | |
| 4/01/91 | 60 | 3:45 | 77 | | | | | | | | | | | | Rail Replaced |
| 4/01/91 | 60 | 4:00 | 76 | | | | | | | | | | | | |

| RAIL STRAIN DATA FROM BLUEFIELD, WV | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | |
| NEW SECTION 3 | (End Section) | | | | | | Low Rail | | | | | | | | |
| Date | Amb | Time | | 1 | Neut | | 2 | Neut | | 3 | Neut | | 4 | Neut | |
| | Temp | | Strain | Temp | Temp | Strain | Temp | Temp | Strain | Temp | Temp | Strain | Temp | Temp | Comments |
| 3/05/90 | | 12:30 | 15 | 84.0 | 73.3 | -19 | 76.3 | | 511 | 77.5 | 58.1 | 1808 | 75.1 | 63.0 | (x2.42), #1 Taken @ 1:30 |
| 3/06/90 | | 11:00 | -85 | 66.1 | 61.4 | -324 | 66.0 | | 353 | 67.0 | 57.1 | 1607 | 59.6 | 59.5 | Old Ind. Box (x2.42) |
| 3/06/90 | | 2:30 | 261 | 96.5 | 71.0 | -5 | 94.0 | | 673 | 94.2 | 65.1 | 1965 | 92.0 | 70.4 | Old Ind. Box (x2.42) |
| 3/07/90 | | 9:00 | -477 | 45.2 | 64.1 | -610 | 44.1 | | 82 | 43.6 | 50.0 | 1297 | 43.8 | 62.4 | Old Ind. Box (x2.42) |
| 3/07/90 | | 11:30 | -133 | 64.6 | 62.8 | -353 | 66.4 | | 332 | 67.9 | 59.2 | 1638 | 68.1 | 66.2 | Old Ind. Box (x2.42) |
| 4/25/90 | 80 | 10:30 | -32 | 92.4 | 84.5 | | | | 442 | 94.2 | 78.9 | 1850 | 97.2 | 82.5 | Wired Direct to Ind. Box |
| 4/25/90 | 88 | 1:24 | 218 | 109.9 | 87.0 | | | | 679 | 110.6 | 81.1 | 2138 | 112.0 | 80.0 | Wired Direct to Ind. Box |
| 6/06/90 | 74 | 10:10 | 48 | 90.4 | 77.7 | | | | 462 | 90.6 | 74.1 | | | 96.5 | Rec. by J. Pietrak (TSC) |
| 6/06/90 | 84 | 11:40 | 214 | 106.1 | 83.4 | | | | 674 | 109.8 | 80.6 | 2136 | 110.4 | 78.5 | Rec. by J. Pietrak (TSC) |
| 7/30/90 | | 9:44am | -74 | 83.0 | 77.7 | | | | 329 | 78.2 | 69.7 | 1742 | 84.9 | 76.7 | |
| 7/30/90 | 84 | 10:44 | -163 | 95.2 | | | | | 188 | 83.5 | | 1606 | 95.3 | | After Cut, Anchors Off |
| 7/30/90 | 87 | 11:14 | -88 | 103.3 | 98.8 | | | | 272 | 97.3 | 92.3 | 1736 | 105.7 | 97.9 | Bolted Joint |
| 2/04/91 | 70 | 1:50 | 241 | 86.4 | 62.1 | | | | 440 | 86.4 | 71.3 | 1854 | 84.3 | 69.4 | |
| 2/04/91 | 65 | 4:05 | 203 | 84.9 | 62.9 | | | | 393 | 81.1 | 68.8 | 1807 | 81.7 | 69.6 | |
| 2/05/91 | 45 | 8:20 | -334 | 42.9 | 53.2 | | | | -81 | 43.0 | 59.2 | 1283 | 42.7 | 62.1 | |
| 2/05/91 | 65 | 12:55 | 14 | 70.7 | 60.1 | | | | 234 | 74.6 | 71.8 | 1661 | 71.3 | 68.0 | |
| 2/05/91 | 69 | 2:30 | 109 | 77.1 | 60.8 | | | | 317 | 77.7 | 69.9 | 1750 | 77.8 | 69.1 | |
| 4/01/91 | 60 | 3:45 | | | | | | | | | | 1503 | | | Rail Replaced |
| 4/01/91 | 60 | 4:00 | | | | | | | | | | 1502 | | | |

