


AAR Coupling System and Truck Castings Committee (CSTCC)

Presented for:

The Association of American Railroads Coupling System and Truck Casting Committee

by

Dan Moseng – BNSF
David Cackovic – AAR/TTCI

Today's Discussion

- CSTCC
- Tools and methods for addressing failures of industry castings
  - NCM bolsters and side frames -- examples
- Specification upgrades and updates, and new specification development
- RFID
- Questions and answers

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Committee Members -- CSTCC Overview

- CSTCC formed 3Q'04, first activity November 10, 2004.

- Dan Moseng – BNSF – Chairman
- Tim Ward – NS – Vice Chairman
- Randy Gaston – UP
- Kim Bowling – CSX
- Rick Brueckert – TTX

- Jon Hannafious and David Cackovic – AAR/TTCI

CSTCC Overview

- The Coupling System and Truck Castings Committee (CSTCC) promotes policies, practices and procedures that will maintain/improve supplier casting practices and promote new and improved products for the railroad industry.

- The CSTCC:
  - Addresses failures from an industry perspective, and develops improved specifications, procedures and processes to eliminate future failures.
  - Manages foundry (trucks, side frames) certification status
  - Is responsible for about 70 Standards, Specifications and Recommended Practices pertaining to castings.
  - Supports about 10 AAR Interchange Rules covering couplers, truck castings and other castings

Today's Discussion

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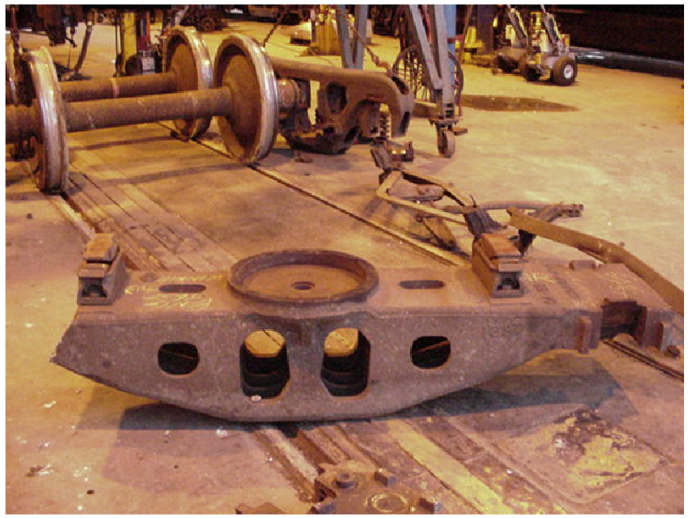
- ***Tools and methods for addressing failures of industry castings***
  - ***NCM bolsters and side frames -- examples***
- Specification upgrades and updates, and new specification development
- RFID
- Questions and answers



Testing, Analysis and NDT (NCM Bolsters)

In 2002, due to the service failures and 6 derailments – the Equipment Engineering Committee (EEC) directed that National Castings of Mexico bolsters undergo the following evaluation:

- Nondestructive Testing
  - Visual inspection and Radiographic inspection
- Fatigue Testing (ASF – 7, Packer Engineering – 4, TTCI – 7)
- Failure Analysis and Finite Element Analysis

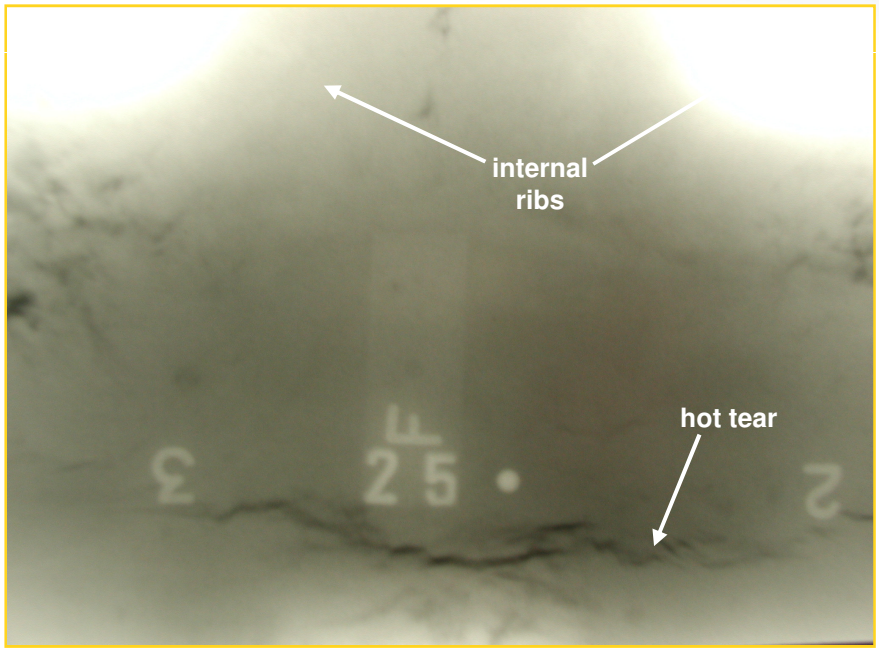
- The bolsters were failing due to a combination of improper weld repair, inclusions, hot tears and improper heat-treating.

- The AAR EEC targeted over 24,000 cars for inspection and bolster replacement. The research in Pueblo led to a managed, safe inspection and replacement program.

Testing, Analysis and NDT (NCM Bolsters)

