

# AN EVALUATION OF REMEDIATION TECHNIQUES FOR CONCRETE TIE RAIL SEAT ABRASION IN THE FAST ENVIRONMENT

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## Background and Scope of Concrete Crosstie Rail Seat Abrasion

Concrete crosstie rail seat abrasion was first recognized as a problem in the late 1980's. An early industry survey revealed that 15% or more of concrete railroad ties in service for five years or more required some early repair. Closer analysis of this survey showed particular climates, track geometry and loading conditions where the abrasion was taking place. In 1993, railroads reported repairing 500,000 rail seats at a cost of \$5,000,000. Additional costs incurred as a result of service disruptions were not included.

During the past four years, a large matrix of materials intended to eliminate or control concrete tie abrasion has been monitored as part of the Facility for Accelerated Service Testing (FAST)/Heavy Axle Load (HAL) program at AAR's Transportation Technology Center, Pueblo, Colorado. Results after 300 MGT (million gross tons) of HAL traffic point to new repair techniques as well as several promising preventative measures for resisting abrasion. Further testing of matrix materials will be needed to determine whether the most promising methods have a sufficient life cycle to be considered a permanent solution or whether they require periodic inspection and replacement to maintain abrasion resistance.

In addition to tests conducted at FAST, a number of field sites in revenue service contain segments where new materials are being evaluated. Results from these sites also should be evaluated to determine material performance.

The "life between material replacement" is targeted as a minimum measurement of the rail replacement life cycle for maintaining abrasion resistance. This life cycle could range from 500 to over 1000 MGT on curves which may be subject to abrasion or between three and fifteen years, depending on local conditions (rail type, curvature, traffic, axle loads, speeds, etc.) under present heavy haul operations.

## What is Rail Seat Abrasion?

Concrete tie abrasion results when tie material under the pad is lost to abrasion, hydraulic action and motion transmitted from the rail. The loss appears in the form of a localized breakdown of cement paste under the rail seat. (See Figure 1.) Abrasion is typically compared, in appearance, to tie plate cutting in wood ties. Wood, however, is subject to both fiber crushing and decay, which allows the tie plate to cut into the surface of the tie.

## Overview

Rail seat abrasion became a concern in the mid to late 1980's when several North American concrete tie users noted significant >0.08-inch (> 2-mm) abrasion depths at certain locations. Some railroads reported extreme cases of up to 1/2-inch depth before repair and/or remedial techniques were applied.

Abrasion was noted in a number of areas. Wherever significant, the following characteristics existed:

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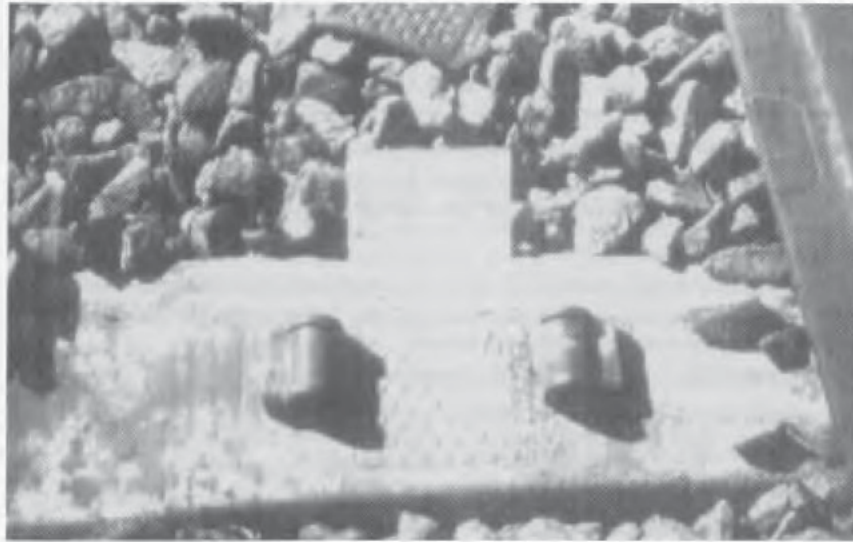


Figure 1.