| Rail Movement | | | | Section 1 | | Santa Fe | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | |
| Date | Amb | Time | | W1 | | | | Wc | | | | W4 | | | |
| | Temp | | HR | LR | W | dW | HR | LR | W | dW | HR | LR | W | dW | Comments |
| | | | | | | | | | | | | | | | |
| 2/14/90 | 37 | 9:00 | 0.00 | 0.00 | 92.5 | | 0.00 | 0.00 | 89.5 | | 0.00 | 0.00 | 88.5 | | |
| 4/02/90 | | | -3.06 | -2.75 | 91.5 | -1.0 | 0.19 | -0.94 | 89.0 | -0.5 | -1.31 | -1.94 | 87.1 | -1.4 | |
| 4/03/90 | | 9:45 | | | 91.6 | -0.9 | | | 89.0 | -0.5 | | | 87.0 | -1.5 | |
| 4/04/90 | | 9:30 | 1.63 | | 91.6 | -0.9 | -1.88 | | 89.3 | -0.3 | -2.00 | | 87.0 | -1.5 | Before High Rail Cut |
| 4/04/90 | | 10:30 | 1.06 | | 91.5 | -1.0 | -1.75 | | 89.1 | -0.4 | -2.06 | | 87.0 | -1.5 | After High Rail Cut |
| 6/27/90 | 60 | 5:40am | | | 89.5 | -3.0 | | | 88.1 | -1.4 | | | 86.9 | -1.6 | |
| 6/27/90 | 65 | 6:40 | | | 89.3 | -3.2 | | | 87.8 | -1.7 | | | 86.9 | -1.6 | |
| 6/27/90 | 68 | 7:12 | | | 89.0 | -3.5 | | | 88.1 | -1.4 | | | 87.1 | -1.4 | |
| 6/27/90 | 84 | 8:25 | | | 89.3 | -3.2 | | | 87.6 | -1.9 | | | 86.9 | -1.6 | |
| 6/27/90 | 89 | 9:29 | | | 89.0 | -3.5 | | | 88.3 | -1.2 | | | 87.1 | -1.4 | |
| 6/27/90 | 92 | 10:33 | | | 89.0 | -3.5 | | | 88.3 | -1.2 | | | 86.4 | -2.1 | |
| 6/27/90 | 95 | 12:00 | | | 88.8 | -3.7 | | | 88.1 | -1.4 | | | 87.1 | -1.4 | |
| 6/27/90 | 98 | 1:00 | | | 89.0 | -3.5 | | | 88.1 | -1.4 | | | 86.9 | -1.6 | |
| 6/27/90 | 105 | 2:00 | | | 89.0 | -3.5 | | | 87.6 | -1.9 | | | 86.9 | -1.6 | |
| 6/27/90 | 95 | 2:55 | | | 89.0 | -3.5 | | | 87.8 | -1.7 | | | 86.4 | -2.1 | |
| 7/24/90 | | 9:45 | | | 89.5 | -3.0 | | | 88.5 | -1.0 | | | 87.3 | -1.3 | |
| 7/24/90 | | 11:10 | | | 89.4 | -3.1 | | | 88.4 | -1.1 | | | 87.0 | -1.5 | |
| 7/24/90 | | 12:12 | | | 89.5 | -3.0 | | | 88.8 | -0.8 | | | 87.3 | -1.3 | |
| 7/24/90 | | 1:09 | | | 89.5 | -3.0 | | | 88.5 | -1.0 | | | | | |
| 7/25/90 | | 8:00am | | | 89.8 | -2.8 | | | 88.5 | -1.0 | | | 87.5 | -1.0 | |
| 1/29/91 | 32 | 9:40 | | | 90.8 | -1.7 | | | 92.1 | 2.6 | | | 87.3 | -1.2 | New Measurement Devic |
| 1/29/91 | 38 | 1:40 | | | 90.8 | -1.7 | | | 92.5 | 3.0 | | | 87.1 | -1.4 | |
| 1/30/91 | 39 | 9:00 | | | 91.0 | -1.5 | | | 92.3 | 2.8 | | | 87.3 | -1.2 | |
| 1/30/91 | 52 | 1:00 | | | 90.6 | -1.9 | | | 92.4 | 2.9 | | | 87.8 | -0.7 | |
| 1/30/91 | 52 | 3:05 | | | 90.8 | -1.7 | | | 92.1 | 2.6 | | | 87.3 | -1.2 | |
| 4/03/91 | 89 | 9:50am | | | 91.0 | -1.5 | | | 92.6 | 3.1 | | | 87.5 | -1.0 | |
| 4/03/91 | 73 | 12:25 | | | 91.0 | -1.5 | | | 92.6 | 3.1 | | | 87.5 | -1.0 | |
| 4/03/91 | 69 | 3:30 | | | 90.9 | -1.6 | | | 92.6 | 3.1 | | | 87.3 | -1.2 | |
| 4/04/91 | 51 | 8:45am | | | 90.8 | -1.7 | | | 92.5 | 3.0 | | | 87.3 | -1.2 | |
| 4/04/91 | 74 | 1:25 | | | 90.8 | -1.7 | | | 92.5 | 3.0 | | | 87.3 | -1.2 | |
| 5/22/91 | | 9:55 | | | 90.5 | -2.0 | | | 92.4 | 2.9 | | | 87.6 | -0.9 | |
| 5/22/91 | | 12:00 | | | 90.8 | -1.7 | | | 92.5 | 3.0 | | | 87.5 | -1.0 | |
| 5/22/91 | | 3:50 | | | 90.5 | -2.0 | | | 92.3 | 2.8 | | | 87.3 | -1.2 | |
| 7/16/91 | | 10:40 | | | 90.8 | -1.7 | | | 92.5 | 3.0 | | | 87.6 | -0.9 | |
| 7/16/91 | | 1:00 | | | 90.8 | -1.7 | | | 92.6 | 3.1 | | | 87.8 | -0.7 | |
| 7/17/91 | | 9:30 | | | 90.9 | -1.6 | | | 92.5 | 3.0 | | | 87.8 | -0.7 | |
| 7/17/91 | | 12:30 | | | 90.5 | -2.0 | | | 92.5 | 3.0 | | | 87.8 | -0.7 | |
| 8/15/91 | | 9:15 | | | 90.5 | -2.0 | | | 92.5 | 3.0 | | | 87.5 | -1.0 | |
| 8/15/91 | | 1:30 | | | 90.6 | -1.9 | | | 92.5 | 3.0 | | | 87.8 | -0.7 | |

| | | | Section 2 | | Santa Fe | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | |
| Date | Amb | Time | | W1 | | | | Wc | | | | W4 | | | |
| | Temp | | HR | LR | W | dW | HR | LR | W | dW | HR | LR | W | dW | Comments |
| 2/14/90 | 37 | 9:10 | 0.00 | 0.00 | 69.5 | | 0.00 | 0.00 | 86.6 | | 0.00 | 0.00 | 74.0 | | |
| 4/02/90 | | | 0.63 | 0.31 | 69.8 | 0.3 | -2.44 | -1.84 | 86.3 | -0.3 | -0.81 | -0.47 | 74.3 | 0.3 | |
| 4/03/90 | | 9:45 | | | 70.0 | 0.5 | | | 86.3 | -0.3 | | | 74.3 | 0.3 | |
| 4/03/90 | | 1:00 | 1.63 | 0.81 | | | -2.03 | -1.63 | | | -1.38 | -0.78 | | | Before High Rail Cut |
| 4/03/90 | | 1:30 | 1.34 | 0.75 | | | -2.25 | -1.66 | | | -1.66 | -0.94 | | | After High Rail Cut |
| 4/03/90 | | 2:34 | 1.31 | 0.75 | | | -2.34 | -1.66 | | | -1.72 | -0.91 | | | Before Low Rail Cut |
| 4/03/90 | | 2:48 | 1.31 | 0.75 | | | -2.31 | -1.69 | | | -1.75 | -0.91 | | | After Low Rail Cut |
| 6/27/90 | | 5:40am | | | 69.4 | -0.1 | | | 85.9 | -0.7 | | | 74.2 | 0.2 | |
| 6/27/90 | | 6:40 | | | 69.8 | 0.3 | | | | | | | | | |
| 6/27/90 | | 7:12 | | | 69.6 | 0.1 | | | 86.4 | -0.2 | | | 74.4 | 0.4 | |
| 6/27/90 | | 8:25 | | | 70.1 | 0.6 | | | 85.9 | -0.7 | | | 74.4 | 0.4 | |
| 6/27/90 | | 9:29 | | | | | | | | | | | | | |
| 6/27/90 | | 10:33 | | | 69.6 | 0.1 | | | 86.4 | -0.2 | | | 74.4 | 0.4 | |
| 6/27/90 | | 12:00 | | | 70.1 | 0.6 | | | 86.4 | -0.2 | | | 74.4 | 0.4 | |
| 6/27/90 | | 1:00 | | | 70.6 | 1.1 | | | 86.4 | -0.2 | | | 74.4 | 0.4 | |
| 6/27/90 | | 2:00 | | | 70.1 | 0.6 | | | 86.6 | 0.0 | | | 74.4 | 0.4 | |
| 6/27/90 | | 2:55 | | | 69.8 | 0.3 | | | 86.4 | -0.2 | | | 74.4 | 0.4 | |
| 7/24/90 | 81.3 | 9:45 | | | 69.3 | -0.3 | | | 86.4 | -0.2 | | | 74.4 | 0.4 | |
| 7/24/90 | 78 | 11:10 | | | 69.9 | 0.4 | | | 86.3 | -0.3 | | | 74.4 | 0.4 | |
| 7/24/90 | 83 | 12:12 | | | 69.8 | 0.3 | | | 86.4 | -0.2 | | | 74.3 | 0.3 | |
| 7/25/90 | 73 | 8:00am | | | 69.8 | 0.3 | | | 86.5 | -0.1 | | | 74.8 | 0.8 | |
| | | | | | | | | | | | | | | | |
| 1/29/91 | 32 | 9:40am | | | 69.3 | -0.2 | | | 86.0 | -0.6 | | | 74.1 | 0.1 | |
| 1/29/91 | 38 | 1:40 | | | 69.3 | -0.2 | | | 86.0 | -0.6 | | | 74.4 | 0.4 | |
| 1/30/91 | 39 | 9:00am | | | 69.3 | -0.2 | | | 86.0 | -0.6 | | | 74.5 | 0.5 | |
| 1/30/91 | 52 | 1:00 | | | 69.6 | 0.1 | | | 86.3 | -0.3 | | | 74.8 | 0.8 | |
| 1/30/91 | 52 | 3:05 | | | 69.7 | 0.2 | | | 86.1 | -0.5 | | | 74.9 | 0.9 | |
| | | | | | | | | | | | | | | | |
| 4/03/91 | 64.9 | 9:45am | | | 69.8 | 0.3 | | | 86.4 | -0.2 | | | 74.3 | 0.3 | |
| 4/03/91 | 73.3 | 12:25 | | | 69.8 | 0.3 | | | 86.4 | -0.2 | | | 74.5 | 0.5 | |
| 4/03/91 | | 3:30 | | | 69.8 | 0.3 | | | 86.3 | -0.3 | | | 74.8 | 0.8 | |
| 4/04/91 | | 8:45am | | | 69.8 | 0.3 | | | 86.2 | -0.4 | | | 74.8 | 0.8 | |
| 4/04/91 | | 1:25 | | | 69.8 | 0.3 | | | 86.3 | -0.3 | | | 74.8 | 0.8 | |
| 5/22/91 | | 9:55 | | | 69.8 | 0.3 | | | 86.0 | -0.6 | | | 74.5 | 0.5 | |
| 5/22/91 | | 12:00 | | | 70.0 | 0.5 | | | 86.3 | -0.3 | | | 74.8 | 0.8 | |
| 5/22/91 | | 3:50 | | | 70.2 | 0.7 | | | 86.8 | 0.2 | | | 74.8 | 0.8 | |
| 7/16/91 | | 10:40 | | | 70.0 | 0.5 | | | 86.3 | -0.3 | | | 74.8 | 0.8 | |
| 7/16/91 | | 1:00 | | | 70.0 | 0.5 | | | 86.4 | -0.2 | | | 74.8 | 0.8 | |
| 7/17/91 | | 9:30 | | | 70.0 | 0.5 | | | 86.1 | -0.5 | | | 74.6 | 0.6 | |
| 7/17/91 | | 12:30 | | | 69.9 | 0.4 | | | 86.5 | -0.1 | | | 74.8 | 0.8 | |
| 8/15/91 | | 9:15 | | | 69.9 | 0.4 | | | 86.4 | -0.2 | | | 74.8 | 0.8 | |
| 8/15/91 | | 1:30 | | | 69.9 | 0.4 | | | 86.6 | 0.0 | | | 74.6 | 0.6 | |

