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Electronically Controlled Pneumatic Braking

Regulatory Impact Analysis

Pipeline and Hazardous Materials Safety Administration
Federal Railroad Administration
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Executive Summary

In response to the mandate of § 7311(c) of the Fixing America's Surface Transportation (FAST) Act, the Pipeline and Hazardous Materials Safety Administration (PHMSA) and the Federal Railroad Administration (FRA) updated the regulatory impact analysis (RIA) issued with the Pipeline and Hazardous Materials Safety Administration's May 8, 2015, final rule titled "Enhanced Tank Car Standards and Operational Controls for High-Hazard Flammable Trains" (Final Rule). See 80 Fed. Reg. 26643 (HM-251). The FAST Act required the Department of Transportation (DOT) to enter into an agreement with the National Academy of Sciences (NAS) to test Electronically Controlled Pneumatic (ECP) brakes and reevaluate the economic analysis supporting the ECP brake requirements of the Final Rule. The FAST Act also included a provision for the United States Government Accountability Office (GAO) to review the potential costs and benefits of ECP brakes. GAO has completed two audits of the ECP brakes economic analysis, both of which are discussed in this final 2017 RIA.

Although the FAST Act contained specific language requiring DOT to contract with NAS to perform "testing of ECP brake systems during emergency braking application, including more than 1 scenario involving the uncoupling of a train with 70 or more DOT–117 specification or DOT–117R specification tank cars," NAS explained that they could not agree to perform the testing in a letter dated March 17, 2016, that was addressed to FRA's Director of Research and Development. In the letter, NAS referred to a preliminary cost estimate of more than $100 million provided by the Association of American Railroads (AAR) to perform the testing described in § 7311. Additionally, NAS believed it was "highly unlikely" that the schedule described in § 7311 could be met. As a result, DOT determined it would be impossible to perform the identified crash tests because the specific party that DOT was required to contract with declined to do the testing as described in the FAST Act and such testing was not otherwise feasible from both a budgetary and time perspective. As an alternative, DOT proposed to meet the intent of the FAST Act by contracting with NAS to review and monitor a test plan that was intended to "objectively, accurately, and reliably measure the performance of ECP brake systems relative to other braking technologies or systems, such as distributed power and 2-way end-of-train devices," in accordance with § 7311(b)(3) of the FAST Act. NAS formed a committee of experts to fulfill these duties.

Consistent with the direction provided in the FAST Act, FRA performed live tests intended to increase the accuracy of the assumptions used in FRA's modelling of derailments and spills under alternative braking systems, including a puncture test of a DOT-117 car and a series of brake actuation tests, and numerous computer simulations based on the data from the tests. The committee of experts formed by NAS reviewed and commented on FRA's test plan and attended the various tests outlined in the plan. The documents related to these activities are contained in the public docket associated with this RIA. During the public comment period, PHMSA and FRA received the final NAS report on the testing and modeling FRA performed. Responses to the NAS report can be found below in section 7.3.

In response to the GAO audits and analysis of updated information gathered since the issuance of the original 2015 RIA, in this final 2017 RIA, PHMSA and FRA have reanalyzed and updated assumptions used in the original 2015 RIA, as well as the costs and benefits of the ECP brake provisions contained in the Final Rule.

As noted in the original 2015 RIA, costs will be incurred installing ECP brakes on tank cars, equipping locomotives with ECP systems, and training railroad employees. Using low and high ranges, for the 20-year period of analysis, the estimated total cost for ECP brakes is between $427.3 million and $554.8 million. Discounted at 3 percent, the costs are between $402.1 million and $524.1 million. Discounted at 7 percent, the costs are between $375.6 million and $491.7 million.

To evaluate and estimate the benefits of the Final Rule ECP brake provision, FRA used updated projections for carloads of crude oil and ethanol, as well as the number of derailments involving carloads of either crude oil or ethanol. Based on these updated projections and data, FRA estimates the total safety benefits to be between $48.2 million and $78.2 million discounted at 7 percent. Similarly, FRA adjusted the business benefits based on the updated projections of carloads of crude and ethanol and also took into account increased use of dynamic braking. Business benefits include set-out relief, fewer brake tests, wheel savings, and fuel savings. Over a twenty-year period, the total business benefits of the ECP braking systems mandated by the Final Rule would range between $82.9 million and $119.8 million, discounted at 7 percent.

Using the low and high ranges, for the 20-year period of analysis, the estimated total benefits for ECP brakes are between $257.5 million and $374.0 million. Discounted at 3 percent, the benefits are between $188.5 million and $278.8 million. Discounted at 7 percent, the benefits are between $131.0 million and $197.9 million.

Table E1: 20-Year Total and Annualized Costs and Benefits in Millions (7 and 3 Percent) [1]

	7 Percent		3 Percent	
	Low	High	Low	High
Total Costs	$375.6	$491.7	$402.1	$524.1
Total Benefits	$131.0	$197.9	$188.5	$278.8
Annualized Costs	$35.5	$46.4	$27.0	$35.2
Annualized Benefits	$12.4	$18.7	$12.7	$18.7

[1] A full table of the 7 percent and 3 percent low and high ranges is presented in Section 12.

Table E2: 20-Year Annualized Costs and Benefits in Millions by Section (7 and 3 Percent)

	7 Percent		3 Percent	
	Low	High	Low	High
Total Costs	**$35.454**	**$46.415**	**$27.028**	**$35.225**
Safety Benefits	$4.546	$7.381	$4.516	$7.356
Business Benefits				
Set Out Reliefs	$0.554	$0.703	$0.554	$0.709
Class IA Brake Test	$2.599	$4.346	$3.029	$4.377
Wheel Savings	$2.527	$3.531	$2.425	$3.556
Fuel Savings	$2.143	$2.723	$2.144	$2.743
Total Benefits	**$12.368**	**$18.685**	**$12.669**	**$18.741**

For comparison purposes, Table E3 below shows the estimated costs and benefits from the 2015 Final Rule RIA.

Table E3: Final Rule (2015) 20-Year Total and Annualized Costs and Benefits in Millions (7 and 3 Percent)

	7 Percent		3 Percent	
	Low	High	Low	High
Total Costs[2]	$492.0	N/A	$579.4	N/A
Total Benefits	$470.3	$613.4	$711.5	$932.5
Annualized Costs	$46.4	N/A	$38.9	N/A
Annualized Benefits	$44.4	$57.9	$47.8	$62.7

Discounted at 7 percent, the revised analysis results show estimated low range costs that are $117 million lower than the costs estimated in the original 2015 RIA, while the high range estimated costs are $1 million lower than the original 2015 RIA estimates. These high range costs are slightly higher due to the fact that more locomotives would be retrofitted, incurring a higher cost. The revised analysis results show low range benefits, discounted at 7 percent, that are $339.3 million lower than the low range estimate provided in the Final Rule RIA, and high range estimates that are $415.5 million lower than the original 2015 RIA estimates. The decreases in both costs and benefits are mainly due to a decrease in the predicted number of carloads over the 20-year period, which is discussed in greater detail below.

[2] In the 2015 Final Rule, FRA did not provide a range for the estimated costs.

1. Introduction

The effective use of braking on a train set can improve accident avoidance and potentially lessen the consequences of an accident by diminishing the number of derailed cars. Currently, FRA promulgates brake system standards for freight and other non-passenger trains and equipment in 49 CFR part 232 (part 232). Specifically, part 232 provides general requirements for brake systems and requirements for inspection and testing and periodic maintenance of those brake systems, requirements for end-of-train devices and ECP braking systems, as well as a process for the introduction of new brake system technologies. In this final 2017 RIA, FRA is analyzing the impacts of the Final Rule's requirement that all High Hazard Flammable Unit Trains (HHFUT)[3] be equipped with ECP brakes.

2. Statement of the Problem and Need for Action

The principal anticipated benefit of the Final Rule is a reduction in the risk of High Hazard Flammable Train (HHFT)[4] accidents and mitigation of the consequences when such accidents do occur. This final 2017 RIA only addresses the risks of HHFT accidents by requiring ECP brakes on HHFUTs. This would reduce both the chance of a derailment and the impact of a derailment should one occur.

2.1 Federal Solution

When promulgating new or revised regulations, it is necessary to consider whether the regulation should be issued at the Federal level or at the State and/or local level. This issue would be extremely difficult and cumbersome for both State and local jurisdictions to develop and implement. Also, railroads that operate in more than one jurisdiction would have to conform with potentially differing regulations across jurisdictions. State regulation of this issue for many railroads would also be cumbersome and probably more burdensome. If a regulation is needed, most railroads (or any railroad that operates in more than one State) would prefer a uniform Federal regulation to simplify compliance and reduce administrative costs.

2.2 Market Failure

In accordance with Executive Order 12866 and Circular A-4, DOT is to determine if a market failure has occurred, which would warrant a regulation. In the case of ECP brakes, a potential market failure arises due to the existence of negative externalities. Shippers and carriers may not consider the full social cost of any damages associated with a derailment when determining the level of safety, they provide. Carriers are generally liable for damages resulting from derailments, and they tend to self-insure or obtain insurance to pay for these damages. However, liability and insurance alone are in many cases insufficient to fully internalize the negative

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[3] An HHFUT is defined as "a single train transporting 70 or more loaded tank cars containing Class 3 flammable liquid." 49 CFR 171.8.

[4] An HHFT is defined as "a single train transporting 20 or more loaded tank cars of a Class 3 flammable liquid in a continuous block or a single train carrying 35 or more loaded tank cars of a Class 3 flammable liquid throughout the train consist." Id.

externalities associated with a derailment. Additionally, there are barriers to coordination between shippers and carriers that would ensure that investments in safety would occur in the absence of market intervention.

Shippers and rail companies are not always insured against the full potential consequences of incidents involving hazardous materials. Even if insurance is adequate to cover potential claims, it is unclear whether full compensation for the consequences of events that may result in severe injury or death is possible, and some external costs may go unrecompensed regardless of the insurance carried by the railroad. Also, to process a claim for compensation, those harmed must incur transaction costs because they must undertake efforts to meet standards for demonstrating real harm and value lost. In the case of damage to the environment, the actual monetary value of lost or damaged assets can be difficult to determine. As a result, some damages from a derailment may go uncompensated, and the externalities due to these events are not fully internalized.

Class I railroads commonly retain self-insurance of $25 million, although it can be as much as $50 million, especially when material toxic by inhalation (TIH material) is involved. Smaller regional and short line carriers (i.e., Class II and Class III railroads) on the other hand, typically maintain retention levels well below $25 million as they usually do not have the cash flow to support substantial self-insurance levels. Further, the maximum coverage available in the commercial rail insurance market appears to be $1 billion per carrier, per incident. While this level of insurance is sufficient for the vast majority of accidents, it is inadequate to cover some higher-consequence events.

One example of this issue is the accident that occurred at Lac-Mégantic, Quebec, in July 2013.[5] The rail carrier responsible for the incident was covered for a maximum of $25 million in insurance liability and declared bankruptcy because that coverage and the company's remaining capital combined were insufficient to pay for more than a fraction of the harm resulting from the accident (economic losses were estimated at more than $1 billion). This is an example where rail carriers and shippers had insufficient coverage to bear the entire cost of "making whole" those affected by a rail accident involving hazardous materials. Further, some damages are unlikely to lead to liability, including any damages to the American public's non-use values of an area where a release occurs, as well as small amounts of per capita damages that can be large overall if they affect a large number of people. For instance, if a release causes an evacuation, the affected groups may not suffer enough harm to overcome the transaction costs of litigating that harm.

Moreover, reliance on private insurance can lead to the problem of a moral hazard, which can occur when the insured party is insulated against consequences the risk of which may be affected by its own actions (such as preventive safety practices or investments) and when the insurer cannot perfectly monitor the behavior of the insured. However, it should be noted that DOT does not have specific evidence of insurance-related moral hazard behavior by rail carriers in the U.S.

[5] The RIA for the 2015 Final Rule has a more in-depth discussion of all major crude oil and ethanol accidents that have occurred in the United States in recent years. The RIA has been placed in the docket.

Shippers' responsibilities are typically limited to buying or leasing the tank cars in which hazardous materials are shipped, and loading the material into the tank cars. Shippers do not generally bear liability for an incident, which gives rise to another potential market failure. Once a rail carrier has accepted shipment, the carrier assumes liability for the materials themselves as well as any consequences resulting from any incident involving those materials. Moreover, rail carriers generally cannot refuse shipments because of their common carrier obligation. Thus, shippers themselves do not bear the costs of failing to provide adequate safety. At the same time, any safety improvements that generate benefits accrue to carriers (in terms of reduced liability costs) or to the public as whole (in terms of reduced damages due a reduced number and severity of incidents). In addition, while rail carriers generally can charge higher rates for carrying riskier products, there may be instances where rail carriers are unable to charge a price that reflects the full private marginal cost they bear, let alone the full marginal social cost of transporting hazardous materials, because rail carriers are obligated to accept shipments under their common carrier obligations and the rates they charge are regulated by the Surface Transportation Board. Shippers, by virtue of not bearing liability for the hazardous materials they ship, lack the appropriate incentive to invest in the socially optimal level of tank car safety.

If the expected private benefits to carriers of a safety improvement are greater than the total expected costs, then it would be efficient for carriers to compensate shippers for incurring costs associated with a safety improvement. However, a single tank car could be carried by many different railroads over its life span, and at the time a tank car is constructed, the identities of the rail carriers likely to carry the tank car may be largely unknown. A further complication in the case of ECP brakes is that the safety and business benefits are fully realized only when every tank car in a train is ECP brake-equipped. Achieving any ECP brake benefits at all necessarily requires a high upfront investment, which acts as a further disincentive for carriers to pursue such a course of action.

Again, as noted previously, some of the expected benefits of ECP brakes do not accrue to private parties but to society as whole. That is, the social benefits exceed the private benefits, which is an additional complication preventing the private market's ability to achieve a socially optimal outcome. Where private benefits are less than costs, but social benefits are greater than costs, government intervention could provide the correction needed to reach the socially desirable outcome.

3. Findings

This analysis includes qualitative discussions and quantitative measurements of the costs of the ECP brake mandate of the Final Rule. Using low and high ranges, for the 20-year period of analysis, the estimated total cost for ECP brakes is between $427.3 million and $554.8 million. Discounted at 3 percent, the costs are between $402.1 million and $524.1 million. Discounted at 7 percent, the costs are between $375.6 million and $491.7 million.

Using the low and high ranges, for the 20-year period of analysis, the estimated undiscounted total benefits for ECP brakes are between $257.5 million and $374.0 million. Discounted at 3 percent, the benefits are between $188.5 million and $278.8 million. Discounted at 7 percent, the benefits are between $131.0 million and $198.0 million.

When compared against the costs and benefits that were initially estimated in the original 2015 final rule analysis, the revised analysis results in costs, discounted at 7 percent, that are $117 million lower than the 2015 estimate at the low end of the range while the high end of the range is nearly identical to the 2015 RIA estimate. The revised analysis results in benefits, discounted at 7 percent, that are $339.3 million at the low end of the range and $415.5 million lower at the high end of the range. Overall, the revised analysis found that total costs, in general, had decreased while the total benefits had decreased as well. The decreases in both costs and benefits are mainly due to a decrease in the predicted number of carloads over the 20-year period, which is discussed in greater detail below. The high end of the range of estimated costs is higher than the low end of the range due to the fact that more locomotives would be retrofitted in the high range scenario.

4. FAST Act and GAO Recommendations

PHMSA issued the Final Rule in May 2015. Since issuance of the Final Rule, FRA and PHMSA have received numerous comments from stakeholders, and GAO audited the agencies' analysis of the costs and benefits of the ECP brake provision of the Final Rule. The following provides a summary of actions since the RIA was published in 2015.

4.1 FAST Act

On December 4, 2015, President Barack Obama signed into law the FAST Act, Pub. L. 114-94, 129 Stat 1686 (Dec. 4, 2015). Section 7311 of the FAST Act, codified in the Federal railroad safety laws at 49 U.S.C. 20168 (the Statute), requires the Secretary of Transportation to fully incorporate the results of the evaluation by GAO and the testing into an updated RIA for the ECP brake system requirements. Furthermore, under subsection (c)(1)(B), DOT is required to solicit public comment in the Federal Register on the revised RIA for not more than 30 days. Within two years of the FAST Act (i.e., December 4, 2017), the Secretary must determine, based on whether the final RIA demonstrates that the benefits exceed the costs, whether the ECP brake system requirements are justified. If the Secretary does not publish this determination, the Secretary must repeal the ECP brake system requirements.

The FAST Act also required DOT to enter an agreement with NAS to physically test ECP brakes. The tests were required to include more than one scenario involving the uncoupling of a train with 70 or more tank cars. Although the FAST Act contained specific language requiring DOT to contract with NAS to perform "testing of ECP brake systems during emergency braking application, including more than 1 scenario involving the uncoupling of a train with 70 or more DOT–117 specification or DOT–117R specification tank cars," NAS explained that they could not agree to perform the testing as described in the FAST Act. NAS noted that the preliminary estimate of costs to perform the testing described in the § 7311 was in excess of $100 million dollars. Additionally, NAS believed it was "highly unlikely" that the schedule described in § 7311 could be met. As a result, DOT determined that it would be impossible to perform the identified crash tests because the specific party that DOT was required to contract with declined to do the testing as described in the FAST Act and such testing was not otherwise feasible from both a budgetary and time perspective. As an alternative, DOT met the intent of the FAST Act by contracting with NAS to review and monitor a DOT test plan that was intended to "objectively, accurately, and reliably measure the performance of ECP brake systems relative to other braking technologies or systems, such as distributed power and 2-way end-of-train devices," in accordance with § 7311(b)(3) of the FAST Act.

FRA performed several live tests, including a puncture test of a DOT-117 car, a series of brake actuation tests, and numerous computer simulations based on the data from the tests. NAS formed a committee of experts that reviewed and commented on FRA's test plan and attended the various tests outlined in the plan. The documents related to these activities are contained in the public docket associated with this RIA. During the public comment period, PHMSA and FRA received the final NAS report on the testing and modeling FRA performed. Responses to the NAS report can be found below in section 7.3.

4.2 GAO Audit #1: October 2016

GAO submitted a report, which has been provided in the docket, to the Senate Committee on Commerce, Science, and Transportation concerning the ECP brake mandate of the Final Rule. GAO recommended that:

- DOT take into account, in the updated RIA conducted in response to the FAST Act, potential uncertainty in key variables and assumptions, such as, but not limited to, fuel prices and future rail traffic of crude oil and ethanol, discuss this uncertainty, and present ranges of possible scenarios.
- DOT create a plan to collect data from railroads' ongoing and future operational experiences using ECP brakes. The plan should include details on how the agency will work with railroads to collect this data, ensure that such data are reliable, and analyze these data to conduct a retrospective analysis of the ECP brakes requirement that could help inform any potential future actions regarding ECP brakes.
- If, based on its updated analysis, DOT promulgates a new rule on the applicable ECP brake system requirements, require that freight railroads, once they equip with ECP brakes in response to the requirement, collect and provide data to FRA on their ongoing operational experience with ECP brakes.
- Publish information—including data inputs, formulas, and results of all simulations and assumptions regarding DOT's use of the LS-DYNA[6] model and related analyses to support the original 2015 final rule—that would allow a third party to fully assess and replicate the analysis.

DOT has attempted to address GAO's recommendations in this updated analysis, with certain limitations. DOT has acknowledged uncertainty throughout this analysis and given ranges for costs and benefits. Additionally, DOT has updated the letter report on the LS-DYNA model (also referred to in this analysis as the Sharma model; see section 6.1) and posted it in the docket, which provides the information needed to evaluate its validity. However, with regard to GAO's recommendations regarding data collection from railroads regarding their use of ECP brakes, DOT did not receive the required semi-annual data from the 5,000 mile ECP test trains operated

[6] The LS-DYNA model (i.e., Sharma model) is described further in the Sharma letter.

by BNSF and NS. Instead DOT received a summary PowerPoint after the conclusion of the tests. The report did not contain pertinent ECP metrics, which would be essential for a detailed analysis.

4.3 GAO Audit #2: May 2017

GAO, in response to an inquiry from Senator John Thune, compared forecasts used in the original 2015 Final Rule RIA to actual values for 2015 and 2016, including the forecasted shipments of crude oil and ethanol, the number of crude oil and ethanol derailments, the amount of product lost in such derailments and the related costs of cleanup, and the number of injuries and deaths. GAO submitted a report, which is available in the docket, to the Senate Committee on Commerce, Science, and Transportation on May 31, 2017. The report indicated that DOT's forecasted values for some of the variables may be higher than values realized in 2015 and 2016 based on preliminary data. GAO noted that forecasts are uncertain by nature, and it is expected that the forecasts would not be found to exactly match actual data.

DOT has revised forecasts in this final 2017 RIA for the number of derailments, injuries, fatalities, and gallons of product released. GAO also suggested DOT provide ranges for its estimates to increase confidence in their estimates and to address stakeholders' concerns. In this final 2017 RIA, FRA has addressed this comment by including ranges for both the costs and benefits sections.

5. Purpose and Methodology of this Economic Analysis

The purpose of this revised RIA is to update the original 2015 RIA associated with the ECP brake provision issued with the Final Rule in response to the FAST Act's requirements, including the recommendations in GAO's audits, and to update the costs and benefits based on current economic conditions. Within the 20-year period of this analysis, costs are assessed in terms of changes in the current regulatory burden being added by these rule changes. In economics, this type of analysis is referred to as a marginal analysis. Implementation of the ECP brake provision would result in additional regulatory burdens in some areas while also providing both an increase in railroad safety and operational business benefits to rail carriers.

This final 2017 RIA adheres to methodologies historically followed and accepted by DOT. It is consistent with the guidelines in DOT's Regulatory Policies and Procedures;[7] Executive Order 12866, "Regulatory Planning and Review" and amendments;[8] Executive Order 13563,

[7] See 44 FR 11034, February 26, 1979.
[8] "Economic Analysis of Federal Regulations Under Executive Order 12866." http://www.whitehouse.gov/omb/inforeg_riaguide, January 11, 1996.

"Improving Regulation and Regulatory Review;"[9] and the Office of Management and Budget's (OMB) Circular A-4 on Regulatory Analysis.[10]

The results of this revised analysis are a product of the assumptions, estimates, theories, methodologies, and procedures used in it. This information is provided to enhance transparency of the regulatory process. This transparency should assist interested parties by providing greater access to the information used to identify, assess, and estimate impacts.

Data and calculations used in this analysis are provided so that the reader may replicate the analysis and quantify the assessments using information and data discussed and assumptions noted.

All the spreadsheets and simulations used for this analysis have been developed using a non-proprietary software package. Some rounding of numbers has been performed for the sake of presentation clarity and is noted where applicable.

This analysis is intended to be a pragmatic instrument designed to ensure that the Government and its relevant officials, and the public view the expected consequences of the regulation.

6. Assumptions and Inputs Used in this Analysis

This economic analysis uses certain assumptions and, unless otherwise noted, the following assumptions apply to this analysis, its exhibits, and appendices.

Sunk costs are not factored into this analysis, unless necessary for comparison purposes. This analysis projects both the additional costs that would be incurred by the railroad industry as a result of the Final Rule and the related benefits that would accrue to both rail carriers and society at large, over a 20-year period. Several key assumptions in the analysis are presented here:

- The present value (PV) of cost flows are calculated in this analysis. PV provides a way of converting future costs into equivalent dollars today. Consequently, it permits comparisons of cost streams that involve different time paths. The formula used to calculate these flows is: $1/(1+r)^t$, where "r" is the discount rate and "t" is the year of analysis. Discount rates of 3 and 7 percent are used.
- The analysis uses a value of $9.6 million per statistical life saved, consistent with current DOT guidance.[11]

[9] Executive Order 13565–Improving Regulation and Regulatory Review." http://www.whitehouse.gov/the-press-office/2011/01/18/executive-order-13563-improving-regulation-and-regulatory-review, January 18, 2011

[10] "Circular A-4: Regulatory Analysis." September 17, 2003. Go to http://www.whitehouse.gov/omb/circulars_default to access OMB Circular A-4 under the heading OMB Circulars in Numerical Sequence.

[11] See *Guidance on Treatment of the Economic Value of a Statistical Life in U.S. Department of Transportation Analyses (2016).* Available at https://www.transportation.gov/office-policy/transportation-policy/revised-departmental-guidance-on-valuation-of-a-statistical-life-in-economic-analysis

- All costs and benefits in this analysis are stated in 2016 dollar amounts unless otherwise stated.
- FRA assumed that the first implementation year would be 2018.[12]
- FRA used the year 2016 to determine wage rates. Wage rates will vary based on the job description.

6.1 Sharma Model

Prior to adopting the Final Rule, FRA conducted simulations to better understand the effect on energy dissipation and stopping distance of different brake signal propagation systems: two-way EOT devices and ECP brakes. The simulations were developed by Sharma & Associates to study the dynamics and energy levels under a variety of operating conditions. The parameters evaluated by the model are provided in Table 6.1b.

Table 6.1b: Parameters Evaluated in FRA's Purpose Built Model

Parameter Category	Subcategory	Description
Brake System	Two-Way End of Train (TWEOT)	Two-way EOT device capable of initiating emergency from the rear based on signal from lead locomotive
	ECP (NBR 12 percent)	ECP brakes with a set net brake ratio of 12 percent. This is the same brake ratio as TWEOT system in the purpose-built model.

The results of these simulations show the benefits of an increased net braking ratio, a decreased brake signal propagation time and train stability during an emergency brake application relative to a conventional brake system. Thus, additional requirements for advanced brake signal propagation systems are feasible for addressing HHFUT risk.

In August 2017, Sharma & Associates performed new modeling[13] that considers the comments received after publication of the Final Rule. This updated model, specifically designed for the testing of ECP brakes, confirms that ECP brakes provide substantial safety benefits in emergency braking situations compared to two-way end-of-train (EOT) devices. For purposes of this analysis, the two-way end-of-train is equivalent to a distributive power locomotive at the rear of the train. While a comprehensive discussion of effectiveness rates is provided in the March 2015 Sharma Letter Report, some highlights are provided below. See "Letter Report: Objective Evaluation of Risk Reduction from Tank Car Design & Operations Improvement – Extended Study," Sharma & Associates, March 2015.

The number and severity of puncture hazards depend on a variety of factors, including operating conditions and train speed, which can make it difficult to objectively quantify the overall safety improvement that ECP brakes provide. The updated model provided by Sharma & Associates encapsulates a variety of factors in an effort to assess the real-world impact of the various

[13] For additional information about the model used please see the 2017 Letter Report which has been placed in the docket.

braking alternatives. The Sharma model is validated by the general agreement between the actual number of tank cars punctured in 22 hazardous material derailments and those predicted by the model.

Based on the new models developed by Sharma & Associates, DOT believes that ECP brakes, in isolation, can be expected to reduce the number of cars punctured by up to 14.0 percent compared to two-way EOT devices.

The ECP brake system provides an advantage over two-way EOT devices in terms of the likely number of tank cars punctured. This is true regardless of the location of the derailment within the train because the brakes are being applied to each car in the train at the same time. FRA's simulations considered derailment at locations with 100, 50, and 20 cars trailing the point of derailment (POD). A polynomial fit of the resulting derailment and puncture results data from the simulations enabled FRA to evaluate the results of a derailment at any location in the train through interpolation and extrapolation.

The results of the evaluation indicate that the POD does affect the estimated number of cars punctured for any of the simulated brake systems, including a reduction in the estimated number of cars punctured for trains operated in ECP brake mode. This is expected given that if a derailment occurs at the 50th car in a train rather than the first car in the train, there are fewer cars to derail after the POD. In every simulation but one, the ECP brake system reduced the number of cars punctured compared with two-way EOT devices. See table 6.1a.

Table 6.1a: Updated Derailment and Puncture Simulation Results

DOT-117		Most Likely Number of Punctures	
Latest simulations			
Cars behind the POD	Speed, mph	2-way EOT	ECP Brakes
		(DP: lead + rear)	
100 cars	30	3.2	2.8
	40	5.8	4.7
	50	8.2	7.3
50 cars	30	2.5	2.2
	40	4.5	3.7
	50	5.7	5.2
20 cars	30	1.7	1.5
	40	2.2	2.2
	50	3.4	3.1

According to the August 2017 Sharma & Associates analysis, the risk reduction benefits for ECP brake systems are most pronounced for long trains. As trains become shorter, the differences in puncture rates become diminished between ECP brakes and two-way EOT devices because of the reduced time needed to initiate emergency braking across all cars in the train.