Radiographic Test (RT) results

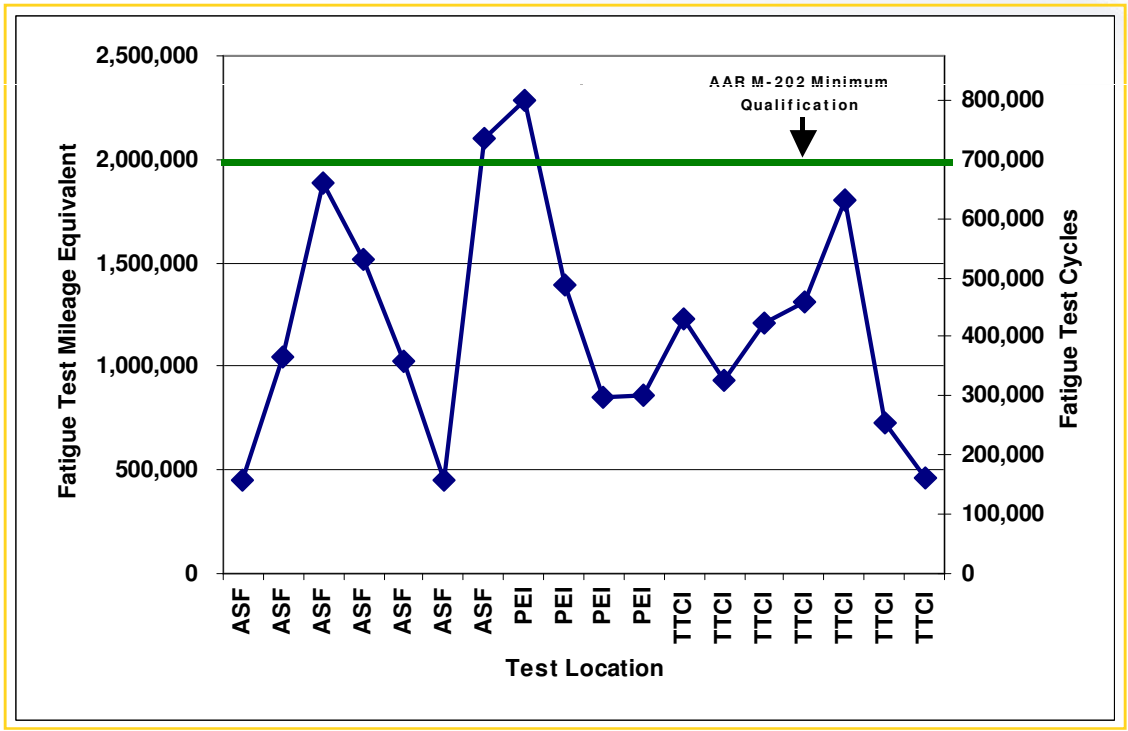
- ASTM Standards for Radiographic Inspection of Large Steel Castings were used.
  - High rates of NCM bolsters were rejected, primarily for hot tears.



Testing, Analysis and NDT (NCM Bolsters)

Dynamic Fatigue Testing

Two of the 18 bolsters tested met the minimum performance acceptance criteria of 700,000 cycles without failure.



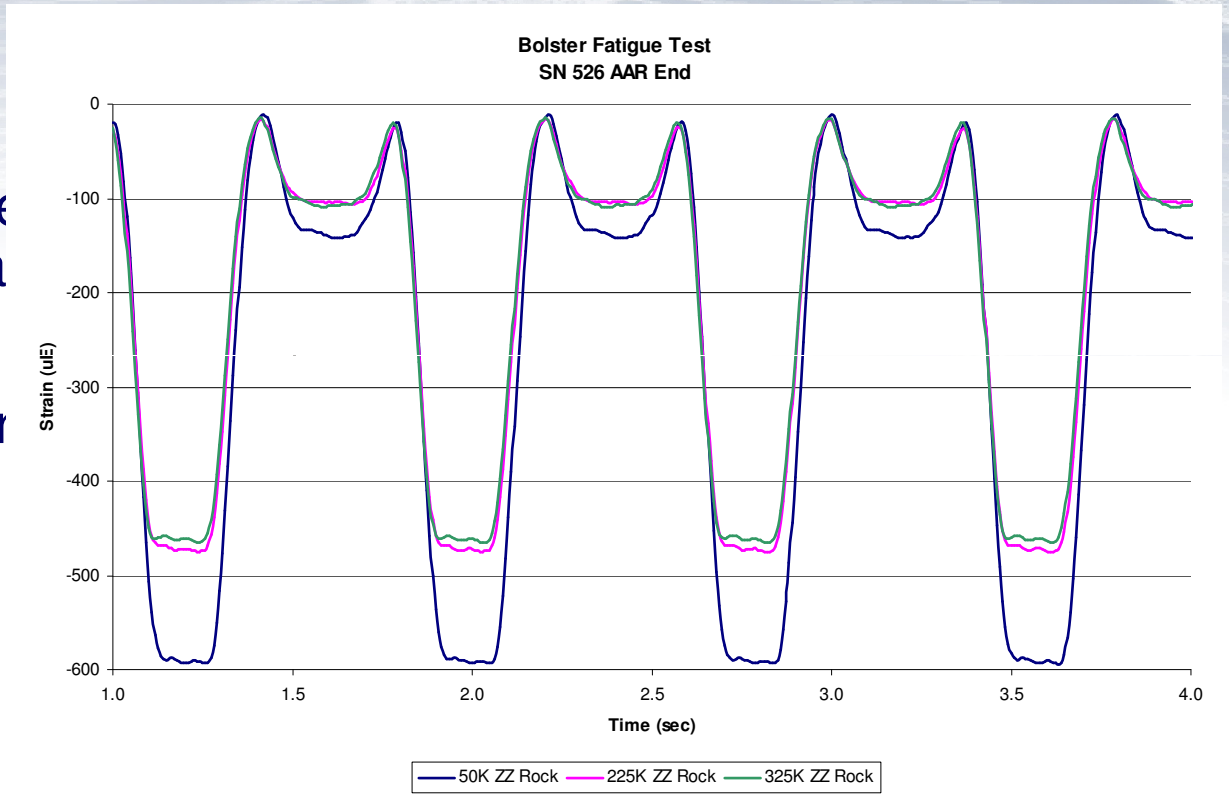
Testing, Analysis and NDT (NCM Bolsters)

Strain Gage Results (rock load cycles):

Analysis of the strain data shows that the cracks developed before the visual inspection was performed.

Cracks initiated between 50,000 and 225,00 cycles

Exact point in time of crack initiation not apparent



Testing, Analysis and NDT (NCM Bolsters)

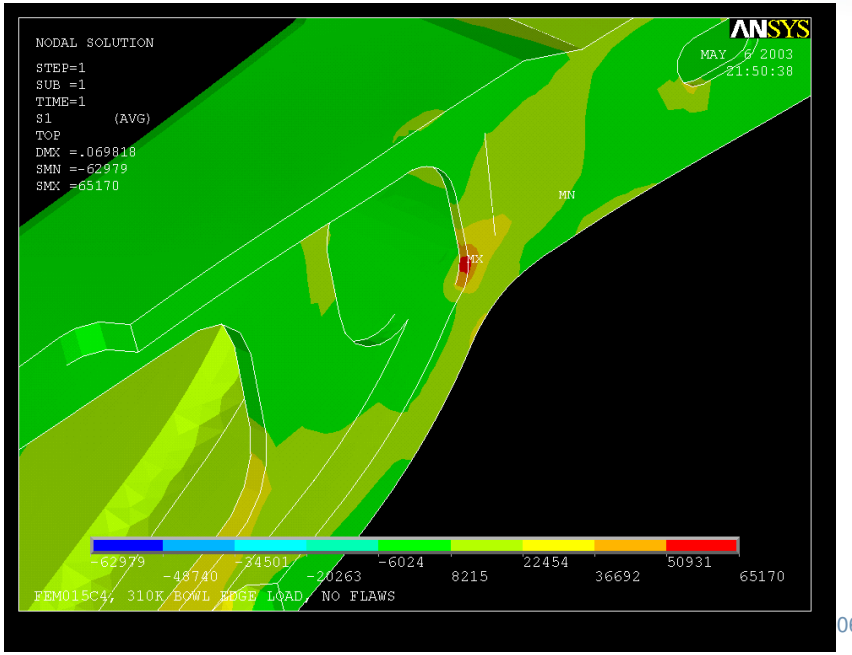
Failure Analysis, Fracture Behavior and Finite Element Analysis

Analysis shows that discontinuities provide initiation sites for fatigue failure:

- Hot tears, Voids, Sand Inclusions

Finite Element Analysis verified the effect on stress concentrations due to discontinuities and defects.