| Section 3 | | Sante Fe | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | W1 | | | Wc | | | W4 | | |
| Date | Amb | Time | | | | | | | | | | |
| | Temp | | | W | dW | | W | dW | | W | dW | Comments |
| 2/14/90 | 38 | 9:20 | | 103.5 | 0.0 | | 125.0 | 0.0 | | 96.0 | 0.0 | |
| 4/02/90 | | | | 103.8 | 0.3 | | 126.3 | 1.3 | | 96.3 | 0.3 | |
| 4/03/90 | | 9:45 | | 103.5 | 0.0 | | 124.8 | -0.3 | | 96.4 | 0.4 | |
| 7/24/90 | 81 | 9:45 | | 103.8 | 0.3 | | 125.3 | 0.3 | | 96.5 | 0.5 | |
| 7/24/90 | 78 | 11:10 | | 103.8 | 0.3 | | 125.3 | 0.3 | | 96.5 | 0.5 | |
| 7/24/90 | 83 | 12:12 | | 103.8 | 0.3 | | 125.3 | 0.3 | | 96.5 | 0.5 | |
| 7/25/90 | 73 | 8:00am | | 103.8 | 0.3 | | 125.5 | 0.5 | | 96.8 | 0.8 | |
| 1/29/91 | 32 | 9:40 | | 103.3 | -0.2 | | 124.8 | -0.2 | | 96.1 | 0.1 | New Measurement Device |
| 1/29/91 | 38 | 1:40 | | 103.1 | -0.4 | | 125.1 | 0.1 | | 96.4 | 0.4 | |
| 1/30/91 | 39 | 9:00 | | 103.3 | -0.2 | | 125.0 | 0.0 | | 96.1 | 0.1 | |
| 1/30/91 | 52 | 1:00 | | 103.4 | -0.1 | | 125.4 | 0.4 | | 95.9 | -0.1 | |
| 1/30/91 | 52 | 3:05 | | 103.4 | -0.1 | | 125.9 | 0.9 | | 96.5 | 0.5 | |
| 4/03/91 | 89 | 9:50 | | 103.8 | 0.3 | | 125.3 | 0.3 | | 96.1 | 0.1 | |
| 4/03/91 | 73 | 12:25 | | 103.8 | 0.3 | | 125.4 | 0.4 | | 96.3 | 0.3 | |
| 4/03/91 | 69 | 3:30 | | 103.8 | 0.3 | | 125.5 | 0.5 | | 96.3 | 0.3 | |
| 4/04/91 | 51 | 8:45 | | 103.5 | 0.0 | | 125.5 | 0.5 | | 96.4 | 0.4 | |
| 4/04/91 | 74 | 1:25 | | 103.4 | -0.1 | | 125.6 | 0.6 | | 96.4 | 0.4 | |
| 5/22/92 | | 9:55 | | 103.2 | -0.3 | | 125.0 | 0.0 | | 95.9 | -0.1 | |
| 5/22/92 | | 12:00 | | 103.3 | -0.2 | | 125.2 | 0.2 | | 96.0 | 0.0 | |
| 5/22/92 | | 3:50 | | 103.4 | -0.1 | | 125.3 | 0.3 | | 96.4 | 0.4 | |
| 7/16/91 | | 10:40 | | 103.5 | 0.0 | | 125.3 | 0.3 | | 96.4 | 0.4 | |
| 7/16/91 | | 1:00 | | 103.5 | 0.0 | | 125.3 | 0.3 | | 96.4 | 0.4 | |
| 7/17/91 | | 9:30 | | 103.8 | 0.3 | | 125.4 | 0.4 | | 96.4 | 0.4 | |
| 7/17/91 | | | | 103.6 | 0.1 | | 125.2 | 0.2 | | 96.4 | 0.4 | |
| 8/15/91 | | 9:15 | | 103.6 | 0.1 | | 125.2 | 0.2 | | 96.3 | 0.3 | |
| 8/15/91 | | 1:30 | | 103.8 | 0.3 | | 125.4 | 0.4 | | 96.4 | 0.4 | |

