William W. Hay Railroad Engineering Seminar

Union Pacific's Next Generation Track Technologies
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Union Pacific Railroad
University of Illinois at Urbana-Champaign
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Talking Points

• Rail industry health
• U. P. profile & infrastructure
• Remote track assessment systems
• Vision-based evaluation systems
• Next generation rail steels
• High speed passenger turnouts
• Concrete & advanced fastening systems
Freight Rail Industry Vibrant and Growing

- 1916 – 254,521 route miles
- 1940 vs. 2011 - 93% < miles
- 1940 vs. 2011 - 460% > ton miles
- 1944 vs. 2011 – 230% > aver. tons/car
- 2011 – 138,623 route miles
Background on Union Pacific Railroad

- Largest railroad in North America.
- Operates western 2/3rd of U. S.
- 150 year old company.
  - Founded in 1862.
- Fortune 143 company with revenues of $19.5 billion.
- Primary role is freight with increasing passenger participation
- 45,000 Employees
Operating Infrastructure

- 32,006 mi route
- 112 Million ties
- 12,245 mi of yards, sidings, & industry leads
- 31,434 Turnouts
- 18,031 Bridges (417 mi)
- 296 Tunnels (62.2 mi)
- 26,441 Active public crossings
- 6,793 Buildings
- 62 Auto or intermodal ramps
- 62 Car and loco shops
- 45 Major switching yards
- 12,500 Signal facilities
U. P. Commodities Carloads

- Energy: 2.0 million
- Industrial: 0.9 million
- Agricultural: 0.8 million
- Chemicals: 0.9 million
- Intermodal: 3.6 million
- Automotive: 0.4 million
U. P. Engineering Department

- Designing, constructing and maintaining track, bridges, structures and signals
- Engineering Sub-departments
  - Design
  - Track Renewal
  - Construction
  - Track Maintenance
  - Bridges
  - Signal
- Resources
  - 12,500 employees
  - 5,719 Vehicles
  - 4,463 Pieces of Equipment
Remote Track Assessment (VTI)

- Vehicle Track Interaction (VTI)
  - System measure wheel/axle impacts (force) and car body acceleration (G’s) to identify possible track defects from the rail car’s perspective.
  - Installed on 52 locomotives & 2 cars
- Provide notification of critical locations.
  - High Priority exceptions inspected within 24 hours.
  - Mediums inspected within 7 days.
- Measures: CB Vertical & Lateral, Truck Lateral, Axle Vertical, CBR.
- Newest measurements: Mid Chord Offset & Combo Cluster

<table>
<thead>
<tr>
<th>Exception</th>
<th>High Priority</th>
<th>Medium Priority</th>
<th>Low Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>CB Vertical</td>
<td>&gt; 1.25 G</td>
<td>&gt; 1.1 G &lt; 1.25 G</td>
<td>&gt; 1.0 G &lt; 1.1 G</td>
</tr>
<tr>
<td>CB Lateral</td>
<td>&gt; .8 G</td>
<td>&gt; .71 G &lt; .8 G</td>
<td>&gt; .48 G &lt; .71 G</td>
</tr>
<tr>
<td>Truck Lateral</td>
<td>&gt; .45 G</td>
<td>&gt; .41 G &lt; .45 G</td>
<td>&gt; .38 G &lt; .41 G</td>
</tr>
<tr>
<td>Axle Vertical</td>
<td>&gt; 140 kips</td>
<td>&gt; 120 kips &lt; 140 kips</td>
<td>&gt; 100 kips &lt; 120 kips</td>
</tr>
<tr>
<td>CBR</td>
<td>&gt; 3. Deg</td>
<td>&gt; 2.5 Deg &lt; 3. Deg</td>
<td>&gt; 1.5 Deg &lt; 2.5 Deg</td>
</tr>
</tbody>
</table>
Mid Chord Offset (10’) Exception