7. Revisions to the RIA

7.1 Revisions from 2015 Final Rule RIA

In response to the FAST Act, GAO reports, and additional testing and modeling, FRA is issuing this final 2017 RIA. In response to these recommendations and information, FRA updated estimates throughout the RIA. The following sections describe what changes are made in this final 2017 RIA as compared to the original 2015 RIA issued with the Final Rule related to ECP brake systems.

Ranges for Estimates

GAO recommended that, because of uncertainty, DOT use ranges to estimate costs and benefits. FRA has developed ranges for the costs and benefits that could be gained from ECP brakes. Providing these ranges helps to increase the confidence of FRA's findings while also addressing GAO's concerns.

Collecting New Data

DOT collected updated data on the efficacy of ECP brakes, and on numerous other measures that were used to estimate expected costs and benefits of the Final Rule. FRA conducted physical tests on oil trains with 100 cars to determine the latency of EOTs and Distributed Power when in emergency transition. The results of these tests were incorporated into DOT's modeling. This complied with the FAST Act's suggestion to work with NAS, however; FRA was unable to get the results of NAS's final study prior to the publication of this RIA. Both PHMSA and FRA have updated the data that was used in the original 2015 RIA, such as the number of carloads of crude and ethanol, cost of ECP brake equipment, and several assumptions with respect to the use of dynamic braking. DOT also updated data on the number of derailments, deaths and injuries, but did not update estimates of the costs of spills. These changes are reflected in the sections below.

New Simulations

In response to the GAO comments, FRA ran additional simulations to include more observations and provide additional support for the original findings. These simulations considered derailment at locations with 100, 50, and 20 cars trailing the POD. A polynomial fit of the resulting derailment and puncture results data from the simulations enabled FRA to evaluate the results of a derailment at any location in the train through interpolation and extrapolation. The results of the evaluation indicated a reduction in the estimated number of cars punctured for trains operated in ECP brake mode as compared to a two-way EOT train device.

The Sharma model (see section 6.1 below) was developed specifically to calculate the number of punctures likely to occur in a derailment and to enable PHMSA and FRA to calculate the effectiveness of the tank car design, speed at the time of derailment, and brake system.

Moreover, DOT evaluated the effectiveness of these variables assuming a particular type of train make-up, in this case a unit train. Another model with similar capabilities does not exist. An updated letter report describing the rationale and methodologies employed by the model was posted in the docket to provide an opportunity for public review. PHMSA and FRA did not receive any comments pertaining to the updated Sharma letter during the public comment period.

Locomotives and Other Equipment

Given that the carload forecast has changed since the Final Rule RIA, the number of unit trains on the network has also changed. PHMSA and FRA estimated that the maximum number of HHFUTs on the general network at any given time would be between 357[14] and 464.[15] These were estimated using the peak year carloads forecasts using an average of 80 carloads of ethanol per unit train and 100 carloads of crude per unit train.

Not all locomotives in a railroad's entire fleet would need to be retrofit since the equipment with ECP brakes is part of a captive fleet,[16] and therefore the locomotives would be part of that captive fleet. Although most of these trains operate with three locomotives, PHMSA and FRA are conservatively assuming four locomotives per train to accommodate out-of-service locomotives or any additional locomotives needed to operate HHFUTs with ECP brakes. Therefore, DOT estimates that between 1,428 and 1,856 ECP-equipped locomotives will be required to meet the Final Rule requirements for ECP brake operation.

One of the major railroads while operating an ECP-equipped subset of their fleet purchased additional runaround cables used to by-pass a locomotive that may not be equipped for ECP braking. PHMSA and FRA assume that other railroads would follow this business practice, and purchase one set for each ECP-equipped locomotive in service. This would prevent any bottlenecks or slowdowns from occurring if an ECP-equipped locomotive was not available. With these runaround cables, any locomotive not equipped with ECP brakes could be used as a non-controlling locomotive on the HHFUT, providing the required power to operate the train.

PHMSA and FRA assume that ECP-equipped tank cars will be on an overlay system, as opposed to a stand-alone ECP brake system. The overlay system would allow any locomotive to move these cars in non-ECP mode, assuming they are traveling no more than 30 mph, even if the number of cars in the train constitute a HHFUT. This would allow switching locomotives to avoid having ECP brakes installed to comply with the rule and would also allow railroads the flexibility to only equip the portion of their fleet with ECP brakes used in HHFUT trainsets.

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[14] Calculation: [417,477 (crude carloads in peak year for all carloads) * 0.84 (proportion of crude hauled on unit trains) ÷ 100 (crude cars per train) ÷ 280 (operating days per year) * 16 (days per cycle)] + [467,034 (ethanol carloads in peak year for all carloads) * 0.47 (proportion of ethanol hauled on unit trains) ÷ 80 (ethanol cars per unit train) ÷ 280 (operating days per year) * 16 (days per cycle)] = 357 unit trains

[15] Calculation: [659,660 (crude carloads in peak year for all carloads) * 0.84 (proportion of crude hauled on unit trains) ÷ 100 (crude cars per train) ÷ 280 (operating days per year) * 16 (days per cycle)] + [438,112 (ethanol carloads in peak year for all carloads) * 0.47 (proportion of ethanol hauled on unit trains) ÷ 80 (ethanol cars per unit train) ÷ 280 (operating days per year) * 16 (days per cycle)] = 464 unit trains

[16] For the purposes of this analysis, DOT is defining a captive fleet as a fleet whose are trains that solely operate as HHFUTs. They are not broken up for other service. Therefore, ECP brakes would only be required on these trains.

Training and Wages

ECP brakes may be deployed over any rail route that is currently designated to carry HHFUTs, which currently is 62 percent of the general rail network. This estimate was updated from the original 2015 RIA using the Waybill sample. The overall methodology has remained the same. With ECP-equipped trains operating over such a large portion of the network, there will be an incentive for rail carriers to provide necessary training on ECP brakes for broad sections of their operating and maintenance personnel to ensure the trains are handled correctly and maintained in a timely manner. PHMSA and FRA have included training costs in the analysis for all locomotive engineers, conductors, and carmen that would work on any part of the HHFUT routes. This accounts for 62 percent of those employees. By properly training these employees, problems can be reviewed and corrected in a timely fashion, thereby limiting the amount of out-of-service time.

DOT examined the routes of the HHFUTs to determine how many crews could be affected. Using the waybill sample, FRA determined that approximately 62 percent of the total ton-miles were on routes that had crude or ethanol unit trains. PHMSA and FRA adjusted the estimate to include 62 percent of the total crews as the other 38% of crews work on track that does not carry crude oil or ethanol. Based on these assumptions, approximately 12,321 engineers and 18,618 conductors, and 4,471 carmen would receive additional training. The cost of training these personnel is discussed in more detail in section 9.4 below.

Enhanced Inspections

In the past three years since issuance of the original 2015 RIA, the derailment rate (derailments per 1,000 carloads) of HHFTs has declined. Railroads have been proactive in re-evaluating their track inspection frequency along crude oil routes and have increased the frequency of their Automated Track Inspection Program (ATIP) and rail integrity inspections on such routes. This has resulted in railroads paying closer attention to their own track inspections and the more thorough inspections are catching problems before they lead to track-caused derailments. Also, FRA has implemented CORTEX (Crude Oil Route Track Examination) where FRA sends numerous additional inspectors to specific geographical regions of the country to conduct detailed track inspections on crude oil routes. The CORTEX program has provided an additional level of scrutiny by FRA inspectors in addition to the agency's normal oversight of railroads and the track inspections the railroads are required to do on a weekly basis. These inspections focus on the condition of track, including: ballast, ties, rail, loose, or missing hardware, and track inspection records maintained by the railroads. FRA also incorporates its ATIP car[17] in these detailed track inspections when it is available in the region. After the CORTEX audits, the local regional inspectors conduct follow-up inspections to address concerns.

Railroads have also implemented additional wayside detector technology on many of their crude oil routes. Within the last few years, railroads have increased the installation at strategic

[17] An ATIP car is a railcar that is used by FRA as an inspection tool to gather "track geometry data to assess compliance with the *Federal Track Safety Standards*. Priorities for ATIP inspections include passenger, major Hazardous Material (HAZMAT) and Strategic Rail Corridor (STRACNET) routes, and other track, which present a safety concern to the FRA." https://www.fra.dot.gov/Page/P0633

locations of wayside detectors which provide additional rolling equipment inspections en-route. These additional wayside detectors and enhanced track inspections may have contributed to the reduction in derailment rates since the Final Rule was first published.

Benefits

DOT has revised the business benefit estimates in this revised RIA. The new projections for number of carloads of crude oil and ethanol are presented below and are used to calculate ranges for the safety and business benefits. Additionally, the applicable wage rates are no longer increased on a yearly basis.[18] This revised analysis also adjusts the business benefits for the increased use of dynamic braking across industry.

Costs

DOT has revised the estimates of some cost components in this final 2017 RIA. Costs were updated to account for the change in forecasted carloads of crude oil and ethanol. The new estimates are presented and described in the Costs of Rulemaking section. Key changes include the cost to retrofit locomotives and tank cars with ECP. As discussed above, training costs were also revised to update the number of employees and current wage rates. Overall, the costs decreased compared to the original 2015 RIA. However, when looking at the estimated range of costs within the final 2017 RIA, the high end of the range is higher than the low end due to the fact that more locomotives would be retrofitted in the high range scenario, thus incurring a higher cost.

7.2 Public Comments to Revised RIA

I. Carload Forecast

PHMSA and FRA received several comments regarding the revised RIA's forecast of carloads of crude and ethanol used to evaluate the costs and benefits of the Final Rule. Commenters consistently expressed the view that the revised forecast overestimates future carloads, especially for crude oil. One of the commenters suggested that PHMSA and FRA may have double counted carloads in extracting the historic estimates used to forecast future carloads. That commenter asserted that the overestimation of future carloads may have led to higher estimated benefits. Commenters note that the methodology used by PHMSA and FRA to forecast future carloads overestimates carloads for 2016 and 2017 based on partial-year EIA crude-by-rail movement data.

PHMSA and FRA recognize a great degree of uncertainty exists regarding future carloads of crude and ethanol shipped by rail. Recently the shipment of crude by rail has been very volatile. Until 2013 crude-by-rail carloads were low – generally well below 100,000 carloads shipped per year. Starting in 2013 and continuing through 2015 carloads spiked dramatically to over 500,000 carloads in 2014 and 2015, followed by a decline to less than 300,000 in 2016. In this final 2017

[18] DOT's updated guidance on the Value of a Statistical Life no longer recommends increasing values over time to account for potential real income growth in the future. See https://www.transportation.gov/regulations/economic-values-used-in-analysis

RIA, PHMSA and FRA developed a range of forecasts, including sensitivity analysis, to account for the instability seen in the crude oil industry over the last decade.

The highest carload forecast used by PHMSA and FRA was based on methodology introduced in the RIA accompanying the HM-251 NPRM. In response to the NPRM's RIA, commenters requested that PHMSA and FRA incorporate an industry forecast which was significantly higher than the forecast used in the NPRM RIA. Due to the decrease in demand for U.S. crude oil relative to that indicated in the 2015 Final Rule, PHMSA and FRA have based the current analysis on the Energy Information Administration's (EIA) crude oil production forecast.

The low range forecast used by PHMSA and FRA has carloads roughly 20 percent lower than the high range estimate presented in this document. Commenters criticized this forecast as being too high as well, citing the actual carloads transported in 2016. One of the commenters suggested that the use of a timeframe for establishing a boom and bust forecast could be improved because there is no way of knowing how long the current crude oil trough might last. PHMSA and FRA agree that there is uncertainty in this estimate as well, however; we believe that this forecast is a reasonable scenario. One commenter filed favorable comments regarding the boom and bust cycle forecasted.

Commenters also noted that increased pipeline capacity and access to the Bakken may be another reason that PHMSA and FRA overestimated future carloads. PHMSA and FRA presented a lower carload forecast in section 13.1 – the sensitivity analysis section – that forecasts further declines in carload volume to approximately 50 percent of our highest carload forecast. We explicitly stated that the intent of using this forecast was to capture a scenario in which an increase in pipeline capacity or other factors could further limit the carloads of crude oil transported by rail.

As discussed below, another commenter stated that PHMSA and FRA may have overestimated historic carloads because of double counting shipments in the waybill sample. PHMSA and FRA re-examined their sampling technique and concluded that the methodology for extracting the data was appropriate and the estimates obtained are accurate.

In summary, PHMSA and FRA evaluated ECP brake technology over a range of crude and ethanol carloads. These forecasts included a wide range of carloads over a 20-year analysis period. The carloads ranged from over 1 million carloads, in our highest carload forecast, to below 600,000 in the sensitivity analysis. The benefit cost ratio is roughly equivalent for the central and lower carload forecasts, and also for the high carload forecast scenario, if High Consequence Event (HCE) benefits are excluded, indicating that while benefits fall as carloads fall, costs drop commensurately. The forecast scenarios considered by PHMSA and FRA encompass a wide range and given the fact that benefit cost ratios are relatively stable throughout that range, PHMSA and FRA do not believe that another forecast scenario would change the conclusion of this analysis.

II. Waybill Sample

One of the commenters noted that carload moves are sometimes reported on more than one waybill which could result in double counting. However, each waybill record includes enough information to identify duplication. PHMSA and FRA found that between 2 and 3 percent of carloads could have been double counted; however, most of the possible duplicate records were eliminated from the sample because the Standard Transportation Commodity Code (STCC) from the waybill did not match. Therefore, PHMSA and FRA are confident that the estimate provided in the proposed RIA is valid.

For additional clarity on our methodology, PHMSA and FRA used the standard Surface Transportation Board (STB) 2016 Quarterly Waybill Sample (Sample) to estimate the rail tonnage at each link on the North American Rail Network. The agencies used a subset of the Sample developed by the STB for the Department of Energy (DOE) to estimate the crude and ethanol tonnage traversing each link of the rail network for comparison to all rail tonnage.[19] The agencies found that 62 percent of all rail tonnage shares track with HHFUTs.

III. Effectiveness Rate

PHMSA and FRA received comments regarding inaccuracies in Table 10.2a of the revised RIA. In the proposed revised RIA, PHMSA and FRA failed to update the volume weights to include 2015 and 2016 spill volumes, resulting in an incorrect effectiveness rate. PHMSA and FRA recalculated the *Total Spill Volume* and *Share of Total Volume* for Table 10.2a with information provided during the public comment period, to ensure that the spill volumes for 2015 and 2016[20] were included. In reviewing the public comments, PHMSA and FRA discovered that there was a transcription error in the effectiveness rate for derailments that occurred at 35-44 mph. This transcription error was corrected and resulted in a further reduction in the ECP effectiveness rate. The adjustment of the total spill volume and ECP effectiveness rate (35-44 mph), reduced the overall ECP effectiveness rate from 15.5% to 14.0%. The adjusted values can be found in Table 10.2a below.

IV. Derailment Rate

One commenter stated that PHMSA and FRA “selectively considers incident data from 2015 and 2016” when calculating derailment rates, thereby overestimating the likelihood and severity of future derailments. They stated that those years saw significant increases and improvements in rail safety, with lower average spill sizes, lower speeds, and lower resulting cumulative ECP brake effectiveness rates. PHMSA and FRA have examined the calculations to derive both the

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[19] One month after the end of each quarter, the Surface Transportation Board develops a customized version of the confidential Quarterly Waybill Sample for DOE which includes petroleum and all other energy products moving by rail. Unlike the standard Quarterly Sample, the DOE version includes STCC. FRA used the STCC codes listed in Table 2, page 2 of “U.S. Energy-by-Rail Data Methodology” prepared by the U.S. Energy Information Administration, the statistical and analytical agency within DOT. See https://www.eia.gov/petroleum/transportation/methodology.pdf.

[20] Tank cars involved in 2016 derailments would include a higher number of CPC1232 tank cars which would result in fewer spills. This has been reflected in the ECP Effectiveness rate.

derailment rate and average spill size associated with mainline incidents. For this final 2017 RIA, PHMSA and FRA fully incorporated data from 2015 and 2016 (in addition to 2014 incidents, which were excluded from the 2015 final rule RIA because data for some incidents was still preliminary) into the calculations that produced the derailment rate of 0.007391 derailments per thousand carloads shipped, and the average spill size of 71,358 gallons. However, the more recent incidents were only partially incorporated into the calculations that generate ECP effectiveness rates because many of the incidents involve CPC1232 tank cars and therefore are not indicative of the spill rate for DOT-111 tank cars, but this has been addressed in the Effectiveness Rate section above.

V. High Consequence Events

Two commenters suggested that PHMSA and FRA overestimated the number of high consequence events. The Railway Supply Institute claimed that it is unlikely that four high consequence events (HCE) will occur. One commenter argued that PHMSA and FRA should have downward adjusted the central estimate of HCEs from two. No additional information or data was provided to substantiate their claim. PHMSA and FRA agree that there is a high degree of uncertainty regarding how many HCEs might occur. It is important to note that our assumption of the most likely number of HCEs was two, and that four HCEs represents the upper bounds used in the Monte Carlo Analysis. The agencies based an upper bound of four HCE on the comparison of the carload forecast under the Final Rule and the current upper end carload forecast. HCE damages are only used for our highest end benefits calculations, and basing the HCE rate on this forecast is reasonable given that it is only this forecast that incorporates HCE damages into the analysis. PHMSA and FRA believe the central figure of two is reasonable in the context of the high carload forecast volumes. Although the commenter questioned that number they did not provide a rationale on which to base a different number.

VI. Cost Per Gallon Spilled

One commenter stated that the cost per gallon spilled should have been updated from the value used in the 2015 RIA. They argue that the crude oil fleet has improved significantly and crude oil shipments have declined while ethanol shipments may continue to increase as a result of renewable fuel standards. The commenter did not suggest an alternate figure or cite to any new research that might legitimize a different value. PHMSA and FRA continue to maintain that $200 is a reasonable value to monetize these incidents.

VII. Benefits

PHMSA and FRA received comments regarding the benefit implementation schedule, specifically stating that it was impractical that railroads would be able to meet the implementation schedule due to a lack of available supply of ECP brake equipment. As outlined in the 2015 RIA, PHMSA and FRA believe that the manufacturers ECP brakes systems could ramp up their production in order to meet the demand for ECP brakes for the given implementation period.

PHMSA and FRA received comments concerning the estimates for some business benefits, such as set-out relief and wheel wear, stating that the estimated benefits were too high. PHMSA and FRA reduced the business benefits in the 2015 final rule RIA in accordance with public comments at the time. This resulted in a reduction of approximately 75 percent of business benefits when compared to the proposed? 2015 RIA. The public comments regarding the business benefits being overinflated cited that, during testing, railroads experienced higher cycle times as well as higher wheel wear. PHMSA and FRA believe that as railroads train more employees and incorporate ECP brakes into their fleet, they will begin to experience the business benefits. To take this comment into account PHMSA and FRA removed any benefits from the first year (2018) and instead started benefits in year two (2019). This would provide a full year of implementation prior to benefits being realized. The removal of benefits from year one can be seen within the benefit section (Section 10) below.

Other comments pointed out that PHMSA and FRA relied upon international operations that weren't applicable to U.S. operations and are thus misleading. PHMSA and FRA believe that the international application of ECP brakes demonstrates the effectiveness of ECP brakes. While the international applications of ECP brakes aren't exactly like U.S. operations, there are enough similarities that PHMSA and FRA believe the use of the international operation examples is appropriate.

VIII. Market Failure

A commenter stated that it is false that shippers "do not bear the costs of providing for adequate safety", and pointed out that rail shippers have regulatory obligations and that non-compliance with those requirements can carry administrative and even criminal penalties. However, PHMSA and FRA maintain that rail shippers generally do not bear the full costs of failing to provide adequate safety. If an incident occurs that results in liability, the carrier is generally held liable absent a showing of negligence on the part of the shipper. It is true that shippers can face liability for failure to comply with regulations, but that does not provide an incentive to provide a greater level of safety than the regulations require even if doing so would be economically efficient for society.

The commenter also stated that it is wrong to infer that railroads have no power to influence shipper behavior through rate setting, but PHMSA and FRA do not make that claim. Instead, PHMSA and FRA note that there may be instances where rail carriers are unable to charge a price that reflects the full private marginal cost they bear. We acknowledge that in some instances railroads charge a lower price for using equipment that is safer than what the regulations require.

IX. Cost Estimates

One commenter questioned the cost for runaround cables on locomotives. The commenter stated that it would require three runaround cables for locomotives, whereas PHMSA and FRA estimated one runaround cable per locomotive. For the purposes of this analysis, the cost was for 70 feet of cable, regardless on if it was considered one large cable or three smaller cables. PHMSA and FRA incorporated the cost of using 70 feet of cable, which would be required for a locomotive. Each 70 feet of cable was estimated to cost $1,000. Three short cables would be equal 70 feet, and would cost the same amount. Therefore, PHMSA and FRA stand by the estimate of $1,000 for runaround cables and one set per locomotive.

X. FRA Should Focus on Derailments

One commenter said that FRA should be focusing its efforts on preventing derailments instead of requiring ECP brakes. FRA has been focusing on preventing derailments through the RSAC process. Currently, there is a Track Standards Working Group and a Rail Integrity Working Group. ECP brakes will not only help to reduce the number of cars punctured after a derailment, it will also improve train handling and reduce in-train forces which likely would prevent some derailments caused by excessive draft or buff forces.

7.3 Response to NAS Report

In accordance with the FAST Act, PHMSA and FRA entered into an agreement with NAS to evaluate and test the effectiveness of ECP brakes. In October of 2017, NAS reported the following:

"The committee is unable to make a conclusive statement about the emergency performance of ECP brakes relative to other braking systems on the basis of the results of testing and analysis provided by DOT."

PHMSA and FRA caution that this NAS statement about the inability to reach a conclusion about the relative effectiveness of ECP brakes should not be misinterpreted as a definitive statement on the relative effectiveness of ECP brakes. In the sections below, PHMSA and FRA have responded to several of the comments provided within the NAS report.

I. Model Validation

One of the main comments from NAS pertained to the Sharma model and the validity of that model. Overall, NAS stated that the Sharma model lacked sufficient model validation and excluded variables that could explain the severity of derailments. The Sharma model that was used in the analysis does not attempt to determine the number of punctures for a specific derailment type but rather estimates the relative benefit of ECP brakes when compared to conventional braking.

Model validation efforts need to consider the purpose of the model and how the results from the model will be used; the intent of the model was to evaluate the relative risk reduction from various design or operational mitigating strategies, and not to capture the specifics of an individual derailment. Thus, the ability of the model to reconstruct a specific accident is not necessarily a good measure of its validity to predict overall risk reduction. Expectations that validation of the methodology require high fidelity simulations of specific derailment events are unreasonable and not relevant to the ability of the model to estimate the relative risk reduction resulting from various mitigation strategies. In general, risk models are focused on estimating the global risk reduction offered by specific changes, not on how a specific event would be affected, and PHMSA and FRA's model has a similar goal.

Nonetheless, comparison of relevant outputs from the model to the accidents such as the one at Aliceville showed the reliability of the model. The presence or absence of 3-D terrain elements does not automatically validate or invalidate a model. The effect of terrain on a derailment is to alter some of the derailment energy and to thus affect the forces experienced during such a derailment. The distance traveled by the last locomotive, the number of cars derailed, and the number of cars punctured compared well between the model and the derailment for the Aliceville incident.

The validity of the model does not rest on the accurate simulation of one specific incident (such as Aliceville). Considering derailment data from the FRA derailment database (covering several hundred incidents) as well as derailment data from unit tank car trains carrying hazardous materials, the model accurately tracks the mean and distribution of the number of cars derailed and number of punctures as a function of speed or car design.

In addition to the review of car derailment and car puncture data, several other elements of the DOT methodology addressing model confidence were also studied (outlined in the updated letter report), including:

- Confidence in the input parameters
- Confirmation that the trends of model prediction are in line with expectations
- Comparison with other studies

These efforts further confirmed PHMSA and FRA's confidence in its approach.

Furthermore, a review of the methodology used by DOT conforms to the model maturity requirements as outlined in the Sandia document that NAS referenced.[21] Based on the maturity requirements, the DOT model would qualify as at least a Maturity Level 1 and possibly as a Maturity Level 2, both of which levels would be adequate for an economic analysis.

Additional comments received from NAS discussed how the Sharma model lacked variables that could significantly contribute to tank car punctures and thus, without these variables, the reliability of the model was unknown. The NAS report suggested that PHMSA and FRA use a multivariate regression analysis to determine whether there were other variables which had been excluded from the Sharma model, including terrain, that would affect the relative performance of ECP brake systems. PHMSA and FRA decided not to include terrain in its this regression analysis because we do not believe that terrain would affect the relative performance of ECP brake systems over other braking systems and thus that terrain need not be considered in the Sharma model. Moreover, data on terrain in our incident history is not readily available and would be difficult to ascertain after an incident took place. The extensive matrix of over 370 simulations showed that the variety of pileup configurations, number of cars derailed, and the number of punctures introduced a comparable measure of randomness to the methodology.

[21] More information regarding the Maturity Levels of models and how they are determined can be found here: http://prod.sandia.gov/techlib/access-control.cgi/2015/157455.pdf

Results showed that the spread in the number of cars derailed and in the number of punctures reasonably represented the spread of variation seen in real life.

A review of results from the PHMSA and FRA simulations show that the methodology accurately captures the risk reduction resulting from increasing shell thickness and the risk reduction from lower operating speeds, both without explicit modeling of 3D terrain elements. The effect of ECP brakes is essentially to alter the speed profile of a given derailment by a few mph.

Additional details about the multivariate analysis can be found in the 2017 Letter Report which has been placed in the docket.

PHMSA and FRA stand by the variables that were used within the model as the inclusion of the 3-D features, such as terrain, are not necessary to provide physics based estimations. Even today, brake systems are designed and validated using scalar and 1-D systems. Therefore, the inclusion of 3-D features should not be the deciding factor when it comes to the validation of a model.

II. Issues with the Simulations

PHMSA and FRA received comments from the public and NAS regarding how, given the limited number of simulations that were run, no statistical significance could be gained from any simulation results. PHMSA and FRA disagree with these comments. The simulations are statistically valid. For the updated RIA, PHMSA and FRA ran more than 370 simulations, with each simulation having multiple iterations, using various speeds, brake systems and train lengths, as well as a variation of ground friction coefficients, track stiffness values, and lateral force values used to initiate the derailment. The 18 scenarios mentioned in the NAS report each have multiple iterations. They were conducted in addition to the other simulations that have been run and were included to assure a reasonable spread of derailment conditions in the analysis.

Both the NAS report and public comments discussed how the model simulations were not vetted by outside experts. PHMSA and FRA note that the methodology was described in several times in various public documents with sufficient detail to allow any independent expert to develop an equivalent model. Additionally, the specific inputs and their values were also supplied thus making all relevant and necessary information available to any subject matter expert. An example of this can be seen in the DOT response to the GAO audit, where DOT defined each element that was needed in order to replicate the analysis as well as provided sources within the documentation to assist in the duplication of the analysis.

8. Background

In 2008, FRA promulgated new regulations establishing a regulatory process by which railroads could implement ECP brakes (49 CFR part 232, subpart G). FRA initiated the rulemaking in response to a petition for rulemaking from BNSF Railway (BNSF) and Norfolk Southern (NS). The ECP brake regulations incorporate by reference AAR’s 2007 ECP brake standards developed by its standards-making body. In July 2014, AAR updated its ECP brake standard to resolve issues identified during ECP operations and improve the standard. Also in 2014, BNSF and NS began moving forward with a pilot program waiver that allowed the two carriers to jointly operate an ECP-equipped train up to 5,000 miles between brake inspections.[22]

On March 9, 2011, AAR, on behalf of its members and its Tank Car Committee (TCC or Committee), jointly petitioned PHMSA and Transport Canada (TC) to establish new standards for DOT Specification 111 tank cars used to transport hazardous materials in packing groups I and II. The petition (P-1577), which was an outgrowth of a TCC executive working group, proposed new design standards and specifically recommended no modification for existing tank cars. AAR agreed to forward the petition to PHMSA on behalf of the TCC because of the Committee's unanimous decision.

