Reliability-Centered Maintenance Program on the ACELA Express Train sets
Amtrak ACELA Express

- Amtrak currently runs ACELA Express Service from Washington, DC to New York City and Boston.
- There are currently 34 train assignments in this current time table representing the Northeast Corridor covering every hour from 5 am to 7 pm.
- The ACELA Fleet has 20 Train sets configured with two Power Cars and six Coach Cars each.
Acela Power Cars

- Continuous 4,600 kW/ 6,000 HP
- 4 asynchronous AC traction motors
- 3 GTO-Type inverters, 2 for propulsion and 1 for auxiliary power required by the power car and passenger cars.
- Top operating speed of 150mph (165mph designed)
- The Main Transformer has two primary windings connected in parallel for operating overhead AC supply of 12kV at 25Hz or 12.5kV at 60Hz and series connection when the overhead input is 25kV at 60 Hz.
- Braking system incorporates blended regenerative/rheostatic dynamic Braking
High Speed Trainset Tilting System

- Each Passenger Car is equipped with an active computer controlled and electro hydraulically activated tilting system.
- Maintains low lateral acceleration through curves at high speed.
- The curve detection is sensed by the lead power car triggering the tilt function.
- Amtrak currently operates at 7 inch cant deficiency (it is designed and tested at 9 inch cant deficiency).
ACELA Passenger Demand for Service

Required Fleet

2005 2006 2007 2008 Future?
Amtrak developed Continuous Maintenance program (CM) for Planned Maintenance (PM) to increase availability of equipment.

- PM requirements divided into manageable segments performed during Service and Inspection dwell time.
- Previous to CM two Trainsets were shopped for PM
Amtrak and RCM: Background

- Amtrak established Condition-Based Maintenance (CBM) as corporate policy in July 2006
- Amtrak reviewed and validated all Acela Train set maintenance requirements using Reliability-Centered Maintenance (RCM), per 49 CFR Part 238 Appendix E.
- Acela Level I (Daily), Level II (92Day) and Level III (Long Term) requirements were reviewed and completed in 2006.
Reliability-Centered Maintenance

Reliability-Centered Maintenance (RCM) as used by Amtrak incorporates several techniques and tasks:

- Maintenance Effectiveness Review
- Root Cause Analysis
- Condition Based Monitoring
Maintenance Effectiveness Review (MER)
Maintenance Effectiveness Review

MER analysis identify the applicability and effectiveness of maintenance tasks.

• Applicability criteria is the specific set of conditions for a given task type that must be met to improve or maintain system or equipment inherent reliability.

• Effectiveness criterion judges whether a specific task would be capable of reducing the failure for its failure consequence.

✓ Task periodicities are based on evidence of need and assessment of risks.
Maintenance Effectiveness Review

Cross Functional Stakeholders

- Mechanics who perform the tasks
- Operational Management Representative
- Equipment Engineering Representative
- Operator or End User
- OEM Representative
- Facilitator
Maintenance Effectiveness
Review

Task Type

- **On Condition**, renew life based on comparison with standard, initiating action upon reaching potential failure point.

- **Age Limit**, renew life regardless of condition, taking action prior to “anticipated” failure point.

- **Failure Finding**, determine whether a hidden failure has occurred, initiating corrective action when initial failure occurs.
Failure Consequences

- **Safety**, functional failure results in possible loss of occupants or equipment
- **Operational**, functional failure results in indirect economic loss plus direct cost of repair
- **Non-operational**, functional failure results in direct cost of repair
MER Component Analysis Spreadsheet

1. Component Information
   - Part Number
   - Description
   - Car (PC/TC)
   - Quantity

2. Functional Description

3. Risk Assessment
   - Probability of Failure (failure history: OEM and Rev. Service)
   - Severity of Failure (FMECA failure effects)

4. Condition Baseline
   - OEM Recommended Life Cycle
   - Bench Test Results
   - Teardown Inspection Results

5. In-Service Monitoring Plan
   - Current ITM and Monitoring
   - Additional Diagnostic Capabilities
   - Additional Test Procedures
Root Cause Analysis
Root Cause Analysis

Amtrak has incorporated a standard maintenance practice on how a Root Cause Analysis session is performed. The method used is based on Reliability Center Incorporated’s PROACT system.

