AN EVALUATION OF THE WEAR AND MAINTENANCE BEHAVIOR OF TURNOUTS AND FROGS/GUARD RAILS DURING THE FIRST FAST EXPERIMENT

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Early work on this experiment was performed by Boeing Services International, INC., at the Transportation Test Center

16. Abstract

This report describes the service evaluation of frogs, switches and guard rails on the Facility for Accelerated Service Testing track near Pueblo, Colorado. The selected components were measured and inspected at scheduled intervals determined by service loading. Wear and maintenance data per MGT are given for each metallurgy and location, and the conditions influencing performance are here thoroughly discussed.

The authors note that engineering personnel from participating (donor) railroads and suppliers were frequently on hand to observe the frog and turnout performance tests and that changes in design and maintenance practices have resulted.

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LIST OF ACRONYMS AND ABBREVIATIONS

AAR	Association of American Railroads
AREA	American Railroad Engineering Association
BHN	Brinell Hardness Number
CCW	Counterclockwise
DH	Depth Hardened (Metallurgy)
E	East
FAST	Facility for Accelerated Service Testing
LH	Left Hand
MGT	Million Gross Tons
N	North
RBM	Rail Bound Manganese
RH	Right Hand
S	South
Std	Standard Carbon (Metallurgy)
TDT	Train Dynamics Track
W	West

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EXECUTIVE SUMMARY

When the initial testing began on the FAST loop, it was agreed that since the loop contained several turnouts which would receive full 100-ton car service exposure at a rate of about 1 MGT per day, it would be useful to accumulate certain data about wear and hardness in the frogs and switches.

The selected locations consisted of three pairs of #20 turnouts and a group of eight #14 rail bound manganese steel frogs with guard rail lengths of 9'5" at four frogs and 12'6" at four frogs. Measurements at each frog location included hardness and vertical wear at nine points along the wheel loaded portion of the frog and wing rail, guard rail flangeway gap, and a limited number of surveying measurements (vertical, lateral and longitudinal rail position changes). Maintenance records were kept, examined, and adjusted to reflect mantenance effort associated with the region immediately surrounding the test frog and switch.

Analyses of the data accumulated indicated the following:

1. East and West FAST Turnouts -- No significant differences between measurements at the "glued" East FAST and field welded West FAST were observed. At 13.8 manhours per 100 MGT, the maintenance effort on the glued turnout is some 50% greater than on the welded turnout due to greater switch maintenance required, possibly because of more severe lateral dynamic loading anticipated in East FAST, which is located on a spiral of a 5 degree curve at the bottom of a 2% grade.

2. East and West By-Pass Turnouts -- No significant differences were observed in wear or hardness change measurements between identical turnouts, which served as a "control" for other test pairs that were not in essentially identical track positions. The initial average increase of hardness with MGT (BHN 150) for these one charge explosive hardened frogs appears to be about 50% greater than that observed at other turnouts such as East and West FAST, where one frog was standard and one was press hardened. The average maintenance manhours per 100 MGT of 7.3 for these two turnouts, in which traffic is not diverged, is about 35% less than the maintenance effort at the other three diverging turnouts.

3. West TDT and Impact Turnout -- This pair of turnouts incorporated standard rail bound manganese steel frogs. The wear and hardness change measurements are slightly greater for the diverging West TDT turnout. The maintenance effort of 6.8 manhours per 100 MGT for West TDT is some 60% greater than that at the Impact track turnout.

4. Test Frogs in Section 11 -- The depth hardened frogs appear to have slightly less wear and require less maintenance than standard RBM frogs. Somewhat less maintenance was required at test frogs with long guard rails.

While this rather crude and limited investigation produced no really definitive conclusions, some worthwhile observations can be made:

1. Despite some differences in material variables from site to site, there appears to be a detrimental effect of FAST traffic divergence on frog wear for these #20 turnouts. The three frogs that diverged traffic experienced more than twice as much wear as those supporting a straight through move.

2. The relatively high number of frog "tail" cracks observed at many locations and the high wear rates of standard switch points at severely loaded diverging turnouts has contributed to the development of design and maintenance changes. The selective use of manganese steel switch point inserts is an example.

3. Perhaps one of the greatest benefits of this test was derived from direct observations of day-to-day changes by engineering personnel from participating railroads and supplier groups.

1.0 INTRODUCTION

The installation, maintenance, and inventory of track turnouts and switch and frog hardware are major cost items for railroads. This cost naturally increases with the introduction of heavier wheel loads, especially at physical interruptions and potential weak points of the track such as at switches and frogs.

The FAST test loop, of necessity, contains a number of turnouts in order to provide access to other test tracks such as the Railroad Test Track (in the initial years of FAST), the Impact Track, the Train Dynamic Track (TDT), a FAST Loop By-Pass track in Section 10, and a West Facility access track in Section 09.

Therefore, it was decided in the early FAST planning to include a test of selected turnout hardware using these loop locations and several special in-track installations of frogs. Where possible, test hardware variables such as field welded and epoxy bonded turnouts, length and type of guard rails, and rail bound manganese frogs with different hardness characteristics were introduced.

In this first turnout test there are, of course, significant limitations in scope, number of samples, and local service environment, as well as uncertainties associated with previously untried measurement techniques. Nevertheless, a few test variables were selected and introduced in certain locations, usually in "pairs" or groups where performance comparisons could more directly be made. This report describes the results of this initial testing phase on turnouts. Results of hardness and wear measurements, as well as maintenance records, are presented for the test locations and variables described in the following section.

This experiment was conducted during the period August 1976 (0 MGT) to May 1978 (240 MGT). As observed in FAST rail metallurgy and wear experiments (Reference #1), the state of rail lubrication changed significantly during this period. Even though two track lubricators were installed initially, the first 40 MGT were characterized by ineffective lubrication. Two more lubricators were then added and the level of lubrication approached what has been characterized as "generous" after 45 MGT. Therefore, higher than normal wear in turnout hardware might be anticipated during the initial stages of this experiment.

2.0 DESCRIPTION OF TEST LOCATIONS AND PURPOSES

The principal test locations consist of three pairs of #20 turnouts and a group of eight #14 rail bound manganese steel frogs with two different guard rail lengths arranged in an alternating pattern on the inner and outer rails in FAST Section 11. A summary of these locations and specifications is provided in Table 1 for the turnouts and Table 2 for the test frogs. A layout of the test locations on the FAST loop is provided in Figure 1. Highlights of these test locations and the main test purposes are given in the following paragraphs under each subgroup.

2.1 EAST AND WEST FAST TURNOUTS

The hardware in these two turnouts was nearly identical except that the major turnout components were field welded into the track in the Section 15 and 16 locations in West FAST and epoxy bonded ("glued") into the track in Sections 21 and 22 in East FAST. The glued left hand turnout was located off the spiral of a 5 degree curve at the foot of a descending 2% grade in East FAST, while the welded right hand turnout in West FAST was just east of a concrete slab road crossing removed later at 240 MGT. Also, a high guard rail was used in West FAST.

Detailed layouts of these turnouts are given in Figure 2 for East FAST and Figure 3 for West FAST. A photo of the East FAST switch, looking CCW along the FAST loop, is shown in Figure 4. In this photo, and in all subsequent ones included in this section of the report, the switch is in the open position, that is, not lined for FAST. An overall view of the West FAST switch, again looking CCW, is shown in Figure 5 and a closer view of the switch points, showing the proximity of the concrete crossing, is provided in Figure 6. A close-up of the frog and guard rail, showing the paint marked locations for flangeway gap measurement, is provided in Figure 7.

At both locations FAST traffic runs on a diverging movement through the turnout.

The primary reason for including this pair of turnouts was to compare the performance of glued and welded turnouts under the same traffic even though it was recognized that the track grade and curvature configurations in these two locations were not identical.

2.2 EAST AND WEST BY-PASS TURNOUTS

The turnouts at either end of the passing track in Section 10 were of identical design but supplied by a different donor than the #20 turnouts in East and West FAST, described above. The rail bound manganese steel frogs were explosive hardened with only one charge. In this case the normal FAST traffic ran on the main line or straight side of the turnouts as shown in Figure 8 for the East By-Pass and Figure 9 for the West By-Pass. The load environment is believed to have been essentially identical at these turnouts.

A photo of the West By-Pass, looking CCW, i.e. east, is shown in Figure 10. A close-up of the frog and guard rail is shown in Figure 11.

TABLE 1. SUMMARY OF TEST TURNOUT LOCATION AND HARDWARE.

	EAST FAST	WEST FAST	EAST BY-PASS	WEST BY-PASS	WEST TDT	IMPACT
LOCATION	Sec. 15 & 16 (402)	Sec. 21 & 22 (306)	Sec. 10 & 11 (403)	Sec. 9 & 10 (404)	Sec. 1 & 22 (305A)	Sec. 14 & 15 (401)
SW.HB	15-0763	22-0037	11-0034	09-0349	22-1160	15-0036
FG.PT	16-0058	21-0044	10-0894	10-0051	01-0060	14-0443
TURNOUT #	20 LH	20 RH	20 RH	20 LH	20 LH	20 LH
TYPE	WELDED	WELDED	C&O STD.	C&O STD.	MOPAC STD.	MOPAC STD.
FIELD JOINT	EPOXY	WELDED				
SWITCH	59'-6" long curved (39'-0" Mn. Steel Replacement Points)	59'-6" long curved (39'-0" Mn. Steel Replacement Points)	30'-0" long STRAIGHT	30'-0" long CURVED	39'-0" long CURVED	39'-0" long CURVED
FROG AREA # TYPE	621 R.B. STD. Mn. (52' Length)	621 R.B. Press hardened (52' Length)	621 Single Explosive hardened	621 Single Explosive hardened	621 R.B. Mn.	621 R.B. Mn.
GUARD RAIL LENGTH TYPE	24'-0" STD.	24'-0" HIGH	10'-0" ONE PIECE	10'-0" ONE PIECE	22'-6" AREA 504 EXC. LENGTH	22'-6" AREA 504 EXC. LENGTH
COMMENTS	On curve at foot of descending 2% grade & 5° curve with poor alignment	Tie transition zone wood to concrete just beyond FROG	Crossing drainage problem		Always lined for FAST & run on curved SW POINT	Run on tangent SW POINT

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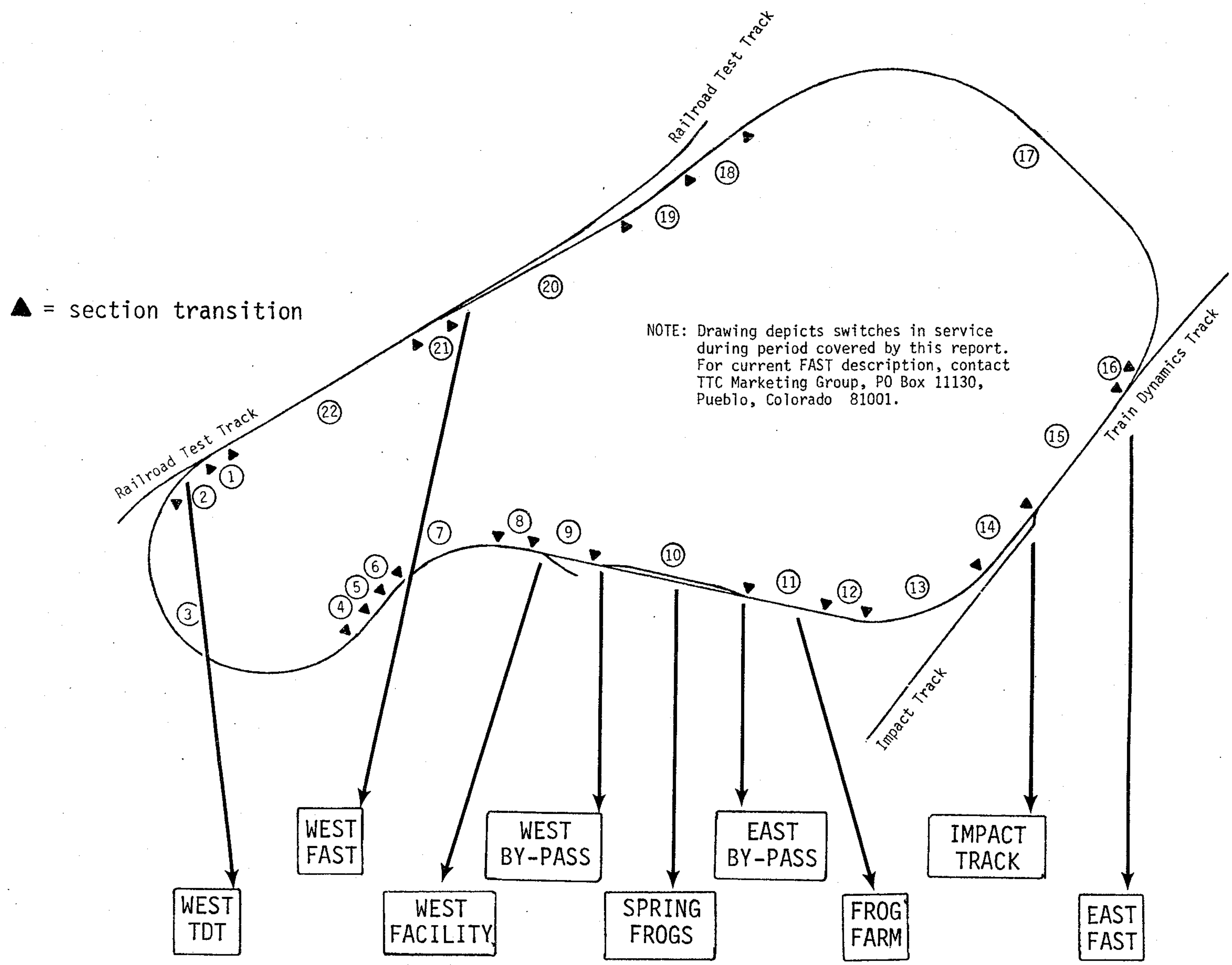
TABLE 2. SUMMARY OF TEST FROG LOCATIONS IN FAST SECTION 11 AND HARDWARE TYPE.

FROG #	1	2	3	4	5	6	7	8
FROG INSIDE OR OUTSIDE	I	O	I	O	I	O	I	O
RAIL #	010	011	015	016	020	021	025	026
TIE # RANGE	0187 to 0201	0233 to 0246	0283 to 0296	0328 to 0342	0379 to 0392	0424 to 0437	0474 to 0487	0519 to 0532
GUARD RAIL LENGTH	9'-5"	12'-6"	9'-5"	12'-6"	9'-5"	12'-6"	9'-5"	12'-6"
STANDARD or DEPTH HARDENED	D.H.	D.H.	Std.	Std.	D.H.	D.H.	Std.	Std.



SECTION	1&22	21&22	9	9&10	10	10&11	11	14&15	15&16
TURNOUT RAIL WEIGHT = (...#)	#20 L.H. MoPac Std. (136#)	#20 R.H. Welded; Field-Welded Joints (140#)	#10 R.H. AREA Std. (136#)	#20 L.H. C&O Std. (132#)	See Tables 1 & 2 (133#)	#20 R.H. C&O Std. (132#)	See Tables 1 & 2 (136#)	#20 L.H. MoPac Std. (136#)	#20 L.H. Welded, w/ Epoxy Joints (140#)
SWITCH	Site#: 305A 39'0" Curved	Site#: 306 59'6",Curved Switch Points:39'0"	16'6" Straight	Site#: 404 30'0" Straight	See Tables 1 & 2	Site#: 403 30'0" Straight	See Tables 1 & 2	Site#: 401 39'0" Curved	Site#: 402 59'6",Curved Switch Points:39'0"
FROG	AREA 621 R.B. Manganese	AREA 621 R.B. Mang. (Depth Hrd.)	AREA 621 R.B. Mang.	AREA 621 R.B. Mang.	#14 Spring UPRR Std.	AREA 621 R.B. Mang.	AREA 621 #14 R.B.	AREA 621 R.B. Mang.	AREA 621 R.B. Mang. Std.
GUARD RAIL	AREA 504 22'6" Exc.Length	24'0" (High)	AREA Std. 9'5"	10'0" (one-piece)	12'0"	10'0" (one-piece)	See Tables 1 & 2	AREA 504 22'6" Exc.Length	24'0" Std.

FIGURE 1. FAST TRACK LAYOUT.

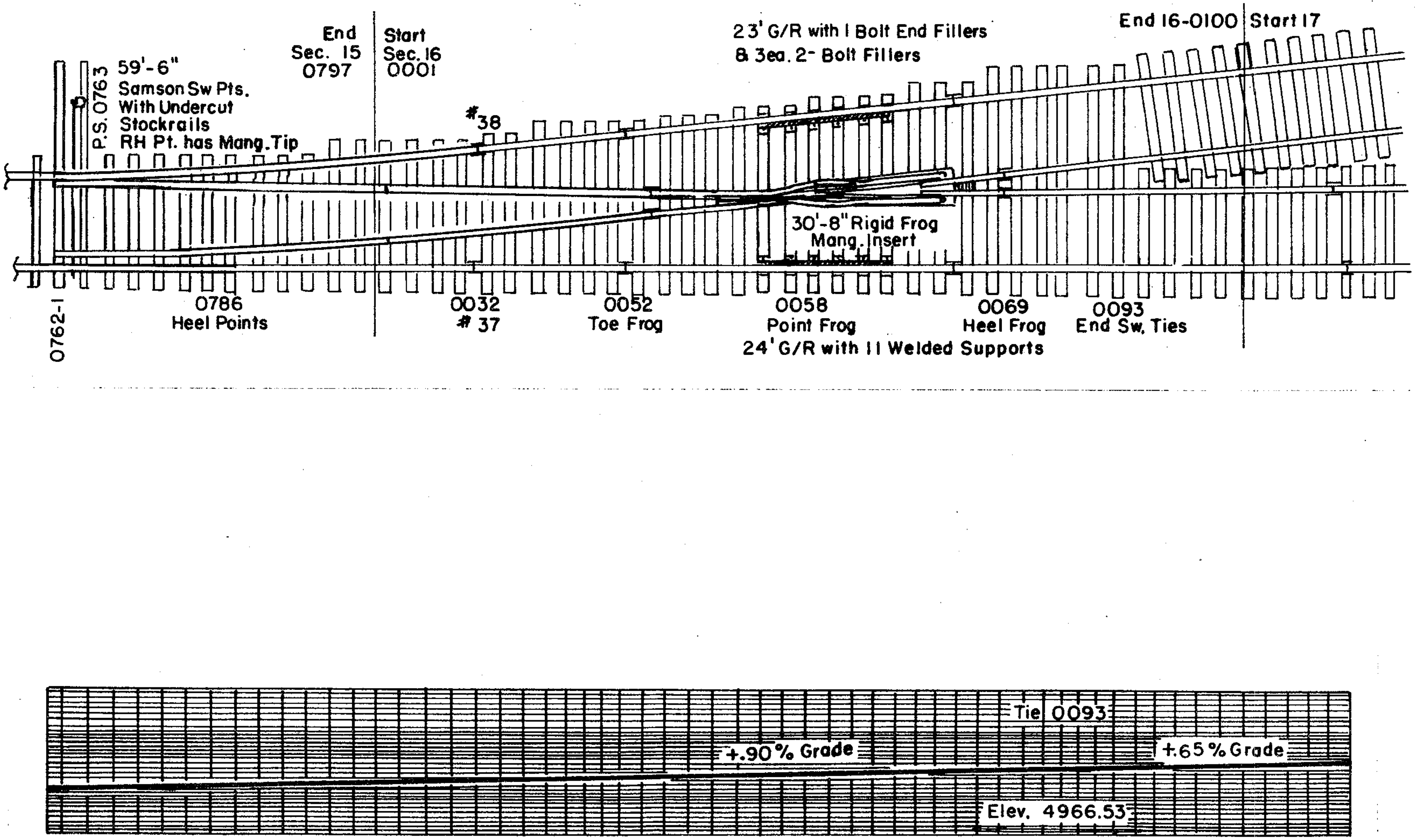
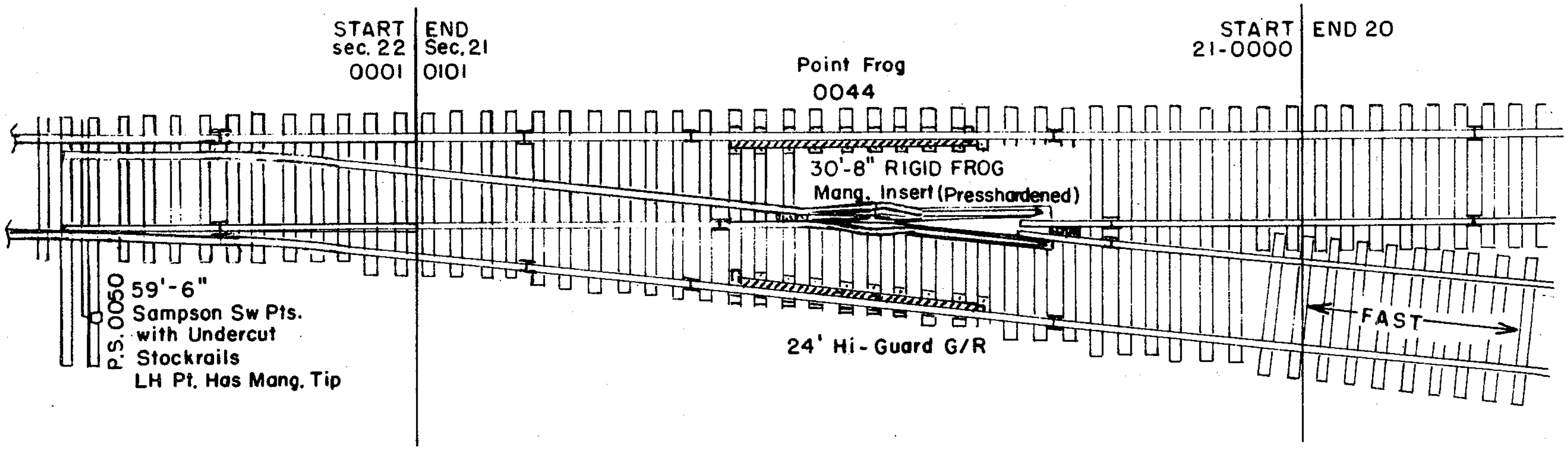


FIGURE 2. LAYOUT OF EAST FAST TURNOUT.



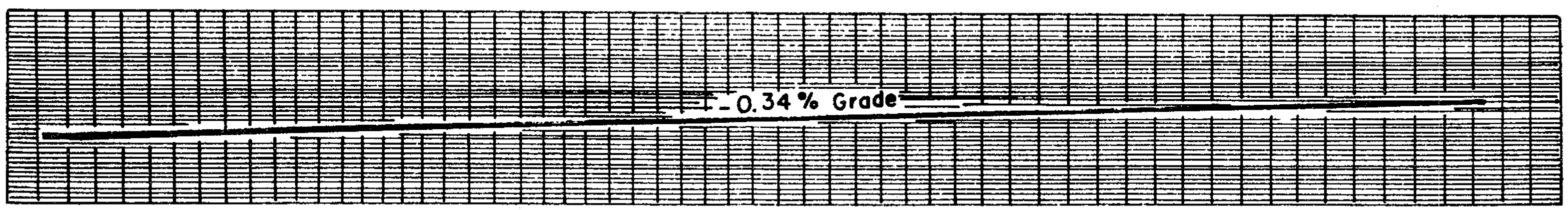


FIGURE 3. LAYOUT OF WEST FAST TURNOUT.

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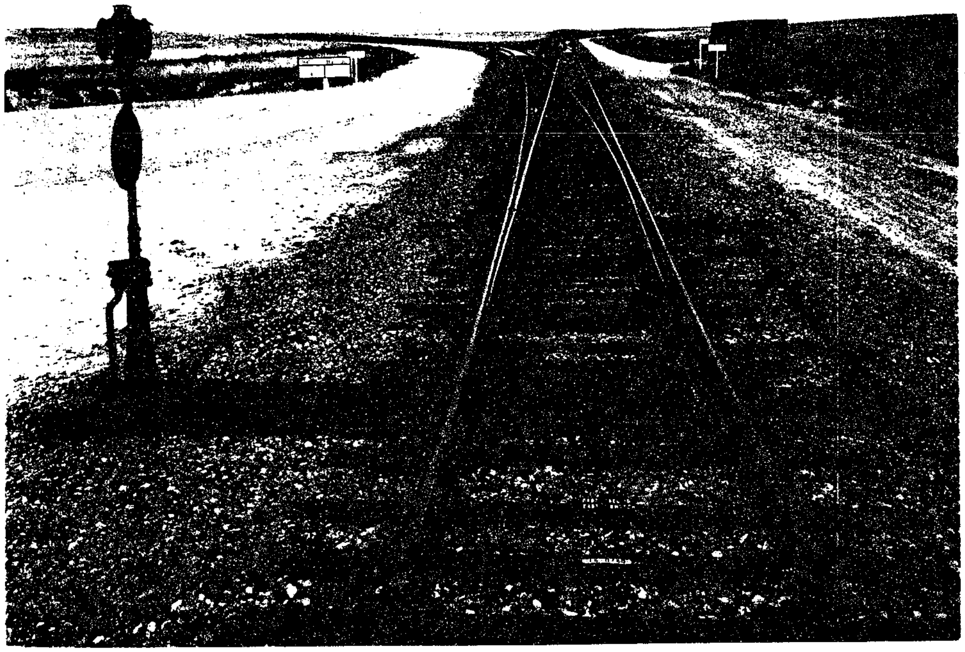


FIGURE 4. EAST FAST TURNOUT LOOKING CCW (SWITCH NOT LINED FOR FAST).

76 5983

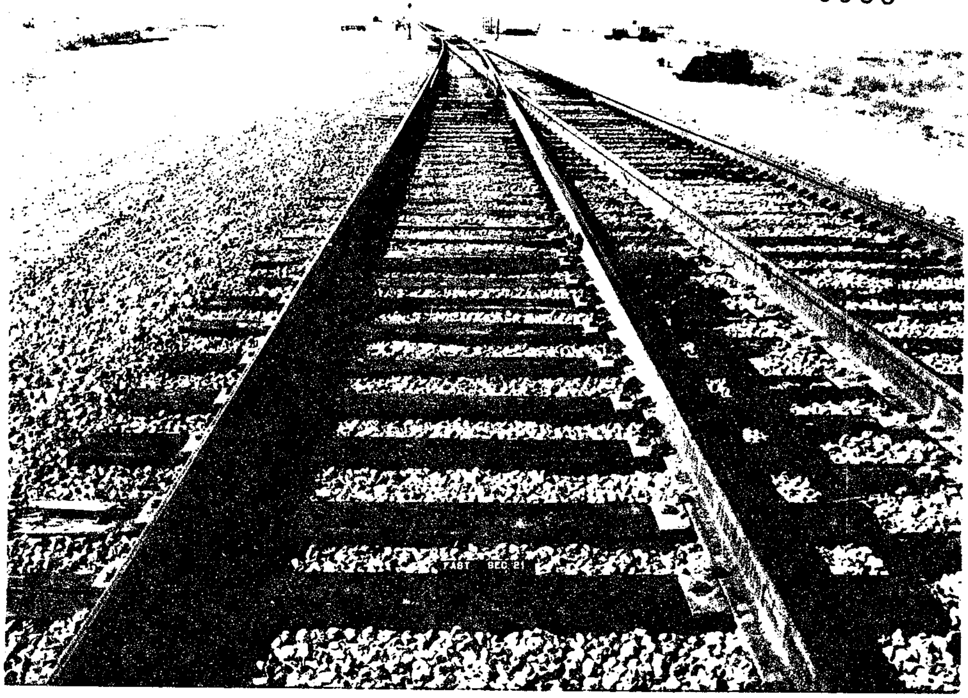


FIGURE 5. WEST FAST TURNOUT LOOKING CCW.

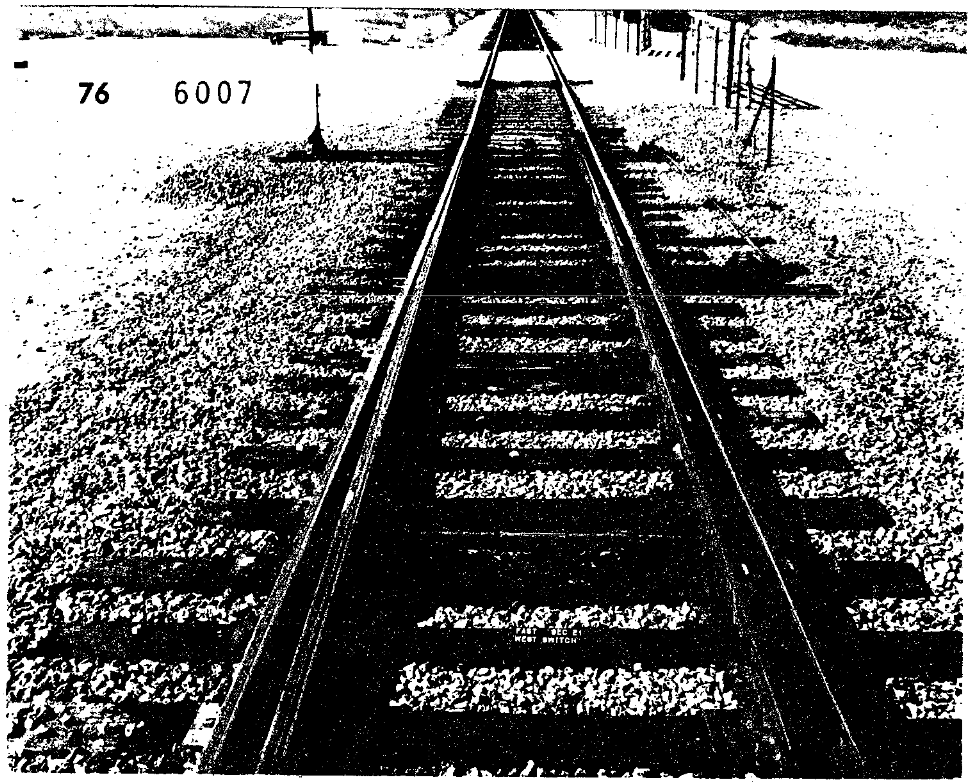


FIGURE 6. WEST FAST SWITCH, SHOWING PROXIMITY OF CONCRETE CROSSING.

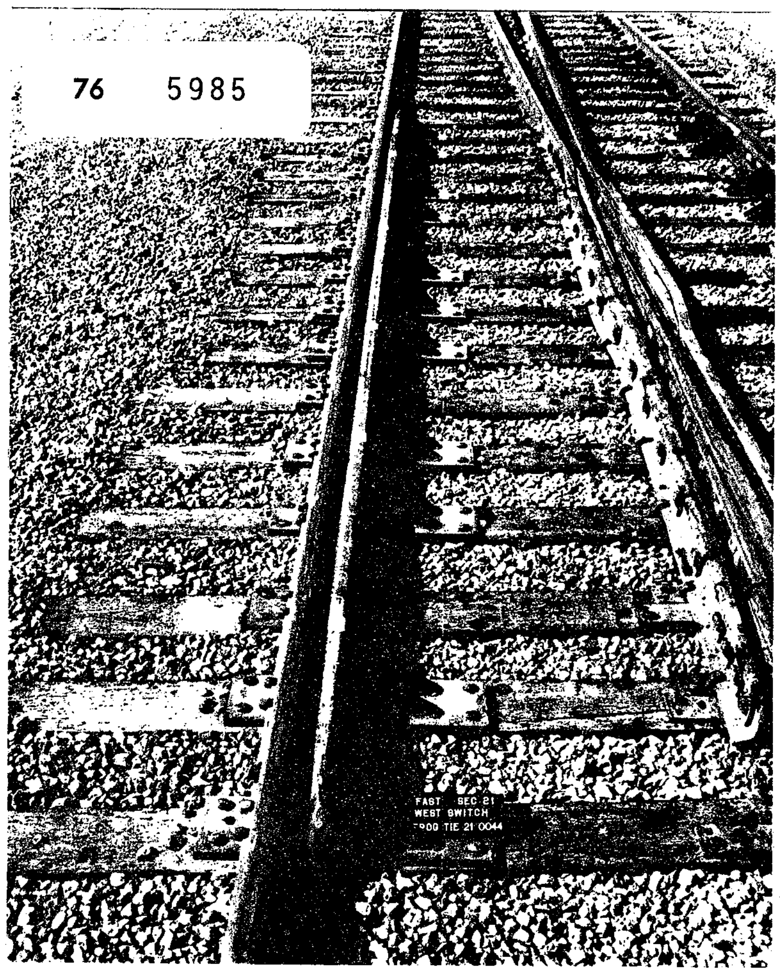


FIGURE 7. WEST FAST FROG AND GUARD RAIL.

(Note paint mark locations for measurement of guard rail gap.)