In addition, the design was found to be marginal in terms of the ability to tolerate manufacturing flaws.



Testing, Analysis and NDT (NCM Bolsters) AAR Action

RAILINC

SUMMARY OF BOLSTER EW'S

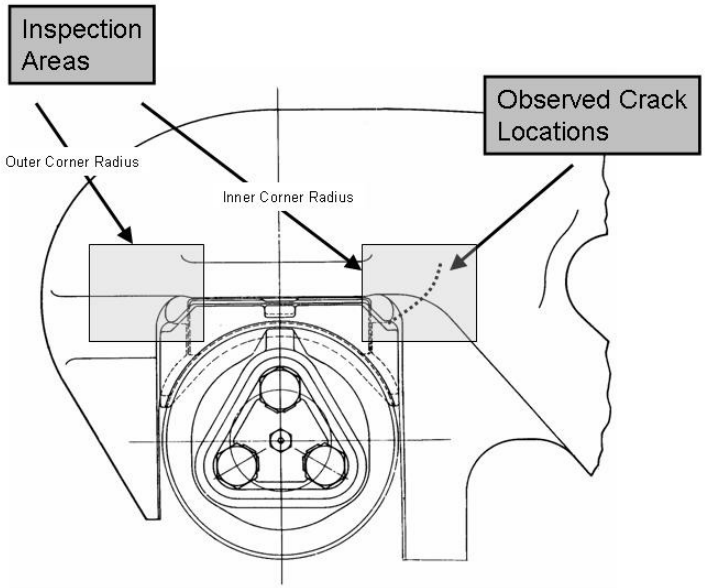
18-Sep-06

AAR EARLY WARNING SUMMARY				$ Carr Assigned (All Carr Lazr MH and MI)	Inspected and Repaired (MH)	Inspected and Returned to Service (MR)	Temporarily Removed from Service (Stored)	Inspected and Moving to Shop, Unloading or Scrap	Non-Compliant[2] (Carr not yet seen AND carr in	Carr With Extended Deadline (EX)[3]	% Completed (MH+MR/Total)	% Completed/ Out of Service/ Moving to Shop
A	B	C	D	E	F	G	H	I	J	K	L	M
EW $	Cat	Description	Date/ Deadline	Assigned	Repaired	Final Insp	Out of Service	Moving to Shop	Open	Extended	% Completed	% Handled
5193	III	Failed Truck Bolsterr: NCM. Non Tank Carr. 52122	1/12/2003	4,174	3,058	977	0	50	139	0	96.7%	97.9%
			3/31/2004	100.0%	73.3%	23.4%	0.0%	1.2%	3.3%	0.0%		
5194	I	Failed Truck Bolsterr: NCM Truck Bolsterr. 52122	1/26/2003	2,474	2,084	389	0	1	1	0	100.0%	100.0%
			9/30/2003	100.0%	84.2%	15.7%	0.0%	0.0%	0.0%	0.0%		
5195	II	Failed Truck Bolsterr: NCM. Mill Gondolar and Coal Carr. 52122	5/2/2003	3,219	2,197	696	0	37	326	0	89.9%	91.0%
			12/31/2003	100.0%	68.3%	21.6%	0.0%	1.1%	10.1%	0.0%		
5196	II	Failed Truck Bolsterr: NCM. Mill Gondolar and Coal Carr. 52202	5/4/2003	2,309	1,694	547	0	5	68	0	97.1%	97.3%
			12/31/2003	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
5197	III	Failed Truck Bolsterr: NCM. Mircellaneour. 52202	8/1/2003	5,926	3,788	1,466	0	258	672	0	88.7%	93.0%
			3/31/2004	100.0%	63.9%	24.7%	0.0%	4.4%	11.3%	0.0%		
5199	III	Failed Truck Bolsterr: NCM. Mircellaneour GE Carr. 52202	6/5/2003	2,769	1,860	897	0	3	12	0	99.6%	99.7%
			9/30/2003	100.0%	67.2%	32.4%	0.0%	0.1%	0.4%	0.0%		
5200	I	Failed Truck Bolsterr: NCM. GE Tank Carr. 52202	6/18/2003	451	448	0	0	1	3	0	99.3%	99.6%
			9/30/2003	100.0%	99.3%	0.0%	0.0%	0.2%	0.7%	0.0%		
5201	I	Failed Truck Bolsterr: NCM. GATX Tank Carr. 52202	8/26/2003	225	225	0	0	0	0	0	100.0%	100.0%
			9/30/2003	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
TOTL				21,547	15,354	4,972	0	355	1,221	0	94.3%	96.0%
				100.0%	71.3%	23.1%	0.0%	1.6%	5.7%	0.0%		
											F+G/E	F+G+H+I/E
TOTL	I	Failed Truck Bolsterr: NCM. Tank Carr.		3,150	2,757	389	0	2	4	0	99.9%	99.9%
			9/30/2003	100.0%	87.5%	12.3%	0.0%	0.1%	0.1%	0.0%		
TOTL	II	Failed Truck Bolsterr: NCM. Mill Gondolar and Coal Carr.		5,528	3,891	1,243	0	42	394	0	92.9%	93.6%
			12/31/2003	100.0%	70.4%	22.5%	0.0%	0.8%	7.1%	0.0%		
TOTL	III	Failed Truck Bolsterr: NCM. Mircellaneour.		12,869	8,706	3,340	0	311	823	0	93.6%	96.0%
			3/31/2004	100.0%	67.7%	26.0%	0.0%	2.4%	6.4%	0.0%		
GRND				21,547	15,354	4,972	0	355	1,221	0	94.3%	96.0%
				100.0%	71.3%	23.1%	0.0%	1.6%	5.7%	0.0%		

Testing, Analysis and NDT (NCM Side Frames)

AAR Action:

AAR issued MA-94 on 10/21/05. The Maintenance Advisory described reports of six (6) failures of truck side frames from two North American foundries, NCM and Buckeye. The Maintenance Advisory was issued to notify the industry to carefully inspect these side frames when in shops or on repair tracks.