- 10’ Mid Chord Offset (MCO)
  - Axle accelerations are effective for detecting wheel impacts.
  - Axle Accelerations can be used to derive space curves and calculate MCO.
  - 10’ chord recommended and detection added to VTI’s.
  - MCO initially developed to find the short profile exceptions in concrete tie track.
Mid Chord Offset (10’) Exception

<table>
<thead>
<tr>
<th>Rank</th>
<th>Subdivision</th>
<th>MP</th>
<th>MCO Value</th>
<th>Date/Time</th>
<th>LATITUDE</th>
<th>LONGITUDE</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>BOONE SUB</td>
<td>256.4</td>
<td>-3.45</td>
<td>2/26/2010 2:17</td>
<td>42.054967</td>
<td>-94.820717</td>
</tr>
</tbody>
</table>

Graph showing Mid Chord Offset (MCO) values over a distance range.
Combo Cluster Exception

Example “Combo Cluster”

- Combines urgent, near urgent and priority MCO’s, CBV’s, CBL’s, CBR’s and Axle VTI exceptions.
- Provide the ability to determine and manage potential high risk derailments locations.
- Cluster exceptions are identified as repeat VTI exceptions occurring at the same location, typically containing two or more different types of VTI exceptions.
- Ranks based on average track speed, type of exception, quantity of exceptions and relative age.
- Types of exceptions found from inspection: non-supported joints, striped insulated joints, broken concrete ties, transitions from wood to concrete (turnouts, bridges, crossings etc.), crushed heads and rail conditions with signs of pumping.
Remote Track Assessment (ATGMS)

- Autonomous Track Geometry Measuring Systems (ATGMS)
- ATGMS systems can be mounted on locomotives or rail cars and operated without an operator.
- FRA is operating an ATGM system and technology is still be tested.
- U. P. does not have a system mounted on a locomotive or car.
  - Have similar system mounted on truck.
- Provides a tool for monitoring the health of the railroad.
Remote Track Assessment (MRail)

- **MRail Track Deflection Msmt. System**
  - Sensor system consists of a digital vision system and two line lasers.
  - Lasers projected onto the rail surface four feet in front of a loaded wheel.
  - Changing vertical support generate a variation in track deflection.
  - Large deflection have found bad welds, joint conditions, broken or missing ties.
  - Produces exceptions that correlate with 10-ft MCO and 10-ft ECO values generated from space curve data collected with the EC-5 vehicle.
  - Currently running a monthly test on South Morrill Subdivision to study degradation.
Machine Vision Technology

- **Purpose:**
  - Develop and implement “vision” based systems for conducting asset inspections, inventory verifications and overall condition assessments.

- **Potential Opportunities:**
  - Concrete tie evaluation
  - Wood tie evaluation
  - Rail surface conditions
  - Joint bar Inspections
  - Rail brand recognition
  - Fastening recognition and evaluation
  - Rail seat abrasion on concrete ties

- **Benefits**
  - Reduce demand for visual inspections
  - Improve track availability and reliability
  - Asset inventory
Improvements in Rail

- U. P. is installing rail that is 100% head hardened.
  - 72% premium head hardened (400+ brinell) rail
  - 28% intermediate head hardened (360 – 370 brinell)
- 480’ Long rail
- 2 welds per 1440 ft string vs 17.
- Future rail will increased hardness at ¾” depth.
- Improved plant welds
Plant Weld Improvement

- Some plant welds fatiguing on heavy tonnage rail
- Induction coils will be used to perform post weld heat treating of plant welds.
- Objective is to reduce residual stress and the width of the heat affected zone,
Results Western Mega Sites Premium Rails

• Rolling contact fatigue (RCF) occurrence can be significant, if not controlled.

• Significant benefits from preventive grinding or top of rail friction control to control RCF and reduce wear.