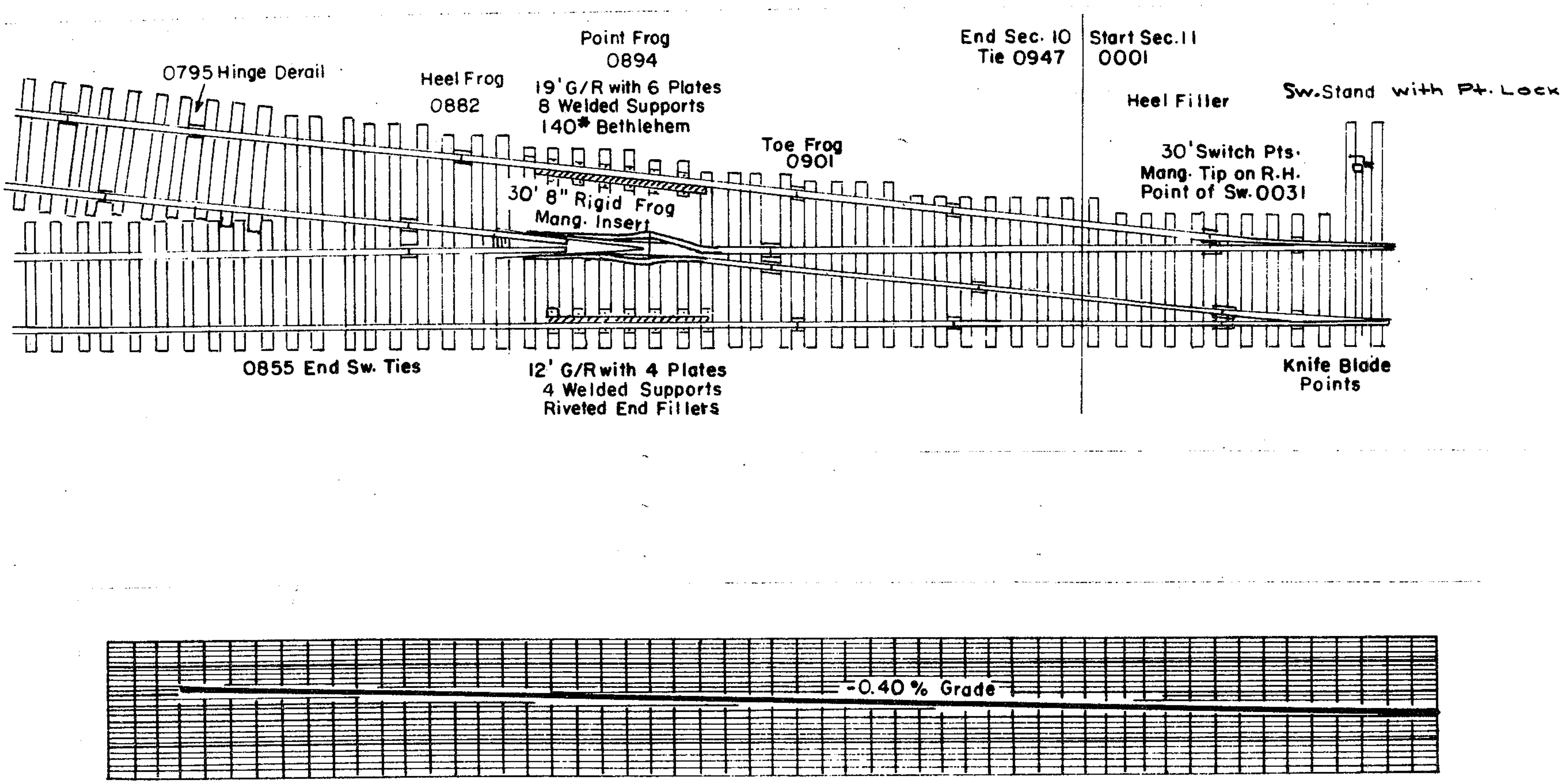


FIGURE 8. LAYOUT OF EAST BY-PASS TURNOUT.

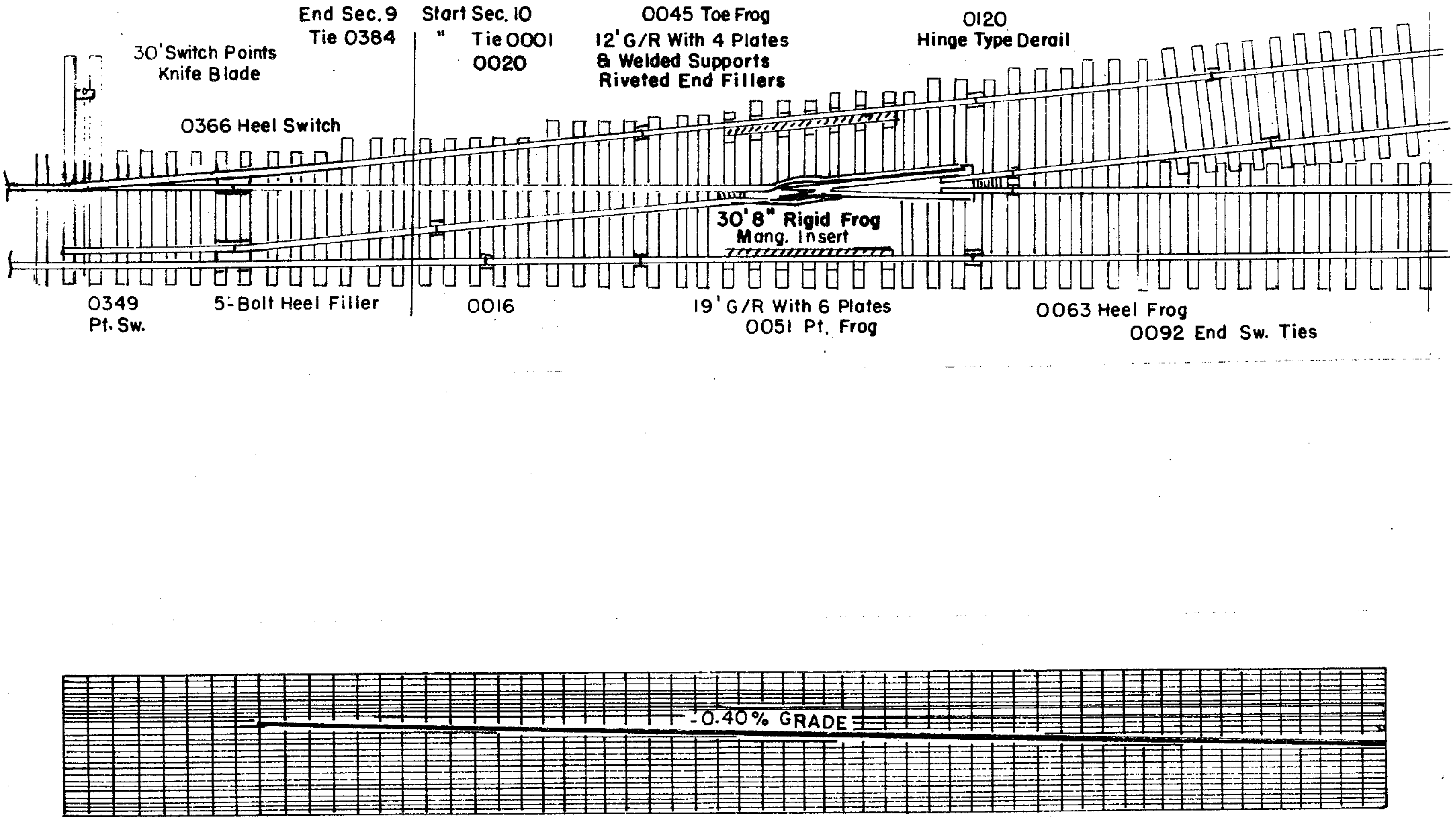


FIGURE 9. LAYOUT OF WEST BY-PASS TURNOUT.

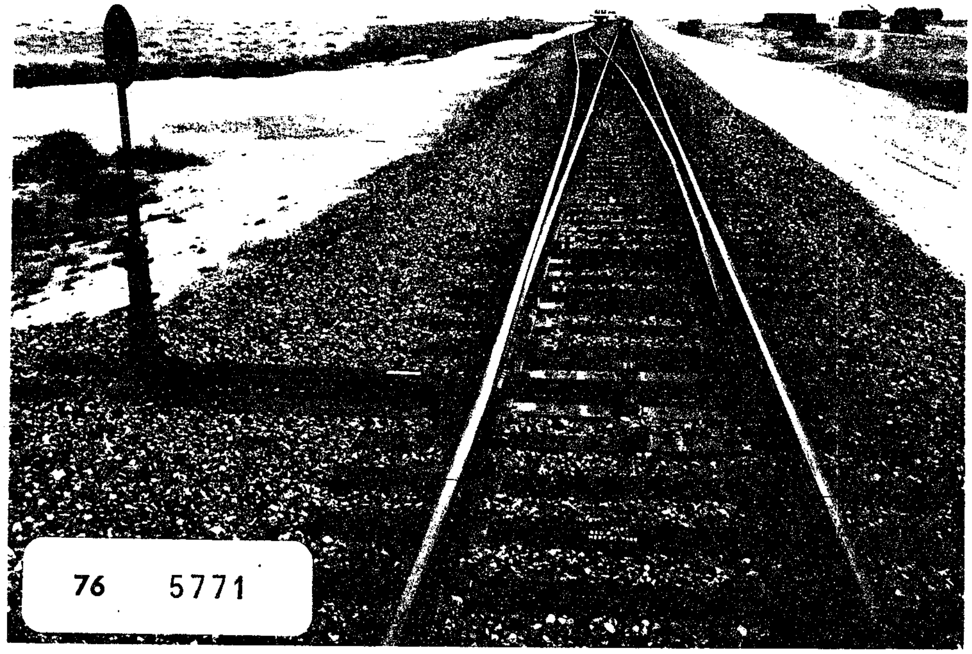


FIGURE 10. WEST BY-PASS TURNOUT LOOKING CCW.

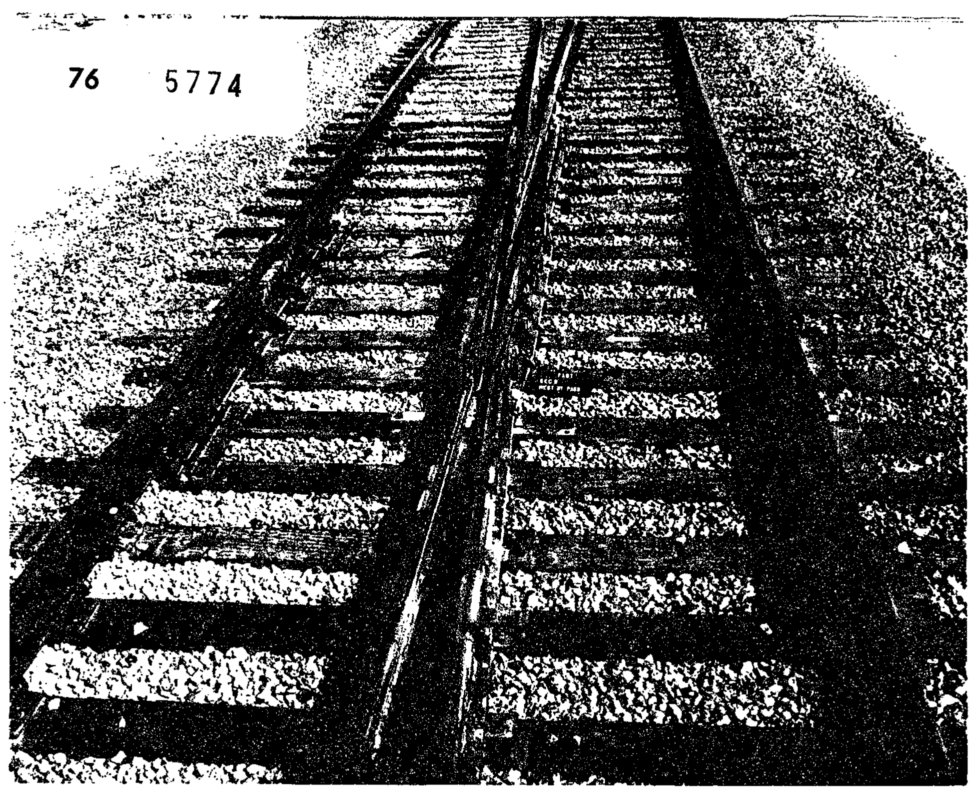


FIGURE 11. WEST BY-PASS FROG AND GUARD RAIL.

2.3 WEST TDT AND IMPACT TRACK TURNOUTS

This pair of #20 turnouts represented still another donor type or manufacture. In the case of the West TDT turnout, the FAST traffic diverged (CCW) onto the curved switch rail while at the Impact track, traffic ran through on the FAST track or straight side. Therefore, any differences of wear and maintenance requirements at this pair might be expected to reflect the effect of these differences in traffic divergence.

The turnout layouts are shown in Figure 12 for West TDT and in Figure 13 for the Impact track. An overall view of the West TDT switch is shown in Figure 14 (looking CCW) and a close-up of the frog and guard rail is given in Figure 15.

2.4 TEST FROGS IN FAST SECTION 11

The alternating arrangement of #14 frogs and guard rails, shown in the Figure 16 layout and the Figure 17 photo, was designed to allow a comparison of the performance of two types of frog hardening and two lengths of guard rails. The standard rail bound manganese (RBM) steel frog is compared to a depth hardened RBM frog.

Twenty twelve-foot long ties (not centered in track) were installed under each frog.

2.5 MISCELLANEOUS TEST LOCATIONS

A #10 right hand turnout was also included in the test at the West Facility switch in Section 09 as shown in the detailed layout in Figure 18. In addition, two #14 spring rail frogs, one on each rail, were included in Section 10 (Figure 19). However, the spring rail mechanism in the two frog assemblies was not actuated and was not part of the test.

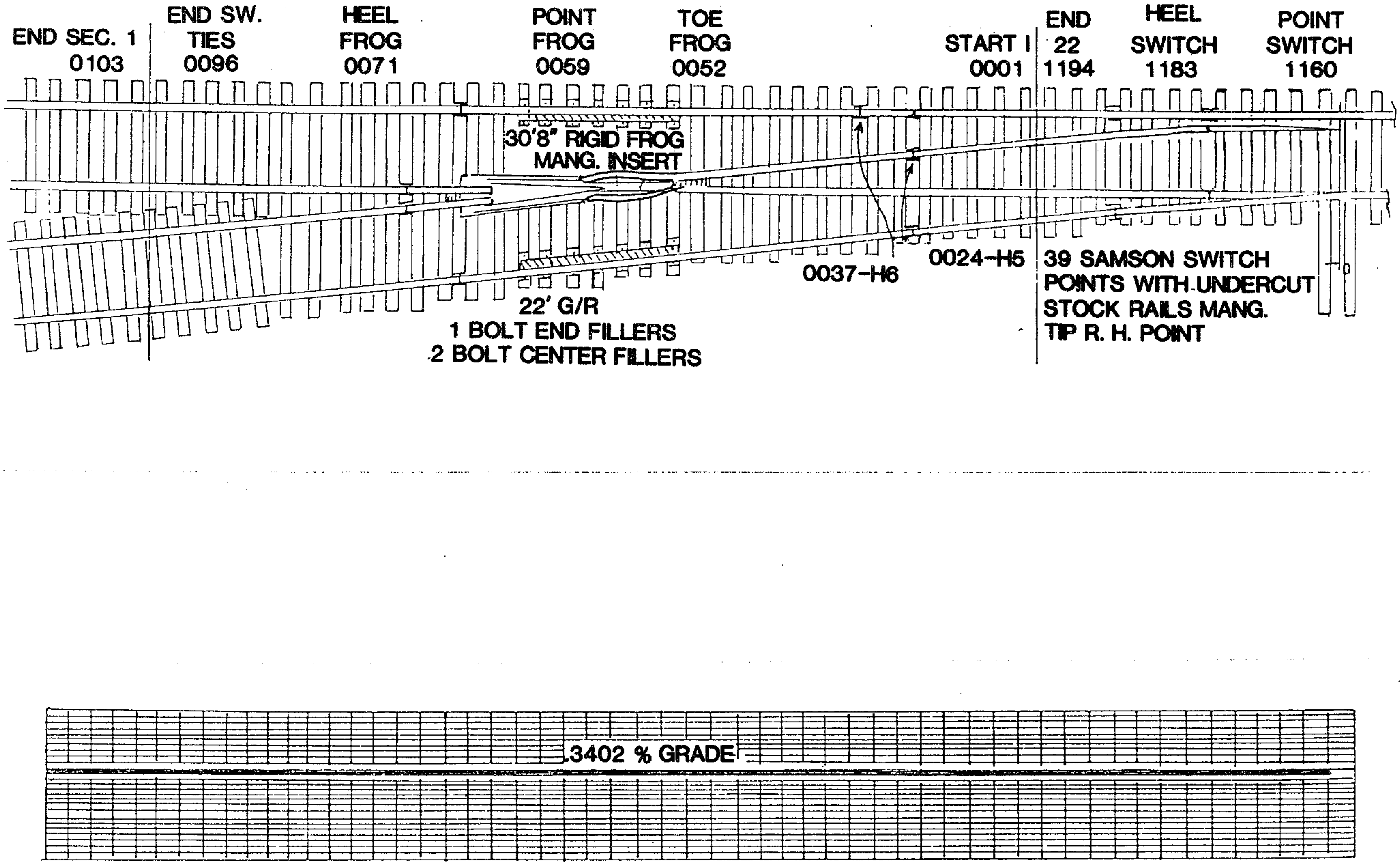
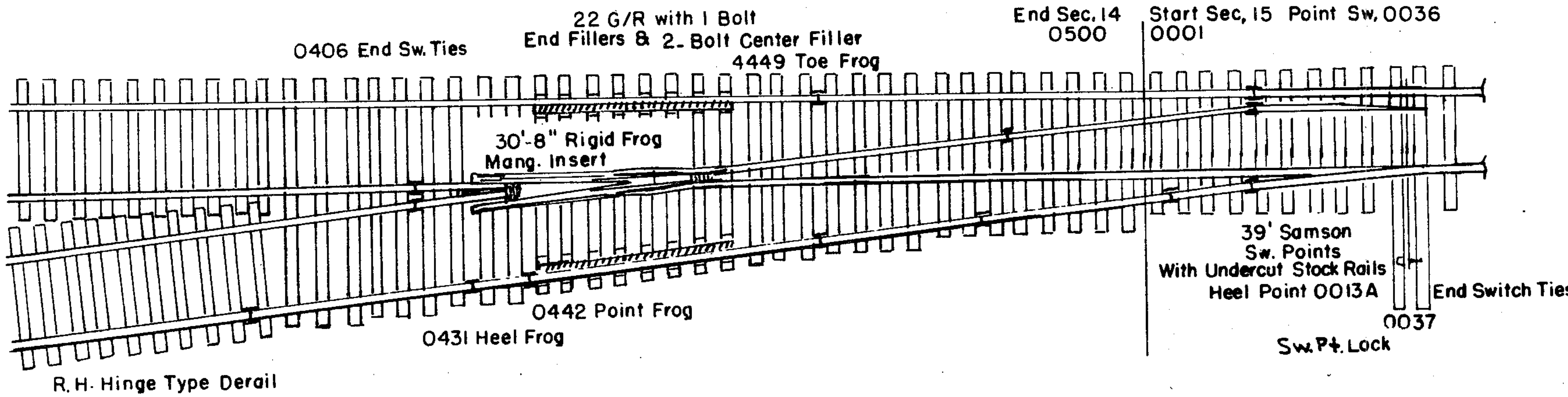


FIGURE 12. WEST TDT TURNOUT LAYOUT.



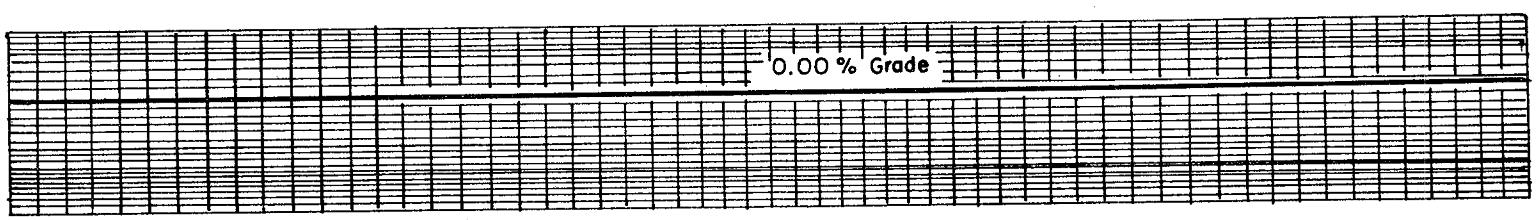


FIGURE 13. LAYOUT OF IMPACT TRACK TURNOUT.

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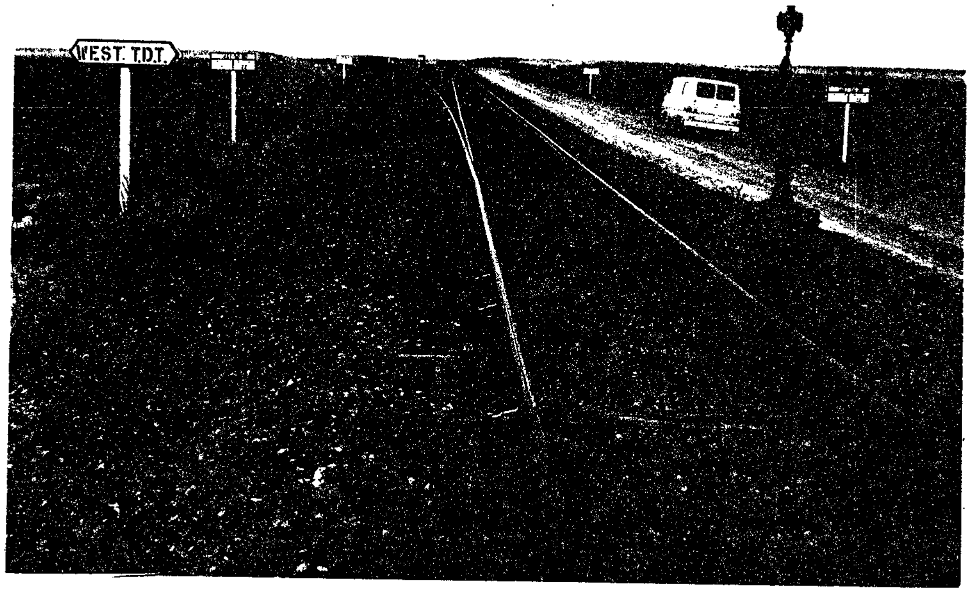


FIGURE 14. WEST TDT TURNOUT LOOKING CCW.

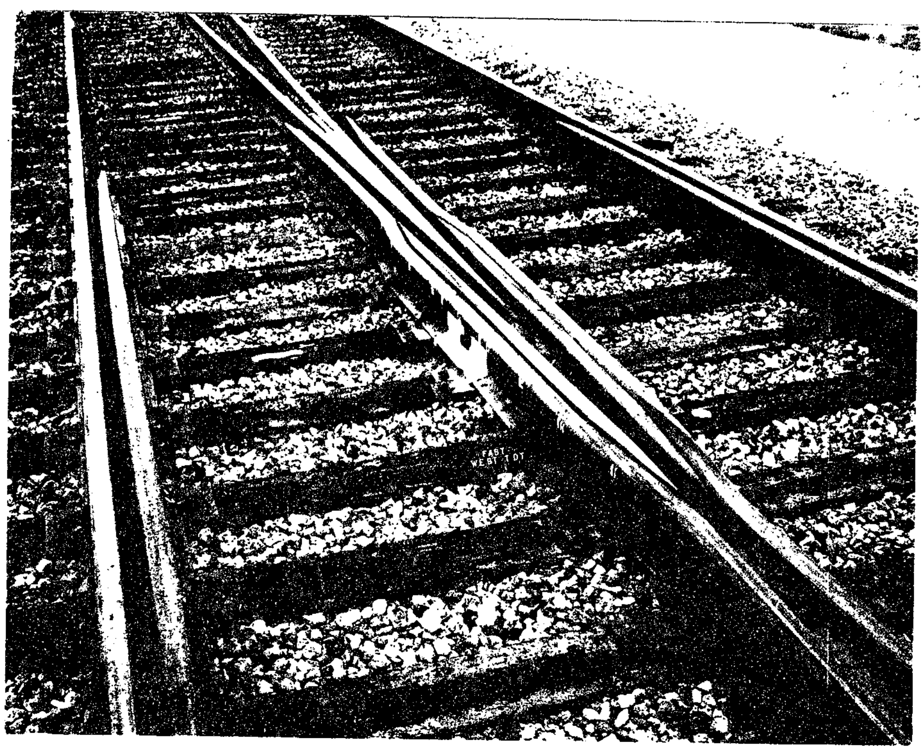


FIGURE 15. WEST TDT FROG AND GUARD RAIL. (Note paint marks for measurement locations.)

C6

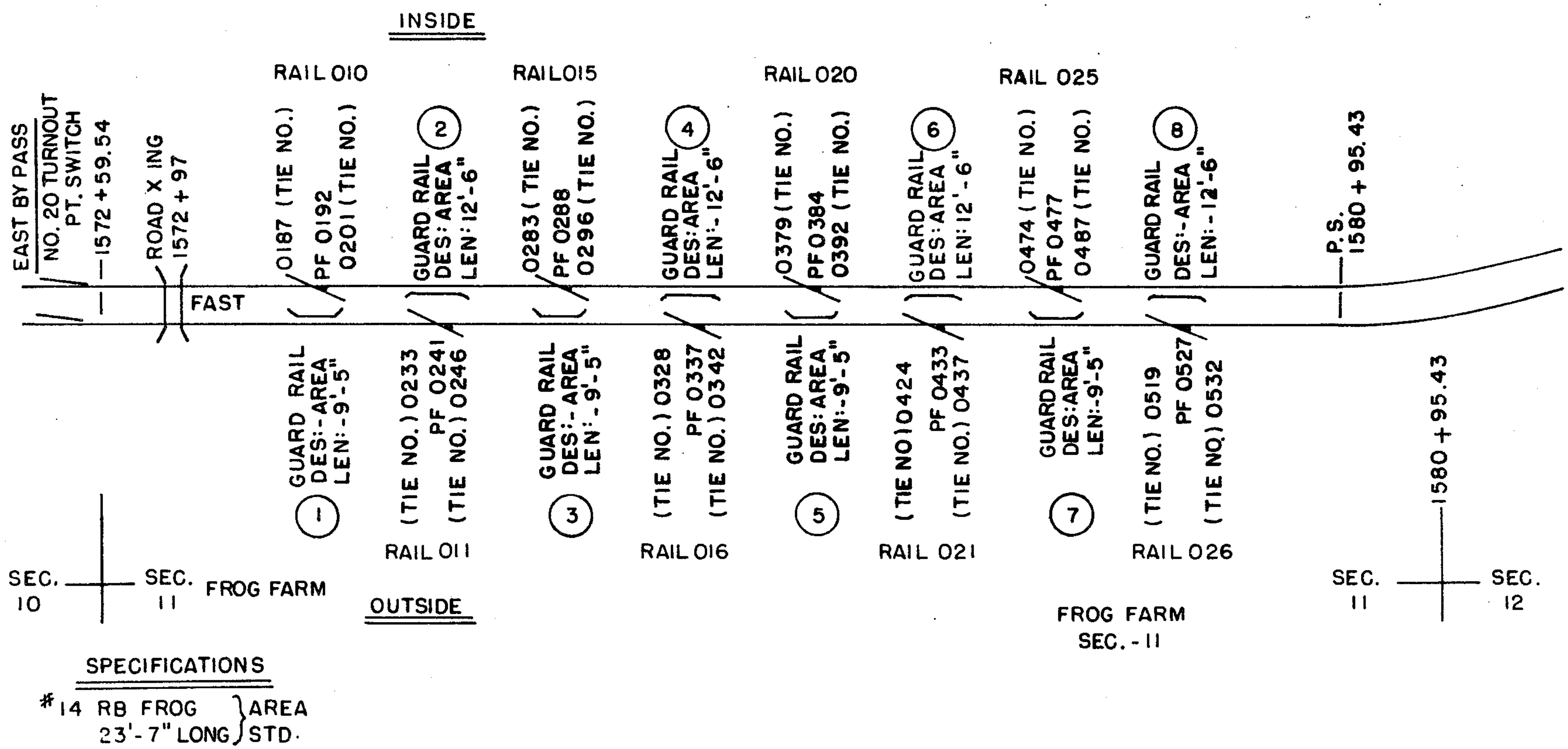


FIGURE 16. FROG FARM LAYOUT.

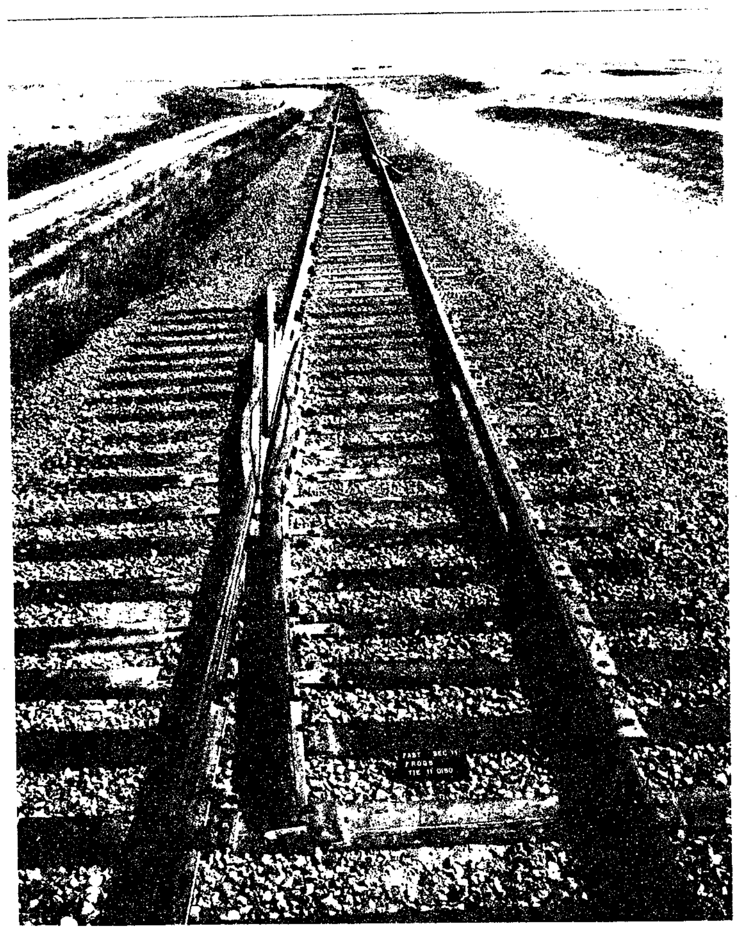


FIGURE 17. SECTION 11 TEST FROG NO. 1 IN FOREGROUND LOOKING CCW.