On May 10, 2011, FRA met with the Railway Supply Institute's (RSI) Tank Car Committee to discuss improvements to tank cars used for the transportation of crude oil in unit trains. FRA requested this meeting to discuss improvements to tank car safety specific to crude oil given the increase in the demand for these cars at the time. The main intent of the meeting was to spur discussion about innovative solutions that improve tank car safety for future changes in the hazardous materials transportation supply chain. The advent of increased shipments of crude oil in unit train quantities provided an avenue to discuss safety enhancements prior to a major tank car build. FRA suggested several potential safety enhancement technologies such as spray-on thermal protection, manway redesign, and tank car design improvements (rounding edges of components) for consideration by the tank car builders/owners.

The meeting resulted in the RSI members offering to develop an industry standard (non-regulatory) in collaboration with the AAR, the Renewable Fuels Association (RFA), Growth Energy, and the American Petroleum Institute (API). This collaborative effort was conducted through TCC's Task Force T87.6.

The T87.6 Task Force carried out technical analyses and generated information for tank car safety improvements, including findings on alternative brake propagation systems. The advanced brake signal propagation systems considered in the T87.6 Task Force meetings included conventional air brakes, ECP brakes, distributed power (DP) systems, and two-way EOT devices.

Informed by FRA's 2008 rule on ECP braking systems,[23] the task force at that time estimated unit costs for ECP to be $4,500 per car for new construction with an overlay (dual-use) system, $5,000 per car for retrofit with an overlay system and $44,000 per locomotive.

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[22] Notwithstanding AAR's alternative assertions in response to the new ECP brake requirement for HHFUTs, the carriers' petition for rulemaking and subsequent pursuit of the waiver in 2014 provides some evidence that until recently they considered ECP brake systems safe and reliable for use in U.S. rail transportation. Otherwise, they would not have pursued a regime that would allow for fewer inspections of ECP-equipped trains during the development of the 2008 rule and in its 2014 waiver petition, which would need to be justified with data from the pilot program. FRA currently allows brake inspections to take place every 3,500 miles on ECP-equipped trains instead of the traditional 1,000 miles or 1,500 miles for long haul trains operating with pneumatic brakes. See 49 CFR 232.607.

[23] For the FRA Final Rule, https://www.federalregister.gov/articles/2008/10/16/E8-22549/electronically-controlled-pneumatic-brake-systems

Based on the simulation results and analysis of the data the Task Force concluded that the alternatives considered provided marginal benefits. Moreover, the identified obstacles to implementation represented a considerable time and cost investment and the predicted benefits would not be realized for months or years in the future. As such, the task force did not make a recommendation related to alternative brake signal propagation systems.[24]

In the September 6, 2013, ANPRM, PHMSA specifically requested comments pertaining to advanced brake signal propagation systems (ECP brakes, DP systems, and two-way EOT devices) to reduce the number of cars and kinetic energy associated with derailments. In addition, FRA and the Railroad Safety Advisory Committee (RSAC) have considered and evaluated the usefulness of advanced brake signal propagation systems.

On August 1, 2014 DOT issued an NPRM titled "*Enhanced Tank Car Standards and Operational Controls for High-Hazard Flammable Trains.*" This NPRM reviewed, and when relevant, incorporated comments received in the ANPRM. DOT also requested additional comments pertaining to the advanced brake signal propagation systems.

On May 8, 2015, a Final Rule was issued. The revisions made between the NPRM and Final Rule relied heavily on the comments received after the publication of the NPRM. For a detailed description of the comments and the changes made, please see the Final Regulatory Impact Analysis for *Enhanced Tank Car Standards and Operational Controls for High-Hazard Flammable Trains.* This analysis has been placed in the docket.

While the Final Rule established a requirement to implement ECP brake systems for certain operations, DOT recognizes that the railroad industry may develop a new brake system technology or an upgrade to existing technology that is not addressed in 49 CFR part 232, subparts E (for two-way EOTs) and G (for ECP braking systems). That rule was not intended to "lock in" the status quo with respect to ECP braking systems as the only form of brake system that can be used on unit trains operating in excess of 30 mph while transporting 70 or more loaded tank cars of flammable liquids. If a new technology were developed, railroads were directed to apply to FRA to obtain special approval for the technology pursuant to part 232, subpart F.

Through these efforts, FRA and DOT have gathered information from multiple sources and conducted extensive research to better understand the effect on energy dissipation and train stopping distance of different brake signal propagation systems.

8.1 Description of Braking Systems

A two-way EOT device includes two pieces of equipment linked by radio that initiate an emergency brake application command from the front unit located in the controlling locomotive, which then activates the emergency air valve at the rear of the train. The rear unit of the device

[24] T87.6 Task Force Summary Report, PHMSA-2012-0082-0012, http://www.regulations.gov/#!documentDetail;D=PHMSA-2012-0082-0012

sends an acknowledgment message to the front unit immediately upon receipt of an emergency brake application command. A two-way EOT device is more effective than conventional brakes because the rear cars receive the emergency brake command more quickly.

Distributive Power (DP) is a system that provides control of a number of locomotives dispersed throughout a train from a controlling locomotive located in the lead position. The system provides control of the remote (rearward) locomotives by command signals originating at the lead locomotive and transmitted via radio to the remote locomotives.

ECP brake systems simultaneously send a braking command by electric train line signal (wire) to all cars in the train, reducing the time before a car's pneumatic brakes are engaged, compared to conventional brakes. The system also permits train crews to monitor, in real time, the effectiveness of the brakes on each individual car in the train and provides real-time information on the performance of the entire braking system of the train. ECP brake system technology also reduces the wear and tear on brake system components and can significantly reduce fuel consumption.[25] All cars in a train must be equipped with wiring that allows the ECP brake signal to be relayed through the entire train before a train can operate in ECP brake mode.

Braking systems reduce kinetic energy and therefore help prevent and mitigate the effects of train accidents. FRA has conducted research on the effectiveness of advanced brake signal propagation systems, which provide improved brake signal propagation time. PHMSA and FRA used that research to inform the need for advanced brake signal propagation systems requirements, particularly on longer, heavy trains carrying large quantities of flammable liquid when issuing the Final Rule in 2015.

8.2 Fleet Forecast

Since publishing the Final Rule in 2015, the price of crude oil has fallen and the production of Bakken crude oil has decreased. PHMSA has provided new estimates for the projected number of carloads of crude and ethanol over the 20-year analysis. These estimates are presented below and are based on two different methodologies for forecasting crude oil shipments by rail, to capture some degree of uncertainty regarding future volumes of crude oil transported by rail; and a single methodology for ethanol.

For the 2015 Final Rule, DOT made minor adjustments to a forecast submitted as part of the Railway Supply Institute's (RSI) comments on HM-251 NPRM.[26] For this revised analysis, DOT did not receive new data from RSI on the expected growth in the number of tank cars needed to transport crude oil.[27]

PHMSA and FRA therefore reverted to the methodology as used in the HM-251 NPRM to forecast crude oil and ethanol, which involved a simple regression of waybill carloads for each

[25] These are explained in Section 11.6 and 11.7.
[26] See comments from the Railway Supply Institute to the HM 251 docket, specifically Exhibit B4 without regulation scenario. Available online at https://www.regulations.gov/docket?D=PHMSA-2012-0082.
[27] RSI does not generally forecast demand for crude oil, but did so as a comment after the publication of the NPRM.

commodity against domestic production estimates presented by the Energy Information Administration (EIA).[28] For crude oil, the off shore and Alaska production figures were subtracted from total U.S. oil field supply data to obtain lower 48 on shore production estimates. For Ethanol, U.S. production estimates were converted from thousands to millions of barrels to put them in the same units as forecast values. PHMSA used estimated production data from 2010 – 2016, found in the footnoted links, and the Annual Energy Outlook lower 48 on shore production forecast for future years. The results of this estimation were then applied to the AEO reference case forecast from AEO 2017 to obtain a forecast carload volume for each commodity.

PHMSA and FRA also applied an alternative methodology for forecasting crude oil shipments using a flat average projection for crude oil. This method assumes that crude-by-rail volumes follow a boom and bust cycle as has been observed over the past half-decade. Rail can access new oil fields or new sections of oil fields faster than pipelines, and PHMSA and FRA reasonably assume that what may drive crude oil by rail volumes is a short-term spike in volume as new oil fields open and are served by rail, followed by a tapering off as pipeline infrastructure is built out to service those fields at a lower transportation cost. Thus, crude-by-rail volumes may exhibit peaks and valleys, but over time these peaks and valleys largely cancel one another out and it is not possible to perfectly predict when they may occur. However, an average that includes both peaks and valleys would provide a reasonable expected volume in any given year. This methodology results in a forecast using a constant annual crude oil projection for all years from 2017-2037.

For the alternate volume forecast, PHMSA and FRA estimated expected annual volume by averaging the past 5 years for which waybill data is available – 2012 through 2016. This average includes one peak surrounded by valleys in 2012 and 2015-16. This alternate forecast for crude oil is added to the ethanol forecast to get a total carload forecast for high volume flammable liquid shipments. The results of the linear models and the data used to estimate them are presented in Appendix C. The raw waybill data for crude oil and ethanol, and forecast carloads through 2037, are presented in Table 6.2a below.

[28] EIA U.S. crude oil production estimates can be found at: https://www.eia.gov/dnav/pet/pet_crd_crpdn_adc_mbblpd_a.htm. Ethanol production estimates are found at: https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=M_EPOOXE_YNP_NUS_MBBLD&f=A

Table 8.2a: Carload Forecast

	Linear Model for Both Commodities			5 Year Average for Crude	
Year	**Crude Carloads**	**Ethanol Carloads**	**Total**	**Crude Carloads**	**Total**
2010	34,776	411,863	446,639	34,776	446,639
2011	65,596	409,429	475,025	65,596	475,025
2012	237,932	369,082	607,014	237,932	607,014
2013	454,873	373,887	828,760	454,873	828,760
2014	576,581	388,929	965,510	576,581	965,510
2015	525,231	488,620	1,013,851	525,231	1,013,851
2016	292,767	486,470	779,237	292,767	779,237
2017	415,064	459,467	874,530	417,477	876,944
2018	482,597	467,034	949,631	417,477	884,510
2019	520,761	465,773	986,534	417,477	883,250
2020	543,638	461,873	1,005,511	417,477	879,350
2021	564,779	456,583	1,021,362	417,477	874,060
2022	583,678	453,636	1,037,314	417,477	871,113
2023	595,880	451,559	1,047,439	417,477	869,035
2024	608,393	450,696	1,059,089	417,477	868,173
2025	621,076	449,205	1,070,282	417,477	866,682
2026	634,541	443,070	1,077,612	417,477	860,547
2027	640,204	440,047	1,080,251	417,477	857,524
2028	646,799	439,556	1,086,355	417,477	857,033
2029	655,008	438,288	1,093,297	417,477	855,765
2030	659,660	438,112	1,097,772	417,477	855,588
2031	659,453	428,423	1,087,876	417,477	845,900
2032	655,793	424,059	1,079,852	417,477	841,536
2033	640,800	424,089	1,064,889	417,477	841,566
2034	640,099	424,089	1,064,188	417,477	841,566
2035	636,982	424,089	1,061,071	417,477	841,566
2036	643,613	424,088	1,067,701	417,477	841,565
2037	647,297	423,491	1,070,787	417,477	840,967

Values for 2010 through 2016 are taken from the Waybill Sample while 2017 through 2037 are forecasted values.

The new predictions at the low and high range are lower than what was presented in the RIA accompanying the Final Rule in 2015. DOT believes these variations are due to changing market conditions and the drop in crude oil production over the past two years.

8.3 Unit Trains (HHFUTs)

The Final Rule requires the use of ECP brakes only on certain long unit trains of Class 3 flammable materials, classified as HHFUTs operating at greater than 30 mph. An HHFUT is any train comprised of 70 or more loaded tank cars containing class 3 flammable liquids. This maximizes the return on investment for ECP brakes, as only tank cars that are regularly used in unit trains will be equipped with them. The 70-car threshold should exclude manifests made up of mixed freight trains hauling ethanol and focus only on traditional unit trains of both commodities. Under the Final Rule, the mandate for operating HHFUTs with ECP brakes is effective January 1, 2021 or May 1, 2023, depending on the consist of the train. (If there are one or more tank carloads of Packing Group I flammable liquids, the earlier date applies.)

8.4 Crude Oil Traffic

For the low range, crude oil shipments are constant over the entire 20-year period at an estimated 417,477 carloads per year. For the high range, the peak crude oil carload count occurs in 2030, with an estimated 659,660 carloads. The sensitivity analysis considers a continued decline in crude by rail volumes with constant shipments of 120,000 carloads per year after 2020.

DOT estimated that 84 percent of crude oil shipments traveled in unit trains, traveling from the loading facilities to the oil refineries and back. This estimate remains unchanged from the Final Rule RIA and was developed using the Waybill Sample. The experience of FRA's regional staff is that substantial quantities of crude oil and ethanol are currently being transported in unit trains, and many companies advertise the transportation of these commodities as being shipped in unit trains. For the low range, applying the 84% estimate leads to 350,681[29] projected carloads for HHFUTs. For the high range, applying the 84% estimate leads to 554,114[30] projected carloads for HHFUTs in the 2030 peak year.

8.5 Ethanol Traffic

DOT estimated the low and high ranges for total carloads. Ethanol traffic has historically been stable and therefore remained the same in both estimates. For the low range, the peak year for total carloads (both crude and ethanol traffic) is 2018, which corresponds to an estimated 467,034 carloads of ethanol. For the high range, the peak year for total carloads is 2030, which corresponds to an estimated 438,112 carloads of ethanol. After discussions with ethanol stakeholders and FRA regional staff, in conjunction with data from the Waybill Sample, PHMSA and FRA believe that 47 percent of ethanol travels by unit trains. In the peak carloads year for the low range, there would be 219,506[31] ethanol carloads for HHFUTs. In the peak carloads year for the high range, there would be 205,912[32] ethanol carloads for HHFUTs.

[29] 417,477 (carloads of crude) * 0.84 (proportion of carloads on unit trains) = 350,681 (carloads of crude on unit trains)
[30] 659,660 (carloads of crude) * 0.84 (proportion of carloads on unit trains) = 554,114 (carloads of crude on unit trains)
[31] 467,034 (carloads of ethanol) * 0.47 (proportion of carloads on unit trains) = 219,506 (carloads of ethanol on unit trains)
[32] 438,112 (carloads of ethanol) * 0.47 (proportion of carloads on unit trains) = 205,912 (carloads of ethanol on unit trains)

8.6 Utilization Rates for HHFUT

In this analysis, PHMSA and FRA estimated it would take about 16 days for an HHFUT to travel from pickup point to destination and back. This is above the average days seen in research and in discussions with various stakeholders.

For the low range, assuming a cycle time of 16 days for HHFUTs, the rail industry would need:

- 20,039[33] tank cars to annually transport 350,681 carloads of crude traffic; and
- 12,543[34] tank cars to annually transport 219,506 carloads of ethanol.

For the high range, assuming a cycle time of 16 days for HHFUTs, the rail industry would need:

- 31,664[35] tank cars to annually transport 554,115 carloads of crude traffic; and
- 11,766[36] tank cars to annually transport 205,912 carloads of ethanol.

8.7 ECP Efficiencies

Certain business benefits were discussed and monetized in terms of labor cost savings in the RIA accompanying the Final Rule in 2015. For instance, it was estimated that fewer brake tests would be required, resulting in labor time savings. FRA regulations allow ECP-equipped trains to have a Class IA brake inspection every 3,500 miles, as opposed to every 1,000 or 1,500 miles required for other conventionally braked trains. However, PHMSA and FRA did not take into account a higher equipment utilization rate or increased capacity provided by unit trains operating in ECP brake mode. According to subject matter experts, PHMSA and FRA estimated that each brake test would take an hour to complete.

Modern conventional air brake valves are fast-acting and sensitive. However, in cold weather, zero degrees Fahrenheit or below, the rubber seals between the air hoses of conventional brakes can shrink, creating excessive brake pipe leakage and higher air flow rates. As a result, braking response can be erratic from increased leakage in long trains during cold weather. To compensate, most railroads, including Class I railroads, operate shorter trains in this inclement weather to manage the excessive leakage and still be able to pass a Class I brake test. These trains can be shortened between 25-30 percent. Since ECP brakes do not depend on the modulation of brake pipe pressure to send the brake propagation signal, ECP brakes would support safer operation of longer trains in cold weather conditions where brake pipe pressure is harder to maintain on conventional brake systems. FRA assumes this would be common in very cold climates—like those in North Dakota—where a significant amount of the crude oil carloads

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[33] Calculation: 417,477 (crude carloads in peak year for all carloads) * 0.84 (proportion of crude hauled on unit trains) ÷ 280 (operating days per year) * 16 (days per cycle) = 20,039

[34] Calculation: 467,034 (ethanol carloads in peak year for all carloads) * 0.47 (proportion of ethanol hauled on unit trains) ÷ 280 (operating days per year) * 16 (days per cycle) = 12,543

[35] Calculation: 659,660 (crude carloads in peak year for all carloads) * 0.84 (proportion of crude hauled on unit trains) ÷ 280 (operating days per year) * 16 (days per cycle) = 31,664

[36] Calculation: 438,112 (ethanol carloads in peak year for all carloads) * 0.47 (proportion of ethanol hauled on unit trains) ÷ 280 (operating days per year) * 16 (days per cycle) = 11,766

originates. Railroads would benefit from using ECP brakes because they will be able to maintain normal train lengths, reducing the need for additional tank cars and train sets.

ECP braking also improves the handling of longer trains. Maximum train length would become a function of available power (locomotives) and siding lengths. FRA has informally surveyed its regional staff to determine the average length of crude oil unit trains and found that a number of the unit trains contained 120 tank cars or more. FRA believes that the rail industry will increase train length when operating in ECP brake mode. Increasing the average train length from 100 tank cars to 120 tank cars equates to a 17 percent reduction in the number of trains required to move the same number of carloads. This reduction of trains could enhance safety as there would be fewer derailments.

Current FRA regulations, due to the real-time equipment health monitoring requirements of AAR standard S-4200 in ECP-equipped locomotives, permit trains to operate with a minimum of 95 percent of brake operative at the initial terminal inspection of the train. This allows defective cars to be retained in the unit train until it reaches its destination and/or a prime repair location. The existing ECP regulations also permit defective equipment discovered en route to be hauled to the train's destination or a prime repair location before being repaired. Trains with conventional brakes are statutorily permitted to haul a car with defective brakes only to the nearest location where the necessary repairs can be made. This can result in long distance trains stopping while in transit to set-out defective equipment. Each of these stops can result in hours of delay. These delays are avoided by trains operating with ECP brake systems.

AAR currently specifies a 12.0 percent brake ratio;[37] however, AAR allows trains using ECP brakes to increase the brake ratio to 14.0 percent. This increased brake ratio plus the addition of graduated release with ECP brakes will allow trains to keep an optimal speed because with graduated release the locomotive engineer can ease off the brakes instead of releasing and reapplying brakes as required to reduce a brake effort under conventional braking.

PHMSA and FRA have reviewed reports and other research on the efficiency rate of ECP brakes. Stakeholders have indicated that that a reduction in equipment used can be seen between about 5 -15 percent. A 2006 report by Booz Allen Hamilton[38] discussed this topic. This report was cited in FRA's 2008 ECP brake rule noting, "[t]his, in combination with the reduced wait time . . . has reduced cycle time experienced during ECP brake domestic initial implementation ranges from a low of 14 percent to a high of 33 percent."

In a BNSF analysis[39] of its coal operations, it was reported that it experienced a 5-10 percent reduction in its car fleet on trains equipped with ECP brakes. Another report[40] from 1999 noted that the Quebec Cartier Mining Company had seen an increase of 14 percent in the average tonnage per train compared to conventional trains with the same horsepower of locomotives.

[37] The brake ratio is the power of a full brake application of a car (or locomotive) divided by the weight of the car.
[38] 'Benefit-Cost Analysis and Implementation Plan for Electronically Controlled Pneumatic Braking Technology in the Railroad Industry,' Booz Allen Hamilton, August 2006, p. II-6.
[39] Maryott, D. 2008. ECP Perspectives. Proceedings of the 100th Annual Convention and Technical Conference, pp.57-62 Chicago, IL: Air Brake Association
[40] McLaughlin, B. 1999 EP-60 ECP train Operation Data at Quebec Cartier Mining. Proceedings of the 91st Annual Convention and Technical Conference, Chart 2. Chicago, IL: Air Brake Association

With ECP as the only contributing factor to improved efficiencies, this would, allow railroads to have 14 percent fewer cars to provide the same service as was rendered. Even though the rail network has more capacity in the United States, these efficiencies would still be expected to result, as they are based on cycle times.

In a public hearing[41] on October 19, 2007, Mike Iden, a general director for the Union Pacific Railroad, presented a graphic example of the potential efficiencies of ECP brakes. In this example, he cited a UPS test train that traversed the country from New Jersey to California. In order to meet the schedule with conventional brakes, a special 75 mph speed limit was required. Mr. Iden pointed out that with the regulatory relief from inspections a minimum of two hours could be saved from each origin to destination. ECP would allow UPS to meet the same transportation time from origin to destination traveling at a 70-mph speed limit which would not only save fuel, but also reduce congestion caused by overtaking slower trains. He states in this hearing, "[m]y comments today will be focused not only on how ECP brake technology may impact the business of railroading but also on how ECP braking could be a positive factor for future railroad capacity."

On June 15, 2010, Jim Forrester, Manager Equipment Planning and Business Development for Norfolk Southern's Coal Business Group, presented a paper[42] to the National Coal Transportation Association to update it on NS's ECP brake pilot project. In this report, he concluded that through direct testing comparing conventional trains and ECP-equipped trains (both would have dynamic braking) that ECP-equipped trains experienced a reduction in dwell time, ECP-equipped trains operated at track speed for longer periods of time, ECP-equipped trains were able to better control their speed, and ECP-equipped trains had faster loading processes and better car loading performances. On moderate grades, ECP-equipped trains stopped 33 percent faster and returned back to track speed 25 percent sooner. On heavy grades ECP-equipped trains stopped 50 percent faster and returned to track speed 97 percent sooner (as the hand brakes did not need to be applied to recharge the air brakes, as required on a conventionally braked train).

Based upon this and other anecdotal evidence PHMSA and FRA determined that ECP brakes will deliver a 5-15 percent reduction of equipment used. PHMSA and FRA used a utilization rate of eight percent for crude oil.[43] As the ethanol HHFUT are only 47 percent of the total ethanol fleet, PHMSA and FRA are estimating a 5 percent[44] utilization rate. Again, this percentage is appropriate as some studies have shown a much more significant reduction in the amount of equipment required.

Low range

[41] United States Department of Transportation, Federal Railroad Administration. Public Hearing on Electronically Controlled Pneumatic Brake Systems. October 19, 2007. Rosemont, Illinois.
[42] Forrester, J. 2010. Norfolk Southern ECP Brake Pilot Project Update. National Coal Transportation Association. Coeur d'Alene ID.
[43] This is the same utilization rate that was used in the final rule RIA. See page 235 of that RIA for further discussion.
[44] The amount of crude oil shipped in unit trains is 84 percent. With only 47 percent of the fleet in unit train service you may lose some of the efficiencies. We used an improvement that was the lowest reported, which is 5 percent.

Using an eight percent reduction from the 20,039 tank cars required for crude service, ECP braked equipment would require 1,603 fewer tank cars. Using a five percent reduction to the 13,362 tank cars required for ethanol service, ECP braked equipment would require 668 fewer tank cars.

High range

Using an eight percent reduction from the 32,599 tank cars required for crude service, ECP braked equipment would require 2,608 fewer tank cars. Using a five percent reduction to the 12,413 tank cars required for ethanol service, ECP braked equipment would require 621 fewer tank cars.

Using the low and high ranges, DOT estimates that between 2,271 and 3,229 fewer tank cars would need to be equipped over the 20-year period. These costs savings are discussed in further detail in Section 9.

The Final Rule required all HHFUTs be equipped with advanced braking systems. All HHFTs would operate with either a two-way end of train device (EOT), or distributed power (DP). In addition, after December 31, 2020, a train 1) consisting of 70 tank cars or more of flammable liquids, and 2) operating at a speed exceeding 30 mph must be operated in ECP braking mode.

8.8 Dynamic Braking

Dynamic braking is not a substitute for train air brakes (electronically controlled or otherwise), but a supplementary system that provides an additional means of train-speed control.

The ability to use ECP brakes on top of the dynamic brakes further improves fuel efficiency by as much as five percent compared to using dynamic braking alone, depending on the routes and railroad practices.[45] Fuel benefits are not always easy to measure and FRA believes this likely understates fuel efficiency benefits. For instance, a railroad using ECP-equipped trains may decide to trade fuel efficiency for higher average speeds or longer, heavier trains (as evidenced by the Australian experience). If that is the case, then the railroad is effectively using the potential fuel savings to pay for operational improvements—therefore the operational improvements must be worth at least as much as the potential fuel savings.

Railroads will continue to experience brake-induced wheel wear where pneumatic brakes are used, but if the railroads rely on dynamic braking they could experience increased rail wear, with the attendant increased risk of broken rail accidents and increased track maintenance costs. PHMSA and FRA estimate that the use of dynamic braking in conjunction with ECP brakes would reduce the dynamic brake induced rail wear by at least 25 percent based on Canadian Pacific's (CP) experience.[46] Further, in spite of initial increases in thermal mechanical shelling due to heavy "experimenting" by train crews during the familiarization phase, CP found a four

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[45] Wachs, K. 2011. Electronically-Controlled Pneumatic (ECP) Brake Experience at Canadian Pacific, *Presented to the International Heavy Haul Association (IHHA) Conference, Calgary, AB.,* p. 4
[46] Wachs, K.,p. 4

percent improvement in average wheel life.[47] Once operations "settle in," improvements in wheel life may reach ten percent, thus reducing the estimated wheel wear benefit by 75 percent.

ECP brakes can be operated at a steadier speed nearer the speed limit by using the graduated release feature of ECP brakes rather than applying full release and waiting for the brakes to recharge.[48] This allows for a more optimum use of dynamic brakes. Modulating the speed with ECP brakes also greatly reduces in-train forces by applying the brakes evenly through the train rather than just at the locomotive.

Further, as more employees are properly trained in using ECP brakes, railroads will begin to fully experience the maximum benefit available by using a combination of ECP and dynamic braking. This change in operating culture will take time. This is one of the reasons why any benefits associated ECP brakes on a given HHFUT are not accounted for until one year after that HHFUT is estimated to be equipped with ECP brakes. However, computer devices, such as LEADER and Trip Optimizer,[49] are proliferating within the United States rail network and permit engineers to better manage the train speed and use of braking. This promotes efficient usage of ECP brakes during the initial period when engineers are learning the new technology, and as locomotive engineers become more comfortable with this braking system, the benefits of ECP brakes blended with dynamic braking will be greater than those estimated in this analysis.

Finally, while dynamic braking has an important role in controlling the speed of modern freight trains, FRA does not consider it to be a primary braking system for the purposes of meeting the power brake requirements of 49 U.S.C. § 20302 or the requirement of 49 CFR § 232.103. These require that a primary brake be capable of stopping the train with a service application from its maximum operating speed within the extant signal spacing on the track over which the train is operating. Dynamic braking does not contribute to reducing emergency stopping distances and does not have a fail-safe element to stop the train if the integrity of the dynamic brake fails in use. Both conventional pneumatic brakes and ECP brakes meet these statutory elements.