• Premium rails continue to show excellent wear performance, without internal defects identified.
Results Western Mega Sites Premium Rails

- Friction control is effective in controlling RCF and reducing natural wear
  - 960 MGT without recurring RCF
- Preventive grinding is effective, but leads to more rail section area loss
- Rail wear on 2-degree test curve at 1,660 MGT tonnage
  - 17% of railhead cross section on the curve with grinding
  - 12% of railhead on the test curve with friction control
Premium Rail in Revenue Service

- Premium test rails in the 1-degree curve were replaced in Feb. 2013 for sporadic severe RCF spots.
  - No RCF maintenance strategies implemented for the 1-degree test curve, similar to those implemented for the two 2-degree curves

  - Summary of past test results:
    - For the 1-degree test curve, moderate but isolated RCF spots were observed only after 960 MGT since the rail installation
    - For the 2-degree test curves, however, severe RCF occurred at 300-350 MGT after the rail installation

- Future testing at the mega-site will:
  - Monitor performance of next generation premium rails compared to previous generation premium rails
    - RCF, wear, internal flaws
  - Develop and demonstrate “optimized” strategies to prevent RCF and reduce rail wear
Organize around specific asset classes to build expertise, improve product development/R&D, improve field assessment/support, improve product quality and decrease product development/implementation cycles.
Union Pacific Turnout Facts

- The UPRR system has over 13,000 mainline turnouts.
  - In addition to this there are thousands of yard and industry turnouts.
- Turnouts are a hodge-podge of different sizes, layouts and configurations.
- UPRR utilizes concrete turnout primarily where concrete tie mainline track is located.

<table>
<thead>
<tr>
<th>Turnout Size</th>
<th>Switch Point Length</th>
<th>Point Type</th>
<th>Recommended Speed (MPH)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 7</td>
<td>11'</td>
<td>Straight</td>
<td>5</td>
</tr>
<tr>
<td>7 to 8-1/2</td>
<td>15' or 16' 6''</td>
<td>Straight</td>
<td>10</td>
</tr>
<tr>
<td>9 to 10</td>
<td>16' 6''</td>
<td>Straight</td>
<td>15</td>
</tr>
<tr>
<td>10</td>
<td>19' 6''</td>
<td>Curved</td>
<td>15</td>
</tr>
<tr>
<td>11 to 12</td>
<td>22'</td>
<td>Straight</td>
<td>15</td>
</tr>
<tr>
<td>11 to 12</td>
<td>19' 6''</td>
<td>Curved</td>
<td>20</td>
</tr>
<tr>
<td>14</td>
<td>24'</td>
<td>Straight</td>
<td>30</td>
</tr>
<tr>
<td>15</td>
<td>26'</td>
<td>Curved</td>
<td>30</td>
</tr>
<tr>
<td>16</td>
<td>30'</td>
<td>Straight</td>
<td>35</td>
</tr>
<tr>
<td>20</td>
<td>30'</td>
<td>Straight</td>
<td>35</td>
</tr>
<tr>
<td>20</td>
<td>39'</td>
<td>Curved</td>
<td>40</td>
</tr>
<tr>
<td>24</td>
<td>39'</td>
<td>Curved</td>
<td>50</td>
</tr>
<tr>
<td>30</td>
<td>115' 6''</td>
<td>Curved</td>
<td>60</td>
</tr>
</tbody>
</table>
Passenger Service on Union Pacific

<table>
<thead>
<tr>
<th>Route</th>
<th>Weekly Riders</th>
<th>Weekly Trains</th>
<th>On-Time %</th>
</tr>
</thead>
<tbody>
<tr>
<td>UP Commuter (incl Capitol Corridor)</td>
<td>647,000</td>
<td>1,450</td>
<td>94%</td>
</tr>
<tr>
<td>Amtrak on UP</td>
<td>89,000</td>
<td>328</td>
<td>85%</td>
</tr>
<tr>
<td>Total UP</td>
<td>736,000</td>
<td>1,778</td>
<td>92%</td>
</tr>
</tbody>
</table>
SPCSL Line – St. Louis to Chicago