- High annual tonnage
- High moisture (rain, snow, etc.)
- Severe curvature and high L/V conditions
- Heavy axle loads
- Rail grinding
- Use of locomotive sanding
- Ties equipped with EVA pads

These characteristics are often found in the severe areas of heavy haul railroads where concrete ties had been installed to eliminate previous problems such as wood tie splitting, gage widening and tie plate cutting. With rail seat abrasion, the primary concern is that excessive loss of rail seat depth can reduce the effectiveness of conventional elastic fasteners, which can lead to fastener fallout, running rail and wide gage.

#### **Locating Rail Seat Abrasion**

Unless excessive, abrasion is generally hidden from view by normal track inspection techniques. The most reliable procedure to inspect, measure and quantify abrasion requires removal of rail and tie pads so that the rail seat area can be observed closely. In addition to monitoring locations listed above, the following signs and indications can determine where more detailed visual inspections are warranted.

#### ***Automated Inspection***

Automated track inspection vehicles, such as track geometry cars (TGC) and track loading (gage restraint measurement devices) produce large data bases, parts of which can be used to indicate abrasion. These indications include:

- Increase in gage widening between successive TGC runs that cannot be explained by rail wear.
- Uniform change in superelevation between successive runs which may indicate significant low rail abrasion.
- Localized and unexplained wide gage in otherwise “good” track.
- Large differentials between loaded and unloaded track gage.

All of these indications could be the result of track problems in addition to abrasion. As such, they can be used as a flag for more detailed follow-up field inspection.

#### *Manual/Visual Inspection*

Once an area has been identified as a potential site for abrasion, closer inspection will be needed to verify whether it exists, and if so, the depth and extent. This inspection will help dictate the type of remedial action to take. Visual indicators include:

- Powder or residue leaching from beneath the tie pad area
- Relative relationship of tie pad surface to top of tie
- Tie pad edges which are turned up and curled
- Frequent clip fallout without apparent reason
- Longitudinal running of the rail due to reduction in clip hold-down force
- Wear on insulator components and, if any, on fastener shoulders
- Wide static gage
- Change in rail cant, often noted during profile grinding efforts

Once ties have been inspected and abrasion has been confirmed, a number of options exist. If the abrasion depth is minimal or non-existent, the existing pads may be acceptable for limited continued use. As an alternative, new pad materials that are able to inhibit additional abrasion should be considered. Abrasion depths which might result in loss of fastener hold-down should be repaired by installing materials that restore rail seat height and rail cant to original configurations. Repair materials should not only resist abrasion, but last the life of the tie.

#### *Evaluation of Materials to Reduce Rail Seat Abrasion at FAST*

In response to industry concerns about abrasion, a limited evaluation of methods to eliminate, reduce or repair abrasion was installed at FAST in 1991. The original objective was to “determine methods and material combinations, in-field repairs, and manufacturing process, that are effective in preventing, reducing, or stopping rail seat abrasion.”

In order to address this objective, a number of new concrete ties and ties from revenue service with various amounts of abrasion were obtained and installed in FAST during the December, 1990 track rebuild. A range of tie pads and repair techniques was introduced into this matrix of concrete ties. During the initial and follow-up phases of the FAST abrasion test, the matrix of ties and pads installed was accomplished under the direction of the Ad-hoc Concrete Tie Rail Seat Abrasion Committee. Committee members included representatives from railroads, suppliers, and the academic and research communities.

Tests and evaluations conducted at FAST were selected by the committee based on projected performance of new technologies being offered, and results observed from various field locations. In addition to the tests at FAST, a number of materials and methods are being evaluated by railroads and the supply industry in revenue service. For example, ties manufactured with convex rail seats were first installed in one revenue service site. Initial examination of this site (after about 60 MGT of traffic) indicated promising results, and additional ties of this design have been provided for evaluation in FAST.

Field sites offer a wider range of climate and operating conditions than at the TTC, while FAST provides a known, controllable environment and the opportunity for precise, periodic inspection and measurement. Data and results for this presentation are based primarily on observations and measurements from materials located in the FAST track. Results from both FAST and field/revenue service evaluations should be examined before definite conclusions can be drawn.

Two test zones at FAST which surround the existing concrete tie test zone in Section 3 (a 5° curve) were selected. (See Figure 2.) The relatively sparse natural moisture normally available in the Pueblo area required supplemental tie watering once every second day of operation. After committee members inspected the test at 30 MGT, watering was increased to twice during each shift of train operation. Using a specially fitted truck to spray the additional water, approximately 21 inches of annual effective moisture was added to the natural 11 inches per year. Thus FAST abrasion zones simulate an environment where approximately 32 inches of rain falls on the track annually.