Testing, Analysis and NDT (NCM Side Frames)

FRA Actions

FRA issued Safety Advisory 2006-1 on 03/08/06

UP Actions

UPRR is in the process of replacing 400 car sets of the suspect NCM side frames

Testing, Analysis and NDT (NCM Side Frames)

- **TTCI AND CSTCC INVESTIGATION UPDATE – Phase I and II**
  - **In response to the failures, the AAR CSTCC initiated a test program. After the first set of testing was recently completed, additional testing has been planned. TTCI and the CSTCC developed a test and analysis program to quantify the problem and to allow future actions to be considered.**
    - Final results will include:
      - pass/fall M-203 test results
      - fatigue life predictability
      - crack growth rate charts from the M-203 tests
      - estimated life to failure for M-203 loads
      - estimated life to failure for the OTR loads
    - After study and result interpretation, further action by the AAR in possible maintenance and inspection plans, rule changes, and specification changes may result

Testing, Analysis and NDT (NCM Side Frames)

- **TTCI AND CSTCC INVESTIGATION UPDATE**
  - **The initial goal of the investigation was to develop an ability to predict fatigue life for WOW, MOR, and BOB samples, and to determine if the sample castings will pass M-203 requirements.**
  - **UP provided three NCM side frames for testing. Stress risers existed but no cracks were evident in these first castings.**
  - **CSX and TTCI inspected trains for Buckeye Side Frames.**

Testing, Analysis and NDT (NCM Side Frames)

- **TTCI AND CSTCC INVESTIGATION UPDATE**
  - **The NCM side frames were instrumented to measure stress in the critical locations. FEA was used.**
  - **The side frames were calibrated to obtain ratios of strain vs. quasi-static vertical and lateral loads.**
  - **AAR Spec M-203 fatigue test procedures were followed and M-203 test loads were used.**
  - **TTCI also collected 286K OTR Data for bolsters and side frames, as part of the Freight Car Fatigue Task Force test program. This information is being used to augment the M-203 data during the analysis phase.**

Testing, Analysis and NDT (NCM Side Frames)

Figure 1: Location L1 side view (left) strain gage installation at L1 (right)

Figure 2: Location L1 curve location (left), strain gage installation at L1 (right)

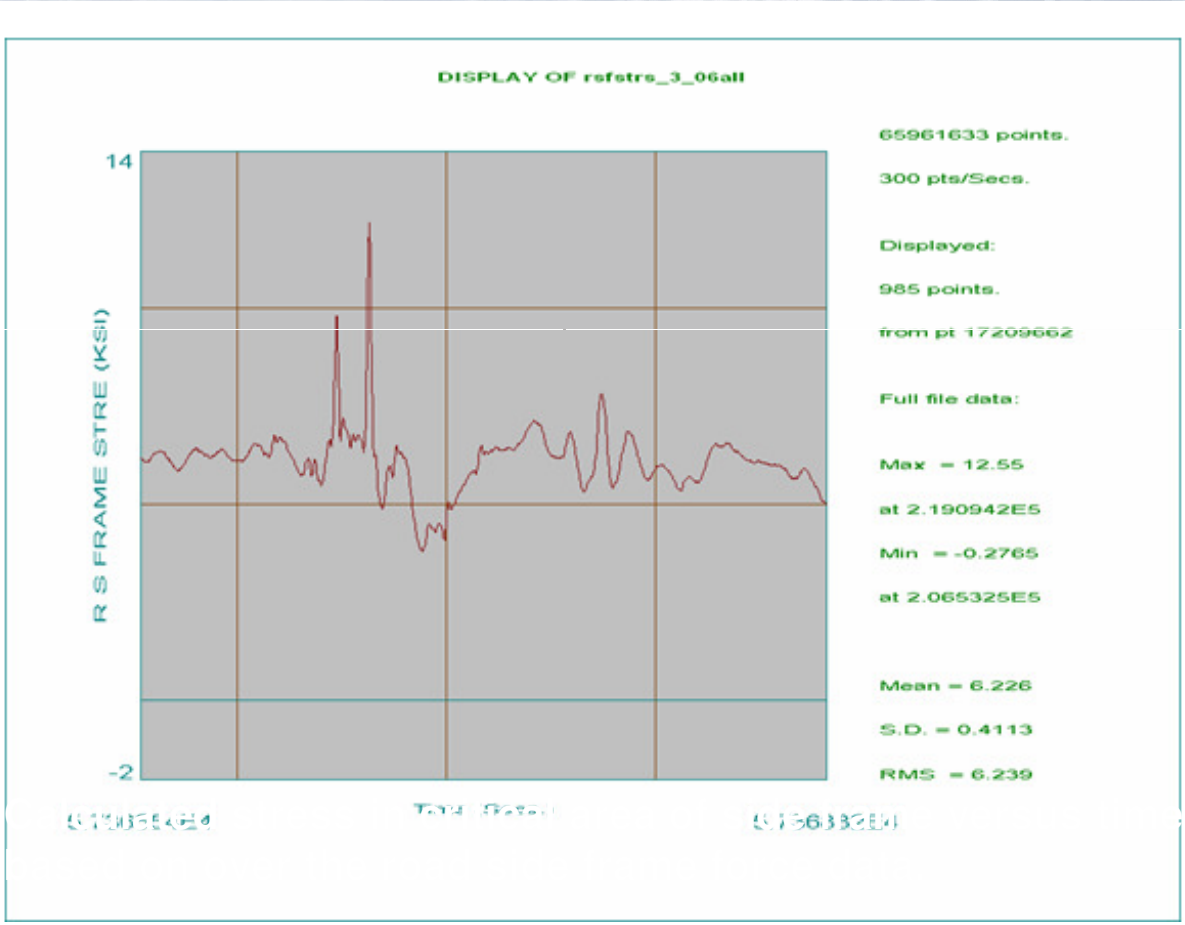
Testing, Analysis and NDT (NCM Side Frames)

- **INVESTIGATION – Preliminary Test Results**
  - After completion of the M-203 dynamic tests on the worst UP sample casting (NCM), TTCI then tested the side frame beyond M-203 requirements (52% above required dynamic loads) – crack growth in the critical defect was found to be 0.05” or less.
  - This result, though only one sample, suggests that the design is robust.
  - However, the failures in service have occurred, and poor finish castings with similar defects as those which caused the fractures are common, and subsequent inspections of side frames removed at UP revealed moderate to severe cracks … so modeling was performed, and more testing is beginning.