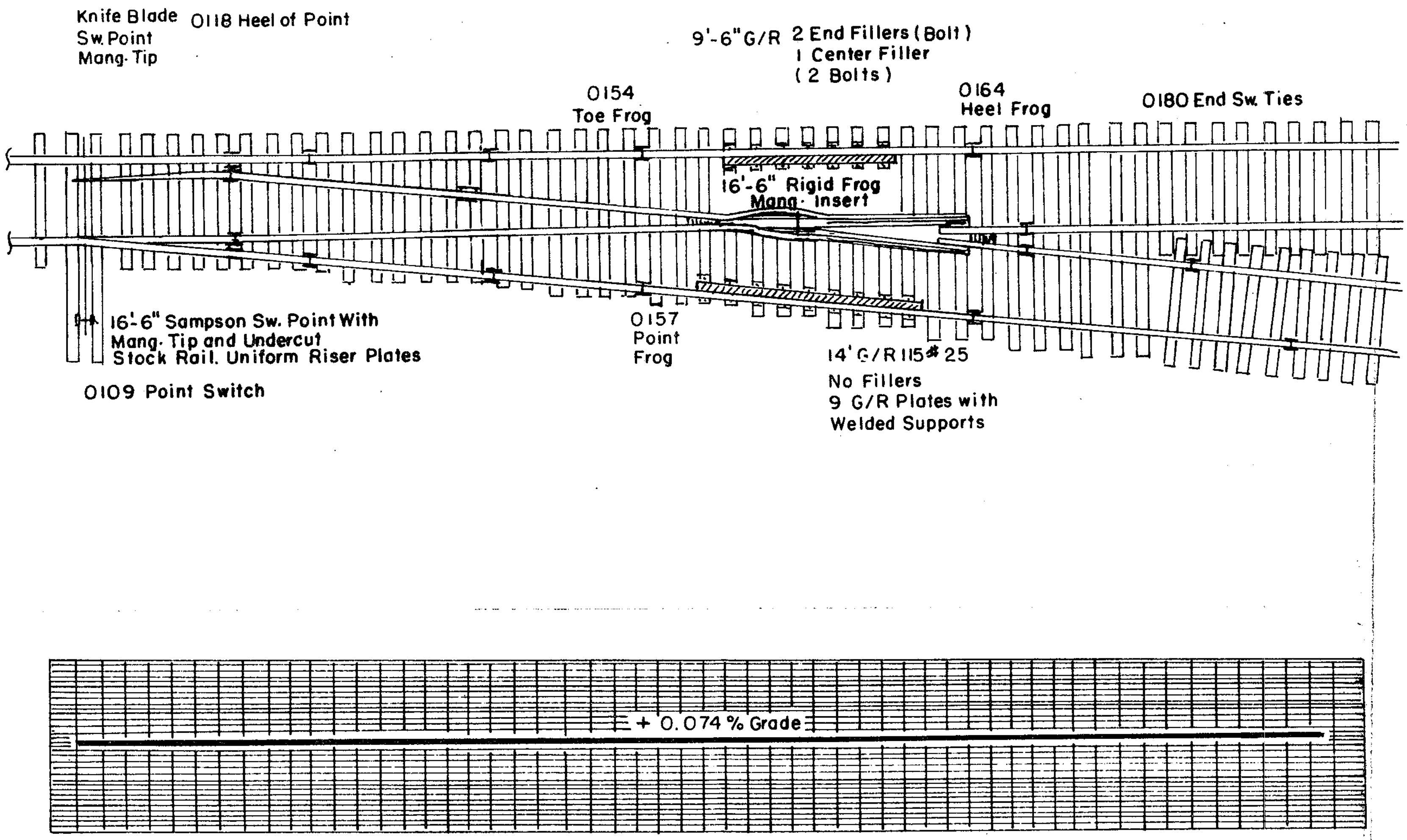


FIGURE 18. LAYOUT OF WEST FACILITY TURNOUT.

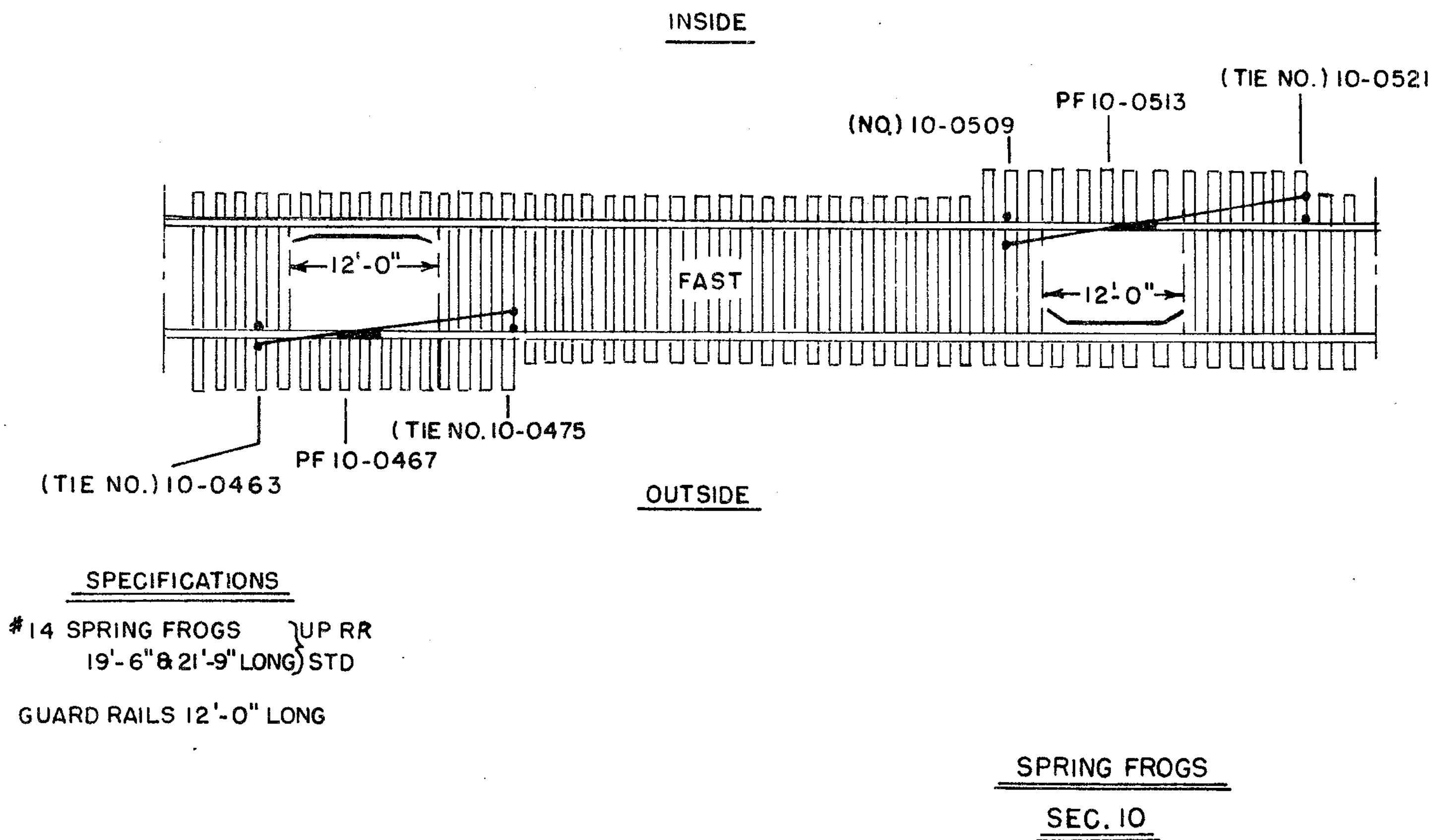


FIGURE 19. LAYOUT OF SPRING RAIL FROG INSTALLATIONS.

3.0 MEASUREMENTS AND DATA REDUCTION

The performance in FAST of the turnout and frog hardware described in the previous section was characterized by several types of measurements taken at frequent intervals during the accumulation of tonnage. The method of obtaining these measures of dimensional change, hardness and maintenance manhours, and the associated data reduction techniques and assumptions are discussed in the following paragraphs.

In order to illustrate the method of data collection, reduction, and presentation, the detailed results at one of the test locations, the West FAST turnout, are selected for illustration in this report section. Results from all the test locations are summarized and discussed in the following report, Section 4.0.

3.1 FROG HARDNESS

Measurements of frog and wheel loaded wing rail hardness were made at point marked locations illustrated in Figure 20 and in the photo shown in Figure 21. The type of portable hardness unit selected for use was an ESEWAY dynamic hardness tester shown in Figure 22. A description of this unit and instructions for data collection are reproduced in Appendix A. Only one reading was recorded for each measurement point.

For most of the test, calibration readings on a high and low hardness master block were taken, recorded, and entered into the computer data base. There were, however, some changes in calibration practice and, for a short period, a change in the type of hardness measuring instrument used during the three year course of the experiment. These changes, together with the inherent variability in making field hardness measurements at locations that tended to vary from the original paint marked targets, introduce a significant degree of uncertainty regarding the reliability and consistency of the data. Some appreciation of this inherent variability may be inferred from the statistical measures listed in Appendix B, Table B-1, for hardness calibration readings taken throughout the experiment. The standard deviation over the duration of test (240 MGT) was 28 BHN. That is, 33% of the hardness readings of a presumably fixed standard were more than 28 BHN off the mean value. This is especially significant in view of the fact that only single hardness readings were made and recorded for each position at each measurement occasion.

If the average hardness readings over all measurement positions A through E on the frog and F through I on the wing rail are plotted as a function of MGT for all test locations, then the overall trend, illustrated in Figure 23, of early hardness increase with subsequent abrupt drop, followed by an apparent re-hardening is observed. An attempt was made to damp out some of the variations that may have been due to measurement practice by adjusting the data by a factor determined by the recorded calibration hardness values explained in Appendix B. Even with this adjustment the basic trend shown in Figure 23 is still apparent although the variability is somewhat reduced.

A typical graphical display of these adjusted hardness data is given in Figure 24 for one of the test locations (West FAST). In this case the average

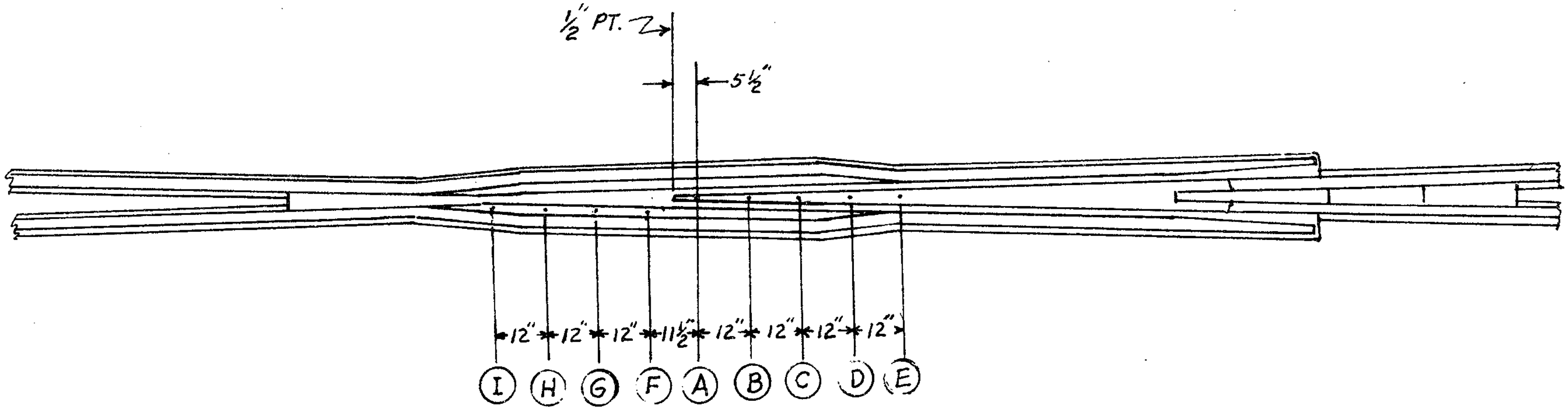


FIGURE 20. FROG MEASUREMENT POINTS.

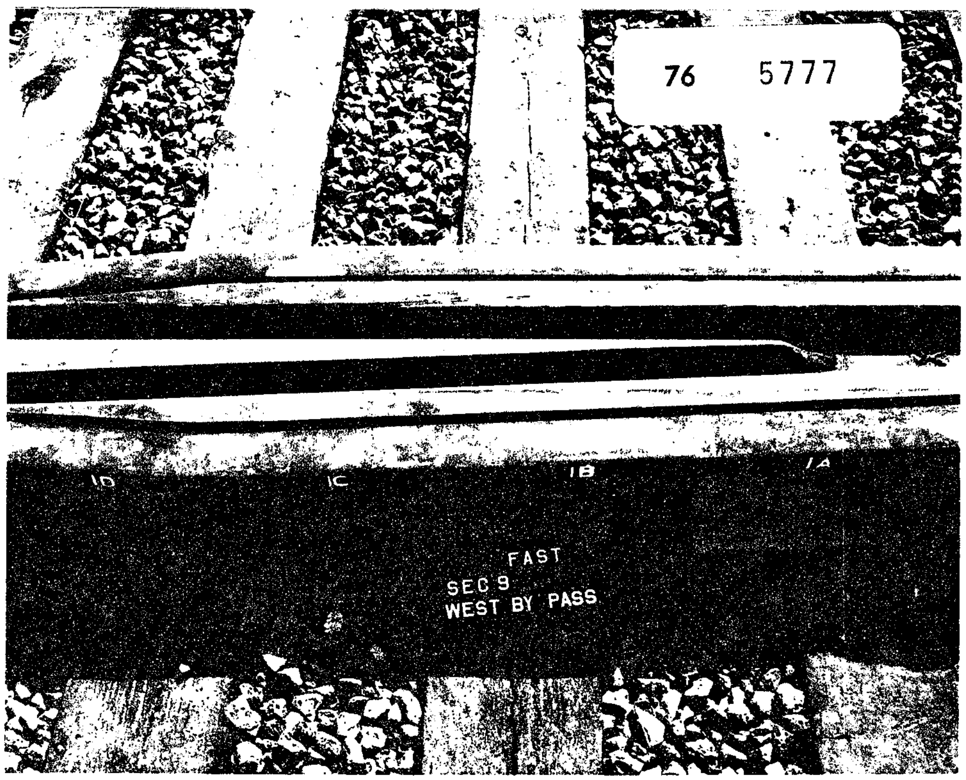
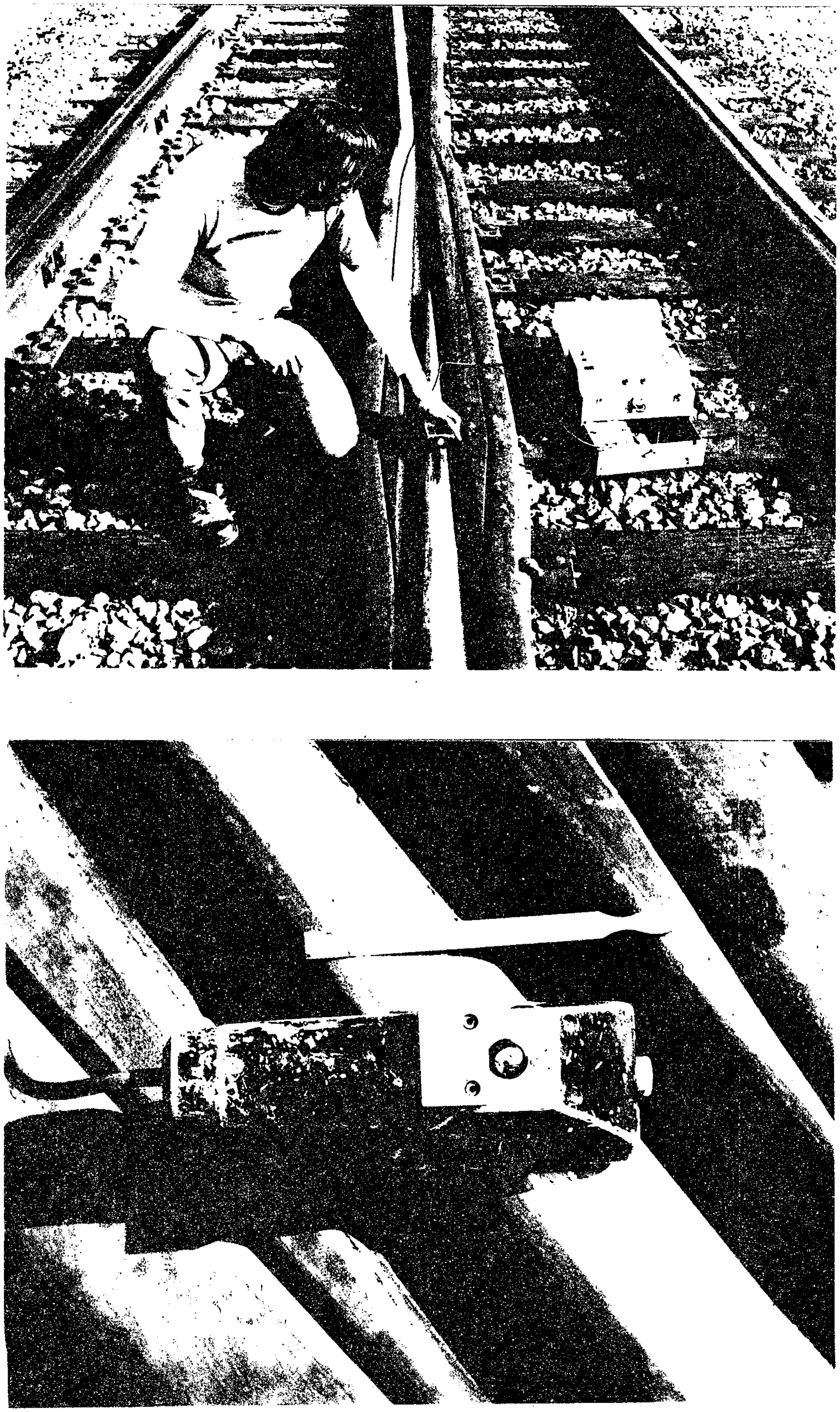


FIGURE 21. WEST BY-PASS FROG.
(Note paint mark locations for hardness and wear measurement.)



(a)

(b)

FIGURE 22. PORTABLE HARDNESS UNIT IN USE AT EAST BY-PASS FROG.

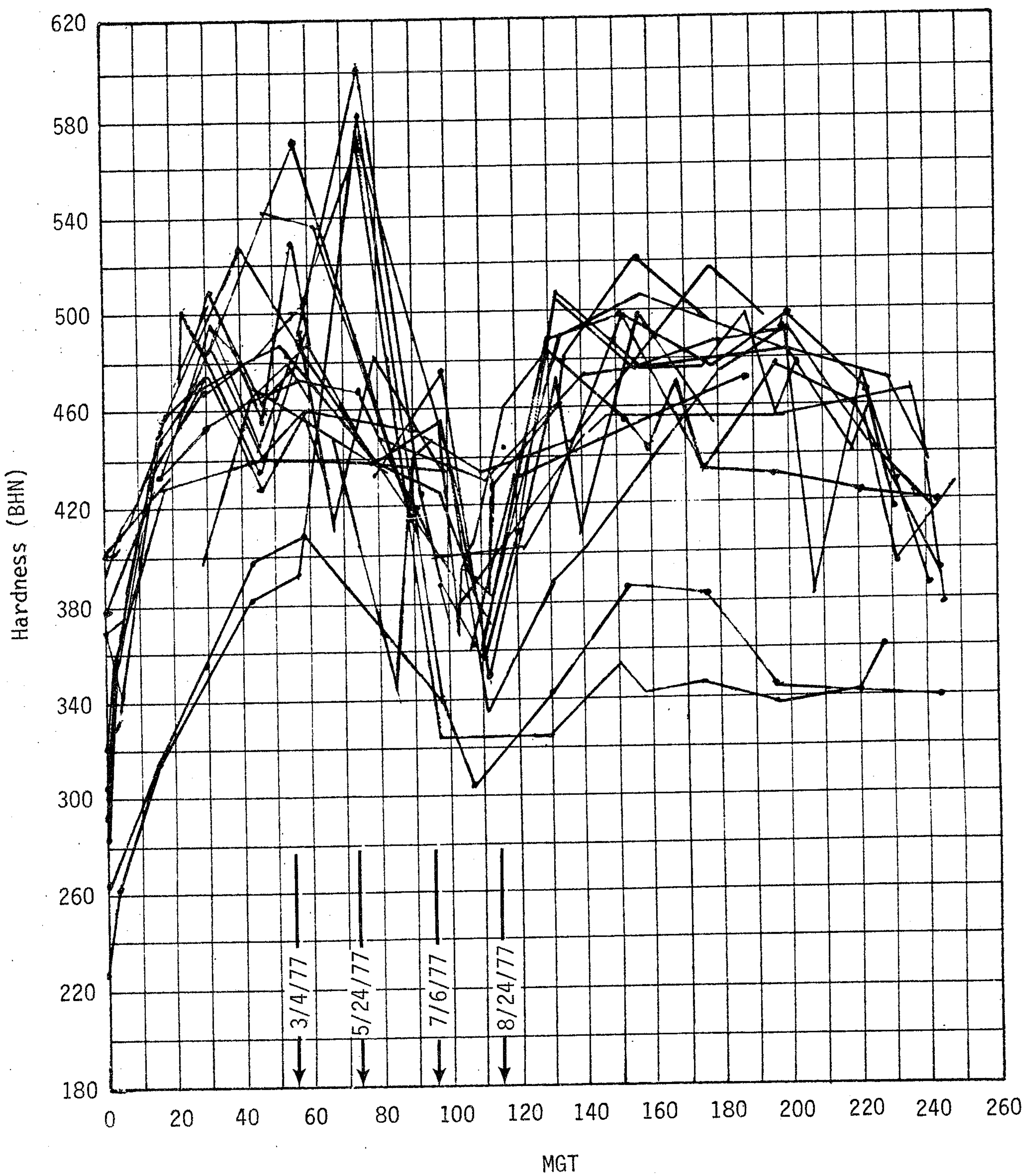


FIGURE 23. VARIATION OF AVERAGE HARDNESS (POSITIONS A THROUGH I) WITH MGT FOR ALL 17 FROGS IN FIRST TURNOUT EXPERIMENT.

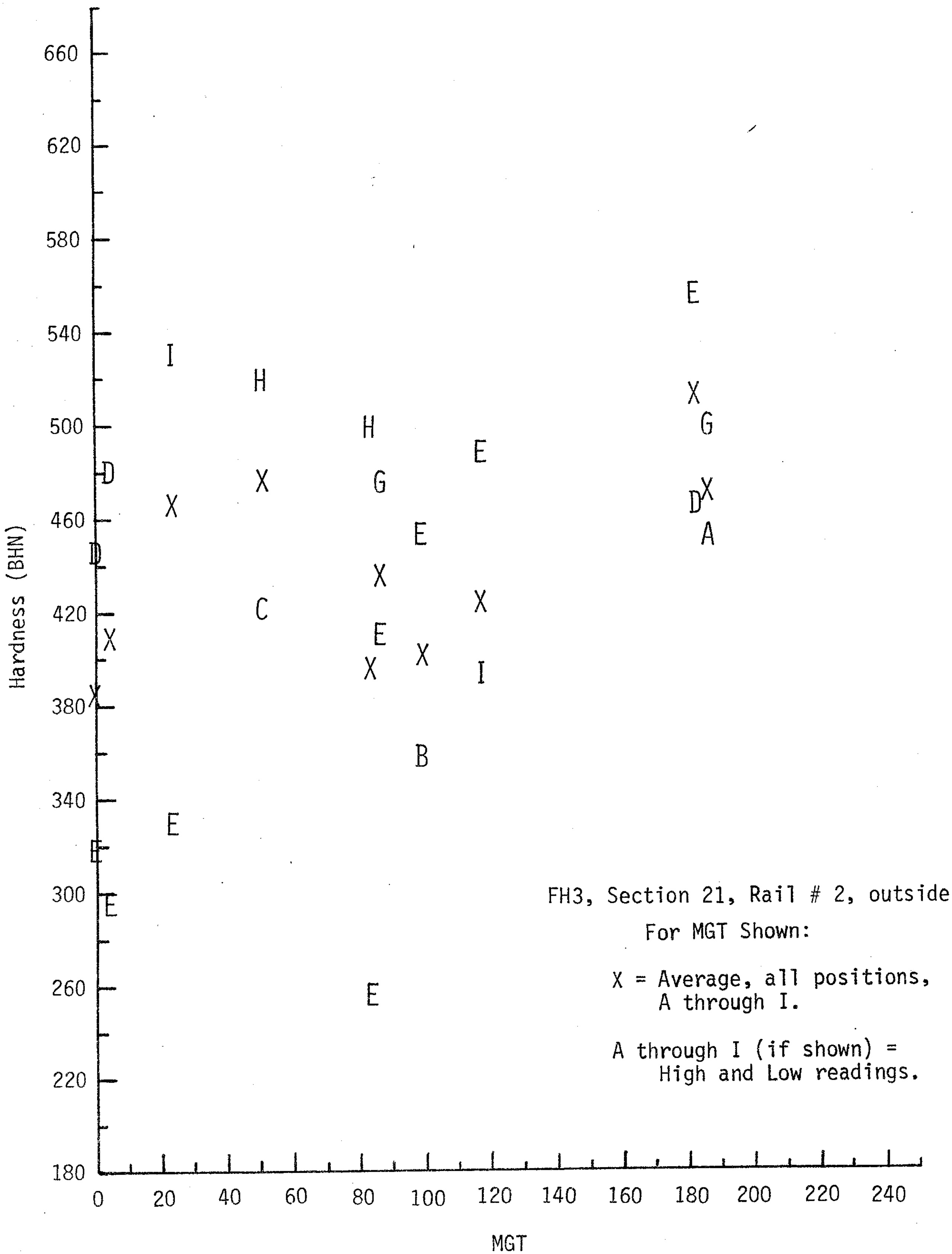


FIGURE 24. FROG HARDNESS VS. MGT.

hardness over all positions A through I is plotted as an X for each MGT when measurements were made. In addition, the position letter of the high and low measurements at this time is plotted.

The same data in terms of hardness CHANGE is presented in the following Figure 25. In this case the initial hardness measured at each location at the start of test has been subtracted from all subsequent measurements at the same location.

Some of the hardness variation with MGT may reflect things like a hardness change/lubrication interaction or the effect of seasonal temperature variation on the measurement process. However, these possibilities were not explored in this experiment.

In order to examine the data for the possibility of measurement position effect, average hardness over all MGT intervals was plotted versus measurement position for all frogs. A typical plot is shown in Figure 26 for hardness CHANGE versus position. Again the X denotes average over life and the letter F denotes the hardness change at final measurement. In this case of hardness CHANGE the initial measurement, denoted by letter I, is of course, zero.

3.2 FROG WEAR

The indicator of "wear" of the frog was taken as the change in vertical distance between a straight edge placed across the frog wings or wing rails (when measuring away from the vicinity of point) and the top running surface of the frog point. This vertical distance was measured at 5 paint marked locations A through E from the point to the heel at the same locations described above for hardness measurements. A taper gage was used, as illustrated in Figure 27, to measure this distance. There were certain practical difficulties with this method as the frog was exposed to weather and wear that tended to obliterate paint marked measurement locations. Naturally, most of the wear occurred on the side of the frog point having FAST traffic. This resulted in a section contour that made precisely repeatable taper gage placement difficult. Also, accurate and repeatable placements of the straight edge was difficult.

From a review of all these measurements it appeared that the greatest changes occurred at measurement position B and the least wear at position E near the heel. This is illustrated by Figure 28 which shows the average wear over MGT plotted as an X versus position. Also shown are the initial and final (F) measurements. Furthermore, it appeared that some of the data scatter associated with changes in measurement technique from day-to-day and person-to-person might be eliminated by computing the DIFFERENCE in wear between position B and E. This DIFFERENTIAL wear index was selected and in fact seemed to reflect a steady wear rate with MGT as illustrated in Figure 29. As may be seen in the Figure 21 photo, position B is the location where the frog point initially picks up tread load.

3.3 SWITCH POINT WEAR

The original test plan called for a measurement of height profile of the switch point as it wore using a micrometer caliper referencing off the base of

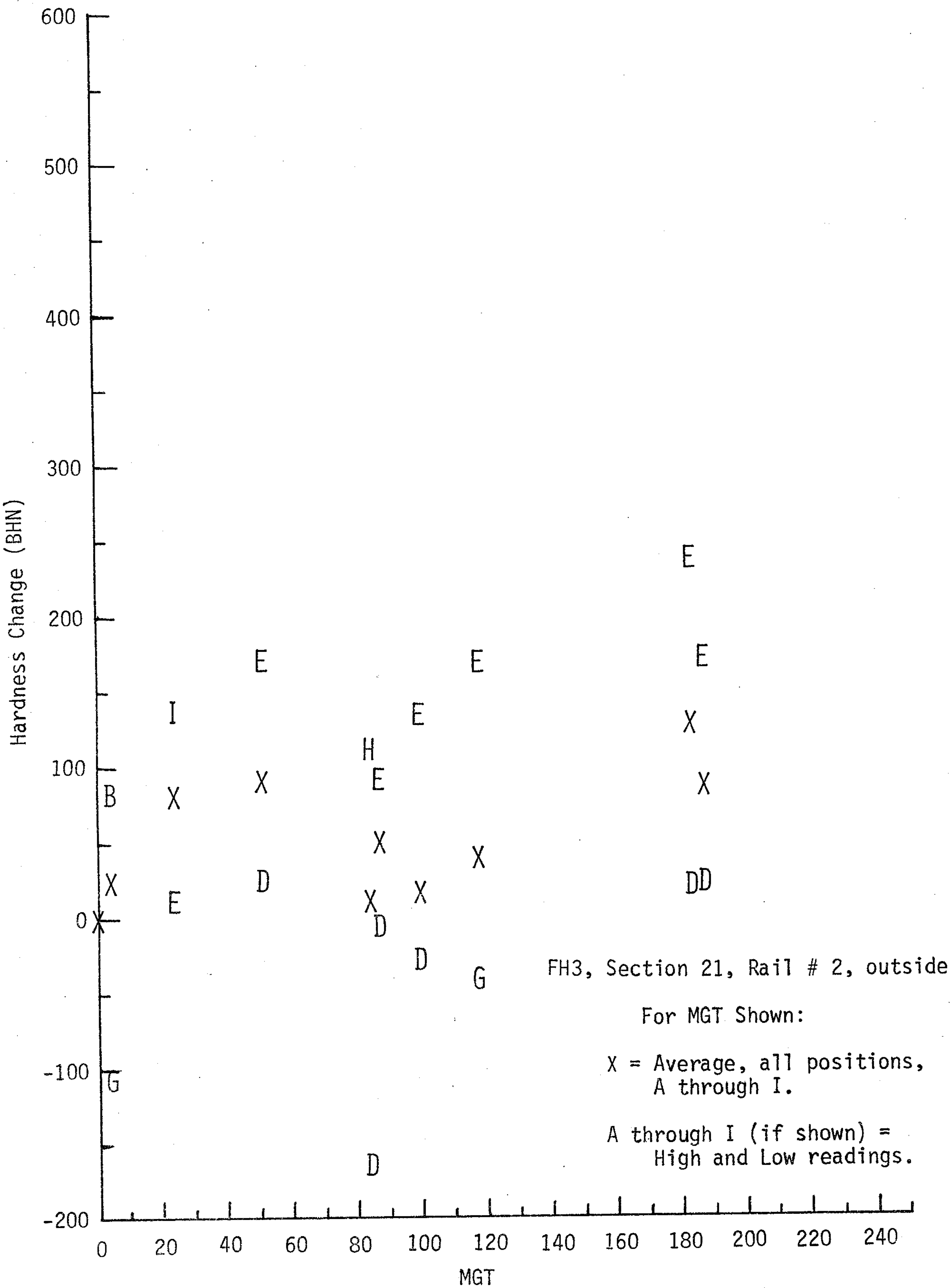


FIGURE 25. FROG HARDNESS CHANGE VS. MGT.

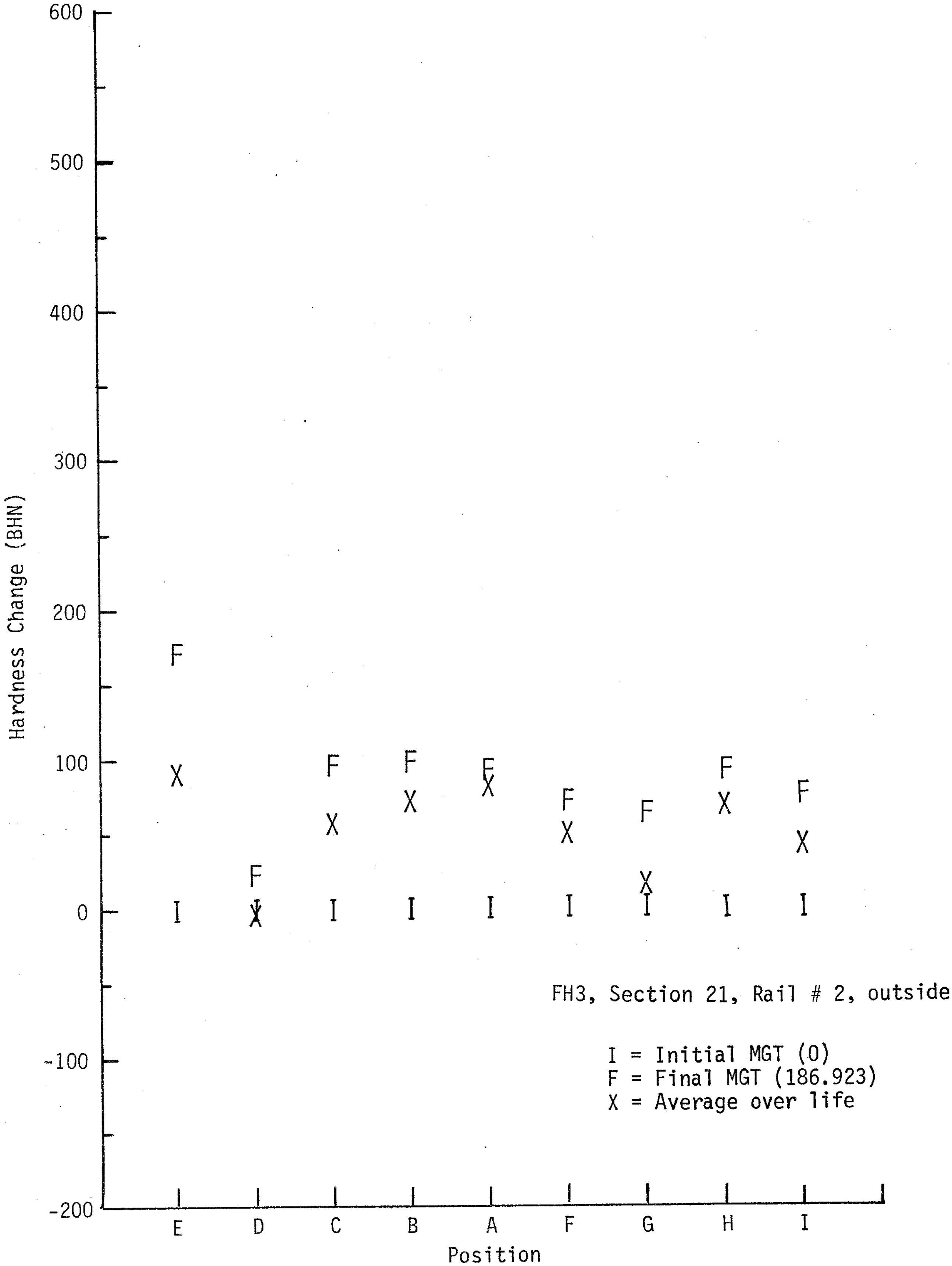


FIGURE 26. FROG HARDNESS CHANGE VS. POSITION.