- Preserving Event Data
- Ordering the Analysis Team
- Analyzing the Data
- Establishing Root Causes
- Communicating the Findings
- Tracking for Results
TILT SYSTEM RCA RESULTS

• Constant displacement pump and unloading circuit installation
  – Increased pump reliability and reduction in service delays
  – Improved onboard oil filtration, decreasing hydraulic oil contamination and reduction in component wear
  – Reduction in necessary periodic external filtration to maintain standard ISO level
• Minimum and centering pressure switch upgrade
  – Reduction of in service failures
• Tilting load locking valve replacement with dual pressure transducer
  – Allows for condition based monitoring and implementation of continuous maintenance tasks
  – Reduction of in service failures
• Quick connect fitting upgrade
  – Reduced external hydraulic leakage
  – Reduction of in service failures
Acela Tilting Delay Minutes

ACELA Tilting Delay Minutes By Month
Based on Amtrak’s ARROW Reports
Condition Based Monitoring
Condition-Based Monitoring

- Dynamic Monitoring detects potential failures that emit abnormal energy such as vibration or acoustical waves.
- Particle and Chemical Monitoring detects potential failures by analyzing discrete particles or traceable quantities of chemicals released in the component’s operational environment.
- Physical Monitoring detects potential failures by analyzing changes in the physical structure such as cracks, wear or dimension.
- Temperature Monitoring detects potential failures by sensing temperature differentials in the component’s operational environment.
- Electrical Monitoring detects potential failures that produce changes in resistance, conductivity, dielectric strength and potential.
Remote Condition Monitoring

- Scheduled download of condition monitoring data
- Critical event notification in route

Email Server receives condition data & critical event info

Server receives data

Database storage

Data analysis, Reporting

Web reports of detailed Maintenance Events Analysis for the Trainset

Director Reviews Fleet Status

Maintenance Engineer comments

Work Order created / updated

TMM plans repairs

Act. Sup. reads Critical event info while train is enroute
Actual, En-route Notification of Reportable DC Ground Fault

---

Warning, 2 Faults detected remotely by ME-1000!

This is an automated message from Trainset [TS7].

<table>
<thead>
<tr>
<th>CAR NUMBER</th>
<th>SET TIMESTAMP</th>
<th>RST DATE</th>
<th>RST TIME</th>
<th>MILE</th>
<th>SYSTEM</th>
<th>CODE</th>
<th>EDR</th>
<th>CAT</th>
<th>DESCRIPTION</th>
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<tbody>
<tr>
<td>2032</td>
<td>8/16/2007 2:25:19 AM</td>
<td>08-16-07</td>
<td>02:25:20</td>
<td>0073.2</td>
<td>MPU1</td>
<td>3201</td>
<td>Flt</td>
<td>DC Gnd flt AC2</td>
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</tr>
<tr>
<td>2032</td>
<td>8/16/2007 2:25:19 AM</td>
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<td>02:25:20</td>
<td>0073.2</td>
<td>MPU1</td>
<td>3401</td>
<td>Flt</td>
<td>DC Gnd flt AC4</td>
<td></td>
</tr>
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</table>

This email alerts you to an in-service locomotive fault. Please be aware that fault codes can be generated during routine Service & Inspections. Please notify appropriate maintenance personnel to determine severity of fault so appropriate action can be taken.
Element of June 2007 Acela Fleet Health Analysis