Testing, Analysis and NDT (NCM Side Frames)

- **INVESTIGATION**
  - Initiation and crack growth modeling:
    - Perform crack initiation estimates using actual railroad route data and the stress environment created by the M-203 testing load spectra.
    - Perform crack growth rate estimates using actual railroad route data and the stress environment created by the M-203 testing load spectra.
    - The modeling performed is a simple example and thus simulates fatigue and crack growth on the side of the frame where the strain gage was shown, above the more critical corner radius area.

Testing, Analysis and NDT (NCM Side Frames)



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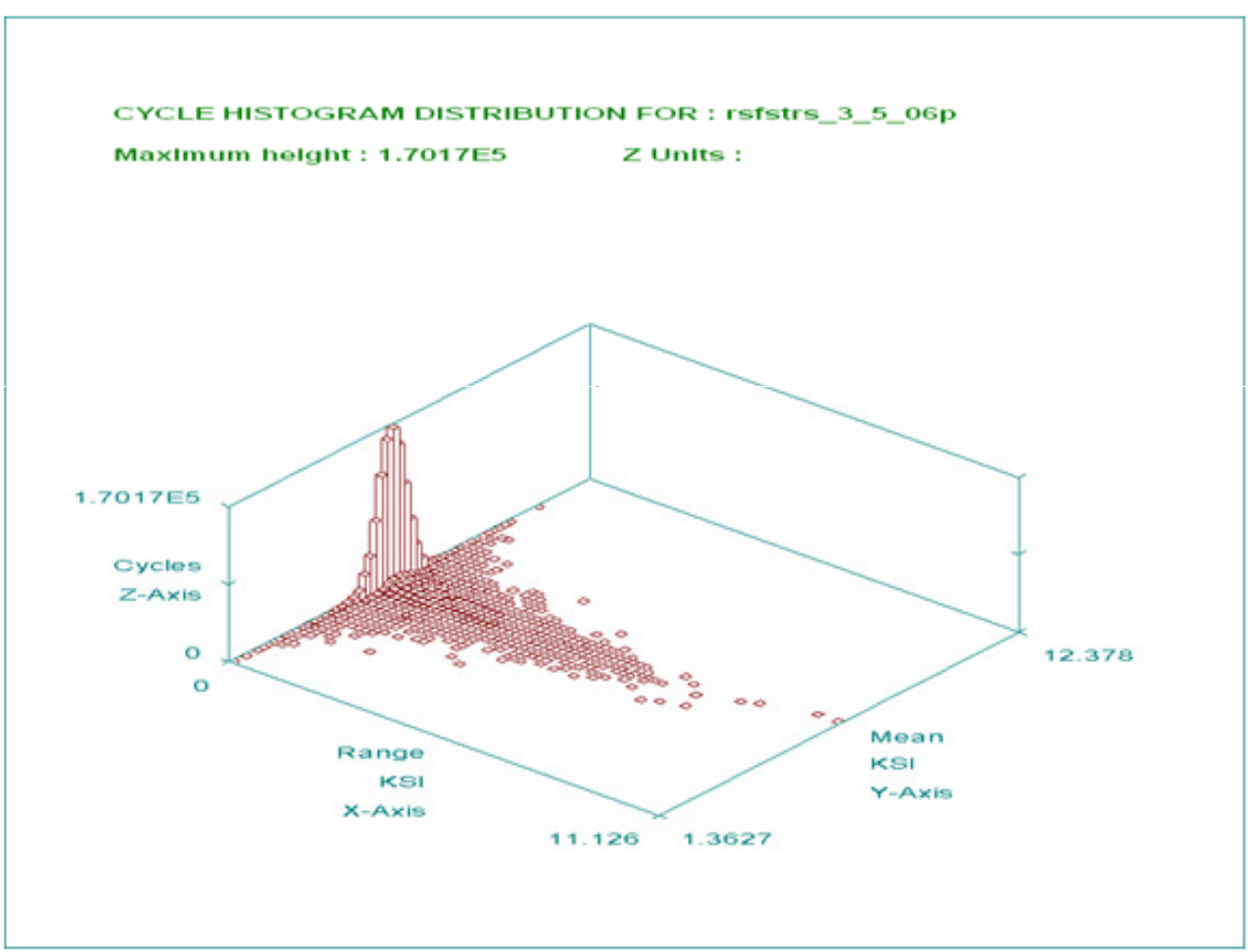
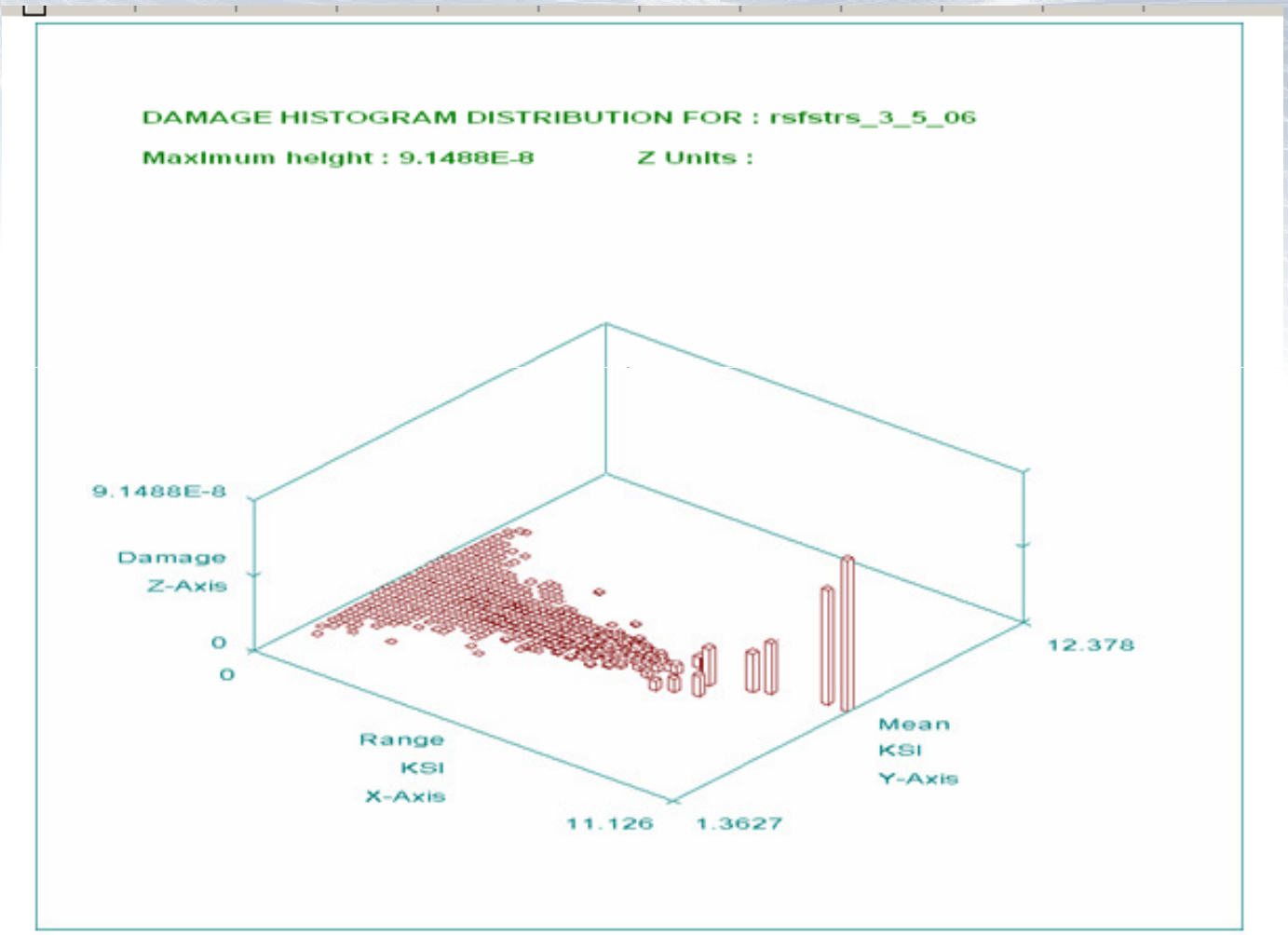