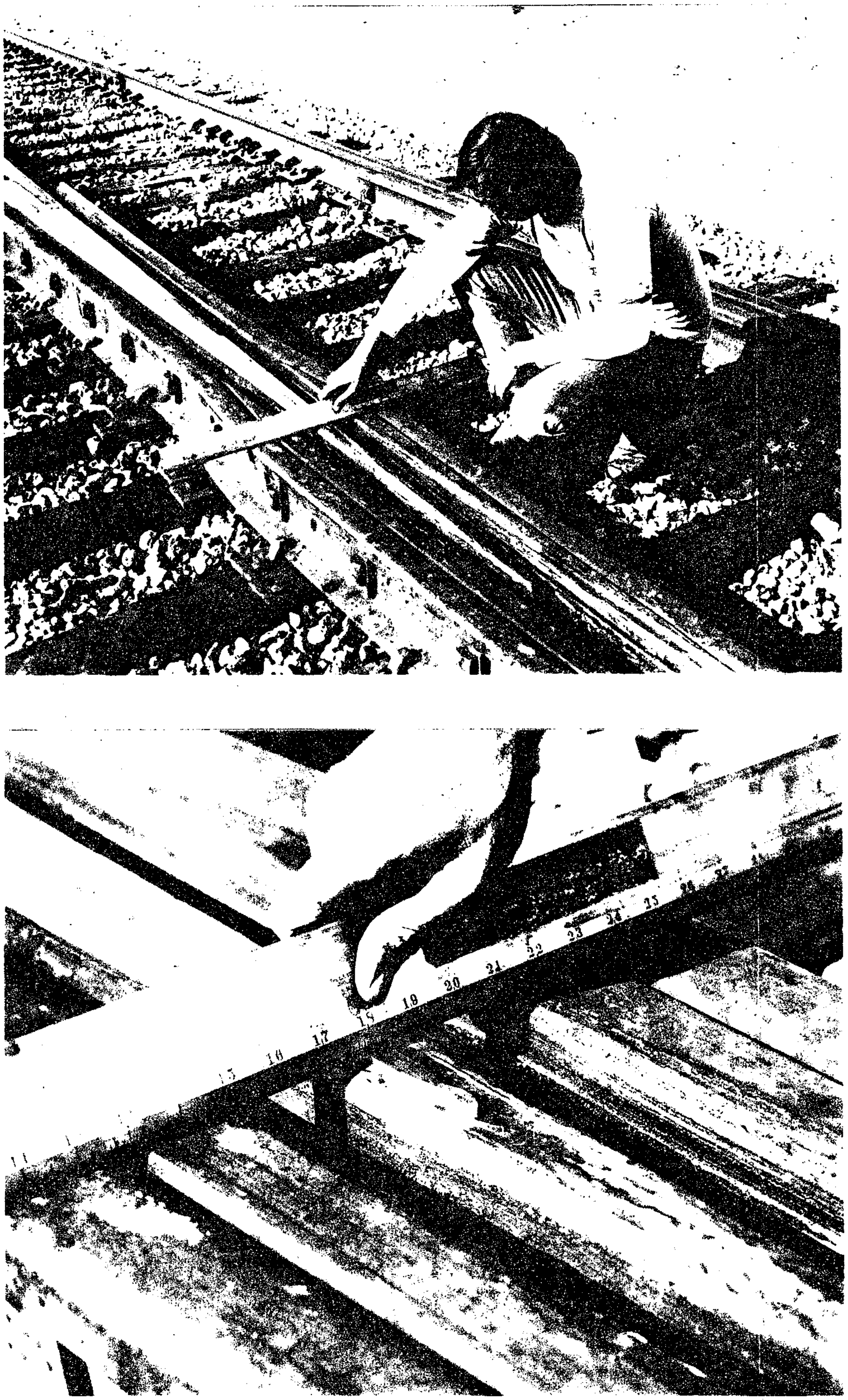


FIGURE 27. TAPER GAGE MEASUREMENT OF FROG POINT WEAR AT EAST BY-PASS SWITCH.

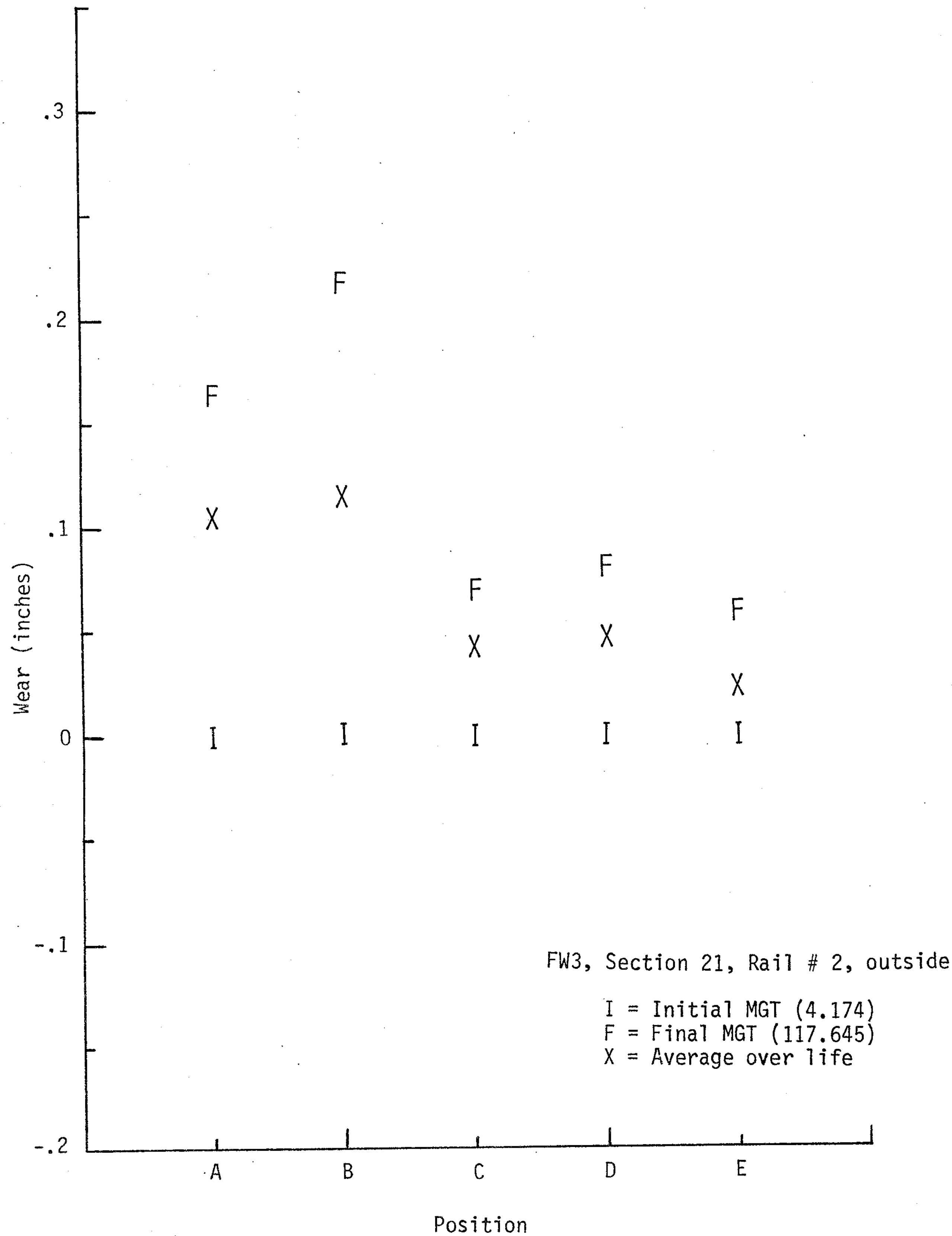


FIGURE 28. FROG WEAR VS. POSITION.

41

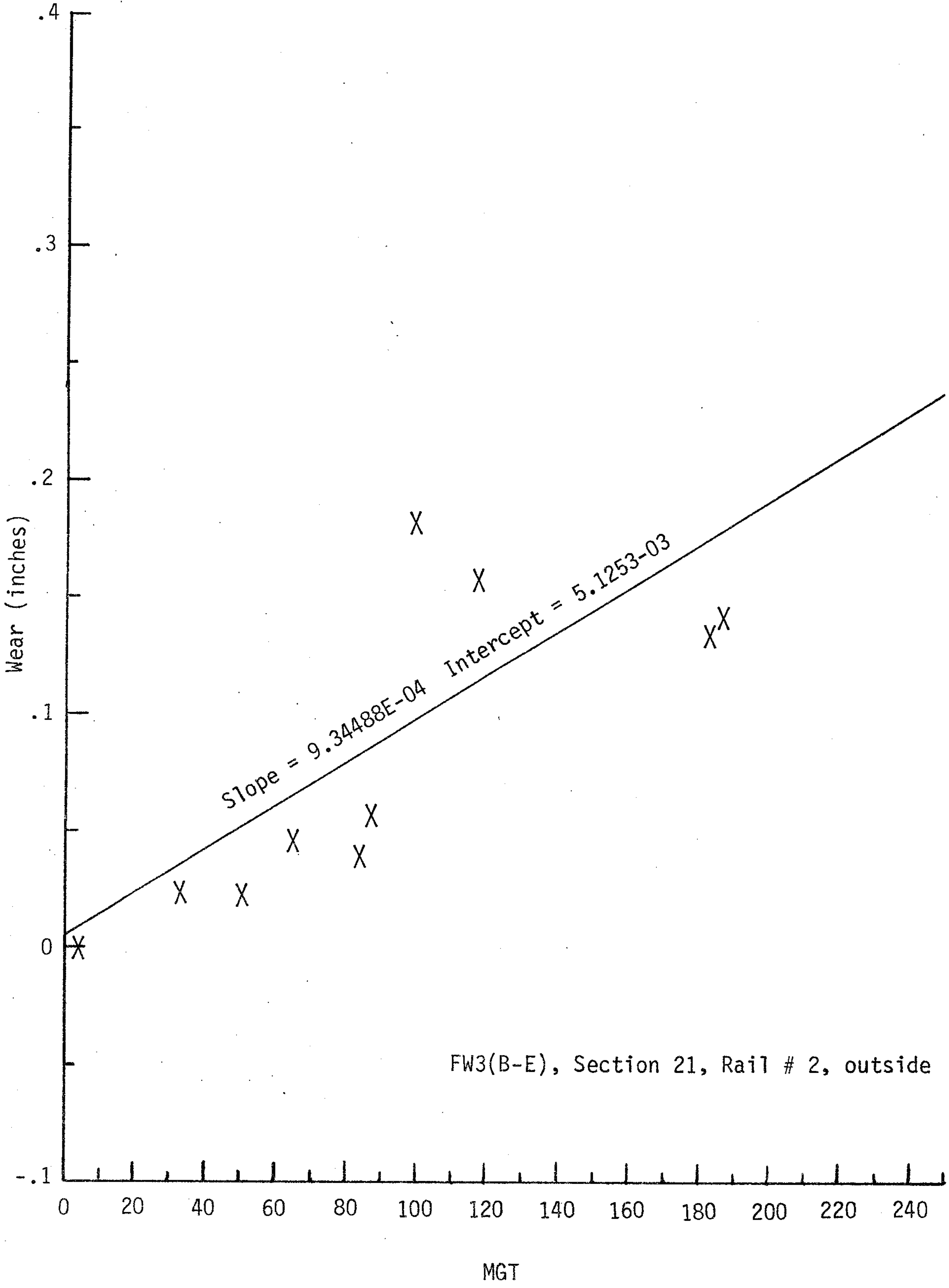


FIGURE 29. FROG WEAR VS. MGT.

the switch rail at various locations back from the tip. This proved to be very difficult to do in any repeatable way and therefore was abandoned as a measurement after less than 30 MGT into the test.

3.4 GUARD RAIL FLANGEWAY GAP

At five locations along the flangeway of each guard rail, inside of the planed flare ends, measurements of the gap were attempted. For this purpose a simple I.D. caliper was used. It was placed into the flangeway to a depth below the running rail head estimated by eye to be 5/8 inch. The caliper setting was then read to the nearest 1/32 of an inch using a scale initially and later a vernier caliper. See Figure 30. Obviously, the location of the measurement point was difficult to re-establish as the running rail gage corner wore. Late in the test a tranverse stop bar was added to the caliper to assist the technician in placing the calipers repeatedly at a flangeway depth of 5/8 of an inch.

The gap development or wear was obtained as usual by subtracting initial measurement from subsequent ones. However, it appeared that some of the initial measurements differed significantly (greater than 1/8 of an inch) from the standard gap. Little variation in separator blocks is realistic. Therefore, in order to avoid perpetuation of early measurement error or bias, the "wear" was simply computed by subtracting the standard gap from subsequent measurements. Even with this definition, there were a number of instances of apparently impossible circumstances such as gap closure. This is illustrated in Figure 31 which shows the Initial (I) average over all MGT (X) and final (F) gap change from standard plotted versus position letter A through E, located as shown in Appendix A, Table A1.7. Nevertheless, an attempt was made to obtain a measure of average gap wear from this admittedly imperfect data. To this end the grand average over MGT of all the average gap changes over position was taken. For example, this grand average gap change from Figure 32 is 0.05 inches.

3.5 SURVEY TO BENCHMARK

An attempt was made to measure rail displacement (vertical, lateral, and longitudinal), track gage, and cross-level change with MGT at three of the turnout locations (West Facility and East and West FAST) and the eight test frogs in Section 11.

For rail displacement measurements, an electronic measuring device (HP Surveyor 3810A), Figure 33, was set up over a benchmark at point B, shown schematically in Figure 34. From this point, readings were made of vertical and horizontal distances to another benchmark, C, shown in the Figure 35 photo and to a target on the rail, shown in the Figure 36 photo. The current lateral and vertical position of the rail relative to the fixed benchmarks were then computed. The longitudinal rail displacement from a line of sight perpendicular between the benchmarks was also read off a scale on the rail target.

Track gage and cross-level variance were measured using a special track gage device equipped with a superelevation bubble instrument and a gage variance indicator.

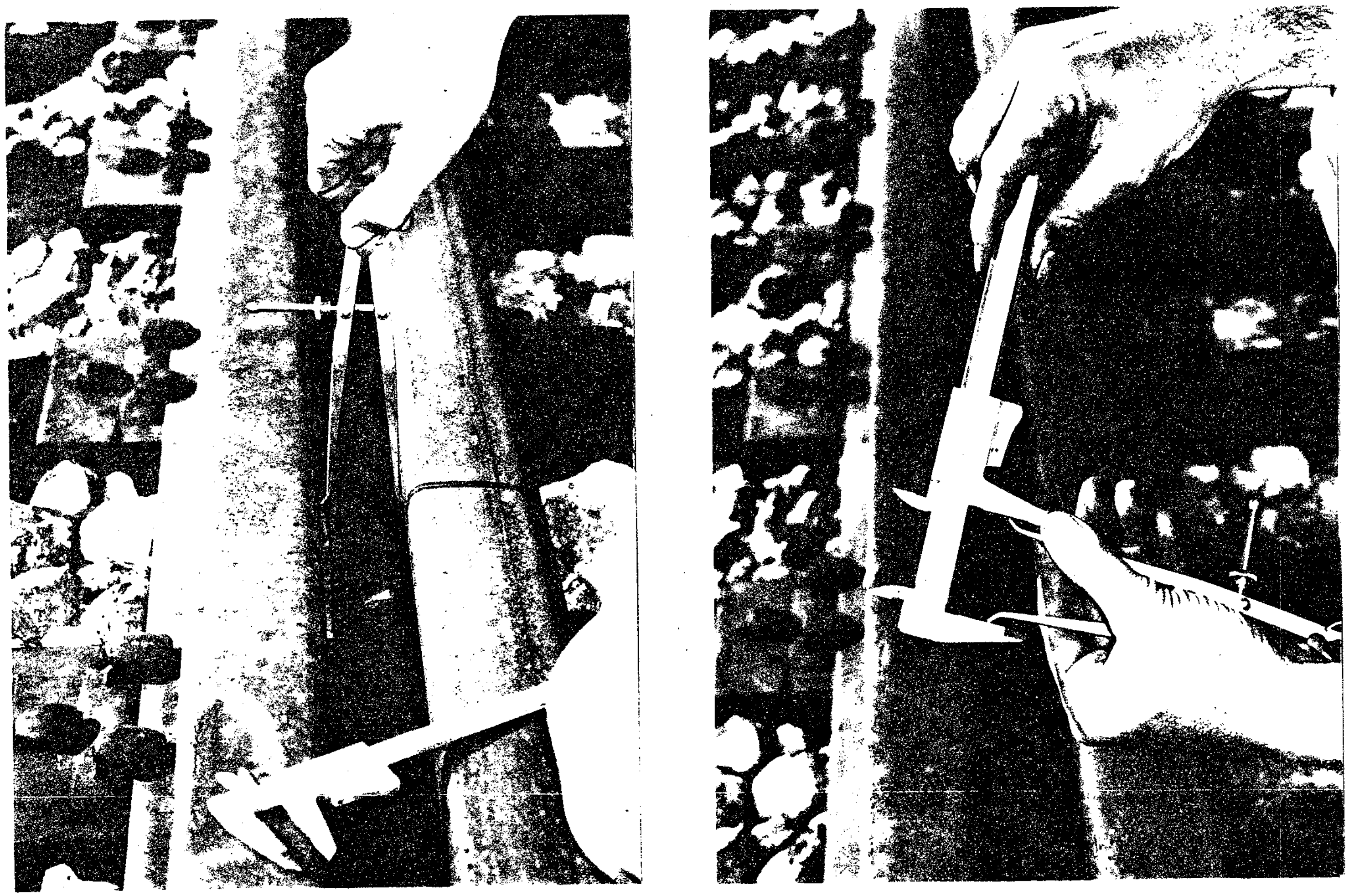


FIGURE 30. GUARD RAIL FLANGEWAY GAP MEASUREMENT.

44

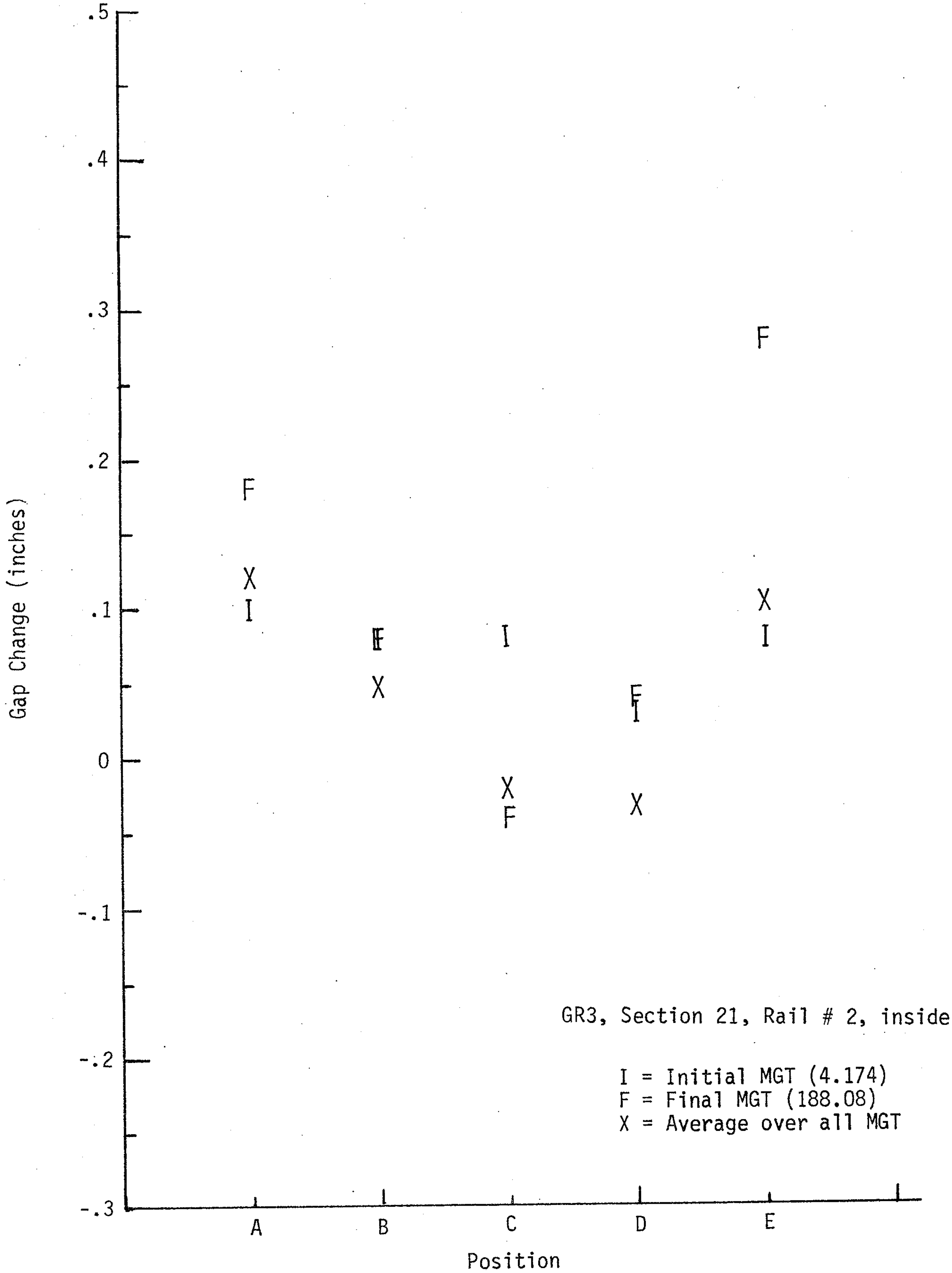


FIGURE 31. GUARD RAIL GAP CHANGE VS. POSITION.

45

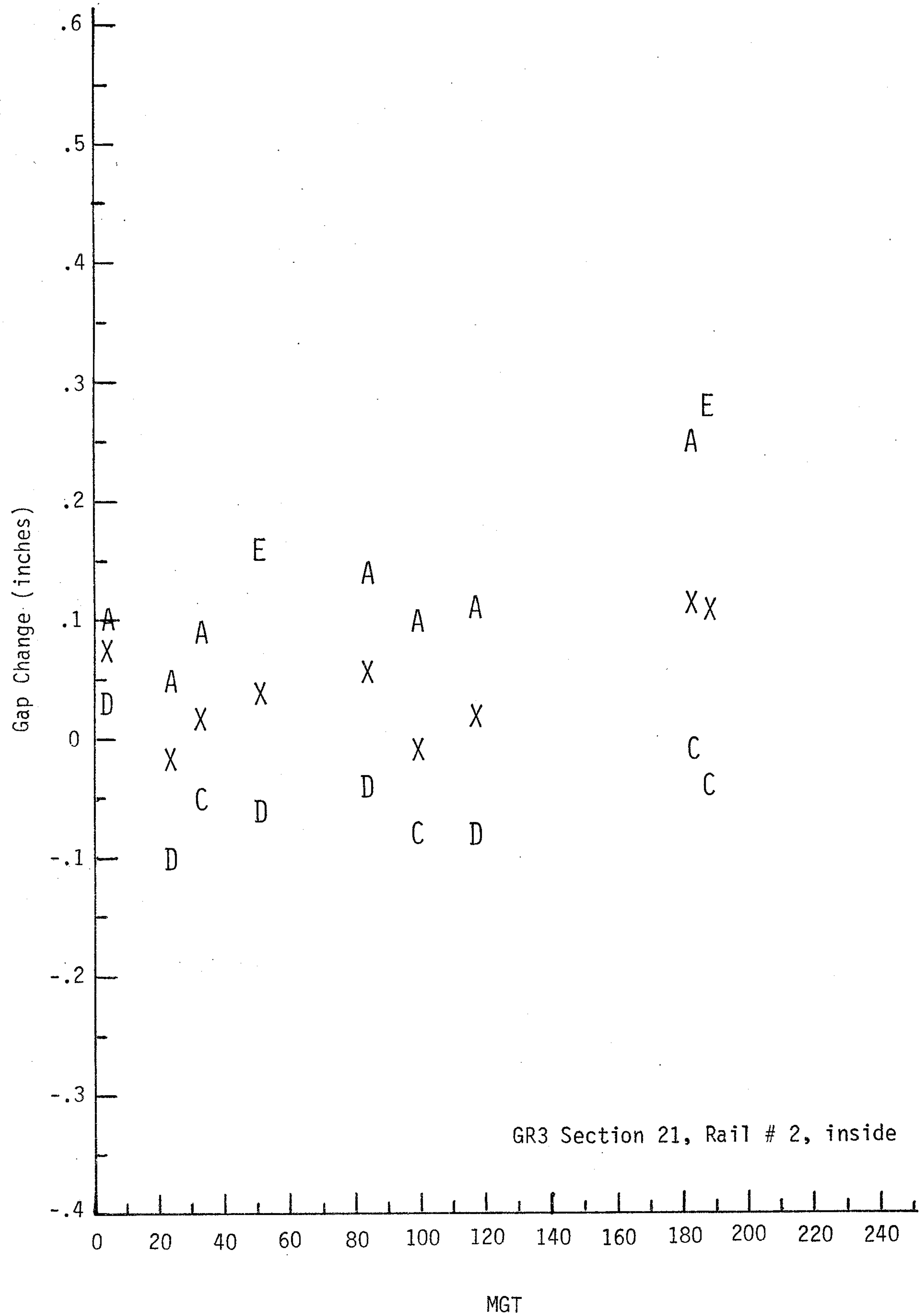


FIGURE 32. GUARD RAIL GAP CHANGE VS. MGT.

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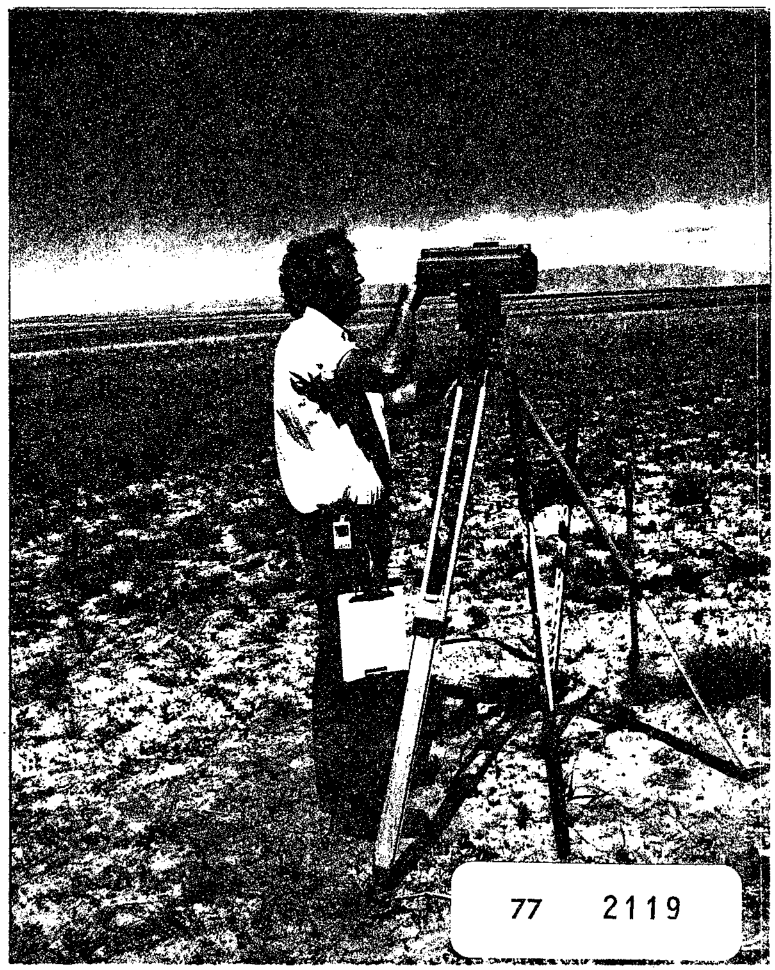

FIGURE 33. ELECTRONIC MEASUREMENT DEVICE USED FOR SURVEY TO BENCHMARK MEASUREMENT.

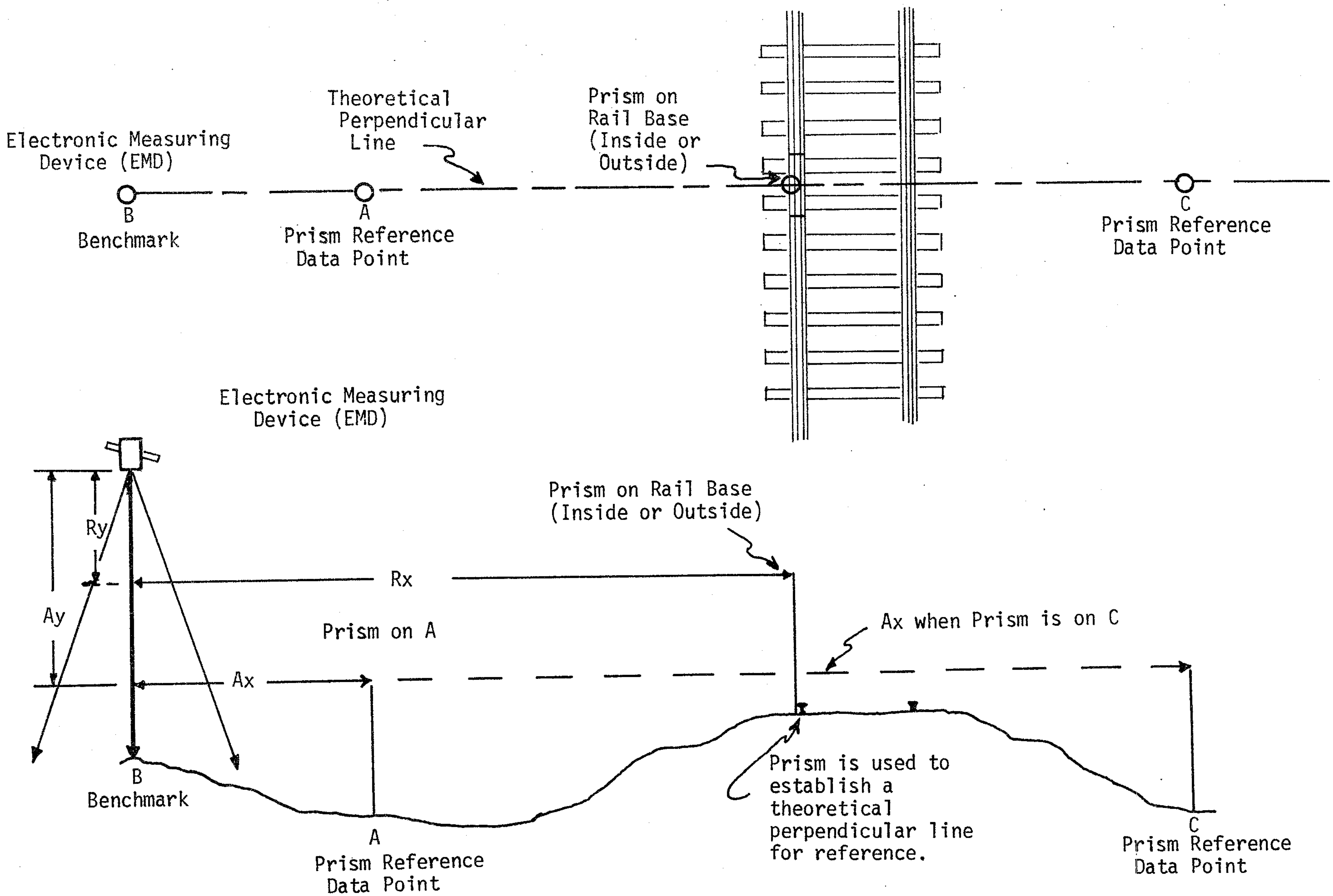

FIGURE 34. SET UP OVER A BENCHMARK.