8.9 ECP Experience in Australia and Other Countries

I. Australian Experience

In contrast to the experience in the United States, railroads in countries such as Australia have accepted this new technology.[50] Australia has been using ECP brakes on a portion of its fleet for over a decade.[51] Australia operates over 28,000 cars in ECP brake mode. The fleet Australia has been operating in ECP brake mode has many similarities to the United States' HHFUT fleet. Both fleets operate in heavy haul service, and both fleets transport commodities that are a

[47] Wachs, K., p 6
[48] Wachs, K., p. 3
[49] http://www.up.com/aboutup/corporate_info/sustainability/preserve_environment/fuel_efficiency/index.htm
[50] South Africa is another strong adopter of ECP brakes, with about 7,000 railcars equipped with ECP brake technology. It is similar to Australia in that ECP brakes are being used in heavy haul coal service where the trains operate in a continuous loop and the railroads own their own railcars for this service.
[51] "The ECP Brake—Now it's Arrived, What's the Consensus?," Sismey, B. and Day, L., Presented to the Conference on Railway Excellence, 2014, Adelaide, Australia.

substantial source of revenue for the railroad. Many stakeholders have noted that the increase in crude oil is equivalent to the mining boom in Australia. Indeed, although coal trains have traditionally been the bread and butter of railroad services, crude oil recently has become relatively more important.[52]

The 2014 Sismey and Day report identifies several bulk commodity services in Australia that have used ECP brakes since 2005 and a unit train mineral service that retrofit its trains with ECP brakes starting in 2012. The report details how the ECP brakes performed in practice, highlighting the benefits and challenges. The report concludes that the challenges experienced in practice are largely resolved and that there is a business case to expand the use of ECP brakes into intermodal service.

Australia recognizes the value of ECP brakes in conjunction with their booming mining industry, which led to railroads purchasing new cars and locomotives to support this service. Australian railroads used the opportunity to implement ECP brakes, which they believed would produce benefits in the bulk commodity services. However, in this country ECP adoption has been slow because of a perceived insufficiency of business benefits, structural issues (i.e., ownership of cars by shippers rather than railroads), and competing regulatory priorities (i.e., implementation of positive train control (PTC) requirements) have presented hurdles in voluntarily establishing the use of ECP brake technology on unit trains transporting flammable liquids.

Another major factor in the Australian adoption of ECP brakes is that railroad companies, rather than shippers, own their fleets of railcars, so the benefits and cost of the equipment are captured by a single entity, thereby avoiding the type of market failure described in Section II of this analysis. Indeed, Genesee and Wyoming Inc. (G&W), which operates lines in the United States, Australia, and Europe, has adopted ECP brake systems in its Australian operations but not the United States. There are many differences—in addition to those described above—between the types of operations G&W has in the United States versus those in Australia that inhibit G&W's ability to implement ECP brakes in its United States operations. For instance, in the United States, G&W is a shortline and regional railroad operator and would handle an HHFUT for only a small portion of its journey. As a result, its decision to equip a train with a certain type of brake is largely determined by the technology used by the interchanging Class I railroad. The G&W operation in Australia is more like a Class I railroad, and it provides an example of the benefits a carrier can attain from using ECP brakes when there is a seamless operation of a single unit train from the originating location to the delivery location while also owning the cars used in such an operation.

We also note that the largest adopter of ECP brakes in the United States is NS, which owns the majority of its coal cars. In contrast, BNSF has hauled, until recently, ECP-equipped coal cars that are leased by a shipper. BNSF and the shipper's plans to update its fifteen-year-old ECP fleet to the latest AAR S-4200 standards and an overlay system are presently on hold pending the resolution of the present rule.

[52] "Oil-by-Rail Shipments Cutting into Coal Deliveries" Cunningham, Nick Oilprice.com, 8/6/14, http://oilprice.com/Energy/Crude-Oil/Oil-by-Rail-Shipments-Cutting-Into-Coal-Deliveries.html

PHMSA and FRA researched the quantifiable benefits that Australia has experienced since implementing ECP brakes. Some of the anticipated benefits in our analysis differ from those experienced in Australia due to different operational practices. Because Australia does not have an equivalent safety regulatory body to FRA that would collect data of the safety benefits of ECP brakes, PHMSA and FRA looked to private reports that assessed the success and benefits associated with ECP brakes. The Sismey and Day report discusses the safety benefits of ECP brakes, and it appears that Australians are encouraged by those findings. The report concludes that the shorter stopping distances and real time monitoring makes them safer than conventional brakes. It specifically notes that "ECP trains can be considered safer in terms of providing real time feedback to the driver on the integrity of the train and also how many wagons are operable and enforcing a stop if the number of wagons operable reduces to less than 85%." Additionally, it notes that "[s]ome have described the shorter stopping distances as a 'get out of [jail] card' as a Signal Passed At Danger (SPAD) incident with a [Pneumatically Controlled Pneumatic] braked train would probably be avoided with an ECP braked train." Additionally, from a safety standpoint, it is ideal to have a system which will not have any brakes that become stuck to the wheel. Australian operators felt that this had been a perennial problem with conventional air brakes, but using ECP brakes had alleviated the problem. The report also detailed that the installation of ECP systems prevented the train from running if the brakes on the last car are cut-out. This is another significant safety feature of ECP brakes. These are just some examples of the safety benefits seen by the Australian carriers.

The Sismey and Day report also interviewed operators, one of whom said, "[g]raduated" release is very impressive. This and constant charging are probably the two best features of ECP." Another operator commented, "ECP braking allows (and forgives) poor or mismanaged brake applications." Anecdotally, it appears that expectations related to fuel savings in Australia have not matched the estimates used in our analysis. This is because rail carriers in Australia have traded those benefits for other operational improvements (generally higher average speeds and significantly longer trains), indicating that there is an even greater internal benefit from those operational improvements than the carriers would have experienced from reduced fuel. In this way, their estimated fuel savings could understate the benefit. When holding operational conditions constant, fuel savings are expected to be higher than what has been observed. Due to infrastructure limitations, PHMSA and FRA do not anticipate that railroads would operate crude oil or ethanol trains that exceed 140 cars. Per this rule, FRA Emergency Order 30, and the voluntary actions taken by the railroads to limit speeds, higher top speeds are generally not available as a benefit in the United States. In order to allow trains longer than that, sidings would need to be expanded which would be a significant investment. This is an example of how Australia traded fuel saving for longer trains, and explains why such an operational trade-off likely would not occur in the United States.

As mentioned above, Australian railroads have experienced the benefits of ECP brakes, and ECP brake systems have become the preferred method of operation. All new heavy-haul operations in Australia are being planned for and equipped with ECP braking. Many of the overlay systems initially installed in Australia are being replaced by stand-alone ECP brake systems, indicating that the technology is accepted, proven, mature, and effective. ECP braking has been implemented without an Australian government mandate and has been voluntarily adopted by the railroads. Although there has been a learning curve in switching from conventional braking to

ECP braking, the positive result of the Australian experience is clear evidence that ECP brake systems could be a proven and reliable option for HHFUTs in the United States.

II. South African Experience

In 2008, Transnet, South Africa's nationally owned railroad[53] began testing the feasibility of ECP brakes on its Ermelo-Richards Bay coal export line and shortly after decided to equip about 7,000 railcars and 230 locomotives with ECP brakes.[54] These 100 car coal trains operate in a 261-mile continuous loop over undulating terrain at speeds of 27-31 mph.[55] Similar to the Australians, the rail carriers in South Africa own the fleet of railcars, so the benefits and cost of the equipment are once again captured by a single entity.

South Africa began considering the use of ECP brakes as early as 2000 when a study was conducted on the improvements that ECP brakes could bring to Transnet Rail.[56] The Van der Meulen study found that ECP brakes provided shorter stopping distances when approaching signals and descending grade speeds. The typical stopping distance for ECP brakes was compared against the stopping distance of pneumatic braking. The study found that a train traveling at 28 mph on a 1.52% descending grade using pneumatic brakes had a stopping distance of approximately 4,600 feet while a train traveling at 28 mph on 1.52% descending grade using ECP brakes had a stopping distance of approximately 1,500 feet.[57] A similar decrease in stopping distance of 60 to 70 percent was found in an additional study conducted in 2001, however; the specific parameters of that study weren't detailed.[58]

In addition to the decreased stopping distance, the 2000 Van der Meulen study found that ECP lowered the car wheel temperature, when compared to pneumatic brakes. The study found that with pneumatic brakes, the average and standard deviation of the car wheel temperature was 236ºF and 91ºF while ECP brakes had an average and standard deviation of 222ºF and 69ºF. These temperature averages and standard deviations were recorded despite speeds increasing from 28 mph to 31 mph on long descending grades.[59] The decreased temperature that resulted from the use of ECP could help with reducing thermal cracks which can lead to wheel failure. A similar decrease in wheel temperature was found in a 2001 study in which the authors found that with pneumatic brakes the average and standard deviation of the car wheel temperature was

[53] "Company Overview." Company Overview. Accessed August 02, 2017. http://www.transnetfreightrail-tfr.net/Aboutus/Pages/Company-Overview.aspx.
[54] "ECP braking to Richards Bay." Railway Gazette. July 1, 2007. Accessed August 02, 2017. http://www.railwaygazette.com/news/single-view/view/ecp-braking-to-richards-bay.html.
[55] Kull, Robert C. "ECP Brake Applications on Heavy Haul Railways." Proceedings of 7th International Heavy Haul Conference. 2001.
[56] Van der Meulen, Dave, and Alan Cortie. "Evaluation of Wireline ECP braking and DP on the Ermelo-Richards Bay Coal Export Line." Railway Research. 2000. www.railcorpstrat.com/.../2000%20ABA%20Evaluation%20of%20wireline.pdf.
[57] Van der Meulen.
[58] Kull, Robert C. "ECP Brake Applications on Heavy Haul Railways." Proceedings of 7th International Heavy Haul Conference. 2001.
[59] Van der Meulen.

230°F and 105°F while ECP brakes had an average and standard deviation of 192.2°F and 69.8°F.[60]

In both the Van der Meulen and Kull studies, ECP brakes were found to decrease both the average and standard deviation of the car wheel temperatures, as well as reduce the stopping distance by 30% to 70%. The experience in South Africa further helps support the safety and business benefits that ECP brakes could bring to the railroad industry.

While the experiences in Australia and South Africa have similarities to U.S. operations, they also have differences. FRA acknowledges that in both cases, the trains in Australia and South Africa operate on a closed system however, in both the Australia and South Africa cases, the trains are operating with heavy loads and hauling a large number of cars. Even with the heavy load and large number of cars, both countries experienced a reduction in the stopping distance ranging from 30-70 percent. Furthermore, both countries continued to install ECP brakes after their trial periods, which suggests that the benefits of ECP brakes outweighed the costs to install.

9. Costs of the Rulemaking

The Final Rule established a phase-in period for ECP brake systems, with the requirement that all HHFUTs, as previously defined, be equipped with and operate in ECP brake mode on January 1, 2021, when transporting one or more tank carload of a Packing Group I flammable liquid while traveling in excess of 30 mph. All other HHFUTs were required to be equipped with and operate in ECP brake mode on May 1, 2023. This schedule is based on feedback received during the NPRM comment period and estimates based on the new/retrofitted tank cars and new locomotive construction. PHMSA and FRA believed that this schedule supports installation of ECP brakes predominantly on new equipment. However, PHMSA and FRA expect that the phase-in period will likely be pushed forward as railroads gather ECP-equipped trains in advance of the deadline. The expectation is that railroads will have an incentive to put ECP-equipped trains in service, once acquired, to take advantage of the business benefits related to operating in ECP brake mode (e.g., reduced fuel consumption, longer inspection intervals). For the purposes of this analysis, DOT is assuming that the installation of ECP brakes would begin in 2018.

PHMSA and FRA recognize that this rule will have significant costs to many entities (e.g., rail carriers, car lessors, and car owners). In the Final Rule, PHMSA and FRA tried to minimize the costs to all stakeholders by only requiring ECP brakes on HHFUTs, which was intended to ensure the highest safety and business benefits return per unit equipped.

9.1 Tank Car Costs for ECP Brakes

As previously discussed, for purposes of this updated analysis PHMSA and FRA are using an estimate of $7,800 per tank car to retrofit with ECP brakes. Currently, very few tank cars are being produced so it is assumed that all ECP tank cars will be retrofits. This assumption is further supported by the carload forecast shown in 8.2a, which shows that carloads are projected

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[60] Kull, Robert C. "ECP Brake Applications on Heavy Haul Railways." Proceedings of 7th International Heavy Haul Conference. 2001.

to stay well below the forecasted amounts in the 2015 analysis. PHMSA and FRA believe that, railroads would not need to purchase new tank cars in order to meet the peak year carloads and will instead use their existing fleet. Most new tank car orders are set for several years. Since railroads would not be able to easily add ECP onto those orders, DOT assumes that ECP installation on tank cars would solely be achieved by retrofitting.

PHMSA and FRA estimated that 32,582 tank cars would be required to have ECP brakes in the low range scenario. In the high range, 43,430 tank cars would be required to have ECP brakes. Furthermore, DOT estimates that between 2,271 and 3,229 fewer tank cars would need to be retrofitted over the 20-year period at a cost of $7,800 per tank car. In accordance with the phase-in schedule, all HHFUT's would be equipped with ECP brakes by the May 1, 2023 deadline. Using the low and high ranges, the total 20-year cost to equip these tank cars with ECP would be between $231.7 and $311.2 million discounted at 7 percent or between $243.8 and $326.2 million discounted at 3 percent.

Buffer cars are required for the transportation of these commodities by train and these buffer cars would need to work with ECP brakes. PHMSA and FRA believe that it is not cost beneficial to retrofit buffer cars with ECP brakes; however, PHMSA and FRA believe that each car would be equipped with cables that would connect the locomotives to the first tank car. This would allow the trains to operate in ECP brake mode. FRA's ECP braking systems regulations allow for only 95 percent of the train to be operating with ECP brakes, therefore; the buffer cars would not have to operate with ECP brakes. PHMSA and FRA estimate that the cables will cost $1,000 per buffer car and assume that two buffer cars per train will be used. Using the low and high ranges, between 714 and 928 buffer cars would be needed. The total cost of those additional buffer cars would be $714,000 and $928,000. Twenty-year discounted costs at 3 percent are between $683,884 and $909,799. Twenty-year discounted costs at 7 percent are between $648,352 and $866,777.

PHMSA and FRA have included costs for various components, such as batteries and electrical cables, which would need to be replaced every five years. PHMSA and FRA believe these replacements would take place during a tank car's normal maintenance services. PHMSA and FRA estimate that the batteries per tank car are $87 and that the cables that would be $300 per tank car. In this analysis, both of these components would need to be overhauled every five years, on each tank car. Using the low and high ranges, over a twenty-year period, the total cost of batteries and cable replacement is between $37.3 million and $50.0 million. Costs discounted at 3 percent over a 20-year period are between $26.9 million and $36.1 million. Costs discounted at 7 percent over a 20-year period are between $18.1 million and $24.3 million.

As discussed earlier, due to the efficiencies of ECP brakes, fewer tank cars will be needed to provide the same service. The total cost savings of ECP brakes would be between $17.7 million[61] and $25.2 million.[62] Over a 20-year period the cost discounted at 3 percent is between $15.3 million and $21.7 million. Over a 20-year period the cost discounted at 7 percent is between $12.6 million and $18.0 million.

[61] 2,271 (fewer tank cars) * $7,800 (incremental cost difference) = $17,713,800
[62] 3,229 (fewer tank cars) * $7,800 (incremental cost difference) = $25,186,200

Summary of Tank Car Costs for ECP Brakes

Using the low and high ranges, for the 20-year period of analysis, the estimated total cost related to ECP brakes on tank cars is between $274.5 million and $364.5 million. Total discounted costs at 3 percent are between $256.2 million and $341.5 million. Total discounted costs at 7 percent are between $237.8 million and $318.5 million.

9.2 Locomotive Costs for ECP Brakes

As earlier discussed, for purposes of this updated analysis PHMSA and FRA estimate that after the implementation date of May 1, 2023, the maximum number of unit trains on the general network at any given time would be between 367 and 481 trains. Although the majority of these trains operate with three locomotives, DOT is estimating the cost to retrofit between 1,468 and 1,924 locomotives, which would accommodate for out-of-service locomotives or any additional locomotives needed to operate the HHFUT's with ECP brakes. Class I railroads are currently not purchasing new locomotives equipped with ECP. Therefore, any locomotives that are to be equipped with ECP brakes will be retrofits. New locomotive orders are planned several years in advance. Since this rule will only give railroads approximately 3-5 years to install ECP on their HHFUT fleet, railroads will not be able to install ECP on new locomotives.

FRA estimates that it will cost $80,000 per locomotive to retrofit with ECP brakes. Over a 20-year period, the total cost to equip the locomotives with ECP brakes is between $114.2 million and $151.4 million. Discounted at 3 percent the costs are between $109.4 million and $145.6 million. Discounted at 7 percent the costs are between $103.7 million and $138.7 million.

One of the major railroads currently operating an ECP-equipped subset of their fleet has purchased additional runaround cables used to bypass a locomotive that may not be equipped for ECP. These cables cost $1,000 each. PHMSA and FRA believe that other railroads would follow this business practice, and purchase one set for each locomotive in HHFUT service. This would prevent any bottlenecks or slowdowns from occurring in the eventuality of an ECP-equipped locomotive that was not available. With these runaround cables, any locomotive not equipped with ECP brakes could be used as a non-controlling locomotive on the HHFUT, providing the required power to operate the train. Using the low and high ranges, DOT estimates it would cost between $1.4 million[63] and $1.9 million[64] to purchase these additional cables. Over a 20-year period, discounted at 3 percent, that total would be between $1.4 million and $1.8 million. Over a 20-year period, discounted at 7 percent, that total would be between $1.3 million and $1.7 million.

Summary of Locomotive Costs for ECP Brakes

For the 20-year period of analysis, the estimated total cost ECP brakes on locomotives is between $115.7 million and $153.2 million. Discounted values at 3 percent are between $110.8 million and $147.4 million. Discounted values at 7 percent are between $105.0 million and $140.4 million.

[63] Calculation: 1,428 locomotives * $1,000 (cost of runaround cable per locomotive) = $1,428,000
[64] Calculation: 1,856 locomotives * $1,000 (cost of runaround cable per locomotive) = $1,856,000

9.3 Asset Management for ECP Brakes

PHMSA and FRA acknowledge that initially an extra burden could be required to manage these assets associated with ECP braking systems. The railroads and shippers may currently have employees who already manage the crude oil and ethanol fleets. The additional cost would be attributed to determining the best way to manage these fleets in the first year of operation.[65] PHMSA and FRA estimate that an additional 8,000 labor-hours would be sufficient to manage all assists for the stakeholders involved. After the initial year of the management of these assets, further management would be included in the regular duties of the current asset managers. PHMSA and FRA assume the burdened hourly wage to be $65.31,[66] in 2016. The total cost of this burden would be $522,480 using both the low and high ranges. Discounted values would be the same since this cost would be incurred in the first year.

9.4 Training Costs for ECP Brakes

Current employees will be trained over the first three years. This analysis has accounted for these costs. Any new employees that are hired throughout the 20-year period analyzed, will also need to be trained on ECP. However, PHMSA and FRA assume this training will be incorporated into the current training model and will not increase the time requirements. Therefore, no additional cost has been taken for this training. Additionally, PHMSA and FRA assume that the ECP brake requirement would add no training time to refresher training and therefore the cost of any refresher training that would occur has already been accounted for in the training standards final rule.[67] No comments that pertained to these assumptions were received during the comment period.

PHMSA and FRA believe that there are two parts of the costs of training employees regarding ECP brakes. The first part is the training of the supervisors. These supervisors would then train the engineers, conductors, and carmen, which is the second part of the cost associated with training.

PHMSA and FRA looked at the routes of the HHFUT's to determine how many crews could be affected. Using the current waybill sample, FRA determined that approximately 62 percent of the total ton-miles were on routes that had crude or ethanol unit trains. This was a decrease from the 68 percent used in the Final Rule due to updated waybill data. If carloads increase, then the proportion of ton-miles on the HHFUT network would likely increase. However, if non-HHFUT commodities increase as well, then this proportion may remain constant. DOT assumed that the percentage of ton-miles that traversed over the HHFUT network would represent the maximum number of employees that need to be trained on ECP. Employees who traverse over that network

[65] The first year we estimate the fleets would be operating with ECP is 2019; therefore, the cost to initially manage these fleets would take place in the prior year (2018).

[66] PHMSA used the 2016 STB's Wage Statistics of Class I railroads to determine the number of Class I railroad employees who would be impacted by the proposed rule. Statement A-300 and the AAR Fact Book provided an employee count to assess the number of impacted railroad employee. PHMSA included all employees from Professional and Administrative and Transportation (Train and Engine). PHMSA incorporated a 75% overhead cost as well.

[67] See 49 CFR Part 243

may have the possibility of working on a unit train with ECP. PHMSA and FRA adjusted the estimate to include 62 percent of the total crews, minus a small percentage of employees who are already trained in ECP. All training would be expected to take place during the first three years following the publication of the Final Rule.

Locomotive Engineers and Conductor Supervisors

PHMSA and FRA estimate that seven training classes of supervisors, with a class size between 25 and 30, would take place at a centralized location for each of the railroads. The training would last two weeks and each of the trainers would require an additional 2 weeks to prepare for the training sessions.[68] PHMSA and FRA are using the burdened hourly wage rate[69] of $65.31.[70] The total cost for each trainer of locomotive engineers and conductors would be $57,473.[71] PHMSA and FRA assume that 200 locomotive engineer and conductor supervisors would travel to each of the railroad's centralized locations for this two-week training. The total cost of travel, hotel, food, and wages would be $7,422 per employee.[72] For 200 supervisors, the total cost would be approximately $1.5 million[73] which would take place in the first year of this analysis.

Carmen Supervisors

PHMSA and FRA estimate that seven training classes of carmen supervisors, with a class size between 25 and 30, would take place at a centralized location for each of the railroads. PHMSA and FRA estimate that the training would last two weeks, and that each of the trainers would require an additional two weeks to prepare for the training sessions.[74] PHMSA and FRA assume the burdened hourly wage rate to be $65.31. The total cost for the training of carmen supervisors would be $57,473.[75] PHMSA and FRA assume that 98 carmen supervisors would travel to each railroad's centralized location for this two-week training. The total cost of travel, hotel, food, and wages would be $7,422 per employee.[76] For 98 supervisors the total cost would be $727,336,[77] which would take place in the first year of this analysis.

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[68] As some of the railroads already operate with ECP brakes, only 4 railroads would have to develop new training programs.

[69] The burdened hourly wage rate accounts for any employer costs other than salaries (e.g., benefits, overhead, office space). All wages have been multiplied by 1.75 to account for this cost to employers.

[70] Surface Transportation Board, 2016, Group No. 500 "Transportation (Other than Train & Engine)." Calculation: $37.32 (straight time rate) * 1.75 (benefits) = $65.31

[71] [$65.31 (Wage rate) * 80 (Hours of training) * 7 (Number of classes)] + [65.31 (Wage rate) * 80(Hours to prepare for training) * 4(Number of trainers)] = $57,473

[72] [12 (Days of the trip) * $100 (Daily hotel room cost)] + [315 (Average Cost of Flight)] + [12 (Days of the trip) * 46(Average per diem)] + [130 (Other transportation costs)] + [80 (Hours of training) * $65.31 (Wage rate)] = $7,422

[73] 200 (Number of supervisors) * 7,422 (Cost of training) = $1,484,360

[74] As stated earlier, some of the railroads already operate with ECP, therefore; only 4 railroads would have to develop new training programs.

[75] [$65.31 (Wage rate) * 80 (Hours of training) * 7 (Number of classes)] + [65.31 (Wage rate) * 80 (Hours to prepare for training) * 4 (Number of trainers)] = $57,473

[76] [12 (Days of the trip) * $100 (Daily hotel room cost)] + [$315 (Average Cost of Flight)] + [12 (Days of the trip) * $46(Average per diem)] + [130 (Other transportation costs)] + [80 (Hours of training) * $65.31 (Wage rate)] = $7,422

[77] 98 (Number of supervisors) * $7,422 (Cost of training) = $727,336

The second part of the training would be to train the locomotive engineers, conductors, and carmen on how to use, inspect, and maintain the ECP brakes.

PHMSA and FRA looked at the routes of the HHFUT's to determine how many crews could be affected. Using the waybill sample, FRA determined that approximately 62 percent of the total ton-miles were on routes that had crude oil or ethanol unit trains. PHMSA and FRA adjusted the estimate to include 62 percent of the total crews. Based on these assumptions, around 12,321 engineers, 18,618 conductors, and 4,471 carmen would receive additional training.[78] It is estimated to take two days to train locomotive engineers. It is estimated to take one day to train conductors.

Locomotive Engineers

PHMSA and FRA believe that the locomotive engineer training classes would take place at the local sites in classrooms of 30 employees. These classes would be taught by the supervisors who were trained as described in the previous section. With approximately 12,321 locomotive engineers, there would be around 411 classes taught. Training classes are expected to last two days, including a day of on-the-job training. The costs associated with the supervisors to train the locomotive engineers would be $429,479.[79] This would ensure that all locomotive engineers are trained to confirm safe operations of the trains. The cost to train all the locomotive engineers would be $10.9 million.[80]

Conductors

PHMSA and FRA estimate that there are 18,618 conductors who would also need to be trained. Similar to the previously described locomotive engineer training sessions, these would take place at the local sites in classes of 30 employees. These classes would be taught by the supervisors who are already trained. There would be approximately 621 classes taught for all the conductors. Training classes are estimated to last one day. The costs associated with conductor supervisory trainers would be $324,460.[81] 18,618 conductors would need to be trained in order to ensure safe operations of the trains. The cost to train these conductors would be $8.2 million.[82]

Carmen

PHMSA and FRA estimate that there are 4,471 carmen who would also need to be trained.[83] Similar to the previous sessions, these would take place at the local sites in classes of 30 employees. These classes would be taught by the supervisors who were trained as described in the previous section. With an estimated 4,471 carmen to be trained, there would be

[78] An additional 2 percent of locomotive engineers, conductors, and carmen were not included as PHMSA believes that these employees already operate with ECP-equipped trains, and therefore have received the proper training.
[79] 411 (Number of classes) * 16 (Hours of training) * $65.31 (Wage rate) = $429,479.
[80] 12,321 (Number of engineers) *16 (Hours of training) * $55.25 (Wage Rate) = $10,891,439.
[81] 621 (Number of classes) * 8 (Hours of training) * $65.31 (Wage rate) = $324,460.
[82] 18,618 (Number of conductors) *8 (Hours of Training) * $55.25 (Wage Rate) = $8,228,869.
[83] An additional 5 percent of carmen were not included as PHMSA believes that these employees already operate with ECP trains and therefore have received the proper training.

approximately 149 classes taught. PHMSA and FRA estimate that these training classes would last six days, including on the job training. The costs associated with the supervisors to train the carmen would be $544,947.[84] All affected carmen would need to be trained in order to ensure safe operations of the trains. The cost to train these carmen would be $13.8 million.[85]

Summary of Training Costs for ECP Brakes

For the 20-year period of analysis, the estimated total training costs for ECP brakes is $36.6 million. Discounted at 3 percent, the total cost will be $34.6 million. Discounted at 7 percent, the total cost will be $32.3 million. PHMSA and FRA assume that any additional future training required for ECP would be tied into the current refresher training programs and would therefore have minimal additional costs.

9.5 Phase-in Period

PHMSA and FRA assume that benefits will accrue the year after ECP brakes are installed on a tank car for an HHFUT, and that 33 percent of the cars used in crude oil unit trains will be equipped with ECP brakes each year starting in 2018, until all cars are equipped by the end of 2020. Thus, the benefits from operations involving ECP brakes on crude oil unit trains will start at 33 percent of the full performance level by the end of 2018, rising to the full performance level at the end of 2020. Ethanol unit trains will need to be equipped with ECP brakes by May 1, 2023. In this updated Final Rule analysis PHMSA and FRA assume that 20 percent of the cars used in ethanol unit trains will be equipped with ECP brakes each year from 2018 through 2021, and that 10 percent of the cars used in unit trains will be equipped with ECP brakes in 2022. The last 10 percent of cars used in ethanol unit trains will be equipped in the first five months of 2023. Thus, the benefits from operations involving ECP brakes on ethanol unit trains will start at 20 percent of the full performance level by the end of 2018, rising to the full performance level by May 1, 2023.

Table 9.5a: ECP Phase-In Schedule

	Benefit Percentage (%)	
Year	Crude Oil Unit Trains	Ethanol Unit Trains
2018	33%	20%
2019	67%	40%
2020	100%	60%
2021	100%	80%
2022	100%	90%
2023	100%	100%
2024	100%	100%

[84] 149 (Number of classes) * 56 (Hours of training) * $65.31 (Wage rate) = $544,947.
[85] 4,471 (Number of carmen) * 56 (Hours of Training) * $55.25 (Wage Rate) = $13,832,083.