The matrix of test ties and pads has undergone two revisions, once after about 130 MGT of traffic and again after 200 MGT of traffic. These revisions allowed for installation of new materials not previously available, and eliminated certain materials that did not appear to exhibit any abrasion reduction capabilities.

A detailed list of the latest matrix is included in the attached appendix. Major combinations of pads and repair techniques included variations in the following categories:

- Dual Durometer Rubber pads
- Rubber/reinforced pads
- EVA pads\*
- Various pad materials with various shape factors
- Polyurethane
- Tie pads bonded/glued to the tie surface

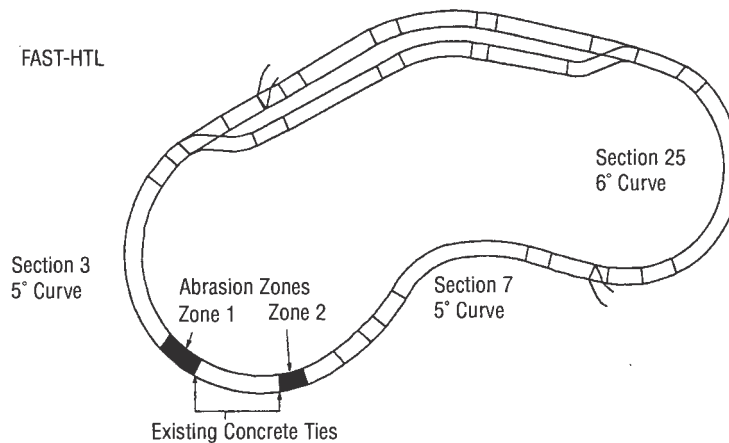


Figure 2. Concrete Tie Rail Seat Abrasion Experiment.

\*No one has suggested EVA pads are a cure—they are part of the problem.

- Pads with a sealing ring built into the surface
- Three part sandwich pads (foam/steel plate/pad material)
- Steel plate cast into new tie
- Steel plate/epoxy repair
- Epoxy repair
- Variety of filler materials for repair
- Alternative insulator materials
- Tie surface coatings
- Alternative concrete mixes
- Rail seat surface shape factors

Note that EVA pads were included in the FAST test matrix as a “control,” not as a proposed cure. Field sites equipped with EVA pads have often exhibited abrasion. These pads were included at FAST to determine the scope of abrasion under conditions at FAST.

The attached Tables 1 and 2 are a summary of the major differences in component materials. Each system offers a different approach to solving the abrasion problem. For example, glued pads sealed to the tie surface could eliminate infiltration of water, sand and other particles, thereby eliminating the sources of abrasion. Unfortunately, this particular matrix was not successful in reducing abrasion at FAST. The glue used was ineffective in adhering the pads to the tie surface for any duration (less than 2 MGT). Perhaps glue materials developed in the future will prove to be longer lasting.

The limitations of this abrasion test summary cannot accommodate both a complete description of all 65+ pad/material combinations and the theory behind each technique.

#### Data

Few data collection cycles were available to measure the abrasion depth, primarily because rail had to be removed, pads had to be individually picked up and the rail seat had to be cleaned. Data was initially obtained on a 50 MGT cycle; however, it became apparent that inspection and measurement processes could adversely affect the ability of some pad combinations to continue resisting the abrasion process. Subsequent measurements were conducted on 100+ MGT cycles.

A modified version of an existing abrasion gage utilizing a dial indicator was fabricated. This modification improved the data resolution of a tie pad footprint on the rail seat, which is measured with respect to depth relative to the non-wearing tie surface. Initially, the data was collected with mechanical dial indicator gages, however, updated versions now permit automated and continuous data collection. Nonetheless, this measurement is time consuming and conducted only at infrequent (50-100 MGT) intervals. A sample data plot showing two successive measurements is shown in Figure 3.

#### Results/Observations to Date

Has the rail seat abrasion problem been solved? Based on the solutions under evaluation at FAST, it appears that abrasion can be controlled by certain combinations of pads and materials, but the life cycle of these techniques has not been fully quantified. Several solutions including very soft pads, dual-durometer pads, and sandwich pads appear to either prevent or minimize the formation of abrasion. At this time, though, they do not appear to be permanent solutions; they must be replaced during the life of the tie or during rail replacement. Many of the softest rubber pads at FAST have shown no abrasion, but after 100 to 150 MGT of service, the pad has worn through or must otherwise be replaced.