FIGURE 35. SURVEY TO BENCHMARK REFERENCE C.

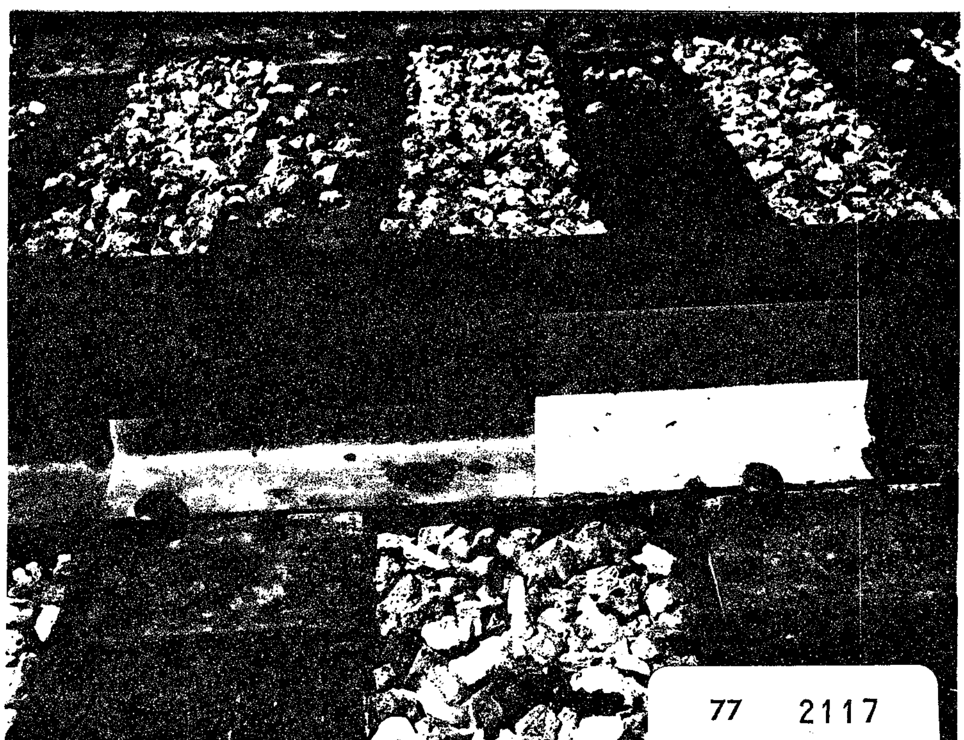

FIGURE 36. SURVEY TO BENCHMARK RAIL TARGET.

Measurements were not continued beyond about 40 MGT, however. Plots of these measurements are illustrated for two reference locations each at the East and West By-Pass in Figures 37 and 38, respectively. It appears that further measurement effort was discouraged by the frequently large variations and reversals of directions observed.

3.6 MAINTENANCE

The FAST maintenance data base contains a record of maintenance operations by location, manhours, date, and maintenance code. The maintenance codes that were selected as pertinent to the performance of turnouts and test frogs in this experiment are listed in Tables 3 and 4. The section and tie limits of maintenance "zones" around each test location are given in Tables 5 and 6. The manhours recorded for any pertinent maintenance operation that included these "zones" were prorated by a factor equal to the number of ties in the test zone divided by the ties covered by the entire operation reported.

Generally, the maintenance zones for a turnout extended 10 ties beyond the switch head block and 10 ties beyond the long turnout ties in the other direction. The split between switch and frog was taken at the insulated joint or mid-point of the closure rails.

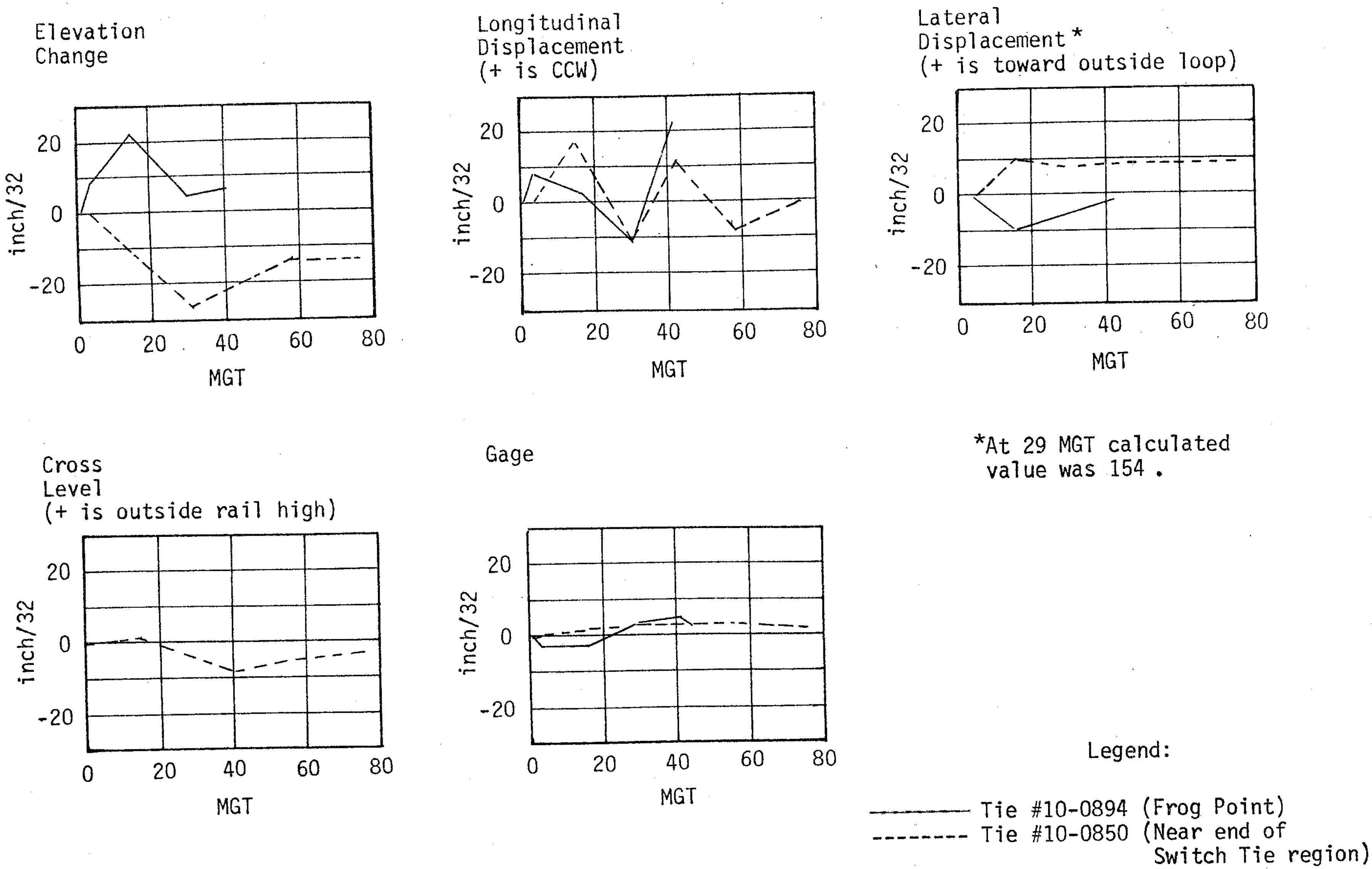

FIGURE 37. SURVEY TO BENCHMARK CHANGE AT FAST EAST BY-PASS SWITCH.

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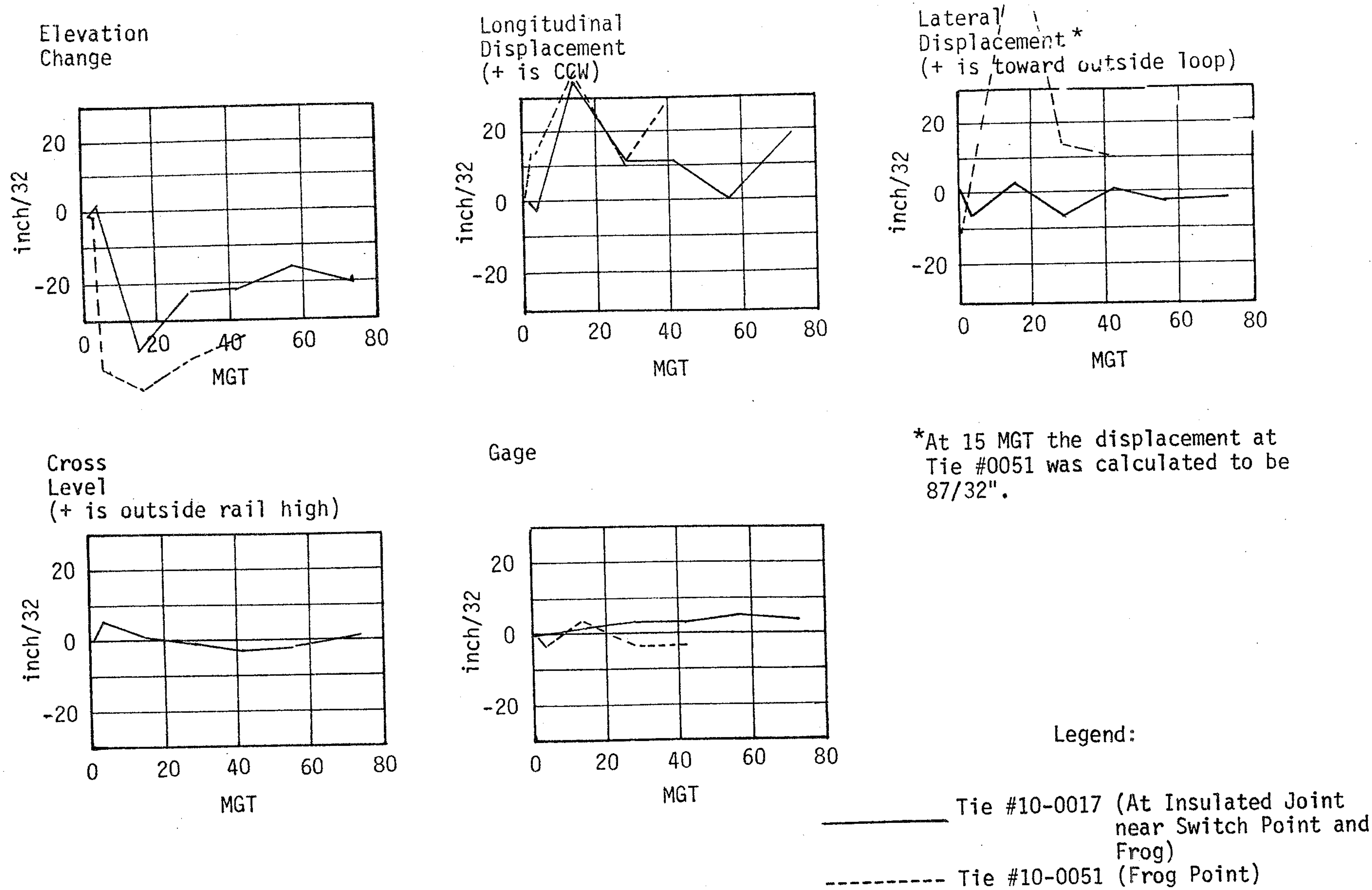

FIGURE 38. SURVEY TO BENCHMARK CHANGE AT FAST WEST BY-PASS SWITCH.

TABLE 3. LIST OF MAINTENANCE CODES SELECTED FOR TURNOUTS.

CODE	DESCRIPTION
1B	Lubricating switch slider plates
1C	Adjusting linkage, rods, throw
1F	Grinding switch points & stock rails
1G	Welding, build-up & grind switch pts. & stock rail
1J	Tamping switches
1I	Welding, build-up & grind frog pts.
1L	Tamping & lining switches
1M	Regaging
1Q	Replacing points
1R	Relaying rails
1S	Tightening or replacing switch parts
3H	Slotting joints
3J	Welding, building-up & grinding joints
4B	Redriving spikes
4D	Regaging - one side only
5A	Replacing ties in kind
6C	Spot tamping - no lining
6D	Tamping joints
9A	Replace track materials, plates, spec. equipment
9F	Relaying rail, no betterment
A1.3	Temporary repairs - plug spike holes
A1.8	Rebuilding frog
A1.12	Reinstall switch point
1A	Cleaning sand from switch points
1D	Replacing switch ties
1E	Tighten frog bolts
1H	Grind frog points
1K	Lining switches
1N	Removing ballast from switch point cribs
10	Regaging guardrails
2B	Respiking frogs
2D	Tightening frog bolts
3A	Replacing joints with field welds

TABLE 3. LIST OF MAINTENANCE CODES SELECTED FOR TURNOUTS (CONTINUED).

CODE	DESCRIPTION
3F	Retightening joint bar bolts
3G	Adding or removing huck fasteners
3I	Grinding joints
3K	Replacing broken angle bars
3L	Replacing broken angle bar bolts
4C	Spike lining
5I	Repositioning slewed ties
6A	Complete out-of-face surface tamp. lining
6B	Tamping out-of-face
6G	Spot tamping joints
7A	Reapplying anchors
7C	Applying new anchors
7D	Replacing clip fasteners
8B	Applying ballast
8D	Spread ballast
9D	Surface grind rail, spot
9J	Relaying rail due to failure
A1.0	Replacing rail brace
A1.2	Replacing broken angle bar
A1.5	Temporary repairs - replacing filler blk.
A1.6	Grind frog
A1.7	Adjust foot lock
A1.10	Grinding heel block
A1.11	Reapplying wedge

TABLE 4. LIST OF MAINTENANCE CODES SELECTED FOR TEST FROGS IN SECTION 11.

CODE	DESCRIPTION
1H	Grinding frog point
1I	Welding, building-up & grinding frog points
1S	Tightening or replacing switch parts
2A	Regage guard rail
2B	Respike frog
2D	Tighten frog bolts
3F	Retightening joint bar bolts
3H	Slotting joints
3J	Welding, building-up & grinding joints
3K	Replacing broken angle bars
3L	Replacing broken angle bar bolts
5I	Repositioning slewed ties
6A	Complete out-of-face surfacing/tamp./lining
6B	Tamping out-of-face
6C	Spot tamping - no lining
6D	Tamping joints
6F	Lining operation only, spot
6G	Spot tamping joints
7D	Replacing clip fasteners
8B	Applying ballast
9A	Replace track material, plates, special equip.
A1.0	Replace rail brace
A1.6	Grind frog
A1.8	Rebuilding frog

TABLE 5. SECTION/TIE LIMITS FOR MAINTENANCE SUMMARIES OF TURNOUTS.

LOCATION	SWITCH		FROG	
EAST FAST	15-0763	16-0000	16-0036	16-0120
	15-0797	16-0036		
WEST FACILITY	09-0099	09-0133	9-0134	0-0190
WEST FAST	21-0086	22-0085	21-0085	21-0001
	21-0101	22-0055		
WEST TDT	22-1128	1-0001	1-0005	1-0089
WEST BY-PASS	09-0339	10-0001	10-0021	10-0105
	09-0383	10-0020		
IMPACT	15-0000	14-0500	14-0394	14-0477
	15-0046	14-0477		
EAST BY-PASS	10-0927	11-0001	10-0927	10-0843
	10-0947	11-0050		
SPR. RAIL INSIDE			10-0499	10-0526
SPR. RAIL OUTSIDE			10-0393	10-0429

TABLE 6. SECTION/TIE LIMITS FOR MAINTENANCE SUMMARIES OF TEST FROGS.

LOCATION	SWITCH	FROG	
Frog #1		11-0187	11-0201
#2		11-0233	11-0247
#3		11-0283	11-0296
#4		11-0318	11-0352
#5		11-0369	11-0408
#6		11-0414	11-0447
#7		11-0464	11-0497
#8		11-0519	11-0532

4.0 SUMMARY OF RESULTS

From the graphical presentations of hardness and wear data for each test location as a function of MGT and position, such as those illustrated in the previous section, tabulations of selected average measurement changes were made in order to facilitate an overview and comparison of results.

In general, average quantities were dealt with, either in terms of average overall measurement positions for specific MGT exposure, or overall MGT exposure at specific measurement positions at a particular test site. This was done in part to lessen the impact of "outlier" data points on any overall interpretations of performance. Tabulations of results in these terms are provided in Table 7 for the major test turnouts and in Table 8 for the test frogs in Section 11.

The average hardness changes over all positions from initial measurement at significant points in the plot of hardness versus MGT are tabulated in the top three rows in these tables. The characteristic plot of hardness change with MGT features an initial rise to a high or peak early in test, a subsequent drop to a low value at an intermediate MGT, followed by a steady rise to a final average value. In some cases, particularly with the test frogs, the later rise in hardness seems to reach a plateau or crest followed usually by a drop in final hardness. In these cases the final crest and low are tabulated.

The highest average measurement and position letter where the highest hardness change occurs throughout the test are tabulated in the fourth row from the top of the table followed by that for the next highest position. This selection was made in an attempt to identify any possible position effect.

The best index of frog wear, as discussed in the previous section, appears to be the change in vertical measurement at position B near the frog point minus the wear at E near the heel. Since plots of this relative wear quantity versus MGT were successfully represented by a best fit straight line, only the 0 MGT intercept and slope or relative wear rate are tabulated in rows six and seven of the summary tables. As a confirmation of the fact that the greatest wear usually occurs at point B and as an alternative to the linear relative wear extrapolation, the final average wear over all measurement positions and the highest wear position letter are also given in table row number eight.

A crude index of the change in guard rail flangeway gap from the standard 1 7/8 inch spacing at each location is provided in the ninth row of the tables. This index is simply the average overall measurement positions and MGT. Some indication of the pattern or shape of this gap change with position on the guard rail may be gathered from the tabulation of the measurement position letter at the low data point or minimum change from the standard gap. These are the differences in guard rail end point gap minus the low point, which is usually an interior point.

This "shape" or pattern of wear along the guard rail is illustrated in Figure 39 for the turnouts and Figure 40 for the Section 11 test frogs. At each position A through E along the guardrail, the average gap change measured over the duration of the experiment is plotted. Several exceptions to the general trend of greater wear at the ends may be observed.

TABLE 7. AVERAGE MEASUREMENT CHANGES AT SWITCHES WITH MGT AND POSITION.

			EAST FAST	WEST FAST	EAST BY-PASS	WEST BY-PASS	WEST TDT	IMPACT
AVG. HARDNESS CHANGE (ΔBHN)	WITH MGT	INIT. HI AT MGT	100 at 50	90 at 50	130 at 60	170 at 50	140 at 40	100 at 50
		SUB. LOW AT MGT	20 at 90	10 at 85	10 at 95	80 at 105	0 at 105	0 at 95
		FINAL AT MGT	100 at 180	100 at 180	125 at 200	100 at 240	50 at 235	40 at 235
	WITH POSITION	MAX AT PT.	95 at E	90 at E	140 at E	160 at E	70 at H	-70 at I
		NEXT AT PT.	80 at C	80 at A	115 at H	115 at G	60 at G	60 at B
DIFF. FROG WEAR (INCH)	WITH MGT	INTERCEPT	0.02	0.01	0.04	0.03	0.04	-0.01
		RATE IN./100 MGT	0.10	0.09	0.02	0.02*	0.06**	0.04
	WITH POSITION	FINAL AT PT.	0.26 at B	0.21 at B	0.13 at A	0.07 at B	0.22 at B	0.17 at B
AVG. GUARD RAIL STD. GAP CHANGE (INCH)	WITH MGT	OVERALL AVG.	0.07	0.05	0.06	-0.06	0.05	0.06
	WITH POSITION	LOW PT.	B&C	D	B	E	C	C
		PT. A - L.P.	0.03	0.15	0.04	0.20	0.12	0.10
		PT. E - L.P.	0.10	0.14	0.10	0	0.05	0.09

* Excluding spurious data > 130 MGT.
** Excluding data > 200 MGT.

TABLE 8. AVERAGE MEASUREMENT CHANGES IN FROG FARM WITH MGT AND POSITION.

		TEST FROG # →	#1	#2	#3	#4	#5	#6	#7	#8
AVG. HARD-NESS CHANGE (ΔBHN)	WITH MGT	INIT. HI AT MGT	150 at 30	200 at 30	170 at 50	170 at 40	180 at 35	175 at 35	160 at 30	150 at 35
		SUB. LOW AT MGT	----	100 at 100	80 at 110	50 at 100	80 at 110	----	100 at 100	100 at 100
		FINAL AT MGT	---- ----	180 at 200 100 at 230	160 at 200 60 at 240	150 at 200 90 at 240	160 at 170 ----	---- ----	170 at 180 100 at 240	170 at 180 ----
	WITH POSITION	MAX. AT PT.	140 at G	160 at D	155 at E	120 at E	180 at E	135 at F	150 at F	160 at E
		NEXT AT PT.	115 at D	140 at D&B	140 at G	110 at B	140 at G	130 at B	140 at G	120 at C
DIFF. FROG WEAR (INCH)	WITH MGT	INTERCEPT	-0.01	-0.04	0	-0.04	0.03	-0.01	-0.01	-0.02
		RATE IN./ 100 MGT	0.04	0.10	0.07	0.09	0.08	0.11	0.09	0.18
	WITH POSITION	FINAL AT PT.	0.02 at B	0.15 at B	0.23 at B	0.22 at B	0.19 at B	0.06 at B	0.30 at B	0.27 at B
AVG. GUARD RAIL STD. GAP (INCH)	WITH MGT	OVERALL AVG.	0.13	0.09	0.07	0.11	0.12	0.08	0.06	0.04
	WITH POSITION	LOW PT.	A	C	C	D	A	C	C	B
		PT.A-L.P.	0	0.07	0.05	0.16	0	0.05	0.12	0.08
		PT.E-L.P.	0.07	0.05	0.08	0.04	0.03	0.06	0.10	0.03

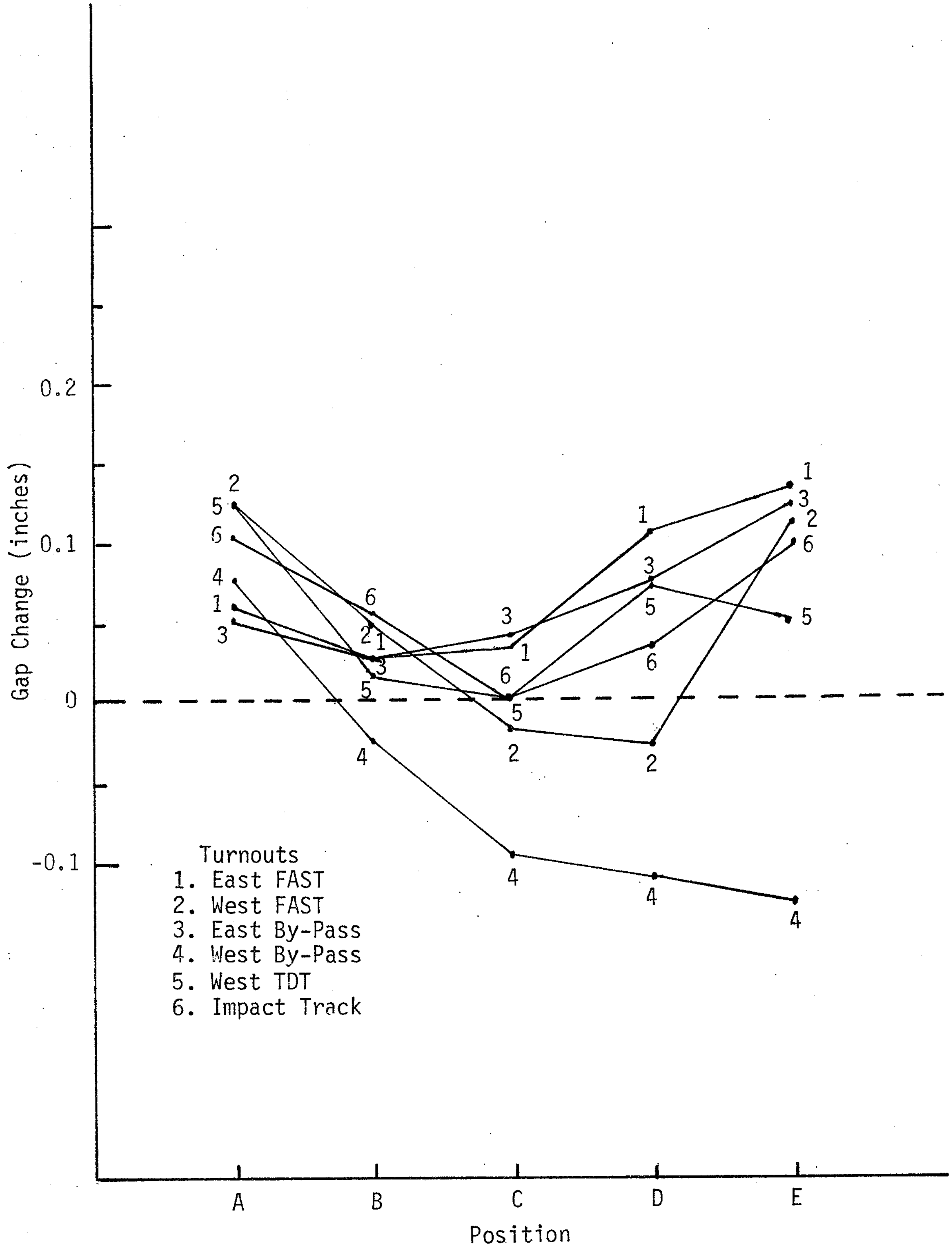

FIGURE 39. GUARD RAIL GAP CHANGE WITH POSITION - AVERAGE OVER TEST PERIOD, TURNOUTS.

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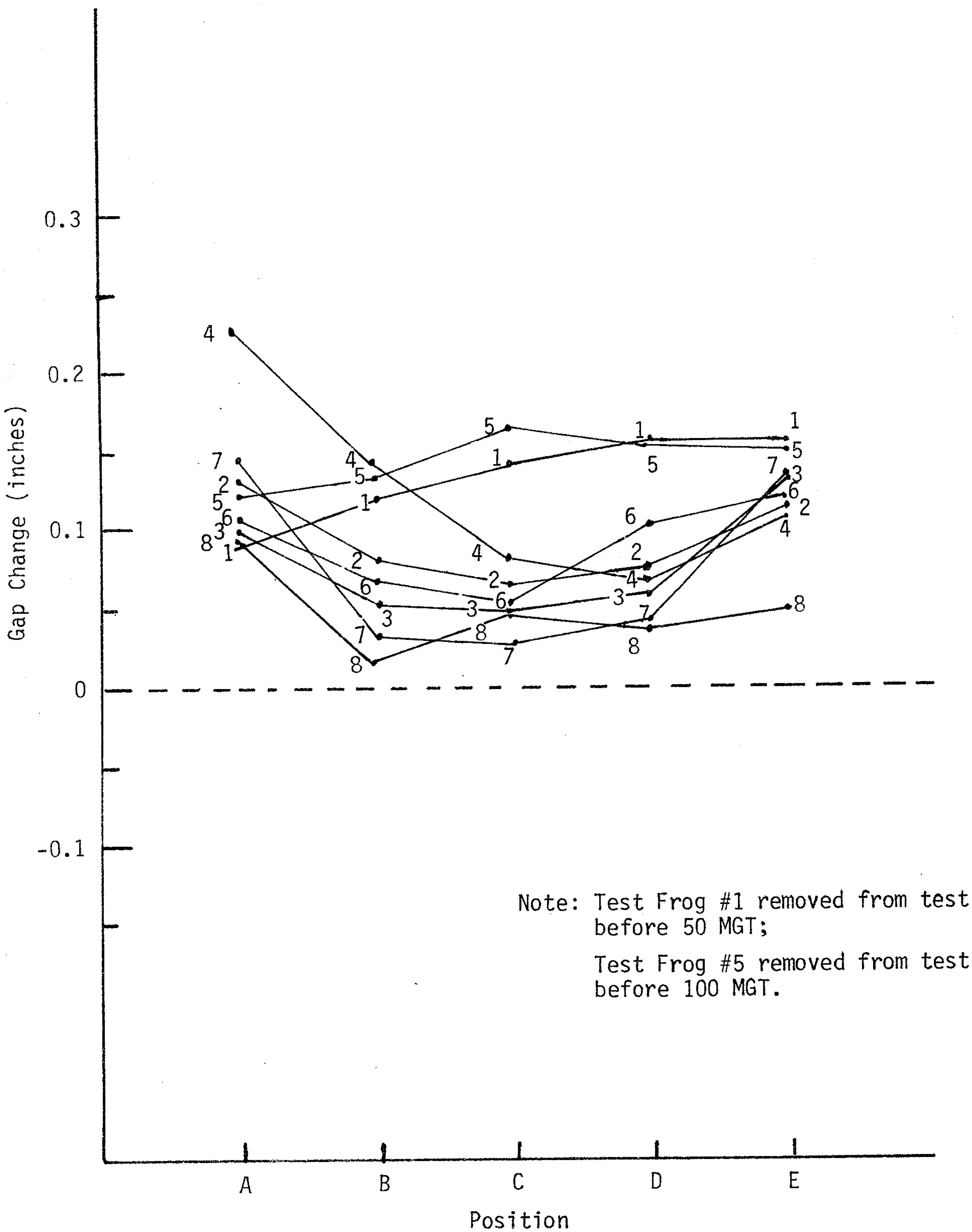

FIGURE 40. GUARD RAIL GAP CHANGE WITH POSITION - AVERAGE OVER TEST PERIOD, TEST FROGS - SECTION 11.

The attempt to obtain actual wear rates at the guard rail exit/entrance flares for each test location was frustrated by the high degree of variability and relatively few data points. However, some suggestion of the rate of guard rail flangeway opening may be derived from Figure 41 for all the turnouts and Figure 42 for the Section 11 test frogs. In these plots of gap change versus MGT, only the point (A, B, C, D, or E) having the greatest gap change at each MGT measured is plotted. The subscripts refer to the particular turnout or test frog. An overall average rate of maximum flangeway opening of about 0.14 inches per 100 MGT is indicated from these plots. However, the considerable scatter of data is also evident.

The quantity selected for the summary of the survey to benchmark data was simply the average over all MGT (which only included early testing) for lateral and longitudinal displacement, elevation, and gage change. Since only a few measurements were made at some turnouts, only the results at the test frogs are tabulated in Table 9.

Maintenance data, in terms of manhours expended within the tie regions identified with each test location in the previous report section, are summarized in Table 10 for the major test turnouts and in Table 11 for the test frogs of Section 11.

A discussion and interpretation of these summary results by test pairs or group follows.

4.1 EAST AND WEST FAST TURNOUTS

From Table 7 there appears to be no significant differences in hardness change between the two turnout frogs. They each show a characteristic 90 to 100 BHN rise above their initial measurement at about 50 MGT, followed by a drop in hardness before 100 MGT, then an apparent "recovery" of this increase by the time the last measurement was recorded at about 180 MGT (but not the end of test). The greatest hardness change over all MGT is at measurement position E nearer the heel.

The differential wear of the frog is slightly greater in East FAST, perhaps 20% greater in terms of relative wear at 100 MGT. It should be noted that the manganese steel frog in West FAST was press hardened. Probable differences in dynamic and tractive wheel loads at these sites must again be acknowledged. More severe conditions might be expected at East FAST due to its position on the spiral of a 5 degree curve at the foot of a 2% grade.

The guard rail gap or flangeway average increase over the standard gap appears to be slightly greater (0.07" vs. 0.05") at East FAST.

There is greater maintenance effort on East FAST (13.8 manhours per 100 MGT vs. 9.0 manhours per 100 MGT) with the biggest difference being on switch maintenance subtotals. This may be expected because of the more severe lateral loading anticipated in East FAST. However, in West FAST the effect of vertical wheel pounding as the train consist leaves the nearby concrete crossing may be reflected in the higher spot tamping (8.1 manhours vs. 4.7 manhours) required there. Frog related maintenance was only slightly different, being somewhat higher in the lining/tamping (1L), spot tamping (6C), and welding (3J) categories for the West FAST turnout.

