DOT Response to NAS Letter Report on **Electronically Controlled Pneumatic Brakes**

Review of Test and Simulations
July 06, 2017

Summary

- The NAS had three primary recommendations:
  - Consider specific brake response profiles
  - Confirm parameters through multi-variate analysis
  - Additional model validation
- The DOT has responded to these recommendations as outlined here:
  - Conducted additional field and rack testing to capture brake response profiles
    - Included these in the simulations and analyses
  - Conducted regression analysis and interfaced with the RSI-AAR project on this effort
    - These confirmed that the variables included in the DOT's analyses were appropriate, inclusive, and prudent
  - Reasonable validation has been completed

NAS Recommendation # 1
Emergency Brake Propagation Profiles

1.1 Use test racks to simulate the performance of the different braking systems

1.2 Measure the time required for the emergency application of ECP brakes and DP and EOT systems from initial train separation to the point at which all of the brakes on the train are fully applied.

- Conduct tests on in-service, full-scale locomotive and revenue car trains that are standing and moving slowly.
- Collect EOT and DP radio-system operational delay times and then apply them in test rack simulations.

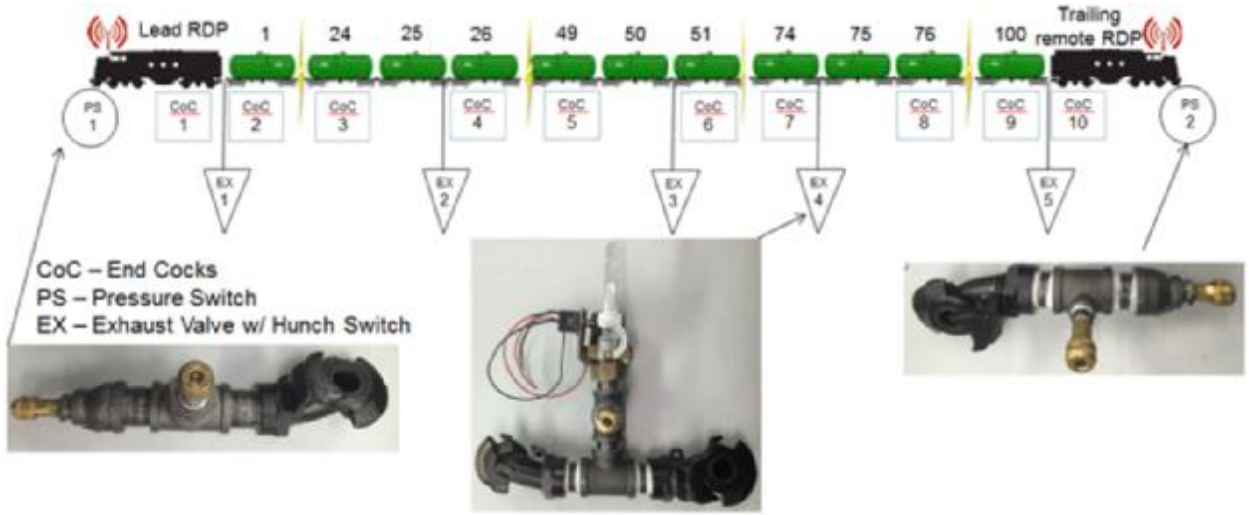
DOT Test Actions – Brake Propagation Times

- Field Testing at the NS yard in Conway, PA on a 100-car oil train to measure:
  - Operational delays from DP and EOT trains
  - Brake cylinder pressure build-up curves from an operational train
- Rack testing at the NYAB rack in Watertown, NY to measure:
  - Brake propagation and cylinder build-up profiles for DP, EOT, and ECP systems from the point of hose separation

Overview of Conway, PA Tests

- Field testing was conducted on a stationary revenue train in Norfolk Southern's Conway Yard on May 31, 2017.
- Testing and primary data collection was performed by NYAB, Wabtec, and Sharma & Associates for the FRA. Additional data collection was performed by GE.
- Observers included representatives from AAR, NS, BNSF, CN, TRB, FRA and NTSB.

Test Process



DP Train Configuration

- At various locations throughout train, the following actions were performed:
  - Brake pipe was vented to initiate emergency
  - Time between BP venting and loss of BP pressure at each end of train was collected
  - Difference between these times is the radio system transmission latency
  - Brake cylinder build-up profiles at multiple cars were also collected.

DOT Test Results – Conway, PA Tests

- A total of 32 tests were performed, 26 of which produced radio latency data.

