Overview of FRA Research

Operational Enhancements for Tank Car Safety

Presented At the NTSB Rail Safety Forum

On April 22, 2014

FRANCISCO GONZALEZ
KARL ALEXY
ANAND PRABHAKARAN
Overview

• Reducing Derailment Severity & Consequences
  – Improving the car design
  – Reducing the kinetic energy in a derailment

• Achieved by:
  – Reducing operating speed
  – Implementing advanced braking systems

• How do we quantify benefits?
  – New approach to evaluate likelihood of puncture

• Train Operations/Braking Simulations
  – Kinetic energy reductions resulting from implementing advanced braking

• Other Research
Effectiveness of Mitigation Strategies

• As we review potential mitigating strategies/solutions for implementation, it becomes critical to have an objective measure of the expected improvements that these solutions afford.

• What is the overall reduction in risk afforded by:
  – Increasing the minimum required shell thickness to ‘X’ inches?
  – Making a given operational change, such as a speed restriction?

• While not intended to predict the precise results of a given accident, this methodology will provide a basis for comparing the relative benefits of various mitigation strategies.
Process for Evaluating Likelihood of Puncture

- Derailment Scenarios
- Derailment Load Spectrum
- Impactor Size Distribution
- Car Strength Capacities

Likely No. of Cars Punctured

Process Validation
## Comparing Puncture Risk Mitigation Strategies

<table>
<thead>
<tr>
<th>Tank Type</th>
<th>Most Likely Number of Punctured Cars</th>
<th>% Improvement Compared to Base Case</th>
<th>% Improvement Due to Speed Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Case</td>
<td>30 mph 40 mph</td>
<td>30 mph 40 mph</td>
<td>40 to 30 mph</td>
</tr>
<tr>
<td>7/16&quot; A516-70 No Jacket</td>
<td>8 11</td>
<td>~ ~</td>
<td>29%</td>
</tr>
<tr>
<td>Alternate</td>
<td>5/8&quot; TC128B 11 Gage Jacket</td>
<td>4 6</td>
<td>52% 47%</td>
</tr>
</tbody>
</table>
Effectiveness of ECP under Derailment Conditions
Safety Advantages of ECP Brakes

• Instantaneous brake signal communication leads to quicker brake application and therefore reduced stopping distances.
  – Additional cars might also be able stop before they reach the POD.
  – A given car would have a reduced velocity before it reaches the point of derailment (POD) or pileup, reducing the potential damage.

• Uniform deceleration rate for all cars minimizes relative car velocities and, therefore, coupler forces.
  – Leads to enhanced stability in the longitudinal direction, which would have a positive influence on the severity of derailment.

• Potential for increased braking force, further resulting in reduced stopping distances.
Scenarios Simulated

- Emergency braking is initiated on a train traveling at a nominal 46 mph on level grade.

- The simulations compared the dynamic behavior of an ECP brake equipped train to a conventional train and to a Distributed Power (DP) train under these emergency braking conditions.
Brake Cylinder Pressure Buildup

Brake cylinder pressure build-up: conventional braking vs. ECP vs. DP
Emergency application, bailed off, 100 car train

Graph showing brake pressure build-up over time for different braking systems:
- **ECP, all cars**
- **DP, first car**
- **DP, last car**
- **car 34, conv.**
- **car 68, conv.**
- **conv, first car**
- **conv, last car**
- **conv, car 34**
- **conv, car 68**

Y-axis: Brake cylinder pressure, psi
X-axis: Time, sec

Legend:
- Black line: ECP, all cars
- Red line: conv, first car
- Blue line: DP, first car
- Orange line: conv, last car
- Green line: DP, last car
- Light blue line: DP, car 34
- Red line: conv, car 68
- Dark blue line: DP, car 68
Emergency application, locos bailed off 100 loaded cars, 46 mph, level grade

Stopping Distance Comparisons

<table>
<thead>
<tr>
<th>Method</th>
<th>Stopping Distance, feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECP braking</td>
<td>2258</td>
</tr>
<tr>
<td>lead, mid and rear</td>
<td>2319</td>
</tr>
<tr>
<td>lead and 2/3 point</td>
<td>2339</td>
</tr>
<tr>
<td>lead and rear</td>
<td>2380</td>
</tr>
<tr>
<td>Conventional braking</td>
<td>2522</td>
</tr>
</tbody>
</table>

Fewer Cars in the Pileup
Potential Speed Reductions @ Point of Derailment

The difference between 25 mph and 18 mph could have a big effect on the severity of the damage in a pile-up.
Other Related Research
Barriers to ECP Implementation

- The benefits of ECP brakes are well documented and numerous:
  - Better stopping distances
  - Better train control
  - Improved readiness for re-application, graduated release
  - Improved fuel efficiency
  - Reduced wear on components
  - Reduced train inspection intervals, etc.
  - Reduced derailment damage
  - Increased safety

- Why then, given all the benefits of the system, have ECP brakes been slow to gain wide-spread acceptance?

- FRA is studying approaches to identify and address the challenges.

- This is ongoing work.
EDHB Development

- FRA R&D has been developing an Electrically Driven Hand Brake (EDHB) that has the potential to be applied remotely.

- The EDHB:
  - Push button application from side of car
  - Eliminates need to climb ladders and get between cars
  - Eliminates physical effort of applying/releasing hand brakes
  - Provides feedback on state of the hand brake – Clear signal of whether it is applied or released
  - Keeps all normal manual functions

- Prototype units have been developed, tested, and are undergoing ‘in-service’ tests on three test cars running on the FAST track at TTCI.

- Such a device has the potential to prevent an ‘runaway’ train accidents.
Sample installation on test car with push-button control from side of car.
Fire Test & Model Validation

• Fire test one-third scale model of tank car with North American insulation system
  - Will full scale system survive 100 minutes in 871° C blackbody fire?

• Test data will be used to validate the AFFTAC software model, which is now the industry standard.

• A series of six tests is planned.
Sample Pictures from Prior Tests
Fittings Protection Research

• Identify critically exposed fittings

• Evaluate survivability under rollover derailment conditions

• Develop concepts for improving protection

• Confirm & validate models used through appropriate full scale tests

• Guide the development of industry standards for fittings protection
It was seen from prior tests that:

- Unprotected fittings were completely destroyed in the base case test, with a rapid release of lading resulting.

- Deflective skid structure succeeded in protecting the fittings at a test speed of 18 mph with no resulting lading release.

- Bolt-on sleeve with reinforcing cone also was successful in protecting the fittings at a test speed of 12 mph with no lading being released.
Thank You!
Some Backup Slides
Sample Animation – 30 mph
Derailment Distribution – 40 mph
Collision Force Histograms

![Histogram showing collision force magnitudes in million lbs for two speeds: 30 mph and 40 mph.](image)
Car Strength Characteristics

Variable Internal Pressure
Side Impact Analyses

- DOT111A100W1 - 7/16" A516-70 (R31)
- P1577/CPC1230 1/2" TC128B (R37)
- T87.6 3/8" TC128B & 1/4" Jacket (R38)

Puncture Force (lbs)

Ram Face Characteristic Length (in)
Potential Impactor Size Distribution

![Bar chart showing the distribution of potential impactor sizes](chart.png)
Process Validation

Number of Derailed Cars vs. Train Speed

Number of cars derailed

Train speed, mph

Derailment Data
Average of Simulation Data
Process Validation

Number of Punctures vs. Train Speed