| Rail Movement | | | Bluefield, WV | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| TS1 | | | | | | | | | |
| Date | Amb | Time | | | | | | | |
| | Temp | | W1 | dW | Wc | dW | W4 | dW | Comments |
| | | | | | | | | | |
| 3/05/90 | | 4:45 | 62.3 | | 62.0 | | 62.3 | | Reference Values |
| 3/06/90 | | 4:00 | 61.2 | -1.0 | 60.1 | -1.9 | 60.1 | -2.2 | |
| 3/07/90 | | 10:15 | 61.1 | -1.2 | 60.1 | -2.0 | 60.0 | -2.3 | |
| 4/23/90 | 79 | 11:40 | 61.0 | -1.3 | 59.6 | -2.4 | 60.5 | -1.8 | |
| 4/23/90 | 85 | 12:30 | | | | | | | After Lining and Tamping |
| 4/23/90 | 85 | 12:30 | | | 60.3 | | | | Ref Peg Wc Moved |
| 4/23/90 | 88 | 12:40 | | | 61.9 | | 62.3 | 0.0 | Wc Peg Moved Again |
| 4/23/90 | 85 | 4:23 | 62.3 | 0.0 | 60.1 | | 62.8 | 0.5 | |
| 4/24/90 | 58 | 9:00 | 62.0 | -0.3 | 59.3 | | 62.0 | -0.3 | |
| 4/24/90 | 65 | 9:15 | | | 59.1 | | | | New Wc Ref Point |
| 4/24/90 | 80 | 10:50 | | | 59.1 | 0.0 | | | After Both Rails Cut |
| 4/24/90 | 90 | 2:20 | 62.0 | -0.3 | 59.5 | 0.4 | 62.1 | -0.1 | After Welding, Anchors On |
| 4/25/90 | 68 | 9:45 | 61.8 | -0.5 | 59.0 | -0.1 | 61.6 | -0.6 | Wc Peg Questionable |
| 6/06/90 | 72 | 9:30 | 61.5 | -0.8 | 58.5 | -0.6 | 61.5 | -0.8 | Rec. by J. Pietrak (TSC) |
| 6/06/90 | 92 | 2:45 | 62.0 | -0.3 | 57.8 | -1.4 | 61.8 | -0.5 | Rec. by J. Pietrak (TSC) |
| 6/06/90 | 89 | 3:40 | 62.0 | -0.3 | 57.9 | -1.3 | 62.0 | -0.3 | Rec. by J. Pietrak (TSC) |
| 6/06/90 | 90 | 4:30 | 62.0 | -0.3 | 57.9 | -1.3 | 61.8 | -0.5 | Rec. by J. Pietrak (TSC) |
| 7/30/90 | 96 | 12:15 | 62.0 | -0.3 | 59.0 | -0.1 | 62.5 | 0.3 | Wc Reference Peg Bent |
| 2/04/91 | 67 | 3:00 | 61.6 | -0.6 | 58.0 | -1.1 | 62.5 | 0.3 | New Measurement Device |
| 2/05/91 | 48 | 9:00 | 61.4 | -0.9 | 58.3 | -0.8 | 62.9 | 0.6 | |
| 2/05/91 | 66 | 1:20 | 62.0 | -0.3 | 59.0 | -0.1 | 62.9 | 0.6 | |

| Rail Movement | | | Bluefield, WV | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| NEW TS2 | | | | | | | | | |
| Date | Amb | Time | | | | | | | |
| | Temp | | W | dW | W | dW | W | dW | Comments |
| | | | | | | | | | |
| 3/05/90 | | 4:45 | 52.3 | | 60.5 | | 65.0 | | Reference Values |
| 3/06/90 | | 3:45 | 51.4 | -0.9 | 59.5 | -1.0 | 64.3 | -0.7 | |
| 3/07/90 | | 10:30 | 51.2 | -1.1 | 59.3 | -1.2 | 63.9 | -1.1 | |
| 4/23/90 | 79 | 11:06 | | | 59.3 | -1.3 | | | During STPT's |
| 4/23/90 | 86 | 3:49 | 50.6 | -1.6 | 59.8 | -0.8 | 64.4 | -0.6 | After STPT's |
| 4/23/90 | 85 | 4:42 | 50.6 | -1.6 | 60.0 | -0.5 | 64.5 | -0.5 | |
| 4/24/90 | 56 | 8:30 | 50.0 | -2.3 | 59.6 | -0.9 | 64.3 | -0.8 | |
| 4/24/90 | 88 | 12:50 | | | | | 64.3 | -0.8 | New Top Points, Pre-Cuts |
| 4/24/90 | 87 | 1:35 | | | | | | | After Cuts |
| 4/24/90 | 85 | 4:25 | 49.4 | -2.9 | 59.5 | -1.0 | 64.5 | -0.5 | After Weld, Anchors On |
| 4/25/90 | 67 | 9:45 | 49.9 | -2.4 | 59.4 | -1.1 | 64.0 | -1.0 | |
| 6/06/90 | 72 | 9:15 | 49.8 | -2.5 | 59.3 | -1.3 | 64.0 | -1.0 | Rec. by J. Pietrak (TSC) |
| 6/06/90 | 92 | 2:45 | 50.1 | -2.1 | 59.5 | -1.0 | 64.3 | -0.8 | Rec. by J. Pietrak (TSC) |
| 6/06/90 | 89 | 3:40 | 50.0 | -2.3 | 59.5 | -1.0 | 64.3 | -0.8 | Rec. by J. Pietrak (TSC) |
| 6/06/90 | 90 | 4:30 | 50.0 | -2.3 | 59.5 | -1.0 | 64.5 | -0.5 | Rec. by J. Pietrak (TSC) |
| 7/30/90 | 96 | 12:15 | 51.0 | -1.3 | 59.5 | -1.0 | 64.3 | -0.8 | |
| 7/31/90 | 92 | 1:41 | 51.0 | -1.3 | 59.1 | -1.4 | 64.0 | -1.0 | Wc reference pin bent |
| 7/31/90 | 67 | 3:00 | 50.8 | -1.5 | 59.3 | -1.2 | 64.1 | -0.9 | New Measurement Device |
| 2/05/91 | 48 | 9:00 | 50.9 | -1.4 | 59.0 | -1.5 | 63.8 | -1.2 | |
| 2/05/91 | 66 | 1:20 | 51.0 | -1.3 | 59.4 | -1.1 | 63.9 | -1.1 | |

| NEW SECTION 3 | | (End Section) | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Date | Amb | Time | | | | | | | |
| | Temp | | W | dW | W | dW | W | dW | Comments |
| 3/05/90 | | 4:45 | 64.8 | | 65.8 | | 89.3 | | Reference Values |
| 3/06/90 | | 9:30 | 63.5 | -1.3 | 64.3 | -1.5 | 89.3 | 0.0 | |
| 3/06/90 | | 3:15 | 63.6 | -1.2 | 64.7 | -1.1 | 89.6 | 0.4 | |
| 3/07/90 | | 10:45 | 63.5 | -1.3 | 64.3 | -1.5 | 88.4 | -0.8 | |
| 4/25/90 | 80 | 10:30 | 63.4 | -1.4 | 64.6 | -1.1 | 88.5 | -0.8 | |
| 4/25/90 | 87 | 2:38 | 63.5 | -1.3 | 64.9 | -0.9 | 88.6 | -0.6 | |
| 6/06/90 | 72 | 9:30 | 63.4 | -1.4 | 64.5 | -1.3 | 88.4 | -0.8 | |
| 6/06/90 | 92 | 2:45 | 63.8 | -1.0 | 64.8 | -1.0 | 88.5 | -0.8 | |
| 6/06/90 | 89 | 3:40 | 63.8 | -1.0 | 64.8 | -1.0 | 88.5 | -0.8 | |
| 6/06/90 | 90 | 4:30 | 63.8 | -1.0 | 64.8 | -1.0 | 88.8 | -0.5 | |
| 7/31/90 | 92 | 1:41 | 63.5 | -1.3 | 64.8 | -1.0 | 87.8 | -1.5 | |
| 2/04/91 | 67 | 3:00 | 63.3 | -1.5 | 65.1 | -0.7 | 88.4 | -0.8 | New Measurement Device |
| 2/05/91 | 48 | 9:00 | 63.6 | -1.2 | 64.9 | -0.8 | 88.1 | -1.2 | |
| 2/05/91 | 66 | 1:20 | 63.8 | -1.0 | 65.1 | -0.7 | 87.9 | -1.3 | |