9.6 Summary of Costs

Using the low and high ranges, for the 20-year period of analysis, the estimated total cost for ECP brakes is between $427.3 million and $554.8 million. Discounted at 3 percent, the costs are between $402.1 million and $524.1 million. Discounted at 7 percent, the costs are between $375.6 million and $491.7 million. Table 9.6a below summarizes the costs.

Table 9.6a: Total Costs for ECP Brakes (7 Percent)

	Low Range	High Range
Tank Cars	$237,755,215	$318,492,228
Locomotives	$105,033,048	$140,417,816
Asset Management	$522,480	$522,480
Training	$32,288,700	$32,288,700
Total	$375,599,442	$491,721,224

10. Benefits

10.1 Expected Benefits Pool Estimation

This section develops the societal damage pool to which ECP braking effectiveness is applied to obtain estimated benefits for this updated analysis. PHMSA and FRA break down the benefit pools into two types, those involving lower consequence events (LCE), which are based on events that have occurred in the U.S. safety record to date, and high consequence events (HCE) which are based on the possibility of events that exceed any seen to date in the U.S. safety record, in terms of severity, but could potentially occur. Generally speaking, such an event may look similar to those that have occurred in the U.S. safety record, but because of the micro location, would produce outsized damages – either environmental or a large number of deaths and injuries. An example would be a derailment with an oil spill that impacted a building holding a large number of people, or one that because of the specifics of the local environment entailed very large cleanup costs. LCE are an estimation of the number of HHFT accidents involving flammable liquids in absence of the Final Rule and an estimation of the expected damages from accidents extrapolated from the existing United States hazardous materials accident records. The LCE events look at the projected damages that might occur if the rate and size of future accidents were similar to the existing United States safety record. In addition to these projected accidents, there might be one or more higher-consequence events. The HCE are an estimation of how many of these higher-consequence events could occur in absence of the Final Rule and an estimation of expected damages from those higher-consequence events.

We begin with an explanation of how LCE damages are calculated. The process begins by using the carload forecast presented in the Fleet Forecast section above. The values in that table are combined with a derailment rate and estimated spill size to obtain a forecast of the number of derailments that might be expected in the future and their severity. Appendix A presents the crude and ethanol derailments that occurred after publication of the Final Rule, as identified by PHMSA and FRA. Table 10.1a below summarizes these incidents: the number that occurred per year, total quantity spilled per year, and quantity spilled per derailment. This methodology is identical to that used in the Final Rule – differences are attributable to the inclusion of new incident data.[86]

Table 10.1a: Summary of Mainline Derailment Frequency and Spill Amount[87]

Year	Number of Derailments	Total Quantity Released	Release per derailment
2006	5	520,155	104,031
2007	3	100,557	33,519
2008	3	93,333	31,111
2009	8	241,259	30,157
2010	3	81,793	27,264
2011	6	1,006,741	167,790
2012	6	354,785	59,131
2013	6	945,458	157,576
2014	6	98,107	16,351
2015	9*	722,524	80,280
2016	4**	45,405	11,351
Total	**59**	**4,210,117**	**71,358**

*At the Final Rule stage the Agency predicted 11.9 derailments for 2015 based on a forecast value of 1,119,000 combined carloads of crude and ethanol shipped

**At the Final Rule stage the Agency predicted 11.95 derailments for 2016 based on a forecast value of 1,124,000 combined carloads of crude and ethanol shipped.

The addition of the 2014 – 2016 yearly incidents resulted in an average spill size that was approximately 14.6 percent lower than that used in the 2015 Final Rule RIA. In addition to updating the average spill volume, PHMSA and FRA updated the derailment rate per 1,000 carloads of crude and ethanol shipped. For the Final Rule RIA, PHMSA and FRA calculated this rate by dividing the number of derailments that occurred in the most recent 5 years for which data were available by the total number of carloads, in thousands, that were shipped in those 5 years. The resulting rate was 0.010636 derailments per thousand carloads shipped.[88] Applying this same calculation to the most recent 5 years available when drafting this updated analysis (2012-2016) yields a derailment rate of 0.007392 derailments per thousand carloads shipped. This is a decline of about 30.5 percent in the rate of derailment compared to that estimated at the Final Rule stage.

Commodity specific derailment rates vary from year to year. Since 2009, the ethanol derailment rate per thousand carloads has varied but was relatively high from 2009-2012, at over 0.01 derailments per thousand carloads, before falling significantly to about 0.0026 derailments per thousand carloads in 2013 and 2014. In the past two years for which data is complete, the rate has ticked back up to approximately 0.006 per thousand carloads, though still significantly below pre-2013 levels. Crude oil volumes were negligible by current standards until 2012, and the years 2010-2012 did not feature a single crude oil derailment. 2013-2015 featured higher derailment

[86] See pages 83-84 of the HM 251 Final Rule RIA.
[87] Please see Appendix A of this document for commodity specific release volumes.
[88] See page 78 of the HM 251 Final Rule RIA for an explanation of this calculation.

rates, at or near 0.01 per thousand carloads, but the rate fell significantly in 2016 to 0.03 derailments per thousand carloads.

To obtain the derailment forecast and overall expected societal damages from these derailments, PHMSA and FRA multiplied the derailment rate above by the number of carloads in each future year as presented in Table 11.1aa above divided by 1,000, then multiplied this derailment estimate by the adjusted average quantity spilled per derailment – 58,137 gallons. This adjustment (from a raw value of 71,358) is necessary because the vast majority of incidents to date have involved unimproved DOT-111 tank cars, whereas the fleet at present features a substantial portion of CPC-1232 tank cars. A similar baseline adjustment was made in the Final Rule RIA. This adjustment was made to account for the baseline makeup of CPC-1232 tank cars relative to older designs of DOT-111 tank cars. The improvements attributable to existing DOT-117s is adjusted further below when retrofit/retirement and replacement improvements are phased in. The adjustment reduces the expected spill size for the increased presence of CPC-1232 tank cars in the fleet. The methodology used to reduce the average spill size from 71,358 to 58,137 is as follows: This adjustment begins by calculating the percentage of the baseline fleet made up by unimproved DOT-111s (and for now ignoring the DOT-117 portion of the fleet, which is dealt with later). Phase out of legacy DOT-111s has occurred rapidly, especially in crude oil transport, where they have been virtually eliminated from the fleet. As a result, legacy DOT-111s make up about 40.4 percent of the non-DOT-117 baseline fleet, while unjacketed CPC-1232s make up 28.4 percent of the fleet and Jacketed CPC-1232 tank cars make up 31.1 percent of the fleet.[89] DOT assumes that incidents would be proportional to the percentage of the fleet made up of each car type – and that that portion that would involve DOT-111 would still produce spill sizes approximated by the unadjusted spill size presented above 71,358 gallons. That value is multiplied by 40.4 percent to obtain the unimproved DOT-111 contributions to spills. The CPC-1232s are adjusted by multiplying their percentage of the baseline fleet by 1 minus the expected reduction in spill size relative to an unjacketed DOT-111. This adjustment controls for the expected involvement of CPC-1232 tank cars in incidents and the degree to which they are expected to reduce spill size.

The effectiveness rates presented in the 2015 Final Rule RIA are used to estimate the expected spill size reductions attributable to CPC-1232 tank cars. For jacketed CPC-1232 tank cars, the effectiveness relative to a DOT-111 unjacketed car is 45.9 percent, meaning that a derailment involving these cars is likely to be 45.9 percent smaller, on average, than a derailment involving an unimproved non-jacketed DOT-111, leaving 54.1 percent of damages remaining. Thus, the reduction for jacketed CPC-1232s is to multiply 54.1 percent by their fleet percentage (31.1) and multiply that product by the unadjusted expected spill size. The same calculation was done for non-jacketed CPC-1232s, using an effectiveness rate of 14.9.[90] These three products are added together to obtain the adjusted expected spill size of 58,137 gallons.

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[89] A similar reduction was made at the HM-251 Final Rule stage, however the methodology used in this revision is slightly more complex. The methodology used at the Final Rule stage did not distinguish between CPC-1232 tank car types but in this update we consider the portion of the fleet made up of jacketed and unjacketed CPC-1232 tank cars rather than treating both with one adjustment factor. See page 91 of the HM-251 RIA for this adjustment.

[90] DOT interpolated this effectiveness in the following manner: A DOT-117 has a 9/16ths inch shell, thermal protection and a jacket with full height head shields. An unjacketed CPC-1232 tank car has half height head shields and an 8/16ths inch shell thickness. A legacy unjacketed DOT-111 has no head shields and a 7/16ths inch shell

The methodology used to reduce the average spill size from 71,358 to 58,137 is described above. This method produces an estimated total spill volume per year, which is monetized as in the Final Rule RIA by multiplying the total quantity spilled per year by $200 per gallon spilled.[91] This figure was derived using a combination of review of academic literature, values used by other federal agencies that have estimated oil spill costs, and examination of PHMSA oil spill cost data. To this figure PHMSA and FRA added the costs of expected fatalities and injuries. Table 10.1b below presents the fatalities and injuries that occurred in derailments involving crude and ethanol from 1995 – 2016. Fatalities are monetized using a VSL of $9.6 million. Injuries involving hospitalization are monetized at 26.6 percent of the VSL (equivalent to a very serious injury on the MAIS scale), and non-hospitalization injuries are monetized at 0.3 percent of VSL (equivalent to a minor injury on the MAIS scale).[92] The total monetized damages from the incidents in Table 10.1c below was divided by the total carloads shipped from 2006-2016, to obtain monetized value per carload shipped. This figure was multiplied by the expected number of carloads shipped in each future year (as presented in the carload forecast in Table 10.1a above) to obtained a monetized estimate of future damages. The fatality and injury damages were added to the spill damages to obtain total monetized damages. This methodology is the same that was used in the Final Rule RIA.

Table 10.1b: Deaths and Injuries in Crude and Ethanol Derailments, 2006 - 2016

Year	Hazmat Fatalities	Hospital Injuries	Non-Hospital Injuries
2006	0	0	0
2007	0	1	0
2008	0	0	2
2009	1	2	6
2010	0	0	0
2011	0	0	0
2012	0	0	2
2013	0	0	0
2014	0	0	0
2015	0	1	0
2016	0	0	0
Total	**1**	**4**	**10**

thickness. Thus, replacement with a DOT-117 increases the shell thickness by 1/8th of an inch, adds full height head shields, and thermal protection and a jacket. The difference between the upgrade of a DOT-111 to a DOT-117 and a non-jacketed CPC-1232 and a DOT-117 is a sixteenth of an inch of shell thickness and a half height head shield – which is the improvements of the unjacketed CPC-1232 compared to a legacy DOT-111. DOT subtracted the effectiveness gained by a DOT-117 over an unjacketed CPC-1232 from the improvement gained by replacing an unjacketed legacy DOT-111 with a DOT-117.

[91] See pages 85-89 of the HM 251 Final Rule RIA for a discussion of how this figure was arrived at.

[92] This is the same methodology as used in the Final Rule RIA. See pages 90-91 for the data and explanation of methodology used to develop these costs.

PHMSA and FRA used the same calculation methodology to obtain the rate of fatalities and injuries per carload as was used in the 2015 RIA in order to estimate expected fatality and injury damages. Injuries and fatalities are relatively rare in rail incidents and these impacts make up a relatively small portion of the damage pool at roughly $3.5 million per year over the analysis period, or roughly 4 percent of total monetized damages. Years with no resulting deaths or injuries, in which volumes are high, and the number of derailments substantial, are common. It is therefore not clear whether derailment rates play a major role in driving the deaths and injuries associated with these incidents – one incident featuring a tragic confluence of location and circumstances can feature a significant number of casualties and drive these impacts to a substantial degree. For example, combined carloads of crude and ethanol were very high from 2012 – 2015 and only one injury occurred over those 4 years. As a result, the monetized damages per carload due to deaths and injuries has fallen when compared to the Final Rule RIA with the addition of these high-volume years to the calculation of the monetized rate of injuries and fatalities per carload shipped. PHMSA and FRA solicited public comment on whether it would be appropriate, advisable, or necessary to adjust these damages by the decline in derailment rate however, PHMSA and FRA did not receive any comments that pertained to the injury and fatality projection. Nevertheless, PHMSA and FRA have made an adjustment to the injury and fatality damages that reflects the decline in the derailment rate that occurred between the figure used in the 2015 final rule RIA and this final 2017 RIA.

As noted above, derailments of crude and ethanol trains that result in deaths or injuries are rare, and the sample size of incidents involving these consequences is small. A derailment is necessary for such incidents to occur, but in addition to the derailment, the specific characteristics of the location at which the derailment occurs partially determines if deaths or injuries occur and if so, how many. A higher derailment rate should, however, make derailments in locations with characteristics that lead to a possibility of death or injury more likely, and hence PHMSA and FRA believe it appropriate to make the adjustment. The methodology used was to calculate death and injury damages per carload shipped as described above, which yields a value of approximately $3.28 per carload shipped. This is somewhat lower than that used in the 2015 final rule because only one injury and no deaths have occurred in the intervening years despite substantial rail volumes of both crude and ethanol. The derailment rate between the 2015 final rule RIA and this final 2017 RIA fell by 30.5 percent. PHMSA and FRA therefore adjusted $3.28 per carload by multiplying by one minus .305 (which yields .695) to reduce the figure to approximately $2.28.[93]

Table 10.1c below presents the raw expected monetized damages from LCEs. As noted above, these damages are based on the U.S. safety record.

[93] $3.28 x .695 = $2.28.

Table 10.1c: Total Monetized Societal Damages, Unadjusted

Year	Total Monetized Damages High	Total Monetized Damages Low
2018	$83,769,154	$78,024,714
2019	$87,024,488	$77,913,514
2020	$88,698,432	$77,569,459
2021	$90,096,720	$77,102,860
2022	$91,503,910	$76,842,890
2023	$92,397,015	$76,659,620
2024	$93,424,689	$76,583,537
2025	$94,412,032	$76,452,039
2026	$95,058,610	$75,910,856
2027	$95,291,482	$75,644,190
2028	$95,829,860	$75,600,825
2029	$96,442,221	$75,489,007
2030	$96,837,006	$75,473,429
2031	$95,964,066	$74,618,793
2032	$95,256,233	$74,233,825
2033	$93,936,338	$74,236,489
2034	$93,874,519	$74,236,489
2035	$93,599,526	$74,236,489
2036	$94,184,391	$74,236,419
2037	$94,456,623	$74,183,685
Total	$1,862,057,314	$1,515,249,131
7 % Discount Rate	$975,480,933	$807,823,557
3% Discount Rate	$1,378,867,840	$1,130,386,089

Several adjustments must be made to these figures to identify the societal damages that might be mitigated by ECP brakes. The Final Rule established several new requirements for high hazard flammable trains, including improvements to the tank car used to haul flammable liquids, and speed restrictions in high threat urban areas. In addition, the industry response to the Final Rule and to a fall in production and crude oil prices has resulted in a crude and ethanol tank car fleet configuration that is different than that anticipated by PHMSA and FRA in 2015. An updated fleet profile was obtained from the Association for American Railroads and used to update the baseline fleet composition and carry through retrofits and retirements to tank cars based on FAST Act mandated deadlines.

Table 10.1d below presents the starting fleet composition used to adjust for the improvement that occurs in the fleet (and resulting reduction in likely spill size from incidents) in the baseline and as the FAST Act deadlines approach. Some explanation of the baseline figures is necessary.[94] PHMSA and FRA used 2016 figures from the AAR data, however, there appear to have been a substantial number of CPC-1232 tank cars that were idle in 2016, but used in 2015. Since both forecasts have crude oil volumes that are higher than 2016 volumes, it is assumed that the CPC-1232 tank cars will be pulled back into crude oil service as volumes by rail return closer to their 2015 levels. Virtually all legacy DOT-111 tank cars used in HHFTs are used in ethanol service. The vast majority of CPC-1232 tank cars, both jacketed and unjacketed, appear to be used in crude oil service. PHMSA and FRA therefore assume that legacy DOT-111s will be retrofitted or retired on the schedule associated with ethanol rather than crude. For the CPC-1232 tank cars PHMSA and FRA break out commodity and retrofit according to that commodity's schedule. What matters for the purposes of updating the ECP brake section of the analysis is not the raw number of cars of each type but the proportion of each type as a percentage of the total fleet. So long as those proportions remain relatively stable, incident severity reductions should approximate those used in this section.

Table 10.1d: Baseline Tank Car Fleet Profile

Tank Car Type	Baseline Fleet
DOT-111 Unjacketed	28,870
DOT-111 Jacketed	423
CPC-1232 Unjacketed	20,599
CPC-1232 Jacketed	22,558
DOT-117 New	4,864
DOT-117 Retrofit	1,904
Total	**79,218**

The first adjustment is to modify the expected spill size for baseline fleet composition, as described above. Having obtained the baseline expected spill size, the next step is to adjust the expected damages further to account for improvements in the fleet that will occur as FAST Act mandated deadlines for retiring and replacing legacy cars with new DOT-117s or retrofitting existing legacy cars to the DOT-117R standard are realized. PHMSA and FRA make the same assumptions regarding the mix of retirements to retrofits as made in the Final Rule RIA for legacy DOT-111s. We assume the industry will retrofit all CPC-1232 tank cars, and that 28 percent of unjacketed legacy 111s will be retired. Since they make up such a small portion of the current fleet, we assume all jacketed legacy DOT-111s will be retired from crude and ethanol service rather than retrofit.

In order to make the damage reductions, PHMSA and FRA divided the total size of the fleet into the number of each car of each type that has been retrofit or retired in a given year to get a percentage of the total fleet that has been upgraded for that car type, and then multiply this percentage by the corresponding effectiveness rate. This matrix is then multiplied by the adjusted damage pool to further reduce the expected damages as the tank car fleet improves. Adjustments for existing DOT-117s are made in 2018 as part of this process.

[94]Appendix E provides the supplemental tables that were used to estimate the tank car phase-in as well as to account for the upgrade tank car adjustment factors. The tables presented in Appendix E are used to estimate the estimate LCE and HCE damages.

Table 10.1h below presents the final benefit pool for both derailment forecasts, adjusted for fleet improvements, and then subsequently adjusted for the speed restrictions in high threat urban areas (HTUAs) for HHFTs that are not made up of DOT-117/117R tank cars, as mandated by the HM-251 Final Rule. The effect of these restrictions phases out as tank cars are upgraded to the DOT-117 standard. This is the pool of societal damages that could be further reduced by the use of ECP braking technology on HHFUTs. These calculations are identical to those used to estimate tank car benefits and subtract them from the pool of total benefits as done in the HM-251 Final Rule RIA. Differences are attributable to minor changes in the retrofit timeline as mandated by the FAST Act and changes in the fleet composition. The differences are mostly attributable to a smaller proportion of legacy DOT-111s in the baseline fleet compared to expectations at the Final Rule stage.

Table 10.1h: Adjusted LCE Damages

Year	LCE Damages High Carload Prediction	LCE Damages Low Carload Prediction	Speed effectiveness	ECP Societal Damage Pool, High Carload Prediction	ECP Societal Damage Pool, Low Carload Prediction
2018	$76,196,734	$70,971,571	7.44%	$70,528,338	$65,691,883
2019	$77,092,140	$69,021,027	5.93%	$72,519,341	$64,926,974
2020	$74,986,695	$65,578,131	4.91%	$71,306,597	$62,359,774
2021	$72,214,010	$61,799,217	3.86%	$69,423,528	$59,411,182
2022	$64,496,482	$54,162,670	3.14%	$62,469,801	$52,460,710
2023	$64,779,717	$53,746,200	1.39%	$63,878,130	$52,998,175
2024	$65,471,457	$53,669,279	0.59%	$65,086,941	$53,354,078
2025	$66,127,031	$53,547,691	0.34%	$65,902,456	$53,365,837
2026	$66,579,900	$53,168,642	0.00%	$66,579,900	$53,168,642
2027	$66,743,006	$52,981,867	0.00%	$66,743,006	$52,981,867
2028	$67,120,090	$52,951,493	0.00%	$67,120,090	$52,951,493
2029	$67,548,993	$52,873,175	0.00%	$67,548,993	$52,873,175
2030	$67,825,504	$52,862,264	0.00%	$67,825,504	$52,862,264
2031	$67,214,089	$52,263,669	0.00%	$67,214,089	$52,263,669
2032	$66,718,316	$51,994,034	0.00%	$66,718,316	$51,994,034
2033	$65,793,850	$51,995,900	0.00%	$65,793,850	$51,995,900
2034	$65,750,552	$51,995,900	0.00%	$65,750,552	$51,995,900
2035	$65,557,944	$51,995,900	0.00%	$65,557,944	$51,995,900
2036	$65,967,589	$51,995,851	0.00%	$65,967,589	$51,995,851
2037	$66,158,263	$51,958,916	0.00%	$66,158,263	$51,958,916
Total	$1,360,342,362	$1,111,533,399		$1,340,093,228	$1,093,606,225
7 % Discount Rate	$731,513,146	$609,108,196		$714,672,695	$594,134,997
3% Discount Rate	$1,018,295,076	$838,782,191		$999,641,133	$822,235,822

High Consequence Event Damages (HCE)

For purposes of this updated analysis, PHMSA and FRA re-ran the Monte Carlo simulation run at the HM-251 Final Rule stage with a modification on the number of HCE events at the upper bounds.[95] PHMSA and FRA continued to use 2 HCE as the central estimate, and one at the lower bounds estimate, with LCE damages as an estimate of 0 HCE events. This treatment is the same as was used in the HM-251 Final Rule. In the Final Rule, PHMSA and FRA estimated that 5

[95] See pages 96 – 111 for a discussion of how HCE damages were estimated at the HM 251 Final Rule stage.

HCE would occur during the 20-year period. This estimate was primarily driven by the high number of carloads, as the calculation to arrive at the number of HCE over the period is 4. This figure was arrived at by comparing the number of carloads forecast for the HM 251 final rule RIA to the high forecast from this document. The 20-year total has declined by roughly 20 percent, from 26.1 million to 21.1 million carloads of crude and ethanol combined.

Thus, due to the reduction in forecasted carloads, the number of HCEs on the upper bound decreased from 5 to 4 HCEs (20 percent or 1.5^{th} lower) over the 20-year period. As a result, DOT used 4 events as the upper bound limit for the Monte Carlo HCE simulation, using an asymmetric triangular distribution centered on 2 events as the most likely number of events to be drawn in each run, bounded by one on the lower end and 4 on the upper end.

With Monte Carlo simulations, each model run produces slightly different results, so PHMSA and FRA ran eight rounds of simulations, each of which contained 10,000 runs, and averaged the estimates obtained from these 8 rounds. The results obtained with 4 HCE events at the upper bound were approximately 88 percent of those generated with 5 as the upper bound limit. The HCE damage estimates used in the Final Rule were reduced by 12 percent to account for this change. The mean HCE damages are presented in Table 10.1i below. These are analogous to the figures presented in the Final Rule RIA and reflect a reduction in the forecast carloads shipped and a longer safety record over which only 1 HCE has occurred in North America. Table 10.1i also applies the combined effectiveness of the tank car and speed restrictions to obtain estimated remaining societal damages that may be further mitigated by deployment of ECP braking technology on HHFUTs.

Table 10.1i: High Consequence Event Damages

Year	Mean HCE Damages	Aggregate Tank Car and Speed Effectiveness	Remaining HCE Damages, Mean HCE
2018	$123,420,000	84.19%	$103,911,846.83
2019	$123,420,000	83.33%	$102,848,487.74
2020	$123,420,000	80.39%	$99,220,019.78
2021	$123,420,000	77.05%	$95,100,596.86
2022	$123,420,000	68.27%	$84,258,944.78
2023	$123,420,000	69.13%	$85,325,686.79
2024	$123,420,000	69.67%	$85,984,019.48
2025	$123,420,000	69.80%	$86,150,895.44
2026	$123,420,000	70.04%	$86,444,470.74
2027	$123,420,000	70.04%	$86,444,470.74
2028	$123,420,000	70.04%	$86,444,470.74
2029	$123,420,000	70.04%	$86,444,470.74
2030	$123,420,000	70.04%	$86,444,470.74
2031	$123,420,000	70.04%	$86,444,470.74
2032	$123,420,000	70.04%	$86,444,470.74
2033	$123,420,000	70.04%	$86,444,470.74
2034	$123,420,000	70.04%	$86,444,470.74
2035	$123,420,000	70.04%	$86,444,470.74
2036	$123,420,000	70.04%	$86,444,470.74
2037	$123,420,000	70.04%	$86,444,470.74
Total	**$2,468,400,000**		**$1,780,134,147**
PV 7%	**$1,307,513,238**		**$960,717,527**
PV 3%	**$1,836,177,947**		**$1,334,450,352**

The values in the HCE and LCE adjusted damage tables are multiplied by a combination of the updated ECP effectiveness rate, as determined by the testing and simulations conducted by FRA, and the percentage of traffic of each commodity that is expected to travel in HHFUT service in a given year. These calculations are presented below, in section 10.2, and determine the estimated benefits of ECP brake technology deployment on HHFUTs.

Benefits Uncertainties

As noted above, the derailment rate and spill quantity have been lower in the past three years than observations taken at the Final Rule stage. Both of these factors indicate an improvement in the safety environment.

Spill volume is partially explained by the fact that crude oil has been transported in safer, more robust tank cars. As evidenced by the updated fleet profile, virtually all crude oil over the past two to three years has been moving in CPC-1232 tank cars. While the safety improvement of unjacketed CPC-1232 cars is marginal when compared to unimproved 111s, fully half the crude oil fleet appears to be jacketed CPC-1232 tank cars, and these cars offer a substantial improvement over legacy cars. In addition, a non-trivial, though still small, segment of the fleet is made up of new and retrofit 117/117R cars, the safest cars authorized for crude oil transport. All of these factors have improved the safety environment, and it is possible that some may have been influenced by DOT emergency orders and the 2015 Final Rule.

To the extent that the improved safety environment is attributable to falling crude oil volumes, if crude by rail bounces back do to an increase in production (which could be brought on by an increase in crude oil production or a new breakthrough in extraction technology) the safety environment has the potential to backslide to some degree. For example, with high enough transport demand, the industry may bring retired legacy 111s back into crude and ethanol service.

Predicting future volumes is difficult, and there is a high degree of uncertainty surrounding PHMSA and FRA's carload and derailment forecasts. Many factors could influence both crude and ethanol volumes. For example, rapid adoption of electric vehicles may lower demand for gasoline, which would reduce demand for ethanol and crude oil, as both are motor fuel production inputs. A change to the renewable fuel standard could dramatically affect the demand for ethanol. Changes in production of crude oil in other parts of the world may cause global crude oil prices to rise, thereby stimulating production. Derailment rates could rise again, or continue to fall further.

Costs Per Spill for Cleanup and Environmental Damage

As was discussed in the 2015 Final Rule RIA, a great deal of uncertainty surrounds the cost to society imposed by spills of crude and ethanol. PHMSA and FRA have chosen to use its central estimate from that document to enable a ready comparison of the FAST Act mandated test results to those used in 2015. The mix of crude and ethanol volumes would undoubtedly affect the cost figure, as crude oil poses more cleanup and environmental damage problems than ethanol. Should crude oil volumes continue to fall, it is likely that ethanol derailments would make up a greater portion of releases, and in that case perhaps a lower value than $200 would be appropriate to use. Uncertainty is especially high for how many HCEs, if any, may occur in the future. PHMSA and FRA have acknowledged some uncertainty by providing a range for the low consequence event damages, but even this range may not capture future risk perfectly. Finally, high consequence, low probability events vary in both size/potential impacts and likelihood. The uncertainty that any such events may occur over the 20-year analysis period is reflected in consideration of the ECP requirement using only LCE damages. The Monte Carlo simulations are used to capture the uncertainty of the size and likelihood of one or more of these events occurring over the 20-year analysis period. That is, given at least one high consequence event, with some potential for multiple such events to occur, what is the potential distribution of societal damages that might result if these events were to occur. The distribution provides a wide range of damages that capture this uncertainty. Monte Carlo simulations allow the number and severity of events to vary within the bounds of a user defined distribution, and hence is one way to produce estimates reflecting high levels of uncertainty.