	DP Radio Latency Time, sec		EOT Radio Latency Time, sec	
	front to back	back to front	front to back	back to front
average	1.83	2.29	1.81	N/A
std dev	0.17	0.31	0.12	N/A
number of tests	12	7	7	

- Note that, although EOT transmits emergency message to the lead loco, the locomotive does not dump brake pipe in response to this signal.

Overview of Watertown, NY Tests

- Rack Testing was conducted on NYAB brake rack with:
  - Conventional air brakes in both DP and EOT configurations, and
  - ECP brakes in a standalone configuration
- Testing and primary data collection was performed by NYAB and Wabtec.
- Observers included representatives from AAR, NS, GE, BNSF, TRB, and FRA.

Test Process

- Other configuration details
  - The DP units were connected to each other through a wired network; no additional delay was added.
  - The EOT configuration was laboratory specific and thus, 0.5 seconds of delay was added.
- At various locations throughout train, the following actions were performed:
  - Brake pipe was vented to initiate emergency
  - Time between BP venting and loss of BP pressure at each end of train was measured
  - Time from hose separation to the last car reaching full brake cylinder pressure was measured
  - Brake cylinder build-up profiles at multiple cars were also collected

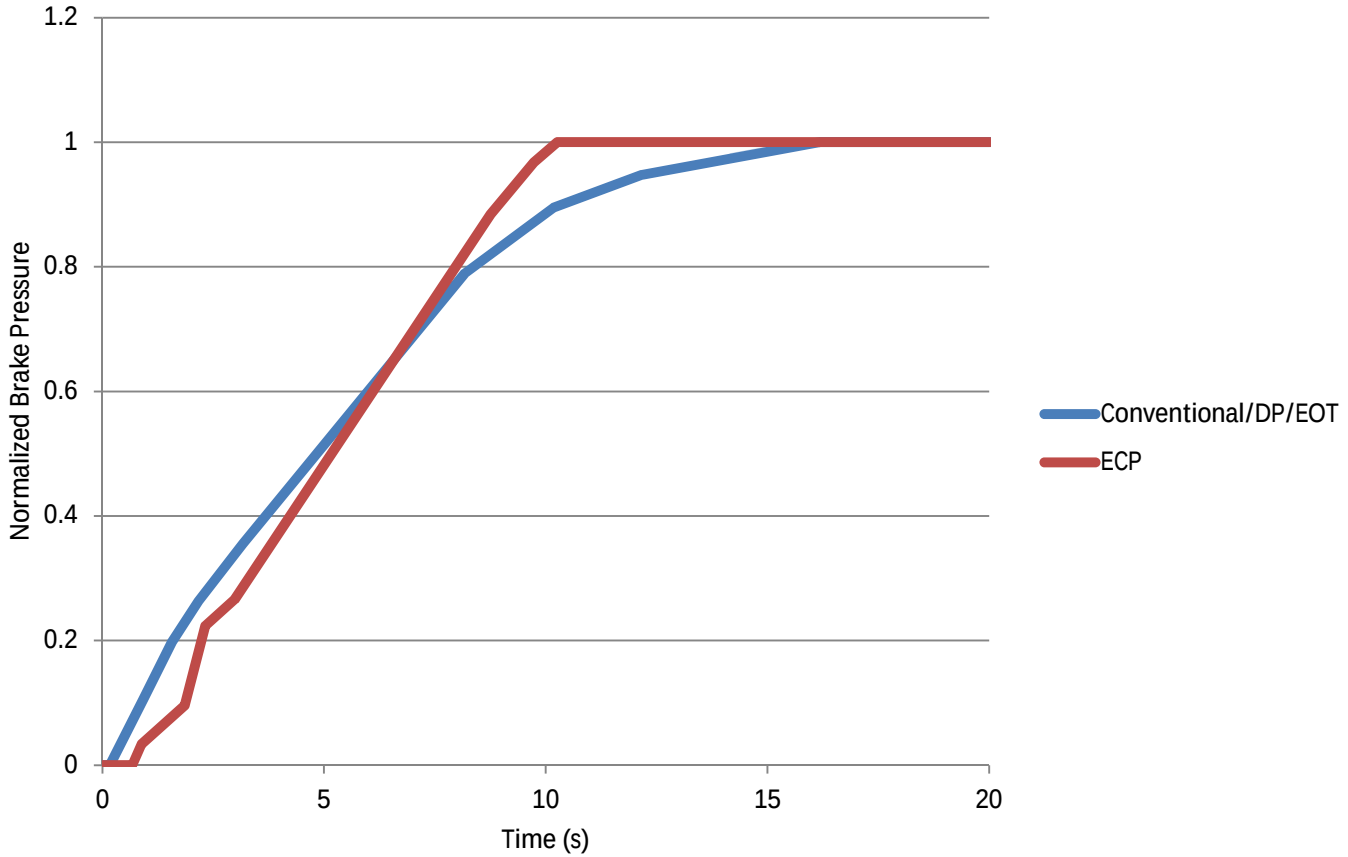
Test Results – Watertown, NY Tests

- Average DP latency: 2.2 seconds
- Average EOT latency: 1.95 seconds
- Time for last car to achieve full brake pressure:
  - DP/EOT systems: 13.8 to 10.8 seconds, depending on location of hose break
  - ECP systems: 10 seconds (regardless of venting location)
- Time delta between hose separation and brake initiation on adjacent car:
  - DP/EOT/Conventional Systems: 0.17 seconds
  - ECP Systems: 0.67 seconds (for all cars)

Updated Analysis Configurations

- Based on the test results from Conway, PA and Watertown, NY, the derailment simulations and puncture analyses were revised.
- Revisions included:
  - DP/EOT radio transmission delay of 2 seconds
  - Measured brake cylinder pressure profiles
  - Measured brake propagation times, adjusted for brake pipe length
  - Measured time delta between hose separation and brake initiation on first adjacent car:
    - DP/EOT/Conventional Systems: 0.17 seconds
    - ECP Systems: 0.67 seconds (for all cars)

Revised Brake Cylinder Pressure Profiles



- The data for the conventional/DP/EOT system is a composite of the measured brake cylinder pressure profiles from the GE data.
  - This data includes the effect of the actual brake rigging on the cars, and is thought to represent actual field conditions better than test rack data.
  - Propagation time is not shown on this chart for conventional and DP

Revised Analysis Results

- The likely number of punctures was recalculated for a 100 car train (100 cars behind the Point of Derailment) at 40 mph.

Analysis	Likely No. of Punctures			ECP Advantage over Conventional	ECP Advantage over DP/EOT
	Conventional	DP/EOT	ECP/OL		
Original	6.6	5.9	4.3	35%	27%
Revised	6.3	5.8	4.7	25%	19%