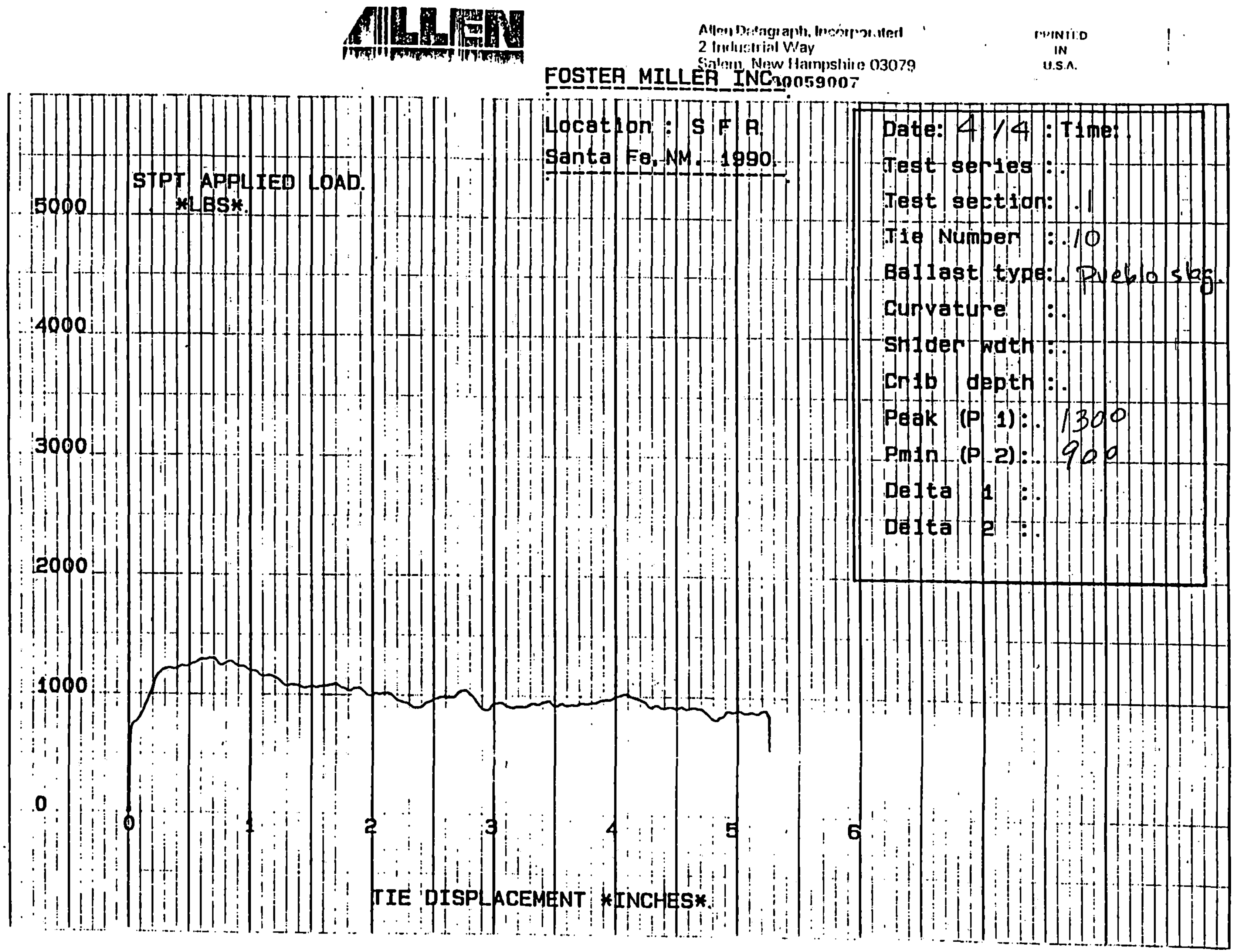


**Figure B-1. Typical Low Resistance STPT**

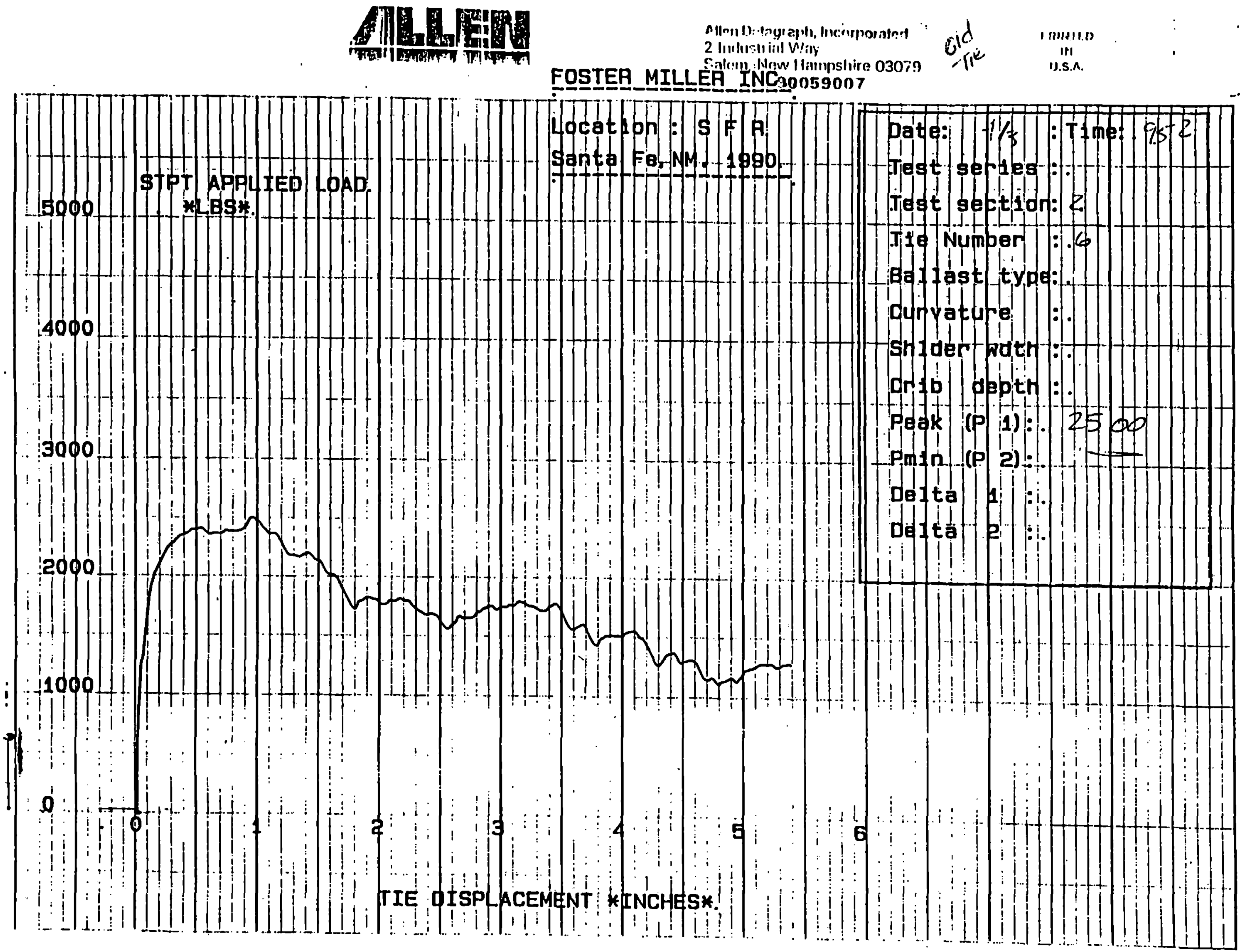


**Figure B-2. Typical Average Resistance STPT**

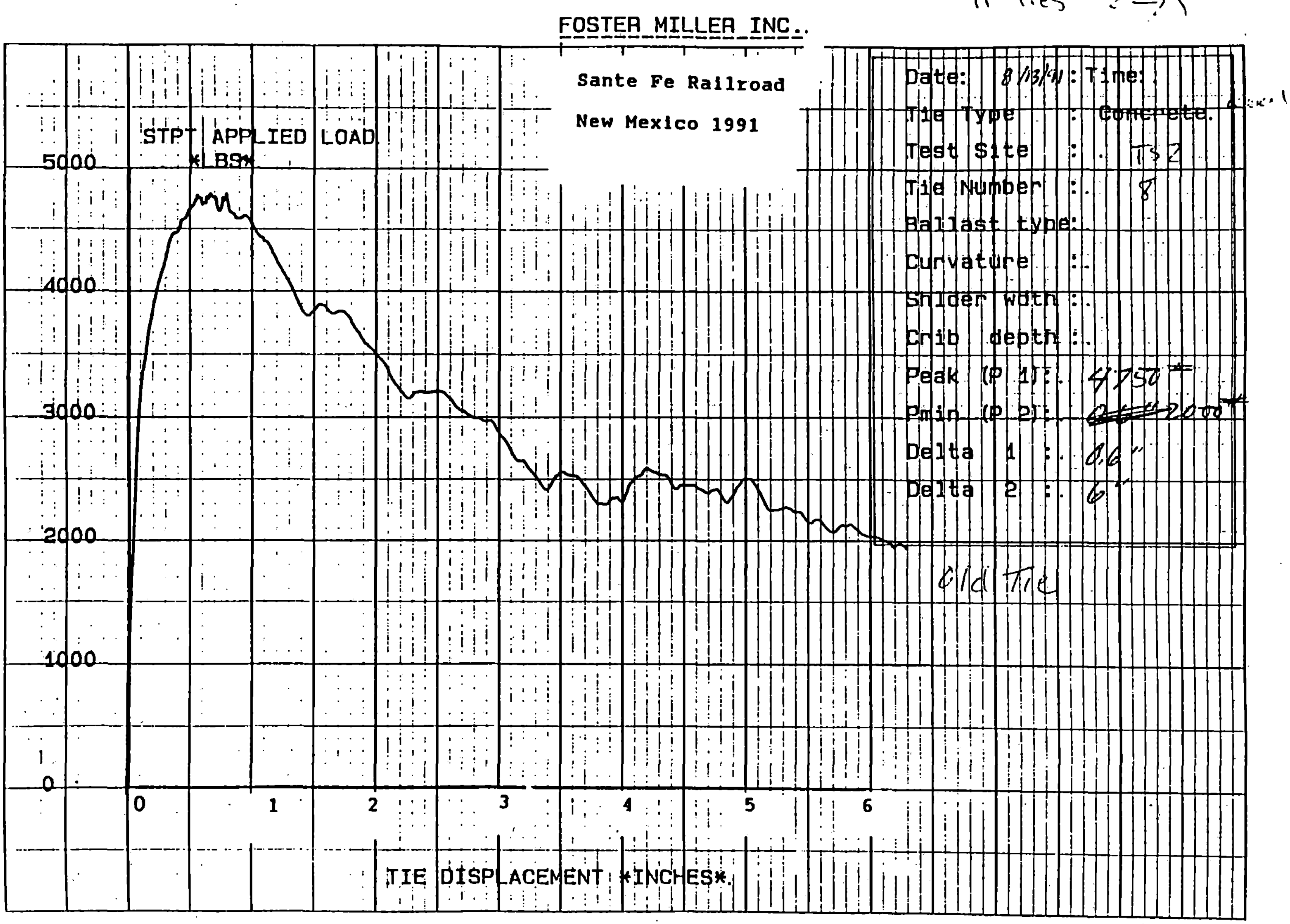