10.2 Safety Benefits of ECP Brakes

The potential violence and destruction of a HHFUT accident is substantial and ECP brakes would help to mitigate the magnitude of an accident by providing a faster brake response than conventional pneumatic braking currently offers. ECP brakes replace the air pressure controlled valves, which are used on conventional pneumatic braking, with electronically controlled valves. This allows the response time for braking to occur essentially at the speed of light, rather than the speed of sound. Research shows that the quicker and more uniform braking from ECP brakes can reduce the stopping distance of a train from 40 to 60 percent and has even been shown to reduce Brake shoe wear by 20 to 25 percent.[96] By reducing the stopping distance of a train ECP brakes helps to reduce the number of tank cars that have the potential to go past the point of derailment (POD) and thus reduces the risk associated with tank car punctures. The lower risk of tank car punctures helps to increase safety benefits through reductions in property damages and lower fatalities and injuries.

The survivability of tank cars can also be improved by decreasing the force of the impacts experienced in a derailment. This can be accomplished by reducing the energy of the train as quickly as possible through reduced speeds and/or faster and uniform braking. ECP brakes result in substantially greater reductions in kinetic energy than EOT or DP brake systems. PHMSA and FRA have data from Sharma on the estimated effectiveness rates for ECP brakes at 30, 40, and 50 mph. In estimating what the safety benefits would be PHSMA and FRA took a weighted average of those results, weighting by severity using the quantities of crude oil and ethanol released in the historical record. By assigning historical derailments under 35 mph to the 30-mph effectiveness rate, assigning derailments between 35 and 45 mph to the 40-mph effectiveness rate, and assigning derailments over 45 mph to the 50-mph effectiveness rate we were able to produce a weighted average effectiveness rate. The simulations indicate that 14 percent fewer tank cars would puncture if a HHFUT derailment were to occur involving a train set with ECP brakes relative to a train set operating with a two-way-EOT (see Table 6.1a).[97] PHMSA and FRA used this effectiveness rate of 14 percent to estimate the benefits that would result from deployment of ECP braking on HHFUT.

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[96] George Bibel, *Train Wreck: The Forensics of Rail Disasters* (Baltimore, Maryland: The John Hopkins University Press, 2012), page 251.

[97] PHMSA and FRA also looked at the effectiveness rate based on a speed of 40 mph. The speed of 40 mph is based on the weighted average of speeds of derailment for the accidents in Appendix B weighed by product loss in the derailment. Bins of 10 mph increments (0-10, 11-20, 21-30, 31-40, 41-50, >50 mph) were used in the calculation, which resulted in a weighted average speed of 37 mph, which is close to 40 mph. Our modeling and simulations indicate that 20.0 percent fewer tank cars would puncture if an HHFUT derailment were to occur at 40 mph, involving a train set with ECP brakes relative to a train set operating with a two-way EOT or DP in the rear. However, for the purposes of this analysis we used the more conservative 14.0 percent effectiveness rate, which is calculated using modeling results at all speeds.

Table 10.2a: Effectiveness Rate of ECP Brakes Weighted by Volume of Product Spilled in a Derailment

	Number of Incidents	Total Spill Volume	Share of Total Volume	ECP Effectiveness Rates at 30, 40, 50 mph	Cumulative Effectiveness rate
Below 35 mph	45	1,752,510	41.6%	12.4%	5.2%
35-44 mph	8	1,515,551	36.0%	18.3%	6.6%
45 mph and above	6	942,056	22.4%	10.0%	2.2%
Total	59	4,210,117			14.0%

To estimate benefits, the projected incident damages in the absence of this rule are multiplied by the percentage of cars equipped with ECP brakes in each year and by the effectiveness of ECP braking, which as noted is 14.0 percent. The percentage of crude oil traffic and ethanol traffic that would be transported on HHFUT has also been broken out.

As explained in more detail in Section 10.1 of this analysis, "Expected Benefits Pool Estimation" there are expected benefits for low consequence events (LCE), and for high consequence events (HCE).

Under the requirements of the Final Rule, ECP brakes would gradually be implemented over approximately five years, as the rule mandates a date of May 1, 2023.[98] Table 10.2b and Table 10.2c show the high and low range estimated benefits[99] by year for HHFUT crude oil and ethanol LCE while Tables 10.2d and Table 10.2e show the high and low range estimated benefits of crude oil and ethanol HCE. The low and high estimated benefits were calculated using the damages data provided in Table 10.1h and Table 10.1i above.[100]

[98] There is a January 1, 2021, deadline for HHFUTs transporting one or more tank carload of a Packing Group I flammable liquid while traveling in excess of 30 mph. All other HHFUTs must meet the deadline of May 1, 2023.
[99] Total Damages for LCE and HCE are described in detail in the Benefits Section of this document.
[100] The methodology and example calculations for 2018 for both the LCE and HCE is provided within Appendix D.

Table10.2b: LCE ECP Benefits for Crude Oil and Ethanol Traffic (Low Range Estimate)

Year	Total Crude and Ethanol ECP Benefits	7 percent discount	3 percent discount
2018	$0	$0	$0
2019	$3,283,069	$3,068,289	$3,187,446
2020	$4,774,762	$4,170,462	$4,500,671
2021	$4,970,744	$4,057,608	$4,548,935
2022	$4,574,487	$3,489,854	$4,064,373
2023	$4,806,100	$3,426,683	$4,145,784
2024	$4,839,694	$3,224,893	$4,053,168
2025	$4,843,047	$3,016,006	$3,937,841
2026	$4,834,609	$2,813,787	$3,816,485
2027	$4,822,320	$2,623,022	$3,695,906
2028	$4,820,321	$2,450,407	$3,586,772
2029	$4,815,168	$2,287,652	$3,478,580
2030	$4,814,450	$2,137,673	$3,376,758
2031	$4,775,062	$1,981,481	$3,251,585
2032	$4,757,320	$1,844,971	$3,145,149
2033	$4,757,443	$1,724,316	$3,053,622
2034	$4,757,443	$1,611,511	$2,964,681
2035	$4,757,443	$1,506,085	$2,878,331
2036	$4,757,440	$1,407,555	$2,794,494
2037	$4,755,010	$1,314,800	$2,711,715
Total	**$89,515,934**	**$48,157,055**	**$67,192,298**

Table10.2c: LCE ECP Benefits for Crude Oil and Ethanol Traffic (High Range Estimate)

Year	Total Crude and Ethanol ECP Benefits	7 percent discount	3 percent discount
2018	$0	$0	$0
2019	$3,872,358	$3,619,026	$3,759,571
2020	$5,826,908	$5,089,447	$5,492,419
2021	$6,148,196	$5,018,759	$5,626,470
2022	$5,751,556	$4,387,835	$5,110,183
2023	$6,085,583	$4,338,936	$5,249,477
2024	$6,219,479	$4,144,301	$5,208,715
2025	$6,317,353	$3,934,130	$5,136,586
2026	$6,411,773	$3,731,710	$5,061,513
2027	$6,440,629	$3,503,276	$4,936,206
2028	$6,486,548	$3,297,432	$4,826,601
2029	$6,541,044	$3,107,603	$4,725,389
2030	$6,574,127	$2,918,991	$4,610,960
2031	$6,533,231	$2,711,059	$4,448,813
2032	$6,488,896	$2,516,506	$4,289,924
2033	$6,380,082	$2,312,435	$4,095,132
2034	$6,374,990	$2,159,430	$3,972,683
2035	$6,352,339	$2,010,988	$3,843,270
2036	$6,400,516	$1,893,682	$3,759,629
2037	$6,424,852	$1,776,525	$3,664,004
Total	**$117,630,459**	**$62,472,070**	**$87,817,545**

Table10.2d: HCE ECP Benefits for Crude Oil and Ethanol Traffic

Year	Total Crude and Ethanol ECP Benefits	7 percent discount	3 percent discount
2018	$0	$0	$0
2019	$5,200,592	$4,860,367	$5,049,119
2020	$7,597,076	$6,635,581	$7,160,973
2021	$7,956,764	$6,495,090	$7,281,566
2022	$7,347,241	$5,605,175	$6,527,928
2023	$7,737,697	$5,516,871	$6,674,605
2024	$7,799,523	$5,197,152	$6,531,978
2025	$7,818,351	$4,868,876	$6,357,035
2026	$7,860,371	$4,574,808	$6,205,050
2027	$7,868,029	$4,279,687	$6,030,189
2028	$7,869,280	$4,000,343	$5,855,483
2029	$7,872,511	$3,740,173	$5,687,269
2030	$7,872,961	$3,495,689	$5,521,937
2031	$7,897,986	$3,277,383	$5,378,144
2032	$7,909,447	$3,067,420	$5,229,076
2033	$7,909,367	$2,866,719	$5,076,722
2034	$7,909,367	$2,679,176	$4,928,856
2035	$7,909,367	$2,503,903	$4,785,297
2036	$7,909,369	$2,340,097	$4,645,921
2037	$7,910,948	$2,187,443	$4,511,503
Total	**$146,156,247**	**$78,191,951**	**$109,438,651**

The safety benefits of ECP will range from $48.2 million to $78.2 million; discounted at 7 percent, or $67.2 million to $109.4 million; discounted at 3 percent.

10.3 Difference in Safety Benefits

Since the Final Rule analysis in 2015, several of the original assumptions have been altered due, in large part, to changes in the crude oil energy market. This section will address several of the assumptions that have changed, including changes in the low consequence event damages; the number of high consequence events that are forecasted to occur; the methodology to forecast carloads of crude oil and ethanol; and the overall effectiveness rate of ECP brakes. Furthermore, this section will provide an explanation regarding how any changes in these assumptions could impact the overall future benefits.

I. Low Consequence Events

A 54 percent decrease in the derailment rate (from 0.010636 in 2015 to 0.007391 in this new analysis), coupled with a 14.6 percent decrease in the amount of hazardous material spilled per derailment (from 83,602 gallons per derailment in 2015 to 71,358 gallons per derailment) has lowered the overall damage benefit pool by 62 percent (from $180 million in 2015 to the current $68 million benefit pool).[101] Additionally, since the publication of the Final Rule in 2015, 26,743 older tank cars have either been retrofitted or retired which reduces the overall potential damages avoided due to ECP brakes even further. Combined, these factors help to account for some of the change from the safety benefits that are presented in the 2015 analysis and the safety benefits that are presented within this analysis. Should the derailment rate or the damages per derailment increase, more societal damages could be avoided through the use of ECP brakes.

II. Carload Forecasting

In the Final Rule, PHMSA and FRA, in response to public comments received on the NPRM RIA, used the Railway Supply Institute's (RSI) projected carloads. In the peak year from RSI's forecast 1,004,852 carloads of crude were projected to be originated in 2021. However, an update of the RSI forecast is not available. As a result, PHMSA and FRA utilized the Annual Energy Outlook (AEO) provided by the EIA to forecast the carloads for this revised analysis. Additionally, the crude oil energy market has changed since the publication of the Final Rule in 2015. In 2014 and 2015, crude oil production was at an all-time high and RSI projected that this trend would increase carloads.[102] However, the price of crude oil declined drastically after 2015, which in turn reduced domestic crude oil production and thus the number of carloads that were being moved by rail.

In the high range scenario used this analysis, FRA and PHMSA have projected that 659,660 carloads of crude would be originated in the peak year (2030). This is a 32% reduction in peak year origination of carloads of crude from the Final Rule. The total originated carloads of crude projected over 20 years in the Final Rule was 17,893,953. However; the total originated carloads of crude projected in the high range in the final 2017 RIA is 12,281,051. This is a 29% reduction from the Final Rule. The change in forecast methodology, coupled with the recent decline in annual carloads significantly decreased the ECP brake safety benefits as the number of carloads is a major input in most, if not all, of the safety benefits. If the number of carloads were to increase, and come closer to the original forecasted carloads, then the safety benefits could increase greatly. The costs could increase at a slower rate because new locomotives would need to be purchased and the cost to install ECP on new locomotives is approximately $40,000 less than retrofitting.

[101] Neither the $180 million nor the $68 million in societal damages take into account the effectiveness of ECP brakes or the implementation schedule of ECP brakes and therefore is the pre-discounted benefit pool.
[102] In the 2015 analysis, RSI estimated that the peak year would be 2021 with just over 1 million carloads annually. In the revised analysis, PHMSA and FRA estimate that the peak year will be in 2032 with approx. 670,000 carloads annually.

In the Final Rule, due to the high demand for crude oil at that time, PHMSA and FRA assumed that new locomotives would be purchased for this increased traffic. An increase in the number of carloads may dictate that once again, new tank cars and locomotives would be needed. Purchasing new locomotives with an ECP overlay system would decrease the costs compared to retrofitting locomotives.[103]

If the price of oil increases, the fuel savings benefit (discusses in Section 11.7) would also rise. The demand for crude oil production in the United States has decreased, correlating with the price of oil. Any future surge in oil prices may have effects on numerous assumptions of this analysis. Changes in these assumptions would adjust the number of carloads needed and therefore adjust the safety and business benefits.

III. High Consequence Events

In the Final Rule, PHMSA and FRA estimated that 5 HCE would occur during the 20-year period. This estimate was primarily driven by the high number of carloads (26.1 million over 20 years). In the high carload forecast estimated for this document, the carload volume dropped by almost exactly 20 percent from that used in the final rule (21.1 million carloads). Thus, we reduce the number of HCEs from 5 to 4.[104]

Thus, as the carloads decreased from the Final Rule in 2015 to the current forecasted carloads, the number of HCEs on the upper bound decreased from 5 to 4 HCEs over the 20-year period. The decrease of 1 HCE resulted in the total safety benefits decreasing by approximately 24 percent.[105] Should the total annual carloads increase to approximately 1.2 million the number of HCEs could increase from 4 to 5, which has the potential to increase the overall safety benefits.

IV. Overall Effectiveness Rate

The overall effectiveness rate, as calculated using the Sharma model, decreased 29 percent (from 19.7 percent to 14.0 percent) from the 2015 Final Rule analysis to the current analysis. For this analysis FRA adjusted the model to accommodate the signal delay time (identified during the FAST Act mandated testing).[106] Therefore, the simulations resulted in a decrease in the difference between the numbers of punctures in cars in an ECP and TWEOT equipped trains. This resulted in a decrease in the effectiveness rate to 14.0 percent.

11. Business Benefits of ECP Braking

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[103] The cost of an overlay system for a locomotive is $44,000 and the cost to retrofit a locomotive is $80,000.
[104] 21.1/26.1 = .808429 x 5 = 4.042, or approximately 4.
[105] The mean HCE damages in 2015 was $140 million while in the current analysis the mean HCE damages are $106 million.
[106] In the original 2015 RIA, FRA estimated that there was no time delay between activation and signal response of ECP brakes. However, during recent testing, FRA discovered that there is a slight delay. This delay was incorporated in the updated Sharma model. More information about signal delay time can be found in the updated Sharma letter.

ECP braking systems also have additional potential operational benefits for rail carriers. In 2008, FRA issued a Final Rule permitting the use of ECP brake systems. In an accompanying analysis,[107] FRA found that ECP brakes offered major benefits in train handling, car maintenance, fuel savings, and increased capacity under the operating conditions present in that timeframe. ECP brake use could also significantly enhance rail safety in ways beyond reducing the severity of derailments.

Compared with the potential performance of ECP brakes, conventional braking systems contribute to greater in-train forces, more complex train handling, longer stopping distances, and safety risks of prematurely depleting air brake reservoirs. Traditional train-handling procedures require anticipating draft (pulling) and buff (compressive) forces within the train, particularly on hilly terrain; and any misstep can result in derailment. Conventional brakes can also stop functioning on individual cars en route without the locomotive engineer being aware of it. These challenges and concerns are greatly reduced in the ECP brake mode of operation, during which all cars brake simultaneously by way of an electronic signal. ECP brake systems simultaneously apply and release freight car air brakes through a hardwired electronic pathway down the length of the train, and allow the engineer to "back off" or reduce the braking effort to match the track grade and curvature, without having to completely release the brakes and having to recharge the main reservoirs before another brake application can be made.

These differences in the operation of the two braking systems give ECP brakes several business benefits. Operationally, ECP brakes have the potential to save fuel reduce wear and stress on wheels and brake shoes, and provide train engineers greater control on the braking characteristics of trains. From a safety perspective, ECP brakes greatly reduce the risk of runaway trains due to a diminished reservoir air supply, and reduce the probability of an incident by providing 40 to 60 percent shorter stopping distances. ECP brake wiring also provides the train a platform for the gradual addition of other train-performance monitoring devices using sensor-based technology to maintain a continuous feedback loop on the train's condition for the train crew.

The safety benefits of ECP brakes are included in the general benefits analyzed and accounted for above. The 2008 FRA analysis accounted for four categories of benefits (three categories of safety benefits and one category of business benefits). The safety benefits included reductions in costs of highway-rail grade crossing accidents, reductions in costs of train and equipment accidents, and reductions in environmental and clean-up costs. Those benefits are already accounted for as best as possible, given the available information. The present analysis above does not, however, account for business benefits.

The business benefits below are adjusted from the Final Rule analysis to reflect changes that result from updated data and/or updated assumptions. These changes incorporate GAO suggestions of adding a range to the estimated benefits as well as include the most available

[107] Electronically Controlled Pneumatic Brake Systems, Final Rulemaking. Regulatory Analysis, Federal Railroad Administration, June 2008, Docket ID: FRA-2006-26175-0065, www.regulations.gov

information. The addition of ranged benefits helps to address any uncertainty that might exist within the assumptions or due to limited data.

11.1 Flow Assumptions

I. High Range Estimates

PHMSA and FRA forecast that 84 percent of crude oil carried by rail will be hauled by unit trains, and the average length of haul by crude oil unit trains will be approximately 1,000 miles.[108] In table 11.1a below PHMSA and FRA are forecasting that there will be 482,597 crude oil carloads in 2018. PHMSA and FRA multiply carloads of crude oil by the total round trip miles of a crude oil unit train and then multiply the result by the percentage of crude that travels by unit train to arrive at an estimate of 810,763,632 crude oil carload miles moved by unit trains in 2018.[109] It should be noted that the business benefits are not dependent on whether tank cars are new construction, or retrofitted, nor dependent on shell characteristics, as long as the cars used in unit trains are equipped with ECP brakes and the brakes are functioning.

Also, in this revised analysis, PHMSA and FRA assume that 47 percent of ethanol carloads will be hauled in unit trains. PHMSA and FRA further assume that the average length of haul for an ethanol unit train will be 1,300 miles. In Table 11.1a below PHMSA and FRA are forecasting that there will be 467,034 ethanol carloads in 2018. Similar to the calculations used to estimate the crude oil carload miles moved by unit train, PHMSA and FRA multiply carloads of ethanol by the total round trip miles of an ethanol unit train and then multiply that result by the percentage of ethanol that travels by unit train to arrive at an estimate of 570,715,059 ethanol carload miles moved by unit trains in 2018.[110] Using the total crude oil carload miles and the ethanol carload miles FRA and PHMSA estimate that there will be a total of 1,381,478,691 carload miles of HHFUT in 2018.

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[108] Approximation from AAR Railroad Facts 2016

[109] Calculation: 497,475 crude carloads x (1,000 miles x 2) x .84 (proportion of crude by unit trains) = 835,758,000 crude carload miles moved by unit trains in 2018

[110] Calculation: 497,503 ethanol carloads x (1,300 miles x 2) x .47 (proportion of ethanol by unit trains) = 607,948,666 ethanol carload miles moved by unit trains in 2018

Table 11.1a: HHFUT Car Miles (High Range)

Year	Crude Carloads	Crude Unit Car Miles	Ethanol Carloads	Ethanol Unit Car Miles	Unit Car Miles
2018	482,597	810,763,632	467,034	570,715,059	1,381,478,691
2019	520,761	874,879,152	465,773	569,174,606	1,444,053,758
2020	543,638	913,311,840	461,873	564,408,439	1,477,720,279
2021	564,779	948,828,552	456,583	557,944,670	1,506,773,222
2022	583,678	980,579,544	453,636	554,343,314	1,534,922,858
2023	595,880	1,001,079,072	451,559	551,804,487	1,552,883,559
2024	608,393	1,022,100,072	450,696	550,750,512	1,572,850,584
2025	621,076	1,043,408,352	449,205	548,928,877	1,592,337,229
2026	634,541	1,066,029,216	443,070	541,431,907	1,607,461,123
2027	640,204	1,075,542,888	440,047	537,737,801	1,613,280,689
2028	646,799	1,086,622,152	439,556	537,137,065	1,623,759,217
2029	655,008	1,100,414,112	438,288	535,588,058	1,636,002,170
2030	659,660	1,108,229,472	438,112	535,372,253	1,643,601,725
2031	659,453	1,107,880,872	428,423	523,533,028	1,631,413,900
2032	655,793	1,101,731,904	424,059	518,200,098	1,619,932,002
2033	640,800	1,076,543,832	424,089	518,237,002	1,594,780,834
2034	640,099	1,075,366,488	424,089	518,237,002	1,593,603,490
2035	636,982	1,070,129,256	424,089	518,237,002	1,588,366,258
2036	643,613	1,081,269,336	424,088	518,236,025	1,599,505,361
2037	647,297	1,087,458,288	423,491	517,505,513	1,604,963,801

II. Low Range Estimates

PHMSA and FRA’s low range estimates focus on an alternative forecast of crude oil traffic as that is projected to have the most variability. Ethanol traffic has historically been stable and therefore remained the same in both estimates. Similar to the high range flow estimates provided above, PHMSA and FRA forecast that 84 percent of crude oil will be hauled by unit trains, and the average length of haul by crude oil unit trains will be approximately 1,000 miles. However, unlike the high range flow estimate, PHMSA and FRA assume that the 20-year average crude oil carloads will remain constant at 417,477. This constant estimation of carloads assumes that, while there will be peaks and valleys within the total carloads of crude oil per year, the aggregate level of carloads will remain fairly constant over time. Using the same calculations as presented in the high range flow estimate, PHMSA and FRA multiply carloads of crude oil by the total round trip miles of a crude oil unit train and then multiply the result by the percentage of crude that travels by unit train to arrive at an estimate of 701,361,360 crude oil carload miles moved by unit trains in 2018.[111]

Table 11.1b: HHFUT Car Miles (Low Range)

Year	Crude Carloads	Crude Unit Car Miles	Ethanol Carloads	Ethanol Unit Car Miles	Unit Car Miles
2018	417,477	701,361,360	467,034	570,715,059	1,272,076,419
2019	417,477	701,361,360	465,773	569,174,606	1,270,535,966
2020	417,477	701,361,360	461,873	564,408,439	1,265,769,799
2021	417,477	701,361,360	456,583	557,944,670	1,259,306,030
2022	417,477	701,361,360	453,636	554,343,314	1,255,704,674
2023	417,477	701,361,360	451,559	551,804,487	1,253,165,847
2024	417,477	701,361,360	450,696	550,750,512	1,252,111,872
2025	417,477	701,361,360	449,205	548,928,877	1,250,290,237
2026	417,477	701,361,360	443,070	541,431,907	1,242,793,267
2027	417,477	701,361,360	440,047	537,737,801	1,239,099,161
2028	417,477	701,361,360	439,556	537,137,065	1,238,498,425
2029	417,477	701,361,360	438,288	535,588,058	1,236,949,418
2030	417,477	701,361,360	438,112	535,372,253	1,236,733,613
2031	417,477	701,361,360	428,423	523,533,028	1,224,894,388
2032	417,477	701,361,360	424,059	518,200,098	1,219,561,458
2033	417,477	701,361,360	424,089	518,237,002	1,219,598,362
2034	417,477	701,361,360	424,089	518,237,002	1,219,598,362
2035	417,477	701,361,360	424,089	518,237,002	1,219,598,362
2036	417,477	701,361,360	424,088	518,236,025	1,219,597,385
2037	417,477	701,361,360	423,491	517,505,513	1,218,866,873

11.2 Set Out Relief

One suggestion by GAO was to present the estimates in ranges thus allowing for more variance within the estimates should the assumptions that FRA uses be incorrect. In this section, FRA presents a high and low range for the estimated benefits associated with avoided set-outs.[112] The high and low ranges are based upon the predicted crude oil carloads that will be needed each year.

[111] Calculation: 471,477 crude carloads x (1,000 miles x 2) x .84 (proportion of crude by unit trains) = 701,361,360 crude carload miles moved by unit trains in 2018

[112] A car must be set out when it has a mechanical defect and must be taken off the line for repair.

I. High Range Estimates

For the high range, FRA assumes one brake caused set-out avoided on 10 percent of 1,000 mile trips or one brake induced set-out avoided for every 10,000 miles of unit train travel. To update the numbers from the 2015 Final Rule, PHMSA and FRA used labor cost index values reported by AAR to the STB because the primary cost of a set-out is employee time. In 2015 Class I railroads reported their labor cost index to be 353.1 and they had previously reported the labor cost index in 2008 to have been 288.7. The ratio between 2015 and 2008 is 1.2230, which when multiplied by the 2008 estimate of $400, yields a 2015 estimate of $489; this is assumed to be a reasonable estimate for 2016 as well.[113]

In this revised analysis, PHMSA and FRA estimated that when all ECP-equipped locomotives have joined the fleet, each set of locomotives will operate 125 miles per day, 280 days per year, for a total of 35,000 miles per year. PHMSA and FRA estimate that 1,924 locomotives will be equipped, and that unit trains will require three locomotives (plus one reserve spare) each, thus in the peak year there will be 481 train sets, operating a total of 16,835,000[114] miles per year. If one set-out is avoided every 10,000 miles, these sets will avoid 1,684 set-outs a year, for an annual savings of $823,232[115] at full installation. As discussed above, PHMSA and FRA estimates thirty-three percent of full benefit by the end of 2018, sixty-six percent of full benefit by the end of 2019, and 100 percent of full benefit by the end of 2020.

This revised analysis uses the car miles estimates shown in Table 11.1a above, the unit savings estimate of $489 per set out avoided in 2018, and one set out avoided per 1,000,000 car-miles.[116] The results, used to calculate the business benefits in this analysis, are presented in Table 11.2a below.

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[113] Calculation: $400 x 1.2230 = $489.20 rounded above for simplicity
[114] Calculation: 481 train sets x 35,000 annual miles per train = 16,835,000 miles per year
[115] Calculation: 1,684 avoided set-outs per year x $489 cost of set-out = $823,232231
[116] Calculation: 10,000 unit train miles * 100 cars per unit train = 1,000,000 car miles

Table 11.2a: Set-out Relief Savings (High Range)

Year	Undiscounted	7 percent discount	3 percent discount
2018	$0	$0	$0
2019	$393,689	$367,934	$382,222
2020	$612,207	$534,725	$577,064
2021	$682,245	$556,915	$624,351
2022	$723,470	$551,932	$642,794
2023	$759,360	$541,413	$655,031
2024	$769,124	$512,500	$644,129
2025	$778,653	$484,906	$633,116
2026	$786,048	$457,487	$620,514
2027	$788,894	$429,106	$604,622
2028	$794,018	$403,639	$590,824
2029	$800,005	$380,077	$577,941
2030	$803,721	$356,862	$563,714
2031	$797,761	$331,043	$543,237
2032	$792,147	$307,208	$523,702
2033	$779,848	$282,653	$500,555
2034	$779,272	$263,966	$485,617
2035	$776,711	$245,887	$469,923
2036	$782,158	$231,412	$459,435
2037	$784,827	$217,011	$447,576
Total	$14,184,160	$7,456,676	$10,546,366

II. Low Range Estimates

For the low range, FRA used the same calculations as for the high range set-out estimates however, the low estimate assumes that in the peak year there will be 367 train sets, operating a total of 12,845,000[117] miles per year. If one set-out is avoided every 10,000 miles, these sets will avoid 1,285[118] set-outs a year, for an annual savings of $628,121[119] at full installation.

This revised analysis uses the car miles estimates shown in Table 11.1b, above, the unit savings estimate of $489 per set out avoided in 2018, and one set out avoided per 1,000,000 car-miles. In addition, the crude oil carloads were adjusted as is seen within the low estimate carloads in Table 11.2a above. The 20-year low range estimate for the set-out relief are provided below in Table 11.2b.