NAS Recommendation #2
DOT Analysis and Test Plan

2.1 Use multivariate analysis to ensure DOT's plan is focused on the factors that have significant impact on model predictions.

2.2 Create a merged database for tank car derailment accidents from FRA's RAIRS tank car derailment accident records and tank car–specific information as found in the RSI-AAR tank car accident database.

2.3 Develop a multivariate regression model from the merged database to examine how tank car spillage relates to a set of specific accident circumstances. Seek insights into which analysis predictors are strong, but are known with insufficient accuracy, and therefore are worthy of testing or additional measurements.

DOT Actions in Response – Multivariate Analysis

- Collaborated with RSI-AAR* on the potential for combining the databases and conducting additional analysis
- Conducted multiple regression analysis of data from FRA's RAIRS database
- Both of the above actions confirmed that the variables considered in the DOT's Analysis were appropriate, inclusive, and prudent

* - RSI-AAR Railroad Tank Car Safety Research And Test Project

Engagement with the RSI/AAR Data Group

- The RSI-AAR data group graciously agreed to engage with the FRA on this effort
- Several conference calls were held and the FRA shared a potential list of questions that could be answered by combining the data sets
- In the end, both parties agreed that literally merging the FRA and RSI-AAR databases does not offer any value:
  - However, the RSI-AAR data group identified several key variables that should be considered.

Key Variables From RSI/AAR Data Group

- Car features:
  - Thicknesses of tank head and shell
  - Steel specification for tank
  - Inside diameter of shell
  - Jacketed: yes or no
  - Head shield: none, half-height, full-height
  - Top fittings protection; yes or no*
  - Bottom fittings: present, none*
- Accident details:
  - Train speed at time of derailment
  - Number of freight cars derailed
  - Location of derailed tank car within derailed string

All of these variables were included in the DOT's original analysis

* - Evaluated separately

DOT's Multiple Regression Analysis

- Rail Equipment Accident data was queried from FRA website (RAIRS database)
- 200,908 records reported between 1975 and 2016
- Data was filtered and cleaned
- Statistical analysis: multivariate regression model used to determine factors that have significant impact on derailment damage predictions

Results of Multiple Regression Analysis

Factors with greatest correlation to accident damage:

- Train speed is the single most significant predictor
- Predictors of secondary importance include:
    - Position in train of first derailed car (closer to the front implies greater overall damage)
    - Total train tonnage
- Other factors are insignificant; most of the variation in derailment damage is explained by chance, i.e., it is random and unpredictable.

All three significant factors identified by this analysis were considered as inputs in the DOT's original methodology.