Figure B-2. Typical High Resistance STPT

## APPENDIX C

**Site Photographs: Santa Fe, NM**

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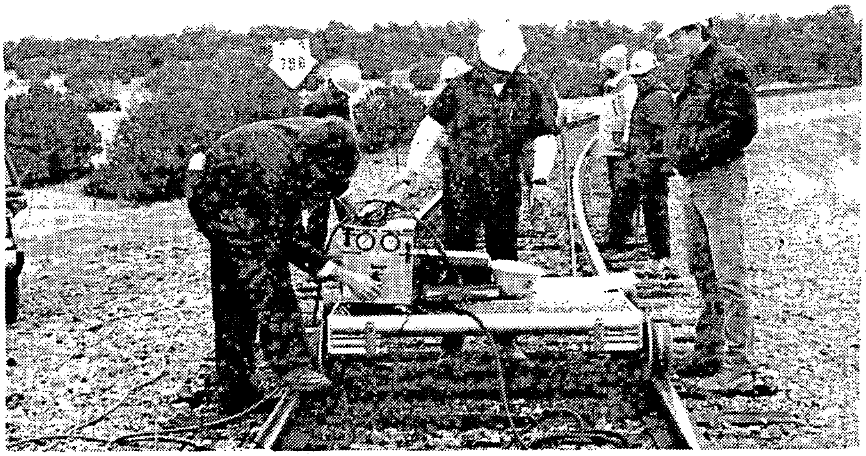