Histogram of rainflow counted stress cycles in critical area – March 5, 2006 PM

Testing, Analysis and NDT (NCM Side Frames)



Histogram of fatigue damage in critical area – March 5, 2006 PM

Testing, Analysis and NDT (NCM Side Frames)

- **Crack Initiation Life – Actual Service**
  - Stress versus load relationships established from test data.
  - Environmental loads used from March 2006 over-the-road test.
  - Lower bound S-N curve for casting material with surface irregularities assumed a life of 2.0E6 cycles at a stress range of 14,000 psi. The curve is assumed straight past 2.0E6 cycles.
  - ***Result – With a .125 inch deep by .0625 inch radius notch the estimated life would be 2.83E6 miles. If a side frame traveled about 120,000 miles per year, estimated life would still be at least 23 years.***

- **Crack Initiation Life – M203 Load Environment**
  - M203 load environment used to establish stress environment
  - Maximum calculated principal stress at Location #1 -20.9 ksi
  - ***Result – Life to crack initiation is estimated to be 191,800 – 216,000 cycles (M203 requirement – 125,000) for about 97% of samples tested.***

Testing, Analysis and NDT (NCM Side Frames)

- **Crack Growth – Actual Service Environment**
  - Class C cast material with a yield of 60ksi and tensile of 90ksi. Paris equation coefficients were assumed. Presence of a weld repair increases the coefficient by a factor of 2.
  - Crack is of elliptical or semi elliptical shape on the surface of a .75 inch thick plate and the ratio of crack depth to ½ of crack length is fro m .5 to 1.0
  - Ratio of crack depth to length is relatively constant.
  - Plain strain conditions assumed
  - Stress conditions are assumed to be primarily tensile.
  - ***Result – The analysis produced significant crack growth when the initial crack was at the base of a .25 inch x .0625 radius "void" and the initial crack depth was at least .12 inches deep.***

SRI 14D: Improved Castings NDT

Objectives

- Reduce failure rates of car component castings through improved castings specifications, with focused NDT methods based on improved methods & in-service performance experience.
  - Lab Studies
    - Knuckle inspection using Magnetic Particle (MT)
    - Bolster inspection using MT, Alcohol Wipe (AW), and Liquid Penetrant (PT)
    - Side Frame inspection using MT, AW, and PT
  - Guidelines
    - Knuckle created for MT inspection
    - Bolsters in process
    - Side Frames in process
  - Field Evaluations to be performed
  - Implementation Support provided on as-and-when needed basis

Findings

Lab Studies

- Bolster inspection using MT, AW, and PT

Complete Zone 1 Inspection

AW – 49 Minutes

MT – 44* Minutes

PT – 62 Minutes

***MT was partial inspection**

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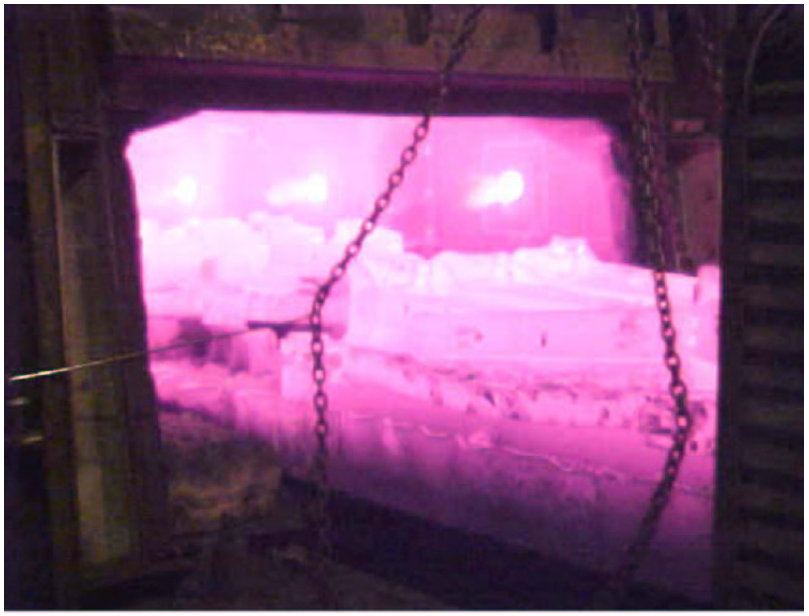


Specification Upgrades
M-201 Steel Castings -- Improvements

- **M-201 was strengthened, in many ways, including:**
  - Heat treatment records and traceability
  - Casting process traceability
  - Document qualifications and inspection procedures.
  - Monitor “tramp” elements which can effect impact properties and weldability. A carbon equivalency formula and acceptance criteria were added.
  - Results of mechanical tests must be found to be in compliance prior to shipment of finished castings.
  - A hardness test shall be completed for each heat either from a casting or a test coupon.
  - Specific procedures for weld repairs to castings are now required.