- Route is a critical freight corridor for UPRR.
- Route will provide a major AMTRAK connection between St. Louis and Chicago.
- Trains will be able to operate at 110 MPH (Class 6) over major sections of the route.
- Major sections of the track will be upgraded to concrete ties and 141 lb. rail.
- Currently single mainline that will be gradually upgraded to double mainline.
Illinois HSR – Chicago to St. Louis
Before & After TRT – Tangent Track MP 194.00
SPCSL Route Challenges - Turnouts

• Class 6 (110 MPH) is a different operating environment for UPRR, who traditionally operates in Classes 1 through 5.

• The 110 MPH speeds require efficient interchange points (or crossovers) that allow trains to move seamlessly between the two mainlines. This will help the network remain fluid and minimize impacts of maintenance interventions, weather etc.

• With the 110 MPH speed a high speed turnout move helps keep traffic moving, a speed of greater than 50 MPH is desired.

• Time reduction is the key.......must be competitive with alternatives.

• Traditional AREA turnouts are designed to maximize space, longer turnouts increase cost and maintenance.
Lateral Forces in Turnouts

- UPRR has done a tremendous amount of strain gauging to understand turnout loading conditions.
- Reduced lateral forces provide higher passenger comfort when transitioning from one track to the other. Reduced forces also allow for faster speeds.
- Reduced lateral forces decrease wear on components.
Lateral Forces in #20 Turnouts

- There is a high peak load about 6 ft. behind the point of switch.
- Figure below provides the average (for five trains) maximum lateral force exerted on the track structure. Highest lateral forces recorded ahead of and behind switch points with a gradual reduction thereafter until a slight peak at the frog (MPF).

<table>
<thead>
<tr>
<th>Ft. Back From Point of Switch</th>
<th>Lateral Force</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 ft. (ahead of points)</td>
<td>9283</td>
</tr>
<tr>
<td>6 ft. (behind points)</td>
<td>17475</td>
</tr>
<tr>
<td>34 ft.</td>
<td>13471</td>
</tr>
<tr>
<td>54 ft.</td>
<td>9767</td>
</tr>
<tr>
<td>94 ft.</td>
<td>6203</td>
</tr>
<tr>
<td>134 ft. (toe of frog)</td>
<td>8735</td>
</tr>
<tr>
<td>176 ft. (heel of frog)</td>
<td>4596</td>
</tr>
<tr>
<td>194 ft.</td>
<td>4933</td>
</tr>
</tbody>
</table>

Max Lateral Force:
- 9283 (0 ft. ahead of point)
- 17475 (6 ft. behind point)
- 13471 (34 ft.)
- 9767 (54 ft.)
- 6203 (94 ft.)
- 8735 (134 ft. toe of frog)
- 4596 (176 ft. heel of frog)
- 4933 (194 ft.)
Desired Load Profile

- Goal is a much more consistent and spread out loading throughout the entire turnout.
- Elimination of high peaks reduces wear on turnout structure.
• UPRR approached voestalpine Nortrak Inc. to determine current switch designs that could reduce lateral loading.

• “Semi” tangential switches, currently installed on MetroLink in CA were identified as targets.

• Tangential means the entry angle is as close to zero as possible.

• Goal is to very slowly move loading on to the point.
### Comparison Standard #24 vs. Semi Tan #24

#### 3” UNBALANCED SUPERELEVATION

<table>
<thead>
<tr>
<th></th>
<th>UP EXISTING #24</th>
<th>SEMI-TANGENTIAL #24</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vmax</td>
<td>61mph</td>
<td>60mph</td>
</tr>
<tr>
<td>Entry jerk : based on Wheel base (the distance between the center of the two wheel sets) L=20m</td>
<td>0.1g/s</td>
<td>0.07g/s</td>
</tr>
<tr>
<td>If we use ACELA coach car L =13.589m, keeping entry jerk =0.1g/s</td>
<td>Vmax=50mph</td>
<td>Vmax=60mph</td>
</tr>
</tbody>
</table>
Comparison #24 Semi-Tan vs. Standard #24