**Figure C-1. STPT Operation**


**Figure C-2. STPT Device**

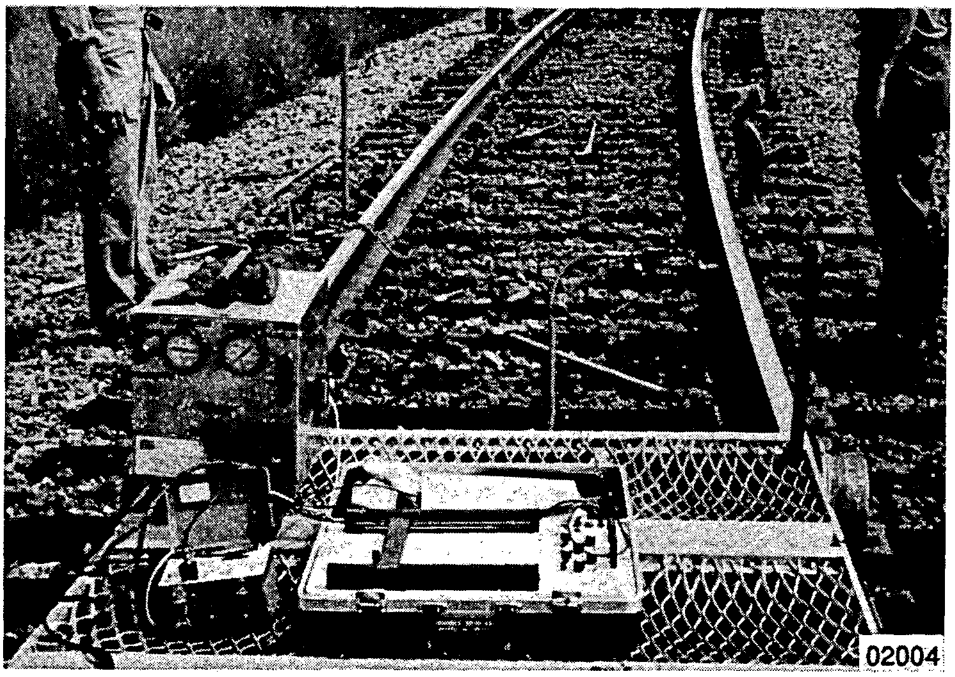


**Figure C-3. STPT Data Acquisition**

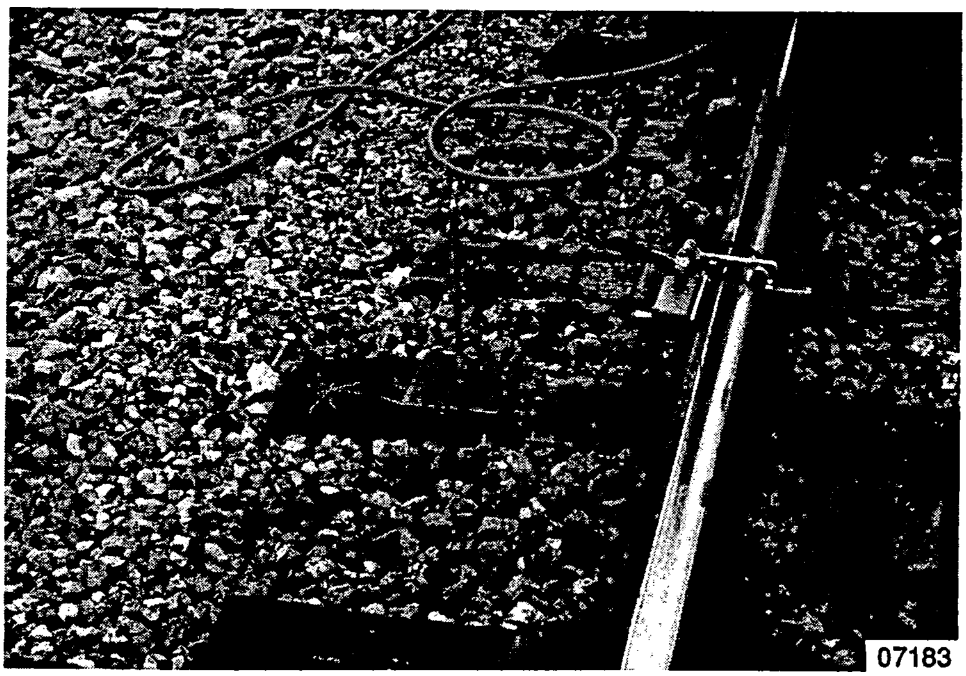


**Figure C-4. STPT Deflection Measurement**

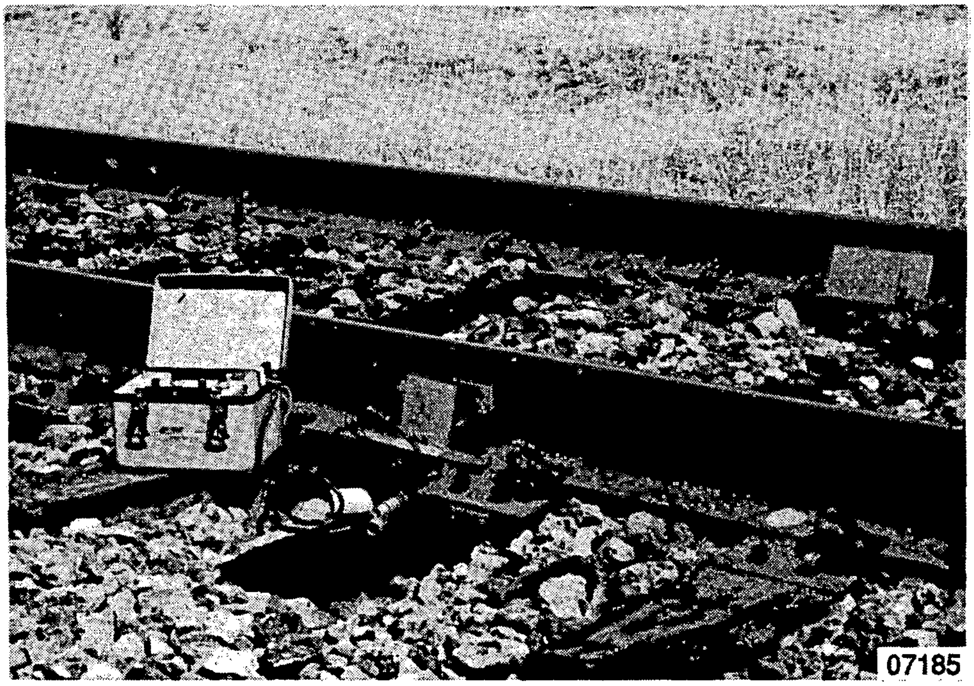


**Figure C-5. Strain Gauge Data Acquisition**


**Figure C-6. Tamping in TSI**

**Figure C-7. Cutting the Low Rail in TS3**

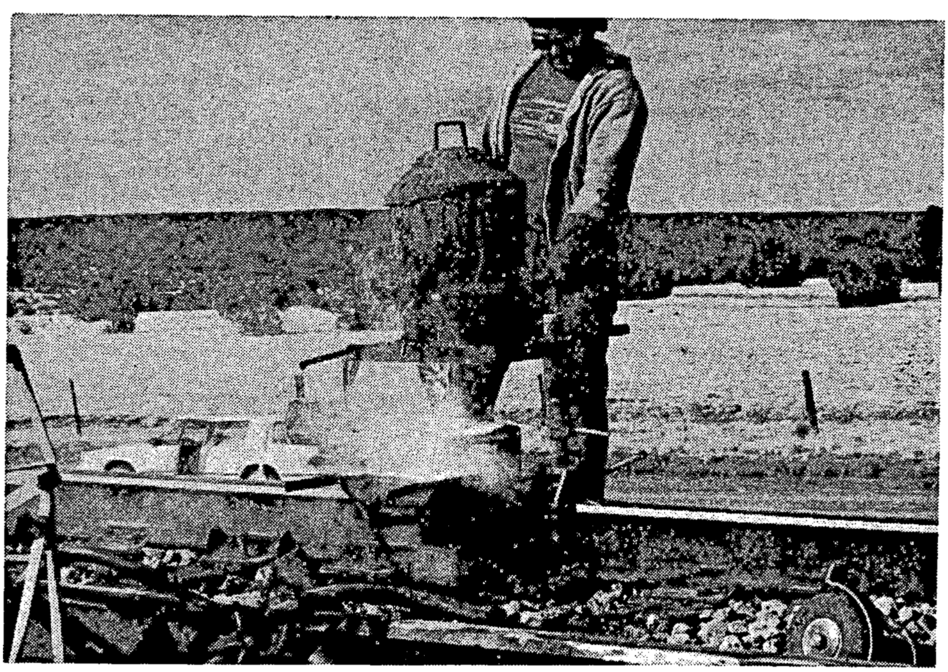

**Figure C-8. Welding the High Rail in TS1**

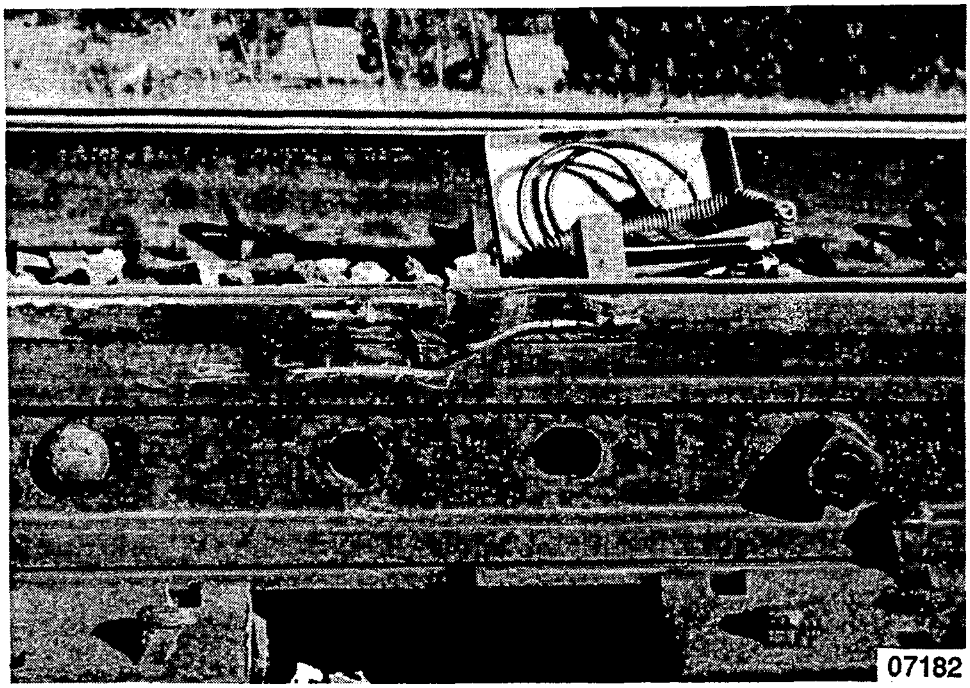


**Figure C-9. Open Gap at Bolted Rail Joint**

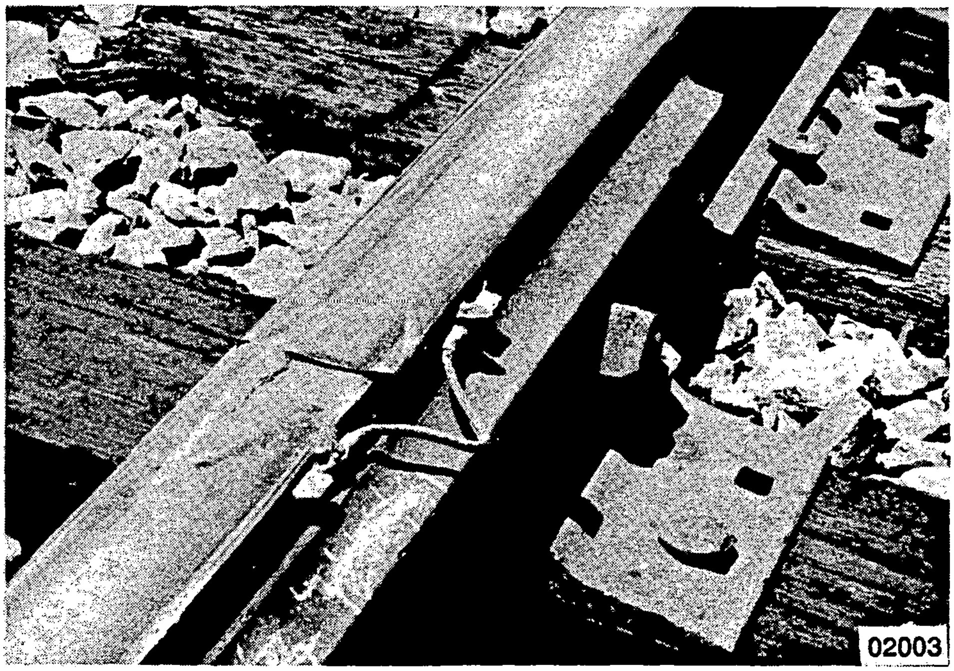


**Figure C-10. Closed Gap at Bolted Rail Joint**

**Figure D-1. Rough Grinding of Rail for Strain Gauge Application**

**Figure D-2. Fine Grinding of Rail for Strain Gauge Application**

**Figure D-3. Welding of Strain Gauge to Rail Neutral Axis**

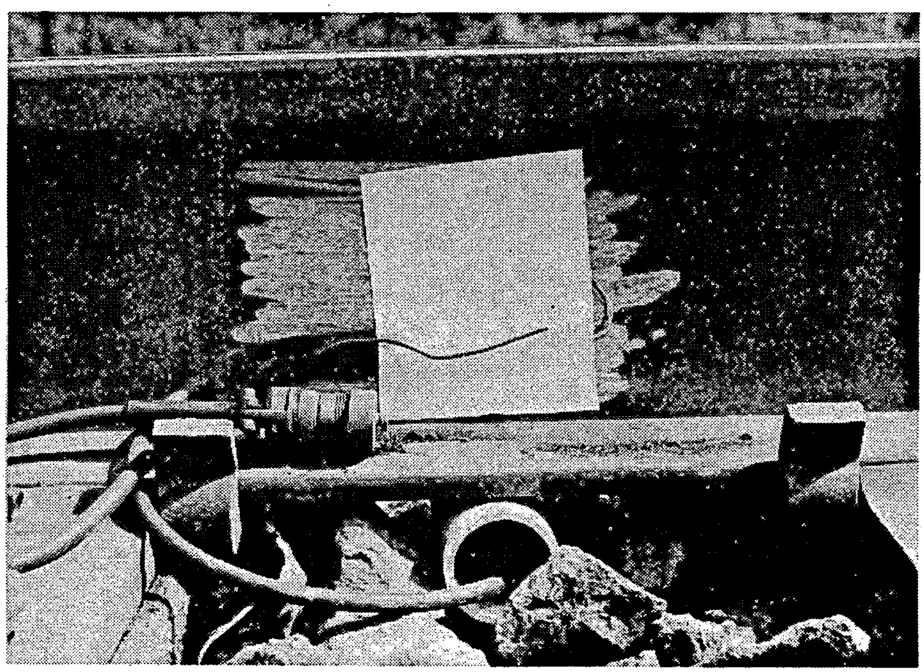

**Figure D-4. Strain Gauge after Application and Weatherproofing**

**FOSTER-MILLER, INC.**
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617 890-3200/FAX 617 890-3489

May 7, 1996

I stole a copy for you and asked Janet to send boxes to Andy

Mr. Gerard Deily
RRD-31
Federal Railroad Administration
Office of Research and Development
400 7th Street, SW
Washington, DC 20590

Dear Mr. Deily,

At the direction of Dr. A. Kish of the Volpe National Transportation Systems Center, 100 copies of the report entitled, "Field Testing of High Degree Revenue Service Track for Buckling Safety Assessment," are provided for FRA dissemination. Kindly direct all questions regarding this document to Dr. Kish.

Sincerely,

FOSTER-MILLER, INC.

Gopal Samavedam

Dr. Gopal Samavedam
Division Manager

DTS-9718-Rev. 3