[117] Calculation: 367 train sets x 35,000 annual miles per train = 12,845,000 miles per year
[118] Calculation: 12,845,000 miles per year ÷ 10,000 miles = 1,284.5 set-outs avoided per year (rounded above for simplicity)
[119] Calculation: 1,285 avoided set-outs per year x $489 cost of set-out = $628,120.5 (rounded above for simplicity)

Table 11.2b: Set-out Relief Savings (Low Range)

Year	Undiscounted	7 percent discount	3 percent discount
2018	$0	$0	$0
2019	$337,688	$315,596	$327,852
2020	$508,563	$444,199	$479,370
2021	$561,234	$458,134	$513,608
2022	$586,932	$447,768	$521,482
2023	$612,798	$436,917	$528,605
2024	$612,283	$407,990	$512,777
2025	$611,392	$380,744	$497,118
2026	$607,726	$353,702	$479,744
2027	$605,919	$329,580	$464,387
2028	$605,626	$307,869	$450,642
2029	$604,868	$287,369	$436,970
2030	$604,763	$268,522	$424,168
2031	$598,973	$248,553	$407,872
2032	$596,366	$231,281	$394,268
2033	$596,384	$216,157	$382,796
2034	$596,384	$202,016	$371,647
2035	$596,384	$188,800	$360,822
2036	$596,383	$176,448	$350,312
2037	$596,026	$164,806	$339,905
Total	$11,036,691	$5,866,449	$8,244,345

The total discounted value of this benefit would range between $5,866,449 and $7,456,676 at 7 percent and $8,244,345 and $10,546,366 at 3 percent.

11.3 Single Car Air Brake Test (SCABT) Relief

The SCABT relief from the 2008 rule only affects trains equipped with ECP brakes. Since the Final Rule required ECP brakes on HHFUT's, equipped trains could potentially realize the benefits permitted by the 2008 rule, which allowed, but did not require ECP brakes.

However, the exception for ECP-equipped cars to avoid SCABTs when they are on a shop or repair track does not apply to dual mode ECP brake systems under 49 CFR §232.611(f). Dual mode systems can operate either in a conventionally equipped train with standard air brakes or in an ECP equipped train. PHMSA and FRA believe all affected tank cars will be equipped with dual mode systems, not stand-alone systems. This is because PHMSA and FRA believe that the railroads will need the flexibility to haul the cars in trains not equipped with ECP when moving them for repairs, hauling commodities in a train not equipped with ECP brakes, operating in a short haul move, or the car has been shifted into service carrying a commodity not affected by the Final Rule. Thus, there is no benefit estimated for this provision.

11.4 Class I and Class IA Brake Test Relief

The Class I and Class IA Brake Test relief from the 2008 rule only affects trains equipped with ECP brakes. Since the Final Rule requires ECP brakes, equipped trains will realize the potential benefits permitted by the 2008 rule, which allowed, but did not require ECP brakes. The 2008 analysis[120] described the benefits of relief from "Class I and Class IA Brake Tests" requirements:

"The rule allows ECP brake-equipped trains to travel to their destination, not to exceed 3,500 miles. Extended haul and other trains are currently limited to 1,500 miles and 1,000 miles, respectively, between brake inspections. Thus, the rule will eliminate, conservatively, at least one Class I brake test or two Class IA brake tests on a long-distance train equipped with ECP brakes, depending on current operations. The long-haul, unit, and unit-like trains are assumed to convert to ECP brake systems. Trains with conventional brakes that meet FRA's extended haul requirements are given 1,500 miles between intermediate terminal brake inspections. These requirements limit the number of times an extended haul train on extended haul can pick up or set out cars en route, and impose additional recordkeeping. Many long-haul unit trains are extended haul trains. FRA estimates that there are 40,000 extended haul trains that operate each year."

"The single largest cost savings in the brake inspection category is expected to be the elimination of the 1,000-mile intermediate terminal brake test (Class IA test) for trains operating in the ECP brake mode. Under current regulations, conventionally-braked trains are required to stop at a terminal for inspection every 1,000 miles, where the brakes on each car are inspected to determine whether they are fully functioning."

With ECP brake systems, there is constant wire-based monitoring of the brake condition on all cars and hence a reduced need to stop and physically inspect the brakes every 1,000 miles after initial terminal departure. More than 10 years ago, the AAR calculated the cost of the intermediate brake test (Class IA) to be $450 per train, including both the direct cost of the inspection and delay costs of setting out or repairing defective equipment when identified.[121] To reflect current costs as confirmed in the Booz Allen Hamilton report, FRA assumes that this cost is at least 10 percent greater 10 years later, or $500 per train. The Class I test is substantially more involved than the Class IA test and is estimated to cost $1,000 per train. Trains operating under the extended haul provisions, estimated at 40,000 trains each year, must receive a Class I test at the beginning of the extended haul segment and a Class I test at the end of the Class I segment if the train goes further than 1,500 miles. Thus, a train that travels more than 1,500 miles and uses the extended haul provision would receive two Class I tests ($2,000). With ECP brakes, the same train would only receive a Class I test at initial terminal, which would permit it to travel to 3,500 miles, or to its destination. A cycle train is a train that operates in a continuous loop(s), without a specific destination, that requires a Class IA test at a location not to exceed 1,000 miles. Every 3,000 miles, a cycle train must receive a Class I test. Many cycle trains are used in coal service, which will implement ECP brakes. With ECP brakes, the Class I test is still

[120] Electronically Controlled Pneumatic Brake Systems, Final Rulemaking, Regulatory Analysis, Federal Railroad Administration, June 2008, Docket ID: FRA-2006-26175-0065 at www.regulations.gov

[121] FRA commissioned a report by Booz Allen Hamilton (BAH) to describe a path to ECP brake implementation. A copy of this report has been placed in the public docket to this rulemaking at Docket Number FRA-2006-26175

required, but two Class I A tests are eliminated. There are approximately 14,000 cycle trains that operate each year that are estimated to receive relief from two Class IA brake tests ($1,000).

"Using the AAR Fact Book, the Freight Commodity Statistics, waybill data, and information provided by one Class I carrier, FRA estimates that approximately 178,071 trains travel more than 1,000 miles to destination and 88,045 (including the 40,000 extended haul trains) travel more than 1,500 miles to destination each year. Of these trains, approximately 25 percent operate over 2,000 miles and thus will receive relief from two Class IA brakes tests (2 X $500 = $1,000). Since extended haul trains are not required to have any Class IA brake tests they would not benefit from this relief."

PHMSA and FRA assume that ECP equipped trains will function as cycle trains, running as a unit, at least from the point at which the trains are assembled, and often on a longer-term basis from the point at which they are loaded, to the destination, typically a refinery, and back to the original assembly point or loading facility. Given the assumption on the distance that these unit trains travel PHMSA and FRA believe that each train will avoid 2 Class IA brake tests every three thousand miles, or 14,583 brake tests per year.

PHMSA and FRA assume that extended haul trains are allowed by regulation to go as far as 1,500 miles before requiring a Class I brake test. As noted above, this analysis assumes that crude oil HHFUTs will travel an average of 1,000 miles, and ethanol HHFUTs will travel an average of 1,300 miles. Trains traveling a round trip, returning residue cars to the loading facility would be traveling 2,000 miles and 2,600 miles, respectively and would need at least one Class I brake test were they not equipped with ECP brakes. This would be true if the train were broken and reassembled at either end of the round trip. It is possible that initial makeup of the unit train might be as residue cars, remaining a unit train through loading. Some trains might remain as unit trains through loading and unloading, in which case the number of Class I brake tests avoided might be greater than one per round trip. As a conservative assumption, PHMSA and FRA assume a benefit of one brake test avoided per round trip. The number of trains is estimated at one per 100 carloads in HHFUTs for crude oil and one per 80 carloads in HHFUTs for ethanol.

The Class IA brake test benefits listed below are adjusted from the Final Rule analysis to reflect changes that result from updated data and/or updated assumptions. These changes incorporate GAO suggestions of adding a range to the estimated benefits as well as take into account the most available information. The addition of ranged benefits helps to address any uncertainty that might exist within the assumptions or due to limited data.

I. High Range Estimates

In order to calculate the high range estimates for the Class IA brake tests the 2008 AAR value per brake test of $500 is updated to 2016 values using the same multiplier for labor costs that is used in estimating the set out relief benefits of 1.2230 which yields a savings per test of $611.53.[122] Assuming that the railroads will avoid 14,583 Class IA brake tests, FRA calculates

[122] Calculation: $500 x 1.2230 (rounded for simplicity) = $611.50

the savings by multiplying the cost of the brake test by the percentage of the locomotives that will be impacted per year to arrive at the total high range estimated benefits of $46,041,344; discounted at 7 percent, or $65,116,955; discounted at 3 percent per year.

Table 11.4a: Class IA Brake Test Savings (High Range Estimate)

Year	Undiscounted	7 percent discount	3 percent discount
2018	$0	$0	$0
2019	$2,434,927	$2,275,633	$2,364,007
2020	$3,788,248	$3,308,803	$3,570,787
2021	$4,213,524	$3,439,490	$3,855,971
2022	$4,465,118	$3,406,417	$3,967,200
2023	$4,683,315	$3,339,139	$4,039,869
2024	$4,744,492	$3,161,455	$3,973,437
2025	$4,804,290	$2,991,870	$3,906,327
2026	$4,851,415	$2,823,568	$3,829,752
2027	$4,869,644	$2,648,764	$3,732,177
2028	$4,901,755	$2,491,804	$3,647,366
2029	$4,939,372	$2,346,660	$3,568,307
2030	$4,962,634	$2,203,469	$3,480,692
2031	$4,926,760	$2,044,430	$3,354,884
2032	$4,892,279	$1,897,310	$3,234,373
2033	$4,815,371	$1,745,312	$3,090,803
2034	$4,811,771	$1,629,913	$2,998,537
2035	$4,795,757	$1,518,214	$2,901,512
2036	$4,829,817	$1,428,969	$2,837,009
2037	$4,846,593	$1,340,123	$2,763,944
Total	$87,577,085	$46,041,344	$65,116,955

II. Low Range Estimates

The calculations for the low range estimates are similar to the high range estimates calculated above. The major difference between the high and low range estimates is the number of carloads that are predicted for the 20-year time period, as is assumed in the previous low range estimates above. Assuming that the railroads will avoid 14,583 Class IA brake tests, FRA calculates the savings by multiplying the cost of the brake test by the percentage of the locomotives that will be impacted per year to arrive at the total low range estimated benefits of $27,538,841; discounted at 7 percent, or $45,066,398; discounted at 3 percent per year.

Table 11.4b: Class IA Brake Test Savings (Low Range Estimate)

Year	Undiscounted	7 percent discount	3 percent discount
2018	$0	$0	$0
2019	$2,084,757	$1,486,403	$1,798,330
2020	$3,140,173	$2,092,430	$2,629,846
2021	$3,456,850	$2,152,753	$2,810,735
2022	$3,611,360	$2,101,845	$2,850,841
2023	$3,766,877	$2,048,931	$2,886,997
2024	$3,763,778	$1,913,314	$2,800,604
2025	$3,758,422	$1,785,599	$2,715,164
2026	$3,736,381	$1,658,998	$2,620,622
2027	$3,725,520	$1,545,958	$2,536,898
2028	$3,723,754	$1,444,136	$2,461,840
2029	$3,719,199	$1,348,009	$2,387,213
2030	$3,718,565	$1,259,607	$2,317,287
2031	$3,683,757	$1,166,183	$2,228,733
2032	$3,668,078	$1,085,252	$2,154,609
2033	$3,668,186	$1,014,284	$2,091,915
2034	$3,668,186	$947,929	$2,030,986
2035	$3,668,186	$885,915	$1,971,831
2036	$3,668,183	$827,957	$1,914,397
2037	$3,666,035	$773,339	$1,857,550
Total	$67,896,247	$27,538,841	$45,066,398

11.5 Impact of Dynamic Braking

In the 2015 final rule RIA, PHMSA and FRA described ECP brake system business benefits from more efficient fuel consumption and reduced wheel wear. In comments provided to PHMSA and FRA during subsequent meetings with the Office of Information and Regulatory Affairs of the Office of Management and Budget held under Executive Order 12866, AAR asserted that a significant portion the benefits claimed in the analysis of the NPRM for wheel savings and fuel savings may not be realized due to the use of dynamic braking. Dynamic braking is an alternative to pneumatic brakes for slowing a train in non-emergency situation, and its use allows a train to operate more efficiently. When trains use dynamic braking and not ECP brakes, they do not get business benefits from ECP brakes. AAR, with data from the two railroads that had requested ECP brake waivers, estimated that 85 percent of the potential fuel and wheel savings benefits of ECP brakes are already being realized through use of dynamic brakes. PHMSA and FRA accept that the fuel and wheel savings should be reduced to account for the use of dynamic braking however, due to limited data, the reduction should be smaller than 85 percent.

The ability to use ECP brakes on top of the dynamic brakes has the potential to further improve fuel efficiency by as much as five percent above dynamic braking alone, depending on the routes and railroad practices. For instance, Canadian Pacific achieved a fuel savings of 5.4 percent from ECP brakes used in conjunction with dynamic brakes during testing in Golden, British Columbia, a route which has particularly advantageous terrain for maximizing the fuel benefits associated with ECP braking.[123] Because not all terrain will be as advantageous as this test region, and because of limited data showing similar fuel savings benefits, PHMSA and FRA reduced the estimated fuel efficiency benefits by 80 percent, corresponding to a fuel improvement rate of 1 percent.

PHMSA and FRA also accept that wheel savings costs should be reduced to account for the use of dynamic braking, but that they should be reduced by less than 85 percent. Railroads will continue to experience brake induced wheel wear where pneumatic brakes are used, but if the railroads rely on dynamic braking they could face a cost not considered in other parts of the analysis, increased rail wear, with attendant increased risk of broken rail accidents and increased track maintenance costs. PHMSA and FRA estimate that the use of dynamic braking in conjunction with ECP braking would reduce the combined wheel wear and dynamic brake induced rail wear by at least as much as 25 percent of the wheel wear benefits estimated using the methodology and assumptions used in analyzing the NPRM. Therefore, PHMSA and FRA are reducing the estimated wheel wear benefit from ECP brakes by 75 percent for purposes of this updated analysis. PHMSA and FRA view this as a conservative assumption.

11.6 Wheel Savings

The wheel savings benefits listed below are adjusted from the Final Rule analysis to reflect changes that result from updated data and/or updated assumptions. These changes incorporate GAO suggestions of adding a range to the estimated benefits as well as take into account the most available information. The addition of ranged benefits helps to address any uncertainty that might exist within the assumptions or due to limited data.

I. High Range Estimates

The industry wide cost of wheelset replacement was $555 million in 2000. According to the AAR fact book, there were 34,590,000,000 car miles in 2000, the cost per car-mile was $0.01605.[124] This number was adjusted for labor costs. The labor index submitted by Class I railroads to the STB for 2000 was 216.4, while the 2015 value was 353.1. The ratio of the 2015 value to the 2000 value, used here as a multiplier, is 1.223. Thus, the cost per car mile, in 2015 dollars would be $0.0196. Since brake-related failures account for only half of wheelset life reduction, the addressable value of wheelset life reduction is $0.00981 per car mile. The high range wheel savings estimates are thus presented below, using the low range flow estimates, in Table 11.6b. Due to the increased use of dynamic braking by the railroads, PHMSA and FRA

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[123] Wachs, K., Aronian, A., Bell, S. Electronically-Controlled Pneumatic (ECP) Brake Experience at Canadian Pacific. *Proceedings from the 2011 International Heavy Haul Conference*, Calgary AB, 2011, available at http://www.ihha.net/IHA/uploads/assets/fin00258.pdf.

[124] Calculation: $555,000,000 ÷ 34,590,000,000 miles = $0.016045 cost per car-mile (rounded above for simplicity)

further reduce the estimated total wheel savings by an additional 75 percent, to $0.00735 per car mile.

Table 11.6a: Wheel Savings (High Range Estimate)

Year	Undiscounted	7 percent discount	3 percent discount
2018	$0	$0	$0
2019	$1,974,801	$1,845,609	$1,917,283
2020	$3,070,918	$2,682,259	$2,894,635
2021	$3,422,240	$2,793,567	$3,131,834
2022	$3,629,029	$2,768,569	$3,224,346
2023	$3,809,060	$2,715,807	$3,285,728
2024	$3,858,037	$2,570,773	$3,231,045
2025	$3,905,835	$2,432,358	$3,175,802
2026	$3,942,933	$2,294,823	$3,112,588
2027	$3,957,208	$2,152,459	$3,032,870
2028	$3,982,910	$2,024,710	$2,963,659
2029	$4,012,941	$1,906,519	$2,899,034
2030	$4,031,582	$1,790,071	$2,827,670
2031	$4,001,686	$1,660,558	$2,724,954
2032	$3,973,522	$1,541,001	$2,626,966
2033	$3,911,829	$1,417,827	$2,510,854
2034	$3,908,941	$1,324,094	$2,435,923
2035	$3,896,095	$1,233,404	$2,357,202
2036	$3,923,418	$1,160,798	$2,304,595
2037	$3,936,807	$1,088,560	$2,245,106
Total	$71,149,794	$37,403,763	$52,902,094

II. Low Range Estimates

The analysis used to determine the low range estimates mirrors the analysis that was used to estimate the high range wheel savings estimates, however; the number of carloads needed was altered to reflect what was predicted under the low range flow estimates, which can be found in Table 11.1b above. The low range wheel savings estimates are thus presented below, using the low range flow estimates, in Table 11.6b.

Table 11.6b: Wheel Savings (Low Range Estimate)

Year	Undiscounted	7 percent discount	3 percent discount
2018	$0	$0	$0
2019	$1,693,891	$1,583,076	$1,644,555
2020	$2,551,026	$2,228,165	$2,404,587
2021	$2,815,229	$2,298,066	$2,576,333
2022	$2,944,137	$2,246,068	$2,615,827
2023	$3,073,884	$2,191,637	$2,651,559
2024	$3,071,298	$2,046,536	$2,572,164
2025	$3,066,830	$1,909,868	$2,493,614
2026	$3,048,441	$1,774,220	$2,406,467
2027	$3,039,380	$1,653,221	$2,329,431
2028	$3,037,906	$1,544,317	$2,260,487
2029	$3,034,107	$1,441,482	$2,191,903
2030	$3,033,577	$1,346,945	$2,127,690
2031	$3,004,537	$1,246,776	$2,045,943
2032	$2,991,456	$1,160,138	$1,977,705
2033	$2,991,546	$1,084,274	$1,920,160
2034	$2,991,546	$1,013,340	$1,864,233
2035	$2,991,546	$947,047	$1,809,935
2036	$2,991,544	$885,090	$1,757,217
2037	$2,989,752	$826,691	$1,705,014
Total	$46,388,791	$26,768,129	$36,082,659

11.7 Fuel Savings

I. High Range Estimates

In this revised analysis, fuel savings estimates are based on car-miles. Class I railroads spent $6.7 billion in fuel, and hauled 35.9 billion car-miles in 2015, according to the AAR fact book. Thus, the cost of fuel per car-miles was $0.18663. A saving of 1 percent would equate to $0.001866 per car mile. PHMSA and FRA believe that, while dynamic braking is widely used over conventional pneumatic braking, there are still some times in which the use of pneumatic braking might still need to be used. Furthermore, PHMSA and FRA believe that a 1 percent reduction in fuel savings attributed to the use of ECP brakes is most likely an understatement of the potential benefits but rather represents a conservative low end range of fuel savings. Using the high range flow estimated carload miles, the high range fuel savings estimates and are presented in Table 11.7a, below.

Table 11.7a: Fuel Savings (High Range Estimate)

Year	Undiscounted	7 percent discount	3 percent discount
2018	$0	$0	$0
2019	$1,523,320	$1,423,664	$1,478,952
2020	$2,368,842	$2,069,039	$2,232,861
2021	$2,639,845	$2,154,900	$2,415,832
2022	$2,799,358	$2,135,617	$2,487,193
2023	$2,938,229	$2,094,917	$2,534,542
2024	$2,976,009	$1,983,041	$2,492,361
2025	$3,012,880	$1,876,270	$2,449,747
2026	$3,041,496	$1,770,178	$2,400,985
2027	$3,052,507	$1,660,362	$2,339,493
2028	$3,072,334	$1,561,819	$2,286,105
2029	$3,095,499	$1,470,649	$2,236,254
2030	$3,109,878	$1,380,823	$2,181,206
2031	$3,086,818	$1,280,920	$2,101,973
2032	$3,065,092	$1,188,696	$2,026,387
2033	$3,017,504	$1,093,682	$1,936,821
2034	$3,015,276	$1,021,378	$1,879,020
2035	$3,005,367	$951,422	$1,818,296
2036	$3,026,443	$895,415	$1,777,716
2037	$3,036,771	$839,692	$1,731,828
Total	$54,883,469	$28,852,484	$40,807,573

II. Low Range Estimates

The low range fuel savings estimates are calculated using the same methodology that was used to calculate the high range fuel savings estimates, with the exception of the carload miles that were used. For the low range fuel savings estimates the number of carloads needed was altered to reflect what is predicted under the low range flow estimates, which can be found in Table 11.1b above. The low range fuel savings estimates are thus presented below in Table 11.7b.

Table 11.7b: Fuel Savings (Low Range Estimate)

Year	Undiscounted	7 percent discount	3 percent discount
2018	$0	$0	$0
2019	$1,306,633	$1,221,152	$1,268,575
2020	$1,967,808	$1,718,760	$1,854,848
2021	$2,171,609	$1,772,680	$1,987,330
2022	$2,271,046	$1,732,570	$2,017,795
2023	$2,371,130	$1,690,583	$2,045,357
2024	$2,369,136	$1,578,655	$1,984,114
2025	$2,365,689	$1,473,232	$1,923,522
2026	$2,351,504	$1,368,597	$1,856,299
2027	$2,344,514	$1,275,260	$1,796,875
2028	$2,343,378	$1,191,254	$1,743,693
2029	$2,340,447	$1,111,929	$1,690,788
2030	$2,340,038	$1,039,005	$1,641,256
2031	$2,317,637	$961,737	$1,578,198
2032	$2,307,547	$894,906	$1,525,560
2033	$2,307,616	$836,386	$1,481,171
2034	$2,307,616	$781,670	$1,438,030
2035	$2,307,616	$730,532	$1,396,146
2036	$2,307,615	$682,740	$1,355,480
2037	$2,306,232	$637,692	$1,315,212
Total	$42,704,811	$22,699,341	$31,900,250

If the price of oil increases, the fuel savings benefit would also rise. The demand for crude oil production in the United States has decreased, along with the declining price of oil. Any surge in oil prices may have effects on numerous assumptions of this analysis. Changes in these assumptions would adjust the number of carloads needed and therefore adjust the safety and business benefits.

11.8 Non-Quantified Benefits

As we reviewed the efficiencies of ECP brakes, many of the benefits were discussed and monetized. However, there are many benefits that we have not quantified in this analysis. Although they have not yet been quantified, they should be considered as they provide significant benefits that will be seen throughout the rail industry. These include both safety, business, and societal benefits.

There are several additional safety benefits of ECP brakes that have not been monetized. Due to the shorter stopping distances and brake system monitoring associated with ECP braking, these include fewer and less-severe collisions with obstacles on the railroad, including vehicles stuck on grade crossings; fewer and less-severe train-to-train collisions; reduced chances of runaway trains; and fewer train-handling accidents.

As PTC is implemented, train sets that operate with ECP brakes can have enhanced braking algorithms with lower variance. PTC and ECP brake systems should work together seamlessly to provide faster braking and enhanced train handling. ECP electronic communication networks can also be configured to transmit car-born sensor data for non-air brake purposes.

ECP brakes will eliminate the majority of dragging brake issues.[125] It can also significantly reduce the possibility of a runaway train. Runaway trains can occur due to a depletion of the main reservoir air. This would be reduced with ECP brakes as the train line operates at a higher pressure and continuously recharges the car reservoirs, as opposed to conventional brakes, which cannot recharge the reservoirs while the brakes are applied. ECP brakes can also reduce undesired emergency applications which could prevent derailments, and increase fuel savings to an even greater extent than that specifically estimated in this analysis. Although these benefits have not been quantified, they should be considered when projecting the impact ECP brakes will have on the rail network.

This Final Rule may also produce societal benefits. One of these potential benefits is reduced emissions due to the fuel savings of ECP.

12. Results

For the 20-year period analyzed, the estimated quantified costs total range from $427.3 million to $554.8 million, undiscounted. The total 7 percent and 3 percent low and high ranges are presented within Table 12a below. Annualized values are presented in Table 12b.

Table 12a: Summary of Costs and Benefits for ECP Brakes (Low and High Range Estimates)

	Total		7 Percent		3 Percent	
	Low	High	Low	High	Low	High
Tank Cars	$274,482,088	$364,480,686	$237,755,215	$318,492,228	$256,181,453	$341,523,970
Locomotives	$115,668,000	$153,252,000	$105,033,048	$140,417,816	$110,789,180	$147,387,381
Asset Management	$522,480	$522,480	$522,480	$522,480	$522,480	$522,480
Training	$36,577,918	$36,577,918	$32,288,700	$32,288,700	$34,621,159	$34,621,159
Total Costs	**$427,250,486**	**$554,833,084**	**$375,599,443**	**$491,721,224**	**$402,114,272**	**$524,054,990**
Damage Mitigation	$89,515,934	$146,156,247	$48,157,055	$78,191,951	$67,192,298	$109,438,651
Set Out Reliefs	$11,036,691	$14,184,160	$5,866,449	$7,456,676	$8,244,345	$10,546,366
Class IA Brake Test	$67,896,247	$87,577,085	$27,538,841	$46,041,344	$45,066,398	$65,116,955
Wheel Savings	$46,388,791	$71,149,794	$26,768,129	$37,403,763	$36,082,659	$52,902,094
Fuel Savings	$42,704,811	$54,883,469	$22,699,341	$28,852,484	$31,900,250	$40,807,573
Total Benefits	**$257,542,474**	**$373,950,755**	**$131,029,815**	**$197,946,218**	**$188,485,950**	**$278,811,639**

[125] A dragging brake refers to a scenario where a brake is fully or partially engaged while the train is moving.

Table 12b: Annualized Costs and Benefits (Low and High Range Estimates)

	7 Percent		3 Percent	
	Low	High	Low	High
Annualized Costs	$35,453,930	$46,415,005	$27,028,395	$35,224,727
Annualized Benefits	$12,368,288	$18,684,723	$12,669,216	$18,740,522

13. Sensitivity Analysis

13.1 Continued Crude Oil Decline Scenario

In this section, the sensitivity analysis is described based on a continued decline in crude-by-rail volumes, as described above in the Benefits Uncertainty section of 10.1. This scenario considers a carload forecast that sees crude by rail declining over the next few years to a relatively modest (by recent standards) 120,000 carloads per year and never rebounding. This scenario is intended to capture the possibility that sufficient pipeline capacity and low crude oil prices keep crude-by-rail volumes modest for the foreseeable future. The table below presents the carload forecast under this scenario. PHMSA and FRA continue to use the baseline ethanol volume forecast, but a lower crude volume forecast than is considered in the two other scenarios presented in this document.

Table 13.1a: 20-year Forecast for Continued Crude Oil Decline Scenario

Year	Ethanol Carloads	Crude Oil Carloads	Total Carloads
2018	467,034	225,000	692,034
2019	465,773	175,000	640,773
2020	461,873	120,000	581,873
2021	456,583	120,000	576,583
2022	453,636	120,000	573,636
2023	451,559	120,000	571,559
2024	450,696	120,000	570,696
2025	449,205	120,000	569,205
2026	443,070	120,000	563,070
2027	440,047	120,000	560,047
2028	439,556	120,000	559,556
2029	438,288	120,000	558,288
2030	438,112	120,000	558,112
2031	428,423	120,000	548,423
2032	424,059	120,000	544,059
2033	424,089	120,000	544,089
2034	424,089	120,000	544,089
2035	424,089	120,000	544,089
2036	424,088	120,000	544,088
2037	423,491	120,000	543,491

In order to obtain the societal damages that might be mitigated by ECP brake technology, PHMSA and FRA follow the same steps as described above in section 10.1. Using the adjusted baseline average spill volume, the retrofit/retirement schedule, and the speed effectiveness the total comparable damages are obtained. Table 13.1b below presents 20 year total societal damages with these adjustments already incorporated. Predicted damages under this scenario are roughly 34 percent lower than for the low scenario presented in section 10.1, and 46 percent lower than those presented in the high forecast scenario of that section.