HVAC Monthly Performance Evaluation
June 2007

 tcu-x histogram
 June 07

TCU-X Code Analysis for June 07

<table>
<thead>
<tr>
<th>TCU-X Code</th>
<th>EVENT DESCRIPTION</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>125</td>
<td>Circuit Breaker Loop Open</td>
<td>48</td>
</tr>
<tr>
<td>130</td>
<td>Low Suction Pressure Fit</td>
<td>39</td>
</tr>
<tr>
<td>131</td>
<td>High Refrig. Pressure Fit</td>
<td>23</td>
</tr>
<tr>
<td>146</td>
<td>High Pressure Switch Fit.</td>
<td>166</td>
</tr>
</tbody>
</table>

Trainset | Trend Analysis | Suggested Preventative/Corrective Action
---|---------------|---------------------------------------------
TS-11 | PC-2036 still generating many fault codes #146. | Fault logic: When compressor is operating the High Pressure Switch is checked once a second. If two HPS feedback readings are low (input low) generate event #146 immediately. For troubleshooting, this switch may need to be changed out.
TS-04 | Experienced 10 faults during the month (shut down mode #3) due to fault code #130. Last event logged May 20, this problem may have been corrected. | Fault logic: When compressor is operating the Low Pressure Transducer is checked every second. If LPT < 15 psig generate event 130. When this event is logged, it typically indicates a refrigerant leak around various devices or some other location in the HVAC unit. Refrigerant leak must be located and corrected.
TS-10 | HVAC A-end experienced 3 faults during the month due to fault code #130. Last event logged on 29 June (three times). | Fault logic: When compressor is operating the Low Pressure Transducer is checked every second. If LPT < 15 psig generate event 130. When this event is logged, it typically indicates a refrigerant leak around various devices or some other location in the HVAC unit. Refrigerant leak must be located and corrected.

Trend of TCU-X Events
### Acela Mechanical Status Board

<table>
<thead>
<tr>
<th>TS #</th>
<th>Location</th>
<th>Train #</th>
<th>Heading</th>
<th>Fault</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ivy City</td>
<td>2166</td>
<td>Stop</td>
<td>Shop</td>
<td>Truck Replacement</td>
</tr>
<tr>
<td>2</td>
<td>Union Station</td>
<td>2158</td>
<td>Stop</td>
<td>Tilt</td>
<td>9080 Fault, reset at Turn repair during S&amp;I</td>
</tr>
<tr>
<td>3</td>
<td>New York Penn</td>
<td>2163</td>
<td>Stop</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>New York Sunnyside</td>
<td>2167</td>
<td>Stop</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Boston</td>
<td>2108</td>
<td>NB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>MetroPark</td>
<td>2155</td>
<td>SB</td>
<td>HVAC</td>
<td>Car 3216 B-End HVAC Low Suction Pressure</td>
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<tr>
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<td>Wilmington</td>
<td>2170</td>
<td>Stop</td>
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<td></td>
</tr>
<tr>
<td>8</td>
<td>Ivy City</td>
<td>2164</td>
<td>NB</td>
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<tr>
<td>9</td>
<td>BWI</td>
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<td>Stop</td>
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<td>SB</td>
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<td>New Haven</td>
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<td>SB</td>
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<tr>
<td>13</td>
<td>Boston</td>
<td>2121</td>
<td>SB</td>
<td>Doors</td>
<td>S2 Fault</td>
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<td>Providence</td>
<td>2110</td>
<td>NB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Marcus Hook</td>
<td>2168</td>
<td>Stop</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Baltimore</td>
<td>2108</td>
<td>SB</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

12:22 PM
Seventy-Two (72) Annulments Have Been Avoided Since October 2006

Cumulative Acela Annulments since January 2006

- Acela annulments trend was 8 per month
- Amtrak takes over Acela Maintenance
- New “RCM” Acela ITM
- Actual annulments now average 3 per month

Savings = 72
Fewer Terminations

Cumulative Acela Terminations since January 2006

- Amtrak takes over Acela Maintenance
- Acela terminations FY06 trend line
- Actual terminations trending lower
- New “RCM” Acela ITM
- Savings = 9
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