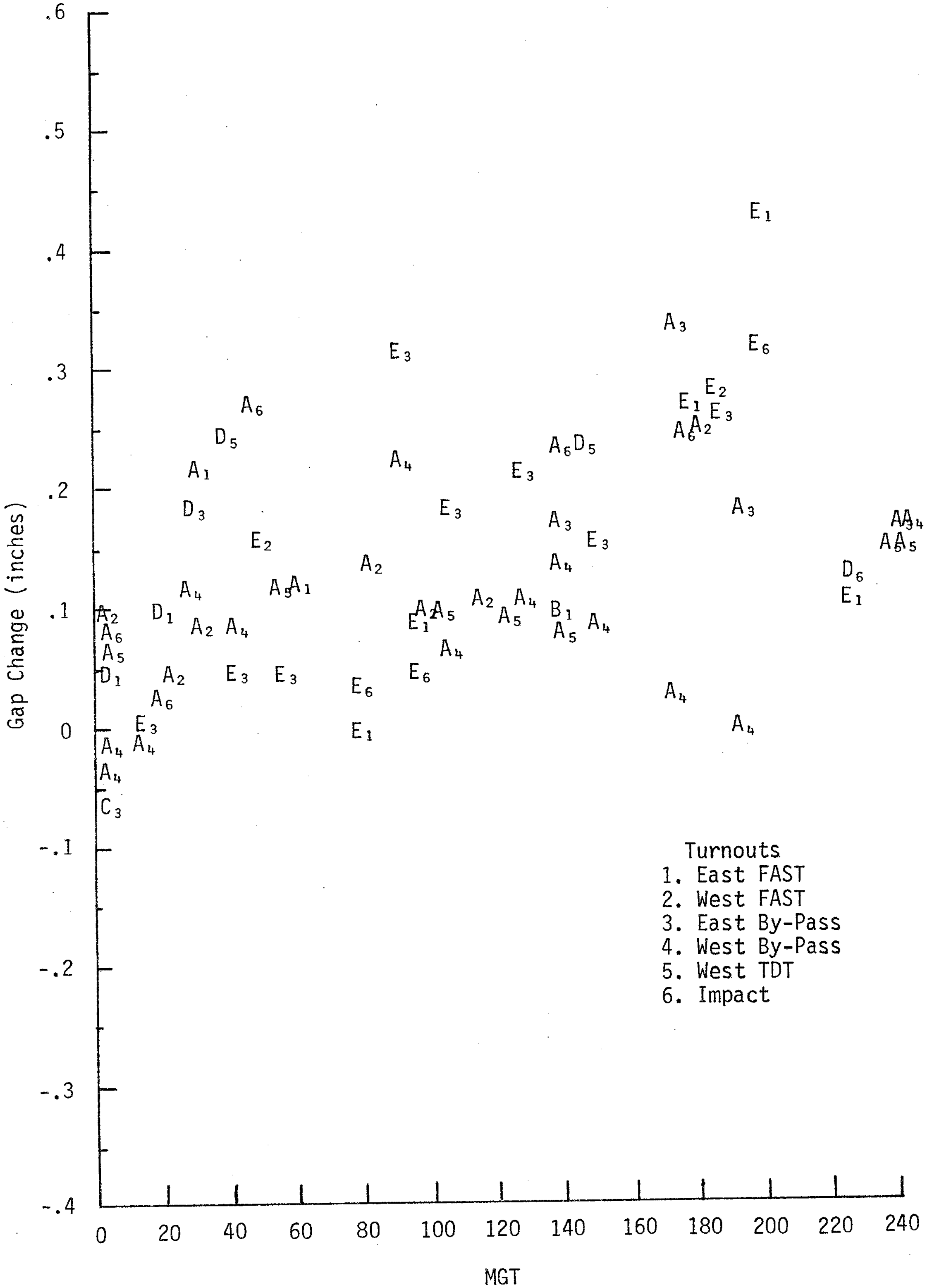

FIGURE 41. MAXIMUM GAP (AT POSITION LETTER) VS. MGT.

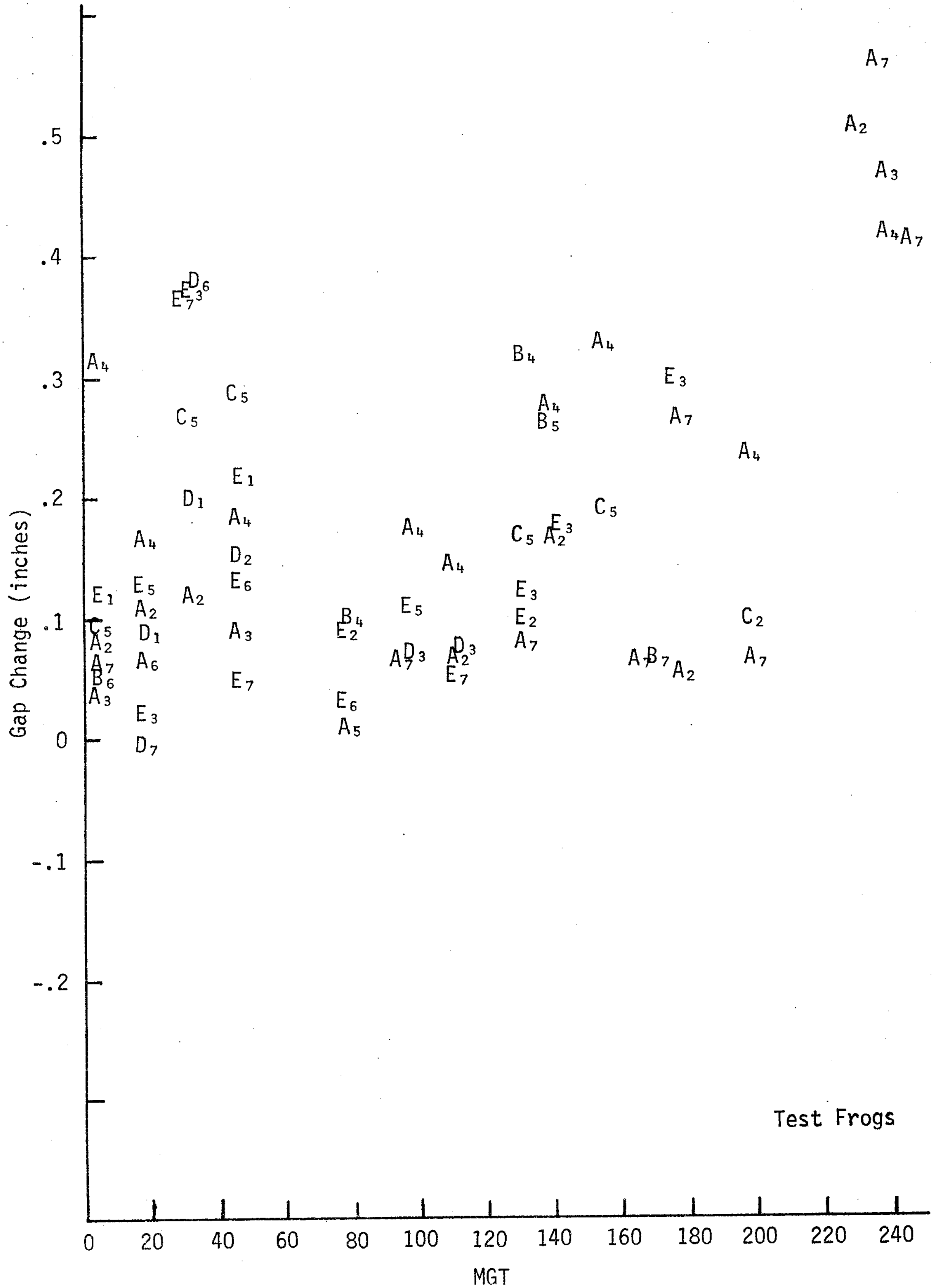

FIGURE 42. MAXIMUM GAP (AT POSITION LETTER) VS. MGT.

TABLE 9. AVERAGE SURVEY TO BENCHMARK DATA (IN 32NDS OF INCH) FOR 1ST TURNOUT EXPERIMENT.

MEASUREMENT	TEST FROG #							
	1	2	3	4	5	6	7	8
AVG. LATERAL DISPLACEMENT	13	-6	5	-13	3	-4	-5	-10
AVG. ELEVATION CHANGE	2	-3	-11	10	-31	10	-13	-6
AVG. LONGITUDINAL DISPLACEMENT	3	-19	14	-14	32	-18	39	21
AVG. GAGE CHANGE	-7	-3	-6	-4	-1	-2	-5	-5

NOTES:

1. + Lateral displacement is toward outside of FAST loop.

2. + Elevation change is up.

3. + Longitudinal displacement is in CCW direction.

4. + Gage change is increase.

5. Averages exclude maximum of one 'outlier' point per location. (Average given in nearest 32nd of inch).

6. Data available for only initial 46 MGT.

TABLE 10. MAINTENANCE MANHOURS FOR TEST TURNOUTS (INDIVIDUAL CODE IF IT CONTAINS AT LEAST 4% OF MAINTENANCE FOR ANY TURNOUT).

CODE	EAST FAST			WEST FAST			EAST BY-PASS			WEST BY-PASS			WEST TDT			IMPACT		
	TOT	SW	FR	TOT	SW	FR	TOT	SW	FR	TOT	SW	FR	TOT	SW	FR	TOT	SW	FR
1B	0.3	0.3	0	0.3	0.3	0	0.3	0.3	0	0.3	0.3	0	0	0	0	0.5	0.5	0
1C	0.9	0.9	0	1.3	1.3	0	0.1	0.1	0	0.2	0.2	0	0.7	0.7	0	0	0	0
1F	1.3	1.3	0	1.0	1.0	0	0.5	0.5	0	0.9	0.9	0	0	0	0	0.3	0.3	0
1G	1.3	1.3	0	1.0	1.0	0	0.1	0.1	0	0.4	0.4	0	0	0	0	0	0	0
1J	3.0	3.0	0	8.2	8.2	0	2.7	2.7	0	2.8	2.8	0	1.9	1.9	0	1.0	1.0	0
1I	0	0	0	0.1	0	0.1	0.5	0	0.5	0.1	0	0.1	0.4	0	0.4	0.8	0	0.8
1L	2.8	2.8	0	1.9	0	1.9	1.2	1.2	0	0	0	0	0	0	0	0.8	0.8	0
1M	0	0	0	0	0	0	0	0	0	1.5	1.5	0	0	0	0	0	0	0
1Q	2.4	2.4	0	0	0	0	3.8	3.8	0	4.8	4.8	0	0	0	0	1.0	1.0	0
1R	2.4	2.4	0	0	0	0	0	0	0	0.6	0.6	0	0.6	0	0.6	0	0	0
1S	0.3	0.3	0	0.1	0.1	0	0.5	0.5	0	0.3	0.3	0	0.9	0.9	0	0.7	0.7	0
3H	0.5	0.4	0.1	0.4	0.3	0.1	1.4	0.3	1.1	0.5	0.3	0.2	0	0	0	0.2	0.1	0.1
3J	0.3	0.1	0.2	0.5	0.1	0.4	0.8	0	0.8	0.3	0	0.3	1.0	0.3	0.7	1.2	0.6	0.6
4B	3.1	2.5	0.6	0	0	0	0.4	0.2	0.2	0	0	0	0.7	0	0.7	0.1	0.1	0
4D	0.8	0.8	0	0	0	0	0	0	0	0	0	0	1.0	0	1.0	0.4	0.2	0.2
5A	0.1	0.1	0	0.1	0.1	0	0	0	0	0.1	0.1	0	2.5	0.2	2.3	0	0	0
6C	4.7	2.8	1.9	8.1	5.8	2.3	5.8	5.5	0.3	0.7	0.2	0.5	4.7	0.1	4.6	1.9	0.5	1.4
6D	0	0	0	0	0	0	0.2	0	0.2	0.2	0.1	0.1	0	0	0	0	0	0
9A	0.1	0	0.1	0	0	0	0.4	0.3	0.1	0.3	0.2	0.1	0.3	0	0.3	0.2	0	0.2
9F	0	0	0	0	0	0	0	0	0	0	0	0	2.4	0.8	1.6	0	0	0
A1.3	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0.1	0.1	0.4	0.4	0
A1.8	0	0	0	0	0	0	0	0	0	2.4	0	2.4	0	0	0	0	0	0
A1.12	8.8	8.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OTHER	3.5	2.1	1.4	1.3	0.7	0.6	2.8	1.4	1.4	0.7	0	0.8	1.8	0.8	0.9	1.5	1.0	0.5
TOTAL	36.6	32.3	4.3	24.3	18.9	5.4	21.5	16.9	4.6	17.2	12.7	4.5	18.4	5.1	13.2	11.0	7.2	3.8
MGT	265			271			264			269			269			262		
MH/100 MGT	13.8	12.2	1.6	9.0	7.0	2.0	8.1	6.4	1.7	6.4	4.7	1.7	6.8	1.9	4.9	4.2	2.7	1.5

TABLE 11. MAINTENANCE MANHOURS FOR TEST FROGS IN SECTION 11.

	1	2	3	4	5	6	7	8		
FROM TIE #	0177	0222	0273	0318	0369	0414	0464	0519	TIE LIMIT	
TO TIE #	0211	0256	0304	0352	0408	0447	0497	0532	TIE LIMIT	
	1	2	3	4	5	6	7	8	TEST FROG #	
TOTAL MH	M A N H O U R S								CODE	DESCRIPTION
0.50			0.15	0.15				0.20	1H	Grinding frog point
3.04	0.60	0.20	0.64	0.60			0.60	0.40	1I	Welding, building-up & grinding frog points
0.11	0.05		0.06						1S	Tightening or replacing switch parts
0.10								0.10	2A	Regage guardrail
0.02			2.02						2B	Respike frog
2.79	0.71	0.35	0.33	0.35	0.45	0.02	0.14	0.44	2D	Tighten frog bolts
0.12		0.02		0.10					3F	Retightening joint bar bolts
0.30								0.30	3H	Slotting joints
0.20				0.20					3J	Welding, building-up & grinding joints
0.25				0.05			0.05	0.15	3K	Replacing broken angle bars
0.11		0.01		0.10					3L	Replacing broken angle bar bolts
2.06	0.40	0.50		0.20	0.51			0.45	5I	Repositioning slewed ties
2.16		0.36	0.36	0.36	0.36		0.36	0.36	6A	Complete out-of-face surfacing/tamp./lining
1.15	0.05	0.25	0.25	0.45	0.05		0.05	0.05	6B	Tamping out-of-face
8.27	1.16	1.16	2.11	1.54	0.56		0.73	1.01	6C	Spot tamping - no lining
0.40		0.03	0.03	0.25	0.03		0.03	0.03	6D	Tamping joints
0.05				0.05					6F	Lining operation only, spot
0.10			0.10						6G	Spot tamping joints
0.02			0.02						7D	Replacing clip fasteners
1.59	0.30	0.30	0.30	0.30	0.03	0.03	0.03	0.30	8B	Applying ballast
0.23	0.05		0.05	0.05	0.02			0.06	9A	Replace track material, plates, special equip.
0.05		0.05							A1.0	Replace rail brace
0.45			0.15	0.20	0.10				A1.6	Grind frog
0.50			0.20					0.30	A1.8	Rebuilding frog
24.57	3.32	3.23	4.77	4.95	2.11	0.05	1.99	4.15	TOTAL MANHOURS	
	64.2	229.0	238.0	238.0	173.0	54.4	245.0	257.3	MGT REMOVED OR END OF TEST	
	5.17	1.41	2.00	2.08	1.22	0.09	0.81	1.61	MANHOURS PER 100 MGT	

A listing of the significant component maintenance and replacement events for East and West FAST is provided in Appendix C, Tables C-1 and C-2.

Although there are no reliable quantitative data on the development of switch point wear, severe wear of the switch point was observed early at both switches as illustrated by the photo shown in Figure 43 for West FAST after only 2 MGT. This initial severe wear may have reflected the initial period of ineffective lubrication. At 28 MGT, wear along the East FAST switch point appeared as shown in Figure 44 and 45. Replacement of the standard steel tips, shown in typical worn condition in Figure 46 at 29 MGT, with manganese steel is shown in Figure 47.

A failure of the manganese steel tip at 74 MGT at East FAST is shown in Figure 48. A frog failure in the manganese casting of this turnout that occurred at 196 MGT is shown in Figure 49.

4.2 EAST AND WEST BY-PASS TURNOUTS

The frog hardness changes are similar at these locations with a slightly greater initial average hardness change (170 vs. 130) in the East By-Pass. The hardness change is also greater nearer the heel for both. The initial increase in hardness for this pair of one charge explosive hardened frogs appears to be greater than that for the standard RBM frog in East FAST and the press hardened frog in West FAST. However, the maximum hardness level attained at about 50 MGT in all four frogs was nearly the same (490 BHN).

The extrapolated differential wear rates are relatively small and essentially the same at both turnout frogs. These wear rates are lower than the RBM frogs in the East and West turnouts. However, the wear at East and West FAST may be expected to be greater because of the more severe load environment.

The average guard rail gap change from the standard is not very significant (± 1/16 inch) at either location, but in the West By-Pass the flangeway worn shape is a bit unusual in that the gap appears to be relatively "tight" at one end (point E).

The maintenance effort was greater in the East By-Pass turnout as a whole due to more manhours (5.8 vs. 0.7) devoted to spot tamping. This is not unexpected because of a drainage problem observed during the early period of test at the East By-Pass near the road crossing. Frog related maintenance was essentially the same for each turnout.

The significant component maintenance and replacement events for the East and West By-Pass turnouts are listed in Appendix C, Tables C-3 and C-4. Failure of the West By-Pass frog heel rail at 144 MGT and the frog "tail" or heel filler block at 166 MGT are shown in Figures 50 and 51, respectively.

4.3 WEST TDT AND IMPACT TRACK TURNOUTS

The initial hardness change is somewhat greater in West TDT (140 vs. 100), but the general pattern is similar in each. At these turnouts the

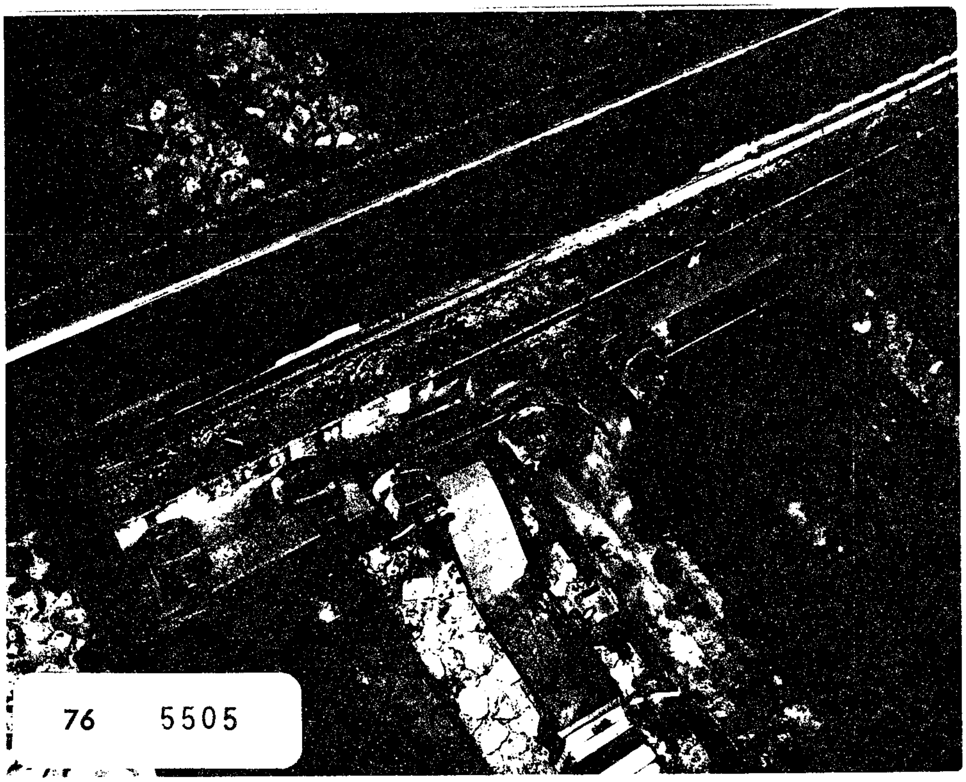

FIGURE 43. WORN SWITCH POINT AT WEST FAST AFTER 2 MGT.

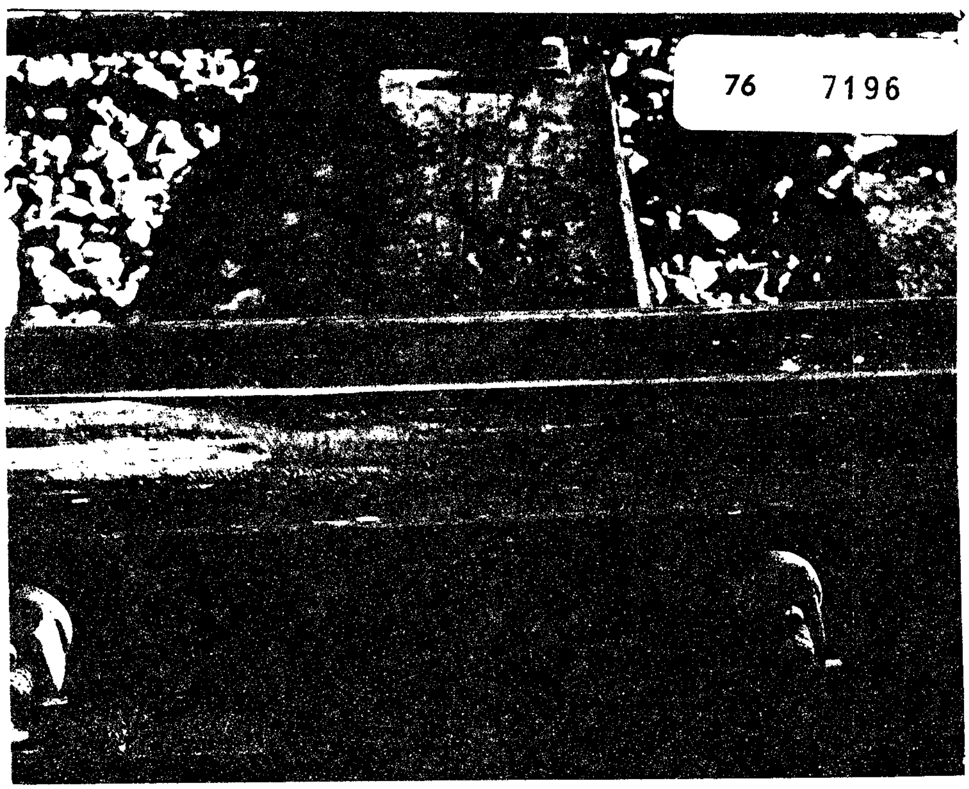

FIGURE 44. WORN EAST FAST SWITCH POINT AFTER [illegible] MGT

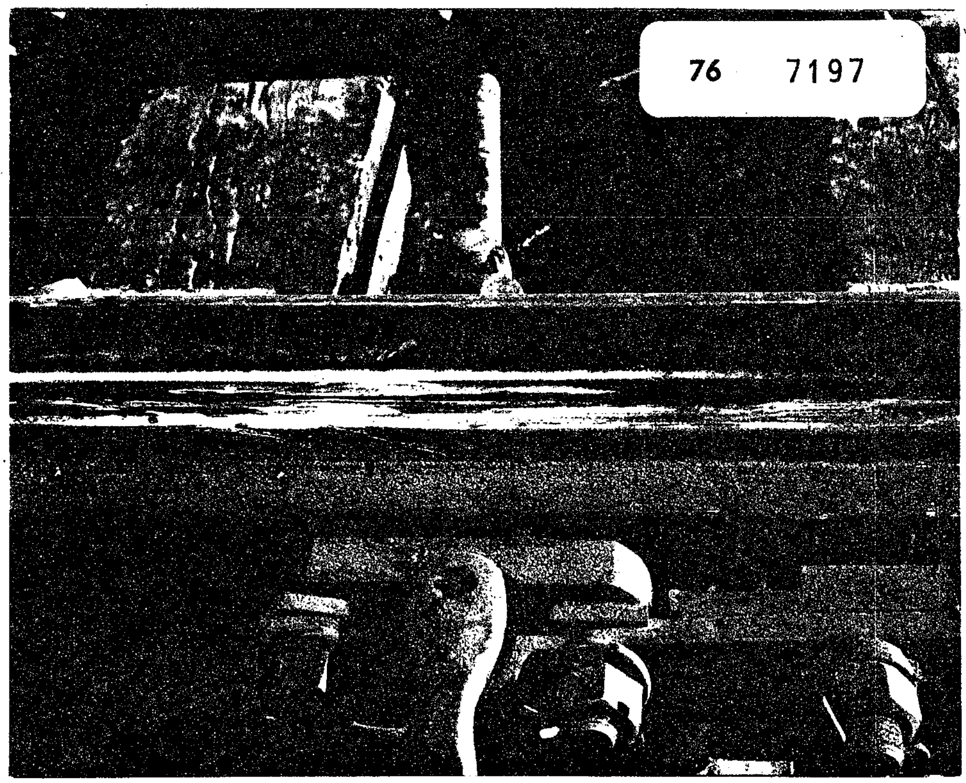

FIGURE 45. WORN EAST FAST SWITCH POINT AT THROW ROD LOCATION.

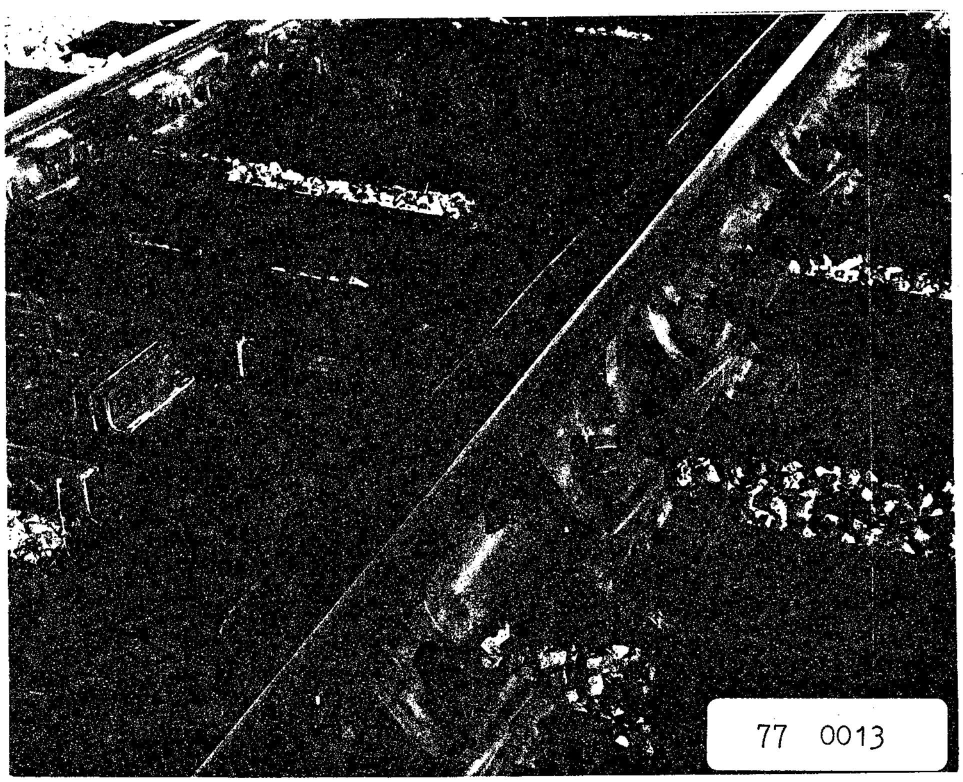

FIGURE 46. TYPICAL WORN CONDITION OF STANDARD SWITCH POINT AT 29 MGT.

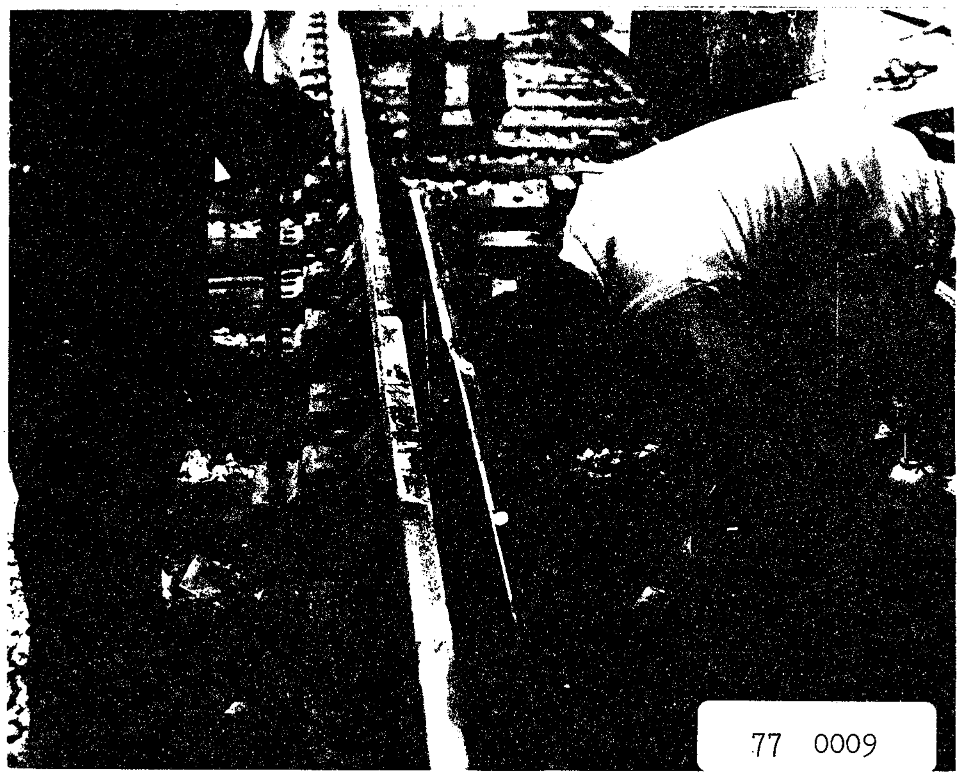

FIGURE 47. REPLACING STANDARD SWITCH POINT WITH MANGANESE STEEL POINT.

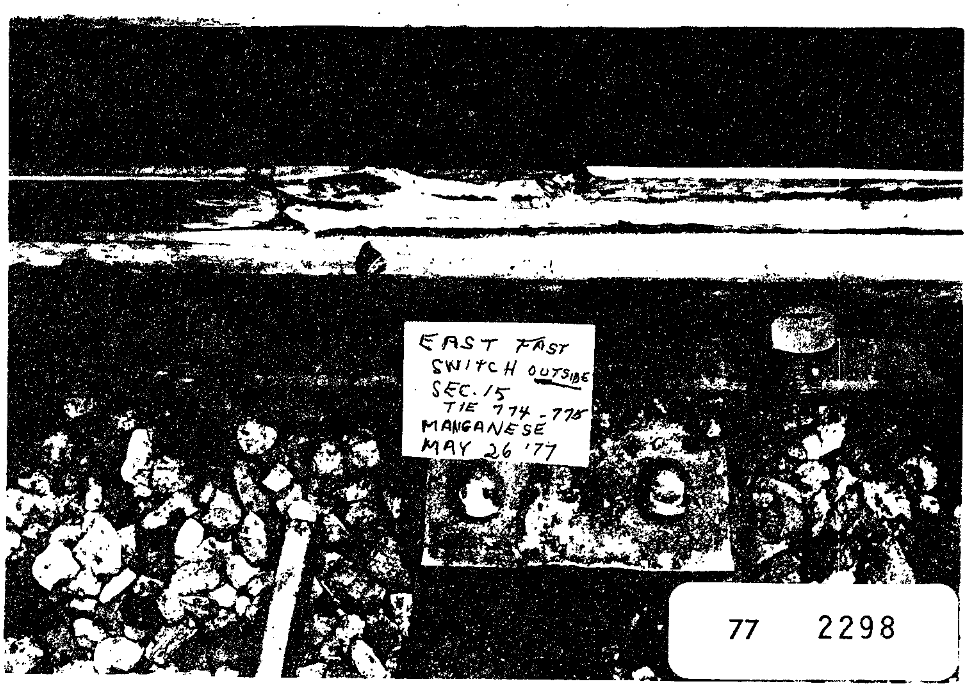

FIGURE 48. A WORN MANGANESE SWITCH POINT REPLACED AFTER 74 MGT.