M-202 Truck Bolster and M-203 Side Frame Tests -- Improvements

- Added test loading scenarios for 286K bolsters and side frames.
- Updated design requirements.
- Increased the number of bolsters required to be tested dynamically.
- A detailed record of crack growth is to be maintained for all tests for later analysis, even when failure occurs and the component is not approved.
- Clarification of what constitutes a failure for a side frame in dynamic test.
- Test reports to include:
  - Metal thickness readings related to drawings.
  - Internal solidity assessment.
  - Chemistry, Mechanical properties including impact.
  - Radiographs of spring seat and bottom tension member.
- ***ADDING REPORTING OUTLINE REQUIREMENTS TO ENSURE TEST REPORTS ARE CONSISTENT***
- ***ADDING CHECK LISTS FOR TEST OBSERVERS***
- ***REVIEWING TEST LOADS FOR IMPROVING PERFORMANCE***

M-210 Truck Bolster and Side Frame Purchase and Acceptance -- Improvements

Implemented August 1, 2006, highlights include:

- Updated gage drawings
- Clarified AAR protocols for foundry audits, repeat audits and unannounced visits
- Improved weld repair procedures
- Auditable Written Requirements for Weld Repair Procedures
- Significantly strengthened finishing requirements including surface condition requirements
- Requirement for furnace tempering of the entire casting when weld repairs in critical (zone 1) areas are performed
- Requirement for manufacturers to supply the AAR with distribution records for traceability of product
- Requirement for process control plans for all critical foundry processes, including critical process definitions
- ***CSTCC is studying several comments for future long-term improvements to M-210.***

CSTCC SPECIFICATION DEVELOPMENT – Sections S1, S2, S3)

- In June, 2007, the Association of American Railroads released the newly created editions of AAR Manual of Standards and Recommended Practices Sections:
  - S: Casting Details
  - SII: Truck Details and Casting Codes
  - SIII: Coupler and Yoke Details

Work is continuing on Castings Specifications (by CSTCC and Industry Partners)

CSTCC SPECIFICATION DEVELOPMENT – M-205

- A Task Force has been formed with CSTCC and suppliers to update and strengthen M-205.

- Objective: Improve yoke casting quality and reliability. Review and updating of current specification as needed (admin, static test procedures and loads, etc.), and add a fatigue test requirement using the draft M-216 load spectra and basic layout.

CSTCC SPECIFICATION DEVELOPMENT – M-211

- A draft for this specification was done in May, 2007. M-211 will be significantly strengthened in a manner similar to M-210.

- One remaining item is that MCSCM has incorporated a gage to accommodate the knuckle tail pad, and have incorporated a gage for the machined lock reduced slack feature. MCSCM will provide for M-211 the new gage numbers for reduced slack. M-211 should be released by November 2007 for comment.

CSTCC SPECIFICATION DEVELOPMENT – M-212

- A Task Force has been formed with CSTCC and the Coupler Reconditioner Association suppliers to update and strengthen M-212.
- Objective: Improve coupler reconditioning quality and reliability. Focus will be on areas with known failures and other problems.
- Work is just beginning.

CSTCC SPECIFICATION DEVELOPMENT – M-214

- A Task Force has been formed with CSTCC and the Truck Component Reconditioner Association to update and strengthen M-214.
- An updated M-214 will go out for Comment in November, 2007.

M-216 Draft Specification

- The AAR Coupling System & Truck Castings Committee (CS&TCC) is currently revising Specification M-211, Freight Car Couplers and Yokes, AAR Approved - Purchase and Acceptance. This work has been ongoing with the Mechanical Committee of the Standard Coupler Manufacturers (MCSCM).

- As part of this effort, the AAR Coupling System & Truck Castings Committee has developed a related draft Specification M-216: FATIGUE TEST for TYPE E & TYPE F KNUCKLES. The specification utilizes known test load data which has been utilized for the past 10 years.

M-216 Draft Specification

- Draft Specification M-216 covers knuckles for freight equipment, and includes test requirements and procedures for evaluating the serviceability and comparative life of knuckles. Test machine requirements, standard test environment definitions, and reporting requirements are defined. This Specification requires fatigue testing of four samples in addition to the static testing defined in AAR Specification M-211.

- The new coupler/knuckle fatigue test specification, M-216, was put out for industry comment via Circular Letter on 12/19/06.

M-216 Proposed Draft Specification

Knuckle Fatigue Test Load Cycles Proposed

Segment	Number of Cycles (Sinusoidal form)	Total Elapsed Cycles	Cycle Load Range
1	4	4	10 – 300 kips
2	2	6	10 – 280 kips
3	7	13	10 – 260 kips
4	10	23	10 – 240 kips
5	31	54	10 – 220 kips
6	77	131	10 – 200 kips
7	65	196	10 – 180 kips
8	73	269	10 – 160 kips
9	89	358	10 – 140 kips
10	105	463	10 – 120 kips
11	129	592	10 – 100 kips
12	187	779	10 – 80 kips
13	279	1058	10 – 60 kips

Proposed out for comment: To be approved, the average life of the four knuckles tested must exceed 700,000 cycles with no individual knuckle exhibiting a life below 600,000 cycles.

CSTCC SPECIFICATION DEVELOPMENT – M-217/218/219 (Articulated Connectors)

- A Task Force has been formed with CSTCC and suppliers to create M-217, M-218, M-219. Objective: Improve articulated connector casting quality and reliability.

- M-217 will be the manufacturing and acceptance specification, M-218 will be the test specification using the draft M-216 basic layout, and M-219 will be for reconditioning. Target date for issuing Circular Letters for Industry Comment: June 15, 2008.

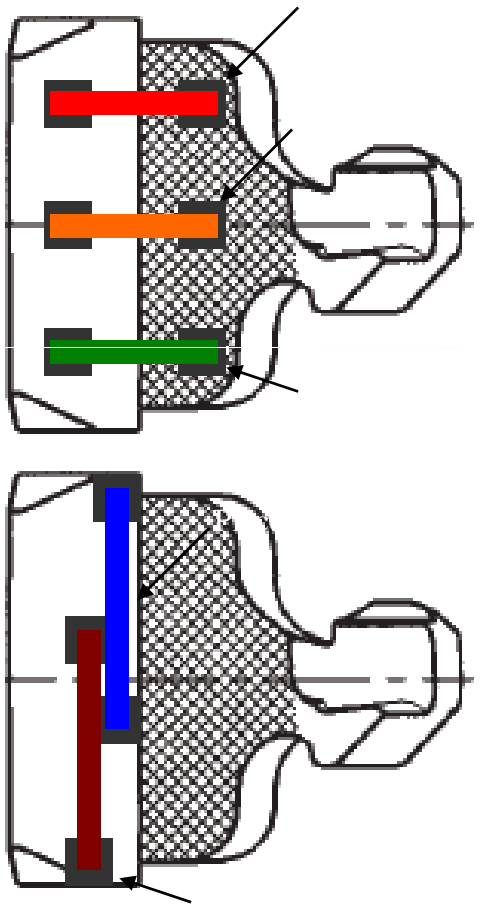
- Work is just beginning.