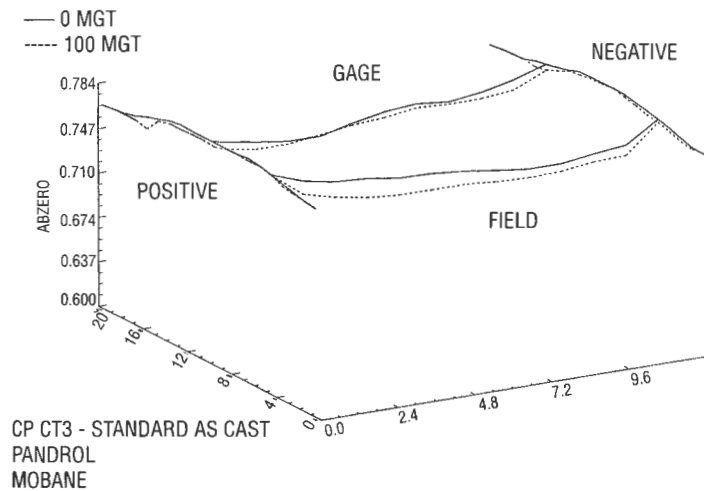


Figure 3. Average Depth Profile

If the life of abrasion eliminating materials can be extended so that they last as long as the rail is in place, then they can be considered as sacrificial components of the concrete tie system and be replaced at relatively little incremental cost during routine, planned rail changeouts. However, if they must be replaced between rail replacement cycles, then a significant increase in cost will be incurred in track time, train delays, and labor effort to declip rail, raise and replace the pad, and replace the rail. Although not "solved," the rail seat abrasion problem can be managed, provided the proper combination of material is selected.

#### Where Do We Go From Here?

Tests at FAST require significant time and effort, thus a laboratory screening method is highly desirable. The performance of a wide range of materials (both at FAST and from a number of revenue service sites) is already known and could be used to calibrate a laboratory test machine/fixture.

In order for a laboratory test to be considered an adequate screen device, it would have to apply loads, moisture, freeze/thaw cycles and other variables that are found in the field and produce abrasion that is similar to that found in revenue service. It would also have to produce abrasion similar to that found in revenue service. These results can be used by railroads to determine which materials are most likely to last at least one rail changeout cycle before needing replacement.

In the interim, pad materials continue to be evaluated at FAST. Currently, the rail seat abrasion program is being evaluated for reconfiguration to allow improved long term evaluation of a very limited number of materials. The test conducted would be revised to allow a smaller number of material variables to be evaluated in larger sections. This will permit smaller numbers of each matrix to be measured on a periodic basis and allow long term evaluation of the most promising materials.

A more concise summary of results from the FAST abrasion test will be presented at the November 6-8, 1995 Engineering Conference to be held in Pueblo, Colorado.

**Table 1. Zone 1**  
**Concrete Tie Abrasion Experiment Materials List June '94**

Zone	Tie #	Tie Type	# in Test	Hardware	MGT	Comments	Committee Suggestions
7A	870-874	FEC	5	Spring Clip/ Plastic		Installed May '94 Removed July '94	
2C	875-879	CN 60C HD-8	5	Pandrol/ Rubber		Standard as cast	
2B	880-884	CN 60C HD-8	5	Pandrol/ Urethane		Standard as cast 1 tie broken/removed	
2A(B)	885-890	CN 60C HD-8	6	Pandrol/ EVA		Standard as cast	
2A(A)	891-893	CN 60C HD-8	3	Pandrol/ Glued EVA		Standard as cast	
4B	894-899	CN 60C HD-8	6	Pandrol/ Miner pads		Standard as cast	
4A	990-904	Itisa HD-10	5	Pandrol/ DD Poly		Post tension ties In HTL since '89 Installed for abrasion 12/92	
2O	905-907	CN 60B HD-8	3	Pandrol/ Rubber		RTR #40	
2N	908-910	CN 60B HD-8	3	Pandrol/ Urethane		RTR #40	
2M	911-914	CN 60B HD-8	4	Pandrol/ EVA		RTR #40	
2L	915-919	CN 60B HD-8	5	Pandrol/ Rubber		Resurf-241	
2K	920-924	CN 60B HD-8	5	Pandrol/ Urethane		Resurf-241	
2J	925-929	CN 60B HD-8	5	Pandrol/ EVA		Resurf-241	
2I	930-935	CN 60B HD-8	6	Pandrol/ Rubber		Chemor-1984 tie	