Table 13.1b: Low Crude Oil by Rail Forecast

Year	LCE Damages Low Carload Prediction	Speed effectiveness	ECP Societal Damage Pool, Sensitivity Analysis
2018	$55,527,568	7.44%	$51,396,784
2019	$50,072,822	5.93%	$47,102,702
2020	$43,393,582	4.91%	$41,263,968
2021	$40,766,526	3.86%	$39,191,233
2022	$35,666,631	3.14%	$34,545,875
2023	$35,348,504	1.39%	$34,856,533
2024	$35,279,662	0.59%	$35,072,464
2025	$35,168,177	0.34%	$35,048,742
2026	$34,789,128	0.00%	$34,789,128
2027	$34,602,353	0.00%	$34,602,353
2028	$34,571,979	0.00%	$34,571,979
2029	$34,493,661	0.00%	$34,493,661
2030	$34,482,750	0.00%	$34,482,750
2031	$33,884,155	0.00%	$33,884,155
2032	$33,614,521	0.00%	$33,614,521
2033	$33,616,386	0.00%	$33,616,386
2034	$33,616,386	0.00%	$33,616,386
2035	$33,616,386	0.00%	$33,616,386
2036	$33,616,337	0.00%	$33,616,337
2037	$33,579,402	0.00%	$33,579,402
Total	$739,706,918		$726,961,745
7 % Discount Rate	$411,410,489		$400,690,092
3% Discount Rate	$561,691,983		$549,891,816

The 20-year costs, given the forecasted carloads of crude oil in Table 13.1a, would be $314.7 million undiscounted, $275.0 million at 7 percent, or $295.4 million at 3 percent. Cost components are presented in Table 13.1c.

The total 20-year benefits, given the forecasted carloads of crude oil in Table 13.1a, would be $175.8 million undiscounted, $94.3 million at 7 percent or $131.8 at a 3 percent discount rate. The decrease in benefits is largely due to the decrease in carloads and a reduction in estimated LCE damages which is explained above. A breakdown of the benefits is presented in Table 13.1c below.

Table 13.1c Summary of Costs and Benefits for ECP Brakes (Sensitivity Analysis)

	Total	7 Percent	3 Percent
Tank Cars	$191,691,409	$165,002,272	$178,387,998
Locomotives	$85,860,000	$77,132,579	$81,840,945
Asset Management	$522,480	$522,480	$522,480
Training	$36,577,918	$32,288,700	$34,621,159
Total Costs	**$314,651,807**	**$274,946,031**	**$295,372,582**
Damage Mitigation	$70,065,299	$37,362,920	$52,410,689
Set Out Reliefs	$6,623,133	$3,562,941	$4,970,284
Class IA Brake Test	$40,285,252	$21,680,752	$30,236,802
Wheel Savings	$33,222,592	$17,872,226	$24,931,663
Fuel Savings	$25,627,215	$13,786,263	$19,231,765
Total Benefits	**$175,823,491**	**$94,265,102**	**$131,781,203**

13.2 AAR Sensitivity Analysis Scenario

In response to the Final Rule, AAR asserted that the rail industry would be required to equip 100 percent of the locomotive fleet with ECP brakes to successful implement ECP for HHFUTs. They also claim that railroads would need to train 100 percent of their employees to operate ECP equipment.

For a sensitivity analysis, DOT estimated the costs of equipping 100 percent of locomotives and training 100 percent of railroad employees. The total cost would be between $2.5 billion and $2.6 billion. The discounted value at 3 percent would be between $2.4 billion and $2.5 billion. The discounted value at 7 percent would be between $2.2 billion and $2.3 billion.

Although there is uncertainty in the number of locomotives that would be needed to be equipped, or the number of employees trained, DOT does not believe that the industry would equip 100 percent of their locomotives with ECP brakes. DOT estimates between 357 and 464 unit trains are on the network at any given time. By only equipping those locomotives that operate unit trains, it ensures optimal utilization of ECP brakes. Under the Final Rule operational requirements for ECP brakes on HHFUTs, the industry may equip additional equipment with ECP brakes on a case-by-case basis to the extent they are able to realize benefits that cover costs. DOT has included costs for asset management which will help use ECP locomotives efficiently.

AAR claims that they would be required to train 100 percent of employees on ECP brakes. DOT estimated that the HHFUT network encompasses 62 percent of general rail network. Therefore, many employees would not be likely to operate or work with a train requiring ECP brakes. By reducing the amount of training, the railroads can save money and still have the necessary employees to operate HHFUT with ECP brakes.

If AAR's claim that every locomotive and tank car would need to be equipped was true, railroads would not advertise the availability of unit trains to their customers. The advertising of unit trains suggests that the railroads are providing a fast and efficient method of transporting crude oil and ethanol from point of origin to refineries and ports. Breaking the unit trains up and allowing the equipment to be used throughout the network will decrease the efficiency that a unit train provides. Therefore, FRA believes that the assertion from AAR is incorrect and believes that the analysis presented within this RIA is more realistic. Furthermore, if railroads were to equip additional non-unit train locomotives or train employees not working within the HHFUT network the marginal safety and business benefits that could be gained would not exceed the marginal costs of equipping or training.

14. Conclusion

In response to the GAO audits and the FAST Act requirements, PHMSA and FRA have revised the Final Rule RIA. This final 2017 RIA uses updated information, including an updated 20-year forecast of both crude oil and ethanol carloads and an updated estimate of the cost to equip both the locomotives and tank cars with ECP brakes. In addition to these updates, PHMSA and FRA adjusted the assumptions that were used to generate both the safety benefits and business benefits that would be generated by the use of ECP brakes. These adjustments were made in order to take into account both recommendations from GAO and stakeholders as well as to incorporate the latest economic data from within the railroad and energy industries.

As stated above, there were two major changes that resulted in significant changes between the 2015 Final Rule analysis and this updated RIA: the number of carloads of HHFUT that would need to be transported, and the use of dynamic brakes within the railroad industry. Due to the reduced number of HHFUT carloads that was forecasted in the final 2017 RIA, both estimated safety benefits and business benefits have decreased. Also, railroads have not made commitments to install ECP on new locomotive orders. Therefore, DOT assumed that installing ECP on locomotives would be done solely through retrofitting. increased the costs while not adding any additional business or safety benefits. Additionally, the increased use of dynamic braking within the railroad industry also decreased the business benefits that railroads could expect to see if ECP brakes were to be installed, especially when compared to the fuel savings and wheel savings that the original 2015 Final Rule analysis estimated.

While the estimates within the revised Final Rule analysis represent the most up to date information that is available to PHMSA and FRA, should the number of HHFUT carloads increase back to the levels that were predicted in the 2015 Final Rule analysis, it could be possible that the railroad industry would see higher amounts of safety and business benefits than what is presented within this revised Final Rule analysis. In the peak year from Final Rule's forecast 1,004,852 carloads of crude were projected to be originated in 2021. In this analysis, FRA and PHMSA have projected that 679,154 carloads of crude would be originated in the peak year (2030). This is a 32% reduction in peak year origination of carloads of crude from the Final Rule. The total originated carloads of crude projected in the Final Rule was 17,893,953.

However; the total originated carloads of crude projected in the high range in the final 2017 RIA is 12,647,147. This is a 29% reduction from the Final Rule.

An increase in the number of carloads may dictate that once again, new tank cars and locomotives would be needed. Purchasing new locomotives with an ECP overlay system would decrease the costs compared to retrofitting locomotives. Decreasing these costs could enable the safety benefits to exceed the total costs.

Finally, the demand for crude oil production in the United States has decreased since 2015, along, correlating with the price of oil. Any future surge in oil prices may have effects on numerous assumptions of this analysis. Changes in these assumptions would change the number of carloads needed and therefore also affect the estimated safety and business benefits.

In conclusion, if the number of carloads were to increase, and come closer to 2015 forecasted carloads, then the safety benefits would increase greatly and it is likely that the total benefits would be greater than the total costs. As the number of carloads drives the calculations for most of the costs and benefits used within this analysis, any increase has the potential to significantly alter the costs and benefits and could bring the relative estimated costs and benefits analysis closer to the results presented in the 2015 Final Rule.

Appendix A: Incident Data

This appendix presents the raw incident data used to estimate average spill size and incident frequency for 2014-2016. Data for earlier years is presented in the 2015 HM-251 Final Rule RIA. The reader is referred to that document for said data.

2014 Main Line Derailments of Crude Oil and Ethanol								
Incident Date	Product	UN Number	Cars Releasing	No. Main Line Incidents	Quantity Released	Unit of Measure	City	State
1/20/2014	Crude Oil	UN1267	0	1	0	LGA	Philadelphia	PA
1/31/2014	Crude Oil	UN1267	4	1	50,350	LGA	New Augusta	MS
2/11/2014	Ethanol	UN1987	1	1	25	LGA	Jacksonville	FL
2/13/2014	Crude Oil	UN1267	4	1	9800	LGA	Vandergrift	PA
4/30/2014	Crude Oil	UN1267	2	1	30000	LGA	Lynchburg	VA
5/9/2014	Crude Oil	UN1267	1	1	7932	LGA	Evans	CO
2014 Total			12	6	98,107			

2015 Main Line Derailments of Crude Oil and Ethanol								
Incident Date	Product	UN Number	Cars Releasing	No. Main Line Incidents	Quantity Released	Unit of Measure	City	State
2/4/2015	Ethanol	1987	7	1	53,180	LGA	Sherrill	IA
2/16/2015	Crude Oil	1267	20	1	362,349	LGA	Mount Carbon	WV
3/5/2015	Crude Oil	1267	10	1	110,543	LGA	Galena	IL
5/6/2015	Crude Oil	1267	5	1	98,090	LGA	Heimdal	ND
6/7/2015	Crude Oil	1267	0	1	0	LGA	St. Paul Park	MN
7/16/2015	Crude Oil	1267	5	1	27,201	LGA	Culbertson	MT
9/19/2015	Ethanol	1987	3	1	49,748	LGA	Scotland	SD
11/7/2015	Ethanol	1987	5	1	20,413	LGA	Alma	WI
11/8/2015	Crude Oil	1267	1	1	1,000	LGA	Watertown	WI
2015 Total			56	9	722,524			

2016 Main Line Derailments of Crude Oil and Ethanol								
Incident Date	**Product**	**UN Number**	**Cars Releasing**	**No. Main Line Incidents**	**Quantity Released**	**Unit of Measure**	**City**	**State**
3/1/2016	Ethanol	UN1987	2	1	1,526	LGA	Ripley	NY
5/1/2016	Ethanol	UN1987	2	1	1,411	LGA	Washington	DC
6/3/2016	Crude Oil	UN1267	5	1	42,448	LGA	Mosier	OR
6/9/2016	Ethanol	UN1987	1	1	20	LGA	Tulare	SD
2016 Preliminary Total			10	4	45,405			

Appendix B: Waybill Sample Data

This appendix provides data on crude and ethanol carloads shipped from 1995 – 2016. These figures are used for various calculations in the Fleet Forecast section above and are presented here to make PHMSA and FRA's analysis fully replicable.

Year	Ethanol Carloads	Crude Oil Carloads	Total
2016	486,470	292,767	779,237
2015	488,620	525,231	1,013,851
2014	388,929	576,581	965,510
2013	373,887	454,873	828,760
2012	369,082	237,932	607,014
2011	409,429	65,596	475,025
2010	411,863	34,776	446,639
2009	356,024	13,148	369,172
2008	291,952	9,684	301,636
2007	199,373	7,180	206,553
2006	138,110	6,128	144,238
2005	76,043	7,300	83,343
2004	62,756	11,474	74,230
2003	49,604	12,868	62,472
2002	41,508	12,408	53,916
2001	37,156	11,746	48,902
2000	35,944	14,274	50,218
1999	27,904	21,999	49,903
1998	27,788	27,679	55,467
1997	25,988	30,833	56,821
1996	19,540	33,784	53,324
1995	27,540	28,333	55,873

Appendix C: Carload Forecast Estimations

This appendix presents the data and model estimation, along with the forecast obtained from the model results, for the linear crude and ethanol carload forecasts. PHMSA and FRA used data from the Waybill sample to obtain carloads of crude and ethanol shipped in the United States from 2010 – 2016. The carload data was regressed on crude and ethanol production estimates from the EIA's Annual Energy Outlook (AEO). Specifically, we use the lower 48 on shore production figures from that publication. For the years 2017 – 2050 we use the production forecast from the 2017 AEO.

We used the EIA's Annual series of crude oil production by PADD, modified to remove offshore and Alaskan production as follows, to obtain lower 48 onshore production estimates that are consistent with the AEO 2017 forecast: we subtracted the sum of PADD 3 offshore production, PADD 5 offshore production, and Alaskan production from total U.S. production.[126]

Model estimation was conducted using Stata Inc. statistical analysis software. This software allows the user to obtain predicted values via a simple post estimation command. PHMSA and FRA therefore ran a simple regression of 2010 - 2016 carloads on 2010 - 2016 production estimates and used the predict command to obtain predicted values for 2010 – 2037 (the last year of the analysis period). The estimated model for crude oil is presented first, with a table below that provides the raw data used to estimate the model and the predicted values obtained from the model.

Crude oil carloads = -335732.4 + 118.7523(crude production)

The t statistic on the crude oil production variable was 4.39 with a probability of 0.007, indicating statistical significance. The F statistic for the model was 19.25, with a probability of .0071, indicating that the model as a whole is statistically significant. The R squared was 0.7938, indicating that the model explains roughly 80 percent of the variability in crude oil carloads. PHMSA and FRA experimented with other models, including one that included crude oil price as well as production. PHMSA and FRA therefore used the forecast that seemed most plausible given recent trends.

[126] Data available online at https://www.eia.gov/dnav/pet/pet_crd_crpdn_adc_mbblpd_a.htm.

Year	Crude Oil Carloads	Production (thousands of barrels per day)	Carload Predicted Values (fitted values)
2010	34,776	3,264	51,875
2011	65,596	3,711	104,958
2012	237,932	4,657	217,297
2013	454,873	5,645	334,625
2014	576,581	6,809	472,852
2015	525,231	7,379	540,541
2016	292,767	6,748	465,608
2017		6,322	415,064
2018		6,891	482,597
2019		7,212	520,761
2020		7,405	543,638
2021		7,583	564,779
2022		7,742	583,678
2023		7,845	595,880
2024		7,950	608,393
2025		8,057	621,076
2026		8,171	634,541
2027		8,218	640,204
2028		8,274	646,799
2029		8,343	655,008
2030		8,382	659,660
2031		8,380	659,453
2032		8,350	655,793
2033		8,223	640,800
2034		8,217	640,099
2035		8,191	636,982
2036		8,247	643,613
2037		8,278	647,297

The model developed to forecast ethanol by rail volumes is identical to that used for crude, and the data sources are the same except for the ethanol production figures, which are taken from the EIA ethanol production estimates.[127] As with the crude oil model, PHMSA and FRA experimented with adding price as an explanatory value, but the addition of price added virtually no explanatory value and significantly lowered the F statistic. The model regressing ethanol carloads on production is presented below.

[127] Available online at https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=M_EPOOXE_YNP_NUS_MBBLD&f=A.

Ethanol carloads = -290297.6 + 774330.8(ethanol production)

The coefficient on ethanol production had a t statistic of 3.73 with a probability of 0.014, indicating statistical significance. The model had an R squared of 0.7360 and an F statistic of 13.94 with a probability of 0.0135. The raw data used to fit this model is presented in the table below along with the predicted values that provide the forward-looking carload forecast.

Year	Ethanol Production (millions of barrels per day)	Ethanol Carloads	Predicted Carloads
2010	0.867	411,863	381,047
2011	0.909	409,429	413,569
2012	0.86	369,082	375,627
2013	0.867	373,887	381,047
2014	0.934	388,929	432,927
2015	0.966	488,620	457,706
2016	1.003	486,470	486,356
2017	0.96827	-	459,467
2018	0.97805	-	467,034
2019	0.97642	-	465,773
2020	0.97138	-	461,873
2021	0.96455	-	456,583
2022	0.96074	-	453,636
2023	0.95806	-	451,559
2024	0.95695	-	450,696
2025	0.95502	-	449,205
2026	0.9471	-	443,070
2027	0.9432	-	440,047
2028	0.94256	-	439,556
2029	0.94092	-	438,288
2030	0.9407	-	438,112
2031	0.92818	-	428,423
2032	0.92255	-	424,059
2033	0.92259	-	424,089
2034	0.92259	-	424,089
2035	0.92259	-	424,089
2036	0.92259	-	424,088
2037	0.92181	-	423,491

Appendix D: LCE and HCE Damage Calculations

The calculations for the LCE and HCE low and high range benefit estimates use the *ECP Societal Damage Pool* from Table 10.1h and the *Remaining HCE Damages* from Table 10.1i. The calculations used and an example for 2018 is provided below for both the LCE (low and high) and the HCE.

LCE Calculation for Section 10.2

Low Range Estimate:

(ECP Societal Damage Pool, Low Carload Prediction x proportion of Ethanol HHFUT of Total Carloads x proportion of ECP implemented x ECP Effectiveness Ratio) + (ECP Societal Damage Pool, Low Carload Prediction x proportion of Crude oil HHFUT of Total Carloads x proportion of ECP implemented x ECP Effectiveness Ratio) = Total Crude and Ethanol LCE Damages

Sample calculation for 2019 (from Table 10.2b):

[$64,926,974(ECP Societal Damage Pool, Low Carload Prediction) x .248 (proportion of Ethanol HHFUT of Total Carloads) x .40 (proportion of ECP implemented in year) x .140 (ECP Effectiveness Ratio)] + [$64,926,974 (ECP Societal Damage Pool, Low Carload Prediction) x .396 (proportion of Crude oil HHFUT of Total Carloads) x .66 (proportion of ECP implemented) x .140 (ECP Effectiveness Ratio)] = $3,068,289 (Total Crude and Ethanol ECP Benefits)

High Range Estimate:

(ECP Societal Damage Pool, High Carload Prediction x proportion of Ethanol HHFUT of Total Carloads x proportion of ECP implemented x ECP Effectiveness Ratio) + (ECP Societal Damage Pool, Low Carload Prediction x proportion of Crude oil HHFUT of Total Carloads x proportion of ECP implemented x ECP Effectiveness Ratio) = Total Crude and Ethanol LCE Damages

Sample calculation for 2019 (from Table 10.2c):

[$72,519,341 (ECP Societal Damage Pool, High Carload Prediction) x .231 (proportion of Ethanol HHFUT of Total Carloads) x .40 (proportion of ECP implemented in year) x .140 (ECP Effectiveness Ratio)] + [$72,519,341 (ECP Societal Damage Pool, High Carload Prediction) x .427 (proportion of Crude oil HHFUT of Total Carloads) x .66 (proportion of ECP implemented) x .140 (ECP Effectiveness Ratio)] = $3,619,026 (Total Crude and Ethanol ECP Benefits)

HCE Calculation for Section 10.2

(Remaining HCE Damages, Mean HCE x Percentage of Ethanol HHFUT of Total Carloads x Percent of ECP implemented x ECP Effectiveness Ratio) + (Remaining HCE Damages, Mean

HCE x Percentage of Crude oil HHFUT of Total Carloads x Percent of ECP implemented x ECP Effectiveness Ratio) = Total Crude and Ethanol HCE Damages

Sample calculation for 2019 (from Table 10.2d):

[$102,848,487 (Remaining HCE Damages, Mean HCE) x .248 (Percentage of Ethanol HHFUT of Total Carloads) x .40 (Percent of ECP implemented in year) x .140 (ECP Effectiveness Ratio)] + [$102,848,487 (Remaining HCE Damages, Mean HCE) x .396 (Percentage of Crude oil HHFUT of Total Carloads) x .66 (Percent of ECP implemented) x .140 (ECP Effectiveness Ratio)] = $4,860,367 (Total Crude and Ethanol ECP Benefits)

Appendix E: Fleet Forecast Tables

This section presents the tank car fleet upgrade schedule (Table E1), the cumulative fleet upgrade schedule (Table E2) as well as the tank car improvement benefits adjustment factors (Table E3) that are used to calculate the benefits in section 10 above.

Table E1 represents the retrofit/phase-out schedule for the existing tank car fleet. Table E2 shows the cumulative number of improved cars over time and Table E3 shows the upgrade factors, which are the percentage of cars upgraded of each type by a particular year multiplied by the effectiveness rates as presented in the 2015 Final Rule RIA.

Table E1: Fleet Upgrade Schedule

					CPC 1232 Unjacketed		Jacketed CPC 1232 Jacketed		117			
	Unjacketed 111		Jacketed 111		Ethanol	Crude	Ethanol	Crude	Ethanol		Crude	
	Retrofit	retire	retrofit	retire	Retrofit	Retrofit	Retrofit	Retrofit	Retrofit	New	Retrofit	New
Starting		28,870		423	2,638	17,961	611	21,947	1,252	2,133	652	2,731
2017	-	-	-	-	-	5,987	-	2,439	1,252	2,133	652	2,731
2018	-	-	-	175	-	5,987	-	2,439	-	-	-	-
2019	-	-	-	-	-	5,987	-	2,439	-	-	-	-
2020	6,929	-	-	-	-	-	-	2,439	-	-	-	-
2021	6,929	-	-	-	879	-	-	2,439	-	-	-	-
2022	6,929	8,084	-	248	879	-	-	2,439	-	-	-	-
2023	-	-	-	-	879	-	-	2,439	-	-	-	-
2024	-	-	-	-	-	-	-	2,439	-	-	-	-
2025	-	-	-	-	-	-	611	2,439	-	-	-	-
2026	-	-	-	-	-	-	-	-	-	-	-	-
2027	-	-	-	-	-	-	-	-	-	-	-	-
2028	-	-	-	-	-	-	-	-	-	-	-	-
2029	-	-	-	-	-	-	-	-	-	-	-	-
2030	-	-	-	-	-	-	-	-	-	-	-	-
2031	-	-	-	-	-	-	-	-	-	-	-	-
2032	-	-	-	-	-	-	-	-	-	-	-	-
2033	-	-	-	-	-	-	-	-	-	-	-	-
2034	-	-	-	-	-	-	-	-	-	-	-	-
2035	-	-	-	-	-	-	-	-	-	-	-	-
2036	-	-	-	-	-	-	-	-	-	-	-	-
2037	-	-	-	-	-	-	-	-	-	-	-	-

Table E2: Cumulative Fleet Upgrade Schedule

					CPC 1232 Unjacketed		Jacketed CPC 1232 Jacketed		117			
	Unjacketed 111		Jacketed 111		Ethanol	Crude	Ethanol	Crude	Ethanol		Crude	
	Retrofit	retire	retrofit	retire	Retrofit	Retrofit	Retrofit	Retrofit	Retrofit	New	Retrofit	New
2017	-	-	-	-	-	5,987	-	2,439	1,252	2,133	652	2,731
2018	-	-	-	175	-	11,974	-	4,878	1,252	2,133	652	2,731
2019	-	-	-	175	-	17,961	-	7,317	1,252	2,133	652	2,731
2020	6,929	-	-	175	-	17,961	-	9,756	1,252	2,133	652	2,731
2021	13,858	-	-	175	879	17,961	-	12,195	1,252	2,133	652	2,731
2022	20,787	8,084	-	423	1,758	17,961	-	14,634	1,252	2,133	652	2,731
2023	20,787	8,084	-	423	2,637	17,961	-	17,073	1,252	2,133	652	2,731
2024	20,787	8,084	-	423	2,637	17,961	-	19,512	1,252	2,133	652	2,731
2025	20,787	8,084	-	423	2,637	17,961	611	21,951	1,252	2,133	652	2,731
2026	20,787	8,084	-	423	2,637	17,961	611	21,951	1,252	2,133	652	2,731
2027	20,787	8,084	-	423	2,637	17,961	611	21,951	1,252	2,133	652	2,731
2028	20,787	8,084	-	423	2,637	17,961	611	21,951	1,252	2,133	652	2,731
2029	20,787	8,084	-	423	2,637	17,961	611	21,951	1,252	2,133	652	2,731
2030	20,787	8,084	-	423	2,637	17,961	611	21,951	1,252	2,133	652	2,731
2031	20,787	8,084	-	423	2,637	17,961	611	21,951	1,252	2,133	652	2,731
2032	20,787	8,084	-	423	2,637	17,961	611	21,951	1,252	2,133	652	2,731
2033	20,787	8,084	-	423	2,637	17,961	611	21,951	1,252	2,133	652	2,731
2034	20,787	8,084	-	423	2,637	17,961	611	21,951	1,252	2,133	652	2,731
2035	20,787	8,084	-	423	2,637	17,961	611	21,951	1,252	2,133	652	2,731
2036	20,787	8,084	-	423	2,637	17,961	611	21,951	1,252	2,133	652	2,731
2037	20,787	8,084	-	423	2,637	17,961	611	21,951	1,252	2,133	652	2,731

Table E3: Tank Car Improvement Benefits Adjustment Factors

					CPC 1232 Unjacketed		Jacketed CPC 1232 Jacketed		117			
	Unjacketed 111		Jacketed 111		Ethanol	Crude	Ethanol	Crude	Ethanol		Crude	
	Retrofit	retire	retrofit	retire	Retrofit	Retrofit	Retrofit	Retrofit	Retrofit	New	Retrofit	New
2017	0	0	0	0	0	0.02342864	0	0.000307885	0.007254	0.013571	0.00378	0.017375
2018	0	0	0	0.00095	0	0.04685728	0	0.000615769	0.007254	0.013571	0.00378	0.017375
2019	0	0	0	0.00095	0	0.07028592	0	0.000923654	0.007254	0.013571	0.00378	0.017375
2020	0.0401476	0	0	0.00095	0	0.07028592	0	0.001231538	0.007254	0.013571	0.00378	0.017375
2021	0.0802952	0	0	0.00095	0.003439749	0.07028592	0	0.001539423	0.007254	0.013571	0.00378	0.017375
2022	0.1204427	0.051432	0	0.00229	0.006879497	0.07028592	0	0.001847307	0.007254	0.013571	0.00378	0.017375
2023	0.1204427	0.051432	0	0.00229	0.010319246	0.07028592	0	0.002155192	0.007254	0.013571	0.00378	0.017375
2024	0.1204427	0.051432	0	0.00229	0.010319246	0.07028592	0	0.002463077	0.007254	0.013571	0.00378	0.017375
2025	0.1204427	0.051432	0	0.00229	0.010319246	0.07028592	7.71289E-05	0.002770961	0.007254	0.013571	0.00378	0.017375
2026	0.1204427	0.051432	0	0.00229	0.010319246	0.07028592	7.71289E-05	0.002770961	0.007254	0.013571	0.00378	0.017375
2027	0.1204427	0.051432	0	0.00229	0.010319246	0.07028592	7.71289E-05	0.002770961	0.007254	0.013571	0.00378	0.017375
2028	0.1204427	0.051432	0	0.00229	0.010319246	0.07028592	7.71289E-05	0.002770961	0.007254	0.013571	0.00378	0.017375
2029	0.1204427	0.051432	0	0.00229	0.010319246	0.07028592	7.71289E-05	0.002770961	0.007254	0.013571	0.00378	0.017375
2030	0.1204427	0.051432	0	0.00229	0.010319246	0.07028592	7.71289E-05	0.002770961	0.007254	0.013571	0.00378	0.017375
2031	0.1204427	0.051432	0	0.00229	0.010319246	0.07028592	7.71289E-05	0.002770961	0.007254	0.013571	0.00378	0.017375
2032	0.1204427	0.051432	0	0.00229	0.010319246	0.07028592	7.71289E-05	0.002770961	0.007254	0.013571	0.00378	0.017375
2033	0.1204427	0.051432	0	0.00229	0.010319246	0.07028592	7.71289E-05	0.002770961	0.007254	0.013571	0.00378	0.017375
2034	0.1204427	0.051432	0	0.00229	0.010319246	0.07028592	7.71289E-05	0.002770961	0.007254	0.013571	0.00378	0.017375
2035	0.1204427	0.051432	0	0.00229	0.010319246	0.07028592	7.71289E-05	0.002770961	0.007254	0.013571	0.00378	0.017375
2036	0.1204427	0.051432	0	0.00229	0.010319246	0.07028592	7.71289E-05	0.002770961	0.007254	0.013571	0.00378	0.017375
2037	0.1204427	0.051432	0	0.00229	0.010319246	0.07028592	7.71289E-05	0.002770961	0.007254	0.013571	0.00378	0.017375