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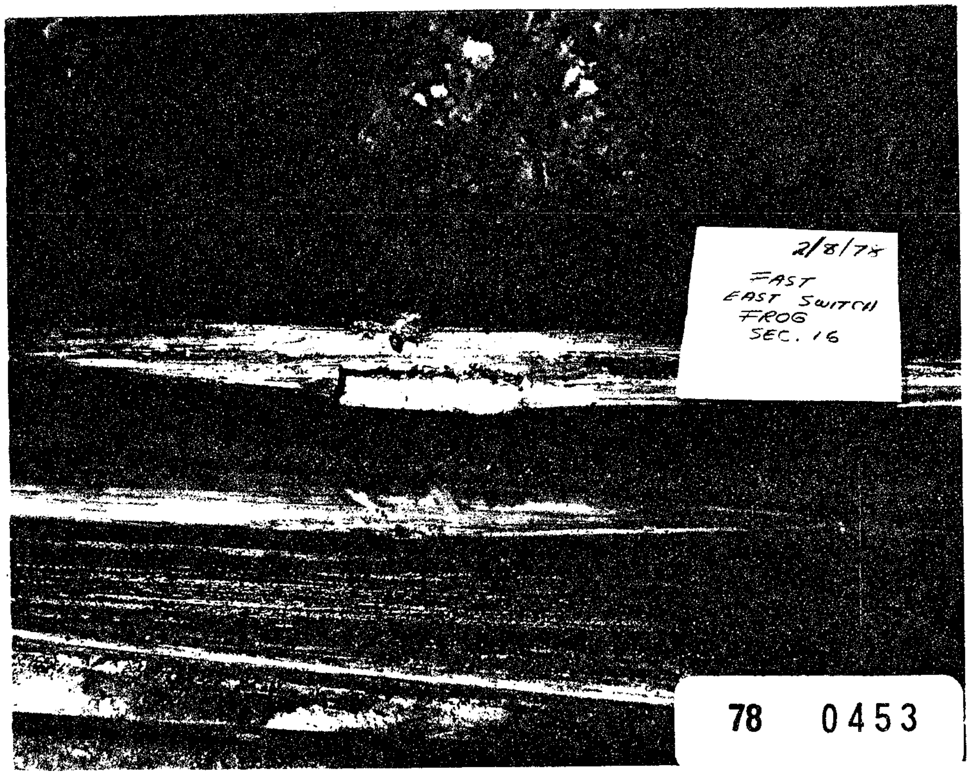


FIGURE 49. A FRACTURE IN EAST FAST FROG AFTER 196 MGT.

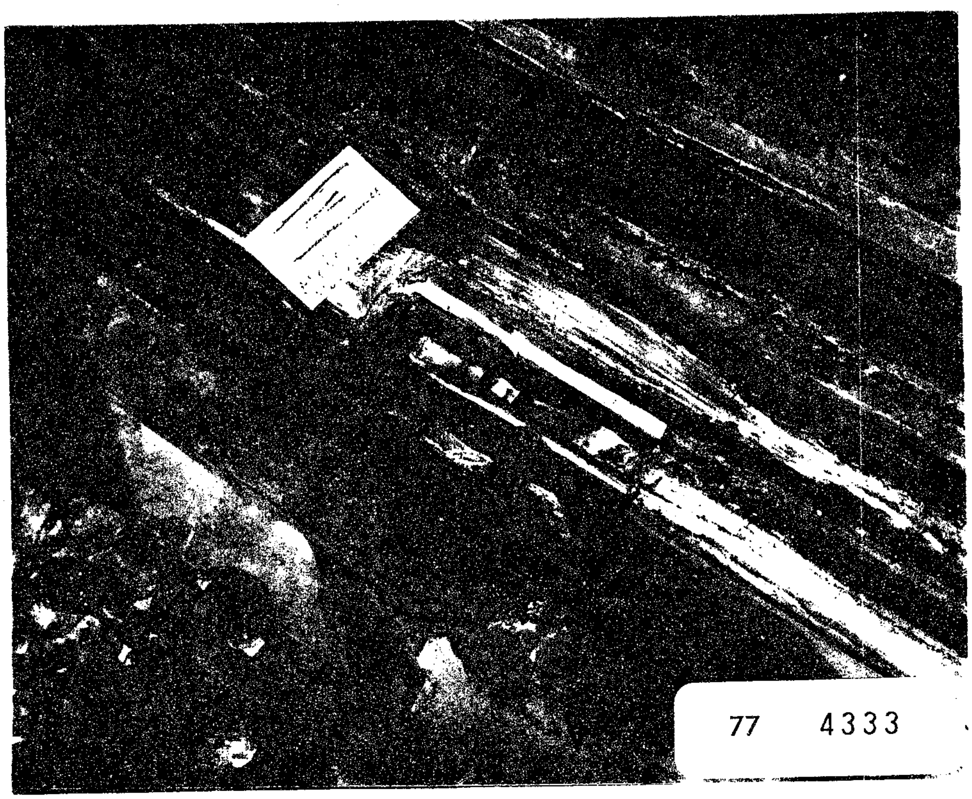


FIGURE 50. BROKEN CLOSURE RAIL IN WEST BY-PASS FROG AT 144 MGT.

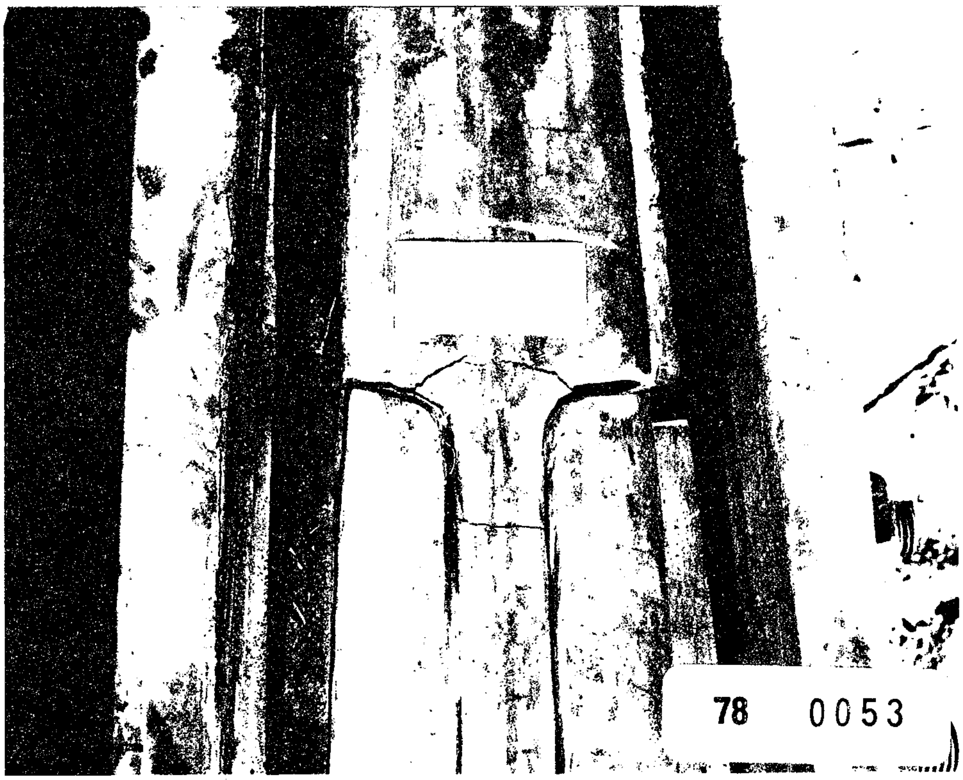


FIGURE 51. CRACKED TAILPIECE ON WEST BY-PASS AT 166 MGT.

greatest absolute hardness change averaged overall MGT occurs at measurement locations on the wing rail leading into the frog point. In the case of West TDT the change is an increase of 70 BHN, while at the Impact track switch it is a 70 point decrease, a phenomenon that is difficult to rationalize but apparently substantiated by the final three measurements at this position (I) on the frog wing rail. This may possibly reflect the difference in diverging traffic at these locations. At the Impact switch turnout location FAST traffic runs through on the straight switch point.

The differential frog wear "rate" is about 30% greater at the West TDT turnout than at the Impact, but still some 30% less than that at East and West FAST.

The guard rail gap shows the same pattern and overall small average change at each location.

The maintenance effort is somewhat greater (6.8 manhours per 100 MGT vs. 4.2 manhours per 100 MGT) in West TDT, due mostly to greater spot tamping and replacing ties. The frog related maintenance was significantly greater in West TDT (4.9 vs. 1.5 manhours per 100 MGT).

The significant component maintenance and replacement events for the West TDT and Impact track turnouts are listed in Appendix C, Tables C-5 and C-6.

4.4 TEST FROGS IN SECTION 11

The hardness change differences among frogs, both standard and depth hardened, appear to be insignificant. The variation of average frog hardness with MGT for all 8 test frogs is illustrated in Figure 52. Also the wear, as measured in terms of relative (position B-E) wear or maximum average wear at end of test, does not appear to be significantly different. Nor does the overall guard rail gap change appear to be significantly different, as shown in Table 8.

Some suggestions of the effect of the alternating pattern of frog placement may be reflected in the survey to benchmark data. With the exception of frog #7 on the inside rail at one end of the test section, those frogs on the inside rail seem to move laterally to the outside of the loop while those on the outside seem to move toward the inside of the loop. The alternating lateral displacement of test frogs may reflect the effects of locomotive truck hunting that was excited and observed during operation through this section. This dynamic reaction and the displacement pattern may result from the alternating placement of test frogs. No pattern of average elevation change is discernable.

With the exception of frog #8, frogs on the outside rail appear to move longitudinally in the clockwise direction, while those on the inside rail appear to move counterclockwise. A slight gage tightening seems indicated at all frogs.

All of the frogs developed cracks in the tail portion and two of the depth hardened test frogs (frogs #1 and #6) were removed early and returned to the donor at his request. The average manhours for the remaining 6 frogs of

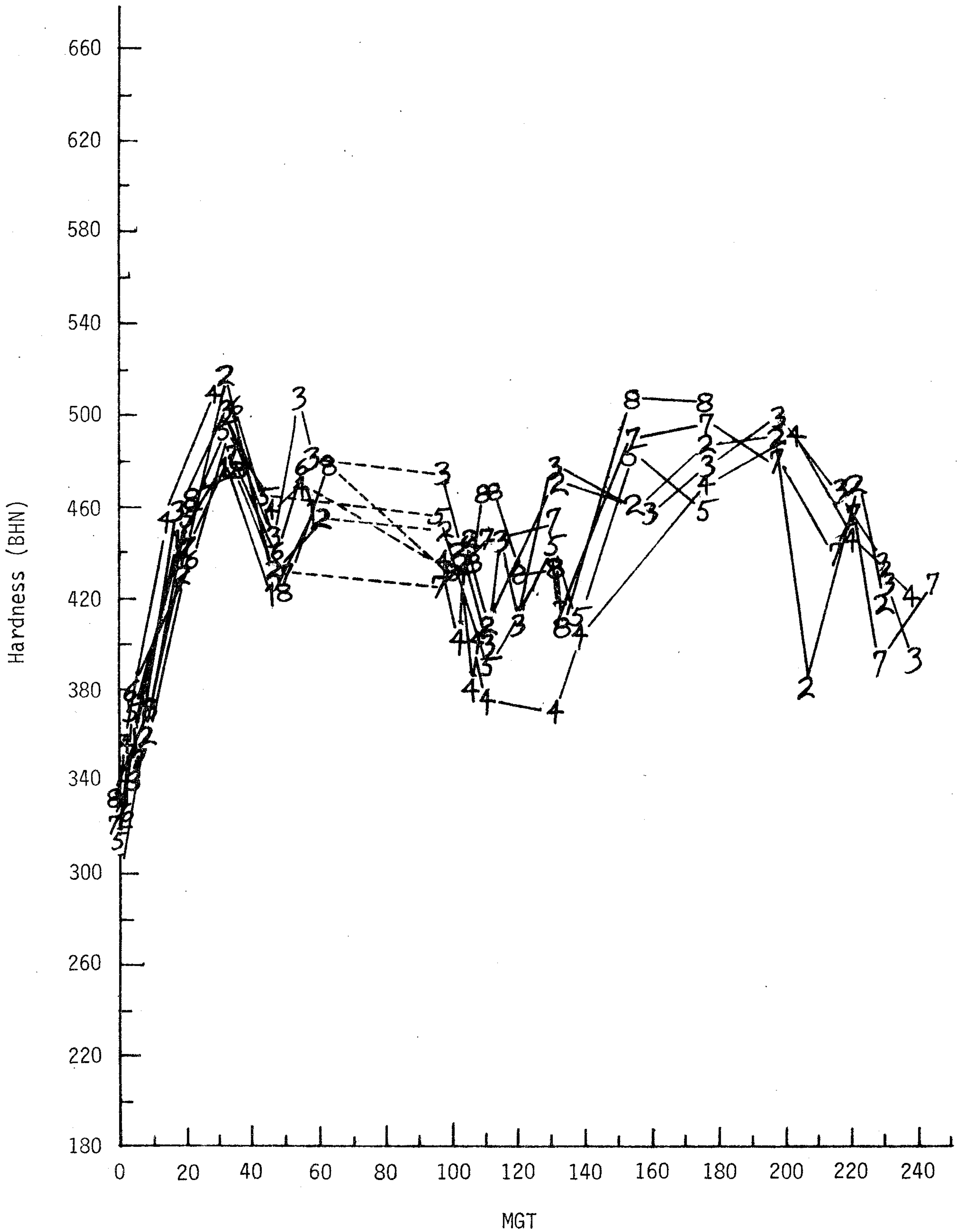


FIGURE 52. AVERAGE FROG HARDNESS FOR 8 TEST FROGS IN FAST SECTION 11.

two types are 1.32 manhours per 100 MGT for the 2 depth hardened frogs and 1.62 manhours per 100 MGT for the 4 standard frogs. Slightly greater wear was also observed with the standard frogs (.11 vs. .09 inches per 100 MGT).

Somewhat less maintenance was required at test frogs with long guard rails. The one depth hardened and two standard frogs with 9 foot 5 inch guard rails had an average maintenance effort of 1.83 manhours per 100 MGT. The same frog types with 12 foot 6 inch guardrails required 1.22 manhours per 100 MGT.

The significant component maintenance and replacement events for these test frogs are listed in Appendix C, Tables C-7 through C-14. The appearance of cracked heel filler block extensions observed in two test frogs is shown in Figure 53 for test frog #5 at 51 MGT and in Figure 54 for test frog #6 at 54 MGT.

4.5 MISCELLANEOUS TEST LOCATIONS

Data were also collected at the #10 West Facility turnout and the two locations in FAST, Section 10, where the #14 spring rail frogs were installed. Brief summaries of measurement and maintenance records follow.

4.5.1 West Facility Turnout

The right hand #10 West Facility turnout was not usually lined to diverge the FAST train. Nevertheless, a pattern of differential (point B-point E) frog wear did develop with a rate (0.08 inches/100 MGT) comparable to that observed with the main #20 main test turnouts that diverged the FAST train.

The pattern of hardness change was similar also. The initial average hardness increase was about 80 BHN.

The overall average guard rail gap change of 0.15 inches (for this 9'-5" long AREA standard rail) was larger than observed at other locations. The usual pattern of wear along the length of the rail with greater wear at the ends was also observed.

The little survey to benchmark data available from early in the test are summarized in Table 12. The average increase in elevation of 13/8 inches from the initial measurement at the frog point location is larger than that observed at the other two turnout frogs measured or at the eight test frogs in Section 11. It's difficult to attach any significance to this, however, other than that it may reflect greater tamping activity.

The total manhours of pertinent maintenance that accumulated over the approximately 260 MGT test duration was 8.56 for a rate of 3.3 manhours per 100 MGT. The largest code category was 1J, tamping switches, at 2.5 hours or 29%.

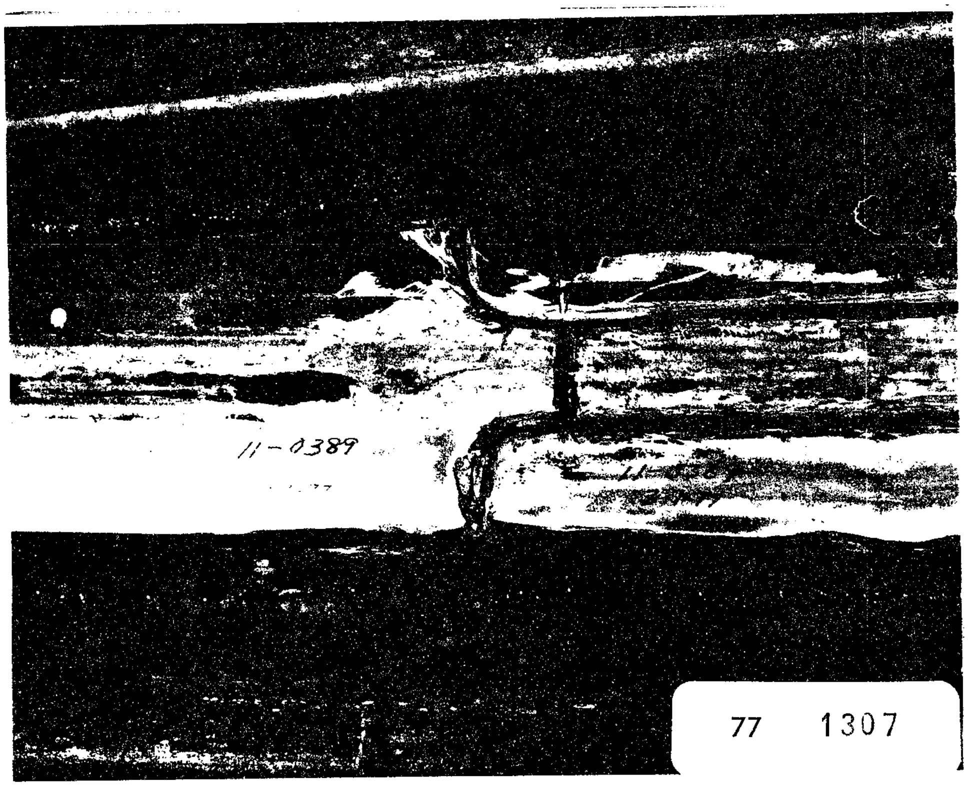


FIGURE 53. BROKEN TAILPIECE ON TEST FROG #5 IN SECTION 11 AT 51 MGT.

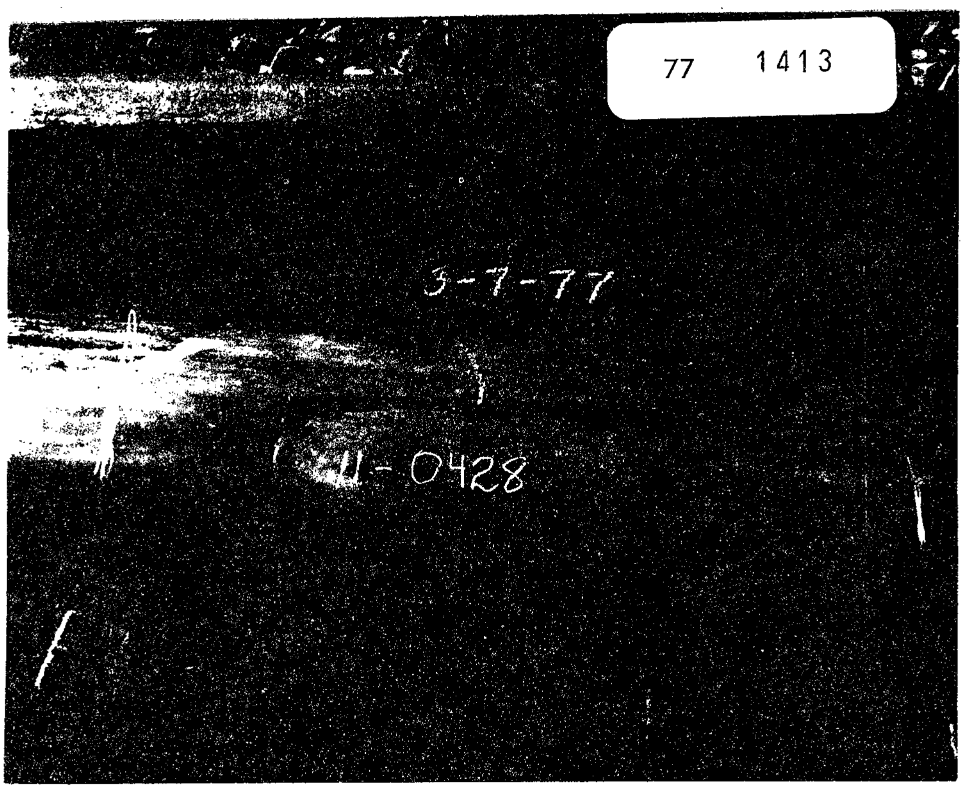


FIGURE 54. BROKEN TAILPIECE ON TEST FROG #6 IN SECTION 11 AT 54 MGT.

TABLE 12. AVERAGE SURVEY TO BENCHMARK DATA (IN 32NDS OF INCH) FOR FROG POINT LOCATION AT THREE TURNOUTS.

MEASUREMENT	TURNOUT LOCATION		
	EAST BY-PASS	WEST BY-PASS	WEST FACILITY
AVG. LATERAL DISPLACEMENT	-4	21	-6
AVG. ELEVATION CHANGE	10	-34	44
AVG. LONGITUDINAL DISPLACEMENT	6	21	10
AVG. GAGE CHANGE	1	-1	1

4.5.2 Spring Rail Frogs

The #14 spring rail frogs arranged in "frog farm" pattern on the inside and outside rail in Section 10 showed little or no differential frog point wear. This is not surprising since the spring mechanism was never actuated to allow full wheel loading on the long point rail.

The initial average hardness change of 150 BHN was comparable to that seen for the test frogs in Section 11.

Little average change in flangeway width or gap at the 12 feet long guard rails was observed. In fact, negative (less than standard) gaps were recorded. The greatest relative gap was still at the rail end, however.

No information is available on any maintenance required.

4.6 EFFECT OF FAST TRAFFIC DIVERGENCE

Although there are material differences from one turnout location to another and data are limited, the effect of FAST traffic divergence on frog wear may be discerned. The differential frog wear is greater for the three diverging turnouts (East FAST, West FAST, and West TDT) than for the turnouts lined for traffic on a straight through move (East By-Pass, West By-Pass, and Impact Track). The differential frog wear rates taken from Table 7 yield an average of 0.08 inch/100 MGT for the diverging turnouts and 0.03 for the straight through turnouts. This difference may be indicative of greater dynamic wheel loading at the diverging turnouts.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations from this initial testing phase with special track hardware are given in the subsections below relative to the originally stated test purposes, adequacy of test technique, and other observations and test benefits derived.

5.1 ASSESSMENT OF RESULTS RELATIVE TO ORIGINAL TEST PURPOSES

The general test purposes or objectives for each of the three pairs of test turnouts and the group of eight test frogs were only partially achieved as described below:

5.1.1 East and West FAST Turnouts

No significant differences between measurements at the "glued" East FAST and welded West FAST were observed. At 13.8 manhours per 100 MGT, the maintenance effort at East FAST is some 50 percent greater than at West FAST due to greater switch maintenance required, possibly because of the more severe wheel traction and lateral loading anticipated in East FAST, which is on a spiral of a 5 degree curve at the foot of a descending 2 percent grade.

5.1.2 East and West By-Pass Turnouts

No significant differences were observed in wear or hardness change measurements between identical turnouts, which served as a "control" for other test pairs that were not in essentially identical track positions. The initial average increase of hardness with MGT (150 Brinell) for these one charge explosive hardened frogs appears to be about 50% greater than that observed at other turnouts such as East and West FAST. The average maintenance manhours per 100 MGT of 7.3 for these two turnouts, in which traffic is not diverged, is about 35% less than the maintenance effort at the other three diverging turnouts.

5.1.3 West TDT and Impact Turnouts

The wear and hardness change measurements are slightly greater for the diverging West TDT turnout. The maintenance effort of 6.8 manhours per 100 MGT for West TDT is some 60% greater than that at the Impact track turnout.

5.1.4 Test Frogs in Section 11

The depth hardened frogs appear to have slightly less wear and require less maintenance than standard RBM frogs. Somewhat less maintenance was required at test frogs with long guard rails.

5.2 CRITIQUE OF MEASUREMENT TECHNIQUES

It was recognized at the outset that this initial test of turnouts included several untried measurement techniques. Indeed, some proved unsatisfactory and were eventually abandoned or modified.

In all of the measurements, better or more positive definition or marking of the test location than paint marks is needed.

5.2.1 Frog Hardness

Achieving repeatable and accurate hardness measurement with a portable hardness tester in the field on curved surfaces is difficult under any circumstances. This difficulty was compounded in this test because of changes in calibration practice. In the future, consideration should be given to the inclusion of requirements for field measurements on an essentially unworn control sample as well as uniform calibration practices and use of standard blocks. Additional hardness testers should be evaluated for possible use, and future instructions should require replicate measurements.

5.2.2 Frog Wear

The straight edge and taper gage method is inadequate as a measure of frog wear. A profile or jig device with positive reference is needed.

5.2.3 Switch Point Wear

The attempt to measure switch point worn profile at several paint marked locations relative to the rail base using a transfer caliper proved impractical and was abandoned early in the test. A profile or jig device would be preferable here also.

5.2.4 Guardrail Flangeway Gap

The use of standard inside diameter calipers is an unreliable method to measure worn conditions. The later addition of a stop bar to the caliper to reproduce measurement location at the worn gage point depth, improved the technique. A special measurement fixture with dial gages is now available for this purpose.

5.2.5 Survey to Benchmark

The use of the automatic electronic surveying device at several of the test sites was abandoned early in the test. Some of the test data variability may have reflected actual physical movements. However, the small amount of data collected made it impossible to draw any conclusions. Carefully selected use of this method for future tests for a sustained period may be appropriate to document position changes caused by operation and maintenance.

5.3 OTHER OBSERVATIONS AND BENEFITS

Despite some differences in material variables from site to site, there appears to be a detrimental effect of FAST traffic divergence on frog wear for these #20 turnouts. The three frogs that diverged traffic experienced more than twice as much wear as those supporting a straight through move.

The relatively high number of frog "tail" cracks observed at many locations and the high wear rates of standard switch points at severely loaded diverging turnouts has contributed to the development of design and maintenance changes. The selective use of manganese steel switch point inserts is an example.

Perhaps one of the greatest benefits of this test was derived from direct observations of day-to-day changes by engineering personnel from participating railroads and supplier groups.

APPENDIX A. MEASUREMENT DATA FORMS AND INSTRUCTIONS

Data forms and measurement procedures used by Transportation Test Center personnel to collect data for this experiment are included in the following tables for:

1. Frog hardness (FH31)
2. Frog wear (FW31)
3. Vertical switch point wear (VS31)
4. Guard rail wear (GR31)
5. Survey to benchmark (SB31)

TRANSPORTATION TEST CENTER

FROG HARDNESS

PAGE __ of __

F H 3 1
1 D.I.C

5 MONTH DAY YEAR

MACHINE
11

OPERATOR/
FOREMAN
13

CORR.
16

LOCATION

17 SEC. 19 RAIL Nº 22 ADD 23 I/O

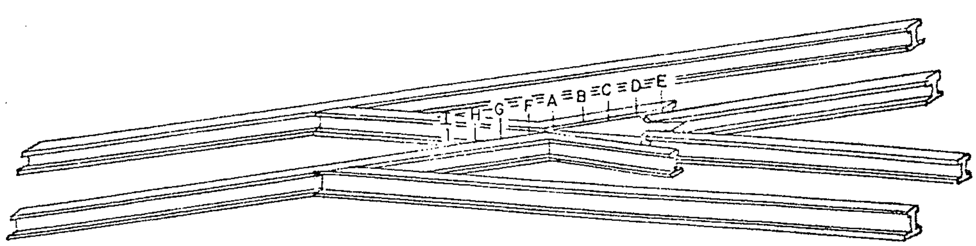
24 A 27 B 30 C

33 D 36 E

39 F 42 G 45 H 48 I

COMMENTS

51 60 65



TTC FORM 5800.5-17 (07/76)

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FROG HARDNESS MEASUREMENT PROCEDURE

FH - 31

1. Fill in today's date. (Boxes 5-10)
2. Indicate machine number used. (Boxes 11-12)
3. Indicate your initials. (Boxes 13-15)

FOR EACH FROG MEASURED:

4. State rail number location I.D. (Boxes 17-23)
5. Place indentor of hardness tester on top of frog point A on running portion of metal, perpendicular to surface.
6. Press trigger, read hardness on meter.
7. Make measurements A-E, F-I as shown on sketch (reverse side).
8. Fill in hardness values measured.

NOTES

Calibrate/check calibrate machine in the morning, noon, and afternoon with 200 and 600 hardness blocks. Always hold hardness indentor in a vertical position.

TRANSPORTATION TEST CENTER

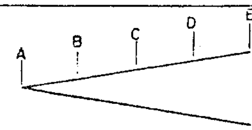
FROG WEAR

PAGE ___ of___

F W 3 1	5 MONTH DAY YEAR	13 OPERATOR/ FOREMAN	16 CORR
D.I.C			

LOCATION

17 SECTION | 19 RAIL Nº | 22 ADD | 23 I/O



A.R.E.A. GAGE
(Y If "GO")

POINT	MEASUREMENT
A	24 INCHES
B	32
C	40
D	48
E	56

	FINISH		CHECK	
	DEPTH	WIDTH	DEPTH	WIDTH
A	28 Y/N	29 Y/N	30 Y/N	31 Y/N
B	36	37	38	39
C	44	45	46	47
D	52	53	54	55
E	60	61	62	63

COMMENTS

64 70 78

TTC FORM 5800.5.13 (08.76)

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FROG WEAR MEASUREMENT PROCEDURE

FW - 31

1. Fill in today's date. (Boxes 5-10)

2. Indicate your initials. (Boxes 13-15)

3. State rail number location I.D. (Boxes 17-23)

4. Place straight edge across frog at point A. Place taper gage between straight edge and frog surface. Read and record amount of wear. (Boxes 24-27)

5. Place A. R. E. A. frog check gage (790 - 55) in flangeway of mainline portion at point A. First, place "Finish" side down, then place "Check" side down. If gage fits, place a "Y" in the respective box. (Boxes 27-31) If gage fails, place "N" in box.

6. Repeat for points B - E. (Boxes 32-63)

7. Comment on any special problems such as metal flaw, chipping, etc.

TRANSPORTATION TEST CENTER

VERTICAL SWITCH POINT WEAR

PAGE ___ of ___

V	S	3	1								

1 D.I.C. — 5 MONTH — DAY — YEAR — 11 OPERATOR/FOREMAN — 16 CORR.

LOCATION

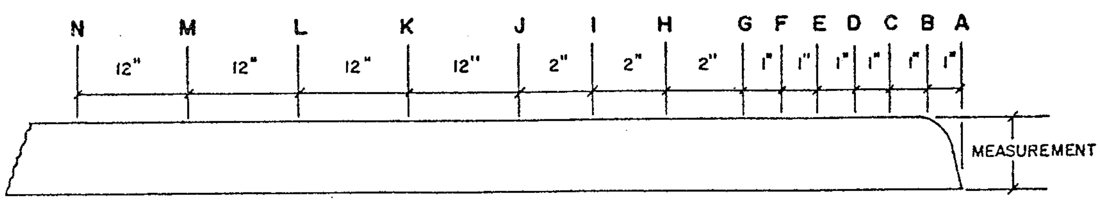
17 SECTION — 19 RAIL Nº — 22 ADD — 23 I/O

POINT WEAR (INCHES)

A — 24
B — 27
C — 30
D — 33
E — 36
F — 39
G — 42
H — 45
I — 48
J — 51
K — 54
L — 57
M — 60
N — 63

COMMENTS

66 — 70 — 75



90

VERTICAL SWITCH POINT WEAR MEASUREMENT PROCEDURE

VS - 31

1. Fill in today's date. (Boxes 5-10)
2. Indicate your initials. (Boxes 13-15)
3. State rail number location I.D. (Boxes 17-23)
4. Open switch (after receiving proper authority) to prevent interference from stock rail.
5. Using caliper or steel rule, (as practical) measure:
   a. Bottom to top of point at A
   b. State values in Boxes 24-60.
6. Return switch to original position.
7. Comment (Boxes 61-80) on any special conditions or wear patterns.

TRANSPORTATION TEST CENTER

GUARD RAIL WEAR

PAGE ____ of ____

G R 3 1 — 1 D I C | 5 MONTH DAY YEAR | 11 OPERATOR/FOREMAN | 16 CORR

17 SECTION | 19 RAIL Nº | 22 ADD | 23 I/O

A (24) | B (27) | C (30) | D (33) | E (36)

COMMENTS

39 … 50 … 55

17 SECTION | 19 RAIL Nº | 22 ADD | 23 I/O

A (24) | B (27) | C (30) | D (33) | E (36)

COMMENTS

39 … 50 … 55

17 SECTION | 19 RAIL Nº | 22 ADD | 23 I/O

A (24) | B (27) | C (30) | D (33) | E (36)

COMMENTS

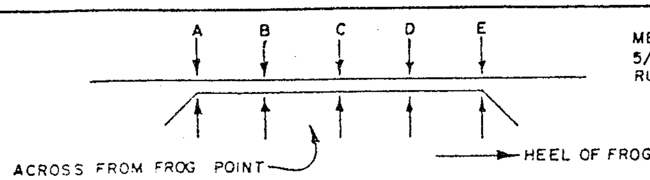
39 … 50 … 55

17 SECTION | 19 RAIL Nº | 22 ADD | 23 I/O

A (24) | B (27) | C (30) | D (33) | E (36)

COMMENTS

39 … 50 … 55



MEASURE GAP AT 5/8" BELOW RAIL RUNNING SURFACE.

GUARD RAIL WEAR MEASUREMENT PROCEDURE

GR - 31

1. Fill in today's date. (Boxes 5-10)

2. Indicate your initials. (Boxes 13-15)

FOR EACH GUARD RAIL

3. State rail number location I.D. (Boxes 17-23)

4. Place measuring calipers inside of guardrail flangeway, 5/8" below top of running rail, at point A.

5. Adjust for a snug fit.

6. Remove calipers sideways, measure using a steel straight edge to nearest .01".

7. Record value for "A". Repeat for locations B through E.

8. Comment on any special conditions or unusual wear patterns.

TRANSPORTATION TEST CENTER

SURVEY TO BENCHMARK

PAGE ___ of ___

| S | B | 3 | 1 |
1 DIC

5 MONTH DAY YEAR

11 OPERATOR/FOREMAN

16 CORR.

LOCATION

17 SECTION

19 TIE №

23 ADD

DATA POINTS

24 A_X (FEET)

30 +/- A_Y (FEET)

36 R_X (FEET)

42 +/- R_Y (FEET)

LONG. RAIL MOVEMENT

48 DIRECTION +/-

49 AMT. (INCHES)

TRACK GAGE VARIANCE

53 +/-

54 INCHES

55 32 nds

BM. LOCATIONS

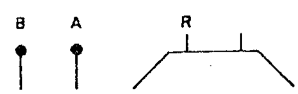
57 I/O

X-LEVEL *

58 +/-

59 INCHES

60 32nds



* THE OUTSIDE RAIL HIGH = +

COMMENTS

62 70 78

TTC FORM 5800 5-19 (07/76)

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SURVEY TO BENCHMARK MEASUREMENT PROCEDURE

SB - 31

1. Fill in today's date. (Boxes 5-10)

2. State survey party chief's initials. (Boxes 11-13)

3. State which tie survey is being taken perpendicular from. (Boxes 17-23)

4. State whether benchmarks are inside or outside of loop. (Box 57)

5. Measure gage of rail at test tie location; record ± deviation from 4' - 8 1/2" to 1/32 of an inch. (Boxes 53-56)

6. Set up electronic surveyor over benchmark B.

7. Line up and zero in cross hair on benchmark B.

8. Measure and record AX, AY. (Boxes 24-35)

9. Measure longitudinal rail movement relative to perpendicular line from AB to R. (+ direction if mark on rail has moved counterclockwise.) (Boxes 48-52)

10. Measure RX, RY; record values. (Boxes 36-47)

11. Comment if there is any apparent damage to either benchmark.

9 /

APPENDIX B. ADJUSTMENT OF HARDNESS DATA.

The machine used for the measurement of hardness at specified points on the frog and on the running surface of the wing rail was an ESEWAY Dynamic Hardness Tester. The principle of operation follows:

> A striker incorporating a piezo-electric crystal and a tungsten carbide ball or diamond indentor hits the surface of the component to be tested with a predetermined force. The deceleration force from the impact produces a voltage across the piezo-electric crystal; the peak of this voltage is proportional to the hardness of the tested surface. This peak voltage is processed through the special electronic system in the instrument case and the direct hardness value reading appears on the meter.

An essential element for reliable hardness measurement with the instrument is accurate calibration on both high (480 BHN) and low (230 BHN) hardness test blocks. It appears that calibration practices and, on at least one occasion, test blocks may have changed during the more than two year course of the experiment. This is reflected in the plot (Figure B-1) high and low calibration hardness readings taken from so-called "FH3 Section 80" data base records. Six MGT blocks were somewhat arbitrarily defined during the course of the test and the overall mean and standard deviation of average calibration hardness readings during these periods were determined as listed in Table B-1. The overall mean values for high and low calibration readings in each section are also presented in Figure B-1 as straight line segment through the scatter of average data points.

In an attempt to adjust the measured hardness data, the following expression for ADJUSTED hardness was developed* using Section 80 (calibration) data:

(HMeas - HCalmeas) X (HCal - LCal) / (HCalmeas - LCalmeas) + HCal

Where:

HMeas	=	Field hardness measurement
HCalmeas	=	Measured hardness of the high hardness calibration block
LCalmeas	=	Measured hardness of the low hardness calibration block
HCal	=	Actual hardness value of the high hardness calibration block stated by the manufacturer
LCal	=	Actual hardness value of the low hardness calibration block stated by the manufacturer

This expression was derived from Figure B-2.

A sample of how this looks may be seen in Figure B-3 for the West By-Pass frog. The "X" is the average of all positions per each MGT. The solid line is the adjusted average using the formula.

The adjustment does reduce the scatter somewhat, but the cyclic character persists.

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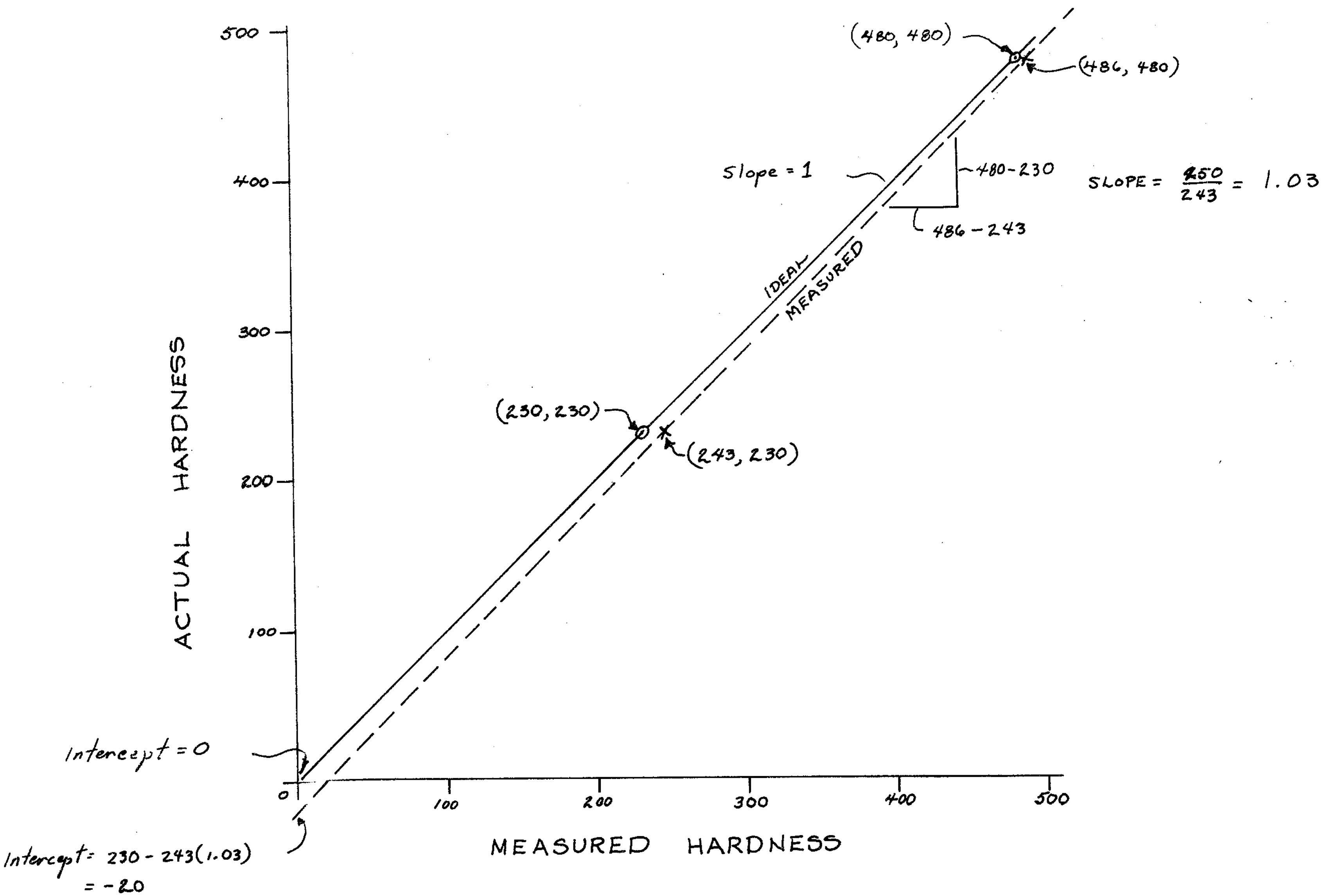
* by Lawrence E. Daniels, AAR/TTC Senior Engineer



Adjustment = (Measured Hardness)(Measured Slope - Actual Slope) + Measured Intercept - Actual Intercept
= (243)(250/243 - 1) + (-20) - (0)
= -13

FIGURE B-1. GRAPHICAL BASIS FOR HARDNESS ADJUSTMENT.

TABLE B-1. MEAN AND STANDARD DEVIATION OF HIGH AND LOW AVERAGE CALIBRATION READINGS FOR 6 MGT BLOCKS DURING TEST.

LOW MEAN	LOW STD.	HIGH MEAN	HIGH STD.	MGT BLOCK
232.7	10.67	486.1	22.82	0 - 58.679
181.9	12.90	486.3	4.72	58.769 - 80.310
227.1	14.60	453.6	34.88	80.310 - 118.595
241.9	18.32	501.4	18.68	118.595 - 170
240.8	32.75	484.2	13.39	170 - 240
229.5	28.20	482.4	27.90	0 - 240

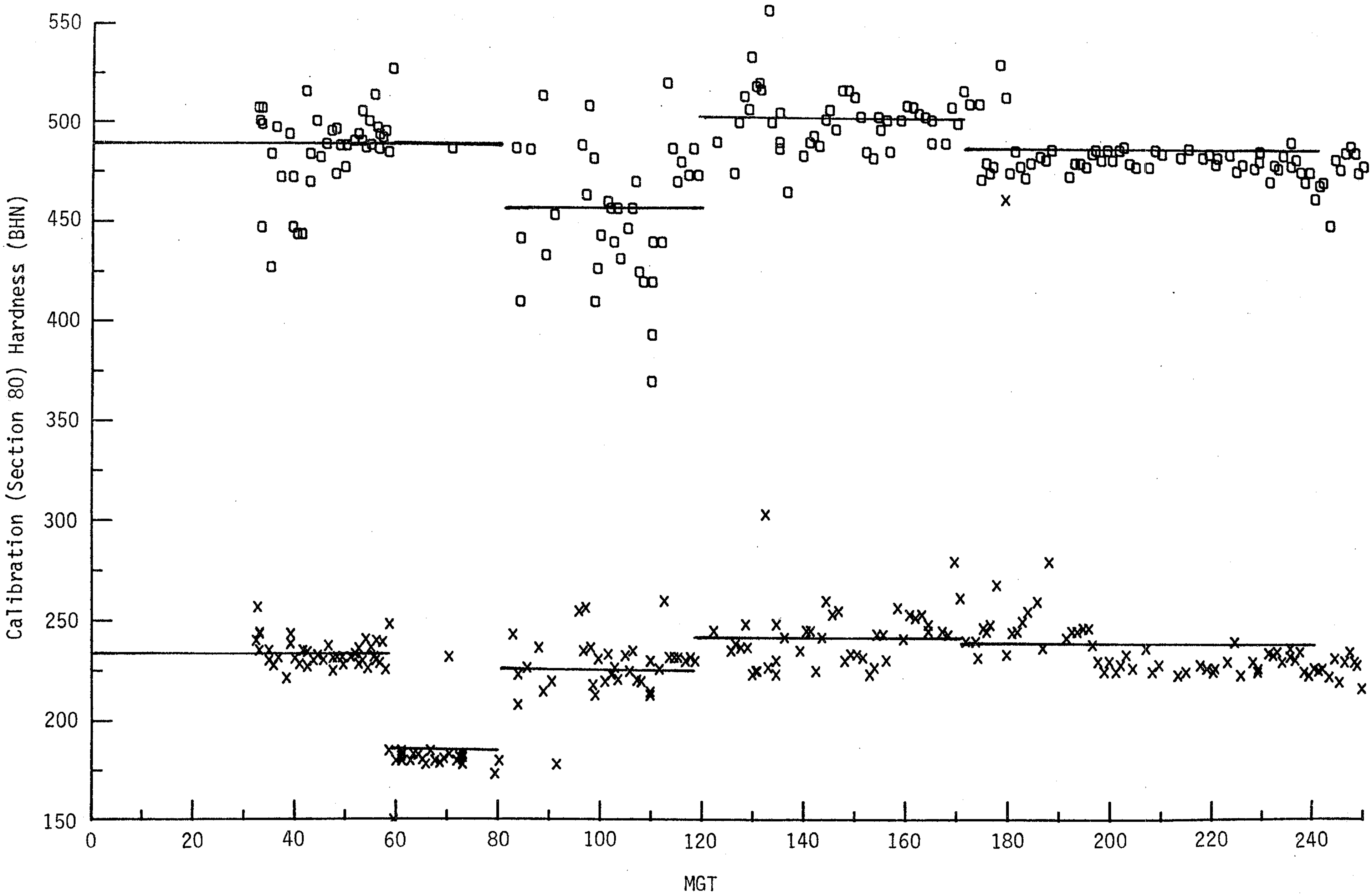


FIGURE B-2. SECTION 80 (CALIBRATION) HARDNESS CHANGES WITH MGT.

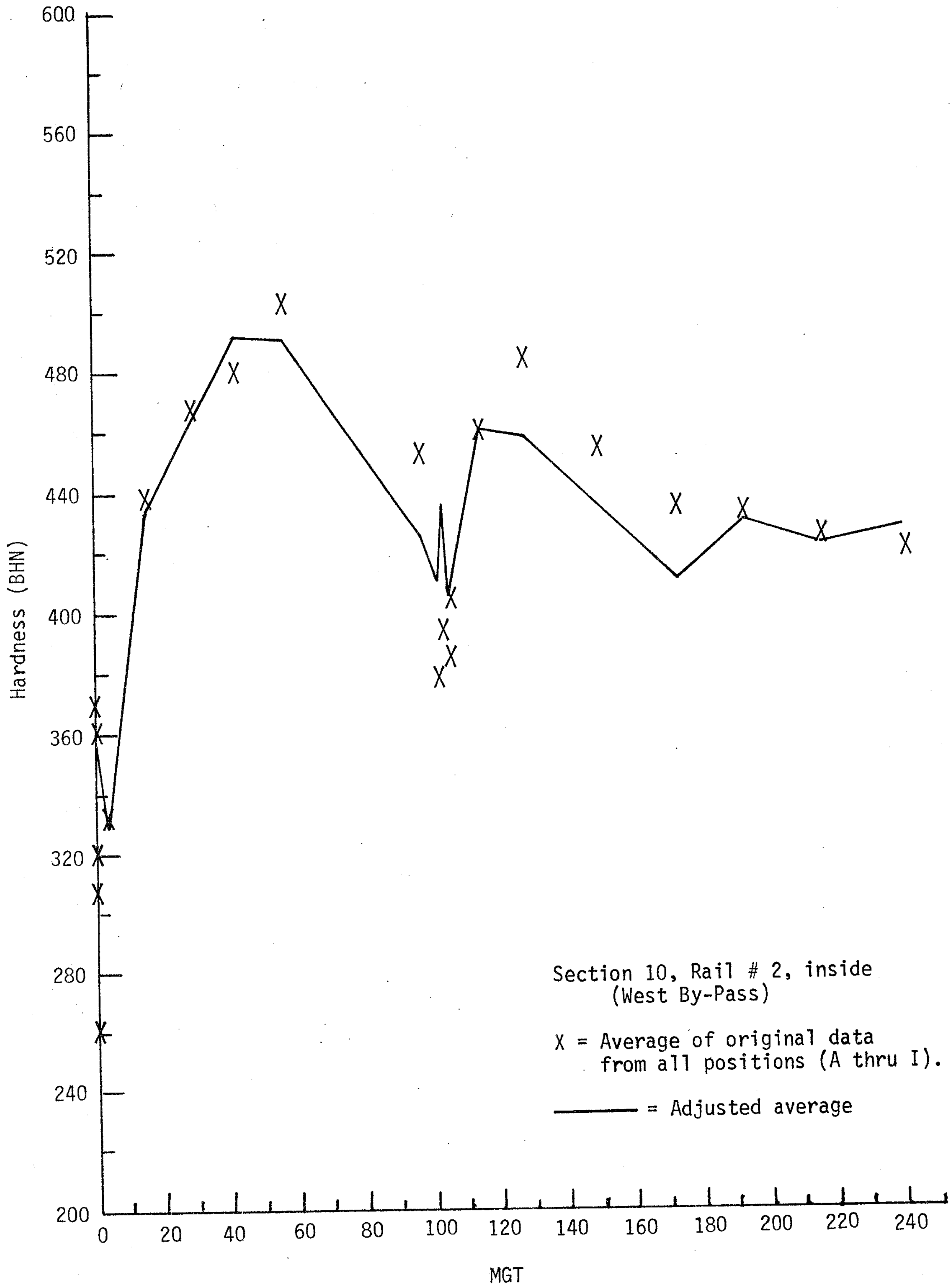


FIGURE B-3. ADJUSTED HARDNESS VS. MGT FOR THE WEST BY-PASS FROG.

APPENDIX C. SIGNIFICANT COMPONENT MAINTENANCE AND REPLACEMENT EVENTS

The following 14 tables (C-1 through C-14) list the significant component maintenance and replacement events for the 6 major FAST turnouts and 8 test frogs in Section 11.

TABLE C-1.

EAST FAST

SIGNIFICANT COMPONENT MAINTENANCE AND REPLACEMENT EVENTS

EVENT	DATE	MGT
Grind switch point	10/19/76	4.7
Tighten frog bolts	11/19/76	18.7
Grind switch point	11/30/76	22.3
Grind switch point	12/1/76	23.1
Grind switch point	12/21/76	28.4
Install manganese steel tip in switch	1/3/77	29.3
Grind stock rail	3/17/77	57.4
Tighten filler block bolts	4/5/77	61.2
Switch weld build-up and grind	5/26/77	74.7
Replace points on switch	5/26/77	74.7
Replace stock rail	5/26/77	74.7
Grind switch point	6/17/77	86.0
Tighten spread rod bolts	8/17/77	108.8
Frog weld build-up and grind (at 0053)	9/16/77	127.6
Replace broken frog bolt	10/3/77	134.6
Replace broken frog bolt	11/29/77	144.4
Replace broken frog bolt (#17)	12/19/77	159.6
Replace broken frog bolt (#18)	12/29/77	167.2
Replace broken frog bolt	1/4/78	170.7
Switch weld build-up and grind point	1/9/78	174.3
Replace broken bolt (at the 0784)	1/9/78	174.3
Replace broken frog bolt	1/17/78	179.0
Switch weld build-up and grind	1/25/78	185.1
Replace broken bolt (at the 0760)	3/1/78	211.9
Repair rail brace on gage plate	3/30/78	233.7
Reinstall switch	4/25/78	235.2
Reapply rail brace	5/4/78	237.2
Reapply rail brace	5/8/78	239.0
Replace broken frog bolt	5/16/78	244.1
Switch weld build-up and grind	6/12/78	260.2
Replace broken frog bolt	6/27/78	267.3

TABLE C-2.

WEST FAST

SIGNIFICANT COMPONENT MAINTENANCE AND REPLACEMENT EVENTS

EVENT	DATE	MGT
Grind switch point	10/18/76	4.2
Grind switch point	11/5/76	10.7
Grind switch point	11/15/76	15.4
Tighten frog bolts	11/19/76	18.7
Install manganese steel tip in switch	1/3/77	29.3
Replace broken frog bolt (at Tie #32)	1/7/77	30.6
Grind switch point	1/17/77	32.5
Grind switch point	1/20/77	33.2
Grind switch point	1/27/77	35.7
Grind switch point	2/14/77	43.5
Switch weld build-up and grind	2/18/77	46.8
Tighten frog bolts	5/25/77	73.9
Grind switch point	6/17/77	86.0
Switch weld build-up and grind	6/24/77	90.5
Grind switch point	7/7/77	97.1
Frog weld build-up and grind	7/29/77	106.4
Frog weld build-up and grind	9/15/77	126.5
Replace broken frog bolt	9/19/77	128.5

TABLE C-3.

EAST BY-PASS

SIGNIFICANT COMPONENT MAINTENANCE AND REPLACEMENT EVENTS

EVENT	DATE	MGT
Replace heel block bolt	11/12/76	14.5
Tighten frog bolts	11/19/76	18.7
Replace heel block bolt	11/24/76	21.0
Replace two frog bolts	1/25/77	33.9
Grind switch point	2/9/77	42.6
Replace broken guard rail bolt	2/15/77	43.8
Replace broken guard rail bolt	2/22/77	47.6
Grind heel block	3/3/77	52.7
Weld and grind frog	3/4/77	53.1
Grind frog	3/15/77	56.2
Replace broken bolt	3/24/77	61.2
Replace broken bolt	5/26/77	74.7
Replace broken guard rail bolt	6/10/77	83.9
Swap FAST and West By-Pass points	6/27/77	91.5
Replace heel block bolt	7/19/77	100.9
Replace heel block bolt	7/20/77	101.5
Grind switch point	8/17/77	108.7
Tighten all frog bolts	8/23/77	113.5
Replace heel block bolt	11/17/77	138.2
Weld and grind frog	12/30/77	168.3
Replace heel block bolt	12/30/77	168.3
Replace heel block bolt	1/6/78	173.0
Replace heel block bolt	1/17/78	178.9
Grind frog	1/20/78	181.9
Replace broken frog bolt	1/24/78	183.9
Replace broken heel block bolt	3/1/78	211.8
Wedges off gage plate	5/3/78	236.2
Wedges off gage plate	5/30/78	251.6
Grind switch point	6/13/78	261.2
Grind switch point	6/14/78	261.4

TABLE C-4.

WEST BY-PASS

SIGNIFICANT COMPONENT MAINTENANCE AND REPLACEMENT EVENTS

EVENT	DATE	MGT
Tighten frog bolts	11/19/76	18.7
Replace broken heel block bolt	11/30/76	22.2
Replace broken frog bolt	11/30/76	22.2
Grind switch point	1/26/77	35.0
Replace point and stock rail	1/26/77	35.0
Grind switch point and stock rail	1/27/77	35.6
Replace broken heel block bolt	2/7/77	41.7
Grind switch points	2/9/77	42.6
Grind frog	2/9/77	42.6
Replace broken heel block bolt	2/17/77	45.8
Replace broken guard rail bolt	2/24/77	49.5
Weld and grind switch point	3/2/77	52.0
Grind switch point	3/15/77	56.2
Replace stock rail	5/13/77	68.7
Swap switch points East and West By-Pass	6/27/77	91.5
Replace frog bolt	6/30/77	93.7
Repair crack in frog	8/18/77	110.7
Grind frog	8/24/77	114.4
Weld frog	8/25/77	115.2
Weld and grind switch point	9/1/77	119.2
Replace broken frog bolt	9/27/77	131.4
Replace broken frog bolt	11/17/77	138.2
Weld and grind switch point	11/21/77	140.5
Weld and grind frog	12/15/77	157.3
Weld and grind switch point	5/15/78	243.0
Grind throat of frog	5/16/78	244.0
Weld and grind frog	5/16/78	244.0
Install switch point	5/17/78	245.0
Replace broken heel block bolt	6/20/78	262.1

TABLE C-5.

WEST TDT

SIGNIFICANT COMPONENT MAINTENANCE AND REPLACEMENT EVENTS

EVENT	DATE	MGT
Tighten frog bolts	11/19/76	18.7
Replace guard rail bolts	2/22/77	47.6
Replace guard rail	2/25/77	49.7
Replace frog bolt	3/4/77	53.1
Replace guard rail bolt	3/7/77	54.1
Replace guard rail bolt	3/9/77	55.1
Replace guard rail bolt	3/18/77	58.0
Replace guard rail bolt	5/4/77	62.9
Replace guard rail bolt	5/23/77	72.5
Replace guard rail bolt	5/25/77	73.8
Replace frog bolt	5/26/77	74.7
Replace frog bolt	5/31/77	76.5
Replace frog bolt	6/2/77	78.3
Replace guard rail bolt	6/8/77	82.2
Replace guard rail bolt	6/22/77	88.8
Install new closure rail	8/1/77	107.1
Replace guard rail bolt	8/1/77	107.1
Replace frog bolt	8/2/77	108.0
Replace guard rail bolt	9/8/77	122.2
Replace guard rail bolt	11/29/77	144.3
Replace guard rail bolt	11/30/77	145.6
Replace guard rail bolt	12/9/77	153.9
Replace guard rail bolt	1/12/78	176.6
Replace frog	5/11/78	241.6
Grind throat of frog	5/24/78	249.6
Weld frog point and grind	6/13/78	261.2

TABLE C-6.

IMPACT TRACK

SIGNIFICANT COMPONENT MAINTENANCE AND REPLACEMENT EVENTS

EVENT	DATE	MGT
Tighten wedge bolts	10/18/76	4.1
Grind points on switch	1/20/77	33.2
Replace filler block	2/25/77	49.7
Weld and grind frog	3/8/77	54.4
Replace broken frog bolt	11/18/77	139.3
Tighten wedge bolts	11/30/77	145.6
Replace heel block bolt	12/20/77	160.7
Replace heel block bolt	1/12/78	176.6
Replace heel block bolt	3/1/78	211.8
Replace switch points	5/22/78	248.0

TABLE C-7.

FROG #1

SIGNIFICANT COMPONENT MAINTENANCE AND REPLACEMENT EVENTS

EVENT	DATE	MGT
Tighten frog bolts	11/19/76	18.7
Replace broken frog bolt	1/10/77	30.8
Replace broken frog bolt	1/20/77	33.2
Replace broken frog bolt	2/16/77	44.7
Replace broken frog bolt	2/23/77	48.5
Replace broken frog bolt	3/2/77	52.1
Weld and grind frog	3/14/77	56.1
Replace broken frog bolt	3/17/77	57.4
Replace broken frog bolt	3/22/77	59.7
Replace broken frog bolt	3/24/77	61.2
Tighten frog bolts	5/3/77	61.9
Replace test frog with standard rail	5/6/77	64.5
Removed	5/6/77	64.5

TABLE C-8.

FROG #2

SIGNIFICANT COMPONENT MAINTENANCE AND REPLACEMENT EVENTS

EVENT	DATE	MGT
Tighten frog bolts	11/19/76	18.7
Replace broken frog bolt	2/4/77	41.1
Frog weld build-up and grind	3/16/77	56.9
Replace broken frog bolt	3/23/77	60.1
Replace broken frog bolt	6/6/77	80.3
Replace broken frog bolt	6/29/77	93.1
Replace broken frog bolt	7/15/77	99.6
Replace broken frog bolt	8/17/77	108.8
Replace broken frog bolt	11/23/77	142.4
Replace broken frog bolt	1/3/78	169.5
Replace broken frog bolt	3/3/78	214.7
Removed	3/22/78	228.969

TABLE C-9.

FROG #3

SIGNIFICANT COMPONENT MAINTENANCE AND REPLACEMENT EVENTS

EVENT	DATE	MGT
Tighten frog bolts	11/19/76	18.7
Replace broken frog bolt	11/30/76	22.3
Weld and grind frog	3/15/77	56.2
Replace broken frog bolt	6/10/77	83.9
Replace broken frog bolt	7/14/77	99.0
Grind frog point	7/28/77	105.7
Weld and grind frog	8/31/77	118.6
Grind frog	9/13/77	124.8
Grind frog point	11/18/77	139.3
Replace broken guard rail bolt	11/21/77	140.5
Grind frog point	11/21/77	140.5
Weld and grind frog point	11/28/77	143.6
Replace broken heel block bolt	12/1/77	146.8
Replace broken heel block bolt	12/21/77	161.9
Replace broken frog bolt	12/29/77	167.2
Weld and grind frog	1/4/78	170.7
Replace broken frog bolt	1/24/78	184.0
Replace broken frog bolt	2/9/78	196.7
Replace broken frog bolt	3/6/78	216.2
Weld and grind frog	3/21/78	227.9
Replace broken frog bolt	3/29/78	232.4
Replace broken frog bolt	5/3/78	236.2
Removed	5/5/78	238

TABLE C-10.

FROG #4

SIGNIFICANT COMPONENT MAINTENANCE AND REPLACEMENT EVENTS

EVENT	DATE	MGT
Tighten frog bolts	11/19/76	18.7
Replace broken frog bolt	12/8/76	26.0
Weld and grind frog	3/24/77	61.2
Replace frog bolt	3/31/77	61.2
Weld and grind throat of frog	5/17/77	70.4
Grind frog	7/12/77	98.0
Grind frog	7/29/77	106.3
Replace frog bolt	8/3/77	108.7
Grind frog point	9/22/77	129.9
Replace frog bolt	2/24/78	208.2
Replace frog bolt	3/13/78	220.4
Replace frog bolt	3/24/78	230.0
Weld and grind frog	5/4/78	237.1
Replace frog bolt	5/4/78	237.1
Removed	5/5/78	238.0

TABLE C-11.

FROG #5

SIGNIFICANT COMPONENT MAINTENANCE AND REPLACEMENT EVENTS

EVENT	DATE	MGT
Tighten frog bolts	11/19/76	18.7
Replace frog bolt	2/4/77	41.1
Replace frog bolt	3/10/77	55.8
Replace frog bolt	5/12/77	67.7
Replace frog bolt	6/15/77	84.5
Grind flangeway of frog	6/27/77	91.5
Grind flangeway of frog	7/28/77	105.7
Tighten frog bolts	9/13/77	124.8
Tighten frog bolts	11/14/77	135.4
Replace broken frog bolt	11/17/77	138.3
Tighten frog bolts	11/21/77	140.5
Replace broken frog bolt	11/30/77	145.6
Replace broken frog bolt	12/6/77	150.5
Replace broken frog bolt	12/21/77	161.9
Removed	1/6/78	178.0

TABLE C-12.

FROG #6

SIGNIFICANT COMPONENT MAINTENANCE AND REPLACEMENT EVENTS

EVENT	DATE	MGT
Tighten frog bolts	11/19/76	18.7
Replace broken frog bolts	1/25/77	34.0
Replace test frog with straight rail	3/7/77	54.2
Removed	3/7/77	54.4

TABLE C-13.

FROG #7

SIGNIFICANT COMPONENT MAINTENANCE AND REPLACEMENT EVENTS

EVENT	DATE	MGT
Tighten frog bolts	11/19/76	18.7
Weld and grind frog	3/17/77	57.5
Replace frog bolt	11/14/77	135.4
Replace frog bolt	12/9/77	153.9
Replace frog bolt	1/17/78	179.0
Weld and grind frog	5/16/78	244.1
Replace frog with standard rail	5/17/78	245.1
Removed	5/17/78	245.1

TABLE C-14.

FROG #8

SIGNIFICANT COMPONENT MAINTENANCE AND REPLACEMENT EVENTS

EVENT	DATE	MGT
Tighten frog bolts	11/19/76	18.7
Replace frog bolt	1/12/77	31.6
Weld and grind heel of frog	5/6/77	64.5
Replace frog bolt	7/11/77	97.6
Replace frog bolt	7/15/77	99.6
Replace frog bolt	8/3/77	108.8
Regage guard rail	8/8/77	110.7
Replace frog bolt	8/31/77	118.6
Replace frog bolt	9/2/77	120.9
Replace frog bolt	9/9/77	123.0
Weld and grind frog	9/13/77	124.8
Grind frog point	9/22/77	129.9
Replace frog bolt	11/22/77	141.3
Grind frog heel	11/30/77	145.7
Replace frog bolt	12/17/77	159.6
Replace frog bolt	12/20/77	160.8
Replace frog bolt	12/21/77	161.9
Grind flangeway of frog	12/22/77	163.2
Replace frog bolt	12/29/77	167.2
Replace frog bolt	1/3/78	169.5
Weld and grind flangeway of frog	1/3/78	169.5
Weld and grind frog	1/9/78	174.3
Weld and grind flangeway of frog	1/9/78	174.3
Removed	6/7/78	257.3

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