Summary – Recommendation # 2

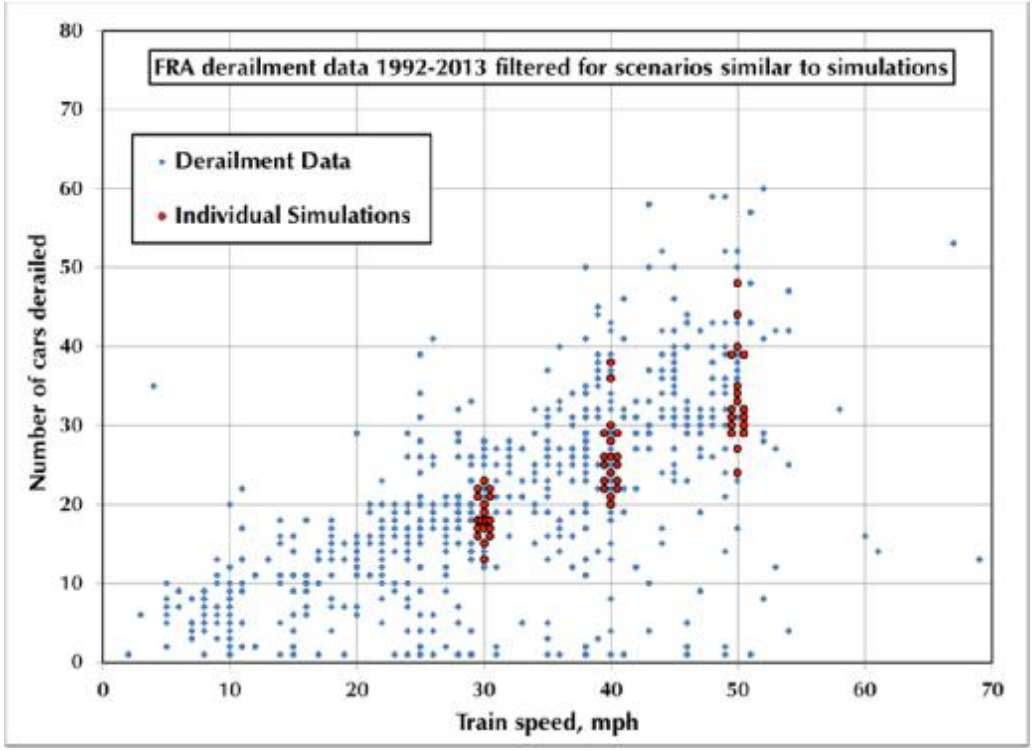
- The DOT puncture analysis approach includes all of the variables identified as significant predictors of derailment severity as recommended by both:
  - The RSI-AAR Tank Car Safety Project
  - DOT's internal multi-variate analysis
- Overall, the DOT believes that the statistical analysis conducted so far confirms that the variables included in the DOT approach are significant, prudent and effective.

NAS Recommendation #3
Model Validation

3.1 Validate the modeling approach by comparing the model's prediction of the outcome of an individual derailment event with the actual outcome of that one event. The type of braking system included in a modeled scenario should be the same as that involved in the actual train derailment with which the model prediction is to be compared.

DOT Response to Model Validation

- Review of accident data (in general), as well as, recent multi-variate analysis have confirmed that there is a large level of variability in accident severity due to random factors
  - The level of scatter in derailments is significant



DOT Response to Model Validation

- Therefore, simulation of a specific derailment may not be a good predictor of model performance
  - Especially, for a model that seeks to estimate an ‘average’ value intended for an economic analysis.
  - It is more critical to ensure that the model captures the mean and the trends appropriately
- Prior work published by the DOT (and shared through letter reports with the NAS and the public) has qualitatively shown excellent agreement on key parameters, such as the number of cars derailed or punctured
  - This work was done at an aggregate level and not at an individual derailment level.

DOT Response to Model Validation

- In addition, the rear car distance traveled in a comparable set of LS-Dyna simulations was compared to the Aliceville locomotive's event recorder data, and found to match with a difference of less than four percent.
  - This shows that in spite of all the potential variations, our derailment simulations closely matched reality, as evidenced by the event recorder download.

Summary

- The NAS had three primary recommendations:
  - Consider specific brake response profiles
  - Confirm parameters through multi-variate analysis
  - Additional model validation
- The DOT has responded to these recommendations as outlined here:
  - Conducted additional field and rack testing to capture brake response profiles
    - Included these in the simulations and analyses
  - Conducted regression analysis and interfaced with the RSI-AAR project on this effort
    - These confirmed that the variables included in the DOT's analyses were appropriate, inclusive, and prudent
  - Reasonable validation has been completed

Questions and Discussion