CSTCC SPECIFICATION DEVELOPMENT – M-220 (NDT)

- CSTCC is developing an NDT spec to address all NDT needs for castings. The specification will include a main body describing the AAR administrative requirements and an Appendix with specific applications.
- The first procedure to be implemented late in 2007 will be for knuckle NDT inspections in field operations. The FM will be revised to allow cause for removal using this method.
- The AAR Strategic Research Program has a supporting program for casting NDT.

CSTCC SPECIFICATION DEVELOPMENT – M-220 (NDT)

1. Purpose
2. Scope
3. Methodology
4. Personnel
5. Definitions
6. References
7. Equipment and Accessories
8. Railroad Knuckle Inspection Procedure
9. Acceptance Criteria
10. Reporting



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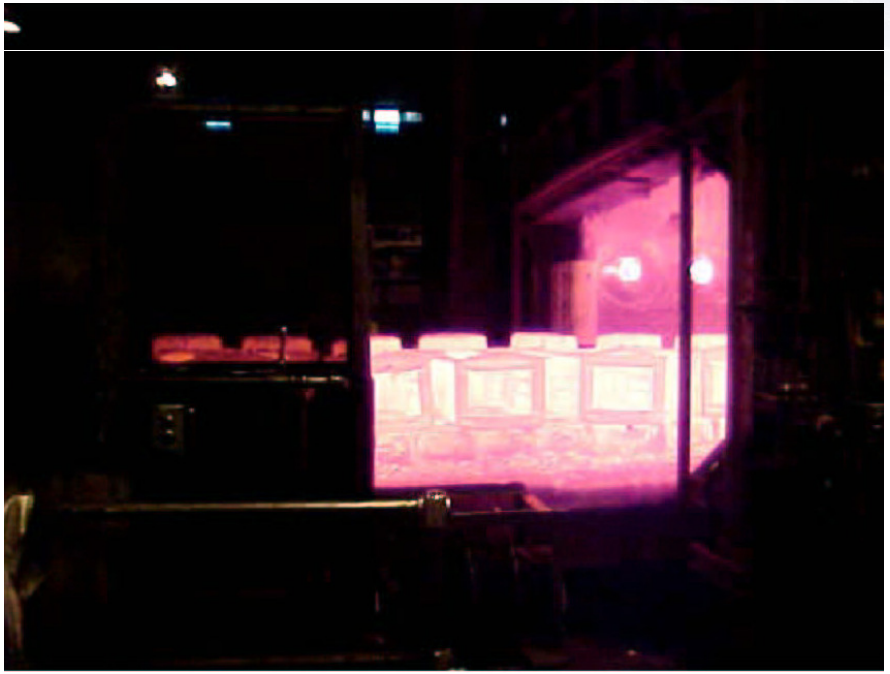
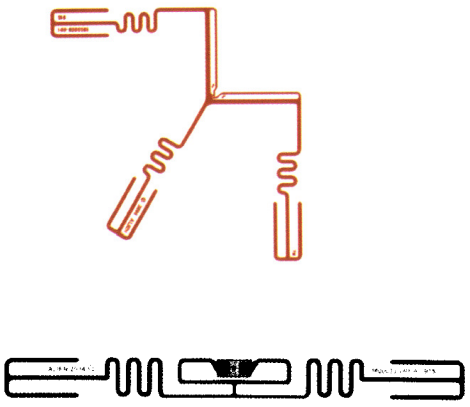


RFID tags for castings.

- In 2007 the AAR Castings Committee asked the question: Can RFID tags be used to track truck castings?
- Purpose: To have the ability of identifying castings that have defects that need to be removed from service.



RFID Demonstration Project

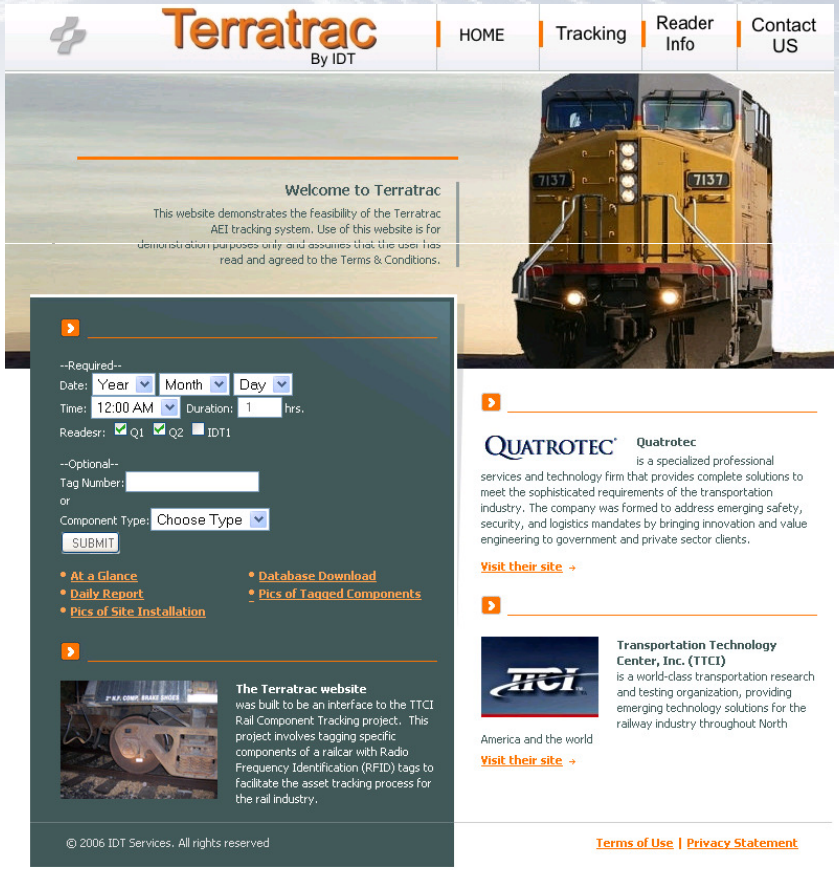
- In March 2007 TTCI in cooperation with a name brand RFID company installed a RFID Test Zone at FAST. The RFID Test Zone consists of 8-RFID Scanner Antennas and 2-AEI Antennas

RFID Demonstration Project

- 156 RFID tags were installed on the bolsters, axles, wheels, and couplers.
- RFID tags were installed using a silicone adhesive.
- RFID tags were installed in multiple locations both inboard and outboard of the components.
- The tests showed that RFID tags could be applied and read on railroad freight car components.

RFID Demonstration Project

- Data from each test day was hosted on an internet web site.



Today's Discussion

- CSTCC
- Tools and methods for addressing failures of industry castings
  - NCM bolsters and side frames -- examples
- Specification upgrades and updates, and new specification development
- RFID
- ***Questions and answers***