- Total Turnout Length:
  - Standard: 267’
  - Semi-Tan: 296’

- Total Switch Point Length:
  - Standard: 39’ 0”
  - Semi-Tan: 61’ 6”
Standard #24 AREA

#24 Semi-Tangential
#24 Semi – Tangential: Athol, IL
Moving Forward

• Union Pacific has had a tremendous amount of success with the semi-tangential turnouts.
• We are currently working to implement revised geometry turnouts in other applications.
• Currently testing similar turnouts on our heavy coal routes.
  – Using revised geometry in addition to other key features to strengthen the turnout.
  – Goal is to reduce peak loads and reduce number of maintenance interventions.
• We will continue to monitor the performance of these turnouts and do additional strain gauge work to monitor loading.
• Of course we will also be actively engaging in the “spilled coffee test” going forward…..
Union Pacific Concrete Tie Facts

- Union Pacific began utilizing concrete ties in spot applications in the 1980’s
- Today over 3,000 route miles are concrete, utilized in three primary applications:
  - High degree of curvature territories such as mountain ranges
  - High tonnage areas such as the Nebraska/Kansas coal routes
  - Locations where operating conditions dictate higher track strength
- UPRR has utilized 9 different fastening systems in various quantities.
Economic Competitors to Concrete Ties

Wood

Steel

Composite
What Drives UPRR Concrete Tie Research?

1. Highest maintenance intervention areas
   1. Curves
   2. Turnouts – Tremendous amount of work done last 3 years

2. Increased fastening system component life cycles
   1. Fastening system degradation, particularly in curves drives cost

3. Increased long term durability

4. Ability to handle long term increased axle loadings
   1. Long term desire to increase from 286K
   2. Better ability to handle high wheel impact loads

5. Decreased surfacing interventions and failure replacements
Advantages of Concrete Ties in Curves

- Increased lateral stability. Concrete ties can have much higher lateral restraint than alternatives.
- Increased gage restraint. Concrete is a much more solid system than alternatives for maintaining tie dimensions and eliminating degradation.
Impact of Forces on Fastening System

• Currently UPRR finds the biggest issues with concrete ties in curvature 3 degrees and greater. Curvature changes the loading conditions heavily and results in excess:
  – Insulator wear
  – Pad wear
• Insulator and pad wear drives the other critical issues in curvature.
  – Rail seat deterioration
  – Shoulder wear or lag screw wear
  – Wide gage
  – Excess cant
How Does UPRR Look for these Conditions?

• UPRR inspects and maintains **aggressively** to the UPRR and FRA requirements.
• Boots on the ground human inspections.
• Measurements are taken in multiple ways to determine performance.
  – By hand by M&R Staff.
  – By Geometry measurement tools such as EC-5.
• Gage restraint measurement systems.
• Physical tie rating teams.
Sample EC Car Strip Chart
Concrete Tie Research

- Curve failures are really driving our research…..we are focusing on the highest most costly failure area.
- Looking for ways to reduce fastening system failures and extend the life to match the life of the rail or the life of the surrounding tangents.
- Developing systems that work with production equipment and are easily maintainable.
- Developing systems that can be produced on large scale.
- Developing systems that can be inspected visually.
2013 Tie and Fastening System Research

• In 2013 UPRR is going to begin a massive test of different types of tie systems in high curvature.

• Over 6,000 Ties of 8 different designs will be produced by multiple U.S. vendors.

• Goal will be to determine which fastening system and tie type performs the best in curvature. Curves will be 3 to 12 degrees.

• Ties will be evaluated in every aspect from fastening system degradation to rail seat abrasion and center binding condition.

• Ties will also be cycle tested using the MTS.
Key Concepts Being Tested – Combating Issues

• Use of stirrups to provide internal end containment.
  – Testing multiple different designs to try and increase tie strength and reduce crack propagation.