NOTES:

2H	936-941	CN 60B HD-8	6	Pandrol/ Urethane		Chemor-1984 tie	
2G	942-946	CN 60B HD-8	5	Pandrol/ EVA		Chemor-1984 tie	
2F	947-952	CN 60B HD-8	6	Pandrol/ Rubber		Jeffamine-1984 tie	
2E	953-958	CN 60B HD-8	6	Pandrol/ Urethane		Jeffamine-1984 tie	
2D	959-964	CN 60B HD-8	6	Pandrol/ EVA		Jeffamine-1984 tie	
5C	965-974	CP CT5	10	Pandrol/ Convex rail seat/urethane		Standard as cast Special Insulators Installed 1/94	
5B	975-979	CP CT5F	5	Pandrol/ 4 Urethane 1 CRP		Standard as cast Tie 977 with CRP pad Installed 1/94	
5A	980-989	CP CT5	10	Pandrol/ Convex rail seat/urethane		Standard as cast Special Insulators Installed 1/94	
1A1	OUT OF TEST	BN 100	3	McKay/Pad cast to rail seat		Installed 1/92 - 60.5 MGT Removed 11/93	
1A(A)	990-994	CP CT3 HD-8	5	Pandrol/ Mobay		Standard as cast	
1A(B)	995-999	CP CT3 HD-8	5	Pandrol/ Dual urethane		Standard as cast	
1A(C)	1000-1004	CP CT3 HD-8	5	Pandrol/ Dual rubber		Standard as cast	
1A(D)	1005-1009	CP CT3 HD-8	5	Pandrol/ Mobay		Standard as cast	
1B(A)	1010-1014	CP CT3 HD-8	5	Pandrol/ Mobay		Jeffamine	

NOTES:



Table 1. Zone 1 (continued)

Zone	Tie #	Tie Type	# in Test	Hardware	MGT	Comments	Committee Suggestions
1B(B)	1015-1019	CP CT3 HD-8	5	Pandrol/ Dual urethane		Jeffamine	
1B(C)	1020-1021	CP CT3 HD-8	2	Pandrol/ Dual urethane		Jeffamine	
1B(D)	1022-1024	CP CT3 HD-8	3	Pandrol/ Dual rubber		Jeffamine	
1B(E)	1025-1029	CP CT3 HD-8	5	Pandrol/ Mobay		Jeffamine	
1F(A)	1030-1032	UP 497 HD-10	3	Pandrol/ Epoxy/steel plate		11/93 Pandrol repair replace 6½ mm poly pad	
1F	1033-1043	UP 497 HD-10	11	Pandrol/ 6½ mm poly		Standard as cast	
1G	1044-1049	UP 497 HD-10	6	Pandrol/ Poly		Jeffamine	
1H	1050-1056	UP 497 HD-10	7	Pandrol/ Poly		Jeffamine	
1I	1057-1063	UP 497 HD-10	7	Pandrol/ Dual rubber		Jeffamine	
1J	1064-1069	UP 497 HD-10	6	Pandrol/ Poly w/glue		Standard as cast	
1K(A)	1070-1071	UP 497 HD-10	2	Pandrol/poly w/seal ring		Standard as cast	
1K(B)	1072-1074	UP 497 HD-10	3	Pandrol/ Dual poly		Standard as cast	
1L(A)	1075-1076	UP 497 HD-10	2	Pandrol/ Poly		Installed with neoprene below poly—wore away by 100 MGT	
1L(B)	1077-1979	UP 497 HD-10	3	Pandrol/ Poly		Installed with BUNA below poly—wore away by 100 MGT	