• Full face insulators and wear surfaces.
  – Goal is to use the entire width of the tie for bearing instead of just a small shoulder area.

• Larger tie sections and different reinforcing patterns to increase center negative strength.

• Different pad and rail seat epoxy types that prevent rail seat abrasion.
MTS Testing Machine

- UPRR recently began utilizing an MTS hydraulic cycle testing apparatus capable of mimicking track loading conditions in a lab environment.
- The machine is capable of performing multiple different tests at loads up to 50,000 lbs. at a rate of up to 5 Hz.
- For example, 3 million cycles (roughly a year in high usage track) can be completed in about 2 weeks.
Epoxy Coating

- All new ties have rail seats that are epoxy coated prior to installation.
- Epoxy is either a two part air activated or a single part UV activated.
- Epoxy is meant to displace water and provide a better seal against sand and dust.
- Research has shown that epoxy can cut RSA by as much as 200%.
- Epoxy coating is used during field replacement operations during mid-life cycle events.
- Hardness is between 80 – 95 Durometer Shore D.
SSL – Half Frame “Sleepers”

- Currently in test on the UPRR and at TTCI
- South Morrill Subdivision (UPRR/TTCI Mega-Site)
  - Three test Locations
    - Bridge Approaches
      » Installed 15 SSL ties on east and west approach
      » Installed April 2011
    - Bridge Approach
      » Installed 15 SSL ties on west approach
      » Standard ties on east approach
      » Installed April 2011
    - Insulated Joint Location
      » Installed 30 SSL ties underneath insulated joints
      » Installed August 2011
- La Grande Subdivision (Curve Test)
  - 7 Degree 14 Minute 37 Second RH Curve
    - Installed June 2012
    - 253 SSL ties installed out of face
Key Features of the Half Frame Tie

- Larger bearing area, results in reduced ballast pressures
- Larger friction surface against horizontal movement. Prevents curves from moving in and out during temperature swings.
- Utilizes the Vossloh fastening system that provides over 7 ½” of wear surface per tie.
- Produced using a single tie carousel system, very tight Quality Assurance and Control checks.
- Utilizes an under tie pad produced by Getzner. Tie pad helps to provide a more consistent ballast loading condition.
Half Frame Ties – Going Forward

• UPRR continues to monitor the test locations.
  – Surface condition
  – Rail condition
  – Ballast condition
  – Top of rail elevations
  – Curve movement

• Going forward the Half Frame ties potential lies in its ability to provide relief in high maintenance areas.
Special Thanks

- Chris Rewczuk, UPRR
- John Jerome, UPRR
- Eric Gehringer, UPRR
- Antonio Buelna, UPRR
- Gary Click, voestalpine Nortrak Inc.
- Gord Weatherly, voestalpine Nortrak Inc.
Take A Ways

- Rail industry is healthy and growing.
- Increased understanding of U. P. and its infrastructure.
- Excellent advances in the industry with new technology.
- U. P. is trying to capitalize on latest technology.
- Still opportunity to find solutions to the challenges that face railroads.
- Looking for practical cost effective solutions.
- Research is driven by demand.
Rail Related Engineering Degrees

• The railroad industry offers graduate engineers a very rewarding environment to work.

• Excellent opportunities for new graduate engineers in the present and coming years.

• Engineering degrees favored for the U. P. Engineering Associates in the Operating Management Training program:
  – Civil
  – Construction Management
  – Electrical
  – Electronic
  – Industrial
  – Structural
  – Mechanical
To Apply and Find Additional Information

- Visit www.up.jobs
Union Pacific would like to thank the University of Illinois Urbana-Champaign for their hospitality.
Wherever you find business, you’ll find us.

For generations, Union Pacific’s dedicated employees have supported American businesses and the nation. Today, we are enhancing UP’s value, achieving ever-higher standards for safe, reliable, economical service our customers can count on.