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1W(A)	1080-1081	K11 1011 HD-10	2	Pandrol/ 4D-2/93 4D-3/94	Standard as cast 4D pads replace double dimple EVA
1W(B)	1082-1083	K11 1011 HD-10	2	Pandrol/ 4D-2/93 4D-3/94	Standard as cast 4D pads replace double dimple poly
1X(A)	1084-1086	K11 1011 HD-10	3	Pandrol/ 4D-3/94	Standard as cast 4D pads replace rubber w/seal ring
1X(B)	1087-1088	K11 1011 HD-10	2	Pandrol/ 4D-2/93	Standard as cast 4D pads replace dual durometer rubber
1X(C)	1089	K11 1011 HD-10	1	Pandrol/ 4D-3/94	Standard as cast 4D pads replace rubber w/seal ring
1Y(A)	1090-1091	K11 1011 HD-10	2	Pandrol/ 4D-2/93 4D-3/94	Rail seat silene treated 4D pads replace double dimple EVA
1Y(B)	1092-1093	K11 1011 HD-10	2	Pandrol/ 4D-2/93 4D-3/94	Rail seat silene treated 4D pads replace double dimple poly
1Y(C)	1094-1095	K11 1011 HD-10	2	Pandrol/ 4D-3/94	Rail seat silene treated 4D pads replace rubber w/seal ring
1Y(D)	1096-1097	K11 1011 HD-10	2	Pandrol/ 4D-2/93	Rail seat silene treated 4D pads replace dual durometer rubber
1Z(A)	1098	K11 1011 HD-10	1	Pandrol/ 4D-2/93	Whole tie silene treated 4D pads replace double dimple EVA
1Z(B)	1099	K11 1011 HD-10	1	Pandrol/ 4D-2/93	Whole tie silene treated 4D pads replace double dimple poly
1O	1100-1109	BN 100	10	McKay/ Rubber	New rubber replaced Std. McKay rubber 2/94

NOTES:

Table 1. Zone 1 (continued)

Zone	Tie #	Tie Type	# in Test	Hardware	MGT	Comments	Committee Suggestions
1P	1110-1119	BN 100	10	McKay/ Sandwich		Standard as cast	
1Q	1120-1131	BN 100	12	McKay Rubber		No air entrainment New rubber replaced Std. McKay rubber 2/94	
1R	1132-1137	BN 100	6	McKay/ Rubber		Pyrament New rubber replaced Std. McKay rubber 2/94	
1S	1138-1147	BN 100	10	McKay/ 8 mm EVA		Silica fume + air	
1T(A)	1148-1149	BN 100	2	McKay/ Poly		Standard as cast Installed with Neoprene/ wore away by 100 MGT	
1T(B)	1150-1152	BN 100	3	McKay/ Poly		Standard as cast Installed with BUNA/wore away by 100 MGT	
1T(C)	1153-1157	BN 100	5	McKay/ Masti Cord		Standard as cast	
1U	1158-1167	BN 100	10	McKay/CRP glue/poly		Standard as cast	
1V	1168-1177	BN 100	10	McKay/ 8 mm poly		Silica fume + air	
2Y(A)	1178-1182	BN 100	5	McKay/ Sika flex		Standard as cast CRP rubber	
2Y(B)	1183-1186	BN 100	4	McKay/ Epoxy		Standard as cast Poly	

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**Table 2. Zone 2**  
**Concrete Tie Abrasion Experiment June '94**

Zone	Tie #	Tie Type	# in Test	Hardware	MGT	Comments	Committee Suggestions
6A(C)	1673-1674	Koppers	2	Pandrol/ 2 pc sandwich poly/poly		Standard as cast Special insulator set up Installed 2/94	
6A(B)	1675-1677	Koppers	3	Pandrol/ 2 pc sandwich poly/Steel		Standard as cast Special insulator set up Installed 2/94	
6A(A)	1678-1681	Koppers	4	Pandrol/ 3 pc sandwich		Special insulator set up Installed 2/94	
3F	1682-1687	BN 100	6	McKay/ Std. EVA		Standard as cast OUT OF TEST	
3	1688-1693	BN 100	6	McKay/ Cast poly		Standard as cast Installed 2/01/93	
3D	1694-1699	BN 100	6	McKay/Steel plate cast in rail seat		Standard as cast Miner tie pads Installed 2/01/93	
3C	1700-1705	BN 100	6	McKay/ Miner pads		Standard as cast Installed 2/01/93	
3B	1706-1710	BN 100	5	McKay/ Double Crafc McKay poly		Standard as cast Installed 2/01/93 OUT OF TEST 1/94	
3A	1711-1713	BN 100	3	McKay/ Single Crafc McKay poly		Standard as cast Installed 2/01/93 OUT OF TEST 1/94	
3A(A)	1714-1715	BN 100	2	McKay/ Single Crafc Crafc rubber		Installed 2/01/93 New Crafc sealant and pad replace Crafc w/poly 1/94	

NOTES:

