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Pipeline and Hazardous Materials
Safety Administration
Washington, D.C. 20590

Final Regulatory Impact Analysis

[Docket No. PHMSA-2012-0082] (HM-251)

Hazardous Materials: Enhanced Tank Car Standards and Operational Controls for High-Hazard Flammable Trains;

Final Rule

Office of Hazardous Material Safety

May 2015

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I. Executive Summary

The Pipeline and Hazardous Materials Safety Administration (PHMSA) and the Federal Railroad Administration (FRA) are issuing a final rule, titled *Hazardous Materials: Enhanced Tank Car Standards and Operational Controls for HHFTs*, in order to increase the safety of hazardous materials transported by rail. The amendments take into consideration public comments from the Advanced Notice of Proposed Rulemaking (ANPRM) and the Notice of Proposed rulemaking (NPRM) on August 1, 2014 (79 FR 45015). This final Regulatory Impact Analysis (RIA) supplements the final rule.

The final rule became necessary due to the expansion in United States (U.S.) energy production that has led to significant challenges in the transportation system. Expansion in oil production has led to increasing volumes of product transported to refineries and other transport-related facilities such as transloading facilities. Traditionally, pipelines and oceangoing tankers have delivered the vast majority of crude oil to U.S. refineries, accounting for approximately 93 percent of total receipts (in barrels) in 2012. Although other modes of transportation—rail, barge, and truck—have accounted for a relatively minor portion of crude oil shipments, volumes have been rising very rapidly. With a growing domestic supply, rail transportation, in particular, has emerged as a flexible alternative to transportation by pipeline or vessel. The volume of crude oil carried by rail increased 423 percent between 2011 and 2012.[1] [2] In 2013, the number of rail carloads of crude oil surpassed 400,000.[3] [4] Based on information from the Association of American Railroads (AAR), the U.S. Energy Information Administration (U.S. EIA) shows the amount of crude oil and refined petroleum products moved by U.S. railroads continued to increase by nine percent during the first seven months of 2014 compared with the same period in 2013. This is demonstrated by Figure ES1 below.

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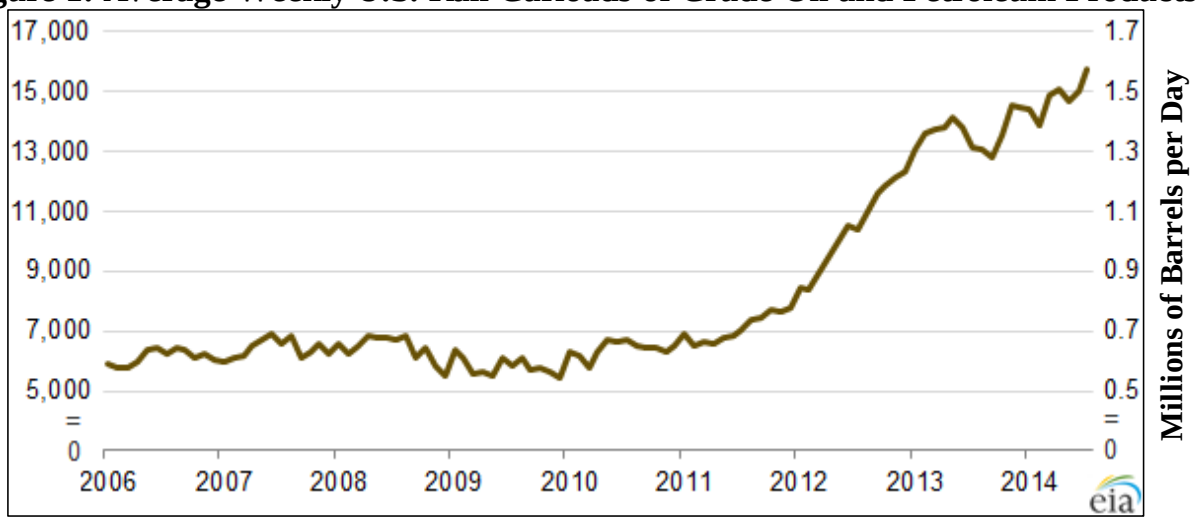
[1] See U.S. Rail Transportation of Crude Oil: Background and Issues for Congress; http://fas.org/sgp/crs/misc/R43390.pdf

[2] See Table 9 of EIA refinery report http://www.eia.gov/petroleum/refinerycapacity/ See also "Refinery receipts of crude oil by rail, truck, and barge continue to increase" http://www.eia.gov/todayinenergy/detail.cfm?id=12131

[3] http://www.stb.dot.gov/stb/industry/econ_waybill.html

[4] http://www.eia.gov/todayinenergy/detail.cfm?id=17751

Figure 1: Average Weekly U.S. Rail Carloads of Crude Oil and Petroleum Products



U.S. ethanol production has also increased considerably during the last 10 years and has generated similar growth in the transportation of ethanol by rail.[5] Ethanol constitutes 26 percent of the total number of hazmat shipments and is 1.1 percent of all railroad shipments.[6]

Approximately 68 percent of the flammable liquids transported by rail are comprised of crude oil or ethanol. While the accident *rate* has declined by 12.7% from 2005-2015, the recent increase in shipments of large quantities of flammable liquids by rail has led to an increase in the number of train accidents, posing a significant safety and environmental concern. The risk of flammability is compounded in the context of rail transportation because petroleum crude oil and ethanol are commonly shipped in large blocks or single commodity trains (unit trains). In recent years, train accidents/incidents (train accidents) involving a flammable liquid release, and resulting in fires with severe consequences, have occurred (e.g., Arcadia, OH; Plevna, MT; Casselton, ND; Aliceville, AL; Lac-Mégantic, Quebec; Lynchburg, VA).

PHMSA is revising the HMR to establish requirements for any "high-hazard flammable train" (HHFT) that is transported over the U.S. rail network. Based on analysis of the risk of differing train compositions, this rule defines an HHFT as a train comprised of 20 or more tank carloads of a Class 3 flammable liquid in a continuous block or 35 or more tank carloads of a Class 3

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[5] Association of American Railroads. 2013. Railroads and Ethanol. Available online at https://www.aar.org/keyissues/Documents/Background-Papers/Railroads%20and%20Ethanol.pdf

[6] http://ethanolrfa.org/page/-/rfa-association-site/Industry%20Resources/RFA.Ethanol.Rail.Transportation.and.Safety.pdf?nocdn=1

flammable liquid across the entire train. For the purposes of advanced braking systems this rule also defines a "high-hazard flammable unit train" (HHFUT) as a train comprised of 70 or more loaded tank cars containing class 3 flammable liquids traveling at greater than 30 mph. The rule ensures that the requirements are closely aligned with the risks posed by the operation of trains that are transporting large quantities of flammable liquids. As discussed further, below, this rule primarily impacts trains transporting large quantities of ethanol and crude oil, because ethanol and crude oil are most frequently transported in high-volume shipments that when transported in a single train, would meet the definition of an HHFT. By revising the definition of HHFT as proposed in the NPRM, we have clarified the scope of the final rule and focused on the highest-risk shipments, while not affecting lower-risk trains that are not transporting similar bulk quantities of Class 3 flammable liquids.[7]

Table ES1 describes the regulatory changes implemented in the final rule and identifies affected entities.

Table ES1: Affected Entities and Requirements

Adopted Requirement	Affected Entity
Enhanced Standards for Both New and Existing Tank Cars Used in HHFTs • New tank cars constructed after October 1, 2015 are required to meet enhanced DOT Specification 117 design or performance criteria. • Existing tank cars must be retrofitted in accordance with the DOT-prescribed retrofit design or performance standard. • Retrofits must be completed based on a prescriptive retrofit schedule.	Tank Car Manufacturers, Tank Car Owners, Shippers / Offerors and Rail Carriers
More Accurate Classification of Unrefined Petroleum-Based Products Develop and carry out testing program for all unrefined petroleum-based products, such as crude oil, to address: • Frequency of sampling and testing that accounts for any appreciable variability of the material • Sampling prior to the initial offering of the material for transportation and when changes that may affect the properties of the material occur; • Sampling methods that ensures a representative sample of the entire mixture, as offered, is collected; • Testing methods that enable classification of the material under the HMR; • Quality control measures for sample frequencies; • Duplicate samples or equivalent measures for quality assurance; • Criteria for modifying the sampling and testing program; • Testing or other appropriate methods used to identify properties of the mixture relevant to packaging requirements	Offerors / Shippers of Unrefined Petroleum-Based Products

[7] In the August 1, 2014, NPRM an HHFT was defined as a train comprised of 20 or more carloads of a Class 3 flammable liquid. This rule defines an HHFT as a train comprised of 20 or more tank car loads of a Class 3 flammable liquid in a continuous block or 35 tank car loads of a Class 3 flammable liquid across the entire train.

Table ES1: Affected Entities and Requirements	
• Certify that program is in place, document the testing and sampling program outcomes, and make information available to DOT personnel upon request.	
<u>Rail routing - Risk assessment</u> • Perform a routing analysis that considers, at a minimum, 27 safety and security factors and select a route based on its findings. These planning requirements are prescribed in 49 CFR § 172.820. <u>Rail routing - Notification</u> • Requires railroads to notify State and/or regional fusion centers and State, local and tribal officials who contact a railroad to discuss routing decisions are provided appropriate contact information for the railroad in order to request information related to the routing of hazardous materials through their jurisdictions. This replaces the proposed requirements to notify State Emergency Response Commissions (SERCs) or other appropriate state delegated entity about the operation of these trains through their States.	Rail Carriers, Emergency Responders
<u>Reduced Operating Speeds</u> • Restrict all HHFTs to 50mph in all areas • Require HHFTs that contain any tank cars not meeting the enhanced tank car standards required by this rule operate at a 40-mph speed restriction in high-threat urban areas[8]	Rail Carriers
<u>Enhanced Braking</u> • Require HHFTs to have in place a functioning two-way end-of-train (EOT) device or a distributed power (DP) braking system. • Require trains meeting the definition of a "high-hazard flammable unit train" (HHFUT)[9] be operated with an electronically controlled pneumatic (ECP) braking system after January 1, 2021 for PG I and May 1, 2023 for all other PG.	Rail Carriers, Emergency Responders

[8] As defined the Transportation Security Administration's regulations at 49 CFR 1580.3, High- Threat Urban Area (HTUA) means an area comprising one or more cities and surrounding areas including a 10-mile buffer zone, as listed in Appendix A to 49 CFR Part 1580.

[9] A "high-hazard flammable unit train" (HHFUT) means a train comprised of 70 or more loaded tank cars containing class 3 flammable liquids traveling at greater than 30 mph.

PHMSA and FRA received over 3,200 public comments representing over 182,000 signatories in response to the August 1, 2014 NPRM and initial RIA. We carefully considered each comment and adjusted the final rule and RIA as appropriate.

This RIA adjusts the methodology used to estimate the benefits resulting from the final rule in the following ways:

1) Performed additional derailment simulations to verify tank car puncture resistance and ECP brake effectiveness
2) Re-estimated the derailment forecast in response to comments
3) Revised the crude and ethanol carload forecast based on comments to the NPRM submitted by the industry
4) Added a review of applicable literature to verify appropriateness of cost estimates for non-safety related damages from crude oil and ethanol releases
5) Scaled down the damages from Lac-Mégantic, to account for a smaller expected number of cars derailed and lower speeds in Higher-Consequence Event Damage Model

This RIA adjusts the methodology used to estimate the costs of applying the final rule in the following ways:

1) Revised the number of offerors and railroads impacted by classification and routing requirements
2) Adopted separate standards for new tank car construction requirements consistent with Option 2 of the NPRM except for the braking component and retrofit requirements for existing tank cars in accordance with Option 3 from the NPRM (excluding top fittings protection and steel grade)
3) Revised assumptions on truck upgrades and transfer of jacketed DOT-111 tank cars to oil sands
4) Revised assumption that no cars would be retired from crude and ethanol service
5) Revised and updated the tank car fleet based on consultations with Transport Canada, comments submitted to the docket by industry, and expected 2015 deliveries
6) Adjusted the estimated cost to equip tank cars with ECP brakes

Table ES2 provides a high-level overview of the adjustments made to the rulemaking from the NPRM to final rule stage based on public comment and further analysis.

Table ES2: NPRM vs. Final Rule Comparison

Topic	NPRM Proposal	Final Rule Amendment	Justification
Scope – High-Hazard Flammable Train	High-hazard flammable train means a single train carrying 20 or more carloads of a Class 3 flammable liquid.	A continuous block of 20 or more tank cars loaded with a flammable liquid or 35 or more tank cars loaded with a flammable liquid dispersed through a	PHMSA and FRA modified the proposed definition to capture the higher-risk bulk quantities transported in unit trains, while excluding lower-risk manifest trains. This revision better captures the intended trains.

Table ES2: NPRM vs. Final Rule Comparison			
Topic	**NPRM Proposal**	**Final Rule Amendment**	**Justification**
		train.	
Tank Car – New Construction	Three options for new tank car standards (See table 13)	A modified version of Tank Car Option #2 from the NPRM.	These design enhancements will reduce the consequences of accidents involving an HHFT. These enhancements will improve puncture resistance and thermal survivability. There will be fewer car punctures, fewer releases from the service equipment (top and bottom fittings). See RIA.
Tank Car – Existing Fleet	Consistent with proposed new tank car standards, the same three options for retrofitted tank car standards. It was proposed that both new and retrofitted cars would meet the same standard.	Tank Car Option #3 from the NPRM for retrofits.	Provides incremental safety benefit over the current fleet while minimizing cost. These design enhancements will reduce the consequences of a derailment of an HHFT. There will be fewer car punctures, fewer releases from the service equipment (top and bottom fittings), and delayed release of flammable liquid from the tank cars through the pressure relief devices. See RIA.
Tank Car – Retrofit Timeline	A five-year retrofit schedule based solely on packing group.	A risk-based ten-year retrofit schedule based on packing group and tank car.	Provides for greater risk reduction by focusing on the highest risk tank car designs first. Accounts for industry retrofit capacity.
Speed Restrictions	A 50 mph restriction across the board for HHFTs and three options for a 40 mph restriction in specific areas	A 50 mph restriction across the board for HHFTs and a 40 mph restriction in HTUA if the HHFT contains any cars not meeting enhanced tank car standards.	Decreases the kinetic energy involved in accidents. Adopts the most cost-effective solution and limits the impact of rail congestion.
Braking	The scaling up of braking systems culminating in ECP braking for HHFTs or a speed limitation for those not meeting the braking requirements	(1) Require HHFTs to have in place a functioning two-way EOT device or a DP braking system. (2) Require HHFUTs be operated with an ECP braking system after December 31, 2020.	Provides a two-tiered, cost-effective and risk-based solution to reduce the number of cars and energy associated with train accidents. Focuses on the highest-risk train sets.
Classification	A classification plan for mined liquids and gases	A classification plan with clarification on the materials subject to	Addresses comments seeking clarity of requirements. We expect the requirements would reduce the

Table ES2: NPRM vs. Final Rule Comparison			
Topic	**NPRM Proposal**	**Final Rule Amendment**	**Justification**
		a plan.	expected damages and ensure that materials are properly classified in accordance with the HMR.
Routing	Require railroads operating HHFTs to conduct a routing analysis considering, at a minimum, 27 factors	Require railroads operating HHFTs to conduct a routing analysis considering, at a minimum, 27 factors.	Track type, class, and maintenance schedule as well as training and skill level of crews are included in the 27 risk factors identified that need to be considered, at a minimum, in a route analysis. Evaluation of these factors could result in prevention of an accident due to either rail defects or human factors/errors.
Notification	Require trains carrying 1,000,000 gallons or more of Bakken Crude oil to notify SERCs	Use the notification portion of the routing requirements (i.e. notification to state fusion centers) to satisfy need for pertinent information.	Addresses concerns over security sensitive and confidential business information. Addresses the need for action in the form of additional communication between railroads and emergency responders to ensure that the emergency responders are aware of the appropriate contacts at railroads to discuss routing issues with.

As mentioned above, this RIA supplements the final rule and addresses the economic impacts associated with the regulatory provisions. Table ES3 shows the costs and benefits by affected section and rule provision over a 20-year period, discounted at a rate of seven percent. Table ES3 also shows an explanation of the comprehensive benefits and costs (i.e., the combined effects of individual provisions), and the estimated benefits, costs, and net benefits of each amendment.

Given the uncertainty associated with the risks of crude oil and ethanol shipments, Table ES3 contains a range of benefits estimates. To calculate the projected benefits for years 2015-2034, the PHMSA uses the U.S. safety record for crude oil and ethanol from 2006 to 2013 adjusted for the projected increase in shipment volume over the next 20 years. That projection is the “low-end” of the estimated benefit’s range. To calculate the “high-end” of that benefits range, PHMSA used probabilistic risk model that produces a range of estimates associated with the projected higher-consequence events.

Table ES3. 20-Year Costs and Benefits by Stand-Alone Proposed Regulatory Amendments 2015-2034[10]			
Affected Section[11]	**Provision**	**Benefits (7%)**	**Costs (7%)**
49 CFR 172.820	Rail Routing+	Cost effective if routing were to reduce risk of an incident by 0.41%	$8.8 million
49 CFR 173.41	Classification Plan	Cost effective if this requirement reduces risk by 1.29%	$18.9 million
49 CFR 174.310	Speed Restriction: 40 mph speed limit in HTUA if the HHFT contains any cars not meeting the enhanced standards*	$56 million – $242 million**	$180 million
	Advanced Brake Signal Propagation Systems	$470.3 million - $1,114 million**	$492 million
49 CFR part 179	Existing Tank Car Retrofit/Retirement	$426 million - $1,706 million**	$1,747 million
	New Car Construction	$23.9 million - $97.4 million**	$34.8 million
Cumulative Total		$912 million-$2,905 million**	$2,482 million

"*" indicates voluntary compliance regarding crude oil trains in high-threat urban areas (HTUA)
"+" indicates voluntary actions that will be taken by shippers and railroads
"**" Indicates that the low end of the benefits range is based solely on lower consequence events, while the high end of the range includes benefits from mitigating high consequence events.

[10] All costs and benefits are in millions over 20 years, and are discounted to present value using a 7 percent rate.

[11] All affected sections of the Code of Federal Regulations (CFR) are in Title 49.

Although we analyze the effects of individual requirements separately, we have taken a system-wide approach covering all requirement areas. This approach is designed to mitigate damages of rail accidents involving flammable liquids, though some provisions could also prevent accidents. As a result, this analysis shows that expected damages based on the historical safety record could be $4.1 billion and damages from higher-consequence events could reach $12.6 billion over a 20-year period in the absence of the rule.

II. Introduction

In this final RIA, PHMSA and FRA analyze the impacts associated with a system-wide, comprehensive final rule that addresses the risk associated with the transportation of flammable liquids in HHFTs. Final rule provisions include:

1) Tank Car Specifications
2) Advanced Brake Signal Propagation Systems
3) Speed Restrictions
4) Routing and Notification Requirements
5) Classification of Unrefined Petroleum-Based Products

Flammable liquids include a wide variety of chemical products. The items listed in the Table T1 below are generally considered Class 3 flammable liquids and are subject to the provisions of the final rule when shipped in a HHFT. Class 3 combustible liquids (i.e. liquids with a flashpoint above 100 °F) are not subject to the provisions of the final rule. Some materials like crude oil, petroleum distillates, and other organic compounds such as amines display a wide range of flash points depending on their composition and as such may not be subject to the provisions in all cases. In other cases, a flammable liquid may be mixed with a non-hazardous material to the point that the flash point is within the range of a combustible liquid and would not be subject to the provisions of the final rule (e.g., dilute solutions of alcohol).

As shown in Table T1, approximately 68 percent of the flammable liquids transported by rail are comprised of crude oil, ethanol, and petrochemical or petroleum refinery products. These include: UN1987 Alcohols, n.o.s.[12]; UN1170 Ethanol; UN1219 Isopropanol; UN1230 Methanol; UN1267 Petroleum crude oil; UN1238 Petroleum distillates, n.o.s.; and UN3295 Hydrocarbons liquid n.o.s. Petrochemical or petroleum refinery products would include commonly shipped items like NA1993 Diesel fuel; NA1993 Combustible liquid, n.o.s.; UN1202 Diesel fuel; UN1202 Gas oil; UN1203 Gasoline; and UN1863 Fuel, aviation, turbine engine. The table below and Appendix A provide summary information for the industries that produce the most flammable liquid.

Further, ethanol and crude oil comprise approximately 65% of the flammable liquids transported by rail. Generally, ethanol is shipped as: UN1170 Ethanol; UN1987 Alcohols, n.o.s.; or UN3475 Ethanol and gasoline mixture or Ethanol and motor spirit mixture or Ethanol and petrol mixture, with more than 10% ethanol. Crude oil is shipped as: UN1267 Petroleum crude oil; UN1268 Petroleum distillates, n.o.s. or Petroleum products, n.o.s.; or UN3295 Hydrocarbons, liquid,

[12] Alcohols n.o.s. is a generic proper shipping name used to cover a variety of mixtures of alcohols such as ethanol mixed with methanol or isopropanol.

n.o.s. PHMSA expects few flammable liquids other than crude oil or ethanol to be shipped in a HHFT.[13]

Table I1. 2012 Class 3 Tank Car Originations by Commodity[14]

UN/NA Identification Number	Commodity	Total Tank Car Originations	Percent of Class 3 Tank Car Originations
NA1993	Diesel Fuel, Fuel Oil, Combustible Liquids N.O.S.	26,662	3.0%
UN1202	Diesel Fuel, Gas Oil	49,877	5.7%
UN1090	Acetone	4,083	0.5%
UN1093	Acrylonitrile, Stabilized	2,684	0.3%
UN1114	Benzene	7,376	0.8%
UN1120	Butanols	1,685	0.2%
UN1145	Cyclohexane	2,755	0.3%
UN1170	Ethanol	12,914	1.5%
UN1203	Gasoline	52,137	5.9%
UN1208	Hexanes	1,505	0.2%
UN1218	Isoprene, Stabilized	1,258	0.1%
UN1219	Isopropanol	2,288	0.3%
UN1230	Methanol	19,283	2.2%
UN1238	Petroleum Distillates, N.O.S	3,917	0.4%
UN1247	Methyl Methacrylate Monomer, Stabilized	4,768	0.5%
UN1265	Pentanes	1,541	0.2%
UN1267	Petroleum Crude Oil	266,495	30.3%
UN1268	Petroleum Distillates, N.O.S	8,202	0.9%
UN1280	Propylene Oxide	4,394	0.5%
UN1294	Toluene	3,956	0.4%
UN1301	Vinyl Acetate, Stabilized	5,053	0.6%
UN1307	Xylenes	10,466	1.2%
UN1863	Fuel,Aviation,Turbine Engine	16,782	1.9%
UN1987	Alcohols, N.O.S	293,451	33.3%
UN1993	Flammable Liquids, N.O.S	36,114	4.1%
UN2055	Styrene Monomer, Stabilized	13,355	1.5%
UN2348	Butyl Acrylates, Stabilized	3,389	0.4%
UN2370	1-Hexene	1,718	0.2%
UN2924	Flammable Liquids, Corrosive, N.O.S	1,242	0.1%
UN3065	Alcoholic Beverages	1,267	0.1%
UN3256	Elevated Temperature Liquid, Flammable, N.O.S	1,849	0.2%
UN3295	Hydrocarbons, Liquid, N.O.S	10,745	1.2%
UN3475	Ethanol And Gasoline Mixture	7,730	0.9%
Total		880,941	

A. Crude Oil

The U.S. is now the global leader in crude oil production growth. With a growing domestic supply, rail transportation, in particular, has emerged as a flexible alternative to transportation by

[13] The estimated number of cars of other flammable liquids that would be appended to HHFTs and hence must meet the new requirements is 354 tank cars. The costs presented in this analysis include retrofits to this small number of tank cars.

[14] Source: Annual Report of Hazardous Materials Transported by Rail by Association of American Railroads and Bureau of Explosives

pipeline or vessel. The volume of crude oil carried by rail increased 423 percent between 2011 and 2012.[15,16] In 2013, the number of rail carloads of crude oil surpassed 400,000.[17] The amount of crude oil and refined petroleum products moved by U.S. railroads continued to increase by 9 percent during the first 7 months of 2014, compared with the same period in 2013.[18] With the average rail tank car holding around 700 barrels of crude oil, about 759,000 barrels of crude oil per day were moved by rail during the first seven months of 2014, equal to 8 percent of U.S. oil production.[19]

Expansion in oil production has led to increasing volumes of product transported to refineries. Traditionally, pipelines and oceangoing tankers have delivered the vast majority of crude oil to U.S. refineries, accounting for approximately 93 percent of total receipts (in barrels) in 2012. Although other modes of transportation—rail, barge, and truck—have accounted for a relatively minor portion of crude oil shipments, volumes have been rising very rapidly. With a growing domestic supply, rail transportation, in particular, has emerged as a flexible alternative to transportation by pipeline or vessel. The transportation of large volumes of flammable liquids by rail under the current regulatory scheme poses a risk to life, property, and the environment. The volume of flammable liquids shipped by rail unit trains has been increasing rapidly since 2006, representing a growing risk. Figure 1 provides the average weekly U.S. rail carloads of crude oil and petroleum products from 2006 through 2014.

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[15] See U.S. Rail Transportation of Crude Oil: Background and Issues for Congress; http://fas.org/sgp/crs/misc/R43390.pdf

[16] See Table 9 of EIA refinery report http://www.eia.gov/petroleum/refinerycapacity/ See also "Refinery receipts of crude oil by rail, truck, and barge continue to increase" http://www.eia.gov/todayinenergy/detail.cfm?id=12131

[17] http://www.stb.dot.gov/stb/industry/econ_waybill.html

[18] http://www.eia.gov/todayinenergy/detail.cfm?id=17751

[19] http://www.eia.gov/todayinenergy/detail.cfm?id=17751

Figure 1: Average Weekly U.S. Rail Carloads of Crude Oil and Petroleum Products

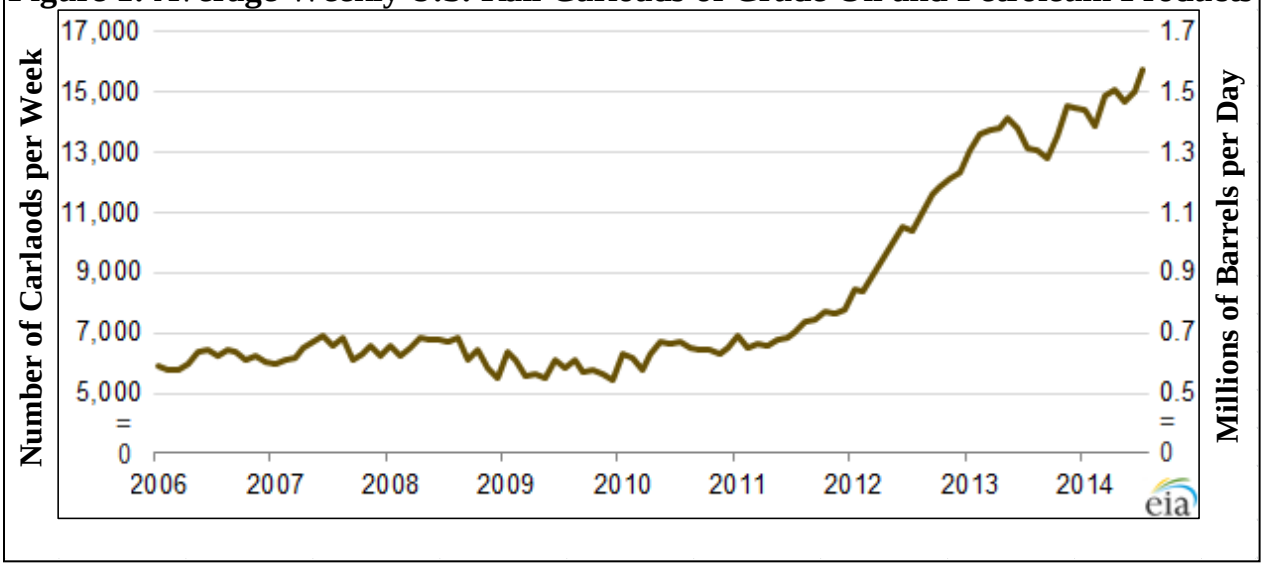
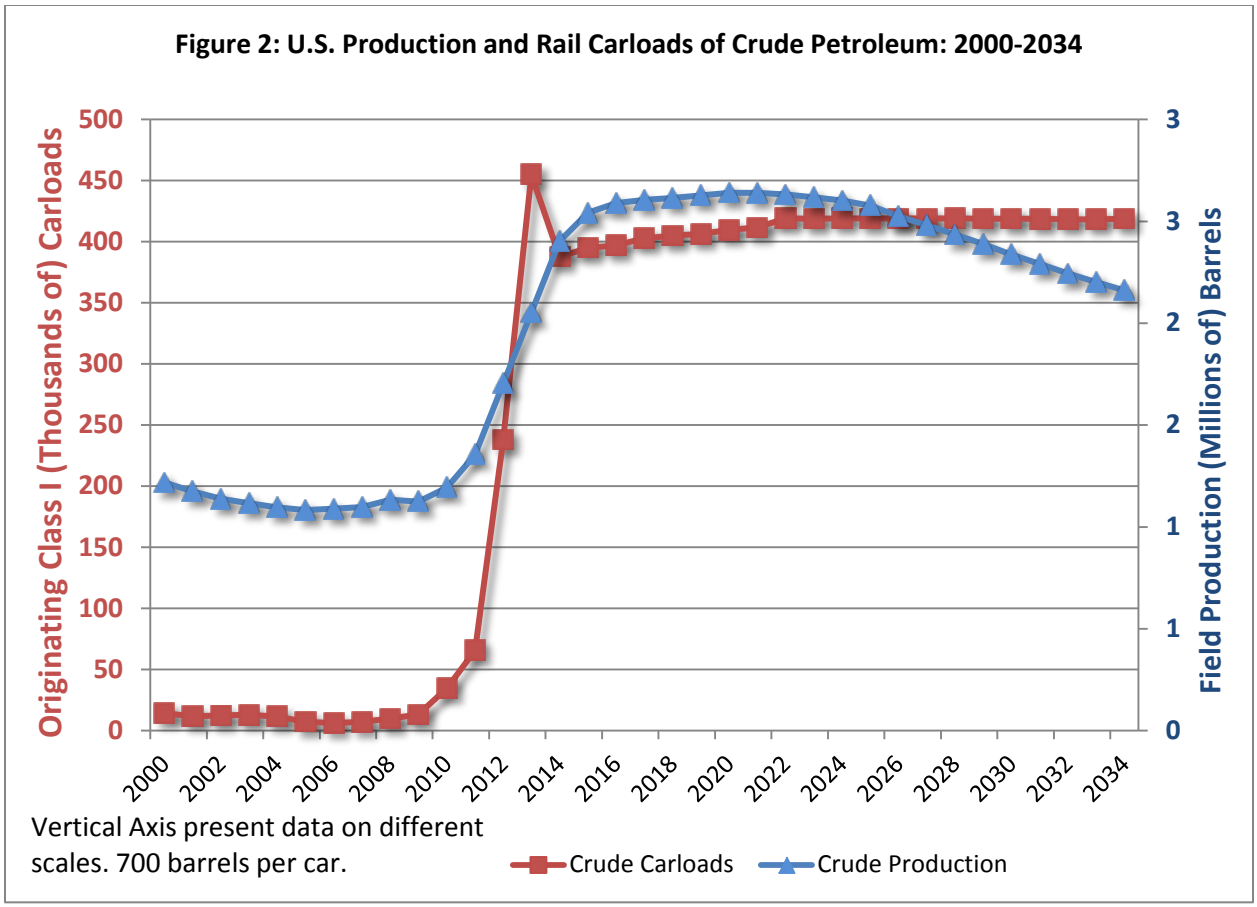


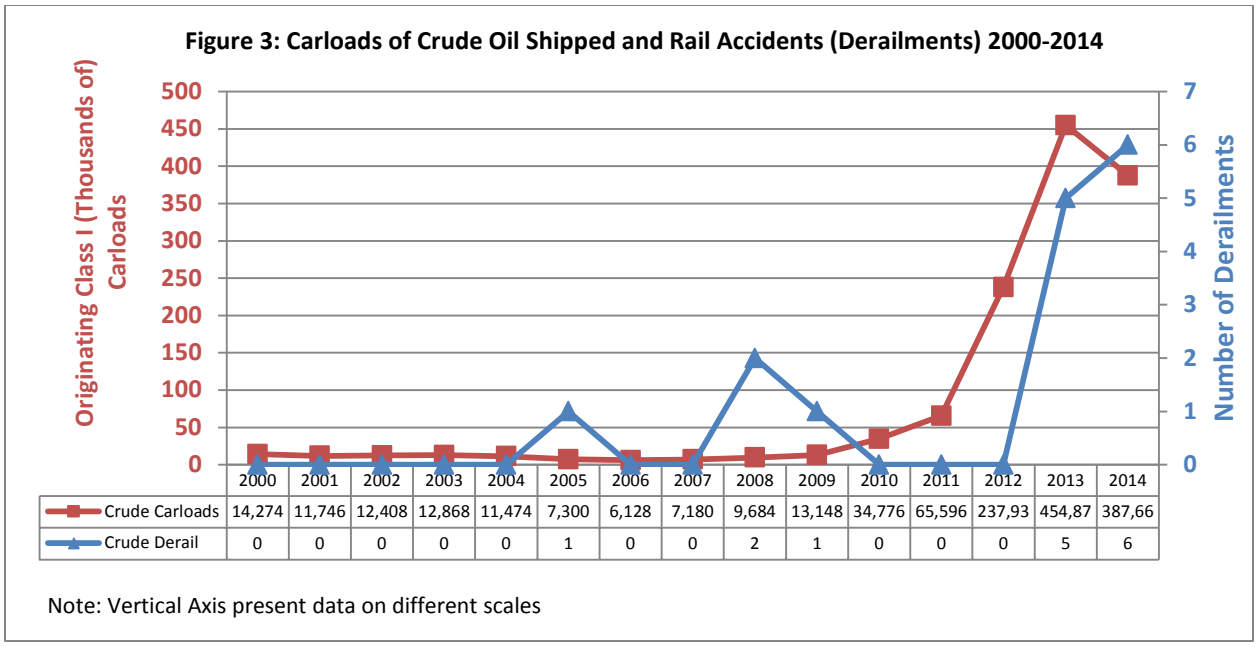
Figure 2 shows the recent strong growth in crude oil production in the U.S., as well as growth in the number of rail carloads shipped. Figure 2 also shows forecasted domestic crude oil production from the Energy Information Administration (EIA) and PHMSA's projected strong demand for the rail shipment of crude oil.



Sources and Notes: Crude Carloads for 2000-2013 obtained from the Surface Transportation Board waybill sample. Forecasts of overall domestic crude oil production and carload figures from 2014-2034 are taken from the report prepared by the Brattle Group on behalf of RSI [Table 14]. Crude production figures were derived from the EIA domestic crude production from 2014 Annual Energy Outlook.

Rail accidents have risen along with the increase in crude oil production and rail shipments of crude oil. Figure 3 shows this rise.[20]

[20] Source: STB Waybill Sample and PHMSA Incident Report Database



Sources and notes: Originating Class I Carloads for 2000-2013 obtained from the Surface Transportation Board waybill sample. 2014 originating carloads are estimated based on EIA production forecast in millions of barrels per year then converted to carloads per year. Incident counts are from the PHMSA and FRA Incident Report Databases.

Based on these train accidents, the projected continued growth of domestic crude oil production, and the growing number of train accidents involving crude oil, PHMSA concludes that the potential for a train accident involving crude oil has increased, which has raised the likelihood of a catastrophic train accident that would cause substantial damage to life, property, and the environment.

B. Ethanol

In the last ten years, the production of ethanol has increased dramatically due to the demand for ethanol-blend fuels. U.S. production of ethanol was 14.3 billion gallons in 2014.[21] Denatured ethanol (approximately 95 percent ethanol is largely shipped from production facilities by rail and is now the largest volume hazardous material shipped by rail. Unit trains commonly ship

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Source: U.S. Energy Information Administration : "January 2015 Monthly Energy Review"

U.S. Energy Information Administration
"January 2015 Monthly Energy Review" Annual Data:
www.eia.gov/totalenergy/data/browser/xls.cfm?tbl=T10.03&freq=m

large volumes of ethanol in up to 3.2 million gallons. Barges can transport up to 2.5 million gallons.[22]

Ethanol is a flammable colorless liquid; a polar solvent that is completely miscible in water. It is heavier than air, and has a wider flammable range than gasoline, with a Lower Explosive Limit (LEL) to an Upper Explosive Limit (UEL)[23] range of 3.3 percent to 19 percent. The flash point for pure ethanol is 55°F, and for fuel ethanol it is much lower (-5°F). Ethanol is still considered a flammable liquid in solutions as dilute as 20 percent, with a flash point of 97°F. Fuel ethanol is shipped with a flammable liquids placard and North American 1987 designation.[24] As shown in Figure 4, EIA projects strong demand for ethanol in the future.

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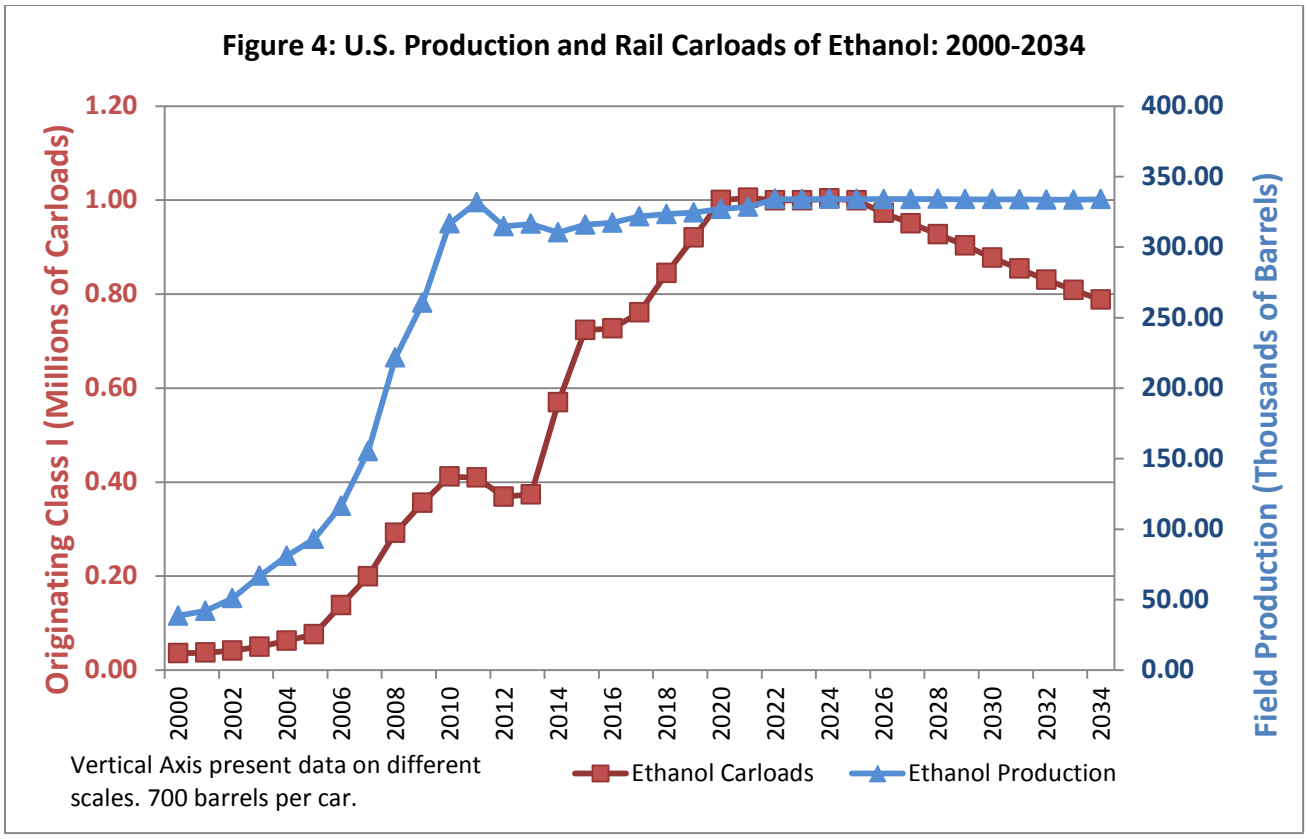
[22] Source: "Large Volume of Ethanol Spills – Environmental Impacts and Response Options" prepared for MassDEP, Commonwealth of Massachusetts Department of Environmental Protection by Shaw in July 2011.

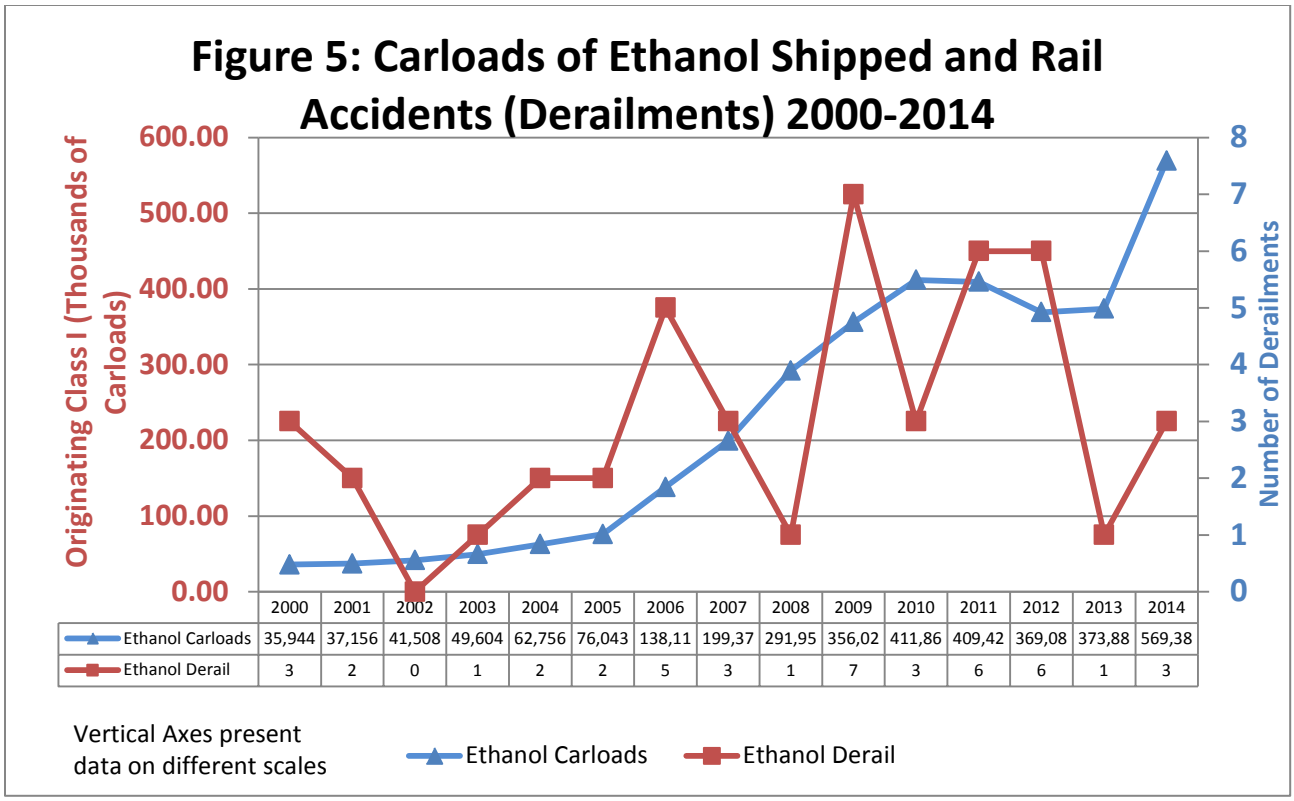
[23] Lower explosive limit refers to the minimum concentration of a combustible gas or vapor necessary to support combustion in air. Upper flammability limit refers to the maximum concentration of gas or vapor necessary to support combustion in air. Beyond these limits the mixture is either too lean or too rich to burn.

[24] Source: Large Volume Ethanol Spills – Environmental Impacts and Response Options, MassDEP, http://www.mass.gov/eopss/docs/dfs/emergencyresponse/special-ops/ethanol-spill-impacts-and-response-7-11.pdf



Sources and notes: Originating Class I Carloads for 2000-2013 were obtained from the Surface Transportation Board Waybill sample. Forecasts of overall domestic ethanol production are obtained from the 2014 EIA forecast. The carload forecast from 2014-2034 is based on production using Excel's Forecast function using an estimated linear trend of historic ethanol carloads based on historic production.

According to a June 2012 white paper by the AAR, U.S. ethanol production increased considerably during the last 10 years and has generated similar growth in the transportation of ethanol by rail. Between 2001 and 2012, the number of rail carloads of ethanol increased by 650 percent. Similarly, the number of rail carloads of crude oil has also exponentially increased. Unfortunately, this growth in rail traffic has been accompanied by an increase in the number of rail accidents involving ethanol and crude oil. Figure 5 plots the total number of rail accidents involving ethanol during the last 13 years compared to the total carloads of ethanol. The left axis shows the total number of rail derailments and the right axis shows total carloads shipped.



Sources and notes: Originating Class I Carloads for 2000-2013 obtained from the Surface Transportation Board waybill sample. 2014 originating carloads are estimated based on EIA production forecast in millions of barrels per year converted to carloads per year. Incident counts are from the PHMSA and FRA Incident Report Databases.

III. Determination of Need

The principal anticipated benefit associated with the final rule is a reduction in the risk of HHFT accidents and mitigation of the consequences when such accidents do occur. The following discussion provides an overview of PHMSA's and FRA's concerns by first discussing rail accidents involving large volumes of flammable liquids, which could increase the risk of potential catastrophic train accidents in the future, and concludes with an appraisal of the regulatory options PHMSA is considering to limit future releases.

A. Market Failures

A market failure at issue is that the shippers and rail companies are not insured against the full liability of the consequences of incidents involving hazardous materials. Even with adequate insurance it is unclear whether full compensation for the consequences of events that may result in severe injury or death is possible, resulting in external costs that go unrecompensed regardless of the insurance carried by the railroad. Incidents involving severe negligence on the part of the carrier may therefore result in harm that goes uncompensated. Finally, to process a claim to insurance compensation, those harmed must demonstrate real harm and value lost. In the case of damage to the environment the actual monetary value of lost or damaged assets is difficult to

determine. As a result, these events impose externalities. In the initial RIA, we indicated that among Class I railroads a self-insured retention of $25 million is common, though it can be as much as $50 million, especially when toxic if inhaled (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 have a more conservative view of risk and usually do not have the cash flow to support substantial self-insurance levels.[25] Further, the maximum coverage available in the commercial rail insurance market appears to be $1 billion per carrier, per incident.[26] 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 incident that occurred at Lac-Mégantic, Quebec, in July 2013. The rail carrier responsible for the incident was covered for a maximum of $25 million in insurance liability and had to declare bankruptcy because that coverage and the company's remaining capital combined were insufficient to pay for more than a fraction of the harm that was caused economic losses preliminarily estimated at more than $1 billion. This is one example where rail carriers and shippers had insufficient coverage to bear the entire cost of "making whole" those affected when an incident involving crude and ethanol shipment by rail occurred. 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 fixed costs of litigating that harm, and coordination among the people affected may be difficult.

On October 9, 2014, American International Group, Inc. (AIG) expanded the excess casualty liability limits for Class I railroads to $1 billion per accident. This was done in response to the demand for transport of crude oil by rail.

According to Jeremy Johnson, president and chief executive officer, Lexington Insurance Company, who will provide the excess coverage, "Rail companies need additional coverage to help protect their balance sheets." [27] Further, Mr. Johnson indicated, "this billion-dollar coverage will help Class I railroads address expanding risks while continuing to serve the growing needs of transportation customers in North America."

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[25] http://www.dot.gov/office-policy/transportation-hazardous-materials-insurance-security-and-safety-costs (section 3.4 Rail Liability and Insurance Controversy).

[26] http://www.dot.gov/office-policy/transportation-hazardous-materials-insurance-security-and-safety-costs (section 3.4 Rail Liability and Insurance Controversy).

[27] http://www.railwayage.com/index.php/freight/class-i/aig-provides-expanded-1-billion-casualty-liability-limits-for-north-american-rail-companies.html?channel=Array

Another issue is that shippers, though responsible for buying or leasing the tank cars in which these products are shipped, and loading the material into the tank cars, but do not generally bear any liability for an incident once a rail carrier has accepted shipment, and rail carriers cannot refuse shipments because of their common carrier obligation.[28] In addition, the rates that rail carriers can charge to move these commodities are generally negotiated between the shipper and the carrier on a contract basis and regulated by the Surface Transportation Board. Shippers, by virtue of not bearing liability, may lack an appropriate full incentive to ensure that the tanks cars are adequate to appropriately address the level of risk.

B. Rail Accidents

As is required of all accidents involving a release of hazardous materials in transportation in the United States,[29] derailments are reported to PHMSA and are recorded in the hazardous materials incident report database. As described in Appendix B, train accidents involving a release of flammable liquids and subsequent fire have occurred with increasing frequency, including:

1) *April 2014*: A train carrying crude oil derailed seventeen cars two of which released a total of approximately 30,000 gallons of crude oil in the James River. Approximately 350 residents were evacuated for approximately 3.5 hours.
2) *December 2013:* A train carrying crude oil derailed and ignited near Casselton, ND, prompting authorities to issue a voluntary evacuation of the city and surrounding area.
3) *November 2013:* A train carrying crude oil to the Gulf Coast from North Dakota derailed in Aliceville, Alabama, spilling crude oil in a nearby wetland and igniting into flames.
4) *July 2013:* An unattended train carrying crude oil derailed in Lac-Mégantic, Quebec, Canada that caused the 47 deaths, extensive damage to the town center, and the evacuation of approximately 2,000 persons from the surrounding area.

The Lac-Mégantic accident resulted in economic losses preliminarily estimated at more than $1 billion.[30] On August 2, 2013, FRA issued Emergency Order No. 28, which identified the following:

1) Crude oil is problematic when released because of its flammability, and the risk is compounded because it is commonly shipped in large volume;

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[28] In an effort to encourage the use of different tank cars, some rail carriers impose a surcharge on customers who offer crude oil in DOT111 tank cars.

[29] See 49 C.F.R 171.15, 171.16.

[30] Please see Appendix C for a description of how these costs were estimated.

2) Similar dangers exist with other hazardous materials such as ethanol, which was transported via rail more than any other hazardous material in 2012;
3) Although the Lac-Mégantic accident occurred in Canada, the freight railroad operating environment in Canada is similar to that in the United States.

On January 23, 2014, in response to its investigation of the Lac-Mégantic accident, the NTSB released a report stating that at least 60 of the 63 derailed DOT-111 tank cars released a total of about 1.6 million gallons of crude oil. According to the NTSB, "The Lac-Mégantic accident shows that railroad accidents involving crude oil have a potential for disastrous consequences and environmental contamination equal to that of the worst on-shore pipeline accidents."

FRA has proposed a separate rulemaking to address train attendance issues, but aspects of the Lac-Mégantic accident are relevant to this rulemaking. This accident occurred in a relatively small town with low rail traffic volumes, but occurred in a congested area with a place of congregation near the tracks.[31]While imperfect, PHMSA uses population density is a proxy for the presence of places of congregation. PHMSA and FRA are taking this regulatory step to mitigate damage from accidents involving HHFTs, including catastrophic accidents that could occur that result in damages even greater than a Lac-Mégantic accident, as well as lower-consequence events that do not involve outsized environmental and property damages or multiple fatalities.

Appendix B highlights this risk by summarizing the impacts of recent accidents involving HHFTs of crude oil and ethanol. While other accidents involving crude oil and ethanol have not released as much product and have not had as significant consequences as those shown in Appendix B, these accidents indicate the potential harm from future releases.

C. Precursors and Forewarnings

To consider the likelihood of future catastrophic accidents in the absence of regulatory changes, PHMSA analyzed modal transportation data, historical accident data, and the market forecasts for crude oil and ethanol. In addition, PHMSA and FRA have many initiatives underway to address freight rail safety including risk reduction programs, track safety standards, positive train control, equipment securement, a retrospective review of the requirements for the carriage of hazardous materials by rail (Part 174) and oil spill response plans. Many of these actions address different parts of rail safety including operational issues that are outside of PHMSA's purview.

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[31] According to the Canada 2011 Census, Lac-Mégantic had a population of 5,932. The town occupies a land area of 21.77 square kilometers (8.41 sq mi) and a population density of 272.5 inhabitants per square kilometer (706 /sq mi). Source; http://www12.statcan.gc.ca/census-recensement/2011/dp-pd/prof/details/page.cfm?Lang=E&Geo1=CSD&Code1=2430030&Geo2=PR&Code2=24&Data=Count&SearchType=Begins&SearchPR=01&B1=All

However, we do not expect these measures to reduce the derailment rate per carload for crude and ethanol trains in the future.

In general, PHMSA and FRA found that several factors give rise to higher expected damages and probability of a catastrophic event when comparing high volume flammable liquid shipments to the historic record, which features comparatively small volumes of flammable liquids shipped by rail. First, the volumes of crude oil and ethanol carried by rail are relatively large when compared to rail shipments of other flammable liquids.[32] In particular, the volume of crude oil shipped by rail has been increasing rapidly during the past several years. Finally, crude oil and ethanol are increasingly shipped in HHFTs, compounding the risk of greater damages when an accident does occur, while other flammable liquids are generally shipped in smaller volumes with other, non-flammable materials.

The North Dakota Industrial Commission adopted new conditioning standards that would require crude oil produced there to have a Vapor Pressure of Crude Oil not greater than 13.7 psi or 1 percent less than the vapor pressure of stabilized crude oil as defined in the latest version of ANSI/API RP3000 whichever is lower. It is our understanding that the level of Pre-treatment described in this order will not have a drastic effect as most of the crude in North Dakota tests below 13.7 already. We are not able make any definitive statements on the impact on the baseline likelihood of future fires or explosions from derailments involving North Dakota crude.

Due to these recent changes, PHMSA and FRA have concluded that the historical train accident record alone does not reflect the probability of a catastrophic event in the future.

D. Appraisal of Final Rule Provisions

In the absence of PHMSA regulatory action (the "no action" alternative), current requirements would remain in place, and no new provisions would be added. In this case, the safety and environmental risks related to HHFTs would not be addressed. A lack of action by PHMSA would ignore the significant consequences experienced in serious train accidents. In order to mitigate the societal costs of future accidents, PHMSA has worked closely with FRA to take regulatory action that will prevent and mitigate future train accidents. The final rule provisions are described in the sections that follow.

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[32] A unit train of flammable liquids increases the number of hazmat cars in a single train and potential number of hazmat cars that could potentially derail in a single event. Previous studies have found that a greater residual train length is expected to result in more cars derailed given all else being equal (e.g., Saccomanno and El-Hage, 1989,1991; Anderson, 2005). If all of the cars in a train contain hazmat, more hazmat would release. Intuitively this would result in a higher likelihood of a catastrophic event.

IV. Final Rule Provisions

The HMR are designed to achieve three goals: (1) to ensure that hazardous materials are packaged and handled safely and securely during transportation; (2) to provide effective communication to transportation workers and emergency responders of the hazards of the materials being transported; and (3) to reduce the likelihood that a train carrying high volumes of flammable liquids will derail, and also minimize the consequences of an incident should one occur. The hazardous material regulatory system is a risk management system that is prevention-oriented and focused on identifying a safety or security hazard, thus reducing the probability and quantity of a hazardous material release.

Under the HMR, hazardous materials are categorized by analysis and experience into hazard classes and Packing Groups based upon the risks that they present during transportation. The HMR specify appropriate packaging and handling requirements for hazardous materials based on such classification, and require an offeror to communicate the material's hazards through the use of shipping papers, package marking and labeling, and vehicle placarding. The HMR also require offerors to provide emergency response information applicable to the specific hazard or hazards of the material being transported. Further, the HMR mandate training for persons who prepare hazardous materials for shipment or who transport hazardous materials in commerce and require the development and implementation of plans to address security risks related to the transportation of certain types and quantities of hazardous materials in commerce, including additional planning requirements for transportation by rail (e.g., the routing of the material).

PHMSA is establishing regulatory requirements for flammable liquids transported in HHFTs. The final rule defines a HHFT as a train comprised of 20 or more tank cars in a block or 35 tank cars across the train consist loaded with flammable liquids and ensures that the rail requirements are more closely aligned with the risks posed by the operation of these trains. Our intent is to address the risks posed by large blocks or unit train shipments of flammable liquids. Generally, ethanol and crude oil are the flammable liquids most frequently transported in high volume shipments, such as HHFTs. By focusing on this growing risk, we will mitigate the vulnerabilities and consequences associated with accidents involving large volumes of flammable liquids, as evidenced in the rail accidents of recent years.

In the section that follows we provide an overview of the following provisions, as adopted in the final rule:

1) Tank Car Specifications
2) Advanced Brake Signal Propagation Systems
3) Speed Restrictions
4) Routing Requirements
5) Classification of Unrefined Petroleum-Based Products

A. Routing Requirements

1. Regulatory Change

In the final rule, PHMSA is requiring rail carriers to perform an analysis that considers 27 safety and security factors for routing HHFTs. The carrier must select a route based on findings of the route analysis. These planning requirements are prescribed in 49 CFR § 172.820 for trains carrying security-sensitive hazardous materials and would be expanded to apply to HHFTs. This replaces the proposed requirements to notify State Emergency Response Commissions (SERCs) or other appropriate state delegated entity about the operation of these trains through their States.

Table P1: Performance Factors Considered in This Safety and Security Risk Analysis		
Volume of hazardous material transported	Rail traffic density	Trip length for route
Presence and characteristics of railroad facilities	Track type, class, and maintenance schedule	Track grade and curvature
Presence or absence of signals and train control systems along the route ("dark" versus signaled territory)	Presence or absence of wayside hazard detectors	Number and types of grade crossings
Single versus double track territory	Frequency and location of track turnouts	Proximity to iconic targets
Environmentally sensitive or significant areas	Population density along the route	Venues along the route (stations, events, places of congregation)
Emergency response capability along the route	Areas of high consequence along the route, including high consequence targets	Presence of passenger traffic along route (shared track)
Speed of train operations	Proximity to en route storage or repair facilities	Known threats, including any threat scenarios provided by the DHS or the DOT for carrier use in the development of the route assessment
Measures in place to address apparent safety and security risks	Availability of practicable alternative routes	Past accidents
Overall times in transit	Training and skill level of crews	Impact on rail network traffic and congestion

2. Overview

Careful consideration of a rail route with regard to a variety of risk factors can mitigate risk of an accident. For some time, there has been considerable public and Congressional interest in the safe and secure rail routing of security-sensitive hazardous materials (such as chlorine and anhydrous ammonia). The Implementing Recommendations of the 9/11 Commission Act of 2007 directed the Secretary, in consultation with the Secretary of Homeland Security, to publish a rule governing the rail routing of security-sensitive hazardous materials. On December 21, 2006, PHMSA, in coordination with FRA and the Transportation Security Administration (TSA) of the U.S. Department of Homeland Security (DHS), published an NPRM under Docket HM-

232E (71 FR 76834), which proposed to revise the current requirements in the HMR applicable to the safe and secure transportation of hazardous materials by rail. Specifically, we proposed to require rail carriers to compile annual data on specified shipments of hazardous materials, use the data to analyze safety and security risks along rail routes where those materials are transported, assess alternative routing options, and make routing decisions based on those assessments.

In that NPRM, we solicited comments on whether the proposed requirements should also apply to flammable gases, flammable liquids, or other materials that could be weaponized, as well as hazardous materials that could cause serious environmental damage if released into rivers or lakes. Commenters who addressed this issue indicated that rail shipments of Division 1.1, 1.2, and 1.3 explosives; Poisonous by Inhalation (PIH) materials; and highway-route controlled quantities of radioactive materials pose significant rail safety and security risks warranting the enhanced security measures proposed in the NPRM and adopted in a November 26, 2008 final rule (73 FR 20752). Commenters generally did not support enhanced security measures for a broader list of materials than were proposed in the NPRM.

The City of Las Vegas, Nevada, did support expanding the list of materials for which enhanced security measures are required to include flammable liquids; flammable gases; certain oxidizers; certain organic peroxides; and 5,000 pounds or greater of pyrophoric materials. While DOT and DHS agreed that these materials pose certain safety and security risks in rail transportation, the risks were not as great as those posed by the explosive, PIH, and radioactive materials specified in the NPRM, and PHMSA was not persuaded that they warranted the additional safety and security measures. PHMSA did note, however, that DOT, in consultation with DHS, would continue to evaluate the transportation safety and security risks posed by all types of hazardous materials and the effectiveness of our regulations in addressing those risks and would consider revising specific requirements as necessary.

The final rule implemented regulations requiring rail carriers to compile annual data on certain shipments of explosive, toxic by inhalation, and radioactive materials; use the data to analyze safety and security risks along rail routes where those materials are transported; assess alternative routing options; and make routing decisions based on those assessments. In accordance with § 172.820(e), the carrier must select the route posing the least overall safety and security risk. The carrier must retain in writing all route review and selection decision documentation. Additionally, the rail carrier must identify a point of contact on routing issues involving the movement of covered materials and provide the contact information to the appropriate State, local, and tribal personnel.

Rail carriers must assess available routes using, at a minimum, the 27 factors listed in Appendix D to Part 172 of the HMR to determine the safest, most secure routes for security-sensitive hazardous materials.

The HMR require carriers to make conscientious efforts to develop logical and defendable systems using these factors. Risk can be minimized practically in two ways: one is to run shipments over the highest-quality track, i.e. track that poses the lowest risk for derailment, collision, or other train accident. The other way risk can be reduced is to reduce exposure to train accidents. Rerouting can address either or both of these risk factors, but in some cases, one factor

must be traded off against another. In some cases, rail carriers might choose a route that eliminates exposure in areas with high population densities but poses a risk for more frequent events in areas with low population densities. In other cases, the risk of derailment may be so low along a section of track that, even though it runs through a densely populated area, it poses the lowest total risk when severity and likelihood are considered.

FRA enforces the routing requirements in the HMR and is authorized, after consulting with PHMSA, TSA, and the STB, to require a railroad to use an alternative route other than the route selected by the railroad if it is determined that the railroad's route selection documentation and underlying analysis are deficient and fail to establish that the route chosen poses the least overall safety and security risk based on the information available (49 CFR 209.501).

On January 23, 2014, in response to its investigation of the Lac-Mégantic accident, the NTSB issued three recommendations to PHMSA and FRA. Recommendation R-14-4, in particular, requested PHMSA work with FRA to expand hazardous materials route planning and selection requirements for railroads to include *key trains* transporting flammable liquids as defined by the AAR Circular No. OT-55-N and, where technically feasible, require rerouting to avoid transportation of such hazardous materials through populated and other sensitive areas.

B. Tank Car Specifications

1. Regulatory Change

In the final rule, PHMSA is adopting enhanced standards for both new and existing tank cars. PHMSA will revise the HMR to require new tank cars constructed after October 1, 2015 (that are used to transport flammable liquids as part of an HHFT) to meet enhanced design criteria (DOT-117), including specific design requirements or performance criteria. In addition, the HMR will require existing tank cars that are used to transport flammable liquids as part of an HHFT to be retrofitted to meet an enhanced CPC-1232 standard, based on Packing Group and tank car based retrofit schedule.

2. Overview

Proper classification is essential when selecting an appropriate packaging for a hazardous material. The HMR is designed to provide a list of packagings for each material that can appropriately contain the material and its hazards. Based on the shipping name of a hazardous material, the HMT provides the list of packagings authorized for use by the HMR. For each proper shipping name, bulk packaging requirements are provided in Column 8C of the § 172.101 HMT.

The offeror must select a packaging that is suitable for the properties of the material and based on the packaging authorizations provided by the HMR. With regard to package selection, the HMR require in § 173.24(b) that each package used for the transportation of hazardous materials be "designed, constructed, maintained, filled, its contents so limited, and closed, so that under conditions normally incident to transportation…there will be no identifiable (without the use of

instruments) release of hazardous materials to the environment [and]… the effectiveness of the package will not be substantially reduced." Under this requirement, offerors must consider how the properties of the material (which can vary depending on temperature and pressure) will affect the packaging.

For most flammable liquids, the authorized packaging requirements for a PG I material are provided in § 173.243 and for PGs II and III in § 173.242. Table P2 has been provided as a general guide for the packaging options for rail transport provided by the HMR for flammable and combustible liquids.

Table P2: Tank Car Options[33]

Flammable Liquid, PG I	Flammable Liquid, PG II and III	Combustible Liquid
DOT 103	DOT 103	DOT 103
DOT 104	DOT 104	DOT 104
DOT 105	DOT 105	DOT 105
DOT 109	DOT 109	DOT 109
DOT-111	DOT-111	DOT-111
DOT 112	DOT 112	DOT 112
DOT 114	DOT 114	DOT 114
DOT 115	DOT 115	DOT 115
DOT 120	DOT 120	DOT 120
	AAR 206W	AAR 206W
		AAR 203W
		AAR 211W

Note 1 Sections 173.241, 173.242, and 173.243 authorize the use of the above tank cars.
Note 2. DOT 103, 104,105, 109, 112, 114, and 120 tank cars are pressure tank cars (HMR; Part 179, Subpart C).
Note 3. DOT-111 and 115 tank cars are non-pressure tank cars (HMR; Part 179, Subpart D).
Note 4. AAR 203W, AAR 206W, and AAR 211W tank cars are non-DOT specification tank cars that meet AAR standards. These tank cars are authorized under § 173.241 of the HMR (see Special Provision B1, as applicable).
Note 5. DOT-114 and DOT 120 pressure cars are permitted to have bottom outlets and, generally, would be compatible with the DOT-111.

The packaging authorizations are currently indicated in the HMT and part 173, subpart F. DOT-111 tank cars are authorized for low, medium and high-hazard liquids and solids (equivalent to Packing Groups III, II, and I, respectively). Packing Groups are designed to assign a degree of danger presented within a particular hazard class. Packing Group I poses the highest danger ("great danger") and Packing Group III the lowest ("minor danger").[34] In addition, the general

[33] Additional information on tank car specifications is available at the following URL: http://www.bnsfhazmat.com/refdocs/1326686674.pdf

[34] Packing Groups, in addition in indicating risk of the material, can trigger levels of varying requirements. For example Packing Groups can indicate differing levels of testing requirements for a non-bulk packaging, or the need for additional operational requirements such as security planning requirements.

packaging requirements prescribed in § 173.24 provide additional consideration for selecting the most appropriate packaging from the list of authorized packaging identified in column (8) of the HMT.

The DOT-111 tank car is one of several cars currently authorized by the HMR for the rail transportation of many hazardous materials, including ethanol, crude oil and other flammable liquids. For a summary of the design requirements of the DOT-111 tank car, see Table P2 in the tank car portion of the discussion of comments. Recent growth in demand for rail carriage of crude oil[35] and ethanol[36] has increased the risk of train accidents involving those materials. Major train accidents often result in the release of hazardous materials. These events pose a significant danger to the public and the environment. FRA closely monitors train accidents involving hazardous materials and documents the damage sustained by all cars involved in the accident.

In published findings from the June 19, 2009, incident in Cherry Valley, Illinois, the NTSB indicated that the DOT-111 tank car can almost always be expected to breach in the event of a train accident resulting in car-to-car impacts or pileups.[37] In addition, PHMSA received numerous petitions encouraging rulemaking and both FRA and PHMSA received letters from members of Congress in both parties urging prompt, responsive actions from the Department. The Association of American Railroads (AAR) created the T87.6 Task Force to consider several enhancements to the DOT-111 tank car design and rail carrier operations to enhance rail transportation safety. Simultaneously, FRA conducted research on long-standing safety concerns regarding the survivability of the DOT-111 tank cars designed to current HMR standards and used for the transportation of ethanol and crude oil, focusing on issues such as puncture resistance and top fittings protection. The research indicated that special consideration is necessary for the transportation of ethanol and crude oil in DOT-111 tank cars, especially in HHFTs.

In addition, PHMSA and FRA reviewed the regulatory history pertaining to flammable liquids transported in tank cars. Prior to 1990, the distinction between material properties that resulted

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[35] In 2013 there were approximately 400,000 originations of tank car loads of crude oil. In 2012, there were nearly 234,000 originations. In 2011 there were nearly 66,000 originations. In 2008 there were just 9,500 originations. Association of American Railroads, *Moving Crude Petroleum by Rail*, http://DOT-111.info/wp-content/uploads/2014/01/Crude-oil-by-rail.pdf (December 2013).

[36] In 2011 there were nearly 341,000 originations of tank car loads of ethanol, up from 325,000 in 2010. In 2000 there were just 40,000 originations. Association of American Railroads, *Railroads and Ethanol*, https://www.aar.org/keyissues/Documents/Background-Papers/Railroads%20and%20Ethanol.pdf (April 2013).

[37] National Transportation Safety Board, *Railroad Accident Report - Derailment of CN Freight Train U70691-18 With Subsequent Hazardous Materials Release and Fire*, http://www.ntsb.gov/doclib/reports/2012/RAR1201.pdf (February 2012)

in different packaging, for flammable liquids in particular, was described in far more detail in § 173.119. Section 173.119 indicated that the packaging requirements for flammable liquids are based on a combination of flash point, boiling point, and vapor pressure.

In 2011, the AAR issued Casualty Prevention Circular (CPC) 1232, which outlines industry requirements for certain DOT-111 tanks ordered after October 1, 2011, intended for use in ethanol and crude oil service (construction approved by FRA on January 25, 2011).[38] The CPC-1232 requirements are intended to improve the crashworthiness of the tank cars and include a thicker shell, head protection, top fittings protection, and pressure relief valves with a greater flow capacity.

C. Advanced Braking Systems

1. Regulatory Change

The final rule requires all HHFTs be equipped with advanced braking systems. All HHFTs would be operated 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 Electronically Controlled Pneumatic (ECP) braking mode.

2. Overview

The effective use of braking on a train set can result in accident avoidance and potentially lessen the consequences of an accident by diminishing the number of derailed tank cars. Currently, the FRA promulgates brake system standards for freight and other non-passenger trains and equipment in Title 49 CFR Part 232. Specifically, this part provides requirements for 1) General Braking, 2) Inspection and Testing, 3) Periodic Maintenance, 4) End-of-Train Devices, and 5) Introduction of New Technologies and Electronically Controlled Pneumatic Braking.

Australian Experience

In contrast to the experience in the United States, railroads in countries such as Australia have been much more accepting of this new technology.[39] Australia has been using ECP brakes on a

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[38] See the Background section of the August 1 NPRM for information regarding a detailed description of PHMSA and FRA actions to allow construction under CPC-1232.

[39] 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.

portion of its fleet for over a decade.[40] 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 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 railroads services, crude oil recently has become relatively more important.[41]

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.

One may question why, if ECP brakes have been widely accepted in Australia, railroads in the United States have not adopted ECP brakes at the same rate. One major factor is that Australian experience a "mining boom", 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. FRA believes that this rule, which requires the retrofit of a large portion of the fleet and the purchase of new tank cars presents the same opportunity in the United States. However, regulatory action is necessary in this country 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 acceptance 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 III 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

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[40] "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.

[41] "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

Unites 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. NS (Norfolk Southern) has extended its ECP brake service within the last three years.[42] In contrast, BNSF hauls ECP-equipped coal cars that are leased by a shipper. BNSF has rebuffed enquiries from the shipper about increasing the size of its leased ECP-equipped fleet and for BNSF to add another train operating using ECP brakes.

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 the safety benefit of ECP brakes. 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 PCP 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."

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[42] NS added a train that operates using ECP brakes in 2014. This train travels round trip between the Powder River Basin and Macon, GA. It is an NS train—using NS locomotive power and NS-owned cars—and NS performs all of the periodic mechanical brake inspections; however, BNSF assists in operating the train because part of the train's route is over BNSF track.

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 are a proven and reliable option for HHFUTs in the United States.

D. Speed Restrictions

1. Regulatory Change

The final rule revises the HMR to restrict all HHFTs to 50 mph in all areas. Further, the regulations will require HHFTs that contain any tank cars not meeting the enhanced tank car standards proposed by this rule operate at a 40-mph speed restriction in high threat urban areas.

2. Overview

High speeds can increase the kinetic energy involved in and the associated damage caused by a derailment. With respect to operating speeds, FRA has developed a system of classification that defines different track classes based on track quality. The track classes include Class 1 through Class 9 and "excepted track," although freight trains transporting hazardous materials currently operate at track speeds associated with Class 1 through Class 5 track and, in certain limited instances, at or below "excepted track" speed limits. Section 213.9 of the FRA regulations on Track Safety Standards provides the "maximum allowable operating speed" for track Class 1 through Class 5 and "excepted track." The speed limits range from 10 mph or less up to 80 mph;

however, AAR design specifications effectively limit most freight equipment to a maximum allowable speed of 70 mph.

In addition, AAR Circular OT-55-N set forth in 2013 a 50-mph maximum speed for any *key train*, including any train with 20-car loads of "any combination of hazardous material." In February 2014, by way of Secretary Foxx's *Letter to the Association of American Railroads*, AAR's Railroad Subscribers further committed to a 40-mph speed limit for certain trains carrying crude oil within the limits of any *High-Threat Urban Area* (HTUA) as defined by 49 CFR § 1580.3.

E. Sampling and Classification Program for Unrefined Petroleum-Based Products

1. Regulatory Change

The final rule requires a written sampling and testing program for all unrefined petroleum-based products, such as crude oil, to address:

1) A frequency of sampling and testing that accounts for any appreciable variability of the material;
2) Sampling prior to the initial offering of the material for transportation and when changes that may affect the properties of the material occur;
3) Sampling methods that ensures a representative sample of the entire mixture, as offered, is collected;
4) Testing methods that enable classification of the material under the HMR;
5) Quality control measures for sample frequencies;
6) Duplicate sampling or equivalent measures for quality assurance;
7) Criteria for modifying the sampling and testing program; and
8) Testing or other appropriate methods used to identify properties of the mixture relevant to packaging requirements.

Further, the provision requires the offeror to certify that a program is in place, document the testing and sampling program, and make program information available to DOT personnel upon request.

2. Overview

An offeror's responsibility to classify and describe a hazardous material is a key requirement under the HMR. In accordance with § 173.22 of the HMR, it is the offeror's responsibility to properly "class and describe a hazardous material in accordance with parts 172 and 173 of the HMR." For transportation purposes, classification ensures that the proper hazard class, Packing Group, and shipping name are assigned to a particular material. The HMR do not prescribe a specific test frequency to classify hazardous materials. However, the regulations in § 173.22 clearly intend for the frequency and type of testing to be based on an offeror's knowledge of the hazardous material, with specific consideration given to the nature of hazardous material

involved, the variety of the sources of the hazardous material, and the processes used to handle and prepare the hazardous material. Section 173.22 also requires offerors to identify all relevant properties of the hazardous material to comply with complete hazard communication, packaging, and operational requirements in the HMR. While the HMR do not prescribe specific requirements to quantify properties relevant to packaging selection, the offeror must follow the general packaging requirements in part 173, subpart B. For example, as indicated in § 173.24(e), even though certain packagings are authorized for a specific HMR entry, it is the responsibility of the offeror to ensure that each packaging is compatible with its specific lading. In addition, offerors should know the specific gravity of the hazardous material at certain temperatures to ensure that outage is considered when loading a rail tank car or cargo tank motor vehicle per § 173.24b(a) of the HMR.

Once an offeror has classified and described the material; selected the appropriate packaging; loaded the packaging; and marked, labeled, and placarded in accordance with the HMR, the offeror must "certify" the shipment per § 172.204 of the HMR. The certification statement indicates the HMR were followed and that all requirements have been met. As such, the offeror is responsible for certifying its material has been properly classified and all packaging requirements have been met. Improper classification can have significant negative impacts on transportation safety. For example, the requirements for safety and security plans required in subpart I of part 172 of the HMR are dependent on Packing Group for many hazardous materials, including flammable liquids. See § 172.800(b)(6).

The physical and chemical properties of unrefined petroleum products are complex and can vary by region, time of year, and method of extraction. Heating, agitation, and centrifugal force are common methods of separation for the initial treatment of unrefined petroleum to reduce the physical and chemical complexities. These methods eliminate much of the gaseous hydrocarbons, sediments, and water from the bulk material. Blending crude oil is another option that can be done in order to achieve a uniform material when other methods are unavailable. However, there may still be considerable variation between mixtures where separation or blending has occurred at different times or locations. While blending may generate a uniform profile for an individual mixture of the material, it does not eliminate the gaseous hydrocarbons or the related hazards. The separation and blending methods both create a new product or additional byproducts that may result in the need to transport flammable gases in addition to flammable liquids. Currently, new state regulations passed December 2014 in North Dakota from the North Dakota Industrial Commission (Oil Conditioning Order No. 25417) will require operators of Bakken crude oil produced in the state of North Dakota to separate the gaseous and light hydrocarbons from all Bakken crude oil that is to be transported. The order also prohibits blending of Bakken crude oil with specific materials. Manufactured goods and refined products, by definition, are at the other end of the spectrum from unrefined or raw materials. This means that the physical and chemical properties are more predictable as they are pure substances or well-studied mixtures.

Crude oil transported by rail is derived from different sources and is most often blended in large storage tanks before being loaded into rail tank cars at transloading facilities. In rare cases, the crude oil is transferred directly from a cargo tank to a rail car, which may result in more variability of properties among the rail tank cars. PHMSA and FRA completed audits of crude oil loading facilities, prior to the issuance of the February 26, 2014 Emergency

Restriction/Prohibition Order, indicated that the classification of crude oil being transported by rail was often based solely on a Safety Data Sheet (SDS). The information is usually generic, provides only basic data, and offers a wide range of values for a limited number of material properties. The flash point and initial boiling point ranges on SDS referenced during the audits crossed the packaging group threshold values making it difficult to determine the proper Packing Group assignment. In these instances, it is likely no validation of the information is performed at an interval that would allow for detection of variability in material properties.

In the case of a flammable liquid (excluded from being defined as a gas per §171.8 of the HMR), the properties needed for proper packing group classification are flash point and initial boiling point. See § 173.120 of the HMR. The offeror may additionally need to identify properties such as corrosivity, vapor pressure, specific gravity at loading and reference temperatures, and the presence and concentration of specific compounds (e.g. sulfur) to further comply with complete packaging requirements.

In addition to the regulations detailing proper classification and characterization of hazardous materials, the rail and oil industry, along with PHMSA input, have developed a recommended practice designed to improve crude oil rail safety through proper classification and loading practices. The American Petroleum Institute spearheaded this effort, resulting in the development of American National Standards Institute (ANSI) / American Petroleum Institute (API) Recommend Practices (RP) 3000, *Classifying and Loading of Crude Oil into Rail Tank* Cars.[43] This API standard, which during its development, went through a public comment period in order to be designated as an American National Standard,[44] addresses the proper classification of crude oil for rail transportation and quantity measurement for overfill prevention when loading crude oil into rail tank cars. While currently not incorporated by reference into the HMR, the development of this document demonstrates that the regulated community realizes the importance of proper classification.

On January 23, 2014, in response to its investigation of the Lac-Mégantic accident, the NTSB issued three recommendations to PHMSA and FRA. Safety Recommendation R-14-6 requested

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[43] The group that developed RP 3000 included a variety of stakeholders representing crude oil producers/suppliers, crude oil purchasers, rail road companies, rail tank car manufacturers, rail tank car lessors, classifiers of crude oil for transportation, crude oil testing laboratories, crude oil testing equipment manufacturers, petrochemical terminal operators and government personnel.

[44] ANSI establishes the consensus procedures that are the basis for the development of American National Standards. ANSI then accredits standards developing organizations that operate in accordance with these procedures, and approve their draft standards provided they are developed via this process. ANSI-approved standards only become mandatory when, and if, they are adopted or referenced by the government or when market forces make them imperative. http://www.ansi.org/about_ansi/faqs/faqs.aspx?menuid=1#stand.

that PHMSA require shippers to sufficiently test and document the physical and chemical characteristics of hazardous materials to ensure the proper classification, packaging, and record-keeping of products offered in transportation. These and other NTSB Safety Recommendations as well as the corresponding PHMSA responses are discussed in further detail in the final rule.

V. Background

PHMSA's mission is to protect people and the environment from the risks of hazardous materials transportation. To do this, PHMSA establishes national policy; sets and enforces standards, educates, and conducts research to prevent train accidents; and prepares the public and first responders to reduce consequences if accidents do occur. Below we describe the NPRM and initial RIA issued by PHSMA to address the growing risk related to HHFTs.

A. NPRM Summary

On August 1, 2014, PHMSA and FRA issued an NPRM, titled *Hazardous Materials: Enhanced Tank Car Standards and Operational Controls for HHFTs*, (79 FR 45015). The NPRM was developed based on comments received in response to the September 6, 2013, advance notice of proposed rulemaking (ANPRM) responding to eight petitions for rulemaking and four NTSB Safety Recommendations related to the transportation of hazardous materials by rail (78 FR 54849) accidents that occurred since the ANPRM was issued, and communications to the agency from the National Transportation Safety Board (NTSB), Congress, and other stakeholders, such as tank car manufacturers, shippers and carriers.

In the NPRM, PHMSA proposed: 1) new operational requirements; 2) improvements in tank car standards; and 3) bolstered requirements for offerors to ensure proper classification and characterization of unrefined petroleum-based products.

These proposed requirements are designed to lessen the frequency and consequences of train accidents involving HHFTs. The proposed changes also address NTSB safety recommendations on the accurate classification and characterization of such commodities, more robust tank car standards, and rail routing. In the NPRM, PHMSA proposed three options for new construction and retrofitting of rail tank cars, as well as three options for a 40-mph speed restriction. In addition to the tank car and speed options, PHMSA proposed four operational controls to reduce the likelihood of derailments and mitigate the consequences should a derailment occur. The proposals are detailed in Table B1 below.

Table B1: NPRM Proposals
New Construction
PHMSA proposed a new DOT-117 tank car to address the risks associated with the rail transportation of ethanol and crude oil and the risks posed by HHFTs (see definition in HHFT section). We analyzed three tank car options for both newly manufactured tank cars and the existing tank car fleet.
Option 1: **DOT and FRA Designed Car**: Incorporates several enhancements designed to increase puncture resistance; provide thermal protection to survive a 100-minute pool fire; protect top fitting and bottom outlets during a derailment; and improve braking performance.
Option 2: AAR Designed Car: Based on the AAR's recommended new tank car standard, approximately 5,000 of which were reportedly ordered by BNSF Rail Corporation. The Option 2 car has

Table B1: NPRM Proposals
most of the same safety features as the Option 1 car, including the same increase in shell thickness, jacket requirement, thermal protection requirement, and head shield requirement, but it lacks rollover protection and the ECP brake equipment.
Option 3: Jacketed CPC-1232: A jacketed CPC-1232 tank car standard, with improvements made to the bottom outlet handle and pressure relief valve. This car is a substantial safety improvement over the current DOT-111 but does not achieve the same level of safety as the Options 1 or 2. This tank car has a 7/16 inch shell, which is thinner than Option 1 or 2 tank cars. This car also lacks rollover protection and ECP brake equipment.
Existing Fleet
Existing DOT-111 tank cars that are used as part of a HHFT may be retrofitted to meet the three Options for the DOT-117 requirements. This retrofit would not include top fittings protections. Alternatively, they could be retired, repurposed, or operated under speed restrictions for up to five years, based on Packing Group assignment.
Speed Restrictions
PHMSA proposed: (1) to establish a 50-mph maximum speed restriction for all HHFTs; (2) to provide three options for a 40-mph speed restriction for any HHFT unless all flammable liquid tank cars meet the enhanced tank car standards; and (3) in the event a rail carrier cannot comply with the enhanced braking requirements, to establish a 30-mph speed restriction for those HHFTs.
Option 1: A 40-mph speed restriction for any HHFT operating in any area unless all flammable liquid tank cars meet the enhanced tank car standards.
Option 2: A 40-mph speed restriction for any HHFT operating in an area that has a population of 100,000, unless all flammable liquid tank cars meet the enhanced tank car standards.
Option 3: A 40-mph speed restriction for any HHFT operating in any high-threat urban area (HTUA)[45] unless all flammable liquid tank cars meet the enhanced tank car standards.
Rail Routing
PHMSA proposed to require the additional safety and security planning requirements prescribed in § 172.820, for HHFTs.
Classification of Mined Gases and Liquids
PHMSA proposed to require a sampling and testing program for Mined Gases and Liquids (referred to as "unrefined petroleum-based products" in the final rule's adopted requirements). This program would be in writing and address the: 1) frequency of sampling and testing; 2) sampling points along the supply chain; 3) sampling methods that ensure a representative sample of the mixture; 4) testing methods to enable complete analysis, classification, and characterization of the material; and 5) statistical justification for sample frequencies.
Enhanced Braking
PHMSA proposed to require advanced braking systems (electronic controlled pneumatic brakes, distributed power, and two-way end of train device) to reduce the number of cars and energy associated with train accidents.
Notification to SERCs

[45] As defined in 49 CFR 1580.3 – High Threat Urban Area (HTUA) means an area comprising one or more cities and surrounding areas including a 10-mile buffer zone, as listed in appendix A to Part 1580 of the 49 CFR.

Table B1: NPRM Proposals
PHMSA proposed to require railroads that operate trains containing one million gallons of Bakken crude oil to notify SERCs or other state approved entities about the operation of these trains through their States.

In the NPRM, PHMSA proposed several revisions to the HMR that would change the specification requirements for rail tank cars authorized to transport crude oil and ethanol. The changes would stipulate a new tank car performance specification, the DOT-117, that would be phased in over time depending on the Packing Group of the flammable liquid. Revising or replacing the current standard for the DOT-111 tank car is not a decision that DOT takes lightly. We provided three tank car options to ensure that the selected tank car will have the greatest net social benefits, with benefits primarily generated from the mitigation of accident severity. The NPRM and initial RIA also clearly noted the large economic effects associated with regulatory changes of this scale, as tank cars are a long-term investment. In Table B2, we clearly indicate the safety features related to each tank car option proposed in the NPRM and the currently authorized tank car.

Table B2: Safety Features by Tank Car Option										
Tank Car	**Bottom Outlet Handle**	**GRL (lbs.)**	**Head Shield Type**	**Pressure Relief Valve**	**Shell Thick-ness**	**Jacket**	**Tank Material***	**Top Fittings Protection****	**Thermal Protection System**	**Braking**
Option 1: PHMSA and FRA Designed Tank Car	Bottom outlet handle removed or designed to prevent unintended actuation during a train accident	286k	Full-height, 1/2 inch thick head shield	Reclosing pressure relief device	9/16-inch minimum	Minimum 11-gauge jacket constructed from A1011 steel or equivalent. The jacket must be weather-tight	TC-128 Grade B, normalized steel	TIH Top fittings protection system and nozzle capable of sustaining, without failure, a rollover accident at a speed of 9 mph	Thermal protection system in accordance with § 179.18	ECP brakes
Option 2: AAR 2014 Tank Car	Bottom outlet handle removed or designed to prevent unintended actuation during a train accident	286k	Full-height1/2 inch thick head shield	Reclosing pressure relief device	9/16-inch minimum	Minimum 11-gauge jacket constructed from A1011 steel or equivalent. The jacket must be weather-tight	TC-128 Grade B, normalized steel	Equipped per AAR Specifications for Tank Cars, Appendix E paragraph 10.2.1	Thermal protection system in accordance with § 179.18	DP or Two-way EOT devices
Option 3: Enhanced CPC-1232 Tank Car	Bottom outlet handle removed or designed to prevent unintended actuation during a train accident	286k	Full height 1/2 inch thick head shield	Reclosing pressure relief device	7/16-inch minimum	Minimum 11-gauge jacket constructed from A1011 steel or equivalent. The jacket must be weather-tight	TC-128 Grade B, normalized steel	Equipped per AAR Specifications for Tank Cars, Appendix E paragraph 10.2.1	Thermal protection system in accordance with § 179.18	DP or Two-way EOT devices
DOT-111A100W1 Specification (Currently Authorized)	Bottom outlets are optional	263K	Optional; bare tanks half height; jacket tanks full height	Reclosing pressure relief valve	7/16-inch-minimum	Jackets are optional	TC-128 Grade B, normalized steel*	Not required, but when equipped per AAR Specifications for Tank Cars, Appendix E paragraph 10.2.1	Optional	EOT device (See 49 CFR part 232)

* For the purposes of this figure, TC-128 Grade B normalized steel is used to provide a consistent comparison to the proposed options. Section 179.200-7 provides alternative materials, which are authorized for the DOT Specification 111.
** Please note that the PHMSA did not propose to require additional top fittings protection for retrofits.

B. Regulatory Review and Notices

Executive Order 12866, "Regulatory Planning and Review," directs all Federal agencies to develop both preliminary and final regulatory analyses if their regulations are likely to be "significant regulatory actions" that may have an annual impact on the economy of $100 million or more. The more recent Executive Order 13563, "Improving Regulation and Regulatory Review" (January 18, 2011) emphasizes careful consideration of costs and benefits and directs

agencies to use the best available techniques to quantify anticipated present and future benefits and costs as accurately as possible and to proceed only if the benefits justify the costs. This RIA was prepared in accordance with the guidance provided by the Office of Management and Budget's (OMB) Circular A-4[46] on the development of regulatory analysis as required under Section 6(a)(3)(c) of Executive Order 12866, the Regulatory Right-to-Know Act, and a variety of related authorities.

The final rule is an economically significant rule under 3(f)(1) of Executive Order 12866; PHMSA has also designated the rulemaking as a "significant" regulatory action because it is of significant public interest. The rulemaking would also be significant under the Department of Transportation's (DOT) regulatory policies and procedures (44 FR 11034; February 26, 1979).

Title II of the Unfunded Mandates Reform Act of 1995 ("the Act," 2 U.S.C. §1532) requires each agency to prepare a written statement for any proposed or final rule that includes a "Federal mandate that may result in the expenditure by State, local, and Native American Indian tribal governments, in the aggregate, or by the private sector, of $100,000,000 or more (adjusted annually for inflation) in any one year." The value equivalent of $100 million in 1995, adjusted for inflation to 2012 levels, is $151 million. The final rule does not impose enforceable duties on State, local, or Native American Indian tribal governments. The Act was designed to ensure that Congress and Executive Branch agencies consider the impact of legislation and regulations on States, local governments, and tribal governments, and the private sector. With respect to States and localities, the Act was an important step in recognizing State and local governments as partners in our intergovernmental system, rather than mere entities to be regulated or extensions of the federal government.

The final rule would result in costs to the private sector that exceed $151 million in any one year and those costs and benefits associated with this rulemaking have been discussed under paragraph A, Executive Order 12866, Executive Order 13563, Executive Order 13610 and DOT Regulatory Policies and Procedures, of this section. In addition, the RIA provides a detailed analysis of the public sector costs associated with the proposed requirements. The RIA is available in the public docket for this rulemaking. PHMSA invites comments on these considerations, including any unfunded mandates related to this rulemaking.

C. Initial RIA Summary

In the initial RIA, the benefits of the proposed requirements include averted damages from lower-consequence events that do not involve multiple fatalities, and higher-consequence events which involve large-scale property damage and multiple fatalities. Costs include the network

[46] See http://www.whitehouse.gov/omb/circulars_a004_a-4

effects of reducing HHFT speeds, the costs of retrofitting the majority of the current crude and ethanol fleet to meet the new performance standard, and the cost of constructing new tank cars relative to the tank car the industry has committed to building in the absence of regulation. Table B3 provides the benefits and costs for the NPRM proposals.

Table B3: Benefits and Costs of NPRM

Category	Justification	Estimated Damages		
		Average Gallons Spilled per Incident	**Total Societal Damages over 20 Years**	
Lower-Consequence Benefits	Avoided costs are based on $300 per gallon of product spilled. As a result, incident severity (property and environmental damage, injuries etc.) is assumed to be correlated with the quantity of product released. Average damages are based on the average quantity released for U.S. crude and ethanol HHFT train mainline derailments.	83,602 gallons	$4.5 billion (Undiscounted)	
Higher-Consequence Benefits	The impacts associated with a higher-consequence incident are assumed to be roughly equivalent to those of the Lac-Mégantic derailment. We estimate costs avoided based on a range of high consequence incidents from 0 to 10 events. We assume that one of those 10 events takes place in an area with a population that is five times denser than average. Because U.S. population densities in many areas of the U.S. along crude oil and ethanol routes are significantly greater than those in Canada, incidents in the U.S. may be more severe due to the greater likelihood that larger numbers of people could be affected. For example, the average mid-sized U.S. city (~30,000 or more people) has a population density that is roughly five times or more than that of Lac-Mégantic.	**Estimated Damages**		
		Societal cost	**Total max societal damages**	
		$1.2 billion	$14 billion (Undiscounted)	
Tank Car Design Standards: Event Mitigation and Cost Estimates	Benefits are based on FRA modelling of the survivability of various tank car configurations relative to one another in the event of a derailment at various speeds. Tank car effectiveness is assumed to be the same for lower and higher-consequence events – e.g., the PHMSA and FRA designed car results in a 51 percent lower probability of release in the event of a derailment than a non-jacketed DOT-111. This car is therefore assumed to reduce the consequences of both higher- and lower-consequence events by 51 percent relative to a train hauling crude or ethanol in non-jacketed DOT-111s.	**Estimated Benefits**		
		PHMSA FRA	**AAR Standard**	**CPC w/ Jacket**
		$822 million - $3.3 billion	$610 million - $2.4 billion	$393 million - $1.6 billion

	Costs are based on comments to the ANPRM on the cost of retrofitting various features onto an existing car, plus the anticipated cost of a new standard relative to the CPC-1232 with a jacket and thermal protection, which is the car the industry has committed to building for HHFT service in the absence of regulation. In addition, increased fuel use and track wear are monetized because the new standard cars would be heavier and hence result in more fuel use and track wear. Retrofitting legacy cars to meet the new performance standard is the largest cost component of the rule.	**Estimated Costs**		
		PHMSA FRA	**AAR Standard**	**CPC w/ Jacket**
		$3 billion	$2.6 billion	$2 billion
40-MPH Speed Restriction: Event Mitigation and Cost Estimates	Benefits are based on the same FRA modeling used to estimate the effectiveness of tank car standards in mitigating the consequences of events. They are applied in proportion to the track miles affected and reduced to account for voluntary actions taken on the part of rail carriers (i.e., reduced speed for HHFTs carrying crude oil in HTUAs).	**Estimated Benefits**		
		System-Wide	**Cities >100K**	**HTUA**
		$199 million - $636 million	$33.6 million - $108 million	$6.8 million - $21.8 million
	The costs of speed restrictions include the effects of traffic slowdowns on crude and ethanol rail corridors. These include slower speeds for both HHFTs and other trains that must reduce speed due to sharing track with HHFTs. Delay/slowdown costs are monetized at $500 per train per hour of delay.	Estimated Costs		
		System-Wide	**Cities >100K**	**HTUA**
		$2.7 billion	$240 million	$22.9 million
Other provisions	Other provisions include routing, classification and testing, and notification of SERCs. Costs for these provisions are minor compared to tank car and speed costs. PHMSA conducted a breakeven analysis to show the reduction in risk required for the benefits to exceed the costs.	**Estimated Costs**		
		Routing	**Class.**	**SERCS**
		$4.5 million	$16.2 million	Not estimated

The options for new and existing tank cars and speed restrictions considered result in nine permutations of the proposed rule. Table B4 presents the costs and benefits of the various combinations of proposed tank car and speed restriction provisions.

Table B4: 20-Year Benefits and Costs of Proposal Combinations of Proposed Regulatory Amendments 2015-2034[47]		
Proposal	**Benefit Range (Millions)**	**Cost (Millions)**
PHMSA and FRA Design Standard + 40 MPH System-Wide	$1,436 - $4,386	$5,820
PHMSA and FRA Design Standard + 40 MPH in 100K	$1,292 - $3,836	$3,380
PHMSA and FRA Design Standard + 40 MPH in HTUA	$1,269 - $3,747	$3,163
AAR 2014 Standard + 40 MPH System-Wide	$794 - $3,034	$5,272
AAR 2014 Standard + 40 MPH in 100K	$641- $2,449	$2,831
AAR 2014 Standard + 40 MPH in HTUA	$616 - $2,354	$2,614
Enhanced CPC-1232 Standard + 40 MPH System-Wide	$584 - $2,232	$4,741
Enhanced CPC-1232 Standard + 40 MPH in 100K	$426 - $1,626	$2,300
Enhanced CPC-1232 Standard + 40 MPH in HTUA	$400 - $1,527	$2,083

VI. Comments on the Initial RIA

PHMSA received over 3,200 public comments representing over 182,000 signatories in response to the August 1, 2014 NPRM and initial RIA. The final RIA summarizes comments specific to the derivation of costs and benefits of the rulemaking proposals and has been revised to align with the changes made to the final rule. Adjustments to the methodology used to estimate the benefits and costs resulting from the final rule are explained in subsequent sections.

A. Comments Related to the Benefits

Baseline Damages

In the initial RIA, PHMSA defined a baseline assessment of future damages associated with derailments of crude oil and ethanol trains in the absence of additional regulation. These damages include estimates of the number of derailments and the damages from those derailments, which can include product releases, property and environmental damage, injuries, and fatalities. To estimate the number of derailments per million carloads shipped, PHMSA used a combination of FRA's derailment database and the public waybill sample to construct a historical series on annual derailments. To determine the average amount of product released and damages associated with derailments, PHMSA utilized the FRA derailment database and the

[47] All costs and benefits are in millions, and are discounted to present value using a 7 percent rate.

PHMSA hazardous materials incident report database. In the initial RIA we asked readers a series of questions regarding the estimates of the number of derailments per year and the average product released per derailment. We also requested additional information regarding the difference in the probability of a derailment involving crude oil versus ethanol and improvements in data collection methods that could inform the baseline assessment.

In a joint submission, Riverkeeper and Scenic Hudson comment that PHMSA's benefits analysis emphasizes accidents in HTUAs. They further state that an oil spill on the Hudson River would be impossible to clean up completely, and would have long-term environmental damages beyond those considered by PHMSA. Several commenters suggest that DOT should focus more on the root causes to prevent accidents. Several other commenters made similar statements regarding the root cause of accidents.

PHMSA Response
PHMSA and FRA focus on prevention, mitigation, and response to manage and reduce the risk posed to people and the environment by the transportation of hazardous materials by rail. When addressing these issues, PHMSA, and FRA focus on solutions designed to reduce the probability of accidents occurring and to minimize the consequences of an accident should one occur.

PHMSA and FRA have used a variety of regulatory and non-regulatory methods to address the risks of the bulk transport of flammable liquids, including crude oil and ethanol, by rail. These efforts include issuing guidance, conducting rulemakings, participating in rail safety committees, holding public meetings, enhancing enforcement efforts, and reaching out to the public. All of these efforts are consistent with our system-wide approach. Train accidents are often the culmination of a sequence of events that are influenced by a variety of factors and conditions. While the Final Rule does not directly address regulations governing the inspection and maintenance of track, securement, and human factors, it does indirectly address some of these issues through the consideration of the 27 safety and security factors as part of the routing requirements. PHMSA and FRA find that existing regulations and on-going rulemaking efforts—together with the amendments in this Final Rule relating to speed, braking, and routing—sufficiently address safety issues involving rail defects and human factors.

Comment
API and the Illinois Commerce Commission commented that PHMSA used derailment data from all commodities and from all track data—mainline, yard, siding and industry—which overestimates the number of incidents used in the trend calculation. API believes PHMSA should only use mainline derailments that release the hazardous materials being regulated with this rule. The Mercatus Center cites results from its own analysis that indicates that the number of rail carloads of crude oil grew much faster than the number of accidents involving these cars, indicating that the accident rate for crude oil rail shipments was actually declining. DGAC also submitted comments noting that the accident rate has been declining. American Fuel & Petrochemical Manufacturers (AFPM) note that in the benefit calculation for the tank car standards, PHMSA only analyzed crude and ethanol derailments and the effect that new and retrofitted cars could have on preventing such incidents. Therefore, PHMSA should conduct a separate analysis to determine the effects of the tank car standards for other flammable liquids in a separate rulemaking process.

PHMSA response
In the final rule, PHMSA revises the HMR to establish requirements for any "high-hazard flammable train" (HHFT) that is transported over the U.S. rail network. This rule defines an HHFT as a train comprised of 20 or more tank car loads of a Class 3 flammable liquid in a continuous block or 35 or more tank car loads of any Class 3 flammable liquid across the entire train. The rule ensures that the requirements are closely aligned with the risks posed by the operation of trains that are transporting large quantities of flammable liquids. While Mercatus and DGAC note that the number of carloads increased at a faster rate than derailments, they fail to note that prior to 2011 relatively few shipments of crude oil were made by rail and that we still have only a few years of high volume shipments.

PHMSA remains focused on the unique risks associated with trains consisting of large blocks of hazardous materials. Crude oil and ethanol are the only types of commodity frequently transported in this configuration. The approach used for the final RIA is adjusted to accommodate these comments by focusing on derailments on mainline and siding track involving crude oil and ethanol.

Comment
The NYU School of Law Center for Policy Integrity commented on PHMSA's cost per gallon spilled estimates that were based on the Lynchburg, VA, accident. It did not offer additional data or analysis, but suggested that the Agency should calculate this cost as an average over several incidents. It also expressed the opinion that the costs reported in the Lynchburg case may be underreported. Conversely, PHMSA received comments that the cost per gallon spilled may be overstated. API commented that PHMSA chose to use cost data associated with the Lynchburg, VA incident, despite having data from 40 mainline derailments involving crude oil and ethanol releases since 2006. The average cost, including Lynchburg, from 2006 to 2013 is $16.67, yet Lynchburg, which had a cost of $300 per gallon, was used.

PHMSA response
PHMSA examined news and railroad reports from two crude oil incidents for which cost estimates are at least preliminarily available, evaluated cost estimates prepared by the NTSB, reviewed cost estimates reported by railroads to PHMSA in hazardous material incident reports for both ethanol and crude oil, and consulted academic literature on the cost of responding to ethanol and crude oil spills exceeding $300 per gallon in some cases. This research suggests that the response and cleanup costs for an individual spill of both crude oil and ethanol vary greatly and are influenced by a variety of factors including the amount of product released, topography, soil type, oil type and whether or not the material entered a waterway. After performing this research, PHMSA has decided to use a cost per gallon value that weights the costs associated with crude oil and ethanol spills and weights the costs by forecast future volume for each commodity. The central estimate for ethanol spills is $144, and the central estimate for crude oil spills is $211. We estimate the weighted average based on the percentage of crude oil and ethanol in the future carload forecast, resulting in a value of approximately $200. The Agency uses separate per gallon cost estimates—for both crude oil and ethanol—that are based on the available data and literature, and then unifies these figures into one figure by applying weights to each figure in proportion to the volume of each commodity expected to be shipped over the next 20 years.

Comment
Hess notes that the draft RIA calculates the benefits of the rulemaking based on assumptions regarding the volatility of Bakken crude oil. Hess disagrees with any assertion or implication that the characteristics of crude oil produced in the Bakken are substantially different than the characteristics of other light, sweet crude oil produced in the United States. Similarly Great Northern Midstream states that studies indicate that the Bakken crude oil is less volatile and less corrosive than most oils produced in the U.S. and globally, but that the NPRM has continued to include this perception in the rules it is proposing.

PHMSA response
PHMSA discusses the relative characteristics of crude oil and ethanol in derailment scenarios later on in this document. The Literature Survey of Crude Oil Properties Relevant to Hanling and Fire Safety in Transport, prepared by Sandia National Laboratories examines the properties of tight crude oils as they relate to potential combustion events in the rail transport environment.[48]

Comment
Great Northern Midstream states that avoided harm and benefits in the NPRM are overstated because of the overstated frequency of future train accidents (14.36 expected accidents in the first year of the analysis, declining to 5.16 in the last year) and the overstated costs per accident ($1.2 billion to $6 billion depending on accident size) used in PHMSA's analysis, among other purported flaws. When more realistic assumptions are used (e.g., since 2006, the average is 2.2 train accidents per year at $5 million per accident), and the appropriate data are properly analyzed, some commenters hold that the costs of complying with the rules and the costs to the rail industry and the economy as a whole from the rulemaking exceed the avoided harm or benefit of the NPRM by a large measure.

PHMSA response
PHMSA discusses its methodology for developing its baseline level of damages expected in the absence of the rulemaking. PHMSA assumed that the downward slope of the derailment trend for all commodities reflects increasing safety for rail cargo transport of all commodities. The estimates PHMSA bases the costs associated with a derailment of crude or ethanol on the average amount of product released when a derailment occurs. As described later on, we do not believe that the reported total damages associated with derailment events appropriately captures the total societal damages. The total damages of a spill will depend not only on the size of a spill, but also where it occurs, the type of material spilled, and the circumstances of the accident. There is likely to be more property damage if a spill occurs in a densely populated area or if it results in a fire. There is likely to be more environmental damage if the spill occurs in an

[48] The full report may be accessed through the following url: http://energy.gov/fe/articles/sandia-national-laboratories-releases-literature-survey-crude-oil-properties-relevant

environmentally sensitive area. Costs of cleanup may be higher for heavier crude oil that does not burn.

Comment
AAR commented on how PHMSA calculated the marginal benefits of the enhanced rail tank cars it would be mandating. PHMSA uses the current fleet as its baseline, but AAR contends that PHMSA uses a baseline that assumes most rail tank cars are "legacy" DOT-111s. Similarly, GWU states that PHMSA did not include in its baseline an expectation that, due to market forces, Option 3 tank cars will become widely used for the transport of flammable liquids in the future. Therefore, measuring increases in efficacy against DOT-111 tank cars, rather than Option 3 tank cars, will overstate the efficacy of PHMSA's rule.

PHMSA response
As discussed in the baseline fleet projection, later in this document PHMSA's analysis reflects that roughly 34 percent of rail tank cars would be jacketed CPC-1232 tank cars in the absence of regulation and adjusts baseline damages accordingly. This addresses the issue AAR raises with regard to the fleet composition in the future having a greater portion of jacketed CPC 1232s. The Agency did not assume that all rail tank cars would be "legacy" cars when considering expected future damages from crude and ethanol incidents. Future damages were adjusted downward in proportion to the jacketed CPC 1232's expected safety improvement and the portion of the fleet expected to be made up of jacketed CPC 1232s. A similar adjustment to the baseline damages was done at the NPRM stage, contrary to AAR's assertion that no adjustment of expected damages were made due to voluntary actions on the part of the industry.

Comment
In a combined submission from the Center for Biological Diversity, Friends of the Gorge, and the Adirondack club, commenters state that PHMSA understates the extent of the problem by estimating a range of future avoided accidents based on data from 2006 to 2013. These commenters suggest that PHMSA should extrapolate upward from the point at which crude oil accidents spiked in 2013, and thereby assume an increase in the number of these accidents.

PHMSA response
PHMSA focuses on derailments of crude oil and ethanol trains from the most recent five years of data. We continue to believe this is an appropriate time period from which to project the frequency of future derailments. The relatively infrequent nature of derailments of trains containing flammable liquids limits the sample size, and the number of derailments is subject to significant variation from one year to the next, so projecting future derailments from a single year, such as 2013, may not adequately represent future expected events. This time frame is fairly short but the advent of high quantities of crude oil shipped by rail was 2011 or 2012, so few years of data exists in which crude oil has been shipped in anything resembling the quantities forecast going forward. PHMSA selected this timeframe because it balances incorporating the years that best represent of crude and ethanol volumes going forward with a sufficient number of years to capture variations in the data reasonably well.

Higher-Consequence Damages

In order to consider the full impacts of this rule, it is necessary to examine the potential for HHFT accidents greater in number or severity than those observed to date in the U.S. While there have been no higher-consequence events in the U.S., we believe that such an event is possible. We considered whether, in addition to the accidents observed in the baseline, one or more higher-consequence events could occur in the absence of the regulation. These events exceed the "typical" derailment event because they would result either in multiple fatalities or injuries, or would cause greater environmental damages than a typical derailment. The upper bound for the damages resulting from any one particular event was described as five times as great as the damages resulting from the event that occurred at Lac-Mégantic, Quebec, adjusted for the track weighted population density along U.S. crude oil and ethanol routes. In the initial RIA we presented figures for zero events and ten events and the associated undiscounted damages. As explained above, we assume that one of those ten events takes place in an area that is five times denser than average.

Comment
Mercatus questions the reliance on a high-consequence event (Lac-Mégantic) for calculating benefits. RSI states that PHMSA's analysis "overstates the likelihood of extra-ordinary events like Lac-Mégantic." AAR comments that the basis for PHMSA's pool of benefits from catastrophic events—9 events with costs exceeding $1.15 billion and one exceeding $5.75 billion—is purely speculative. They state further that there has been only one catastrophic event. AAR calculates that PHMSA's catastrophic event assumptions are equivalent to 0.56 catastrophic events per million carloads, and if this were the case, multiple catastrophic events would have already occurred.

Growth Energy states that the Lac-Mégantic incident is an isolated incident that the new tank car specifications will not address; and that PHMSA overestimates the likelihood of a high-consequence derailment event in the U.S., the likely harm of such an incident, the environmental remediation cost associated with a lower-consequence incident. They also state that PHMSA fails to account for the fact that many derailments do not involve a spill.

PHMSA response
As discussed in more detail in the high consequence event damage section, PHMSA projected higher consequence events over the next twenty years in the absence of the rule. This figure rule based on carloads shipped and an estimate of expected carloads over the next 20 years. PHMSA revised its estimation for the number of events over the next 20 years that could potentially lead to catastrophic damages from the NPRM. In the model, the number of events and the severity was permitted to vary, thus accounting for the inherent uncertainties in projecting damages from unlikely events. Many of the provisions in this rule including improved tank car integrity, proper classification and characterization of materials, speed restrictions, routing analyses and braking are intended to decrease the potential of rail accidents and mitigate the consequence of an accident should one occur. PHMSA based its estimates of the damages associated lower consequence events, i.e. deaths, injuries and environmental and property damages, emergency response costs resulting from lower-consequence events, based on an examination of the historic accidents that include accidents with little to no product release.

Comment
API commented that PHMSA provided insufficient explanation or justification about the number of events it has chosen to model. API also states that PHMSA calculated a range from zero to ten, with ten as the upper bound, but only provided data for the upper bound case. API also criticizes key characteristics of the Lac-Mégantic incident as making it unsuitable to extrapolate from. It cites the fact that PHMSA uses the speed of 65 mph in the Lac-Mégantic accident to calculate the estimated damages for nine of the higher-consequence events, despite its own recognition that the speed of the train and the number of cars derailed are not likely to be seen in the U.S, given the agreed upon speed limit of 50 mph for crude and ethanol unit trains. Further, API adds that the U.S. has never experienced a derailment of more than 31 cars. API comments that another flaw with the agency's logic is that they provide only a point estimate of the potential damages of nine Lac-Mégantic size incidents under the higher-consequence event discussion.

Bridger also states that the incident that occurred at Lac-Mégantic, Quebec was atypical, and that regulatory intervention that is underway at this time by FRA would cause such an incident to not be replicable in the U.S. Further, Bridger contests the premise that the previous losses at Lac-Mégantic, Quebec, are usable for projecting future losses in the U.S. in light of intervening and pending regulatory actions.

The Renewable Fuels Association (RFA) also commented on extrapolating from the Lac-Mégantic Incident to calculate benefits, and states that the inclusion of data from that event still fails to adequately demonstrate that the rule will have positive net benefits. RFA also states that none of the rail car upgrades proposed would have prevented this incident, and that it is "disingenuous to use this human error caused [by a] preventable event to make a point about the ethanol tank car upgrade benefits."

PHMSA response
PHMSA does not mean to suggest that the provisions of this final rule are intended to address the events that led to the accident at Lac Mégantic, Quebec. PHMSA used the Lac-Mégantic event, which did occur in Canada, only to provide a cost estimate for a low-probability/high-consequence event that *could* occur in the U.S. given the increase in total carloads of crude and ethanol shipped in HHFTs. PHMSA looked to the estimated damages of the accident at Lac-Mégantic, Quebec to illustrate the potential benefits of preventing or mitigating higher-consequence events. We acknowledge that there is uncertainty about the potential magnitude, since there has only been one such event in North American rail history. PHMSA considered the comments and scaled down the damages from Lac Mégantic to account for a smaller expected number of cars derailed and lower speeds. This model, its methodology and assumptions are detailed in the section called Higher Consequence Event Damages. Additionally, in its final rule PHMSA acknowledged the August 9, 2014 NPRM that proposed amendments to strengthen the requirements relating to the securement of unattended equipment.

Prioritize Regulatory Action to Address Crude Oil and Ethanol Separately

In addition to cleanup costs, RFA requested that PHMSA differentiate between ethanol and crude oil because the commodities do not share the same chemical composition. Further, RFA commented that PHMSA should not prioritize crude oil and ethanol together. The final rule has

adopted a retrofit timeline that takes a tank car/Packing Group approach to addressing the risks associated with flammable liquids in HHFTs. The approach provides a longer retrofit timeline for a flammable liquid in Packing Group II, than a flammable liquid in Packing Group I. FRA performed analysis of the documented damage to tank cars exposed to pool fire conditions following a derailment of trains that consisted partially or entirely of tank cars containing fuel ethanol and crude oil. The purpose of the analysis was to understand the relative hazards of fuel ethanol and crude oil and their potential to cause catastrophic failure of tank cars in pool fire conditions. Much has been made of the effect of volatility of crude oil on hazards, especially crude oil from the Bakken shale play in the Williston Basin. An important safety policy question currently under debate is whether the increased volatility renders crude oil involved in a derailment more explosive than other flammable liquids necessitating special classification and packaging. The North Dakota Industrial Commission Oil Conditioning Order No. 25417 (the Order) requires Bakken crude oil operators in the state of North Dakota to separate the gaseous and light hydrocarbons from all Bakken crude oil. The Order also prohibits blending of Bakken crude oil with specific materials.

FRA developed and implemented procedures to carefully document damage to each tank car involved in derailments. The fruit of this effort is a catalog of damage to tank cars, specifically DOT-111 tank cars transporting flammable liquids, which can be utilized to understand the behavior/performance of protective design features. Further, vulnerabilities of the specification can be identified and design enhancements evaluated. Data, in the form of photographs, assessment forms and narrative descriptions of damage to all tank cars (containing fuel ethanol and crude oil) involved in derailments and exposed to pool fire conditions was organized and evaluated. First, the damage was evaluated relative to tank car vintages and features to determine if damage could be attributed to these features. Then damage was evaluated relative to the commodity to provide a qualitative relative hazard of the commodities under consideration.

The overall conclusion from this analysis is that: 1) there was no discernable correlation between design features of the tank cars and the damage to the tank cars exposed to pool fires; and 2) fuel ethanol poses a similar, if not greater, risk as crude oil when released from a tank car that fails catastrophically, resulting in a large fireball type of fire with or without an explosion. Further, the properties of the flammable liquids and handling of the cars in large blocks or unit trains presents a unique hazard in that, if released and ignited, the fire will affect adjacent cars. Moreover, adjacent cars will likely, if not certainly in the case of a unit train, contain the same flammable liquid and result in releases of more flammable liquid through the pressure relief valve or a catastrophic failure of the tank. A catastrophic failure involved either a tear in the tank or a violent rupture that nearly or completely separated portions of the tank. Accompanying these failures have been the resulting fireball-type fire (deflagration) and, in some cases, blast wave (explosion) effects. See Figure 6.

Figure 6: Photographs of explosions at recent derailments; Arcadia, OH (fuel ethanol); Casselton, ND (crude oil), and Plevna, MT (fuel ethanol)

The data does not indicate any causal relationship between the attributes of the tank car, pressure relief valve (PRV), location in train, or other attributes and the occurrence of the thermal damage. In other words, the data does not suggest that something other than the commodity could explain the observed thermal damage. Fuel ethanol provided the basis for a relative risk analysis of crude oil. Like fuel ethanol, crude oil is transported in large block trains or unit trains and is classified as a flammable liquid. Fuel ethanol is a Packing Group II material. Crude oil can be a Packing Group I, II or III. Crude oil from the Bakken shale play is typically a Packing Group I material. The available evidence does not suggest that the relatively higher volatility of crude oil (Bakken) has any meaningful impact on the thermal damage that occurs to tank cars during derailments. The documented performance of the tank cars containing these materials involved in derailments and exposed to pool fire conditions provides an objective means to compare the effects of certain properties of these commodities on the survivability of tank cars exposed to pool fire conditions.

The separations[49] (higher energy events) occurred in tank cars containing fuel ethanol.

1) The same number of thermal tears[50] occurred in tank cars containing fuel ethanol as cars containing crude oil.
2) The number of cars involved in derailments in which thermal tears and separations were encountered was nearly equal for fuel ethanol (107) and crude oil (109).

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[49] A separation occurs when a thermal tear propagates circumferentially from each end of the tear and result in the tank completely or nearly fragmenting into multiple pieces.

[50] A thermal tear is typically a longitudinal failure that occurs in the portion of the shell surrounding the vapor space of the tank following exposure of the tank to pool fire conditions. The tank shell fails when the pressure in the tank (and resulting tensile or hoop stress) exceeds the tensile strength of the shell materials that is diminishing with time of exposure to the pool fire. The length of thermal tears measuring during FRA investigation ranges from 2-16 feet. The length of the tear may be a function of the volume of vapor escaping through the failure, flaws in the shell material, and the existence of crack arresters such as welds or stronger, non-heat effected steel.

3) A variety of factors that could have influenced the likelihood of thermal damage were analyzed, including the steel specification, start to discharge pressure, age of car, lading, flow capacity of PRV, location of cars in derailment, and location in the train of the first car to derail.

There is little evidence supporting the position that crude oil (especially that extracted from the Bakken region) poses a heightened risk of a high energy or explosive event when tank cars containing the material are exposed to pool fire conditions. In fact, the failure rate (due to thermal damage) of tank cars containing fuel ethanol is 1.5 times greater than that of a tank cars transporting crude oil.

Literature Review of Impacts of Spills of Crude Oil and Ethanol

The amount of crude oil transported by rail has increased significantly over the past 5 years in the United States, both for originated and terminated carloads. Unlike pipelines, rail transport can offer geographic flexibility and responsiveness to meet the needs of new suppliers and customers looking for quicker ways to transport large shipments (Association of American Railroads). A list of literature reviewed on the cost of spills is in Appendix B.

Research shows that large oil spills can have an impact on trade, tourism, the environment and/or wildlife in the surrounding region immediately after a spill and in the long-run. However, in the event of an oil spill, the responsible party is not initially the sole bearer of costs that arise from the spill. Rather, government agencies, businesses, and individuals incur an array of external costs as a result of the direct and indirect impacts of the oil spill. In "A Taxonomy of Oil Spill Costs: What are the Likely Costs of the *Deepwater Horizon* Spill" Mark Cohen notes that oil spills costs can include: containment and cleanup costs borne by the Federal and local government, costs of repairing public infrastructure, natural resource damages, lost income from affected businesses, lost consumer value from shifting purchases and behavior, and ligation costs. Krupnick, Campbell, Cohen, and Parry note that lost profits is the appropriate measure to assess costs to local industries that directly suffer as a result of a spill. However, the extent to which businesses are compensated for the losses depends on how well they are able to legally document their claims.[51]

Cleanup costs can be broken down into two categories: (1) labor costs and (2) equipment costs for supplies and tools needed to clean up the oil spill. Marruffo, Yoon, Schaeffer, Barkan, Saat, and Werth (627–632) estimated the number of hours required to clean up a railcar oil spill for four different substances: E95, gasoline, crude oil, and diesel fuel. This model suggests that E95 takes the least amount of time to clean up and the longest cleanup time was for diesel fuel. They

[51] Krupnick, Alan, Sarah Campbell, Mark Cohen, and Ian Parry. *Understanding the Costs and Benefits of Deepwater Oil Drilling Regulation.* Washington, DC: Resources for the Future, 2011

also differentiated by the type of soil where the oil is spilled, finding significantly different cleanup times for coarse sand, fine sand, and silt. Ethanol spills tend to have lower cleanup costs compared to other types of oil due to its higher solubility, as noted by Child et al. in the report for the Massachusetts Department of Environmental Protection, which details the impacts and response strategies for ethanol spills.

Random utility models are a common analysis technique used to estimate recreational losses people face as a result of oil spills. In the oil spill cost literature, studies typically used either contingent valuation or hedonic valuation techniques. Specifically, most of the studies employed the same willingness-to-pay or travel cost theoretical concepts and primary data collection surveys of a sample of the affected population. Studies using hedonic price estimation commonly assessed property values to estimate how an oil spill could change people's preferences for the same house and land. Under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), travel cost and contingent valuation methods are officially confirmed as acceptable methods for estimating the costs of damages due to the release of hazardous materials in publicly owned habitats in water and on land.

Several other studies valued the costs of oil spills by estimating the cost per gallon of oil spilled. This technique allows for some comparison across different oil spill events to gauge the severity of different incidents. However, it is important to keep in mind that each oil spill incident is unique, and therefore the degree of costs incurred are subject to the severity of each spill and the spill characteristics (e.g., location and oil type). The estimated per gallon costs from numerous studies are presented in the table below. All estimates are in 2013 dollars, as they were adjusted for inflation using the GDP deflator index.

Table C1: Dollar Per Gallon Estimates by Study

Study	Per Gallon Estimate	Oil Type
Marruffo (2012)[1]	$378.34	Crude
Cohen (2010)[2]	$892.29	Crude
Cohen (1986)[3]	$6.59	Crude / Fuel Oil
Helton and Penn (1999)[4]	$262.26	Crude / Fuel Oil
U.S. Coast Guard (2011)	$271.00	Crude / Fuel Oil
U.S. Coast Guard (2003)	$385.00	Crude / Fuel Oil
U.S. Coast Guard (2013)	$453.33	Crude / Fuel Oil
Etkin (2003)	$633.71	Crude / Fuel Oil
NTSB Tiskilwa, IL (2013)	$6.38	Ethanol
Marruffo (2012)1	$8.22	Ethanol
NTSB New Brighton, PA (2008)	$9.88	Ethanol
NTSB Columbus, OH (2014)	$13.48	Ethanol
NTSB Cherry Valley, IL (2012)	$19.53	Ethanol
NTSB Casselton, ND (2013) – preliminary	$15.25	Crude
Saat et al. (2014)	$144.00	Ethanol

1 Value represents only the labor cleanup cost; other cost factors are not included.
2 Value is an average from the study's estimated range of $543.27 to $1,241.30.
3 Weighted by percent of spill that directly impacted fishing industry, water supply, birds, and recreational activities.
4 Value is an average per gallon estimate from 29 specific spill incidents.

B. Comments Related to the Costs

PHMSA received many comments regarding the capability of the industry to comply with the proposed retrofit schedule, the key assumptions pertaining to the costs of retrofits, and the possible repurposing of existing tank cars to other flammable liquid service. Many questioned PHMSA and FRA's assumptions on the retrofit capacity of the industry. Overall, commenters agree that retrofits must occur, but the suggested timelines range from zero to ten years. In addition, RSI and API commissioned separate reports that evaluated the NPRM's proposed timeline and demonstrated the potential detriment of an overly aggressive timeline.[52] PHMSA has summarized and discussed below the differing viewpoints on the retrofit schedule.

RSI, API, Exxon, APFM and many others in the regulated industry provided specific alternative retrofit timelines which can be viewed in the docket for this rulemaking. RSI-CTC states that PHMSA and FRA should retrofit crude oil and ethanol tank cars first and then other Class 3 tank cars. They estimated that retrofit capacity is only 6,400 units per year, whereas PHMSA assumes 22,061 units per year in its NPRM. RSI continues, "there are 50K non-jacketed tank cars in service (23K crude and 27K ethanol/legacy and CPC-1232) that cannot be retrofitted by 10/01/2017—only 15K can be retrofitted by that time." With an even more conservative estimate, Alltranstek, on behalf of API, estimated a range of 2,430 to 3,000 tank cars that could be retrofit per year in its "base case." In addition, RSI, Archers Daniel Midland, Arkema, and others stated that PHMSA did not consider the highway congestion, emissions, and safety impacts of a shift to highway transportation, should PHMSA's compliance schedule constrain the availability of rail tank cars for transporting hazardous materials. Arkema also expressed concerns that the cost of additional regulations themselves could make rail a less competitive option for shipping hazardous materials, which could lead to more reliance on trucks.

The NYU School of Law Center for Policy Integrity suggested that PHMSA should consider the costs of countervailing risks. This commenter mentions that reduced speed limits increase the amount of time HHFTs spend in proximity to HTUAs and environmentally sensitive areas; and that increased rail tank car weights will add stresses to railway infrastructure, particularly bridges owned by non-Class I terminal railroads.

Phillips 66 cites that the compliance schedule could result in rushed deliveries of retrofit cars. This could result in lower safety outcomes than those calculated by PHMSA.

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[52] The Railway Supply Institute, committee on tank cars commissioned the Brattle group to review PHMSA's initial RIA. Additionally, the American Petroleum Institute commissioned ICF to conduct a review of the economic impacts of PHMSA's NPRM.

The Illinois Commerce Commission, RSI, API, Cenovo, Arkema, and others question the assumption that no retirements would occur as a result of this rule, or that retirements would be avoided due by transferring non-compliant rail tank cars to Canada tar sands service.

PHMSA received a range of comments asking that it consider an immediate ban or other expedited discontinuance of all DOT-111 tank cars for crude and ethanol transport. Specifically, the Center for Biological Diversity, Friends of the Gorge, and the Adirondack club urged that PHMSA immediately ban the use of DOT-111 tank cars used for the rail transport of flammable liquids. PHMSA notes that an immediate ban of DOT-111 tank cars, as The Center for Biological Diversity, et al. recommended, would result in thousands of truck shipments of crude oil and ethanol. PHMSA considered the impacts of immediately banning the use of the DOT-111 tank car in HHFTs. However, an immediate ban of the DOT-111 tank car is not a reasonable alternative because affected industries could not replace rail cars immediately and would not be able to immediately switch to other transportation modes. This would cause supply chain disruptions, increased shipping costs, and increased reliance on trucks to make up for lost transport capacity. This increased reliance on trucks could have detrimental environmental and safety implications. As such, PHMSA concluded that an immediate ban or other expedited discontinuance of all DOT-111 tank cars for crude and ethanol transport is not a reasonable alternative. Therefore, PHMSA more fully examined the impacts of a schedule that would phase out the use of all DOT-111 tank cars in PG I and PG II service by 2018.

PHMSA weighed the benefit of reductions in releases from rail accidents that would result from the 2018 removal of DOT-111 tank cars against increased air pollution and highway accidents, often resulting in releases, that would result from a temporary modal shift, along with extremely high cost to industry and the public, and the other regulatory provisions in this rulemaking that are also aimed at reducing derailments and releases. The retrofit timeline selected in the final rule provides a longer timeline proposed at the NPRM stage. In developing the retrofit schedule, PHMSA and FRA examined the available shop capacity, the comments received, and the potential impacts associated with the retrofit schedule. PHMSA examined the impacts of the potential shift from rail to highway as a result of an overly aggressive retrofit schedule. A faster retrofit schedule could result in fewer tank cars available to ship crude oil and ethanol than production requires. If the deficiency in cars is substantial, shippers will employ other modes of transportation. The customers for crude oil and ethanol rail shipments are spread throughout the U.S. and Canada, and thus the diversion to other modes of transportation is likely to involve substantial numbers of additional trucks carrying flammable liquids. This would result in a decrease in safety, as trains have a much lower accident frequency than trucks when adjusted for the volume shipped. Upon consideration of all these factors, PHMSA recognizes the need to upgrade the rail car fleet, but found that a targeted phase-out of the DOT-111 tank cars was the most prudent and protective approach. As a result, the selected retrofit timeline option indicates that there would be no additional reliance on highway transportation.

PHMSA has accepted feedback regarding its assumption of no retirements and the impracticality of transferring jacketed tank cars to oil sands service. This RIA now considers the number of cars that could be retired early as a result of the rule and the associated costs of doing so. PHMSA believes that rail cars will be retired early when their owners have weighed the cost of meeting retrofit requirements against the marginal cost of acquiring a replacement rail car early.

More specifically, when the discounted replacement cost of a new car is less than the cost to retrofit an existing car, then owners will opt to retire a non-compliant car early.

Further, to aid in the analysis of an appropriate retrofit timeline, FRA developed a model to project the tank car retrofit capacity over time. The model is based on Wright's learning curve theory, which posits that every time the number of units produced doubles the cost of production will decrease by a given percentage[53]. This percentage is known as the learning rate. The first step in developing the model was to reproduce the rail industry's forecast in the Brattle Group Report to accurately identify the capacity for "heavy retrofits" (heavy retrofits include those that go beyond simply adding a valve and bottom outlet to the jacketed CPC-1232 cars). As indicated in the Brattle Report, FRA allowed for a retrofit capacity ramp-up to 6,400 heavy retrofits per year. FRA's model indicates that 40 tank car repair facilities are presently able to dedicate one crew to these retrofits.

Once the industry forecast line was produced (Figure 7), FRA applied variables for the learning rate, number of crews, and number of facilities. The intent was to depict the extent to which the heavy retrofit capacity will increase to a degree over time. The values for these variables in the model are a learning rate of 0.95 (which is relatively low for similar industries[54]), one crew (initially) per facility, and 40 facilities. Using these values as the starting point a parametric analysis was performed to show the values required to meet the retrofit timeline.

As a result, the remaining capacity (around 60 facilities identified by FRA) would focus on the normal workload, including requalifications, bad order repairs, and reassignments. Further, FRA identified 160 tank car facilities capable of performing light modifications, which include adding a valve and bottom outlet to the jacketed CPC-1232 cars. FRA also accounts for industry concerns regarding the readiness of current tank car facilities to perform retrofit services by maintaining the ramp-up period provided by commenters. Other key model assumptions are provided below:

1) A new crew (2 employees) will be added at each facility every 3 months, beginning in month 4 and continuing to month 24.

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[53] Wright, T.P., "Factors Affecting the Cost of Airplanes", Journal of Aeronautical Sciences, 3(4) (1936): 122–128.

[54] It is recognized that repetition of the same operation results in less time or effort expended on that operation. For the Wright learning curve theory, the underlying hypothesis is that the direct labor man-hours necessary to complete a unit of production will decrease by a constant percentage each time the production quantity is doubled. If the rate of improvement is 20% between doubled quantities, then the factor known as the learning percent, would be 80% (100-20=80). While the learning curve emphasizes time, it can be easily extended to cost as well. The learning percent is usually determined by statistical analysis of actual cost data for similar products. http://www.csgnetwork.com/learncurvecalc.html

2) It is expected that productivity will improve throughout the retrofit period with similarly trained employees using the same tools and equipment.
3) Based on Wright's learning curve theory, every time production doubles, the required resources and time will decrease by a given percentage, known as the learning rate. The learning rate coefficient for repetitive welding operations is 0.95.
4) After 24 months, no additional resources are added; the only change is improvement based on the learning curve.

In support of these assumptions, the following diagram indicates the cumulative retrofit capacity for industry's model (based on The Brattle Group report), as well as FRA's model. Based on these assumptions, the FRA model indicates that a heavy retrofit capacity exceeding the industry's projection is achievable.

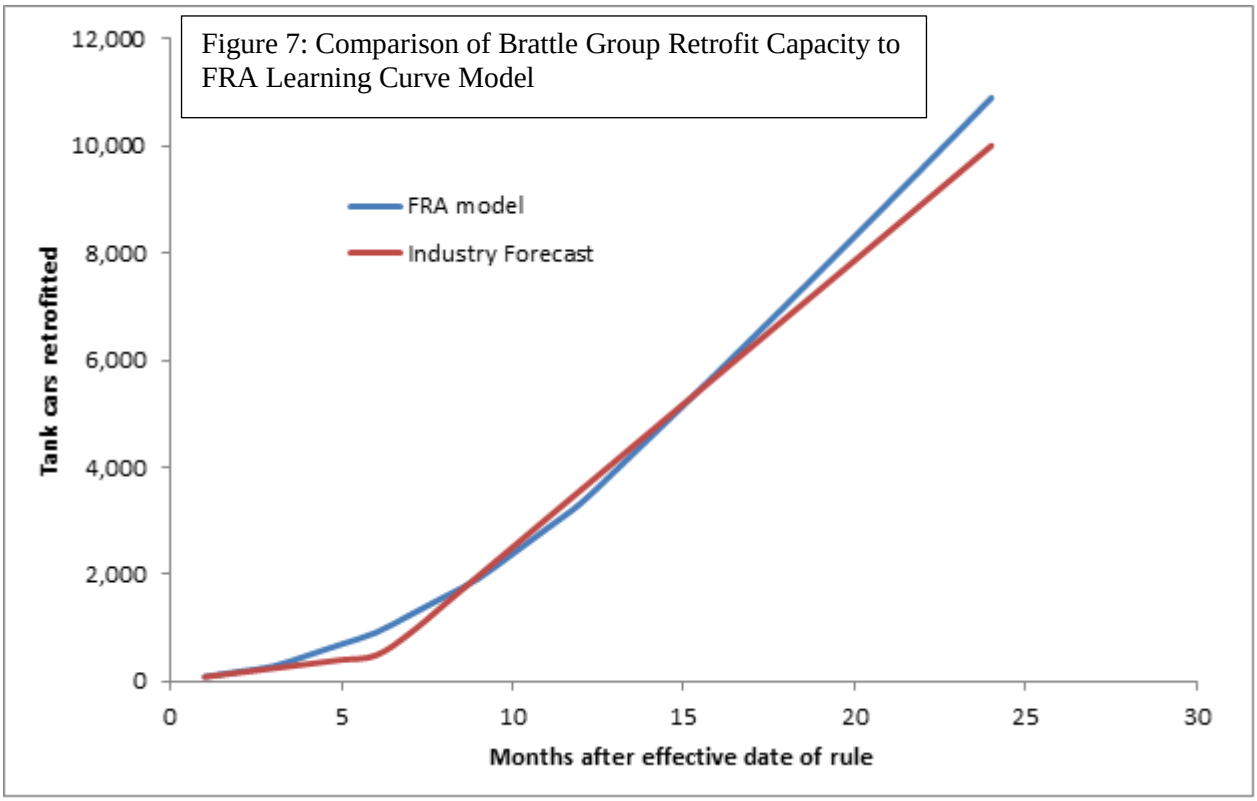


Figure 7: Comparison of Brattle Group Retrofit Capacity to FRA Learning Curve Model

Incorporation of the FRA learning curve into the PHMSA's fleet forecast results in a 22-month total heavy retrofit timeline. The retrofit timeline is provided in Table C2.

Table C2: Timeline for Continued Use of DOT-111 Tank Cars for Use in North America HHFTs			
Tank Car Type / Service	**Fleet Size**	**Canada Schedule**	**DOT Revised Schedule**
Non Jacketed DOT-111 tank cars in PG I service	11,637	May 1, 2017	**(January 1, 2017)**[55] **January 1, 2018**
Jacketed DOT-111 tank cars in PG I	2,268	December 1, 2020	**March 1, 2018**
Non Jacketed CPC-1232 tank cars in PG I service	15,144	July 1, 2023	**April 1, 2020**
Non Jacketed DOT-111 tank cars in PG II service	18,493	December 1, 2020	**May 1, 2023**
Jacketed DOT-111 tank cars in PG II service	88	December 1, 2020	**May 1, 2023**
Non Jacketed CPC-1232 tank cars in PG II service	751	July 1, 2023	**July 1, 2023**
Jacketed CPC-1232 tank cars in PG I and PG II service* and all remaining tank cars carrying PG III materials in an HHFT (pressure relief valve and valve handles).	24,993	May 1, 2025	**May 1, 2025**

Based on the FRA Model, the North American retrofit capacity will continue to grow to over 64,000 total heavy retrofits by June of 2023. Table C3 provides the number of heavy retrofits per year.

Table C3: Heavy Retrofits Per Year	
Year	**Retrofits**
2015	1,918
2016	7,037
2017	7,939
2018	8,236
2019	8,444
2020	8,606
2021	8,739
2022	8,852
2023	4,180

[55] The December 2016 date would trigger a reporting requirement, and shippers would have to report to DOT the number of tank cars that they own or lease that have been retrofitted, and the number that have not yet been retrofitted. December 2017 would still be the hard deadline for all shippers to use retrofitted legacy 111s in PG I service.

PHMSA and FRA reviewed comments, alternative timelines, and data regarding an appropriate retrofit timeline and revised our implementation schedule accordingly. As a result of this analysis, we have adjusted our proposal to more closely align with industry estimates for the retrofit capacity. With these changes, PHMSA is confident that retrofits can be accomplished within the parameters of the timeline adopted in the final rule.

C. Summary of Derailment Modeling

In the sections that follow, this document provides a discussion of the comments received in response to the derailment modeling performed during the NPRM stage of this proceeding. The section following the comment discussion provides a detailed description of the derailment modeling performed during the final rule stage of this proceeding. This section briefly introduces the derailment modeling conducted during the NPRM and final rule stages. The intent is to provide the reader with context and a basic understanding of the initial and final derailment modeling.

1. Summary of Derailment Modeling Performed for the NPRM

In support of the NPRM, two detailed technical supplements were developed and placed in the rulemaking docket:

1) Effectiveness Rates for Tank Car Options, and
2) Effectiveness Rates for Emergency Brake Signal Propagation Systems.

The technical supplements are summarized below.

Effectiveness Rates for Tank Car Options

This document was developed during the NPRM stage to describe the methodology used to calculate the effectiveness rates of alternative standards for tank cars to be used in HHFTs. In the NPRM, PHMSA considered three tank car Options, which incorporated design enhancements to protect the shell and heads of tank car tanks from puncture, protect the top and bottom fittings from damage, and to protect the tank from thermal tears or ruptures when exposed to pool fire conditions. The methodology described in this technical supplement relies on accident data to calculate the effectiveness rates for the entire design as well as individual design enhancement features. The calculated aggregate effectiveness rates and marginal design feature effectiveness rates, for the three proposed tank car Options are provided in the following Table C5.

Table C5: NPRM Tank Car Effectiveness Rates[56]						
Tank Car	**Total**	**Head Puncture**	**Shell Puncture**	**Thermal Damage**	**Top Fittings**	**BOV**
Option 1	54	21	17	12	4	<1
Option 2	51.3	21	17	12	1.3	<1
Option 3	41.3	19	9	12	1.3	<1

Effectiveness Rates for Emergency Brake Signal Propagation Systems

This document was developed to describe the methodology used to determine the effectiveness rates for advanced braking systems proposed for use on tank cars to be used HHFTs. In the NPRM, PHMSA considered four brake signal propagation systems: electronically controlled pneumatic (ECP) brakes, Distributed Power (DP), two way end of train devices (TWEOT), and conventional brake systems. The methodology described in this technical supplement relies on recent research that quantifies effectiveness based on number of cars punctured in a derailment. The inputs to this model included initial speed, tank car specification, and brake signal propagation systems. Holding the first two variables constant enabled the calculation of the effectiveness rate on the third variable, namely, the brake system. Modeling was performed for only one of the brake signal propagation systems so a methodology for estimating the effectiveness of the other brakes systems was developed based on the (train) energy dissipation during emergency brake application conditions. Relative to the conventional brake systems ECP was calculated to have a 36 percent effectiveness rate and EOT, DP and DP (2/3) an 18 percent effectiveness rate.

2. Summary of Derailment Modeling Performed for the Final Rule

In support of the HHFT final rule and this RIA, FRA and PHMSA contracted with Sharma & Associates, Inc. (Sharma) to develop an objective, engineering-based methodology to quantify and characterize the safety benefits and risk reduction or reductions in puncture probabilities, in hazmat rail transportation resulting from the implementation of mitigating strategies, such as improvements in tank car design or revisions to train operating practices (more detailed discussion of benefits is provided in Section VII). The simulations were performed using the Train Energy & Dynamics Simulator (TEDS) program, developed by Sharma to study the dynamics and energy levels under a variety of operating conditions. Sharma relied on TEDS to simulate derailments based on sixteen derailments listed in Appendix B.

[56] These effectiveness rates are measured relative to unjacketed DOT-111 railcars. Modelling and changes to the tank car options since the NPRM has made these obsolete.

The tank car community has focused on improving the derailment/puncture performance of tank cars over the past several years, especially given the recent accident history associated with hazardous material transport. Since the shipment by rail of hazardous material has increased, particularly crude oil, the focus on safety improvements, either through changes in tank car design or train operations, has also increased. In addition to this immediate and current focus on safety improvements, the tank car community has a need for an objective methodology to quantify and characterize the safety/risk benefits of future engineering changes and to use the resultant information to predict the performance of future designs.

As the tank car community reviews potential mitigating strategies/solutions for implementation, it becomes critical to have an objective measure of the expected improvements (i.e., reductions in risk or probability of puncture) that these solutions afford. While the industry has made progress on analytical techniques for quantifying puncture resistance for specific designs and specific impactor sizes, objective mechanisms to translate these analyses into overall safety improvements do not currently exist.

Tank cars are exposed to a wide range of hazards during operations or a derailment. These hazards come in the form of different impactor sizes, shapes, speeds, etc., making it difficult to quantify objectively, the overall safety improvement from any given change. For example, tank shell thickness increases may offer improvements against certain impactors, but not against others. In order to objectively compare the overall effectiveness of a proposed mitigating strategy/solution, whether it is a thickness increase or an operational change, regulatory and standards organizations must be able to understand and quantify the expected safety benefits resulting from the design changes or operational changes under consideration. Regulatory and standards organizations need a measure of how the solution is expected to perform in real life, against a variety of potential hazards. These organizations need to be able to answer questions such as:

1) What is the overall reduction in risk (or reduction in the probability of puncture) afforded by increasing the minimum required shell thickness to X inches?
2) What is the overall reduction in risk (or reduction in the probability of puncture) afforded by making a given operational change/restriction?

The industry's approach to answering this question has been to rely on past statistical data. RA-05-02, a report published by industry, has been used by AAR and other industry partners as a means to answer the above questions as it relates to thickness changes. This approach has several shortcomings, such as:

1) **Limited applicability** – This approach cannot be applied to innovative designs or alternate operating conditions;
2) **Inconsistency** – Risk numbers seem to change with the version of the data/model being used; and
3) **Limited dataset** – Using a limited dataset may not provide an accurate representation of all potential hazards, particularly low probability-high consequence hazards, and car designs/features present only in limited quantities in the general population of tank cars.

Therefore, there is a distinct need to develop an objective, analytical approach to evaluate the overall safety performance and the relative risk reduction resulting from changes to tank car design or railroad operating practices.

By working with Sharma, FRA and PHMSA have developed a model that ties together the load environment under impact conditions, with analytical/test based measures of tank car puncture resistance capacity and adjustments for suitable operating conditions, to calculate the resultant puncture probabilities and risk reduction. Specifically, we have provided an objective methodology for quantifying the safety performance (risk reduction) through the following approach:

1) Developing a consistent measure of the load environment associated with nominal tank car derailments through detailed analytical simulations.
2) Quantifying the puncture resistance of the given tank car designs for a nominal range of impactor sizes and impact forces, either through review of past published research (for conventional cars) or the development of new models (for innovative designs).
3) Adapting the load environment for changes in operating conditions and combining the load environment and the resistance curves with nominal impactor size distributions to evaluate the safety performance or probability of puncture for a set of designs and operating conditions.
4) Confirming the performance of the methodology through review of engineering expectations and comparisons to historical data.

D. Tank Car Performance Simulation Comments

Many commenters who provided data and analysis to refute PHMSA and FRA modeling data did so using Conditional Probability of Release (CPR) modeling. In addition, some commenters challenged PHMSA and FRA modeling as a point of weakness in our analysis. In July 2014, FRA released a study conducted by Sharma entitled "Objective Evaluation of Risk Reduction from Tank Car Design & Operations Improvements" that describes a novel and objective methodology for quantifying and characterizing the reductions in risk (or reductions in puncture probabilities) that resulted from changes to tank car designs or the tank car operating environment. This approach can be used as an alternative to CPR when describing tank car performance. The report is placed in the docket for this proceeding, see PHMSA-2012-0082-0209, and can be accessed online at www.regulations.gov.

The research effort described here addresses this need through a methodology that ties together the load environment under impact conditions with analytical/test-based measures of tank car puncture resistance capacity, which were further adapted for expected operating conditions, in order to calculate the resultant puncture probabilities and risk reduction. While not intended to predict the precise results of a given accident, this methodology provides a basis for comparing the relative benefits or risk reduction resulting from various mitigation strategies.

In addition, some commenters challenged PHMSA and FRA modeling as a weakness in our analysis. For example, Dr. Steven Kirkpatrick of Applied Research Associates, Inc. (ARA), in his September 29, 2014 comments to the NPRM, entitled *Review of Analyses Supporting the Pipeline and Hazardous Materials Safety Administration HM-251 Notice of Proposed*

Rulemaking, Technical Report, challenged the methodology used in the July 2014 Sharma & Associates study. These comments were combined with the AAR and its Transportation Technology Center, Inc. (TTCI) comments under docket reference number PHMSA-2012-0082-3378 of this proceeding. Sharma has worked to provide additional analysis and rationale to address the issues raised in the comments submitted by AAR and ARA. The issues raised and the responses are provided below.

1. ECP Kinetic Energy Effectiveness

Commenters indicate that Sharma's estimated reduction in kinetic energy, upon which PHMSA bases its premise of the effectiveness of ECP brakes, is based on a very limited set of simulations and looks only at derailments that occur at the head end of a train. Sharma has addressed this comment by replacing the data used for the ECP benefits simulation during the NPRM stage of this proceeding with results that more clearly address the specific provisions adopted in the final rule.

2. Length-of-Train Bias

Commenters indicate that another concern regarding the Sharma analysis is the bias resulting from limiting the analysis to trains with 80 cars. The result is likely a bias that overestimates the effect of ECP brakes. When conventional brake systems are used, the longer the train the longer the period for all the train brakes to be applied. Additionally, the deceleration effects of other cars blocking the motion of a car and the ground will be comparatively less for a longer string of cars since the residual mass behind the point of derailment will be larger.

During the NPRM, Sharma worked to identify the worst-case scenario in order to determine the scope available for improvement. In support of the final rule, additional simulations have been performed that include additional derailment simulations. Previously, 12 scenarios were used for each calculated most probable number of cars punctured. The scenarios have been expanded to 18, based on three track stiffness values, three friction coefficients, and two derailment-initiating force values. Additionally, derailment scenarios at different locations throughout the train were performed and the benefits calculations included for this variety of scenarios.

3. TTCI Train Operations and Energy Simulator (TOES) VS. TEDS

Commenters indicate that TTCI's methodology uses output from TOES to model the contribution of the braking system and other forces acting on the train in dissipating the energy in the train. According to comments, TTCI's analysis considered a number of factors that do not appear to be analyzed by PHMSA or Sharma, including:

- *Coefficient of Friction:* Commenters indicates that Sharma does not adequately take friction provided by the ground into account. Indicating that, Sharma uses coefficients of friction between 0.27 and 0.33. ARA contends that those coefficients are far too low and differ from previously published work, including research conducted by DOT's Volpe Center.

The friction factors used in Sharma's analysis are consistent with the friction levels that may be expected between soil and steel. For example, the friction factor between steel and "clean sand, silty sand-gravel mixture, single size hard rock fill" is reported as 0.30[57] with other factors varying between 0.2 and 0.4. Further, the suggestion of using a friction factor of 1.0 does not seem realistic. This value is close to the value of friction between rubber and concrete/asphalt, not soil and steel. As an example, modern high-performance sport cars are able to generate such high friction levels when equipped with specialized performance tires. One does not expect a tank car rolling down an embankment to have the same levels of friction or grip as a Corvette going around a racetrack. Additionally, a friction level of 1.0 would result in a car traveling at 50 mph to decelerate to a stop in 84 feet or about 1.5 car lengths. There is very little evidence of 50-mph derailments coming to a stop within 1.5 car lengths.

The range of friction factors used in Sharma's analysis is reasonable and representative of the relative performance of car designs.

- *Derailment Location in Train:* Commenters raise concerns that the Sharma analysis focused on derailments at the head end of an 80 or 100 car train. Commenters indicate that FRA data shows that the point of derailment is in the first 10 positions of the train in only 25 percent of derailments; in the remaining 75 percent of derailments the point of derailment is distributed evenly throughout the remainder of the train. The commenters indicate that the benefit will vary depending on the point of derailment in the train, which means that derailments that occur at various points in the train must be considered in order to assess the potential benefit of alternate braking systems. Modeling only derailments that occur near the front of the train overstates the effects of brakes on derailment severity, thereby overestimating the effect of ECP brakes.

  Simulations were performed in which the point of derailment (POD) along the train length has effectively, 100, 50, or 20 trailing tank cars. These simulations have been used by the DOT to effectively evaluate the relative performance of designs or operating conditions. It is also key to point out that the base case being considered (two-way EOT) is significantly more susceptible to overestimation of performance than ECP brakes. On a 100-car train, for example, the benefits of two-way EOT devices diminishes rapidly from the POD being at the head end to zero for the POD being at mid-point. For any derailment that happens in the rear half of the train, a two-way EOT train has no performance benefit over a conventional train.

- *Consideration of Non-pileup Derailments:* Commenters raise the concern that the effect of a braking system on derailments in which a pileup does not occur is more difficult to

[57] http://www.finesoftware.eu/help/geo5/en/table-of-ultimate-friction-factors-for-dissimilar-materials-01/

quantify, but should be recognized in an assessment of the potential reduction in accident severity because non-pileup derailments typically release less hazmat. We have considered all the derailments in Appendix B, which include both pile up and non-pile up accidents. Accordingly the full range of derailments outcomes is accounted for in our analysis.

This rulemaking is focused on derailment mitigation and prevention. For mitigation, the intent of the final rule is to reduce the impacts of rail accidents, but we are primarily concerned with those derailments in which large amounts of hazmat are released causing extensive damage and disruption. In regard to accident prevention, we agree with the commenters. 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 braking systems, which provide improved brake signal propagation time. PHMSA and FRA use that research to establish the need for advanced braking systems requirements. We discuss the derailment prevention aspects of advanced braking systems in the Braking Alternatives section of this RIA.

- *TOES Verification Using Event Recorder Aliceville, Brainard, and Wegnere*: The comments indicate the TTCI model concludes that if ECP brakes had been used in Aliceville, the energy in the derailment would have been reduced by only 12 percent, as compared to the distributed power that was actually used on that train. The model predicts that only 1.5 fewer cars would have reached the point of derailment with ECP brakes.

  The TTCI results are from stopping distance simulations while the FRA results are from derailment simulations. The TTC report does not simulate what happens in a derailment. The model developed by Sharma captures the following three elements of a derailment:

  1) stopping distance
  2) energy
  3) reduced chaos

  The Sharma model does include blockage force. All forces between all cars are calculated by the model and informed the development of the force histogram in the Letter report. The TTC report artificially introduces a blockage force because it does not model a derailment.

  Assuming AAR methodology is acceptable, 1.5 fewer cars reaching POD is a significant portion (8 percent) of the cars reaching POD. Further, in reviewing the comments provided by AAR, FRA concludes that calculation of "energy dissipated in derailment," provided in the comments, is three orders of magnitude too low. Also, the energy dissipated by the blockage force does not appear to be factored into the AAR calculation. These adjustments will affect the AAR results.

In the NPRM, PHMSA and FRA provided data produced by Sharma & Associates showing a 36 percent effectiveness rate of ECP brakes over conventional air brakes as expressed in number of cars punctured. In March 2015, Sharma & Associates finalized additional modeling that takes into account the comments received after publication of the NPRM. A comprehensive discussion of effectiveness rates is provided in Sharma's full report, entitled *Objective Evaluation of Risk Reduction from Tank Car Design & Operations Improvements – Extended Study*. The report is available in the public docket for this proceeding (PHMSA-2012-0082). The report indicates that ECP brakes result in substantially greater reductions in kinetic energy than EOT or DP brake systems. Specifically, 25.2 percent fewer tank cars would puncture if a derailment occurs 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.

- *Variables and number of simulations run*: In its comments AAR indicates that TTCI conducted 420 simulations to compare the average percent reduction in energy and the average reduction in the number of derailed tank cars with ECP and conventional braking. According to AAR's comments, TTCI made the following assumptions:

  1) *Train speed at derailment* – speeds of 30, 35, 40, 45, and 50 mph were included.

  2) *Point of derailment within the train* – derailments occurring at the head-end, 1/4-way through the train, 1/2-way through the train, and 3/4-way through the train were included.

  3) *Track grade* – grades of 1 percent uphill, 1 percent downhill and flat (0 percent) were included.

  4) *Brake system* – conventional (head-end), conventional with end-of-train device (ETD), rear-end distributed power (DP), mid-train DP with ETD, DP at 2/3 with ETD, ECP, and ECP with rear-end wired DP were included.

  As a result of the simulations, the TTCI study estimates that ECP brakes will reduce the number of derailed cars by fewer than two cars, on average, compared to other braking systems. Further, according to TTCI, its analysis investigates only derailments that result in a significant blockage at the point of derailment and, therefore, likely overestimates the overall potential benefit, considering other types of derailments.

  The methodology used to support this rulemaking (with Dyna simulations) captures more of the derailment dynamics and puncture probability than a model such as TOES (or TEDS). TEDS kinetic energy analyses were intended as a preliminary study to determine the possible scope for damage reduction with alternate braking systems. Again, the methodology presented by AAR only captures the kinetic energy effects, not the subsequent derailment dynamics or puncture probability. Therefore, FRA contends that the TTCI study only captures a part of the benefit of ECP. Also, as pointed out earlier, the AAR predictions of two-way EOT or DP performance are overestimated, as such benefits are reduced to zero in the second half of the train, and drop steadily from the amount reported at the head end to zero at mid-point.

Commenters indicate that the Sharma analysis has erroneously assumed a linear relationship between the ratio of head puncture velocity and shell puncture force parameters and the probability of an accident-caused release. Commenters indicate that a linear relationship would only be true if the distribution of the impact force were uniform, which DOT's own analysis shows is not the case. Therefore, commenters state that PHMSA has overestimated the expected number of cars releasing for a given speed based on the following:

- *Impact Forces*: Commenters indicate that the approach seems to assume that the quantity lost in a derailment is solely a factor of train speed and not the mobility of the impactor.

  DOT recognizes that this simplification ignores some common modes of tank dynamics (rolling) and energy absorption (override); there are, however, sufficient features represented in the gross motions of the tanks, couplers and draft gears interacting with each other, the track and the ground that the methodology can be used for a first-order estimation of the relative benefits derived from various mitigation strategies.

- *Compression of Lading*: ARA indicates that the incompressibility of liquid lading is not accounted for in the analysis. AAR indicates that the result of modeling empty cars is to omit the high loads that occur when a loaded tank deforms enough to go shell-full and experiences a spike in both internal pressure and impact forces. Further, AAR indicates, as a consequence, the calculated collision force distribution will be incorrect in the analyses. In particular, AAR is concerned that the distribution would be skewed toward lower force levels.

  The intent of the DOT approach was to estimate relative merit of different designs. To that intent, modeling differences such as the one mentioned above are likely to make little difference. DOT is however in the process of evaluating this for a couple of test cases.

  To investigate the effect of internal pressure on the prediction of puncture risk, a set of derailment simulations was performed with a constant 75 psi internal pressure in the tanks, and the puncture risk was compared to a similar set of simulations without internal pressure. Internal pressure was simulated for a full set of 18 simulations for the 40-mph derailment speed, with 50 cars behind the POD. As expected, the predicted number of punctures was, on average, about 22% higher with the internal pressure than without, noting however, that this is a likely an upper bound. However, the relative improvement in puncture performance due to the various tank construction designs was almost identical to that predicted by the runs without internal pressure. The differences in relative puncture performance were only about 1.4% on average, reiterating the principle that minor differences in the modeling approach would make little difference when comparing the relative performance of designs.

- *Distribution of Impactor Size*: Commenters indicate that impactor size distribution is not well validated and engineering judgment suggests that a higher percentage of large impactors should be included, such as tank heads and shells.

The assumed impactor distribution includes a large number of impactor sizes approximating those of couplers and broken rails, and is therefore conservative regarding the probability of puncture. Multiple analyses have been run in which the impactor distribution was varied towards either larger or smaller impactors. It is clear from the results that even within that range of variations, the relative merits of a given design or operating condition are being predicted correctly.

- *Model Verification Method:* Commenters take note that Sharma attempts to validate its simulation model primarily by comparing the model's outputs – i.e., the number of cars derailed per train and the number of cars punctured or releasing product, all as functions of train speed – with the equivalent numbers from twelve actual accidents that occurred in the period 2002-2012. Commenters indicate that the validation is not adequate and should focus on the full range of FRA derailment data. AAR indicates that it cannot replicate Sharma's derailment data from FRA's database.

  FRA derailment database was intentionally filtered for incidents similar to the specific type of derailment simulated in Dyna. For the purpose of validating the Dyna model, only derailments within the intended domain of the simulation were included, such as derailments (not collisions) of freight trains, of a minimum length, on a mainline track, etc. (specific parameter values used for this filtering can be supplied). The Dyna model was intended to simulate the type of tank car unit train derailment leading to hazmat release with the potential for significant damage, not the full range of incidents reported in the FRA database.

  Derailments are highly individual and chaotic events. The intent of the model is not to replicate or predict any specific derailment, but rather to present a methodology that can be used to evaluate the relative merit of various potential strategies for mitigating damage in hazmat derailments. In addition, no attempt was made to characterize or correlate the FRA derailment data; the SA model results are simply presented with the applicably selected FRA derailment data to demonstrate that the model's results are appropriate and reasonable.

VII. Estimation of Expected Benefits

In this section we first describe the methodology and assumptions used by PHMSA for the initial RIA that accompanied the NPRM. We discuss the comments received, and how PHMSA responded to commenters and other additional information in formulating the final analysis.

A. NPRM Analysis

1. Summary of NPRM Benefits

The benefits of the proposed requirements included averted damages from higher consequence events and lower consequence events. The methodology used to calculate the expected pool of damages that could be reduced by promulgating regulations is documented in this section.

Estimated damages resulting from crude and ethanol incidents consist of two elements:

(1) An estimation of the number of HHFT accidents involving flammable liquids in absence of the NPRM and an estimation of the expected damages from accidents extrapolated from the existing U.S. hazardous materials accident records (we term these "lower-consequence events" or LCE); and
(2) An estimation of how many higher-consequence events might occur in absence of the NPRM and an estimation of expected damages from those higher-consequence events (the additional "higher-consequence events" or HCE range of estimates).

PHMSA monetized damages for LCEs based on the amount of product spilled. Damages may vary independently of the quantity released to some extent, but the severity of an incident is likely to be related to the quantity released. We used the known incidents in the U.S. safety record to calculate an average amount of quantity of product released. While we considered a number of data sources on the reported costs of those spills, but due to data quality concerns we used a cost estimate from the Lynchburg, VA accident. We used an estimated trend based on derailments per million carloads of product shipped to forecast the number of incidents that might occur over the analysis period, and monetize these events using the average quantity released and cost per gallon of product lost to estimate the damages from these incidents.

Probability of Major Rail Accident Based on U.S. Safety Record

PHMSA used the following methodology to estimate the probability of a major train accident involving multiple tank cars carrying flammable liquids.

To estimate the number of derailments associated with the movement of flammable liquids, we used FRA's Incident Database and the Surface Transportation Board (STB) Public Waybill Sample to develop an 19-year historical series (1995 – 2013) on annual derailments per million rail carloads, across all commodities.[58,59]

The STB collects cargo waybill data under the requirement that all U.S. railroads that terminate more than 4,500 revenue carloads submit a yearly sample of terminated waybills. This information provides an indication of the volume of freight rail traffic.

We combined these data that obtained through rail accident and incident reports submitted to FRA on from Form FRA F 6180.54, "Rail Equipment Accident/Incident Report" to estimate

[58] http://safetydata.fra.dot.gov/officeofsafety/publicsite/Query/incrpt.aspx

[59] http://www.stb.dot.gov/stb/industry/econ_waybill.html

historical derailment rates. Rail carriers are required to report accidents that occur on the following types of track: main, yard, siding and industry.

For the NPRM analysis, we developed a forecast based on incidents on all types of track. We then used the 18-year historical average (1995 – 2013) for incidents that occurred on mainline and siding track, and multiplied the predicted number of all future incidents by this percentage to isolate derailments that occurred on mainline and siding track only. PHMSA examined only derailments that occurred on mainline and siding track because we believe that the proposed rule will do little to mitigate the derailments that occurred in rail yards. Derailments in yards generally occur at such low speeds that the legacy DOT-111 would survive them, hence the enhancements being considered here would do little, if anything, to further mitigate release of hazardous materials during yard derailments.[60]

2. Other NPRM Analysis

Due to limitations in reported data, PHMSA used the derailment rate of all hazardous materials trains. The analysis was based on carload data, which does not account for distance travelled per train. We use a 19-year time period to obtain the largest possible sample size; Public Waybill Sample data is not readily available by carload prior to 1995.

PHMSA used the trend in this series to extrapolate to the number of derailments per million carloads throughout the forecast horizon (2013 – 2034) using the equation:

$$\text{Derailments per million carloads} = -1.2521 * \text{year} + 2564.5$$

This equation was based on historical derailments for all commodities because neither PHMSA nor FRA databases capture all derailments of all trains carrying crude and ethanol. PHMSA requires an incident report to be filed if a hazardous material is released, so derailments that do not result in a release are generally not represented in the PHMSA database. FRA's derailment database lists whether a derailed train was carrying any quantity of hazardous material, whether or not material released, but does not provide the type of hazardous material present on the train. As a result, it is impossible to use FRA data to identify crude and ethanol derailments. We experimented with other functional forms but none fit the data better than the linear trend and all produced nearly identical predictions, so we used the linear trend for simplicity. The original table from the NPRM displaying carloads, derailments, and derailments per million carloads from 1995 to 2012 is shown below.

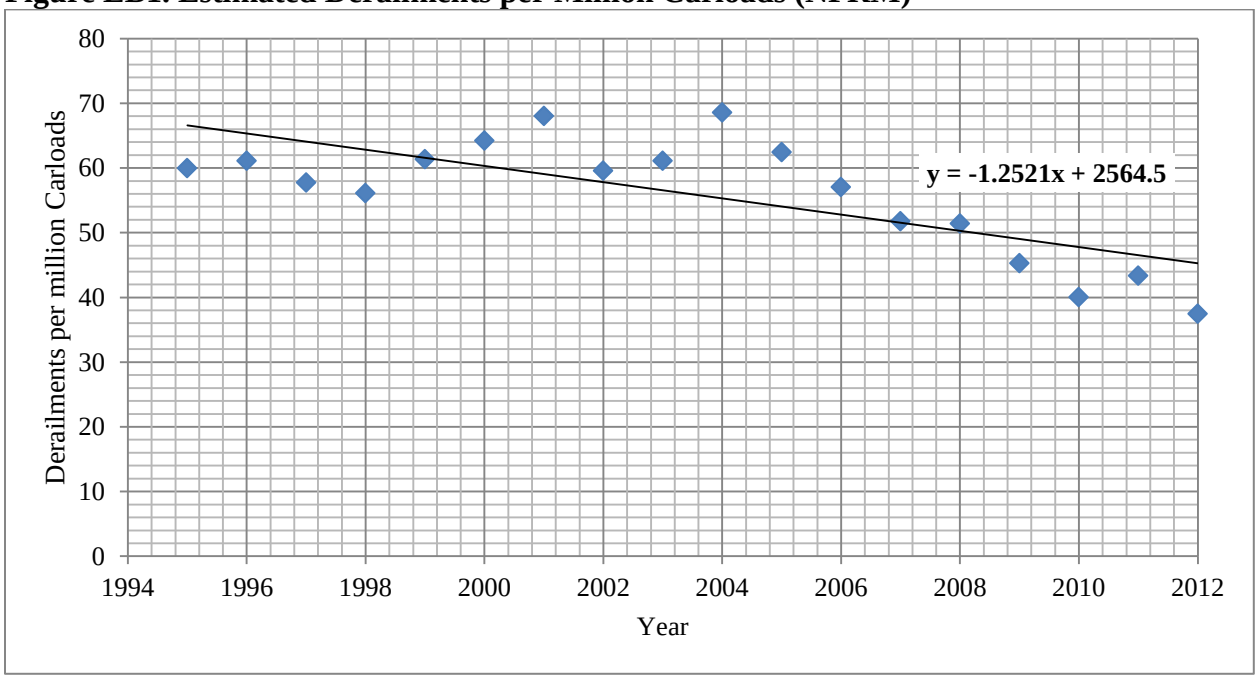
[60] For the purposes of the HMR, the term *movement* is defined in 49 CFR § 171.8.

Table EB1. Carloads Shipped and Derailment Rates, All Commodities, as Estimated in NPRM			
Year	**Carloads**	**Derailments**	**Derailments per Million Carloads**
1995	29,045,247	1,742	59.98
1996	29,723,309	1,816	61.10
1997	30,136,925	1,741	57.77
1998	31,311,638	1,757	56.11
1999	31,966,252	1,961	61.35
2000	32,890,352	2,112	64.21
2001	32,832,391	2,234	68.04
2002	33,385,605	1,989	59.58
2003	34,912,071	2,133	61.10
2004	35,495,079	2,435	68.60
2005	36,897,468	2,305	62.47
2006	38,499,461	2,197	57.07
2007	37,371,510	1,934	51.75
2008	34,817,858	1,790	51.41
2009	30,253,710	1,370	45.28
2010	33,328,373	1,335	40.06
2011	33,845,323	1,468	43.37
2012	34,377,852	1,288	37.47
Source: STB Waybill sample *http://www.stb.dot.gov/stb/industry/econ_waybill.html and PHMSA calculations.*			

PHMSA estimated this trend using data for all derailments (e.g., both yard movement and mainline derailments). As previously noted, commenters reported that mainline derailments have declined at a sharper rate than all derailments over the past 20 years. However, the estimates that result from using the mainline derailment trend alone to project future derailment rates did not seem credible to subject matter experts, because that trend would forecast derailments of crude and ethanol trains to fall to essentially zero by 2026. Subject matter experts contend that, generally, mainline track and car maintenance tend to be related to the total volume of rail shipments, and the recession that started in 2007 may have influencing the mainline derailment trend. Higher volume often means more volume of traffic on rail lines between maintenance, as well as higher car utilization rates, which also results in more ton miles per car between maintenance. As a result, volume affects derailment rates. Rail freight volumes declined significantly in 2008 and had yet to rebound to pre-recession levels by 2012. Concern that the recession may be influencing the steepness of the trend led PHMSA to use a trend based on all derailments.

The trend we estimated results in a 141 percent increase in volume shipped per derailment (total predicted carloads shipped divided by predicted derailments) for crude and ethanol shipment from 2014 to 2034. Looking at mainline derailments for all commodities, the number of carloads shipped per derailment increased by 138 percent from 1995 through 2012.

Figure EB1. Estimated Derailments per Million Carloads (NPRM)



Source: STB Waybill Sample and FRA Office of Safety Analysis

Estimating Mainline Derailments

To predict the expected number of future HHFT mainline derailments in the absence of the rule, we assume that the trends in derailments for crude oil and ethanol will be consistent with other commodities. Earlier, we projected derailment rates for all commodities, based on the trend equation computed above. PHMSA chose not to separate crude oil and ethanol into separate baselines because the materials present similar hazards and are transported in a similar way.

Next, we used 2014 EIA data on production to project future carloads of crude and ethanol.[61] We multiplied those projected derailment rates by the projected carloads to obtain the expected total annual derailments for crude and ethanol.

[61] Source of both crude and ethanol production forecast: Energy Information Administration's Annual Energy Outlook, 2014. Carloads forecast based on production by extrapolating a linear trend based on historic relationships between two series of numbers, and ethanol forecast using an estimated linear trend of historic ethanol carloads based on historic production. Formula for ethanol forecast was EIA ethanol production reference case*1.0476 – 8,814.

Finally, to project mainline derailment rates for crude and ethanol, we assumed that the share of derailments that occur on mainline track is the same for crude and ethanol as it is for all commodities. The FRA derailment data from 1995 to 2012 indicates that approximately 38.5 percent of derailments of all commodities occur on mainline track.[62] We applied these proportions to the predicted number of crude oil and ethanol derailments to estimate the number of future mainline derailments. This derailment forecast is presented in the table below.

Table EB2. NPRM Projected Carloads of Ethanol and Crude and Mainline Derailments (2015 – 2034)

Year	Carloads	Main Line Derailments
2015	898,500	14.36
2016	924,707	14.34
2017	937,808	14.09
2018	949,434	13.80
2019	962,470	13.53
2020	971,605	13.19
2021	969,195	12.69
2022	965,957	12.18
2023	956,047	11.60
2024	948,974	11.05
2025	934,230	10.43
2026	909,673	9.72
2027	892,919	9.11
2028	873,274	8.49
2029	851,981	7.87
2030	829,771	7.26
2031	810,028	6.70
2032	790,030	6.15
2033	772,230	5.64
2034	755,613	5.16
	2015 – 2034 Total:	207

Source STB Waybill Sample and FRA Office of Safety Analysis

There is reason to believe that derailments of HHFTs will continue to involve more cars than derailments of other types of trains. There are many unique features to the operation of unit trains to differentiate their risk. The trains are longer, heavier in total, more challenging to control, and can produce considerably higher buff and draft forces which affect train stability. In addition, these trains can be more challenging to slow down or stop, can be more prone to derailments when put in emergency braking, and the loaded tank cars are stiffer and do not react

[62] http://safetydata.fra.dot.gov

well to track warp which when combined with high buff/draft forces can increase the risk of derailments.

In response to the NPRM analysis, several commenters pointed out that derailments on mainline track have been declining at a faster rate than incidents in rail yards. Thus, using an overall 18-year historical percentage is a limited way to isolate the trend of derailments on main and siding track. For the final rule analysis, we have re-estimated the trend using the average number of annual derailments of crude oil and ethanol over the past five years.

B. Final Rule Analysis

1. Derailment Rate

For the estimation of benefits during the final rule stage, the PHMSA no longer uses the approach of estimating a derailment trend for all trains/carloads or any subset of carloads. Several industry commenters suggested that we should consider only crude and ethanol rail incidents rather than attempting to forecast them indirectly based on a trend that involves other commodities. In addition, the environmental groups commenting on the rule suggested that forecasting derailments involving crude and ethanol forward based on volume shipped was appropriate. The approach used for the final RIA is adjusted to accommodate these comments. Since data available from 2009 to 2013 shows industry is shipping high volumes of crude and ethanol by rail, the PHMSA takes the average number of mainline crude and ethanol derailments for the past 5 years (5.8 derailments), and divides that number by the average number of carloads of crude and ethanol shipped over those 5 years (545,322 carloads). This provides an annual derailment per carload estimate based on the most recent 5 years of data. Because we found derailment rates for crude and ethanol to be nearly constant over time, we have eliminated the declining trend used in the NPRM to predict future derailment rates. We then apply this constant rate per thousand carloads (0.010636) to the annual forecast thousands of carloads of crude and ethanol from 2015 to 2034 to obtain an estimate of the number of derailments that occur. This is a more straightforward approach and also focuses on known crude and ethanol derailments that is driven from recent industry data of carloads shipped and data collected on the number of derailments. PHMSA examined several other models for predicting crude and ethanol incidents which are presented in Appendix F of this document. The model the PHMSA considers most valid for forecasting crude and ethanol derailments, the Poisson regression model presented in Appendix F of this document, provides results that are fairly comparable to those produced using the rate based on the past 5 years of carloads and incidents.

PHMSA and FRA believe that a brief discussion of other recent regulatory actions on the projected derailment rates utilized in this analysis is worthwhile. As none of the recent regulatory actions were designed or intended to specifically address HHFT derailments, PHMSA and FRA do not believe any of the regulatory actions discussed below will significantly reduce the number of HHFT derailments targeted in this analysis. The standards contained in the recently issued Rail Integrity final rule promote the safety of railroad operations by establishing the rail flaw detection standards. This includes officially establishing minimum qualification requirements for rail flaw detection equipment operators and revising the existing requirements. These amendments require the railroads to determine rail inspection frequencies by utilizing a performance-based method. The bulk of the regulation revised FRA's Track Safety Standards by

codifying current industry good practices. In analyzing the economic impacts of the rule, FRA did not anticipate that any existing operation will be adversely affected by these changes, nor did FRA expect that the changes would induce any significant costs. Rather, FRA anticipated that this rulemaking would enhance the current Track Safety Standards by allocating more time to rail inspections, increasing the opportunity to detect more serious defects sooner, providing assurance that qualified operators are inspecting the rail, and causing inspection records to be updated with more useful information. However, the only benefit that was taken was a four hour window which allowed a railroad to finish an inspection sooner. There was no safety benefit taken in the RIA for this regulation, it was only a business benefit.

The recently issued RSIA-mandated Training Standards final rule is generally intended to improve safety on small railroads and their contractors (which may not have adequate training programs) and maintenance-of-way employees, who are not required to be certified and are often contractors. The Training Standards final rule will also address a potential issue that could arise from the changing demographics of the railroad workforce by helping to ensure new employees learn outside of the classroom environment through structured on-the-job training (OJT). The rule will not go into effect until 2018 for Class I railroads and 2019 for smaller railroads, and employees will need to go through the training in order for the rule to have a safety impact; therefore, we will likely not see an impact from this rule until 2020. Moreover, when we do see the impacts, it will likely be on maintenance-of-way and maintenance-of-equipment employee safety and on small railroads and their contractors. PHMSA and FRA believe that there will probably be minimal if any impact on bulk crude oil and ethanol transportation, as the employees involved in the movement, equipment maintenance, and track activities related to these commodities already receive and have received for years the types of training required under the regulations. PHMSA and FRA believe that the regulation will generally maintain current safety levels as we see greater levels of employee turnover in these types of operations. The analysis conducted in support of this rule was a break-even analysis, recognizing that FRA had no way of estimating its safety improvement. The reduction rates assumed in that analysis was intended to be a worst-case scenario for purposes of analyzing the safety risk available for the Training Standards rule to address (only for purposes of conducting a break-even analysis) and still be cost beneficial. Qualitatively, it seems highly unlikely that the Training Standards rule will have a measurable impact on the number of derailments of trains transporting crude oil or ethanol. The safety benefits that support the break-even conclusion are in part to prevent the expected increase in risk associated with generational turnover. The safety areas that are most likely to be affected are railroad employee safety and safety for small railroads and contractors.

The recently issued NPRM related to Risk Reduction Programs proposes to require Class I railroads and freight railroads with insufficient safety performance to develop risk reduction programs. The NPRM would require railroads to conduct hazard analyses to determine and prioritize areas of risk to address in order to achieve continuous safety improvement. Different railroads may have different safety issues that are unique in many respects to their operations. This will result in a tailored/custom approach versus a uniform set of hazards and mitigations across railroads. RSIA required that each risk reduction program have a fatigue mitigation plan and a technology implementation plan, so there will be improvements in these areas of safety across the board. Many Class I railroad crude oil routes would see safety improvements at some point. However, the timeframes and levels of improvement are uncertain because they depend on the operator's development and implementation of mitigations to address hazards unique to

its operation. Risk reduction programs may identify more effective ways of implementing the PHMSA rule, for instance, for the analysis and selection of crude oil routes. The economic analysis for this NPRM used a break-even approach due to the uncertainty regarding the type of accidents and incidents that will be prevented. The rule likely will not become final and in effect until 2016, and the plans would not be required until 2018 or 2019. The safety benefits that result will not be realized until the mitigations are put in place following the hazard assessments. In the meantime, there is a significant multiyear gap in safety. Some forms of mitigation may require significant lead times to implement and improve safety. Safety improvements resulting from the risk reduction rule would likely not be realized for a significant number of years and we do not know what areas of safety will be impacted or addressed during the early implementation of mitigation measures nor will the effects of any mitigation measure be readily known until after having been in place for a period of time. As HM-251 will be published and go into effect prior to the risk reduction program final rule, we would expect the benefits of any risk reduction regulation to account for the safety environment at the time of its publication.

A recent FRA final rule restricting railroad operating employees' use of cellular telephones and other distracting electronic devices followed a 2008 Emergency Order addressing the issue of electronic distraction of operating crews. The rule provides clear guidance on how and when electronic devices may be used during safety-sensitive activities, and prescribes penalties for those using electronic devices when such use is prohibited and could interfere with the performance of safety-sensitive activities. As this rule was implemented prior to the accident at Lac Mégantic, and before there was a major shift in our rail traffic to include a significant amount of oil, we do not believe that the benefit pool from this rule would have any overlap with the benefit pool being used in the current final rule. The majority of rail accidents that we are considering in this analysis involving crude and ethanol occurred after the issuance and implementation of the distracted driving EO and regulations.

PHMSA and FRA further believe that there is little overlap with respect to the accident pool addressed in the recent regulations related to the implementation of PTC systems and this current final rule. Meaning the crude oil accidents, which we reviewed for this final rule, would not have been PTC preventable. In addition, due to several technical and programmatic issues, the vast majority of PTC systems will not be implemented by the December 31, 2015 deadline. FRA's 2010 PTC final rule implied that roughly 44 accidents (not limited to overspeed derailments) per year would be prevented. As noted above, none of the accidents we observed for purposes of this final rule would have been PTC preventable. Overall, there is thus very little, if any, overlap between the prevention measures in the PHMSA rule and the accidents that PTC will prevent.

FRA's recently issued EO 28 requires railroads to review their existing securement protocols to ensure that they identify a sufficient number of handbrakes to be set when leaving trains unattended. Existing FRA regulations already contain specific securement requirements when equipment is left unattended. EO 28 adds to these existing requirements when equipment containing certain hazardous materials are left unattended on mainlines and sidings. PHMSA and FRA do not believe that EO 28 or the related securement NPRM will impact the derailment rates utilized in this final rule.

PHMSA also does not believe that the derailment rate used in the final analysis should be adjusted based on the operating requirements in this rule – such as the speed restrictions and routing requirements – or actions agreed to by railroads to increase track inspections and use routing technology to determine the safest and most secure routes.

In addition to revising the derailment forecast, PHMSA also revised the estimated number of affected carloads expected to be shipped over the analysis period. The original carload projection was based on the historic relationship between production and carloads shipped by rail. While ethanol has a reasonably long historic trend (dating back to 2005) to use for estimating the relationship between production and shipments by rail, the shipment of large quantities of crude oil by rail is a very recent phenomenon. It is obvious that a much larger quantity of crude oil is being shipped by rail relative to total production than has been shipped by rail in the past. Because the Agency's NPRM estimates were based on the historic data, they may have underestimated the total number of carloads expected to be shipped by rail.

For this final rule, PHMSA replaced its original forecast with the figures presented by RSI in their comments to the docket, specifically the figures in Exhibit B4: Crude and Ethanol Rail Traffic Summary in Appendix D of RSI's comments. RSI relied on the same EIA production forecast the Agency used to estimate carloads going forward. However, there has been a major and very recent shift in crude oil shipment patterns (starting in 2011 or 2012) resulting in a greater portion of crude oil being shipped by rail in the past 2-3 years than at any recent time in the nation's history. The short timeframe of high volume crude oil shipments by rail makes forecasting future demand for shipping this commodity by rail difficult. While the Agency attempted to make its forecast at the NPRM stage as accurate as possible, we believe that the RSI knows more about future crude oil shipping patterns, and hence can produce a more accurate forecast of the quantities of crude oil likely to be shipped over the next 20 years. This table provides projected rail carloads from 2014 through 2025 for the North American tank car fleet dedicated to crude and ethanol service. However, RSI's figures contain estimates of crude oil and ethanol rail traffic for the U.S. and Canada, combined. Since this Final Rule is being promulgated by the U.S. Government and is only binding upon U.S. citizens and entities, we must remove the shipments that originate and end in Canada to limit the safety benefit and cost analysis to those that occur in the U.S. Canadian carloads are removed via the following method:

- First, the Agency estimates domestic carloads of ethanol as it did at the NPRM stage. This trend tracks linearly with production and the Agency believes it is fairly accurate. These carloads are subtracted from the RSI carload forecast, leaving a forecast that includes domestic crude and Canadian crude and ethanol shipments.
- Next, reduce the remaining carloads (i.e., those containing domestic crude and Canadian crude and ethanol) by the percentage of the fleet owned and operated in the United States. According to the Canadian Government, their portion of the fleet makes up about 25.7 percent of the North American fleet. It seems reasonable to assume that cars would be

proportional to shipping demand, so we multiply the RSI carload forecast by 0.743 to obtain U.S. carloads of crude oil.

- Since the RSI forecast only goes through 2025, some method is required to project the forecast to 2034. We project forward from 2026 through 2034 based on the percent change in the EIA production forecast.[63]
- Once we have U.S. crude oil carloads, we add U.S. ethanol carloads to this figure to get the total estimated carloads for the two commodities.

The table below shows the total forecast U.S. carloads of crude and ethanol, and the total predicted mainline and siding derailments of crude and ethanol trains for 2015 to 2034. More carloads are forecast to be shipped for the Final Rule analysis than for the NPRM.

The forecast number of derailments was modified slightly to account for the number of higher consequence events. As described in the higher consequence event section we estimate that 2 such events may occur over the 20 year analysis period. As a result, we subtract 2 derailments from the LCE total. The implicit assumption is that the HCEs would be drawn from the pool of LCEs, and hence leaving them in the LCE pool would over-count societal damages and hence benefits. We subtract one derailment from the estimated number in each of the following two years: 2023 and 2027. PHMSA does not assume that HCEs will necessarily occur in these years.

Table EB3: Predicted Crude and Ethanol Derailments

Year	Thousands of Carloads of Crude and Ethanol	Predicted Crude and Ethanol Derailments	Derailment Rate (per thousand carloads)
2015	1119	11.90	0.010636
2016	1124	11.95	0.010636
2017	1164	12.38	0.010636
2018	1250	13.29	0.010636
2019	1327	14.11	0.010636
2020	1409	14.99	0.010636
2021	1416	15.07	0.010636
2022	1418	15.09	0.010636
2023	1418	14.08	0.010636
2024	1422	15.13	0.010636

[63] Source for crude oil production data: 2014 Annual Energy Outlook: http://www.eia.gov/oiaf/aeo/tablebrowser/#release=AEO2014&subject=0-AEO2014&table=14-AEO2014&region=0-0&cases=ref2014-d102413a

2025	1418	15.09	0.010636
2026	1391	14.80	0.010636
2027	1369	13.56	0.010636
2028	1346	14.32	0.010636
2029	1322	14.06	0.010636
2030	1296	13.78	0.010636
2031	1273	13.54	0.010636
2032	1248	13.28	0.010636
2033	1227	13.05	0.010636
2034	1207	12.83	0.010636
	Total:	276.29	

Product Lost Per Derailment

PHMSA bases the costs associated with a derailment on the amount of product released when a derailment occurs. Because damages are higher for derailments on mainline track, these derailments are treated differently than those that occur in yards. In order to monetize mainline derailments it is necessary to determine the average amount of product lost.

PHMSA focused on derailments of crude oil and ethanol trains from 2006 through 2013. We focused on this date range because it encompasses the beginning of the shipment of flammable liquids in HHFTs. We chose to exclude 2014 because information for recent rail accidents may not be finalized. We include the preliminary figures inclusive of the nine rail accidents in 2014 in Appendix B for informational purposes.

PHMSA examined two separate incident-reporting databases to estimate the expected loss of product per derailment:

(1) The PHMSA Hazardous Materials Incident Report database; and
(2) FRA Railroad Safety Information System.

PHMSA collects information on incidents that result in the release of hazardous material in transportation including the type of hazardous material released, the mode of transport, and the number of packages releasing hazardous materials. The FRA collects information on derailments regardless of the commodity, the type of track (mainline, siding, industry), the number of cars derailed, the number of cars that release product and whether hazmat was involved. We combined the information from these two datasets to estimate the number of derailments of crude oil/ethanol cars on mainline and siding track.

PHMSA generally does not collect information on derailments unless the derailment results in the release of hazardous material, and FRA generally does not collect data on the specific hazmat commodity involved in a derailment. Due to each dataset's limitations of the information collected it is possible that some mainline derailments of crude oil/ethanol that did not result in a release of product were not examined.

For the period between 2006 to 2013, we identified 40 mainline derailments that resulted in the release of 3,344,081 gallons of crude oil and ethanol for an average of approximately 83,602 gallons released per mainline track derailment. These 40 mainline derailments are listed in Appendix B. Before beginning computation, we removed derailments that occurred in rail yards and removed incidents that were not the result of a derailment because these accidents are not the focus of the final rule and the provisions would do little to mitigate these accidents.[64] In addition we corrected the data by comparing the PHMSA and FRA incident databases and detailed inspection reports when available.

Based on a review of the reported description of events and a comparison to the FRA incident database we identified the following crude oil/ethanol incidents that either occurred in a yard and are not subject to PHMSA reporting requirements or involved a release of ethanol or crude oil that was not a result of a derailment:

Missoula, MT: 6/18/2006	Harve, MT: 11/1/2010
Kansas City, KS: 12/1/2006	Roanoke, VA: 12/2/2010
Amarillo, TX: 12/25/2006	Jackson, NE: 3/17/2011
Los Angeles, CA 1/9/2007	Antelope, CA: 6/11/21011
Chicago, IL: 8/27/2007	Texas City, TX: 09/13/2011
La Mirada, CA: 4/9/2009	Hitchcock, TX: 09/13/2011
Martinez, CA: 4/13/2009	Stockton, CA: 6/27/2011
Rosemont, IL: 5/18/2009	Pasco, WA: 11/07/2011
Minneapolis, MN: 11/27/2009	Monroe, LA: 12/1/2011
Fresno, CA: 12/17/2009	Las Vegas, NV: 08/11/2012
Birmingham, AL: 2/18/2010	Knoxville, TN: 10/12/2012
	Tampa, FL: 07/25/2013

The PHMSA hazardous material incident report database often contains inaccuracies. The database presents information on releases of hazardous material in transportation and relies on the person in possession of the hazardous material at the time of the incident to report on the incident. Often the amount of product released from a particular tank car is unclear or reported differently in the description of events than in the appropriate incident report fields. Additionally, the PHMSA incident reports often do not reflect the full extent of damages including property damage, cleanup, and remediation costs because it may be months before full damage figures can be reported. By regulation the filer has a maximum of thirty days from the time of the incident to file a report. Even though the filer is responsible for updating or supplementing the initial report if additional information becomes available and has one year

[64] PHMSA reporting requirements only apply to mainline/siding track derailments. Nevertheless, some companies do report yard derailments. Further, this analysis focuses on the damages that result from a derailment, but some companies report releases that were not the result of a derailment.

from the date of the incident to do so, PHMSA do not always obtain full information. When we compared the incident report information from the PHMSA hazardous material incident report Database with data obtained through more thorough investigations, we discovered that the quantity of product lost and number of cars releasing product were misreported in a number of cases. Below are notable examples:

- Parker's Prairie, MN 3/27/2013: The reported release in the report DOT 5800 report field suggested that one car released 10,000 gallons while the description of events reported that four cars derailed and released 15,000 gallons. In this case PHMSA compared this information to the FRA incident database for the same incident. The FRA information confirmed that for this incident 14 cars derailed and 3 cars released approximately 15,000 gallons.

- Aliceville, AL 11/07/2013: The initial estimate of crude oil lost in the Aliceville, AL, derailment was 28,000 gallons. Based on a follow-up from PHMSA personnel, the carrier has since revised this estimate to more than 450,000 gallons.

- Philadelphia, PA 1/20/2014: A 101-car train was travelling from Chicago to Philadelphia derailed on a bridge. Seven cars derailed and six of the derailed cars were carrying crude oil. There was no reported release of the crude oil. This derailment was reported to the FRA, but since it did not result in a release of hazardous material, so it was not reported to PHMSA.

- New Augusta, MS 1/31/2014: The product contained in the incident cars was reported to PHMSA as NA1993 Combustible Liquid, n.o.s. (fuel oil). Information obtained by the FRA during a follow-up investigation revealed that the cars that derailed contained crude oil. Because this was reported to PHMSA as NA1993 and not UN1267, it would not be found using the search for crude oil or ethanol. Based on this additional information, this incident was added to the list of incidents suitable for inclusion. In this analysis, PHMSA elected to use FRA inspection reports that state that for this incident 13 cars derailed and 4 cars released approximately 90,000 gallons.

- Vandergrift, PA 2/13/2014: The incident involved a train carrying crude oil and liquefied petroleum gas. The description of events in the PHMSA incident report states that four cars released a total of 8,300 gallons of product. The report fields for that same report suggested that six cars released 9,800 gallons of product. In this analysis PHMSA elected to use FRA inspection data that says 21 cars derailed and 4 cars released a total of 10,000 gallons.

Monetizing Events Based on Quantity Released

Each incident involving a significant spill of crude or ethanol will have numerous types of costs. In addition to the costs of any injuries or fatalities, which are addressed in the following section, spills will involve cleanup costs. The spills may also involve property damage, costs for emergency response, evacuation costs for residents or workers in the surrounding areas, environmental damage, transportation delays while the spill is being cleaned up, as well as other

costs. As we discuss in the "Higher-Consequence Events" section below, the costs of a spill will depend on not only the size of a spill, but also where it occurs, the type of material spilled, and the circumstances of the accident. There is likely to be more property damage if a spill occurs in a densely populated area or if it results in a fire. There is likely to be more environmental damage if the spill occurs in an environmentally sensitive area. Costs of cleanup may be higher for heavier crude oil that does not burn.

PHMSA estimated the costs of released product by applying a monetary value to each gallon spilled. This implicitly assumes that costs per gallon are linear with (i.e., vary in direct proportion to) the volume of product spilled, but PHMSA intends the value to reflect an average, recognizing the number may be declining with respect to the volume spilled due to economies of scale in cleanup costs. To estimate the cost per gallon of crude or ethanol released, PHMSA examined news and railroad reports from two crude oil incidents for which cost estimates are at least preliminarily available, evaluated cost estimates prepared by the NTSB, reviewed cost estimates reported by railroads to PHMSA in hazardous material incident reports for both ethanol and crude oil, and consulted preliminary modeling by Dagmar Schmidt Etkin on the cost of responding to oil spills.

PHMSA conducted a review of the literature on crude oil and ethanol spill costs, available data from Federal Agency databases on hazardous liquid spill costs, and reports from rail carriers on individual spills, which substantiates an estimate of $200. The review found that damages could be as high as twice that amount for crude oil spills, and substantiates a cost for ethanol spills at $144 per gallon.

From the literature, the Agency derived a cost of $144 per gallon for ethanol spills (see reference in the appendix for Saat et al 2013). The Agency's HMIS database produces estimates of approximately $16 per gallon for both crude and ethanol incidents, but we have serious concerns about the quality of the data submitted to the HMIS database, and since most estimates for crude oil spills exceed $100 per gallon, there seems justifiable reason to be concerned. Much of the literature is focused on maritime spills and it is unclear how applicable those figures are to other modes. However, the few estimates from studies that do consider other modes produce averages that meet or exceed $200 or even $300. The Agency consulted its database on pipeline incidents as well, and has more faith in the quality of the cost data in that database than in the data on rail crude and ethanol incidents. The figures derived from the pipeline data are presented below. For 2011-2015 the cost per gallon for pipeline incidents (dividing total gallons spilled into total costs for all incidents over this time period) produced an estimated cost of $211 per gallon for crude oil incidents, and the estimate for the spill volume category that matches the average historical crude oil and ethanol derailment (50,000 – 99,999) is $368 per gallon.

Table EB4. Pipeline Spill Size and Cost of Spill

Spill size	Total Quantity released	Total Cost	Cost per Gallon
All	7,140,431.8	$1,508,025,860	$211
>100000	4,670,484.0	$1,050,258,418	$225
50000-99,999	474,348.0	$174,363,499	$368
10000-49999	1,309,299.6	$152,408,143	$116
1000-9999	576,685.2	$55,355,979	$96

Table EB4. Pipeline Spill Size and Cost of Spill			
Spill size	**Total Quantity released**	**Total Cost**	**Cost per Gallon**
500-999	51,483.6	$14,226,316	$276
100-499	42,594.3	$19,786,918	$465
50-99	7,447.0	$7,820,282	$1,050
5-49	8,043.0	$19,953,229	$2,481
<5	47.0	$13,853,076	$294,496

The Agency's carload forecast indicates that ethanol will make up approximately 32 percent of total carloads shipped over the next 20 years, and 68 percent of carloads shipped will be crude. Thus, a weighted average of the values for the two commodities produces an estimate of $211 × .68 + $144 × .32 = $190. Given that much of the literature suggests that the costs imposed on society by crude oil spills exceeds that derived from the pipeline data, we round this figure up to $200 per gallon.

The two crude oil incidents for which preliminary cost estimates have been made are the catastrophic incident at Lac-Mégantic, Quebec, and the recent derailment at Lynchburg, Virginia. We do not consider Lac-Mégantic in this estimate. An average based on Lac-Mégantic would not be representative of damages from a typical accident or even a high consequence accident that this rule is intended to mitigate (see Appendix C). The train involved in the Lynchburg incident originated in the Bakken shale region in North Dakota and consisted of two locomotives and 105 cars. On April 30, 2014, seventeen cars were derailed and two of them spilled crude oil in the James River. Approximately 350 residents were evacuated for approximately 3.5 hours.

The Lynchburg incident resulted in 30,000 gallons spilled. The emergency response and cleanup costs for that incident were reported to the FRA by CSX as $8.99 million. Of this $8.99 million cost, an estimated $5 million was due to environmental damage. The CSX estimate of the costs of Lynchburg results in a cost per gallon of crude of about $300.

Table EB5. Breakdown of Damages as a Result of the April 30, 2014 Derailment in Lynchburg, VA		
Description	**Number/Quantity**	**Costs ($ Million)**
Fatalities	None	0
Injuries	None	0
Track Damage		$0.25
Equipment Damage		$3.29
Environmental Damage	30,000 gallons	$5.00
Property Damage		$0.05
Evacuation	350 residents	$0.40
Highway Closure		0
Total Costs		$8.99
Source: CSX as reported to FRA		

PHMSA also examined NTSB reports of rail accidents, PHMSA's own hazardous materials incident report data, modeling done by the U.S. Coast Guard, and several other studies from the literature reviewed.

NTSB investigations of four ethanol and crude oil spills since 2006 are available. NTSB reports that the 2006 New Brighton incident released 485,278 gallons of ethanol and imposed estimated costs of $5.8 million, for a cost per gallon released of $12;[65] the 2009 Cherry Valley incident released 431,708 gallons of ethanol and imposed estimated costs of $7.9 million, for a cost per gallon released of $18;[66] the 2011 Tiskilwa incident released 259,000 gallons of ethanol and imposed estimated costs of $1.6 million, for a cost per gallon released of $6;[67] and the 2013 Casselton incident released 400,000 gallons of crude oil and imposed estimated costs of $6.1 million, for a cost per gallon released of $15.[68]

The NTSB data do not, in most cases, consider remediation and cleanup costs. In its Tiskilwa report, the NTSB's estimated damages represent only property damages. For Cherry Valley, damages seem to be limited to property damages, given where they are presented in the report (though NTSB does not specify). For New Brighton, the damages include $2.5 million that ostensibly accounts for lost product, emergency response, remediation, and incidentals—yet almost 500,000 gallons spilled. This estimate is not credible because the product alone was worth over $1 million. Although the source of the NTSB's damage estimate was the railroad involved, like the source of the Lynchburg damage estimate used in this NPRM, PHMSA does not believe that Norfolk Southern railroad accurately estimated costs in the case of New Brighton.

PHMSA's hazardous materials incident report data are based on incident reports submitted by the involved railroad within 30 days of the incident. Among other information, the railroad is required to report a narrative description of the event, the commodity released, the volume of product lost, and the costs of the incident, including material loss, carrier damage, property damage, response cost, and remediation cleanup cost. Railroads are required to update their initial report if the initial estimates prove inaccurate. Of the 40 mainline derailments involving crude oil and ethanol releases since 2006, hazardous materials incident report data indicate that a total of 3,344,081 gallons were released and total damages were $47,252,409, for an average cost per gallon released of $14.13. Ethanol derailments account for 32 of the 40 total derailments, and the quantity released in those derailments was 2,317,737 gallons, for an average of 72,429

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[65] http://www.ntsb.gov/doclib/reports/2008/RAR0802.pdf

[66] http://www.ntsb.gov/doclib/reports/2012/RAR1201.pdf

[67] http://www.ntsb.gov/doclib/reports/2013/RAB1302.pdf

[68] http://www.ntsb.gov/doclib/reports/2014/Casselton_ND_Preliminary.pdf

gallons released per derailment. Eight of the 40 derailments were crude oil derailments. In total, these derailments resulted in release of 1,026,344 gallons of crude oil for an average per derailment of 128,293.

PHMSA believes that in many cases the hazardous materials incident report data are also incorrect. Total damages from a narrative description of events often do not match the information provided in the corresponding report field. Additionally, damages and costs reported appear to be extremely low. A case in point is the Arcadia, Ohio (2/6/11) derailment (32 cars, the release of 786,245 gallons of ethanol and the evacuation of 25 people for 8 hours); the $187,410 damages reported for this incident is implausibly low. Damage information reported to PHMSA generally includes only the most basic costs such as the value of lost product and preliminary estimates of damages to rail cars or track. PHMSA believes that response costs and basic cleanup costs, when they are reported, do not represent the full costs of an accident or the response. Reports may exclude evacuation of the public, disposal of contaminated soil, air quality and site monitoring and other costs. While it is incumbent upon the person who reports a hazardous materials incident to supplement their initial report, this most often does not happen unless PHMSA follows up with the filer. For example, the initial estimate of crude oil lost in the Aliceville, AL, derailment was 28,000 gallons. Based on a follow-up from PHMSA personnel, the carrier has revised this estimate to more than 450,000 gallons. Beyond simple revisions in volume released, cleanup costs also tend to escalate after an initial report. PHMSA therefore expects costs reported to be biased downward.

Etkin presented preliminary results from a model she developed for estimating the cost of oil spills at the EPA Freshwater Spills symposium in April of 2004.[69] The model was developed from a record of historical oil spill case studies, primarily in inland waterways, and provides a methodology for estimating the cost of an oil spill based on the amount spilled, spill location, and material spilled, among other variables. PHMSA elected not to rely on them but cites other studies by the same author that produce costs per gallon of more than $300.

PHMSA received several comments on its monetary estimate of crude and ethanol spills, but no specific citations to literature or other incidents which substantiate a figure other than the one used at the NPRM stage.

To estimate total property damage, remediation, and cleanup costs as well as socioeconomic costs and lasting environmental damages in the baseline, PHMSA multiplied the total estimated quantity to be released in future mainline derailments by $200. PHMSA estimated elsewhere in this analysis that the average expected release in the event of an accident will be 83,602 gallons. PHMSA noted that at a cost of $200 per gallon released, this implies that the average crude oil

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[69] Etkin, 2004. Modelling Oil Spill Response and Damage Costs. EPA Freshwater Spills Symposium. Available online at http://www.environmental-research.com/erc_papers/ERC_paper_6.pdf

and ethanol mainline derailment results in $16.7 million in total costs (including property damages, cleanup, remediation, emergency response, socioeconomic and lasting environmental damages but excluding deaths and injuries).[70]

Monetization of Deaths and Injuries

To fully monetize these events, we also considered injuries and fatalities. There were one fatality, three injuries that involved hospitalization, and 10 injuries that did not involve hospitalization resulting from crude and ethanol shipments by rail between 2006 and 2014. PHMSA used these incidents to estimate injury and fatality damages per carload shipped for crude and ethanol shipments. PHMSA then monetized these damage estimates and adjusts them by the derailment forecast presented above to account for baseline improvements in industry safety performance. We valued the fatalities at the 2014 Value of a Statistical Life (VSL) as per DOT guidance.[71] The injuries resulting in hospitalization were assumed to be severe injuries on the Abbreviated Injury Scale (AIS), and valued at 26.6 percent of the VSL as per DOT guidance. There were ten injuries that did not involve hospitalization associated with crude and ethanol shipments. These injuries were assumed to be minor on the AIS scale and valued at 0.3 percent of the VSL as per DOT guidance. The Table below presents the fatalities, injuries, and carloads shipped from 2006-2013 for crude and ethanol.

Table EB6. Historic Deaths and Injuries in Crude and Ethanol Mainline Derailments with Carloads Shipped

Year	Sum of Total Hazmat Fatalities	Sum of Total Hazmat Hospitalization Injuries	Sum of Total Hazmat Non-Hospitalization Injuries	Carloads
2006	0	0	0	144,238
2007	0	1	0	206,553
2008	0	0	2	301,636
2009	1	2	6	369,172
2010	0	0	0	446,639
2011	0	0	0	475,025
2012	0	0	2	607,014
2013	0	0	0	828,760
2014 (estimated)	0	0	0	957,052
Grand Total	1	3	10	4,336,089

[70] 83,602 gallons released x $300 per gallon lost = $25,080,600.

[71] http://www.dot.gov/office-policy/transportation-policy/guidance-treatment-economic-value-statistical-life.

The total cost of fatalities and injuries was $17.2 million. Divided by the total crude and ethanol carloads shipped, this came to $3.51 per carload shipped in societal damages. These unit figures were multiplied by the of the forecast number of carloads to calculate expected societal damages for crude oil shipments through 2034.

Baseline Fleet Projections

One further adjustment was made to account for the fact that the industry has recently committed to building only enhanced jacketed CPC-1232 cars for crude oil service going forward. These cars are expected to grow to 34 percent of the fleet by 2019 even without regulatory intervention, due to demand for more cars to ship crude oil. A jacketed, thermally protected CPC-1232 car, with improved pressure relief valves and bottom outlet valves, is significantly safer than either a jacketed or unjacketed DOT-111 tank car. As discussed in the tank car effectiveness section, FRA modelling suggests that 40 percent fewer jacketed CPC-1232 cars would release product in a given derailment relative to a derailment consisting of unjacketed DOT-111s. We therefore adjust our baseline by applying the full expected damages for the 34 percent of the fleet that consists of older tank cars, but only 60 percent of the damages to the remainder of the fleet that would be jacketed CPC-1232 cars. The table below presents how we expect the fleet to evolve going forward if regulations are not adopted.

Table EB7. Expected Evolution of Tank Car Fleet in Absence of Regulation
Baseline CPC-1232 J Fleet Share

Year	Legacy	CPC-1232 J	Total	Legacy %	CPC-1232 J%
2015	61,493	24,933	86,426	0.71	0.29
2016	61,493	31,886	93,379	0.66	0.34
2017	61,493	31,886	93,379	0.66	0.34
2018	61,493	31,886	93,379	0.66	0.34
2019	61,493	31,886	93,379	0.66	0.34
2020	61,493	31,886	93,379	0.66	0.34
2021	61,493	31,886	93,379	0.66	0.34
2022	61,493	31,886	93,379	0.66	0.34
2023	61,493	31,886	93,379	0.66	0.34
2024	61,493	31,886	93,379	0.66	0.34
2025	61,493	31,886	93,379	0.66	0.34
2026	61,493	31,886	93,379	0.66	0.34
2027	61,493	31,886	93,379	0.66	0.34
2028	61,493	31,886	93,379	0.66	0.34
2029	61,493	31,886	93,379	0.66	0.34
2030	61,493	31,886	93,379	0.66	0.34
2031	61,493	31,886	93,379	0.66	0.34
2032	61,493	31,886	93,379	0.66	0.34
2033	61,493	31,886	93,379	0.66	0.34
2034	61,493	31,886	93,379	0.66	0.34

Tables EB8 a & b, below, summarizes damages and assumptions attributable to lower consequence events.

Table EB8a: Summary of Assumptions and Estimates Used in Estimating Lower-Consequence Damages

Data Set Years	Variable	Formula/Input	Base Source
2015-2034	No. of Ethanol Carloads Per Year, 2015-2034	394,977 to 419,078 carloads (depending on year)	EIA Production Projections, DOT Estimates
2015-2034	No. of Crude Oil Carloads Per Year, 2015-2034	723,699 to 1,004,852 carloads (depending on year)	RSI Projections, DOT Estimates
2015-2034	No. of Other Class 3 Flammable Liquid Carloads in HHFT	None	DOT Estimates
DOT Estimate for 2015	No. of Mainline Derailments for Crude and Ethanol Service in 2015	11.90 derailments	Log-linear Trend for Large Volume Hazardous Materials Shipments
2009-2013	Constant rate of crude and ethanol derailments per thousand carloads.	0.010636 derailments per thousand carloads.	FRA Database for All Commodities, STB Waybill Sample for All Commodities, RSI docketed comments on future carloads.
DOT Estimate for 2015	Property/Environmental Damage Cost Per Mainline Derailment	$16,720,400	Product of the Two Variables Below
2014	Avg. Property/Environmental Cost, Per Gallon Released	$200	DOT estimate for final rule (see discussion below)
2006-2014	Avg. Gallons of Product Lost, Per Mainline Derailment	83,602 gallons	PHMSA Database for Crude Oil and Ethanol
2006 --2013	Monetized Non-Hospitalized Injury Risk Per Mainline Derailment	$1,330	Product of .05 (value in next row) x VSL
DOT Estimate for 2015	No. of Non-Hospitalized Injuries Per Mainline Derailment	0.05	FRA Injury Database for Crude Oil and Ethanol
2014	Monetized Cost of Non-Hospitalized Injury (AIS 1)	$27,926	DOT 2014 VSL Guidance, Scaled to 2015
2006-2013	Monetized Hospitalized Injury Risk Per Mainline Derailment	$35,372	Product of the Two Variables Below
DOT Estimate for 2015	No. of Hospitalized Injuries Per Mainline Derailment	0.014	FRA Injury Database for Crude Oil and Ethanol
2014	Monetized Cost of Hospitalized Injury (AIS 4)	$2,476,047	DOT 2014 VSL Guidance, Scaled to 2015
2006-2013	Monetized Fatality Risk Per Mainline Derailment	$447,823	Product of the Two Variables Below
DOT Estimate for 2015	No. of Fatalities Per Mainline Derailment	0.048	FRA Injury Database for Crude Oil and Ethanol
2015	Statistically Monetized Value of Life	$9.3 million	DOT VSL Guidance, Death, updated to 2015 using expected real wage growth

Table EB8a: Summary of Assumptions and Estimates Used in Estimating Lower-Consequence Damages			
Data Set Years	**Variable**	**Formula/Input**	**Base Source**
DOT Estimate for 2015 to 2034	CPC-1232 Jacketed Share without Regulation,	0.29% to 0.34% (depending on year)	Railway Supply Institute at NTSB Forum, 4/22/14; DOT Estimate for Future Years
2014	Risk Reduction, CPC-1232 Jacketed Relative to Weighted Average DOT-111 Tank Car	40%	Applied Research and Associates, Puncture Resistance Model; DOT Estimate for Other Features

Table EB8b: Crude Oil and Ethanol Service: Other Lower-Consequence Damages Estimates and Assumptions		
Variable	**Formula/Input**	**Source**
Difference in Property/Environmental Damages Per Derailment Between Crude Oil and Ethanol	None	DOT Estimate
Difference in Monetized Injury Risk Per Derailment Between Crude Oil and Ethanol	None	DOT Estimate
Change in Share of Crude Oil and Ethanol Production that Travels on HHFT	None	DOT Estimate
Total Property/Environmental Damages from Yard Derailments	Not Estimated	DOT does not expect yard movement damages to materially decrease with this rule
Total Monetized Injury Damages from Yard Derailments	Not Estimated	DOT does not expect yard movement damages to materially decrease with this rule
Total Property/Environmental Damages from Non-Accident Releases (NARs)	Not Estimated	DOT does not expect NARs damages to materially decrease with this rule
Total Monetized Injury Damages from Non-Accident Releases (NARs)	Not Estimated	DOT does not expect NARs damages to materially decrease with this rule
Cars Derailed, Per Mainline Derailment	Not Estimated	Estimate implied in the average of 83,602 gallons of product lost per mainline derailment
Conditional Probability of Release, Per Derailed Car	Not Estimated	Estimate implied in the average of 83,602 gallons of product lost per mainline derailment
Avg. Gallons Lost, Per Releasing Car	Not Estimated	Estimate implied in the average of 83,602 gallons of product lost per mainline derailment

Table EB9 shows the total estimated damages for lower consequence accidents over the next 20 years. These values include both crude and ethanol.

For each year, we calculated the figures in the column labeled "Predicted Damages" in Table EB9 by using the equation:

$$\boldsymbol{Accidents\ in\ a\ YearY\ x\ 83,602\ (Gallons\ Spilled\ per\ Accident)\ x\ \$200 = Monetized\ Damanges\ in\ a\ Year}$$

Where:

$$\$200 = The\ Monetized\ Cost\ in\ Damages\ per\ Gallon\ of\ Product\ Released$$
$$Accidents\ in\ a\ YearY = Expected\ No.of\ Mainline\ Derailments$$
$$83{,}602\ Gallons = Expected\ Quantity\ Lost\ per\ Year\ (see\ Table\ EB8a)$$

From there, we calculated the total expected LCE societal damages, which are represented in the figures in the column labeled "Total Damages" in Table EB9 and following formula.

$$Total\ Societal\ Damages\ for\ LCE=$$
$$[Total\ Damages\ Prior\ to\ Adjustment\ x\ 0.66(Portion\ of\ Legacy\ Cars)]" +$$
$$[0.34(Portion\ of\ Jacketed\ CPC\ Cars)\ x\ 0.60Safety\ of\ CPC\ Cars\ in\ Service]$$
$$x\ Total\ Damages\ Prior\ to\ Adjustment$$

Table EB9: Expected Societal Damages

Year	Predicted Damages, Unadjusted	Predicted Damages, Adjusted for Change in Fleet Composition	Injury & Fatality Damages, Adjusted for Change in Fleet Composition	Total Damages
2015	$198,943,332	$175,986,171	$3,929,242	$179,915,412
2016	$199,823,175	$172,529,914	$3,897,528	$176,427,442
2017	$206,961,703	$178,693,410	$4,084,398	$182,777,809
2018	$222,253,798	$191,896,803	$4,437,946	$196,334,749
2019	$235,930,200	$203,705,186	$4,766,625	$208,471,811
2020	$250,617,527	$216,386,414	$5,123,109	$221,509,522
2021	$251,894,737	$217,489,173	$5,209,978	$222,699,151
2022	$252,237,661	$217,785,258	$5,278,632	$223,063,891
2023	$235,504,432	$203,337,572	$5,340,648	$208,678,220
2024	$252,899,295	$218,356,522	$5,418,118	$223,774,639
2025	$252,231,674	$217,780,089	$5,467,580	$223,247,669
2026	$247,456,360	$213,657,021	$5,427,362	$219,084,383
2027	$226,784,445	$195,808,622	$5,403,715	$201,212,338
2028	$239,427,362	$206,724,680	$5,375,926	$212,100,606
2029	$235,100,740	$202,989,019	$5,341,069	$208,330,088
2030	$230,476,263	$198,996,186	$5,297,794	$204,293,980
2031	$226,337,503	$195,422,727	$5,264,051	$200,686,778
2032	$222,025,417	$191,699,616	$5,224,695	$196,924,311
2033	$218,216,353	$188,410,821	$5,195,654	$193,606,475
2034	$214,598,192	$185,286,854	$5,169,799	$190,456,652
			Total Undiscounted	$4,093,595,927
			Total Present Value at 7% Discount Rate	$2,151,588,358
			Total Present Value at 3% Discount Rate	$3,037,792,406

Higher-Consequence Event Damages

In order to consider the full impacts of this rule, it is necessary to examine the potential for HHFT accidents greater in number or severity than those observed to date in the U.S. While there have been no higher-consequence events (HCE) in the U.S., we believe that such an event is possible. In the previous section we projected damages that might occur if the rate and size of future accidents were similar to the existing U.S. safety record. In this section, we consider whether, in addition to these projected accidents, there might be one or more higher-consequence events. Therefore, any benefits related to preventing or mitigating the accidents examined in this section would be in addition to the benefits from preventing or mitigating the lower-consequence accidents in the previous section.

A high consequence event is characterized by large-scale property damage and multiple fatalities. The only higher-consequence event in the North American crude and ethanol accident history occurred in the town of Lac-Mégantic, Quebec, in July of 2013. The event involved an unattended train that rolled downhill and resulted in a 63-car derailment at 65 mph. The derailment caused a spill of approximately 1.5 million gallons and resulted in the deaths of 47 people and the destruction of much of the downtown area with oil spreading more than 100 kilometers down the Chaudiere River.[72] A year after the event, decontamination of the soil and water/sewer systems is still ongoing. Cleanup of the lake and river that flows from it has not been completed, and downstream communities are still using alternative sources for drinking water. Initial estimates of the cost of this event were roughly $1 billion, but the cleanup costs have doubled from initial estimates of $200 million to at least $400 million, and estimates of the total cost to clean up, remediate, and rebuild the town have risen as high as $2.7 billion.[73]
The frequency and magnitude of these events is highly uncertain. It is, therefore, difficult to predict with any precision how many of these higher-consequence events may occur over the coming years, or how costly these events may be. In the worst-case scenario for a fatal event, the results could be several times the damages seen at Lac-Mégantic both in loss of life and other associated costs.

Estimated Magnitude of a Higher-Consequence Event

We examined -two possible methods for estimating the damages that might result from a higher-consequence event. The first method would be to use the existing U.S. safety record and scale up the damages of one or several of the larger rail accidents in the record to account for possible risk factors that might exacerbate the consequence of the incident if a similar accident were to occur under different circumstances. Risk factors include condition of the track and supporting

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[72] http://www.montrealgazette.com/health/Huge+scope+M%C3%A9gantic+cleanup+comes+into+focus/9348298/story.html

[73] http://www.pressherald.com/2014/04/17/after-end-of-the-world-explosion-lac-megantic-aims-to-rebuild/

infrastructure; the presence or absence of signals; past incidents; population density along the route; environmentally-sensitive or significant areas; venues along the route (stations, events, places of congregation); emergency response capability along the route; measures and countermeasures already in place to address apparent safety and security risks; and proximity to iconic targets. For example, a 2009 19-car derailment in Cherry Valley, IL spilled about 230,000 gallons of ethanol, caused a fire resulting in 1 fatality, 2 injuries, and $7.9 million in property damages, according to the NTSB. If this event had occurred in a more populated area, the consequences could have been significantly larger. This approach would involve placing such an event in another location, and adjusting total costs according to the likely increase in the value of property damaged and number of fatalities that may have resulted. For instance, property values and population densities are much higher in Chicago, IL. If a similar event occurred in Chicago the value of the property damaged would have been much higher, and the damaged infrastructure may have imposed much larger delay costs to commuters and the overall rail network. In addition, more injuries and fatalities may have resulted, though it would be difficult to predict how many fatalities would result from such an event given that fatalities would depend on the exact concentration of people in a particular place at a particular time.

This exercise could be conducted for several other recent events involving crude oil and ethanol. For example, the derailment in Arcadia, OH, occurred very close to a fertilizer plant. Had the derailment hit the ammonia plant, an ammonium nitrate explosion there could have been an explosion the same order of magnitude as the one that occurred in West, TX,74 and the damages would have been much more severe. The train that derailed and punched a 35-foot hole in the wall of an industrial facility in Vandergrift, PA in January of 2014 was carrying heavy crude.75 Had that train been loaded with more easily ignited ethanol or light, sweet crude, a violent release of ignited flammable liquid may have occurred, potentially killing some or all of the 65 employees working at the facility. Alternatively, if the same derailment occurred in the neighboring borough of East Vandergrift the consequences might have been much worse. The derailment in Lynchburg, VA, had it occurred to the town rather than riverside of the track, may have hit a busy lunchtime eatery, resulting in multiple fatalities despite the fact that only one car ruptured. A derailment on a bridge upstream from a reservoir that supplies drinking water to several communities or one large city could result in extensive costs to the municipality if the reservoir were contaminated and the communities that rely on it had to find an alternative supply for drinking water. A recent example of a release of a chemical into a river system impacting drinking water supplies occurred on January 9, 2014. In this case, a chemical leak at the Freedom Industries site that seeped into West Virginia's Elk River a mile and a half upstream of the state's largest water intake. As a result, a "Do Not Use Water Notice" was placed West Virginia American Water customers across nine West Virginia counties. While this release occurred from

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[74] http://www.csb.gov/west-fertilizer-explosion-and-fire-/

[75] http://www.reuters.com/article/2014/02/13/us-energy-crude-derailment-idUSBREA1C13120140213

storage tanks at a fixed facility, the amount of product released (approximately 10,000 gallons) with an unknown amount that entered the river is similar to the circumstances that often surround releases from rail accidents.[76] Scaling up these events based on differences in location, tank car contents, or events, would require making assumptions about when and where such events might have occurred and what consequences would have resulted from those events in alternate locations. Clearly, from the above examples, slight adjustments in the assumed characteristics of an event could result in dramatic increases in event consequences. It is unclear to PHMSA what assumptions would be reasonable.

PHMSA acknowledges that event severity, especially property damage, is likely to be correlated with total quantity of product released, the geographic and environmental aspects of the location in which the event occurs, the proximity of high concentrations of people in said vicinity. Ideally, given enough information, PHMSA would adjust high consequence event damages for all of these factors.

Monte Carlo Approach to Estimating Higher-Consequence Event Damage

For the second method PHMSA developed a risk model to estimate a range of estimates associated with the projected higher-consequence events. PHMSA used a probabilistic risk model, specifically a Monte Carlo simulation to estimate a range of damages that could be observed in future high consequence events (HCE). This model serves as the basis for estimating HCE damages in the final rule. This allowed us to account for the inherent uncertainties in forecasting the frequency and severity surrounding these events.[77]

The Monte Carlo simulations consider uncertainty in the following six factors: (1) Non-Fatality Damages; (2) the Percent of Fatalities within the affected Population per accident; (3) location of the accident (random selection of population density); (4) the expected number of high consequence events that will occur over the next 20 years; (5) damages to wetlands; and (6) the probability of damages to wetlands.

(1) Non-fatality damages

PHMSA used the estimated damages of the accident at Lac-Mégantic, Quebec, scaled down to be more representative of expected damages from a high consequence event in the U.S., to estimate the potential benefits of mitigating higher-consequence events. We acknowledge that

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[76] http://www.epaosc.org/site/site_profile.aspx?site_id=9021

[77] Monte Carlo simulation performs an analysis by building models of possible results by substituting a likely range of values for any factor that has inherent uncertainty. The simulation then calculates results over and over, each time using a different set of random values from the probability functions, to generate a probability distribution of possible outcomes.

there is uncertainty about the potential magnitude of damages from any high consequence event, since there has only been one such event in North American rail history.

PHMSA estimates the total (fatality plus non-fatality) damages from Lac-Mégantic at $1.1 billion and non-fatality damages of $658 million. There is evidence to suggest that this estimate may be conservative. The event at Lac-Mégantic Quebec produced damages close to half a billion dollars in terms of loss of life (47 deaths at an assumed value of a statistical life of about $10 million). Cleanup costs associated with the event, which had initially been estimated at $200 million, are now being estimated at twice that amount.[78] Further it is still unclear when the lake and river that drain from the lake will be completely cleaned up, and nearly the entire downtown has yet to begin reconstruction a year later. The value of lost business activity, temporary unemployment of those working at the businesses destroyed, and other costs may be much more than the initial estimates on which the $1.1 billion figure are based suggest. Recently Canadian officials provided an unofficial estimate of $1.5 billion for the non-fatality damages associated with the incident. Although the Canadian government is uncomfortable placing a value on human life, using the current USDOT VSL of approximately $10 million as noted above the total damages associated with the Lac Mégantic incident would rise to roughly $2 billion.

While PHMSA uses the damage estimates from the Lac-Mégantic event in estimating the higher consequence event damages in the U.S., we acknowledge this accident was unique in many ways. For example, it is highly unlikely that there would be a derailment at 65 mph and the tank car standards proposed here are not intended to be sufficient to prevent or mitigate a puncture at this speed and force—the highest speed of derailments in the U.S. safety record for ethanol and crude is 48 mph, and the rail industry has agreed to limit speeds for crude and ethanol unit trains to 50 mph. Similarly, it is highly unlikely that a 63-car derailment would occur—the largest derailment in the U.S. crude and ethanol record is a 31-car derailment. Thus, PHMSA scales down the damages from Lac-Mégantic detailed below, to account for a smaller expected number of cars derailed and lower speeds of an expected high consequence event in the U.S. We believe extraordinary damages could have occurred even if the train in Lac-Mégantic had derailed at a slower speed. There have been large pool fires in many derailments that occurred at slower speeds. For example, the accidents in Arcadia, OH, Aliceville, AL and Casselton, ND had pool fires.[79]

PHMSA considered various methodologies to estimate a factor for scaling down the damages from Lac- Mégantic. Among the alternatives considered were the following: (a) scaling solely as a function of differences in expected train speed, (b) scaling solely on the basis of differences in expected cars derailed, (c) scaling solely on the basis of differences in expected cars punctured,

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[78] http://www.pressherald.com/2014/04/17/after-end-of-the-world-explosion-lac-megantic-aims-to-rebuild/

[79] See Appendix B for full details of these events.

and (d) scaling on the basis of differences in kinetic energy. PHMSA conservatively uses the kinetic energy approach, which directly takes account of the differences in energy between accidents at different speeds. Kinetic energy is a function of both mass and velocity; consultations with engineers and subject matter experts indicate differences in kinetic energy are likely to translate into proportional reductions in the severity of an accident.[80] FRA identified all crude oil and ethanol rail corridors within the U.S. totaling 20,420 rail links.[81] Rail link lengths range from 0.005 to 25 miles, with average link length of 1.8 miles. FRA identified the *high-threat urban areas* (HTUA)[82] along the fuel rail network as defined by the Department of Homeland Security within the High-Hazard Flammable Train (HHFT).[83] PHMSA applied different scaling factors for the Lac-Mégantic damage estimates that yield separate baseline damage estimates in the non-HTUA portion of fuel rail network and a different baseline damage estimate for the HTUA portion of fuel rail network.

To estimate the scaling factor in the non-HTUA portion of fuel rail network PHMSA compared the differences in speed between the accident in Lac- Mégantic (65 mph) and that which might be expected to occur in the U.S. PHMSA estimated the average speed for the largest (in terms of volume spilled) 10% of accidents in the U.S. crude and ethanol accident history. These accidents were New Brighton (37 mph at derailment), Arcadia (46 mph), Aliceville (39 mph), and Casselton (42 mph). Averaging across these accidents, we obtained average derailment speed of 41 mph. The reduction in kinetic energy of going from 65 mph to 41 mph is about 60%. Applying this reduction in energy to the damages in Lac-Mégantic results in a scaled estimate of total damages of about $440 million ($1.1 billion × (100% - 60%)) and non-fatality damages of $263 million ($658 million × (100% - 60%)). Similarly, to estimate the baseline damages in the HTUA portion of fuel rail network, PHMSA estimated that the reduction in kinetic energy of going from 65 mph to 35 mph[84] is about 71%. Applying this reduction in energy to the damages

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[80] Kinetic energy varies directly with the square of speed (velocity). [Kinetic energy = ½ Mass x $(\text{Velocity})^2$]. 40 mph is 80% of 50 mph. Assuming equal mass, the resulting change in energy is the square of the difference in velocity ($0.8^2 = 0.64$) or a reduction of 36% (1.00 - 0.64 = 0.36).

[81] Total fuel rail network length is approximately 36,500 miles.

[82] Fuel rail network length in HTUAs is approximately 2,400 miles.

[83] Fuel rail network length is approximately 34,000 miles.

[84] Railroad subscribers agreed to adhere to a speed restriction of 40 mph for any HHFTs carrying crude oil in HTUAs, unless the tank cars all meet the CPC-1232 standard. This rulemaking will extend that speed restriction for HHFTs carrying ethanol, and will change the threshold tank car standard to the DOT-117 or DOT-117p. Thus PHMSA expects that any HCEs that occur in HTUAs will be at somewhat lower speeds than the 41 mph assumed for HCEs in the non-HTUAs portion of the fuel rail network. For this reason, PHMSA assumed conservatively the reduction in kinetic energy in the HTUA portion of fuel rail network of going from 65 mph to 35 mph.

in Lac-Mégantic results in a scaled estimate of total damages of about $319 million ($1.1 billion × (100%-71%)) and non-fatality damages of $191 million ($658 million × (100%-71%)).

For purposes of this estimate, the total damages include fatalities,[85] non-fatality damages include property damage to the town, environmental and other cleanup costs, the costs associated with re-routed train traffic, evacuation and emergency response costs, and the value of the rail cars and oil that was lost.

(2) The Percent of Fatalities within the affected Population per accident

The expected number of fatalities from a high consequence ethanol or crude oil accident is estimated using data on the population density in census blocks near railroad tracks. Population density is likely to affect the size of any property damages and the number of any injuries or fatalities. The presence of a place of congregation was a particularly important factor in the damages from Lac-Mégantic. While imperfect, population density is a proxy for the presence of places of congregation. This risk model used the scaled down damage estimate for the Lac-Mégantic accident as described above in conjunction with an estimated population density of the areas within a half-square km of crude oil and ethanol routes in the U.S. Scaling potential risk by population density is a technique used frequently in the literature on the safety of hazardous material shipments. For example Verma uses population exposure as a component of a risk assessment framework for hazardous materials shipments by rail.[86,87] Glickman et al. uses population density as a risk factor to be used in making rail routing decisions for hazardous materials shipments.[88] Saat and Barkan use the number of people affected, which is a function of population density, to scale the consequence levels of hazardous materials rail accidents.[89]

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[85] The U.S. Department of Transportation (USDOT) has established a Value of Statistical Life (VSL) of $9.2 million for 2014 (http://www.dot.gov/policy). USDOT's guidance specifies that the VSL is expected to rise by 1.18 percent per year in response to expected increases in real incomes. That means that, over the 20-year analysis period, the VSL will rise to a value of $11.96 million in the 20th year, and will have an average value over the 20 years of the analysis of $10.72 million. PHMSA uses this value to monetize the casualty costs.

[86] Verma, Manish. 2009. Railroad transportation of dangerous goods: a conditional exposure approach to minimize transport risk. Transportation research part C.

[87] Verma, Manish. 2009. A cost and expected consequence approach to planning and managing railroad transportation of hazardous materials. Transportation research part D

[88] Glickman, Theodore S., Erkut, Efhan, and Zschocke, Mark S. 2007. The cost and risk impacts of rerouting railroad shipments of hazardous materials. Accident Analysis and Prevention. 39. 1015-1025.

[89] Saat, M. Rapik, and Barkan, P.L. 2006. The effect of rerouting and tank car safety design on the risk of rail transport of hazardous materials. Proceedings of the 7th world congress on railway research. Montreal. June.

Kawprasert also uses population density as a factor that influences hazardous material risk.[90] It seems reasonable, given this body of research, to scale our damages to the population densities along the U.S. crude and ethanol routes.

Ideally, the model would have looked at populations very close to the tracks, where the damages from a derailment would be expected to occur. Unfortunately, population data was only readily available by Census blocks for areas throughout the U.S. rail network. In urban areas, Census blocks may be quite small, allowing very granular measurements of populations close to the tracks. However, in more rural areas, Census blocks tend to be considerably larger in area and may not accurately capture the size of populations close to the tracks. If population density is higher away from the tracks, using Census block data will tend to overstate the population close to the track. If population with the block is clustered close to the tracks, then using Census block data will tend to understate the population close to the track.

Another complication of using Census block data is that these data reflect where people live, rather than where they actually are at any particular time of day. For example, Census block data may list a relatively low population within the central business districts of some cities, but there might be a very large number of people working there in the middle of the day. While there are shortcomings to using Census block data, many of these under- or overestimates tend to balance out. Without a much more labor-intensive examination of the areas surrounding individual segments of track, use of Census block data appears to be the most reasonable approach available for estimating populations located close to tracks.

The average fatality rate for high consequence events in the U.S. is assumed to be equal to the fatality rate in Lac-Mégantic multiplied by the scaling factors used to account for likely lower kinetic energy in high consequence events. As with the estimate of non-fatality damages in (1) above, we take into account differences in kinetic energy in the non-HTUA portion of fuel rail network and the HTUA portion of fuel rail network. The fatality rate for these two portions of the network are calculated as follows:

(47/136) × 0.40 scaling factor = 14% in the non-HTUA portion of fuel rail network and (47/136) ×0.29 = 10% in the HTUA portion of fuel rail network, where 47 is the number of fatalities associated with the Lac Mégantic accident, 136 is the average population density per half-square km in the town of Lac Mégantic (and 47/136 yields the fatality rate for that accident), and 0.40 = (100% - 60%) is the scaling factor in the non-HTUA portion of fuel rail network and 0.29 = (100% - 71%) is the scaling factor in the HTUA portion of fuel rail network.[91]

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[90] Kawprasert, Athaphon. 2010. Quantitative analysis of options to reduce risk of hazardous materials transportation by railroad. Ph.D. Dissertation in civil engineering. University of Illinois at Urbana-Champaign.

[91] The accident in Lac- Mégantic, Quebec, resulted in 47 fatalities. In estimating the higher-consequence event damages in the U.S., PHMSA scaled down the damages from Lac- Mégantic by 60% in the HHFT (other than

(3) Location of the accident (random selection of population density)

In addition, PHMSA assumed the risk of accident damage scales with the length of individual fuel rail links. FRA identified all crude oil and ethanol rail corridors within the U.S. totaling 20,420 rail links.[92] Rail link lengths range from 0.005 to 25 miles, with average link length of 1.8 miles. FRA identified the *high-threat urban areas* (HTUA)[93] along the fuel rail network as defined by the Department of Homeland Security within the High-Hazard Flammable Train (HHFT)[94] set of data and provided the average annual tons transported [95] to select in which area the accident occurs. The table below provides a sample of the population densities and rail link lengths for the fuel network provided by the FRA. FRA obtained these population density estimates as shown in Appendix D. The risk model performs a random selection of a population density from custom distributions with points given by the population densities in HTUAs and non-HTUAs as illustrated in the table below. The fuel network rail link lengths are used within HTUA/non-HTUA as a scaling factor to develop the population density custom distributions for HTUAs and non-HUTA networks, assuming the probability the model randomly determines a location and impact based link length and usage.[96] PHMSA uses the average annual tons transported on the fuel network to select in which area the accident occurs and is a proxy for the usage of the rail track in the HTUAs versus the rest of the HHFT network.

HTUAs) portion of fuel rail network, respectively by 71% in the HTUA portion of fuel rail network. PHMSA estimated the number of fatalities the higher-consequence event in the U.S. would also be 60% lower in the HHFT(other than HTUAs) portion of fuel rail network and respectively 71% lower in the HTUA portion of fuel rail network.

[92] Total fuel rail network length is approximately 36,500 miles.

[93] Fuel rail network length in HTUAs is approximately 2,400 miles.

[94] Fuel rail network length is approximately 34,000 miles.

[95] The average annual tons transported on the HHFT, respectively the HTUA network were developed by assigning the 2013 Confidential Waybill Sample, specifically for crude and ethanol, to the rail network. The Department of Homeland Security supplied a polygon layer for the HTUAs. Tons are by individual rail link. Note that the tons on each waybill are assigned to each link that the waybill record traffic traverses between origin and destination. The average annual tons transported on the fuel network data was provided by the FRA to PHMSA on December 19th as follows: 8,009,851,408 tons for the HTUA network, and respectively 49,800,510,555.7 tons for the entire HHFT network.

[96] PHMSA uses the average annual tons transported on the fuel network to select in which area the accident occurs and is a proxy for the usage of the rail track in the HTUAs versus the rest of the HHFT network as described later in this section.

Table EB 10. Sample Population Densities Along Crude Oil and Ethanol Rail Routes				
Rail Link Length	**Population Density (per square mile)**	**Population Density (per half-square kilometer)***	**Probability of an Accident Occurring Along a Given Rail Link****	**Cumulative Probability of an Accident**
0.35	934.52	180.41	0.001%	0.0010%
0.10	934.63	180.43	0.000%	0.0012%
0.73	935.02	180.51	0.002%	0.0032%
4.34	935.13	180.53	0.012%	0.0151%
4.55	935.83	180.66	0.012%	0.0276%
10.74	935.86	180.67	0.029%	0.0570%
0.80	936.16	180.73	0.002%	0.0592%
3.03	936.58	180.81	0.008%	0.0674%
4.08	936.91	180.87	0.011%	0.0786%
0.09	937.13	180.91	0.000%	0.0788%
1.19	937.21	180.93	0.003%	0.0821%
0.10	937.36	180.96	0.000%	0.0824%
5.38	937.38	180.96	0.015%	0.0971%
0.16	937.66	181.02	0.000%	0.0975%
0.17	937.78	181.04	0.000%	0.0980%
0.34	938.19	181.12	0.001%	0.0989%
0.24	938.28	181.14	0.001%	0.0996%
0.33	938.34	181.15	0.001%	0.1005%
0.02	938.37	181.15	0.000%	0.1005%
0.56	938.53	181.18	0.002%	0.1021%
0.22	938.56	181.19	0.001%	0.1027%
4.93	938.58	181.19	0.013%	0.1162%
6.41	938.80	181.24	0.018%	0.1337%
0.02	938.91	181.26	0.000%	0.1338%
0.29	939.22	181.32	0.001%	0.1345%
0.35	939.22	181.32	0.001%	0.1355%
2.11	939.85	181.44	0.006%	0.1413%
0.26	939.87	181.44	0.001%	0.1420%
0.48	939.94	181.45	0.001%	0.1433%
3.91	939.96	181.46	0.011%	0.1540%
6.82	940.58	181.58	0.019%	0.1727%

*PHMSA calculated this column, “Population Density per Half-Square Kilometer (sq km)”, by using this equation:

$$\frac{Population\ Density\ per\ Sq\ Mile}{5.18\ half\ sq\ km/Sq\ mile}$$

For example:

If $1\ mile = 1.609344\ kilometers$

Then $1\ sq\ mile = 2.59\ sq\ km$

Then $1\ half\ sq\ km = \frac{1\ sq\ mile}{2.59\ sq\ km\ x\ 2}$

And $1\ half\ sq\ km = \frac{1\ sq\ mile}{5.18}$

**To calculate the column, "Probability of an Accident Occurring Along a Given Rail Link," PHMSA assumed that the probability of an accident is proportional to the link length.

This probability is represented by the equation:

$$\frac{Rail\ Link\ Length}{Total\ Rail\ Fuel\ Network\ Length}$$

For example, in the HHFT network, for a 0.35 stretch of rail:

$$\frac{0.35\ Miles\ of\ HHFT\ Rail\ Link}{34{,}000\ Total\ Miles\ of\ HHFT\ Fuel\ Rail\ Network} = 0.001\%\ Probability\ of\ an\ Accident$$

Therefore, a 100-kilometer link has twice the likelihood of an accident as a 50-kilometer link, and the population density associated with the 100-km link has twice the likelihood of being chosen as the population density of the 50-km link.

(4) The expected number of high consequence events that will occur over the next 20 years

Next, PHMSA forecasts the number of higher-consequence events that are likely to occur in the absence of this rule over the next 20 years (2015 – 2034).

To do this:

1) PHMSA used the historical number of carloads in the U.S. and Canada to establish a baseline of crude and ethanol shipments. Between 1995 through 2013,[97] there were approximately 4 million carloads of crude oil and ethanol shipped in the U.S. from and over 1 million carloads shipped from Canada between 1999 and 2013.[98]
2) We forecasted the number of carloads expected to ship between 2015 and 2034. PHMSA estimates approximately 26.2 million carloads of crude oil and ethanol will be shipped in the U.S.[99]
3) PHMSA used these numbers in the following equation to forecast the number of higher-consequence events over the next 20 years. It is important to mention that between 1995 and 2013, only one event that fits the "higher-consequence" profile occurred; the Lac-Mégantic accident in Canada on July 6, 2013.

$$\frac{Forecast\ of\ U.S.\ Only\ Carloads\ Shipped\ (2015-2034)}{Total\ No.\ of\ Carloads\ Shipped\ in\ U.S.\ and\ Canada}$$

For example,

$$\frac{26.2\ U.S.\ \ Only\ Carloads}{5.3\ Total\ Carloads} = 4.94\ Forcasted\ HCE\ events$$

Thus, PHMSA estimates the number of higher-consequence events that are likely to occur over the next 20 years in the absence of this rule at up to five events. PHMSA chose a triangular distribution for the number of events distribution in the risk model. Additionally, with definite lower and upper limits we avoided extreme values. PHMSA assumed a point estimate of 2 events with one event and five events as the lower and upper bounds in the risk model. PHMSA estimated conservatively a point estimate of 2 events by taking into account the risk of derailments being reduced by the voluntary actions taken by the railroads including (e.g., speed

[97] Surface Transportation Board (STB) Public Waybill Sample carloads data.

[98] Source: Statistics Canada, "Table 404-0002 – Railway carloading statistics, by commodity, monthly" accessed January 23rd, 2015": 1,058,217 carloads of "Fuel oils and crude petroleum" data. Statistics Canada does not further break down the commodity referred to as "Fuel oils and crude petroleum". Thus, PHMSA assumed all carloads shipped under this category are crude petroleum. There is a total of 453,227 carloads under the category called "Gasoline and aviation turbine fuel", and a total of 63,744 carloads under the category "Alcoholic and non-alcoholic beverages." Statistics Canada mentioned "Ethanol and Gasoline Mixture" can be found under the category called "Gasoline and aviation turbine fuel", and "Ethanol or ethyl alcohol" under the category "Alcoholic and non-alcoholic beverages". However, Statistics Canada does not provide the share of carloads of ethanol as a detailed commodity. Thus, PHMSA assumed ethanol comprises half of the carloads under the last two categories "Gasoline and aviation turbine fuel" and "Alcoholic and non-alcoholic beverages" for a total of 258,486 carloads. The total number of crude petroleum and ethanol shipped by rail in Canada from 1999 to 2013 is 1,058,217 + 258,486 = 1,316,703 carloads.

[99] Please, see Section B. *Final Rule Analysis* in the RIA.

restrictions in HTUAs and routing requirements). PHMSA assumed one event as the lower bound and not zero events because zero HCE events are assumed in the calculation of expected damages associated with lower consequence events. That is, the lower bound of total benefits from this rule represents damages from avoiding LCE events and zero HCE events; the upper bound of benefits associated with this rule arise from avoiding both LCE and a positive number of HCE events (between 1 and 5 HCE events).

(5) Damages to wetlands

PHMSA estimates the clean-up costs for impacted wetlands at $14.7 million per incident based on the values shown in Appendix D. PHMSA evaluated and included wetlands impacts in the risk model to more accurately quantify the higher-consequence event damage estimate.

(6) The probability of damages to wetlands

FRA found that 2 percent of the fuel oil rail network is within 0.28 miles of a wetland and for larger oil spills 10 percent of the fuel oil rail network is within 0.5 miles of a wetland. These estimates were developed based upon expert opinion and previous US accident reports where rail car contents reached the wetland area. The 6% point estimate is the average between the 2% and 10% values mentioned above.

The fatality and non-fatality damages are dependent on the draw of the population density random variable. However, any realized values will be highly correlated.[100,101] The model represents a Monte Carlo simulation by substituting a range of values for these factors that have inherent estimation uncertainty as seen in the table below:

[100] PHMSA expects that for any accident the fatality and non-fatality damages would both be high or low at the same time. Statistically speaking, this means they are highly correlated. Clearly, a highly populated area generally has more buildings and other infrastructure that can be impacted as well as more people. It is possible, however, for these to not occur simultaneously, for example, an expensive warehouse with few people in the area would have high non-fatality damage and low number of fatalities. The model applies randomness to selected variables to allow for a Monte-Carlo analysis (numerous iterations to allow for statistical solution when analytic solutions are not feasible) of the system.

[101] We also ran this model with the same inputs but held fatality and non-fatality damages fixed. This increased the mean total estimated damages by 4.3 percent.

Table EB11. Assumed Distribution of Input Values for Monte Carlo Analysis					
Risk Variables	**Probability Distribution**	**Point Estimate**	**Low**	**Mode**	**High**
Number of Events	Triangular*	2	50%	100%	250%
Percent of Population Fatalities in HHFT	Triangular*	14%	75%	100%	110%
Percent of Population Fatalities in HTUAs	Triangular*	10%	75%	100%	110%
Baseline Non-Fatality Damages in HHFT	Triangular*	$263,310,064	75%	100%	125%
Baseline Non-Fatality Damages in HTUA	Triangular*	$190,860,845	75%	100%	125%
Random Selection of Population Density	Custom**				
Wetlands	Triangular*	$14,654,932	75%	100%	125%
Wetlands Probability	Uniform	6%	2%		10%

*****We chose a triangular distribution for most elements because of its ease of use, only 3 parameters (lower limit, an upper limit and a mode) and allows for skewed distributions, like the percent fatalities above. Additionally, with definite lower and upper limits we can avoid extreme values.

**The random selection of a population density is based on custom distributions with points given by the population densities in HTUAs and the rest of the HHFT rail network as illustrated in the table titled *Population Densities along Crude Oil and Ethanol Rail Routes*. The fuel network rail link lengths are used within HTUA/non-HTUA as a scaling factor to develop the population density custom distributions for HTUAs and non-HTUA networks, assuming the probability of having an accident is proportional to the link length. PHMSA uses the average annual tons transported on the fuel network to select in which area the accident occurs and is a proxy for the usage of the rail track in the HTUAs versus the rest of the HHFT network. Thus, the probability of an accident occurring in the HTUA portion of the network is given by the ratio between the average annual tons transported in the HTUA network to the total tons transported in the entire HHFT network:
$8{,}009{,}851{,}408 \,/\, 49{,}800{,}510{,}555.7 \;=\; 0.1608$.
HTUAs account for 16.08 percent of the HHFT network. In each run of the simulation, a new, random number between 0 and 1 is generated. If this number is less than 0.1608, the incident is modeled as if taking place in a HTUA; otherwise, it is modeled as if taking place outside of a HTUA.

The model executes 10,000 iterations on the randomly selected inputs. Assuming an event has an equal likelihood of occurrence every year the model outputs 10,000 different results. The following table EB12 shows a sampling of 30 possible sets of alternative outcomes (and the damages resulting from those outcomes) that might occur over the 20-year analysis period.

The estimates in Table EB12[102] were calculated as follows. The population density scaling factor was calculated by dividing the population density per half-square km for each rail link by 136

[102] The results presented in the table are rounded to the nearest tenth.

(which is the population density per half-square km for Lac-Mégantic). The non-fatality damage estimates were calculated by multiplying the non-fatality damages by the number of events and by the population density scaling factor to account for the likely differences in the density of buildings and other infrastructure relative to that in Lac-Mégantic.[103] The fatality damage estimates were calculated by multiplying the number of events by the percent of population fatalities, the population density, and the average VSL value over the 20-year period of analysis as determined above.[104]

This model randomly applies selected variables to allow for an analysis with numerous iterations to allow for statistical solution of the system. While we expect that for any accident, the fatality and non-fatality damages would both be high or low at the same time this may not always the case.

Wetlands present special environmental impacts, and thus should be included in a cost-benefit analysis. However, many variables can go into evaluating the impact of a spill on wetlands (e.g., type of oil, viscosity of the oil, slope of terrain, weather – all of which will impact the distance and quantity of the spill to reach the wetlands). PHMSA assumed an accident could impact both the wetlands and the population, therefore the wetland impacts are additive to the fatality/non-fatality damage estimates.[105] Below is the table showing a sampling of 30 possible sets of alternative outcomes (and the damages resulting from those outcomes) that might occur over the 20-year analysis period.

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[103] For instance, the value calculated for the first iteration:
$\$172\ million\ =\ (1.66\ x\ 38.9\ x\ \$266\ million)$
Where: *"number of events" x "scaling factor" x "non-fatality damages"*. The number of events 1.66 is rounded to the nearest tenth to 1.7 in Table EB13 "Sample Outputs of the Risk Model Showing 20-Year Values for Fatality and Non-Fatality Damages."

[104] For instance, the value calculated for the first iteration:
$\$107.7\ million\ =\ (1.66\ x\ 11.4\%\ x\ 53\ x\ \$10.72\ million)$
Where: "$number\ of\ events$" x "$percent\ fatalities$" x "$population\ density\ per\ half-square\ kilometer$" x "$average\ VSL\ over\ the\ 20\ year\ period\ of\ analysis$". The number of events 1.66 is rounded to the nearest tenth to 1.7 in Table EB13 " Sample Outputs of the Risk Model Showing 20-Year Values for Fatality and Non-Fatality Damages."

[105] In order to test whether an accident occurred in a wetland, PHMSA implemented a random selection on the wetlands probability between 2 and -10 % (uniform distribution in which we know the range between the minimum and maximum values and that all values in the range are equally likely to occur). This is used to compare with another random field a random number (0-1) and then testing if less the impact occurred and choose the randomly selected wetland probability. PHMSA would need additional data that would target the likelihood of the larger distance criteria, but for now is assumed uniform and equal weighting across all possible values.

Table EB12. Sample Outputs of the Risk Model Showing 20-Year Values for Fatality and Non-Fatality Damages

Trial values	# of Events	Percent Fatalities	Population Density per half-square km	Scaling Factor	Non-Fatality Damages* (million)	Damages Non-Fatality (million)	Damages Fatality (million)	Wetlands (million)	Total Damages (million)
1	1.7	11.4%	53.0	38.9%	$266.0	$172.0	$107.7	$0.0	$279.7
2	4.1	14.1%	8.1	6.0%	$279.2	$68.2	$50.3	$0.0	$118.5
3	3.6	12.4%	226.0	165.9%	$251.5	$1,517.2	$1,096.4	$0.0	$2,613.6
4	1.8	13.6%	169.3	124.2%	$245.1	$533.6	$433.9	$0.0	$967.5
5	1.8	12.9%	280.8	206.1%	$246.9	$917.8	$702.1	$0.0	$1,619.9
6	2.2	14.2%	82.7	60.7%	$294.9	$389.0	$274.1	$0.0	$663.2
7	2.7	11.2%	67.9	49.9%	$229.2	$307.7	$220.2	$0.0	$527.9
8	2.2	13.0%	23.7	17.4%	$251.2	$97.7	$74.1	$0.0	$171.8
9	3.5	12.2%	218.2	160.2%	$317.1	$1,797.1	$1,012.9	$0.0	$2,810.0
10	2.2	13.0%	166.6	122.3%	$228.4	$612.9	$509.4	$0.0	$1,122.4
11	2.0	14.6%	51.7	38.0%	$274.7	$203.9	$158.7	$15.8	$378.5
12	2.4	12.8%	49.4	36.3%	$240.5	$212.5	$165.1	$0.0	$377.6
13	3.1	13.5%	2.3	1.7%	$299.9	$15.6	$10.2	$15.2	$41.0
14	2.9	14.0%	0.3	0.2%	$304.2	$2.2	$1.5	$0.0	$3.6
15	3.9	13.0%	26.4	19.3%	$265.4	$197.9	$141.7	$0.0	$339.6
16	4.2	9.9%	0.0	0.0%	$198.2	$0.0	$0.0	$0.0	$0.1
17	1.3	13.6%	94.5	69.4%	$249.2	$226.8	$181.1	$0.0	$407.9
18	1.6	14.0%	27.4	20.1%	$271.6	$85.2	$64.2	$0.0	$149.4
19	2.3	10.8%	0.6	0.4%	$197.1	$1.9	$1.5	$0.0	$3.5
20	1.5	12.8%	0.2	0.1%	$300.7	$0.5	$0.3	$0.0	$0.9
21	2.0	9.4%	1,499.1	1100.3%	$194.8	$4,197.8	$2,960.5	$0.0	$7,158.3
22	2.5	11.7%	54.8	40.2%	$260.8	$265.6	$173.6	$0.0	$439.2
23	3.7	12.5%	640.5	470.1%	$273.9	$4,815.7	$3,222.0	$0.0	$8,037.6
24	3.2	13.8%	395.9	290.6%	$283.4	$2,667.3	$1,893.5	$0.0	$4,560.9
25	1.6	13.7%	493.1	361.9%	$272.9	$1,628.3	$1,191.6	$0.0	$2,819.9
26	1.3	12.2%	182.0	133.5%	$271.3	$475.1	$311.8	$0.0	$786.9
27	3.4	14.5%	406.1	298.1%	$257.0	$2,640.7	$2,175.7	$0.0	$4,816.4
28	4.0	9.0%	4,028.9	2957.1%	$162.7	$19,224.2	$15,454.4	$0.0	$34,678.7
29	1.9	11.8%	25.9	19.0%	$224.7	$81.0	$62.3	$0.0	$143.4
30	4.6	12.6%	429.8	315.5%	$281.5	$4,093.1	$2,677.3	$0.0	$6,770.5

Note: *The values represent the Lac-Mégantic baseline non-fatality damages and vary randomly according to the triangular distribution of non-fatality damages set forth in table titled *Assumed Distribution of Input Values for Monte Carlo Analysis*.

The distribution of total estimated damages from high-consequence events over 20 years is shown as a percentile distribution from 0 percent to 100 percent in 5-percentile increments as follows:

Table EB13. Distribution of Total Estimated Damages From Higher-Consequence Events Over 20 Years

Percentile	# of Events	Percent Fatalities	Population Density per half-square km	Scaling Factor relative to Lac-Mégantic	Damages Non-Fatality (million)	Damages Fatality (million)	Wetlands (million)	Total Damages (million)
0%	1.0	7.5%	0.0	0.0%	$0	$0	$0	$0
5%	1.5	9.2%	0.0	0.0%	$0.0	$0.0	$0.0	$0.1
10%	1.6	9.9%	0.2	0.1%	$0.6	$0.4	$0.0	$1.3
15%	1.8	10.5%	0.8	0.6%	$3.4	$2.5	$0.0	$8.7
20%	1.9	11.2%	3.0	2.2%	$13.8	$10.1	$0.0	$24.7
25%	2.0	11.7%	7.5	5.5%	$35.5	$26.3	$0.0	$62.8
30%	2.1	12.0%	14.7	10.8%	$70.9	$51.7	$0.0	$124.3
35%	2.2	12.3%	25.4	18.7%	$117.5	$85.2	$0.0	$203.7
40%	2.3	12.6%	37.8	27.8%	$182.6	$131.1	$0.0	$315.4
45%	2.4	12.8%	54.8	40.2%	$262.9	$190.5	$0.0	$452.6
50%	2.5	13.0%	77.0	56.5%	$360.8	$266.1	$0.0	$631.9
55%	2.7	13.1%	105.1	77.1%	$501.4	$361.7	$0.0	$872.7
60%	2.8	13.3%	137.2	100.7%	$668.5	$493.8	$0.0	$1,173.4
65%	3.0	13.5%	182.8	134.2%	$883.5	$639.5	$0.0	$1,521.5
70%	3.1	13.6%	232.3	170.5%	$1,152.8	$847.6	$0.0	$1,997.1
75%	3.3	13.8%	308.3	226.3%	$1,517.2	$1,095.1	$0.0	$2,621.8
80%	3.5	13.9%	410.6	301.4%	$1,997.6	$1,455.1	$0.0	$3,460.0
85%	3.7	14.1%	554.7	407.2%	$2,792.9	$2,039.2	$0.0	$4,843.7
90%	3.9	14.3%	827.8	607.6%	$4,206.6	$3,053.3	$0.0	$7,241.5
95%	4.2	14.5%	1,532.7	1125.0%	$7,292.1	$5,307.7	$13.1	$12,618.0
100%	5.0	15.2%	23,415.0	17186.2%	$111,443.4	$86,982.0	$18.2	$198,436.5

The median of the distribution (i.e., the 50th percentile) is approximately $632 million. The mean of the distribution is $2.8 billion and represents the average of all possible future outcomes (including some with extremely high damages); the median represents the outcome that has an equal probability that the actual outcome will be higher or lower than the median. The 80th percentile value ($3.5 billion) indicates that there is a 20% chance that the damages could be higher than $3.5 billion. The 95th percentile value ($12.6 billion) indicates that there is a 5-percent chance that the damages could be higher than $12.6 billion.

Alternatively, in Appendix G ("Illustrative Approach to Higher-Consequence Event Damages") we present an approach to show higher-consequence damages using different assumptions. This

appendix contains the same basic method for estimating higher-consequence event damages as used in this analysis, employing a Monte Carlo simulation to run a large number of scenarios where the inputs are allowed to vary. As a basis of the approach in the appendix, there were approximately 5 million carloads of crude oil and ethanol shipped in Canada and the United States from 1995 – 2013, and over that time there was one higher-consequence event, the accident at Lac-Mégantic. PHMSA divides the total number of carloads shipped in US and Canada into the carloads we forecast to be shipped from 2015-2034 in the U.S. only: 26.2/5.3 = 4.94. Thus for this analysis, PHMSA estimates the number of higher consequence events that are likely to occur over the next 20 years in the absence of this rule at five (5) events. This approach resulted in a mean of $7.8 billion. It found at the 80th percentile a value of $11.1 billion, which indicates there is a 20-percent chance that the damages could be higher than $11.1 billion.

2. Total Estimated Damages

To estimate the benefits of this rulemaking PHMSA has estimated the effectiveness rates of several of the provisions. The effectiveness rates of the requirements are interdependent and some requirements, such as routing, can mitigate both the likelihood and the consequences of an accident. The table below presents the total undiscounted damage pool from which benefits are derived.

Table EB14: Expected Societal Damages

Year	LCE Damages	Mean HCE Damages	80th Percentile HCE Damages	95th Percentile HCE Damages
2015	$179,915,412	$140,250,000	$173,000,000	$630,900,000
2016	$176,427,442	$140,250,000	$173,000,000	$630,900,000
2017	$182,777,809	$140,250,000	$173,000,000	$630,900,000
2018	$196,334,749	$140,250,000	$173,000,000	$630,900,000
2019	$208,471,811	$140,250,000	$173,000,000	$630,900,000
2020	$221,509,522	$140,250,000	$173,000,000	$630,900,000
2021	$222,699,151	$140,250,000	$173,000,000	$630,900,000
2022	$223,063,891	$140,250,000	$173,000,000	$630,900,000
2023	$208,678,220	$140,250,000	$173,000,000	$630,900,000
2024	$223,774,639	$140,250,000	$173,000,000	$630,900,000
2025	$223,247,669	$140,250,000	$173,000,000	$630,900,000
2026	$219,084,383	$140,250,000	$173,000,000	$630,900,000
2027	$201,212,338	$140,250,000	$173,000,000	$630,900,000
2028	$212,100,606	$140,250,000	$173,000,000	$630,900,000
2029	$208,330,088	$140,250,000	$173,000,000	$630,900,000
2030	$204,293,980	$140,250,000	$173,000,000	$630,900,000
2031	$200,686,778	$140,250,000	$173,000,000	$630,900,000
2032	$196,924,311	$140,250,000	$173,000,000	$630,900,000
2033	$193,606,475	$140,250,000	$173,000,000	$630,900,000

2034	$190,456,652	$140,250,000	$173,000,000	$630,900,000
Total	$4,093,595,92	$2,805,000,000	$3,460,000,000	$12,618,000,000

3 Non-Quantified Benefits and Uncertainties

Non-Quantified Benefits

This section describes benefits of this rule that were unable to be quantified, but may be substantial. In addition, it describes the uncertainty surrounding many of the Agency's central estimates for monetizing societal damages. One of the primary unquantified benefits of this rule is harmonization with a corresponding Canadian tank car standard. Such harmonization facilitates international trade and cross border shipping of flammable liquids between these two neighboring countries. Without such harmonization, it is possible that crude oil would have to be transloaded from one rail car to another at the U.S. Canadian border, because the tank car containing the material failed to meet the tank car standard of the country to which the product was being shipped. Such trans-loading could impair economic activity, delay shipments of valuable commodities, and decrease the efficiency of the rail network in both countries. Such delays would impose substantial costs on the affected industries in both countries. The baseline for this analysis does not consider the effects of Canadian tank car regulations in the absence of new standards in the United States. In this way, the analysis under counts the benefit of harmonization that is a result of avoiding the aforementioned costs.

Uncertainties surrounding the Agency's Societal Damage Estimates

In this section the Agency describes uncertainties associated with the estimates it developed to monetize damages associated with crude and ethanol train derailments. We begin by discussing the findings of our literature review and data analysis of the costs imposed by crude and ethanol releases. Following that, we present evidence that the sample of events we used to estimate of the size of events/quantity released when a derailment occurs may not be representative of the size and impact of future events. Finally, we discuss uncertainty surrounding our central estimate of the number of high consequence events that may occur over the coming 20 years.

Damage estimates for crude oil and ethanol spills

The literature and information on the costs of crude and ethanol spills is fairly slight given that these incidents make the news on a regular basis. Comprehensive societal costs are especially difficult to obtain for rail incidents for the following reasons:

- Immediate response and clean-up are often the only cost elements reported when an incident occurs.
- Most research efforts have focused on crude oil maritime spills, which may have limited applicability to rail incidents;
- Studies of ethanol spill costs are scarce compared to studies on crude oil spills.
- Few studies examine spills in rail transport.

Spill Cost Literature Review

PHMSA identified and examined the studies[106] included in the RIA Appendix B under the Literature Review section to identify all categories of damage estimates for spills of crude oil and ethanol whether they were monetized or not (e.g., property damage, clean-up, emergency response, environmental damage and other costs). The table below reflects the consolidated categories of damages from the literature review for crude oil and ethanol (ethanol entries are shaded).

Study	Per gallon estimate $FY13	Oil Type	Mode	Response & clean-up costs	Lost Product/Lading	Environmental Damages	Socioeconomic Damages	Property damage (track, structures, and signals)	Evacuation costs	Incidental damages	Liability	Damaged tank cars damages	Train delay costs
Etkin (1999)	$326.00	Crude Oil	Spill response in the U.S.	√									
Marruffo (2012) [1]	$378.34	Crude	Rail	√									
Cohen (2010)	$892.29	Crude	Maritime	√	√	√	√			√	√		
Helton and Penn (1999)	$262.26	Crude / Fuel Oil	Intermodal	√	√	√	√	√	√	√	√		
Helton and Penn (1999) — Pipeline Incidents	$322.00	Crude / Fuel Oil	Pipelines	√	√	√	√	√	√	√	√		
U.S. Coast Guard (2011)	$271.00	Crude / Fuel Oil	Maritime	√		√	√			√	√		
U.S. Coast Guard (2010)	$385.00	Crude / Fuel Oil	Maritime	√	√	√	√	√		√	√		

[106] Excluded studies with cost estimates not based in U.S. dollar and impacts not in the U.S. (e.g., Vanem, Yamada, Kontovas, Montewka, Liu) and studies older than 1986.

Study	Per gallon estimate $FY13	Oil Type	Mode	Response & clean-up costs	Lost Product/Lading	Environmental Damages	Socioeconomic Damages	Property damage (track, structures, and signals)	Evacuation costs	Incidental damages	Liability	Damaged tank cars damages	Train delay costs
U.S. Coast Guard (2013)	$453.33	Crude / Fuel Oil	Maritime	√		√	√				√		
Etkin (2003) [2]	$633.71	Crude / Fuel Oil	Maritime	√		√	√						
Marruffo (2012) [1]	$8.22	Denatured Ethanol	Rail	√									
Saat et al. (2014) [3]	$144 - $225	Pure Ethanol	Rail	√					√		√		√

[1] Costs with labor associated with clean-up times only.
[2] Response costs: shoreline oil removal costs, on water mechanical recovery/on water dispersant response/in-situ burn costs, shore cleanup costs of oil not burned, mobilization, and protective booming/sensitive site protective booming.
[3] Yields 225/gallon when considering 56% increase in consequence costs due to legal settlement expenses.

From the table above we ascertain that more categories of damages were available and used to estimate total damages for crude oil spills than for ethanol spills. However, in some of the crude oil spills related studies certain types of damage categories were not included as seen in the table above (e.g., Etkin, Marruffo). Helton and Penn are the only authors to look at spills associated with multiple transport modes. Helton and Penn do not include and rail incidents but include 5 pipeline incidents. The average cost per gallon for those 5 pipeline incidents is $322/gallon which is higher than the $218 the average cost per gallon for all ocean/maritime incidents[107] they looked at, if the Exxon Valdez incident (an extreme outlier on both cost per gallon and total spill volume) is excluded. Incorporating all non-maritime incidents in Helton and Penn into the average with the pipeline incidents provides an estimate that is virtually identical to the maritime incidents if Exxon Valdez is excluded. This finding provides some evidence that land-based spills may meet or even exceed maritime spills in average cost per gallon. However, given that Helton and Penn are careful to note that their estimates are not derived from spills that are statistically representative of all incidents, this finding should be treated with some degree of caution.

[107] Includes Exxon Valdez.

Given the comparative findings from Helton and Penn, it may be useful to consider whether costs estimated from maritime spills may be applicable to other land-based modes. The average for the three USCG estimates is $370/gallon spilled, but they range from approximately $270 to over $400. Thus, there is evidence that the true cost to society from crude oil spills may be 50 percent, or even double, the Agency's central estimate.

The resources available for estimating damages with ethanol spills are scarce. While the reports available are associated with rail incidents, from the table above we gather that the NTSB reports do not include many categories of damages (e.g., environmental damages to natural resources, socioeconomic damages, network delays, evacuation, and liability). The model described in Marruffo (2012) model is used to predict the relative impact of crude oil or ethanol released from railroad-tank car accidents on soil and groundwater contamination and cleanup times, but no monetized costs are presented.

Saat et al (2014) describes a quantitative, environmental risk analysis of rail transportation of a group of light, non-aqueous phase liquid chemicals including ethanol. The authors developed probabilistic estimates of exposure to different spill scenarios along the N. American rail network. The Agency derived an estimated cost per gallon from this study of $144. The environmental (i.e. soil and groundwater) consequence model in which the clean-up cost and total shipment distance are most significant risk factors, estimating clean-up, evacuation and delays damages. The authors estimate a 56% increase in total consequence cost estimates due to legal settlement expenses. Moreover, the environmental consequence model used in this study focuses on soil and groundwater cleanup. The authors mention that the environmental cost would increase when considering damages to natural resources such as surface water bodies and other hazards.

In addition, this study considers pure ethanol, rather than ethanol mixed with denaturant. Most ethanol transported by rail is mixed with 5% or more denaturant, usually either gasoline or diesel fuel. The costs to clean up this chemical mixture may exceed those to clean up pure ethanol, so applying the cost per gallon obtained from this study to rail incidents may underestimate the costs associated with these incidents since denatured ethanol may be substantially more costly to clean up than pure ethanol.

The weighted average of the per gallon estimates from all the listed literature is between $ 407 to $415[108] per gallon spilled of crude oil or ethanol. In addition, it is unlikely that any of these estimates capture the full comprehensive societal damages that result from these incidents.

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[108] If we average all the per gallon estimates across all the studies from the literature review table we get $407 per gallon when calculating the average with the $144 per gallon from the Saat study, or $415 per gallon when calculating the average with the $225 per gallon from the Saat study.

The USCG estimates as shown in this table are the most complete and current estimates available on the total costs crude oils spills impose on society. Even these cost estimates may undervalue the damages imposed as they use liability claims and NRC estimates as a proxy for environmental damages. In many cases, liability claims may undervalue the full damage imposed on third parties by oil spills – some individual with valid claims may not come forth, and some damaged parties may not be able to prove damages and hence make claims.

As Helton and Penn note in their study:

> *"Complete cost information was not possible to obtain since many categories of cost are not routinely made public. As a result, we excluded spill incidents with minimal cost information. Even among the included cases (see Table 1), cost information was not complete. When cost estimates are reported, they should be considered partial and spill volumes should be viewed with some skepticism."*

Because the costs associated with these spills are hard to obtain and quantify, any source of data is likely to underestimate total spill costs to a greater or lesser extent. The hedonic studies by Hansen et al and Simons et al, see literature listed in Appendix B, in addition to contingent valuation studies by Carson et al and other authors provide evidence of costs imposed by these incidents that are difficult to estimate, but may be substantial. No public reporting by entities responsible for spills is likely to capture the full non-market impacts of a spill. Even careful attempts to quantify all costs associated with spills may come up short.

Data from Agency Sources

PHMSA attempts to collect comprehensive incident costs for both hazardous liquid pipeline spills and spills involving other transportation modes. The Agency consulted EPA for estimates of the costs imposed by spills regulated by EPA, but no reliable estimates were obtained. The EPA has produced past estimates using pipelines data, an indication that the pipeline data may be the most reliable and high quality data available from a public database. The values obtained from the pipelines data were the primary estimate for crude oil costs used by the Agency, but the Agency notes that the literature review conducted resulted in estimates much higher than this figure. The Agency's central estimate should therefore be considered fairly conservative.

Incident Severity

There is reason to believe that the Agency's estimate for incident severity may be low, because there is evidence that the number of flammable liquid cars per train has been growing over the past decade and may continue to grow. FRA analysis of the Waybill sample shows the following growth in the number of crude and ethanol cars per train for all trains hauling 1 or more carload of crude or ethanol.

Table EB15: Incident Severity by Commodity		
Year	**Crude**	**Ethanol**
2005	10.45	5.50
2006	9.86	6.44
2007	11.15	11.70
2008	7.56	17.16
2009	8.04	27.75
2010	61.26	34.94
2011	49.90	38.60
2012	65.77	41.39
2013	77.13	46.19

As can be seen the number of crude or ethanol cars per train has increased significantly over the past decade for both commodities. Below is a comparison between the historical number of hazmat tank cars in a train from the waybill data and the accident data the Agency based its low consequence damages on. (33 ethanol accidents and 13 crude oil accidents):

Table EB16: Historical Incident Severity		
Average Number of Hazmat Cars	**Ethanol**	**Crude**
Waybill data 2013	46	77
Accidents data	38	51
Percentage increase waybill data to accidents data	22%	51%

Ethanol concentration (cars per train) has grown modestly compared to the average for the incidents the Agency used to estimate damages. For crude oil trains, the increase in car-concentration has been much more dramatic. FRA experts believe that further increases in the concentration of cars on crude oil trains is likely, but expect that ethanol consists will resemble the data from 2013 going forward. As can be seen in the table, ethanol trains are likely to contain 22 percent more cars than the Agency's sample of derailed trains contained, on average, and 51 percent more crude oil cars than the Agency's derailment sample. Further concentration of crude oil is likely, but neither PHMSA nor FRA can say where the cars per train figure will stabilize. Accident severity may be associated with an increase in the number of cars hauling hazardous material because the more hazmat cars on the train, the more likely that a higher number of hazmat cars will be involved in the derailment and hence at risk of puncture and release of material.

While the concentration of crude oil and ethanol carloads into unit trains will tend to increase the expected damages of a derailment, it is likely that there will be fewer derailments involving crude oil and ethanol, because there will be fewer trains carrying crude oil and ethanol.

PHMSA and FRA do not have evidence to show that the increase in expected severity will be larger than the decrease in derailment rate that is expected to result from continued concentration of crude oil and ethanol tank cars into unit trains. However, to the extent that the severity rises

more than the derailment rate falls, consolidation of tank cars into unit train service is a potential source of undercounted benefits.

Likelihood and Number of HCEs

One way to predict the number of accidents that will occur in a given period is to look at the past rate of accidents per unit of volume (train miles, vehicle miles traveled, carloads shipped, etc.) and project those incidents forward based on expected future volume. Thus if 1 car crash occurs per 100,000 vehicle miles travelled, one can get an estimate for car crashes going forward if one has a forecast of future traffic volumes. Given their uncertainty and extenuating contributing factors associated with high consequence events, applying such a rate to such events may not produce an accurate forecast. On the other hand, such an exercise can be illustrative of potential risk.

We note that one such event has occurred in the North American safety record – the tragic event at Lac-Mégantic, Quebec in July of 2013, At the time of that event, approximately 5 million carloads of crude and ethanol had been shipped over the course of the time period from 2000-2013 in the U.S. and Canada. Prior to 2000, the quantities of both commodities shipped by rail were fairly negligible. As presented in the Benefits Section in the RIA, we forecast 25 million carloads of crude and ethanol to be shipped over the next 20 years. At a rate of 1 event every 5 million carloads, approximately 5 high consequence events could be expected over this time period. We also note that our Monte Carlo simulation produces results that indicate the possibility of a single event that may exceed Lac-Mégantic in total cost by an order of magnitude or more. Mitigating or preventing one such event might produce benefits that exceed the cost of this rule.

In addition, 5 high consequence events exceed the Agency's best estimate for the likely number of HCEs by 3 events, and is slightly higher than the number of events in the 95th percentile of the Monte Carlo simulation results. These events may occur with less frequency than a crude exposure estimate, such as events per million carloads, produces. However, the fact that one such event occurred so soon after the advent of high volume rail shipments of crude suggests the possibility that additional HCEs may occur. If those events are particularly severe or numerous, the potential damages inflicted on society could be tens of billions of dollars. Mitigating or preventing these events could produce very large societal benefits.

Additionally PHMSA used the following methodology to explore its data to determine the number of potential high consequence events (HCE) in the next 20 years. This methodology applies a derailment forecast to the network to identify how many derailments are likely to occur in densely populated areas; it does not address a high consequence environmental damage event. In order to explore a reasonable number of events, a few baseline figures are necessary. One such event has occurred in North America, involving derailment of a crude oil train in the town of Lac-Mégantic. Lac-Mégantic has a population density of roughly 700 people per square mile, which equates to about 136 people per half-square km. We use population per half square km to approximate the people at risk in the event of a derailment that results in a fire by a crude or ethanol train.

PHMSA ran a different 10,000 iteration Monte Carlo simulation modeling a single derailment placed on the HHFT network to identify what percentage of derailments might occur at various population densities along the rail network. For each iteration, a single derailment was allowed to randomly be placed in a location along the crude oil and ethanol rail network, with two assumptions.

- First, the probability of an accident occurring along a rail link is proportional to the rail link length under the reasonable assumption that a longer link would have a higher likelihood of derailment.
- Secondly, the probability of an accident occurring in a HTUA versus the rest of the HHFT network is based on the tons transported on the fuel network which represents a proxy for the usage of the rail track.

The table below presents population in a half square KM adjacent to the track in the first column, and the percentage of times the 10,000 iterations placed the derailment on a link with that population density in the second column.

Table EB17: Population Density

Population per 5 Sq Mile	Frequency	Percent
0-100	5551	56%
100-200	1172	12%
200-300	710	7%
300-400	460	5%
400-500	381	4%
500-700	491	5%
700-900	243	2%
900-1000	127	1%
1000-1200	159	2%
1200-1400	126	1%
1400-1500	46	0%
1500-1700	84	1%
1700-2000	84	1%
2000-24227	366	4%

The derailment occurs in places with 200 or more people per half-square km roughly 33 percent of the time. This population density is greater than the population density in the location where the one HCE on the North American public safety record occurred. PHMSA predicts 278 derailments to occur over the coming 20 years. Based on historic derailment data, we expect one carload or more of flammable liquid to ignite and cause a fire on approximately 30.4 percent of these derailments, or about 85 derailments. 30.4 is the percentage of derailments from 2006 – 2014 that resulted in release of flammable liquid that ignited to cause a fire (14 of 46 derailments). The Agency believes that any event that results in the ignition of flammable liquid released during a derailment could become an HCE in the right circumstances. Based on the same data, we could expect approximately 13 percent of these derailments to involve a fire with the release of 230,000 or more gallons of product, or approximately 36 derailments. These would be large releases of a high volume of flammable liquids, resulting in a fire which could spread

over a fairly large area and burn for several hours or days. Based on the results of the simulation, 33 percent of the 36 derailments involving a fire would occur in areas with significant population at risk, 36 × 0.33 = 12 derailments involving a fire and release of a large quantity of flammable liquid in a populated area.

The 12 higher consequence events estimate showing derailments likely to occur in densely populated areas coupled with the most recent Lac-Mégantic accident damage estimate of $1.5 billion[109] in clean-up costs, the value of lost business activity, temporary unemployment of those working at the businesses destroyed, reconstruction costs and other non-fatality damage costs suggest that PHMSA's total damage estimates are very conservative.

4. Cost Uncertainties

In the following sections we present the estimated costs and benefits of the various provisions required by the accompanying Final Rule. It is important to note areas where there are uncertainties regarding the cost estimates described below, and where costs may be over or underestimated. The Table below presents some areas where cost uncertainties exist, and whether the estimates used by the Agency are likely to result in overestimation or underestimation of costs.

Table EB 18: Cost Uncertainties

Cost Area	Direction of Uncertainty		Brief Explanation of cause of uncertainty
	Underestimation	Overestimation	
Number of entities affected by Routing Requirements		X	The Agency believes that the number of smaller railroads (class 3) accounted for in the Routing Analysis (160) below may be significantly overestimated. Examination of the Waybill data indicates that fewer than half the number of small railroads used in the Agency's analysis may in fact haul crude or ethanol. The Agency did not rely on the Waybill data because it is possible that it would underrepresent small carriers, but notes that the actual

[109] The Canadian Government representatives' unofficial estimate. Another source cites the total cost for rebuilding the broken town of Lac-Megantic of $2.7 billion over the next decade, which is four times in size the damage estimate used in PHMSA's analysis: http://www.pressherald.com/2014/04/17/after-end-of-the-world-explosion-lac-megantic-aims-to-rebuild/

Table EB 18: Cost Uncertainties			
Cost Area	**Direction of Uncertainty**		**Brief Explanation of cause of uncertainty**
	Underestimation	**Overestimation**	
			number is likely substantially fewer than 160.
Cost of retiring cars from crude and ethanol service		X	The Agency assumes that cars retired from crude and ethanol service are scrapped, rather than repurposed to other rail service. If demand exists for these cars to haul other commodities, the cost of retiring them from crude and ethanol service would be much lower than the cost of scrapping the cars.
Impact on cars hauling other flammable liquids	X		Based on a review of Waybill Data, the Agency has assumed that only a small number of the cars hauling flammable liquids other than crude and ethanol would have to be retrofitted, because few of these commodities are shipped in carload quantities large enough to meet the definition of a HHFT. If future haul patterns differ from historical patterns and a significant number of the cars used to haul other flammable liquids do in fact have to be retrofit to comply with the requirements of this rule, the Agency may have underestimated the costs associated with this provision of the rule.
ECP brakes assumed to need overlays		X	The Agency has assumed that all cars equipped with ECP brakes would require overlay systems so that they could be used in non-ECP mode. However, cars kept in a unit train dedicated to crude or ethanol service would not necessarily need an overlay system, because so long as the cars are kept together in a single train, they could always operate in ECP mode. Thus, by assuming that all cars equipped with ECP braking would have overlay systems, when some may not, the Agency may have overestimated costs.
Out of service times		X	The Agency has assumed that all cars requiring retrofits would be out of service for 8 – 12 weeks while being retrofit. It is likely that, given the volume of cars involved, that retrofitting

Table EB 18: Cost Uncertainties			
Cost Area	**Direction of Uncertainty**		**Brief Explanation of cause of uncertainty**
	Underestimation	**Overestimation**	
			cars will be streamlined and the total out of service time may be reduced relative to the Agency's estimate. One way that owners and lessors may streamline retrofitting is by aligning a given tank car's retrofit with requalification, which is already required. To the extent that owners and lessors are able to do this, the analysis overestimates costs by including out-of-service time that would already have been needed for requalification.
ECP car reductions		X	The ECP efficiencies allow for a reduction in the number of tank cars required. ECP trains have faster cycle times as they can avoid some brake inspections, can have higher brake ratios, and can maintain ideal track speed. This allows fewer trains to provide the same level of production. In our analysis we estimated that 4,835 fewer new tank cars would not need to be purchased due to the ECP efficiencies. Although a new tank car (Jacketed CPC-1232) costs about $127,000 we only used the incremental difference, $3,000, of the DOT 177 to estimate the cost savings. This provided us a cost saving of $14.5 million. If we had used the true cost of a new Jacketed CPC-1232 tank car the total cost savings would have been $614.0 million.
Speed restriction network effects	X		The Agency estimated the costs from slowing HHFTs to 40 mph in HTUAs, which is based on analysis of a rail subdivision to calculate the costs of slowing down other types of trains on that subdivision. The results of this analysis were extrapolated to the crude oil and ethanol rail corridors, but the analysis does not take into account the possibility that some rail traffic that is affected by the speed limit would be diverted onto trucks or other modes of transit. The analysis also does not account for the possibility of slowing down the network aside from the crude oil and ethanol corridors.

In addition to the above cost uncertainties, at least one rail company – BNSF – has committed to phasing out DOT-111s from shale crude oil service within a year, and transitioning from unimproved CPC 1232 cars used in this service within three years. Voluntary measures taken by companies would reduce the impacts of this rule. Voluntary safety actions and investments also suggest rail companies see potential business benefits by reducing risks and consequences associated with HHFT transport.

VIII. Cost Analysis

In each requirement area the "Actions" are derived from the final rule. The alternatives considered by PHMSA are discussed separately and include a review of the costs for each proposed requirement. PHMSA regards the cost estimates as conservative. In all likelihood, the combined forces of the market and technology may result in costs lower than those forecasted.

Below are some of the revisions made when developing the costs of each alternative under the requirement areas:

1) Increase the number of small railroads impacted by the new routing requirements
2) Adopt separate standards for new tank car construction requirements consistent with Option 2 of the NPRM except for the braking component and retrofit requirements for existing tank cars in accordance with Option 3 from the NPRM (excluding top fittings protection and steel grade)
3) Revise tank-car, retrofit timeline based on comments from RSI and others
4) Revise several tank car costs and include costs for truck upgrades
5) Revise and update the tank car fleet based on expected 2015 deliveries and consultations with Transport Canada
6) Limit the ECP braking requirements to trains composed of 70 or more cars of a Class 3 Flammable liquid travelling at a speed of greater than 30 mph
7) Adjust the estimated cost to equip tank cars with ECP brakes

Update number of offerors of unrefined petroleum-based products based on a recent review of active PHMSA registrations

IX. Final Rule Requirement Areas

The final rule and this RIA have six separate requirement areas:

1) Tank Car Specifications
2) Advanced Brake Signal Propagation Systems
3) Speed Restrictions
4) Routing and Notification Requirements
5) Classification of Unrefined Petroleum-Based Products

A. Requirement Area 1 – Rail Routing

Final Action: PHMSA is requiring the expansion of Hazardous Materials Route Planning and Selection.

PHMSA is requiring rail carriers develop and implement a plan that will result in the use of a safer and more secure route for HHFTs, defined as trains with 20 or more tank cars in a block or 35 or more tank cars throughout the train consist loaded with any Class 3 flammable liquids.

1. Determination of Need

There has been considerable public and Congressional interest in the safe and secure rail routing of security-sensitive hazardous materials. In 2008, PHMSA, in coordination with the FRA and the Transportation Security Administration (TSA), issued a final rule requiring rail carriers compile annual data on certain shipments of explosive, toxic by inhalation (TIH or PIH), and Class 7 (radioactive) materials. The rule also required rail carriers to use the data to analyze safety and security risks along rail routes where those materials are transported; assess alternative routing options; and make routing decisions based on those assessments (73 FR 20752). These requirements were codified at 49 CFR 172.820.

The 2008 rule also requires rail carriers transporting "security sensitive materials" to select the safest and most secure route to be used in transporting those materials, based on the carrier's analysis of the safety and security risks on primary and alternate transportation routes over which the carrier has authority to operate.

The NTSB report of January 23, 2014 states that at a minimum, the route assessments, alternative route analysis, and route selection requirements should be extended to *key trains* transporting large volumes of flammable liquids. NTSB Recommendation R-14-4 recommends that PHMSA should:

Work with the Federal Railroad Administration to expand hazardous materials route planning and selection requirements for railroads under Title 49 Code of Federal Regulations 172.820 to include *key trains* transporting flammable liquids as defined by the Association of American Railroads Circular No. OT-55-N and, where technically feasible, require rerouting to avoid transportation of such hazardous materials through populated and other sensitive areas.

Although Class I rail carriers committed to voluntarily apply routing requirements to trains carrying 20 carloads or more of crude oil as a result of the Secretary's Call-to-Action:

1) The voluntary actions do not extend beyond Class I railroads;
2) The voluntary actions do not apply to all HHFTs;
3) The final routing requirements would provide a check on higher risk routes or companies; and
4) The final routing requirements would ensure that rail carriers continue their voluntary actions in the future.

2. Action by the United States and Canada

U.S. Action

In the NPRM, PHMSA proposed to require rail carriers develop and implement a plan that will result in the use of a safer and more secure route for certain trains transporting high-hazard flammable liquids. Specifically, PHMSA proposed to require rail carriers to comply with the additional safety and security planning requirements prescribed in § 172.820, for HHFTs. Specifically, this would require carriers to perform a routing analysis that considers 27 safety and security factors. The carrier must then select a route based on findings of the route analysis.

In November 26, 2008 PHMSA issued a final rule that required railroads to select a practicable route posing the least overall safety and security risk to transport security sensitive hazardous materials (Docket HM-232E: 73 FR 72182). The final rule implemented regulations requiring railroads to compile annual data of current shipment of explosives, Poisonous by Inhalation (PIH) and Class 7 (radioactive) materials.

The key provisions of the 2008 final rule are:

1) Rail carriers transporting hazardous materials that the Department of Homeland Security deems security-sensitive must annually compile information and data on the commodities transported, including the transportation routes over which these commodities are transported.

2) Rail carriers transporting security-sensitive materials must use the data they compile to annually analyze the safety and security risks for the route(s) used to transport a security-sensitive material. In performing this analysis, the rail carrier must seek relevant information from State, local, and Native American Indian tribal officials, as appropriate, regarding security risks to high-consequence targets and the communities' emergency response capability, along, or in proximity to, the route(s) utilized. Rail carriers also are required to use the data to analyze the safety and security of all practicable alternative routes which the carrier is authorized to use. When determining practicable alternative routes, the rail carrier must consider the use of interchange agreements with other rail carriers and the potential economic effects of using the alternative route. The railroad must also consider any remediation measures implemented on a route. Using this process, the carrier must at least annually review and select the practicable route posing the least risk to safety and security. The initial analysis and route selection must include a comprehensive review of a carrier's entire system. Subsequent analysis and route selection determinations must include:
    - A comprehensive, system-wide review of all operational changes,
    - Infrastructure modifications,
    - Traffic adjustments,
    - Countermeasures,
    - Changes in the nature of high-consequence targets located along, or in proximity to, the route,

- Changes to community response capabilities, or other changes affecting the safety or security of the movements of the security-sensitive materials that were implemented during the calendar year.

Rail carriers are required to maintain a copy (or electronic image thereof) of the data collected and the routing analysis for at least two years and make the records available upon request to authorized officials of the Departments of Transportation and Homeland Security.

3) Rail carriers are required to specifically address the security risks associated with security-sensitive shipments delayed in transit or temporarily stored in transit as part of their security plans.

4) Rail carriers transporting security-sensitive materials are required to notify consignees if there is a significant unplanned delay affecting the delivery of the materials.

5) Rail carriers are required to conduct visual security inspections at ground level of rail cars containing hazardous materials to inspect for signs of tampering or the introduction of an improvised explosive device.

This rule addressed both safety and security concerns associated with the transportation of certain types of hazardous materials, particularly PIH materials. One part of the accompanying final rule would apply these route analysis, rerouting, and safety and security requirements to HHFTs. Because PHMSA believes it is rare that commodities other than crude oil and ethanol are shipped in HHFTs, PHMSA restricted the analysis to crude oil and ethanol, though it is possible that small quantities of other flammable liquids could be attached to such trains.

AAR Recommended Railroad Operating Practices for Transportation of Hazardous Materials

At the time that the rail routing rule was promulgated, the rail industry developed a detailed protocol on recommended railroad operating practices for the transportation of hazardous materials. The AAR issued Circular No. OT-55-I (OT-55-I), on August 26, 2005. OT-55-I detailed railroad operating practices for:

1) Designating trains as *key trains* that contain
    a) Five tank car loads or more of PIH materials,
    b) 20 car loads or intermodal portable tank loads of a combination of PIH, flammable gas, Class 1.1 or 1.2 explosives, and environmentally sensitive chemicals, or
    c) One or more car loads of spent nuclear fuel or high-level radioactive waste;
2) Designating operating speed and equipment restrictions for key trains;
3) Designating *key routes* for *key trains*, and setting standards for track inspection and wayside defect detectors;
4) Yard operating practices for handling placarded tank cars;
5) Storage, loading, unloading and handling of loaded tank cars;
6) Assisting communities with emergency response training and information;
7) Shipper notification procedures; and

8) Handling of time-sensitive materials.

These recommended practices were originally implemented by all of the Class I railroad operating in the United States; short line railroads later joined as signatories.

OT-55-I defined a *key route* as:

> *Any track with a combination of 10,000 car loads or intermodal portable tank loads of hazardous materials, or a combination of 4,000 car loadings of PIH (Hazard Zone A, B, C, or D), anhydrous ammonia, flammable gas, Class I.1 or 1.2 explosives, environmentally sensitive chemicals, Spent Nuclear Fuel (SNF), and High-Level Radioactive Waste (HLRW) over a period of one year.*

Any route defined by a railroad as a *key route* was required to meet the standards contained in OT-55-I. For example, wayside defective wheel bearing detectors should be placed at a maximum of 40 miles apart, or an equivalent level of protection may be installed based on improvements in technology. Main track on *key routes* should be inspected by rail defect detection and track geometry inspection cars or any equivalent level of inspection at least twice each year. Sidings on *key routes* should be inspected at least once a year; and main track and sidings should have periodic track inspections that will identify cracks or breaks in joint bars. Further, any track that is used for meeting and passing *key trains* should be FRA Class II track or higher. If a meet or pass must occur on less than Class II track due to an emergency, one of the trains should be stopped before the other train passes. The rail routing enhancements to the existing security rule partly reflected the recommended practices mentioned above, which were already in wide use across the rail industry.

On August 5, 2013 the AAR released a new Circular OT-55-N which expanded the definition of *key trains* to include any train with 20 or more carloads of any hazardous material.[110] That circular placed the following restrictions on such "key trains" which would include any train with 20 or more cars of flammable liquids:

1) Maximum speed - *Key Train* - 50 MPH
2) Unless siding or auxiliary track meets FRA Class II standards, a *key train* will hold main track at meeting or passing points, when practicable.
3) Only cars equipped with roller bearings will be allowed in a *key train*.
4) If a defect in a *key train* bearing is reported by a wayside detector, but a visual inspection fails to confirm evidence of a defect, the train will not exceed 30 mph until it has passed over the next wayside detector or delivered to a terminal for a mechanical inspection. If

[110] Available online at http://www.boe.aar.com/CPC-1258%20OT-55-N%208-5-13.pdf

the same car again sets off the next detector or is found to be defective, it must be set out from the train.

In addition to applying a 50-mph speed limit to HHFTs, which is already in effect due to universal compliance with Circular OT-55-N, this final rule would incorporate the route analysis and rerouting requirements, as well as the safety and security requirements described above as part of HM-232E to HHFTs. The cost of route analysis and rerouting for PIH trains was considered in 2008 in the regulatory evaluation accompanying the final rule.

Canadian Action

On April 23, 2014, Transport Canada issued an Emergency Directive requiring all companies to complete a risk assessment by October 23, 2014. The risk assessment must determine the level of risk associated with each "*key route* over which a *key train* is operated by the company." Specifically, the risk assessment must:

1) Identify safety and security risks associated with that route, including the volume of goods moved on that route, the class of track on that route, the maintenance schedule of the track on that route, the curvature of the track on that route, the environmentally sensitive or significant areas along that route, the population density along that route, emergency response capability along that route and the areas of high consequence along the route;
2) Identify and compare alternative routes for safety and security; and
3) Factor potential or future railway operational changes such as new customers moving good subject to an Emergency Response Assistance Plan under the Transportation of Dangerous Goods Act or municipal changes due to population growth, for routing restrictions.

3. Specific Comments

In general, the comments received regarding the proposed routing requirements in the NPRM are regarding the impact of the definition of HHFTs. The American Short Line and Regional Railroad Association (ASLRRA) commented that the number of short rail line carriers that would be affected by this final rule should be at least 160 instead of 64 as estimated in initial RIA. PHMSA revised the estimated costs with the routing requirements in this rule to account for the updated number of short line carriers impacted by the requirement.

4. Rail Routing Alternatives

Status Quo

Route planning and route selection provisions currently required for explosive, PIH, or Class 7 (radioactive) materials are not required for HHFTs. If the final rule is not adopted, railroads would not be required to conduct route risk analysis nor are they required to reroute shipments over lower-risk routes. Specific identified criteria for the route and alternate route analyses may not be uniformly considered by all railroads, and written analyses of primary and alternate routes

including safety and security risks would not be required. Due to the definition of an HHFT we expect the impact is on HHFTs of crude oil and ethanol. While the railroads are expected to continue voluntarily implementing these measures for crude oil, they have not made a similar commitment for ethanol trains (though PHMSA believes some of them may do so). The costs to society, the government, and the rail industry of an accident involving large shipments of flammable liquids are high. If no action is taken, the threat of catastrophic accidents in large populated areas or other sensitive environments will continue.

Apply Routing to HHFTs

This alternative would apply safety and security routing assessments and rerouting to HHFTs. Railroads would be required to assess current routing of these trains as well as practical alternative routes. Railroads would have to choose the lowest risk practical route to move HHFTs. This alternative focuses the routing requirements on the flammable liquid shipments that pose the greatest risk to public safety.

5. Rail Routing Requirement Cost-Benefit Analysis

As discussed above, on February 21, 2014 the AAR committed to apply the existing routing requirements described above to unit trains with 20 or more carloads of crude oil. Class I railroads have signed on to this agreement, and will voluntarily apply routing requirements to trains carrying 20 carloads or more of crude oil. Since the Class II and III railroads have not signed on to this commitment, the short lines would not voluntarily apply the route analysis requirements to HHFTs, and hence would bear costs associated with analyzing their networks, identifying alternative routes, and rerouting shipments along lower-risk routes where practicable. However, in practice, Class II and III railroads would bear little, if any, cost because much of the work to identify safest routes has already been done in compliance with the previous regulation. In addition, most short line railroads operate along a small number of corridors – often only one – and would therefore not have practical alternative routes for HHFTs. These limited networks also mean that analyzing primary and alternative routes would be a minor task with modest cost for Class III railroads. As a result, we assume that the costs associated with this requirement would modest for Class II and III railroads.

The final rule applies routing requirements to trains with 20 tank cars in a block or 35 tank cars throughout the train consist loaded with any Class 3 flammable liquids. The AAR voluntary commitment only covers crude oil shipments, which leaves open the question of whether any additional burden would be imposed on the requirement to apply route analysis and rerouting to all HHFTs. PHMSA believes that the cost of covering HHFTs containing all flammable liquids, given that railroads are already analyzing their networks to identify lower risk routes for PIH and crude oil shipments, would be minimal. The requirement imposed by these regulations is to analyze the entire network to identify lower risk routes. As described in the HM-232E RIA, the per-carrier costs associated with this analysis depend on the size of a carrier's network, which determined the number of primary and alternative routes that must be analyzed. The total costs are influenced by the number of carriers affected – i.e., the number of carriers that haul crude oil and ethanol.

PHMSA believes that all Class I railroads who haul ethanol also haul these other high-hazard materials. As a result, the inclusion of HHFTs containing ethanol would not result in an increase in the number of routes that would have to be analyzed, nor the number of carriers who would have to analyze these routes to identify lower-risk alternatives. Since these networks are already being analyzed to identify lower risk routes for PIH and HHFTs containing crude oil, we believe that only a minimal amount of additional work, resources, or costs would be imposed by the additional requirement of covering high-hazard ethanol trains under these requirements.

Routing Requirement Costs

Costs associated with the routing requirements of this final rule include costs for collecting and retaining data and performing the mandated route safety and security analysis if not already in place. When necessary, off-the-shelf software is available to perform routing assessments. There could be additional fuel, maintenance, or shipment time if the analysis reveals a need to reroute high-hazard flammable liquid trains that result in increased mileage.

The costs associated with gathering data and analyzing that data using these new requirements are modest. Rail carriers and shippers may incur costs associated with rerouting shipments or mitigating safety and security vulnerabilities identified because of their route analyses. However, because this final rule builds on the current route evaluation and routing practices already in place for most, if not all, rail carriers that transport the types of hazardous materials covered, we do not expect rail carriers to incur significant costs associated with rerouting. The rail carriers already conduct route analyses and re-routing that provides results in line with what this final rule is making a standard practice (in accordance with AAR Circular OT-55-N).

The analysis for the HM-232E final rule attributed minimal costs for rerouting shipments to lower risk routes. At the time of publication, PHMSA asked for comment on whether rerouting shipments covered under the new final rule would impose an undue burden on the industry, and did not receive any adverse comments on the issue. As a result, PHMSA did not modify the assumption that rerouting would impose little if any cost on shippers or rail carriers. PHMSA and FRA make the same assumption for HHFTs in this final RIA.

There is evidence that this assumption is reasonable. First, the industry has voluntarily agreed to apply these same routing requirements to HHFTs containing crude oil, which implies that rerouting does not impose a significant burden or at least that the burden does not significantly exceed the carriers' own expected safety benefits from rerouting. Second, no rerouting would be required if no practical alternative route is available. As noted above, the industry has not expressed concern on this issue in past rulemaking actions. Thirdly, the routing provisions require the rail carriers to consider various factors when selecting route including length of trip. As trip length increases, the exposure to the risk of derailment increases. A shorter route is a safer route, all other things held equal. Rail carriers are required to consider these factors when routing the types of hazardous materials covered under the previous rulemaking, and make the results of their routing plans available for review. In reviewing these plans, PHMSA and FRA observed little if any increase in total shipment mileage because of complying with this requirement.

Therefore, it seems unlikely that mileage or shipping time increases would impose significant costs if routing requirements were applied to HHFTs containing ethanol. Finally, a rail simulation study found that substantial risk reduction (reductions in either the likelihood or severity of an event) could be achieved through rerouting with very modest increases in shipment mileage. As a result, PHMSA did not attribute costs for rerouting of ethanol shipments in this analysis.[111]

In 2008, PHMSA estimated the cost of compliance with the routing final rule based on the size of the company. In this analysis, Class I and regional railroads (Class II) were considered "large railroads" and Class III railroads are considered "small railroads." There are seven Class I railroads, 10 regional railroads, and more than 500 small railroads.[112] Based on that information PHMSA estimated that only 64 short haul rail carriers haul shipments of flammable liquids large enough to fall under the final rule. ASLRRA commented that there would be at least 160 short haul rail carriers instead. Based on this comment PHMSA revised the estimated costs with the routing requirements in this rule accordingly. Table R1 displays the number and size of rail carriers subject to additional routing requirements in the final rule.

Table R1: Rail Carriers Subject to Routing Requirements
Number of Affected Rail Carriers by Size
17 Large Rail Carriers
160 Small Rail Carriers
177 Total Rail Carriers

As a result of the February 21, 2014, commitment to apply routing requirements to trains with 20 or more carloads of crude oil, no costs are attributed to Class I railroads for developing routing plans for crude oil shipments. PHMSA believes Class I railroads may already be applying route analysis to ethanol shipments despite the absence of a requirement or commitment to do so. Even if this is not the case, we believe there would be a minimal cost to add ethanol to routing analysis for crude oil. As a result, we attribute no additional cost to Class I railroads to comply with these requirements.

Since the Class II and III railroads have not signed on to this commitment, we assume Class II and III railroads would not voluntarily apply the route analysis requirements to HHFTs, and hence would bear costs associated with analyzing their networks, identifying alternative routes, and rerouting shipments along lower-risk routes where practicable. In practice, Class II and III railroads would bear modest costs because much of the work to identify safest routes has already

[111] Glickman, Erkut, and Zschocke. 2007. The cost and risk impacts of rerouting railroad shipments of hazardous materials. Accident Analysis and Prevention. 39. 1015-1025.

[112] 'Railroad Facts', Association of American Railroads, 2004, p.3.

been done in compliance with the previous regulation. In addition, most short line railroads operate along a small number of corridors – often only one – and would therefore not have practical alternative routes for HHFTs. These limited networks also mean that analyzing primary and alternative routes would be a minor task.

The labor rate used to estimate costs was $38.17. This labor rate is a combination of two employee groups listed in the Bureau of Labor Statistics May 2013 Industry-Specific Occupational Employment and Wage Estimates.[113] The two employee groups used were NAICS 482000-Rail Transportation occupational code 11-0000 "Management Occupations" and occupation code 43-6011 "Executive Secretaries and Executive Administrative Assistants." To calculate the hourly wage rates for every year of the analysis PHMSA took into consideration an estimated 1.18 percent annual growth rate in median real wages. [114] After inflating the average hourly wage of $38.17 by 1.18 percent, we calculated an average hourly wage of $38.62 in 2014. PHMSA then inflated this wage by 60 percent to account for fringe benefits and overhead of $23.17 per hour, for a total weighted hourly wage of $61.80 in 2014. Following the same series of calculations (and holding the fringe benefit constant at $23.17), the total weighted hourly wage in 2015, the first year of the analysis, was estimated at $62.25. The resulting average hourly wage rate calculated for the subsequent years of the analysis (years 2-20) is $67.21.

PHMSA developed costs analogously to how they were estimated during the HM-232E rulemaking.

The final rule's routing section requires rail carriers to use the data to analyze the safety and security risks for the transportation route(s) used to transport HHFTs on an annual basis. Rail carriers also must analyze this data to establish the primary HHFT routes, analyze its rail network, consider 27 risk factors, and reassess these risks and routing decisions annually. We assumed that the initial incorporation of HHFTs into route analysis would be more resource intensive than assessments in later years. This assumption was based on the belief that limited changes in rail networks make the task of assessing alternative routes and safety risks easier in later years than in the initial year.

Annual Data Collection by Line Segment

As previously noted, the final rule requires a rail carrier transporting HHFTs to use the data it compiles to annually analyze the safety and security risks for the transportation route(s) used to by these trains. In performing this analysis the rail carrier must consult with state, local, and

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[113] Available online at http://www.bls.gov/oes/current/oessrci.htm

[114] Based on real wage growth forecasts from the Congressional Budget Office, DOT's guidance estimates that there will be an expected 1.18 percent annual growth rate in median real wages over the next 30 years (2013-2043). The wage rate in 2014 is calculated as follows: $\$38.17 * 1.0118 + \$38.17 * 1.0118 * 0.6 = \$61.80$.

tribal officials, as appropriate, regarding security risks to high-consequence targets, countermeasures already in place, and the community emergency response capability along, or in proximity to, the route(s) utilized.

Hazmat shipment data is readily available to large railroads. Because small railroads do not frequently carry the hazardous materials addressed in this final rule, they may know exactly what commodities they carry and when. Small railroads that carry hazmat less frequently may not have electronic data and may have to physically search their records for this information. Both large and small railroads are assumed to require 40 hours to collect the data with which they analyze routes. This data would consist of collecting waybill data on the commodities covered by the requirement, examining origins and destinations for these shipments, identifying the routes over which these commodities travel, and identifying viable alternative routes. In addition, information on the safety characteristics of current routes and alternatives would have to be collected. This data includes population densities, derailment rates, track class, etc. These costs reoccur annually. The table below presents the estimated costs for this task for Year 1. [115]

Table R2: Annual Data Collection by Rail Group

Annual Data Collection by Rail Group

Railroad size	Number of Railroads in Class Affected	Max. No. of Hours	Hourly Labor Rate	Max. No. of Hours x Hourly Labor Rate
Class I	0	0	$0.00	$0
Class II	10	40	$62.25	$24,901
Class III	160	40	$62.25	$398,422
			Total:	$423,323

Primary Safety and Security Route Analyses: Year 1

The primary route analyses conducted in year 1 will cost more than the analyses done in subsequent years. The cost estimates presented here may overestimate costs for this requirement because, as mentioned above, much of the analytical work has already been done to comply with previous routing requirements.

An important determinate of costs is the number of routes that must be analyzed. An example of a route is a major corridor. In general, large railroads carry hazmat farther distances than small railroads. Therefore, the large railroads are estimated to have more routes per carrier than the small railroads. It is also anticipated that large railroads will have more complex route analyses to perform. In this analysis, PHMSA assumed that the small railroads, due to their limited size, would typically have no less than one and no more than two primary routes to analyze.

[115] From 2016 to 2034, the total cost of annual data collection is equal to $8,683,304.

Therefore, for 160 small railroads, there is a maximum of 320 primary routes to be analyzed. Because the distance covered by the small railroads' routes is likely contained within a limited geographic region, the hours estimated for analyses are fewer than those estimated for the larger railroads.

The number of routes and hours were used to estimate this cost element to ensure that full costs for developing route analyses and choosing alternative routes is captured. PHMSA assumed in its analysis that the railroads will consider each major corridor as a single route to minimize the number of routes analyzed. The rule does not mandate how the railroads identify each route, but it is reasonable to assume that railroads will use economic best practices. The initial analysis and route selection must include a comprehensive review of a carrier's entire system and include mitigation measures that the carrier intends to implement to increase the safety and security of the route(s).

Class II railroads are more likely to have several primary routes; Class III railroads operate over less track mileage. The Class II railroads analyze all alternate routes to determine, given the operation knowledge of the carrier, the route of a particular shipment on a particular day. Class II railroads are estimated to have a maximum of 50 routes combined. Class III railroads are estimated to have a maximum of 320 routes. These numbers are high and are not intended to suggest that this number of major corridors exist. The numbers are representative of all possible routes for the commodities included in this final rule. These numbers represent existing track infrastructure and are overstated to account for further unexpected route changes and potential acquisitions that may or may not occur.

Class II railroads are estimated to require 80 hours per route to conduct the initial analysis of primary routes. A Class III railroad is estimated to require 40 hours per route. PHMSA calculated total costs for analyzing routes for each class of railroad by multiplying the number of routes by the number of hours required to analyze a route and the calculated labor rate. These costs are presented in the table below.

Table R3: Year 1 Costs of Safety and Security Route Analyses

Primary Route Analysis by Rail Group – Year 1

Railroad Size	Number of Railroads in Class Affected	Number of Routes	Number of Hours per Route	Labor Rate	Number of Routes * Hours * hourly labor rate
Class I	0	0	0	$0.00	$0
Class II	10	50	80	$62.25	$249,014
Class III	160	320	40	$62.25	$796,843
				Total:	$1,045,857

Annual Primary Safety and Security Route Analyses: Years 2-20

After the first year's route analyses are completed, PHMSA expected that analyses performed on the same routes in subsequent years would take less time. We anticipated that the majority of the routes analyzed in year 1 would continue to be used in future years. Therefore, these routes

would require only a review to ensure there have been no changes or planned mitigation measures that would affect the analyses in the future years. It was also assumed that there would be few changes in the high-consequence facilities located along or in proximity to these routes. It was further assumed that the railroads would experience some change in commodity flow that will affect their primary routes each year. However, a learning curve is anticipated. For these reasons, the primary route analyses would be conducted annually, but each subsequent year would take less time.

Rail companies would analyze the same number of routes in later years as described above in the initial year analysis section. PHMSA estimated that a Class II railroad would require 16 hours per route to update route analyses on an annual basis. PHMSA estimated that a Class III railroad would require eight hours per route. The cost estimates for subsequent year analyses are calculated in the same manner as the initial year. The cost estimates for this task are presented in the table below.

Table R4: Years 2-20 Costs of Safety and Security Route Analyses
Route Analysis by Rail Group

Railroad Size	Number of Railroads in Class Affected	Number of Routes	Number of Hours per Route	Number of Routes x Hours x Hourly Labor Rate
Class I	0	0	0	$0
Class II	10	50	16	$1,021,565
Class III	160	320	8	$3,269,009
			Total:	$4,290,574

Alternate Route Economic, Safety, and Security Analyses: Year 1

As previously noted, the final rule requires a rail carrier operating HHFTs to use the data it compiles to annually analyze the safety and security risks for all practicable alternative routes which the carrier is authorized to use. When determining practicable alternative routes, the rail carrier would consider the use of interchange agreements with other rail carriers. We expect that rail carriers would also consider the potential economic effects of using the alternative route, including, but not limited to, the economics of the commodity, route, and customer relationship. The rail carrier would also consider any remediation measures it intends to implement on a route. Using this process, the carrier would be required, at least annually to compare the safety and security risks on the primary and alternative routes and select the practicable route posing the least risk to safety and security.

When selecting a primary route for the transport of hazmat, rail carriers normally analyze all routes they consider commercially and economically practicable. As stated previously, large rail carriers are more likely to have alternate routes than smaller rail carriers, which operate over fewer tracks. The larger rail carriers analyze all practicable alternate routes to determine, given the operational knowledge of the rail carrier, the route of a particular shipment on a particular day. The average number of practicable alternate routes analyzed by Class II railroads is four per railroad. Larger rail carriers, Class I and Class II, carry hazardous materials farther distances than smaller, Class III railroads. A practicable alternate route may not be available in many

instances to a Class III railroad. This analysis conservatively assumes that half of the Class III railroads have practicable alternate routes resulting in 80 routes to analyze.

Class II railroads are estimated to require 120 hours to analyze each alternate route in the initial year for incorporation of HHFTs into routing plans. A Class III railroad is estimated to require 40 hours per alternate route. PHMSA calculated total costs for analyzing routes for each class of railroad by multiplying the number of routes by the number of hours required to analyze a route and the calculated labor rate. These figures are presented in the table below.

Table R5: Alternate Route Analyses by Rail Group– Year 1

Railroad Size	Number of Railroads in Class Affected	Number of Routes	Number of Hours per Route	Labor Rate	Number of Routes * Hours * Hourly Labor Rate
Class I	0	0	0	$0.00	$0
Class II	10	40	120	$62.25	$298,816
Class III	160	80	40	$62.25	$199,211
				Total:	$498,027

Alternate Route Economic, Safety, and Security Analyses: Years 2-20

Subsequent alternative route analysis would include:

- A comprehensive, system-wide review of all operational changes;
- Infrastructure modifications;
- Traffic adjustments;
- Changes in the nature of high-consequence targets located along, or in proximity to, the routes; and
- Any other changes affecting the safety or security of the movements of HHFTs that were implemented during the calendar year, as well as mitigation measures the carrier intends to implement.

Performing the alternate route analyses in years 2 through 20 is assumed to require 10 percent of the time the first year's route analyses required. This is based on estimates of limited changes in commodity flow or shipment volume and other changes that would affect practicable alternative routes to the primary route. The previously analyzed alternate routes will require some review to ensure there have been no changes that would affect the analyses in the future years; however, a learning curve is anticipated. These costs are presented in the table below.

Table R6: Alternate Route Analyses by Rail Group – Years 2-20

Railroad Size	Number of Railroads in Class Affected	Number of Routes	Number of Hours per Route	Number of Routes * Hours * Hourly Labor Rate
Class I	0	0	0	$0
Class II	10	40	12	$612,939
Class III	160	80	4	$408,626
			Total:	$1,021,565

Routing Requirements Total Cost

The table below presents total estimated costs for this final rule over 20 years. These costs reflect the resources required to collect data, analyze current shipping routes for HHFTs, and identify alternative routes, where feasible, that lower the overall risk of transporting this hazardous material. The annual costs for this requirement are shown in Table R7 and the annual cost of this requirement by railroad class is shown in Table R8. The total cost over 20 years will be $12,084,292 at 3 percent discount rate and $8,846,214 at 7 percent discount rate.

Table R7: Annual Costs of Routing
Costs of Regulation by Year

Year	Costs
1	$1,967,207
2	$687,351
3	$692,465
4	$697,639
5	$702,874
6	$708,171
7	$713,530
8	$718,953
9	$724,439
10	$729,991
11	$735,607
12	$741,291
13	$747,041
14	$752,859
15	$758,745
16	$764,702
17	$770,728
18	$776,826
19	$782,995
20	$789,237
Total:	$15,962,650
Present Value at 3% Discount Rate:	$12,084,292
Present Value at 7% Discount Rate:	$8,846,214

Table R8: Annual Cost of Routing Regulation by Railroad Class

Year	Class II	Class III
1	$572,731	$1,394,476
2	$105,360	$581,991

Table R8: Annual Cost of Routing Regulation by Railroad Class		
3	$106,144	$586,321
4	$106,937	$590,702
5	$107,740	$595,134
6	$108,552	$599,619
7	$109,373	$604,157
8	$110,204	$608,748
9	$111,045	$613,394
10	$111,896	$618,094
11	$112,757	$622,850
12	$113,629	$627,662
13	$114,510	$632,531
14	$115,402	$637,457
15	$116,304	$642,441
16	$117,217	$647,485
17	$118,141	$652,587
18	$119,075	$657,750
19	$120,021	$662,974
20	$120,978	$668,259
Total	$2,718,018	$13,244,632
3% Discount Rate	$2,115,627	$9,968,666
7% Discount Rate	$1,609,436	$7,236,778

Routing Requirement Benefits

As noted above, Glickman et al analyzed the risk reduction benefits that might be achieved by rerouting hazardous material rail shipments to lower risk routes using a rail simulation model.[116] The authors found that substantial risk reductions could be obtained for modest or no increase in shipment mileage. In some cases, their modeling identified lower-risk routes that actually decreased mileage. Obtainable risk reductions vary depending on the shipment's origin and destination, but the aggregate conclusion for all routes analyzed was that a 22 percent risk reduction could be obtained with an increase of roughly 5 percent in total shipment mileage.

It is important to note that risk can be minimized practically in two ways: one is to run shipments over the highest-quality track, i.e. track that poses the lowest risk for derailment, collision, or other train accident. The other way risk can be reduced is to reduce exposure to train accidents.

[116] Glickman, Theodore S. Erkut, Efhan, and Zschocke, Mark S. 2007. The cost and risk impacts of rerouting railroad shipments of hazardous materials. Accident Analysis and Prevention. 39. 1015-1025.

Rerouting can address either or both of these risk factors, but in some cases, one factor must be traded off against another.

For instance, rail track may be better maintained in areas of high population density; therefore, accidents may be more likely in a rural area. However, should a hazardous material train accident occur in a high population area, the consequences might be much more severe consequences than in a less populous area because more people are at risk of exposure, injury, or death. In addition property value loss and the amount of infrastructure that may be destroyed is much higher in urban, high population areas.

This final rule requires railroads to balance these factors to identify the route that poses the lower risk. In some cases, rail carriers might choose a route that eliminates exposure in areas with high population densities but poses a risk for more frequent events in areas with low population densities. In other cases, the risk of derailment may be so low along a section of track that, even though it runs through a densely populated area, it poses the lowest total risk when severity and likelihood are considered. Glickman's estimate of safety improvements achievable by routing changes is based on an examination of how routing might vary as a rail carrier applies progressively heavier weights on various safety factors. In practice, it is impossible to know how much weight rail carriers will give to safety when making routing decisions. As noted above, based on past routing plans submitted by rail carriers to FRA for approval, application of the routing requirements resulted in modest changes to company routing decisions. It is therefore unclear to what extent these requirements would improve safety. However, even if very small, reductions in the risk of an adverse event due to the improved routing of HHFTs could produce benefits that outweigh the costs. For example, our current estimate of the total undiscounted lower-consequence damages of crude and ethanol derailments over the coming 20 years is expected to be approximately $4.1 billion.

PHMSA conducted a break-even analysis in Table R9 based on the estimated damages from lower-consequence events. Table R10 shows the prevented damages at the break-even point over the 20 years.

Table R9: Break-even Analysis

	Estimated Damages (in millions)	**Costs of Regulation (in millions)**	**Break-even Effectiveness Rate**
Undiscounted	$4.093	$16	0.39%
PV 3%	$3,037	$12	0.40%
PV 7%	$2,152	$9	0.41%

Table R10: Prevented Damages at the Break-even Point		
Year	**Total Lower-consequence Benefits – Routing - 3% discounted**	**Total Lower-consequence Benefits – Routing - 7% discounted**
2015	$694,855	$691,326
2016	$661,538	$633,573
2017	$665,388	$613,438
2018	$693,923	$615,829
2019	$715,359	$611,120
2020	$737,959	$606,859
2021	$720,313	$570,204
2022	$700,478	$533,774
2023	$636,217	$466,682
2024	$662,372	$467,704
2025	$641,565	$436,077
2026	$611,263	$399,949
2027	$545,047	$343,292
2028	$557,807	$338,195
2029	$531,933	$310,451
2030	$506,434	$284,520
2031	$483,002	$261,212
2032	$460,143	$239,546
2033	$439,214	$220,103
2034	$419,483	$202,357
Total	$12,084,292	$8,846,214

To break even, the routing requirement must achieve an effectiveness rate of 0.40% and 0.41% to be beneficial (the benefits would outweigh estimated costs, excluding the costs of added shipping miles) at three percent respectively seven percent discount rates. PHMSA believes this requirement would achieve at least that level of effectiveness.

Route planning and route selection provisions currently required for explosive, PIH, or radioactive materials are not required on HHFTs. Although crude oil carriers took voluntary actions, codifying the Secretary's Call-to-Action is necessary. Codification is also a check on higher-risk routes or companies. There is nothing in place/no incentive to require continued compliance with voluntary actions.

If the final rule is not adopted, railroads would not be required to conduct route risk analysis nor would they be required to reroute shipments over lower-risk routes. Specific identified criteria for the route and alternate route analyses may not be uniformly considered by all railroads, and written analyses of primary and alternate routes including safety and security risks would not be

required. The costs to society, the government, and the rail industry of an accident involving a HHFT are high. If no action to better evaluate routing decisions, the threat of catastrophic accidents in large populated areas or other sensitive environments will continue.

B. Requirement Area 2 – Tank Car

Final Action: PHMSA is requiring Option 2 car required for new construction, Option 3 car for retrofits

PHMSA is requiring new tank cars constructed after October 1, 2015 used to transport Class 3 flammable liquids in an HHFT to meet either:

1) The prescriptive standards for the DOT-117 tank car, which is consistent with Option 2 of the NPRM except for the braking component;

or

2) The performance standards for the DOT-117P tank car.

In this final rule, we are also adopting retrofit requirements for existing tank cars in accordance with proposed Option 3 from the NPRM (excluding top fittings protection and steel grade). If existing cars do not meet the retrofit standard, they will not be authorized for use in HHFT service after the deadlines specified within the adopted risk-based implementation timeline. This in effect adopts different constructions standards for new and retrofitted cars used in an HHFT.

1. Determination of Need

DOT conducted research on long-standing safety concerns regarding the survivability of the DOT-111 tank cars designed to the current HMR and used for the transportation of crude oil and ethanol. The research found that special consideration is necessary for the transportation of crude oil and ethanol in DOT-111 tank cars, especially when a train is configured as a HHFT. It is not possible to eliminate the probability that an accident involving multiple tank cars will occur. However, the increased number of trains consisting of a large number of tank cars carrying flammable liquid poses an emergent safety risk, as described above.

We estimate that there are approximately 335,000 tank cars (pressure and non-pressure) in today's fleet, of which 272,000 are DOT-111 tank cars. Of those 272,000, approximately 86,000 tank cars are used to transport ethanol or crude oil. Major derailments often result in the release of hazardous materials, the severity of these accidents depends on the weight of a tank car, train speed, and the volume of hazardous materials transported. In published findings from the June 19, 2009, train accident in Cherry Valley, Illinois, the NTSB indicated that the DOT-111 tank car

can usually be expected to breach in the event of a derailment resulting in car-to-car impacts or pileups.

Modeling and simulation of the puncture of DOT-111 tank cars currently used to transport ethanol or crude oil indicate that when struck at a velocity of approximately 7.4 mph at the longitudinal center of the tank shell with a rigid 12" x 12" indenter with a weight of 297,000 pounds, DOT-111s will result in a puncture.[117] Validation of this model has been accomplished using the results of puncture tests performed at the Transportation Technology Center in Pueblo, CO. Further, based on modeling and simulation, the head of an unjacketed DOT-111 tank car will puncture at 7.6 mph when struck with a 12" x 12" indenter weighing 286,000 pounds. Table TC2 provides the tank car shell and head puncture velocities of the DOT-117 tank car Options proposed. Similar to the methodology for estimating the effectiveness of new cars, PHMSA used the calculated puncture velocities to arrive at risk reduction estimates for retrofits. As discussed below and in the NPRM, these data show that the DOT-111 is significantly more likely to puncture than the proposed alternatives.

All of the tank car options were designed to address the survivability of the tank car and would mitigate the damages of rail accidents better than the current DOT-111. Specifically, the tank car options incorporate several enhancements in order to increase puncture resistance; provide thermal protection to survive a 100-minute pool fire; and protect bottom outlets during a derailment. Under all options, the system of design enhancements would reduce the consequences of a derailment of tank cars carrying flammable liquids. There would be fewer car punctures, fewer releases from the service equipment (top and bottom fittings), and delayed and reduced volumes of flammable liquid releases through the pressure relief devices.

2. Proposed Tank Car Specification Requirements

PHMSA proposed three options for newly manufactured DOT-111 tank cars to address the risks associated with HHFTs. In addition, we proposed to allow for tank cars to meet a performance standard equivalent to the selected prescribed tank car standard, which could be accomplished by designing a new car or retrofitting existing DOT-111 tank cars. The changes stipulate a new tank car prescribed and performance tank car—the DOT-117 tank car—that will be phased in over time depending on the Packing Group of the flammable liquid. The provisions allow for tank cars to meet a performance standard equivalent to the DOT-117, which could be accomplished by retrofitting existing DOT-111/CPC-1232 tank cars. Cars that meet the DOT-117 performance standard would be designated DOT-117P.

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[117] "Detailed Puncture Analyses Tank Cars: Analysis of Different Impactor Threats and Impact Conditions" can be found at: http://www.fra.dot.gov/eLib/details/L04420

The following shorthand is used to denote the various car configurations being discussed throughout this document:

1) Non-Jacketed DOT-111 cars: DOT-111NJ
2) Jacketed DOT-111 cars: DOT-111J
3) Non-Jacketed CPC-1232 cars: CPC-1232NJ
4) Jacketed CPC-1232 Cars: CPC-1232J
5) Jacketed CPC-1232 car with an enhanced bottom outlet valve handle and higher-capacity pressure relief valve (enhanced CPC-1232 J or Option 3 tank car)
6) Tank car with 9/16^{ths} inch shell thickness, jacket, full height head shields, thermal protection, enhanced bottom outlet valve handle and high capacity pressure relief valve: AAR 2014 tank car or Option 2 tank car
7) Tank car with all of the above, rollover protection, and ECP brakes (PHMSA FRA tank car or Option 1 tank car)

Three options were considered at the NPRM stage: 1) Universal retrofitting to the Option 1 tank car standard, 2) universal retrofitting of the fleet to the Option 2 standard, and 3) universal retrofitting of the fleet to the Option 3 standard. The final rule that this document accompanies establishes a hybrid approach with one standard for retrofit cars and another for cars that are newly constructed after the date established by the final rule. The retrofit standard requires that cars must perform at a level equivalent to a 7/16ths-inch CPC-1232 car with a jacket, thermal protection, and full height head shields – the Option 3 car. New cars would be built to the AAR standard – the Option 2 car or the performance equivalent of this car. This hybrid approach was supported for by the industry commenters. It ensures that the retrofit standard is technically feasible, and establishes a safer tank car standard for new builds. The estimated costs in this chapter have been adjusted to reflect this change.

Under the HMR, the offeror must select a packaging that is suitable for the properties of the material. The DOT-111 tank car is one of several cars authorized by the HMR for the rail transportation of hazardous materials. The DOT-111 tank car, which can be jacketed or non-jacketed, is the tank car most often used for almost all crude oil and ethanol shipments by rail.

Table TC1: Current Authorized Tank Cars[118]		
Flammable Liquid, PG I	**Flammable Liquid, PG II and III**	**Combustible Liquid**
DOT 103	DOT 103	DOT 103
DOT 104	DOT 104	DOT 104
DOT 105	DOT 105	DOT 105
DOT 109	DOT 109	DOT 109
DOT-111	DOT-111	DOT-111
DOT 112	DOT 112	DOT 112
DOT 114	DOT 114	DOT 114
DOT 115	DOT 115	DOT 115
DOT 120	DOT 120	DOT 120
	AAR 206W	AAR 206W
		AAR 203W
		AAR 211W

In 2011, AAR issued Casualty Prevention Circular (CPC) 1232, which outlines industry requirements for DOT-111 tanks ordered after October 1, 2011, intended for use in ethanol and crude oil service. This construction was approved by FRA on January 25, 2011 – see the Background below for a detailed description of the PHMSA and FRA actions allowing construction under CPC-1232). The key tank-car requirements contained in CPC-1232 include the following:

1) PG I and II material tank cars to be constructed to AAR Standard 286; AAR Manual of Standards and Recommended Practices, Section C, Car Construction Fundamentals and Details, Standard S-286, Free/Unrestricted Interchange for 286,000 lb. Gross Rail Load (GRL) Cars (AAR Standard 286);
2) Head and shell thickness must be 1/2 inch for TC-128B non-jacketed cars and 7/16 inch for jacketed cars;
3) Shells of non-jacketed tank cars constructed of A5l6-70 must be 9/16 inch thick;
4) Shells of jacketed tank cars constructed of A5l6-70 must be 1/2 inch thick;
5) New cars must be equipped with at least 1/2 inch, half-height head shields;
6) Heads and shells must be constructed of normalized steel;
7) Top fittings must be protected by a protective structure as tall as the tallest fitting; and
8) A reclosing pressure relief valve must be installed.

[118] Additional information on tank car specifications is available at the following URL: http://www.bnsfhazmat.com/refdocs/1326686674.pdf

The CPC-1232 is a voluntary industry improvement on the DOT-111. The technical background for its safety features, as well as the proposed safety features in the three tank car options, are described more fully in the preamble to the final rule.

PHMSA is requiring new tank cars constructed after October 1, 2015 to meet the new design or performance standard, if those tank cars are used as part of an HHFT. The retrofit schedule for existing tank cars to an enhanced CPC-1232 standard (Option 3 tank car) when used as part of an HHFT is presented in the following table:

Table TC2: Final Rulemaking: Implementation Timeline based on Recommendations from Public Comments

Tank Car Type / Service	Retrofit Deadline	Estimate of Tank Cars Retrofitted
Non-Jacketed DOT-111 tank cars in PG I service	December 2017 (33 months)	11,637
Non-Jacketed DOT-111 tank cars in PG II service	April 2020 (61 months)	18,493
Jacketed DOT-111 tank cars in PG I and PG II service	November 2020 (68 months)	2,356
Non-Jacketed CPC-1232 tank cars in PG I and PG II service	June 2023 (99 months)	15,895
Jacketed CPC-1232 tank cars in PG I, PG II service, and all remaining tank cars carrying PG III materials in an HHFT (pressure relief valve and valve handles).	April 2025 (121 months)	24,933
Assumes an April 1, 2015 publication date and the retrofit deadline is last day of month indicated. Actual dates will vary depending on publication date.		

The retrofit schedule has been lengthened significantly in response to industry comments regarding the feasibility of completing retrofits under the timelines proposed at the NPRM stage.

The final schedule for when retrofits have to be completed is presented in the table below. Based on comments, we assume that the industry would need a 6 month ramp-up in order to prepare to begin retrofitting cars, and after that, they would retrofit legacy DOT-111s to capacity until work is complete.

Retrofit Schedule		
Tank Car Type / Service	**Fleet Size**	**DOT Revised Schedule**
Non Jacketed DOT-111 tank cars in PG I service	11,637	**(January 1, 2017)**[119] **January 1, 2018**
Jacketed DOT-111 tank cars in PG I	2,268	**March 1, 2018**
Non Jacketed CPC-1232 tank cars in PG I service	15,144	**April 1, 2020**
Non Jacketed DOT-111 tank cars in PG II service	18,493	**May 1, 2023**
Jacketed DOT-111 tank cars in PG II service	88	**May 1, 2023**
Non Jacketed CPC-1232 tank cars in PG II service	751	**July 1, 2023**
Jacketed CPC-1232 tank cars in PG I and PG II service* and all remaining tank cars carrying PG III materials in an HHFT (pressure relief valve and valve handles).	24,993	**May 1, 2025**

3. Tank Car Alternatives

PHMSA considered the status quo and three tank car options at the NPRM stage. In this final rule, PHMSA adopted a hybrid that sets the retrofit standard at the Option 3 standard and the new car standard at the Option 2 standard. In addition, as explained in the braking section of this analysis, some cars in crude oil and ethanol service are required to be equipped with ECP brakes.

No-Action Alternative

This alternative would continue to authorize the use of the non-jacketed and jacketed DOT-111 tank cars, including non-jacketed and jacketed CPC-1232 tank cars, for the transportation of crude oil and ethanol. This alternative would impose no benefits or costs, because it would require no change in flammable liquid packaging.

[119] The January 1, 2017 date would trigger a retrofit reporting requirement, and tank car owners of affected cars would have to report to DOT the number of tank cars that they own that have been retrofitted, and the number that have not yet been retrofitted.

Final Rule Option: Option 2 car required for new construction, Option 3 car for retrofits

The final rule option is the tank car design option enacted into regulation by the final rule document that the final RIA accompanies. As discussed above, this option requires existing cars to be retrofit to an enhanced CPC-1232J, or Option 3 standard and newly constructed cars to be built to the Option 2, or AAR 2014, tank car standard. The features of the Option 2 standard are identical to those on the CPC-1232J except that the Option 2 car has a 9/16ths inch thick shell, whereas the CPC-1232J has a 7/16ths inch shell. This makes the Option 2 car less likely than the Option 3 car to release its contents in the event of an incident such as a derailment or collision. Table TC2 presents the safety features of all cars considered in this document. We considered the costs and benefits of all Options proposed at the NPRM stage as well as the final rule option. Key features of the Option 2 car include the following:

- 286,000 lb. GRL tank car that is designed and constructed in accordance with AAR Standard S-286;
- Wall thickness after the forming of the tank shell and heads must be a minimum of 9/16 inch, constructed from TC-128 Grade B, normalized steel;
- Thermal protection system in accordance with § 179.18, including a reclosing pressure relief device;
- Minimum 11-gauge jacket constructed from A1011 steel or equivalent. The jacket must be weather-tight as required in § 179.200-4;
- Full-height, 1/2 inch thick head shield meeting the requirements of § 179.16(c)(1);
- Bottom outlet handle removed or designed to prevent unintended actuation during a train accident; and
- Top fittings protection meeting the requirements of § 179.102-3 (not applicable to existing tank cars).

Option 1: PHMSA FRA Tank Car

This tank car has the safety features listed above plus:

- ECP brakes; and
- Rollover protection for new construction, but not for retrofits. Retrofitting rollover protection on thinner shelled cars was deemed impossible and hence was not required at the NPRM stage.

Option 3: Enhanced Jacketed CPC-1232 Tank Car

This tank car standard is also presented in detail in the initial RIA. For the details on this option's requirements, the Agency refers the reader to that document. This car has identical safety features to the Option 2 car with the exception of shell thickness, which is 7/16ths inch, an eighth of an inch thinner than the Option 2 car. As previously noted, the final rule establishes this tank car as the standard to which all currently existing cars must be retrofit to.

Table TC3, below, compares the safety features associated with the three tank car options proposed in the NPRM. Since the final rule adopts a hybrid of Options 1 through three, the features of this option are also presented below.

Table TC3: Safety Features by Tank Car Option

Tank Car	Bottom Outlet Handle	GRL (lbs.)	Head Shield Type	Pressure Relief Valve	Shell Thickness	Jacket	Tank Material*	Top Fittings Protection **	Thermal Protection System	Braking
Option 1: PHMSA and FRA Designed Tank Car	Bottom outlet handle removed or designed to prevent unintended actuation during a train accident	286k	Full-height, 1/2 inch thick head shield	Reclosing pressure relief device	9/16-inch minimum	Minimum 11-gauge jacket constructed from A1011 steel or equivalent. The jacket must be weather-tight	TC-128 Grade B, normalized steel	TIH Top fittings protection system and nozzle capable of sustaining, without failure, a rollover accident at a speed of 9 mph	Thermal protection system in accordance with § 179.18	ECP brakes
Option 2: AAR 2014 Tank Car	Bottom outlet handle removed or designed to prevent unintended actuation during a train accident	286k	Full-height, 1/2 inch thick head shield	Reclosing pressure relief device	9/16-inch minimum	Minimum 11-gauge jacket constructed from A1011 steel or equivalent. The jacket must be weather-tight	TC-128 Grade B, normalized steel	Equipped per AAR Specifications for Tank Cars, Appendix E paragraph 10.2.1	Thermal protection system in accordance with § 179.18	DP or Two-way EOT devices
Option 3: Enhanced CPC-1232 Tank Car	Bottom outlet handle removed or designed to prevent unintended actuation during a train accident	286k	Full height 1/2 inch thick head shield	Reclosing pressure relief device	7/16-inch minimum	Minimum 11-gauge jacket constructed from A1011 steel or equivalent. The jacket must be weather-tight	TC-128 Grade B, normalized steel	Equipped per AAR Specifications for Tank Cars, Appendix E paragraph 10.2.1	Thermal protection system in accordance with § 179.18	DP or Two-way EOT devices
DOT-111A100W1 Specification (Currently Authorized)	Bottom outlets are optional	263K	Optional; bare tanks half height; jacket tanks full height	Reclosing pressure relief valve	7/16-inch-minimum	Jackets are optional	TC-128 Grade B, normalized steel*	Not required, but when equipped per AAR Specifications for Tank Cars, Appendix E paragraph 10.2.1	Optional	EOT device (See 49 CFR part 232)

* For the purposes of this figure, TC-128 Grade B normalized steel is used to provide a consistent comparison to the proposed options. Section 179.200-7 provides alternative materials, which are authorized for the DOT Specification 111.

** Please note PHMSA has not required additional top fittings protection for retrofits. While PHMSA expects additional top fittings protection would provide enhanced safety protection, the costs of retrofitting existing cars exceed the safety benefits by $500 million to $1 billion. Newly constructed cars, however, are required to have top fittings protection.

Baseline

The baseline for this assessment is the current HMR, with some modifications to account for other regulatory initiatives that will reduce the risk of a catastrophic event. Later in this section, we use the lower consequence event damages presented as a pool from which to draw benefits. At present, we consider the cost of each proposed tank car standard.

For purposes of analyzing the tank car options, the baseline consists of a forecast of the size of the tank car fleet size, and its characteristics, in absence of the proposed tank car standard. The fleet is expected to evolve the same way for all the Options analyzed here. Regarding the tank car fleet, PHMSA assumed that all newly constructed tank cars for flammable liquid service in HHFTs would adhere to the enhanced CPC-1232 standard (Option 3 tank car) in the absence of a revised standard in the HMR. The CPC-1232 has been the industry standard for orders placed after October 2011, and PHMSA assumed that 100 percent of the newly constructed tank cars will be CPC-1232 jacketed tank car plus improvements to pressure relief devices and bottom outlet valves (i.e., the "enhanced jacketed CPC-1232"). This an assumption based on a commitment made by rail car manufacturers. It is also assumed that the DOT-111 and the CPC-1232 cars have life spans of 40 years and 50 years, respectively.

The fleet figures are based on comments to the NPRM by RSI, with some modifications. The RSI comments project fleet growth to 2025 along with a forecast of the number of carloads shipped by rail. The figures presented by RSI appear to be for the entire North American fleet. The first adjustment PHMSA and FRA made to these figures is to remove the 25.7 percent of cars estimated to be owned and leased by Canadian companies. PHMSA assumed these cars would be built to and governed by standards established by Canadian Transport Dangerous Goods regulations rather than the U.S. HMR. Secondly, it appears that the RSI figures may result in the overbuilding of tank cars for HHFT service. Using their figures results in a declining number of trips the average car makes per year. This was calculated by dividing RSI's estimate of the number projected carloads into RSI's estimate of the number of cars. In 2013 the AAR reported that there were 483,701 crude oil tank cars originating in North America, with 401,813 originating in the US and 81,888 in Canada. This gives us average shipments per car of 11.2[120] per year for crude oil. In 2013, the AAR reported that there were 290,710 alcohols (not otherwise specified) n.o.s. (ethanol) tank cars originating in North America, with 290,709 originating in the US and one in Canada. This gives us average shipments per car of 10.8[121] per year for ethanol.

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[120] 483,701 (Carloads of Crude oil) / 43,288 (number of cars used in 2013) = 11.174

[121] 290,710 (Carloads of Ethanol) / 27,024 (number of cars used in 2013) = 10.757

Based on the 2013 AAR report on car utilization, it appears that the average crude oil car made approximately 11.2 trips. Using RSI's projection, peak carloads for crude oil service results in 1,004,852 carloads transported by roughly 96,590 tank cars. This translates to 10.4[122] shipments per car in the peak year. This shows a 7.1 percent decrease in utilization rate (efficiency) from 2013. Various sources indicate that cycle times have improved over the past year or so – as a result, it seems unlikely that as many cars would be needed as RSI projects. In this analysis, PHMSA estimated a utilization rate of 16.0 (or number of completed round trips annually), or 22.8 days in a cycle time for HHFTs.

Finally, as described in the ECP Braking section, we expect deployment of ECP braking on a portion of tank cars to increase the efficiency of these trains, resulting in fewer cars needed to move the same amount of product. We do not count a reduction in cars as a benefit here. Fewer cars do mean lower new construction costs, but the only benefits claimed in this section are tank car safety benefits. PHMSA assumed that anything scheduled to be delivered in 2015 will be delivered as ordered and retrofit later. Table TC4 shows the current fleet composition:

Table TC4: Estimates for current fleet of rail tank cars[123]

Tank Car Category	Population
Total No. of Tank Cars Hauling Crude Oil	59,401
Total No. of Tank Cars Hauling Ethanol	26,546
CPC-1232 (Jacketed) in Crude Oil Service	24,910
CPC-1232 (Jacketed) in Ethanol Service	23
CPC-1232 (Non-Jacketed) in Crude Oil Service	15,144
CPC-1232 (Non-Jacketed) in Ethanol Service	751
DOT-111 (Jacketed) in Crude Oil Service	3,185
DOT-111 (Jacketed) in Ethanol Service	88
DOT-111 (Non-Jacketed) in Crude Oil Service	16,163
DOT-111 (Non-Jacketed) in Ethanol Service	25,685

[122] 1,004,852 (RSI Forecast of carloads of Crude in 2021) / 965,90 (RSI estimate of number of cars used) = 10.403

[123] Source: RSI presentation at the NTSB rail safety forum April 22, 2014, update provided on June 18, 2014.

The crude and ethanol fleet is relatively new. Consultation with FRA industry experts, industry trade magazines, and crude and ethanol shippers indicates that most of the crude and ethanol fleet has been built since 2000.[124] At the NPRM stage, PHMSA and FRA assumed that virtually the entire fleet would be retrofit. In response to comments, however, we have revised this assumption. Based on comments from several industry groups, we predict that approximately 28 percent of legacy cars (i.e., tank cars that predate the CPC-1232 standard) would be retired rather than retrofit. A review of the distribution of DOT-111 tank car ages corroborates this figure, and PHMSA and FRA therefore believe it to be accurate. This percentage appears to correspond to the percentage of cars that were built prior to approximately the year 2000. Thus, any car older than 15 years of age is likely to be retired rather than retrofit.

As noted above, PHMSA based its fleet projection for the final rule primarily on comments submitted by RSI with adjustments to remove intra-Canadian movements, a reduction to reflect PHMSA's estimated utilization rates, and some adjustment to reflect greater efficiencies that will be gained by adoption of ECP brakes. As can be seen in the table below, the new forecast estimates are lower figures than those used at the NPRM stage. Primarily, this is a function of removing shipments/cars originating and ending in Canada from the fleet. It has become clear that the Agency's NPRM estimates included intra-Canada cars resulting in an overestimation of the U.S. fleet by approximately 25.7 percent.

The table below presents tank car fleet size forecasts for crude oil and ethanol. Although ethanol shipments are forecast to grow moderately for the coming several years, consultation with the industry indicates that the ethanol fleet is large enough at present to accommodate the increase in volume. Since there is no demand or need for more ethanol cars going forward, PHMSA assumed no growth in the manufacture of ethanol cars. We estimate the current ethanol fleet at 30,000 cars. As such, all fleet growth is attributable to the crude oil fleet.

Table TC4: Fleet Forecast DOT-111 and CPC-1232 from 2014-2034

	DOT-111 Unjacketed		DOT-111 Jacketed		CPC 1232 Unjacketed		CPC-1232 Jacketed		Planned New Construction
Base Year Fleet	30,475	11,851	2,356	916	15,895	0	24,933	0	6,953
Year	Retro fits*	Retire ments	Retro fits	Retire ments	Retro fits*	Retire ments	Retro fits	Retire ments	New
2015	0	0	0	0	0	0	651	0	0
2016	4,413	0	0	0	0	0	2,603	0	6,953
2017	7,224	4,526	717	892	0	0	2,603	0	0
2018	0	0	1,576	0	6,662	0	2,603	0	0
2019	0	0	0	0	8,445	0	2,603	0	0

[124] http://ethanolrfa.org/page/-/rfa-association-site/Industry%20Resources/RFA.Ethanol.Rail.Transportation.and.Safety.pdf?nocdn=1

Table TC4: Fleet Forecast DOT-111 and CPC-1232 from 2014-2034									
	DOT-111 Unjacketed		DOT-111 Jacketed		CPC 1232 Unjacketed		CPC-1232 Jacketed		Planned New Construction
2020	5,003	0	0	0	37	0	2,603	0	0
2021	8,739	7,192	0	0	0	0	2,603	0	0
2022	5,076	0	63	25	751	0	2,603	0	0
2023	20	0	0	0	0	0	2,603	0	0
2024	0	134	0	0	0	0	2,603	0	0
2025	0	0	0	0	0	0	859	0	0
2026	0	0	0	0	0	0	0	0	0
2027	0	0	0	0	0	0	0	0	0
2028	0	0	0	0	0	0	0	0	0
2029	0	0	0	0	0	0	0	0	0
2030	0	0	0	0	0	0	0	0	0
2031	0	0	0	0	0	0	0	0	0
2032	0	0	0	0	0	0	0	0	0
2033	0	0	0	0	0	0	0	0	0
2034	0	0	0	0	0	0	0	0	0

4. Cost Areas for Tank Car Options

This section presents the areas of costs associated with the proposed tank car options. The initiative would generate costs in the following areas:

- *Incremental cost of newly constructed tank cars*: the acquisition cost of the Option 2 design tank car option, compared to the baseline Enhanced Jacketed CPC-1232 tank car, was estimated at $2,000 at the NPRM stage. In comments to the docket, Greenbrier estimated that extra shell thickness would cost about $1,500 per 1/16th of an inch. Growth Energy derived an estimate that adding an extra eighth of an inch would cost $3,880 based on calculations used in the draft RIA. For this analysis we elected to use estimates provided by a tank car manufacturer. Since the new car standard is an eighth of an inch thicker than a CPC-1232J, this implies a cost differential of about $3,000 for shell thickness.
- *Cost for ECP Brake Equipment Additional Steel:* For the NPRM Option 1, we estimated a $5,000 cost differential at the NPRM stage. This included $3,000 for ECP equipment and $2,000 to increase shell thickness. It was assumed at the NPRM stage that rollover protection would cost as much as the current standard top fittings protection so no additional cost was attributed to rollover protection. Comments suggested that the costs for ECP, shell thickness, and rollover protection were higher than PHMSA initially estimated. From the comments, PHMSA obtained an estimated cost for rollover protection of $5,000 per car. In addition, PHMSA increased its estimated cost for installing ECP brakes on a new tank car to $7,800 from $3,000 in response to comments. Finally, as discussed above, the cost of extra shell thickness has increased by $1,000 from $2,000 to $3,000. This raises the NPRM Option 1 new car differential from $5,000 to

$14,800. This difference in costs between the two cars, multiplied by the forecast of newly constructed tank cars, reflects a societal cost;

- *New Car differential for NPRM Option 3*. Because this has become the standard car, the industry is manufacturing for HHFT service, no additional incremental costs is attributed to new cars built to this standard.
- *Cost to retrofit existing tank cars*: the cost of labor and materials needed to bring most of the existing fleet up to the standard specified by the relevant option. Full schedules of these costs for all options are presented further below.
- *Out-of-service costs*: in order to implement the retrofits necessary to bring an existing car up to the new standard, a car will need to be taken out of service and cleaned prior to the retrofit. The lost service value for the time needed to complete the retrofits, as well as the cleaning costs, are societal costs. Some retrofits may be conducted during decennial requalification; in these cases, the additional time beyond that normally required for a requalification is used to develop this cost.
- *Cost of retirements*: As noted above, the Agency has revisited its assumption that no cars would be retired from this service in the event of promulgation of a higher tank car standard. We estimate that some portion of the fleet will be retired from this service rather than retrofit. The cost of retiring a car is the cost of the lost service value for the car is remaining service life, minus the scrap value, plus the incremental cost of acquiring a new car to replace the retired car.
- *Costs resulting from increased weight:* the heavier tank cars will lead to increased fuel expenditures and more track maintenance. The added weight of the car would also likely result in additional fees established by the rail carrier.

5. Costs of the Final Rule Option

Unit Cost Estimates

This section presents unit costs used in the analysis to estimate the total costs for the above cost areas. We present a cost analysis of the final rule option, which serves as the basis for the analysis of the Options considered at the NPRM stage.

1. Incremental costs of Newly Constructed Tank Cars

The cost to manufacture a car to the Option 2 standard required by the final rule is estimated based on the sale price of other similar cars, consultation with PHMSA and FRA engineers, and comments received on the ANPRM. The Option 2 tank car standard adds several enhancements to a standard DOT-111 tank car, but only one additional safety feature in comparison to the enhanced CPC-1232J car – increased shell thickness. As a result, the marginal increase in the cost of the Option 2 car relative to a new CPC-1232J is the cost of adding an eighth of an inch of shell thickness: $3,000. The difference in costs between the Option 1 tank car and the Option 3

tank car is $14,800. This figure represents the incremental costs to a buyer who is required to purchase the Option 1 tank car instead of the Option 3 tank car. Relative to the Option 3 tank car, the Option 1 tank car includes:

- New ECP brakes ($7,800)[125]
- An additional 1/8-inch shell thickness ($3,000)[126]
- Roll-over protection $4,000 (relative to top fittings protection)

2. Cost of Retrofitting Existing Tank Cars

The estimated costs to retrofit the various configurations of current in-service tank cars came from comments submitted to the docket by RSI, Dow, Greenbrier, and several other industry commenters. Commenters provided detailed cost information on each of the enhancements necessary to bring older cars up to the new performance standard. These include the cost of top fitting protections, jackets, thermal protection, or replacement of the pressure relief valve, a new bottom outlet valve handle, full-height head shields, and truck upgrades.

Table TC5: Retrofit Costs for Public Comments

Retrofit Option	Cost
Bottom outlet valve handle	$1,200
Pressure relief valve	$1,500
Truck Upgrade	$12,000 (if needed)
Thermal protection, full jacket, and full height head shields	$27,400

We expect that tank cars will meet the Option 3 standard by adding a full 11-gauge jacket, full height head shields, thermal protection, and improved BOV handle and PRV.

NPRM Assumption: No new trucks needed. In consultation with FRA and PHMSA tank car engineers, we made modifications to the costs presented by Watco and RSI for the initial RIA. PHMSA worked under the assumption that the crude and ethanol fleet is relatively new, and that most cars in service were built in the past 15 years. This assumption and would have trucks rated to 286,000 pounds. RSI and other NPRM commenters argued that minor or major upgrades may still be needed for some portion of the fleet, though they were not specific as to how many cars would need upgrades. The only guidance we received on their cost was a provided range between $2,000 and $24,000.

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[125] Federal Railroad Administration, ECP Brake System for Freight Service, Final Report, Booz Allen Hamilton, released August 2006.

[126] The extra cost of increased thickness is based on the amount of steel that is required to be added to a shell/jacket, and a cost per pound of steel of $0.40 per pound. Source: http://www.metalprices.com/p/SteelBenchmarkerFreeChart

It is clear from the tare weight that only the DOT-111NJ should need truck upgrades. A non-jacketed CPC-1232 is heavier than a DOT-111NJ by virtue of having half-height head shields and a thicker shell. This car would have to be short loaded if rated to only 263,000 lbs. A DOT-111J and CPC-1232J would also have to be short loaded if rated to only 263,000 lbs. It seems unlikely that the industry would build a car to a weight rating that would force it to be chronically under-filled. As a result, we assume that only DOT-111s without jackets suffer from the wheel bearing/truck issue. As noted above, RSI presents a wide cost range for upgrading the trucks on these cars. We assume the average retrofit cost for truck upgrades would fall in the middle of this range, or $12,000 per car. This is intended to be an average cost; modifications for some cars may cost more than this, and modification of others may be less.

As noted elsewhere, we have assumed that 28 percent of cars in crude and ethanol service will be retired based on RSI's comments. We assume these cars are the ones that would require the most costly truck upgrades. In addition, the retrofit standard adopted for the final rule results in a lighter car because no increase in shell thickness is required.

Cost of a full-height head shield is included in $23,400 jacket cost. All non-jacketed retrofit cars will have to have jackets and thermal insulation applied to meet the puncture resistance and survivability standards established by this rule. We assume no car would have to have full height head shields mounted directly on the body—the cost of new head shields is built into the cost of a jacket. Comments from Watco at the NPRM stage indicated that head shields are commonly built into jackets and this reduces the cost of applying full height head shields to a car substantially. RSI argued in comments to the NPRM that head shields cost $20,000 and a jacket costs another $16,000. In contrast, Dow presented costs for full height head shields, thermal protection, and a jacket that were less than RSI's estimated cost for a jacket alone – $15,000 - $20,000. As presented above in the itemized cost table, we use a cost of $27,400 for a jacket, full height head shields, and thermal protection. This is substantially more than Dow's estimate but less than RSI's estimate. It is close to the cost used in the initial RIA.

No required top fittings for retrofitted tank cars. In addition, as noted in the preamble and above, retrofit requirements do not mandate top fittings protection, so those costs are omitted from the analysis. All the other tank car models described here have top fittings protections (or rollover protection) as a standard feature.

We expect the non-jacketed DOT-111, the jacketed DOT-111, and the non-jacketed CPC1232 to be retrofitted. The cost of upgrading a non-jacketed DOT-111 to the option 3 tank car standard is presented in the table below. We assume some level of cost savings due to returns to scale, bulk purchasing, and learning curve efficiency improvements given the volume of retrofits, so we apply 10 percent cost reduction factor.

Table TC6: Retrofit Costs for the Non-Jacketed DOT-111 (Option 3 Tank Car)

Retrofit Option	Cost
Bottom outlet valve handle retrofit cost	$1,200
Pressure relief valve retrofit cost	$1,500
Thermal protection retrofit cost	$4,000
Truck upgrade	$12,000

Full jacket + full height head shields retrofit cost	$23,400
Unadjusted Total	**$42,100**
Learning curve cost reduction	10%
Adjusted Total	**$37,890**

The Agency assumes that the CPC-1232NJ would be retrofit by removing the half height head shields that come standard on this car and applying an 11- gauge jacket with full height head shields and thermal protection. It must be noted that the CPC-1232NJ has an 8/16ths inch shell – thicker by a sixteenth of an inch than the CPC-1232J. In theory, this car would meet the retrofit standard with a thinner than normal jacket, but PHMSA assumed the industry would not build a separate jacket for these cars and would apply the standard 11- gauge jacket. As a result of their thicker shell, with the jacket and full height head shields, this car would exceed the safety performance of the CPC-1232J retrofit standard.

Table TC8: Retrofit Costs for the Jacketed DOT-111 (Option 3 Tank Car)

Retrofit Option	Cost
Bottom outlet valve handle retrofit cost	$1,200
Pressure relief valve retrofit cost	$1,500
Thermal protection retrofit cost	$4,000
Truck Upgrade	$0
Full jacket + full height head shields retrofit cost	$23,400
Unadjusted Total	**$30,100**
Learning curve cost reduction	10%
Adjusted Total	**$27,090**

Table TC9: Retrofit Costs for the Non-Jacketed, DOT CPC-1232NJ (Option 3 Tank Car)

Retrofit Option	Cost
Bottom outlet valve handle retrofit cost	$1,200
Pressure relief valve retrofit cost	$1,500
Thermal protection retrofit cost	$4,000
Full jacket retrofit cost with half height head shields	$23,400
Unadjusted Total	**$30,100**
Learning curve cost reduction	10%
Adjusted Total	**$27,090**

Table TC10: CPC-1232J to Enhanced CPC-1232J

Retrofit Option	Cost
Bottom outlet valve handle retrofit cost	$1,200
Pressure relief valve retrofit cost	$1,500
Unadjusted Total	**$2,700**
Learning curve cost reduction	10%
Adjusted Total	**$2,430**

3. Out of Service Costs (Lost Service Value)

PHMSA used a rental price of capital approach to estimate the service value of the tank cars; these values are used to develop cost estimates for taking cars out of service to retrofit them. The approach takes into account depreciation and the opportunity costs of the asset, amortizing the acquisition costs over the average life span of the cars. PHMSA assumed a 7 percent interest rate, and 40 and 50-year life spans for the DOT-111s and CPC-1232s respectively. The acquisition cost of the non-jacketed DOT-111 was assumed to be $60,000, and the non-jacketed CPC-1232s being $85,000. These assumptions produce the annual service values listed in the table below.

PHMSA also estimated that retrofitting DOT-111 cars would take an average of 12 weeks, and retrofitting CPC-1232 cars would take 8 weeks. As shown below, the annual values presented above are prorated accordingly and used to value the lost service time.

Table TC11: Value of Lost Service

Tank Car	Annual Service Value	Time Out-Of-Service from Retrofits	Total Lost Service Value from Retrofits
DOT-111NJ	$4,474	12 weeks	$1,033
CPC-1232 NJ	$6,137	8 weeks	$944
DOT-111J	$4,474	8 weeks	$944

Several commenters argued for higher out of service costs based on reported lease rates (lease rates at the time ranged from $1,400 per month to $4,500 per month). This was a dramatic increase from $400 per month lease rates reported in 2010. It appears that these lease rates reflect unusually high demand for rail tank cars set off by the sharp increase in the volumes of crude oil being transported by rail. Since the time those comments were made there have been deliveries of new tank cars as the new tank cars are delivered we expect lease rates to return to historic norms.

Costs Resulting from Increased Weight

PHMSA and FRA received numerous comments from stakeholders indicating that the increased weight of the shields, TPS, jackets, brakes, valves, fittings, etc. would decrease the carrying capacity of the tank car. Some of the commenters even calculated that they would need to increase their fleet by 9 percent in order to account for the lost capacity. Many commenters focused on CPC 1232 tank cars, in particular, as being potentially affected by the weight of the safety features that would be added during retrofitting. For instance, the Brattle Group submission on behalf of RSI indicated that because some unjacketed CPC 1232 tank cars are already built to 286,000 lbs. GRL, the added weight from a retrofit will decrease carrying capacity. API and AFPM provided similar comments. Bridger commented that the decreased volume capacity for tank cars resulting from the rule would result in shippers and marketers securing more railcars and trains to haul its domestic production to market, contributing to increased congestion on the rails. Hess commented that the proposed Option 2 cars would result in a capacity loss of 2,127 gallons for each of its current CPC-1232 non-jacketed cars, which it states have a tare weight of 74,300 lbs. and shell capacity at 1 percent outage of 30,888 gallons.

PHMSA and FRA disagree with public commenters' claims that the rule will necessarily reduce the load limit (i.e. the weight of the lading) of current and future crude and ethanol tank cars in the absence of this rule, and consequently disagrees with the claim that the increased tare weight will necessitate an increase in the number of carloads required to move a given amount of product. The maximum allowable GRL is 286,000 pounds. PHMSA and FRA believe that, for all but an inconsequentially small number of such tank car loads, the difference between the current weight of a loaded car using standard operating practices and 286,000 lbs. is more than the weight that will need to be added to comply with this rule. This is true for both the current crude and ethanol fleet and new tank cars (including jacketed and non-jacketed CPC-1232 cars) as they would have been placed into this service over the next 20 years in the absence of this rule. Therefore, the vast majority of tank cars will be able to comply with this rule without realizing any meaningful loss in capacity. Consequently we have not accounted for any capacity losses in our analysis.

There are five areas of evidence that PHSMA and FRA rely on to address this concern. First the unit weight of crude oil can vary. The unit weight of crude oil used in this analysis was randomly selected from analytical results from DOT's Operation Classification. One of the comments used a weight of 6.78 lbs/gallon. As this is a valid weight, we acknowledge that there may be lading loss for the heaviest materials. PHMSA and FRA calculated that there will be no loss of innage for crude oil with a unit weight of 6.7 pounds per gallon which is on the high end of the weight of crude oil. 6.56 lbs/gallon is an accurate estimate for light crude. Our calculation also assumes that shippers are loading the materials at the 115F reference temperature (load to the 99% innage). This will be discussed later in this document–we anticipate that there will not be a net loss of material moved because the existing tank cars are currently operating below the maximum gross weight on rail.

Second, the tare weight of the tank cars used to transport Bakken crude range from approximately 66,000 pounds to 95,000 pounds, with the vast majority being at the lower end of the range. Below, PHMSA and FRA have provided the calculations for the increase in weight from all the safety features in this final rule.

Additional Thickness

Unit weight of steel – approximately 492 lbs/cubic foot

Surface area of 2:1 ellipsoidal heads – 217 square foot (sf)
Surface area of 10' diameter shell – 1500 sf
Additional thickness 1/16" = 2.56 lbs./sf
Additional weights for head/shell – 1,717 sf x 2.56 lbs./sf = 4,396 lbs.

Jacket and Headshield

Jacket diameter – 10.66" (allow for 4" of annular space) – This is likely an over estimation because of Plate C clearance restrictions)
Length of shell - 48.41'
Surface area of shell – 1,621 sf
Additional weight of jacket (0.1196") – 1,621 x 4.9 lbs./sf = 7,943 lbs.
Surface area of 2:1 ellipsoidal heads (0.5" thick) - 239 sf x 20.5 lbs./sf – 4,900 lbs.

Total weight for additional thickness, jacket and head shield – 17,239 lbs.

To be conservative, if we added 4,000 pounds for top fittings protection (the top fittings protection would not apply to retrofitted tank cars), the total weight of the enhancements would be 21,239 pounds. As calculated, these safety enhancements have increased the tare weight by approximately 23,000 pounds, which assumes 1,761 pounds for thermal protection and jacket standoffs. The allowable gross rail load is 286,000 pounds (23,000 pounds greater than 263,000 pounds). So, there is not net gain/loss of load limit. These calculations look at retrofitting a DOT 111 to a DOT 117.

If a CPC-1232 is upgraded, its tare weight would be close to that of the DOT 117, calculated above. An unjacketed CPC 1232 built to 286,000 lbs. GLR with a 30,000 gallon tank is estimated to have a tare weight of 74,000 lbs. The added weight from the retrofit requirements is less than that from the new tank car requirements estimated above. The features are a combined 10,893 lbs. (2,450 lbs. for the head shields, and 500 lbs. for jacket stand-offs and 7,943 pounds for a jacket). This brings the total tare weight of the car to 84,893 lbs., which leaves 201,107 lbs. for the load. At 6.7 lbs. per gallon, crude oil that is on the heavier end would weigh 198,990 lbs. when filled to allowable innage (29,700 gallons at 6.7 lbs. per gallon), which means that a fully loaded 117R that was originally an unjacketed CPC 1232 would be under the GRL. As discussed below, the lading temperature and typical operating practices for innage indicate that even 198,990 lbs. of lading is more than is typical.

Third, the majority of the cars in crude oil and ethanol service have a nominal 30,000 gallon shell full capacity. Some of the commenters' tank cars were constructed with a shell full capacity of 31,700 gallons, which is not the typical tank car. This additional capacity, relative to the more common tank car with a nominal shell full capacity of 30,000 gallons, adds 1,000-2,000 pounds to the tare weight. However, those cars are outliers. Assuming the tare weight and shell capacity estimates provided by Hess for its unjacketed CPC-1232 cars are accurate, Hess may experience a reduction in load limit. After retrofitting one of Hess's cars, the tare weight would be 85,193 lbs. (74,300 lbs. + 10,893 lbs. = 85,193 lbs.). Hess asserts that its cars can carry 206,950 lbs. of certain crude oil (30,888 gallons x 6.7 lbs. per gallon = 206,950 lbs.). The post-retrofit tare weight of these cars plus the weight of the current carrying capacity of these cars is 292,143 lbs., which exceeds the 286,000 GRL by 6,143 lbs (85,193 lbs. + 206,950 lbs.). However, when calculated using the typical outage used in the industry of 3-9% (see below), the weight of crude oil using 6.7 lbs. per gallon would be between 190,226 lbs. (28,392 gallons x. 6.7 lbs. per gallon) and 202,769 lbs., which would make the post-retrofit tare weight of these cars plus the weight of the current carrying capacity between 275,419 and 287,962 lbs. (30,264 gallons x 6.7 lbs. per gallon). Further, the weight used for crude oil in this analysis is conservative in that it uses a value of 6.7 lbs. per gallon, which is on the high end for crude oil. Thus, even for these large cars, reduced carrying capacity is not expected to be a significant issue. Finally, PHMSA and FRA believe Hess cars are an outlier.

Fourth, in order to comply with the Federal regulation an offeror must ensure that the outage in the tank would not be less than 1% (or 99% innage) at a lading temperature of 115F (for tank cars without insulation and/or thermal protection). Accordingly, they must measure or estimate the unit weight of the material at 115F. With this information they can calculate the weight that can be put into the tank without the volume exceeding the maximum innage of 99%. Because

most liquids expand upon heating, the unit weight of the lading at a lower temperature will be lower than at higher temperature. So less lading can be put into the tank.

Surprisingly, most, if not all, shippers of crude oil do not know the unit weight of the lading in each tank car at a reference temperature (115F) so they short load the tank. Based an audit of loading facilities in the Bakken, most offerors require a minimum of 3-5% outage after the tank has been loaded. Additionally, based on information obtained during Operation Classification, it was learned that the actual outage in tank car ranges from 3-9%. Short loading ensures a shipper that the tank car is in compliance with current regulations. However, as shippers are required to know the reference temperature of the commodity shipped, tank cars should be loaded to 99% innage. The DOT 117 cars are expected to permit the same capacity when transporting these commodities as the shippers are currently getting, assuming the shipper follows the current federal regulations and load to 99% innage.

Finally, with thermal protection and/or insulation, more lading can be placed in the tank (because of the lower reference temperatures be can be loaded into the tank). Tank cars without insulation and/or thermal protection cannot be loaded in excess of 99% innage at a reference temperature of 115F. For thermally protected tank cars the reference temperature is 110F, and for insulated tank cars the reference temperature is 105F. The vast majority of tank cars used to transport crude oil are currently not equipped with thermal protection or insulation so their reference temperature is 115F. The greater the temperature, the lower the unit weight and the lower the weight of lading that can be placed in the tank.

In conclusion, PHSMA and FRA recognize that some outliers in the crude and ethanol fleet may have a reduction in capacity due to their abnormal shell capacity or particularly high weight of the crude oil that they are shipping. However, PHMSA has not included the impacts to these outliers in its estimates of the rule's benefits and costs. PHSMA and FRA are confident that the bulk of the HHFT fleet will be able to transport the same amount of product as they are currently shipping.

PHMSA expects increased weight would have two primary effects: 1) increase in fuel expenses and 2) increase in repair and maintenance expenses, including track maintenance.

To estimate the increase in fuel expenses required for the additional weight of the retrofits, PHMSA developed an estimate of rail fuel expenditures per ton-mile. To develop the estimate, PHMSA relied on CSX data indicating that the railroads can move a ton of freight 450 miles using one gallon of fuel,[127] or that one ton-mile requires 1/450 gallons of fuel. To value this

[127] See http://www.csx.com/index.cfm/about-csx/projects-and-partnerships/fuel-efficiency/

figure, PHMSA assumed an average retail price for diesel of $2.83 per gallon[128]—$3.14 reduced by 10 percent to allow for bulk purchase discounts. The resulting cost per ton-mile is estimated to be $0.0063.[129]

To estimate the increase in repair and maintenance expenses resulting from the additional weight of the retrofits, PHMSA developed an estimate of the railroads repair and maintenance expenditures per ton-mile. Operating expenditures by the railroads were obtained from STB's *Statistics of Class I Railroads*. PHMSA used the repair and maintenance line items for rails and tracks, ties, bridges and culverts, roadways, and tunnels and subways. These expenses were then divided by total freight ton-miles in the U.S. This was estimated using the rail public waybill data, and inflated to 2013 using BLS' producer price index for railroads. The cost per ton-mile is estimated to be $0.000826.

Table TC13: Increased Fuel and Maintenance Costs

Tank Car	Increased weight to achieve PHMSA and FRA designed car standard (tons)	Miles Per Year, Per Car	Additional Fuel Costs per Ton-Mile	Additional Maintenance Cost per Ton-Mile	Annual Additional Fuel and Maintenance Costs
Retrofitted Non-Jacketed DOT-111	8	15,400	$0.0063	$0.00083	$878
Retrofitted Jacketed DOT-111	2.5	15,400	$0.0063	$0.00083	$275
Retrofitted Non-Jacketed CPC-1232	4.75	15,400	$0.0063	$0.00083	$522
Enhanced Jacketed CPC-1232	0	15,400	$0.0063	$0.00083	$0
Replacement of jacketed CPC-1232 with Option 2 New construction	2.25	15,400	$0.0063	$0.00083	$247
Replacement of retired unjacketed DOT-111 with	10.25	15,400	$0.0063	$0.00083	$1,125

[128] Energy Information Administration. Gasoline and Diesel Fuel Update. Weekly price of diesel for week ending 2/2/2015AvailableAvailable online at http://www.eia.gov/petroleum/gasdiesel/

[129] Extra ton-miles total 77.6 billion over 20 years. The associated cost was calculated as follows: Each car is estimated to make nine 1,100 mile trips per year. The cost of extra fuel is calculated by multiplying the number of trips (14) by the miles per trip (1,100) by the average extra weight per car (2.25 – 10.25 tons) by the cost of fuel per ton mile ($0.0063) or extra maintenance ($0.00083) by the number of cars.

Table TC13: Increased Fuel and Maintenance Costs					
Option 2 New Car					
Replacement of retired jacketed DOT-111 with Option 2 New Car	4.75	15,400	$0.0063	$0.00083	$522

Costs of Retiring Older Tank Cars

In response to public comments and in light of conversations with Transport Canada, PHMSA has included costs of retiring older DOT-111 tank cars early, rather than assuming that they would be repurposed for oil sands service. Comments submitted by RSI indicate that they estimate that 28 percent of DOT-111s will be retired early because of this rule. PHMSA has reviewed this estimate, and data on the distribution of DOT-111 tank car ages from Umler[130] supports this estimate.

PHMSA views an owner's decision to retire a rail tank car early as an evaluation of the tradeoff between bearing the cost of retrofitting the tank car, and replacing that tank car before the end of its normal service life. PHMSA assumed that the cost of early replacement would be the difference in the purchase prices of a new rail tank car today versus the discounted (at a 7 percent rate) cost of purchasing a rail tank car in the future (at the normal end of the service life of the car it is replacing). In addition, PHMSA assumed that tank car owners would be able at least to sell retired rail tank cars for scrap metal.

PHMSA used the following parameters in conducting this analysis:

1) A new rail tank car that is compliant with this rule will cost $130,000.
2) The tare weight of an unjacketed DOT-111 is 67,800 lbs. (30,754 kg), and the tare weight of a jacketed DOT-111 is 72,400 lbs. (32,840 kg).
3) The price of bulk scrap steel is approximately $400 per metric ton.[131] Consequently, a scrapped unjacketed DOT-111 is worth approximately $12,300, and a scrapped jacketed DOT-111 is worth approximately $13,100.

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[130] "The Umler® system is an electronic resource that contains critical data for North American transportation equipment. Originally created in 1968, Umler maintains data for more than two million pieces of equipment used in rail, steamship and highway service." See: https://www.railinc.com/rportal/umler-system.

[131] There are multiple sources for these prices, which vary daily and by region. Data from the London Metal exchange (http://www.lme.com/en-gb/metals/steel-billet/) indicate that steel billet is currently priced around $500 per metric ton (as-of January 16, 2015). Research has indicated scrap steel tend to follow, but are marked below,

4) As follows from parameters 1) and 3), the net purchase cost for purchasing a rail tank car to replace:
    a. An unjacketed DOT-111 is $\$117{,}000$ ($\$130{,}000 - \$12{,}300$)
    b. A jacketed DOT-111 is $\$116{,}900$ ($\$130{,}000 - \$13{,}100$)
5) Materials and out-of-service costs for an unjacketed DOT-111 retrofit are estimated to be $38,923. Those costs for a jacketed DOT-111 retrofit are $28,123.

Parameters 4) and 5) allow an estimate of the number of years at which a tank car owner would be indifferent with respect to the cost of retrofitting a DOT-111 and purchasing a replacement tank car early. Specifically:

1) $Non - Jacketed\ DOT - 111$: $\$117{,}700 - (\$117{,}700 \div (1.07Y)) = \$38{,}923$. Where: solving for Y yields approximately 5.9 years of remaining service life. This number of years represents the boundary for remaining service life. Rail tank cars that are retired early will have at most this number of years remaining. Many cars will actually have fewer years left.
2) *Jacketed DOT-111*: $116,900 – ($116,900 ÷ (1.07Y)) = $28,123. Solving for Y yields about 4.1 years of remaining service life.
3) PHMSA analyzed Umler data on tank car ages[132] and determined that the weighted average remaining service years for unjacketed DOT-111s with 5.4 years or less of remaining service life was 1.9 years. For jacketed DOT-111s with 3.7 years or less of remaining service life, it was 1.3 years. The weighted average number of years foregone is used for the value of Y in the following equations, which are used to calculate the average cost of early retirement.
4) *Non-Jacketed DOT-111*:
   $\$117{,}700 - (\$117{,}700 \div (1.07 * 1.9)) = \$14{,}167$ Average cost of early retirement.
5) *Jacketed DOT-111*:
   $\$116{,}900 - \left(\$116{,}900 \div (1.07 * 1.3)\right) = \$11{,}297$ Avg. cost of early retirement.

Development of Total Cost

In this section, PHMSA combined the per unit cost estimates with quantity estimates to produce total costs estimates for the different cost factors.

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these prices. Consequently, it has used an estimate of $400 per metric ton. Prices posted online by numerous scrap metal buyers conform to this estimate.

[132] The Umler Equipment Management Information System is the rail Equipment Register for North America. We used data on equipment age for this analysis.
https://www.railinc.com/rportal/alf_docs/UmlerReference/UmlerDataSpecs.pdf.

There is a relationship between retrofitting costs, new construction costs, out-of-service costs and lost value of service; therefore, it is necessary to present these costs as a group, together with the methodology used to develop them.

Timing Assumptions

The schedule for when retrofits have to be completed is presented in the table below. Based on comments, we assume that the industry would need a 6 month ramp-up in order to prepare to begin retrofitting cars, and after that, they would retrofit legacy DOT-111s to capacity until work is complete.

Retrofit Schedule		
Tank Car Type / Service	**Fleet Size**	**DOT Revised Schedule**
Non Jacketed DOT-111 tank cars in PG I service	11,637	**(January 1, 2017)**[133] **January 1, 2018**
Jacketed DOT-111 tank cars in PG I	2,268	**March 1, 2018**
Non Jacketed CPC-1232 tank cars in PG I service	15,144	**April 1, 2020**
Non Jacketed DOT-111 tank cars in PG II service	18,493	**May 1, 2023**
Jacketed DOT-111 tank cars in PG II service	88	**May 1, 2023**
Non Jacketed CPC-1232 tank cars in PG II service	751	**July 1, 2023**
Jacketed CPC-1232 tank cars in PG I and PG II service* and all remaining tank cars carrying PG III materials in an HHFT (pressure relief valve and valve handles).	24,993	**May 1, 2025**

Methodology

To facilitate the calculations, the same methodology was used to develop estimates for the following four groups:

- Jacketed Ethanol Fleet
- Jacketed Crude Oil Fleet

[133] The January 1, 2017 date would trigger a retrofit reporting requirement, and tank car owners of affected cars would have to report to DOT the number of tank cars that they own that have been retrofitted, and the number that have not yet been retrofitted.

- Non-Jacketed Ethanol Fleet
- Non-Jacketed Crude Oil Fleet

The methodology consists of the following steps.

1) ***Calculate the Cost of New Construction for Non-Replacement Growth*:** The demand for new tank cars is based on two sources: replacement investment and new investment. Replacement investment occurs when companies purchase a new car to replace one they are transferring to a different service. New investment occurs when companies increase the size of their fleet to accommodate growth in the markets they serve. Replacement investment was addressed in Step 1 above. New investment was calculated in a similar fashion. Again, PHMSA assumed that all buyers would have purchased Option 3 car instead of the Option 1 car. For each year in the forecast horizon PHMSA multiplied the expected number of new tank cars by the incremental acquisition cost of $3,000.
2) ***Calculate Retrofitting Costs:*** For the retrofitting costs, PHMSA used the unit cost presented in the table titled, "Retrofitting Costs by Car Type," combined with cost estimates for taking the cars out-of-service to conduct the retrofits. For instance, for the DOT-111 NJ the retrofit cost of $38,923 per retrofit, including unit costs ($37,890) and out of service costs ($1,033) is multiplied by the number of cars retrofit per year to obtain a total cost for upgrading those cars in each year.

   For the unit costs, PHMSA took the adjusted totals presented in Tables TC8 and TC9. For the out-of-service costs, as explained above and shown in Table TC10, PHMSA divided the values in the table titled "Annual Service Values per Car" by 52 to put them on a weekly basis, and then multiplied them by the estimated number of weeks needed to conduct the retrofits (12 weeks for non-jacketed DOT-111s, 8 weeks for non-jacketed CPC-1232s). Thus, PHMSA calculated that non-jacketed DOT-111 cars would have an out-of-service cost of $1,033. PHMSA calculated that non-jacketed CPC-1232 cars would have an out-of-service cost of $944.

3) ***Compute Total Increased Operating Expenditures:*** Total increased operating expenditures resulting from the increased weight of the retrofits were estimated for fuel and for repair and maintenance. The cost estimates were developed by multiplying the number of retrofitted tank cars operating each year by the per-unit costs, the additional weight of the retrofits (in tons), the average number of carloads per tank car, and an estimate of the average miles per carload. The average number of carloads per tank car was estimated by dividing total crude oil and ethanol carloads (from the waybill) by the respective fleet size. Estimates for average miles per carload were developed using the waybill data. As shown in Table TC 12, this methodology generates an increase in annual operating expenditures of $1,019 for retrofitted non-jacketed DOT-111 tank cars (starting in 2018), $641 for retrofitted non-jacketed CPC-1232 cars (starting in 2018), and $256 for newly constructed cars (starting in 2016).
4) ***Compute Cost of Retirements*:** Multiply the number of retired DOT-111 NJ tank cars (11,851) by the cost of retirement, $14,167. Multiply the number of retired DOT-111 J tank cars (916) by the cost of retiring the DOT-111 NJ, $11,297.
5) ***Calculate Present Values:*** The yearly costs over the forecast horizon were converted to present values using a 7 percent discount rate and 3 percent discount rate.

Cost Estimates Inputs and Sources

The following table summarizes the key inputs and sources for our total cost estimates:

Table TC15: Final Rule Tank Car Option: Enhanced Jacketed CPC-1232 retrofit with NPRM Option 2 New Car Standard		
Variable	**Formula/Input**	**Source**
Number of **DOT-111NJ Retrofitted** 2016-2018	30,130 tank cars	DOT Estimate
Unit Cost Per Retrofit of DOT-111 Non-Jacketed	$37,890	DOT Adaptation of Watco Companies, L.L.C. Public Comment on the 2013 APRM
Time Out-of-Service Cost of DOT-111 Non-Jacketed	$1,033	DOT Adaptation of Watco Companies, L.L.C. Public Comment on the 2013 APRM
Additional Fuel and Maintenance Costs Per Year, Relative to Enhanced Jacketed CPC-1232 (based on 8.93 tons of extra weight)	$878	DOT Adaptation of EIA and CSX Corporation Data
Number of **DOT-111 Jacketed Retrofitted** 2016-2018	2,356	DOT Estimate
Unit Cost Per Retrofit of DOT-111 Jacketed	$27,090	DOT estimate and comments from Watco
Time Out-of-Service Cost of DOT-111 Jacketed	$944	DOT Adaptation of Watco Companies, L.L.C. Public Comment on the 2013 APRM
Additional Fuel and Maintenance Costs Per Year, Relative to Enhanced Jacketed CPC-1232	$275	DOT Adaptation of EIA and CSX Corporation Data
Number of CPC-1232NJ 2021-2025	20,194 tank cars	DOT Estimate
Unit Cost Per Retrofit of CPC-1232 Non-Jacketed	$27,090	DOT Adaptation of Watco Companies, L.L.C. Public Comment on the 2013 APRM
Time Out-of-Service Cost of CPC-1232 Non-Jacketed	$944	DOT Adaptation of Watco Companies, L.L.C. Public Comment on the 2013 APRM
Additional Fuel and Maintenance Costs Per Year, Relative to Enhanced Jacketed CPC-1232 (based on 4.5 tons of extra weight)	$522	DOT Adaptation of EIA and CSX Corporation Data
Number of **CPC-1232 Jacketed Retrofitted** 2016-2018	34,331	DOT Estimate
Unit Cost Per Retrofit of CPC-1232 Jacketed	$2,430	N/A
Time Out-of-Service Cost of CPC-1232 Jacketed	N/A	N/A
Additional Fuel and Maintenance Costs Per Year, Relative to Enhanced Jacketed CPC-1232	N/A	N/A

Table TC15: Final Rule Tank Car Option: Enhanced Jacketed CPC-1232 retrofit with NPRM Option 2 New Car Standard		
Variable	**Formula/Input**	**Source**
Number of **New NPRM Option 2 Cars Constructed for fleet growth**, 2015-2019	6,953 tank cars	DOT Estimate
Incremental Cost of DOT-117, Relative to Enhanced Jacketed CPC-1232	$3,000	N/A
Other Costs from Factory Re-Tooling or Capacity Issues	Not Estimated	N/A
Number of DOT-111 NJs retired rather than retrofit.	11,8511tank cars	DOT Estimate
Cost of retiring DOT-111 NJ	$14,167	N/A
Fuel and maintenance cost of replacing a retired car	$247	N/A
Number of **New DOT-117 Cars Constructed for retirement of DOT-111J**, 2015-2019	916 tank cars	DOT Estimate
Incremental Cost of Retiring DOT-111 J	$11,297	N/A
Other Costs from Factory Re-Tooling or Capacity Issues	Not Estimated	N/A
Additional Fuel and Maintenance Costs Per Year for replacing retired car	$247	N/A

6. Total Costs for Final Rule Option

The table below presents the total estimated 20-year costs for the option implemented by the accompanying final rule.

	DOT 111 Unjacketed		DOT 111 Jacketed		CPC 1232 Unjacketed	CPC 1232 Jacketed	**Total**		**Planned New Construction (Additional Cost)**	**Fuel and track Maintenance**
Year	Retrofits	Retirements*	Retrofits	Retirements*	Retrofits	Retrofits	**Retrofits**	**Retirements***	**New Construction**	**Fuel and track Maintenance**
2015	$0	$0	$0	$0	$0	$2,195,301	$2,195,301	$0	$0	$0
2016	$171,767,199	$0	$0	$0	$0	$8,781,205	$180,548,404	$0	$20,859,000	$5,594,220
2017	$281,179,752	$64,112,759	$20,164,191	$10,073,786	$0	$8,781,205	$310,125,148	$74,186,544	$0	$17,695,120
2018	$0	$0	$44,321,848	$0	$186,762,508	$8,781,205	$239,865,561	$0	$0	$21,602,369
2019	$0	$0	$0	$0	$236,747,130	$8,781,205	$245,528,335	$0	$0	$26,006,939
2020	$194,731,769	$0	$0	$0	$1,037,258	$8,781,205	$204,550,232	$0	$0	$30,420,952
2021	$340,148,097	$101,885,129	$0	$0	$0	$8,781,205	$348,929,302	$101,885,129	$0	$46,191,501
2022	$197,573,148	$0	$1,771,749	$276,777	$21,053,534	$8,781,205	$229,179,636	$276,777	$0	$51,072,104
2023	$768,729	$0	$0	$0	$0	$8,781,205	$9,549,934	$0	$0	$51,089,452
2024	$0	$1,899,362	$0	$0	$0	$8,781,205	$8,781,205	$1,899,362	$0	$51,240,344
2025	$0	$0	$0	$0	$0	$2,897,798	$2,897,798	$0	$0	$51,240,344
2026	$0	$0	$0	$0	$0	$0	$0	$0	$0	$51,240,344
2027	$0	$0	$0	$0	$0	$0	$0	$0	$0	$51,240,344
2028	$0	$0	$0	$0	$0	$0	$0	$0	$0	$51,240,344
2029	$0	$0	$0	$0	$0	$0	$0	$0	$0	$51,240,344
2030	$0	$0	$0	$0	$0	$0	$0	$0	$0	$51,240,344
2031	$0	$0	$0	$0	$0	$0	$0	$0	$0	$51,240,344
2032	$0	$0	$0	$0	$0	$0	$0	$0	$0	$51,240,344
2033	$0	$0	$0	$0	$0	$0	$0	$0	$0	$51,240,344
2034	$0	$0	$0	$0	$0	$0	$0	$0	$0	$51,240,344
NPV 7%	$836,547,207	$116,749,585	$51,304,086	$8,384,297	$324,222,172	$56,897,181	$1,268,970,646	$125,133,882	$18,219,058	$369,902,036
NPV 3%	$1,015,437,919	$142,927,493	$59,231,114	$9,437,431	$387,644,765	$70,604,808	$1,532,918,606	$152,364,924	$19,661,608	$568,965,483

The total 20 year costs of the new tank car standard adopted in the accompanying final rule are $1.782 billion using a 7 percent discount rate, and $2.274 billion using a 3 percent discount rate.

Costs of Enhanced CPC-1232 Standard (Option 3)

PHMSA also considered another standard that mandates all cars to meet or exceed the performance achieved by an Option 3 tank car. This car is already in production and is the standard the tank car manufacturers have committed to build to for flammable liquid unit train service. The costs for mandating this standard are developed in this section. The cost analysis is similar to that for the Option 1, with the following changes:

- Our baseline assumption is that this car would be the car that is produced in the in absence of regulation. As a result, we assume no incremental costs associated with building new cars to satisfy growing demand for tank cars to ship crude oil and ethanol in unit trains.
- The retrofit costs for the DOT-111NJ, DOT-111J, and CPC-1232NJ would be the same as the retrofit costs estimated for the final rule, because the Option 3 tank car is the retrofit standard for the final rule.
- The additional fuel and maintenance costs would be the same for retrofitted cars, but newly constructed cars would not impose these costs, because the Option 3 tank car would be the newly built car regardless.

We continued all other assumptions listed in the cost analysis for the final rule option car. The table below summarizes the information that feeds into the cost analysis for this tank car option.

Table TC16: Retrofit Costs for the Non-Jacketed DOT-111 (Option 3 Tank Car)	
Retrofit Option	**Cost**
Bottom outlet valve handle retrofit cost	$1,200
Pressure relief valve retrofit cost	$1,500
Thermal protection retrofit cost	$4,000
Truck Upgrade	$12,000
Full jacket + full height head shields retrofit cost	$23,400
Unadjusted Total	**$42,100**
Learning curve cost reduction	10%
Adjusted Total	**$37,890**

Table TC17: Retrofit Costs for the Jacketed DOT-111 Tank CAR (Option 3 Tank Car)	
Retrofit Option	**Cost**
Bottom outlet valve handle retrofit cost	$1,200
Pressure relief valve retrofit cost	$1,500
Thermal protection retrofit cost	$4,000
Full jacket retrofit cost with half height head shields	$23,400
Unadjusted Total	**$30,100**
Learning curve cost reduction	10%
Adjusted Total	**$27,090**

Table TC18: Retrofit Costs for the Non Jacketed DOT-111 Tank Car (Option 3 Tank Car)	
Retrofit Option	**Cost**
Bottom outlet valve handle retrofit cost	$1,200
Pressure relief valve retrofit cost	$1,500
Thermal protection retrofit cost	$4,000
Full jacket retrofit cost with half height head shields	$23,400
Unadjusted Total	**$30,100**
Learning curve cost reduction	10%
Adjusted Total	**$27,090**

Table TC19: Retrofit Costs for the Jacketed CPC-1232J Option 3 Tank Car	
Retrofit Option	**Cost**
Bottom outlet valve handle retrofit cost	$1,200
Pressure relief valve retrofit cost	$1,500
Unadjusted Total	$2,700
Learning curve cost reduction	10%
Adjusted Total	**$2,430**

Table TC20: Summary of Cost Estimates for an Option 3Tank Car					
Tank Car	**Increased weight to achieve PHMSA and FRA designed car standard (tons)**	**Miles Per Year, Per Car**	**Additional Fuel Costs per Ton-Mile**	**Additional Maintenance Cost per Ton-Mile**	**Annual Additional Fuel and Maintenance Costs**
Retrofitted Non-Jacketed DOT-111	8	15,400	$0.0063	$0.00083	$878
Retrofitted Jacketed DOT-111	2.5	15,400	$0.0063	$0.00083	$275
Retrofitted Non-Jacketed CPC-1232	4.75	15,400	$0.0063	$0.00083	$522
Enhanced Jacketed CPC-1232	0	15,400	$0.0063	$0.00083	$0
Replacement of jacketed CPC-1232 with Option 3 New construction	0	15,400	$0.0063	$0.00083	$0
Replacement of retired unjacketed DOT-111 with an Option 3 New Car	8	15,400	$0.0063	$0.00083	$878
Replacement of retired jacketed DOT-111 with an Option 3 New Car	2.5	15,400	$0.0063	$0.00083	$275

TC21: Summary of Cost Estimates for an Option 3 Tank Car Enhanced Jacketed CPC-1232 Car		
Variable	**Formula/Input**	**Source**
Number of DOT-111NJ Retrofitted 2016-2018	30,130 tank cars	DOT Estimate
Unit Cost Per Retrofit of DOT-111 Non-Jacketed	$37,890	DOT Adaptation of Watco Companies, L.L.C. Public Comment on the 2013 APRM
Time Out-of-Service Cost of DOT-111 Non-Jacketed	$1,033	DOT Adaptation of Watco Companies, L.L.C. Public Comment on the 2013 APRM
Additional Fuel and Maintenance Costs Per Year, Relative to Enhanced Jacketed CPC-1232 (based on 8.93 tons of extra weight)	$878	DOT Adaptation of EIA and CSX Corporation Data
Number of DOT-111 Jacketed Retrofitted 2016-2018	2,356	DOT Estimate
Unit Cost Per Retrofit of DOT-111 Jacketed	$27,090	DOT estimate and comments from Watco

TC21: Summary of Cost Estimates for an Option 3 Tank Car Enhanced Jacketed CPC-1232 Car		
Variable	**Formula/Input**	**Source**
Time Out-of-Service Cost of DOT-111 Jacketed	$944	DOT Adaptation of Watco Companies, L.L.C. Public Comment on the 2013 APRM
Additional Fuel and Maintenance Costs Per Year, Relative to Enhanced Jacketed CPC-1232	$275	DOT Adaptation of EIA and CSX Corporation Data
Number of New NPRM Option 2 Cars Constructed for fleet growth, 2015-2019	6,953 tank cars	DOT Estimate
Incremental Cost of CPC-1232 Jacketed, Relative to Enhanced Jacketed CPC-1232	$3,000	N/A
Other Costs from Factory Re-Tooling or Capacity Issues	Not Estimated	N/A
Number of New NPRM Option 2 Cars Constructed for retirement of DOT-111NJ, 2015-2019	11,717 tank cars	DOT Estimate
Incremental Cost of Option 2 car Relative to Enhanced Jacketed CPC-1232	$14,167	N/A
Other Costs from Factory Re-Tooling or Capacity Issues	Not Estimated	N/A
Additional Fuel and Maintenance Costs Per Year for replacing retired car	$247	N/A
Number of DOT-111 Jacketed Retrofitted 2016-2018	2,536	DOT Estimate
Unit Cost Per Retrofit of DOT-111 Jacketed	$27,090	DOT estimate and comments from Watco
Time Out-of-Service Cost of DOT-111 Jacketed	$944	DOT Adaptation of Watco Companies, L.L.C. Public Comment on the 2013 APRM
Additional Fuel and Maintenance Costs Per Year, Relative to Enhanced Jacketed CPC-1232	$275	DOT Adaptation of EIA and CSX Corporation Data
Tank Car Capacity Loss from Enhanced Tank Car Standards	None	DOT Estimate
Number of DOT-111 NJ Tank Car Early Retirements (as a result of the cost of retrofits), 2015-2034	11,851	DOT Estimate
Cost per retired tank car	$14,167	DOT Estimate
Number of DOT-111 J Tank Car Early Retirements (as a result of the cost of retrofits), 2015-2034	918	
Cost per retired DOT-111 J tank car	$11,297	

TC21: Summary of Cost Estimates for an Option 3 Tank Car Enhanced Jacketed CPC-1232 Car		
Variable	**Formula/Input**	**Source**
Percentage of Track Capable of Handling 286,000 pounds of Gross Rail Load (GRL)	100%	DOT Estimate
Percentage of DOT-111 Non-Jacketed and CPC-1232 Non-Jacketed in PG II and PG III service	100%	DOT Estimate

Tables TC21 and TC22 summarize the 20-year cost streams for the Option 3 tank car. The first table presents undiscounted costs, the second costs discounted at a 7 percent discount rate.

TC22: Costs for the Option 3 Tank Car

	DOT 111 Unjacketed		DOT 111 Jacketed		CPC 1232 Unjacketed	CPC 1232 Jacketed	**Total**		**Planned New Construction (Additional Cost)**	**Fuel and track Maintenance**
Year	Retrofits	Retirements*	Retrofits	Retirements*	Retrofits	Retrofits	**Retrofits**	**Retirements***	**New Construction**	**Fuel and track Maintenance**
2015	$0	$0	$0	$0	$0	$2,195,301	$2,195,301	$0	$0	$0
2016	$171,767,199	$0	$0	$0	$0	$8,781,205	$180,548,404	$0	$20,859,000	$3,876,450
2017	$281,179,752	$64,112,759	$20,164,191	$10,073,786	$0	$8,781,205	$310,125,148	$74,186,544	$0	$14,639,001
2018	$0	$0	$44,321,848	$0	$186,762,508	$8,781,205	$239,865,561	$0	$0	$18,546,250
2019	$0	$0	$0	$0	$236,747,130	$8,781,205	$245,528,335	$0	$0	$22,950,820
2020	$194,731,769	$0	$0	$0	$1,037,258	$8,781,205	$204,550,232	$0	$0	$27,364,833
2021	$340,148,097	$101,885,129	$0	$0	$0	$8,781,205	$348,929,302	$101,885,129	$0	$41,358,634
2022	$197,573,148	$0	$1,771,749	$276,777	$21,053,534	$8,781,205	$229,179,636	$276,777	$0	$46,233,184
2023	$768,729	$0	$0	$0	$0	$8,781,205	$9,549,934	$0	$0	$46,250,533
2024	$0	$1,899,362	$0	$0	$0	$8,781,205	$8,781,205	$1,899,362	$0	$46,368,302
2025	$0	$0	$0	$0	$0	$2,897,798	$2,897,798	$0	$0	$46,368,302
2026	$0	$0	$0	$0	$0	$0	$0	$0	$0	$46,368,302
2027	$0	$0	$0	$0	$0	$0	$0	$0	$0	$46,368,302
2028	$0	$0	$0	$0	$0	$0	$0	$0	$0	$46,368,302
2029	$0	$0	$0	$0	$0	$0	$0	$0	$0	$46,368,302
2030	$0	$0	$0	$0	$0	$0	$0	$0	$0	$46,368,302
2031	$0	$0	$0	$0	$0	$0	$0	$0	$0	$46,368,302
2032	$0	$0	$0	$0	$0	$0	$0	$0	$0	$46,368,302
2033	$0	$0	$0	$0	$0	$0	$0	$0	$0	$46,368,302
2034	$0	$0	$0	$0	$0	$0	$0	$0	$0	$46,368,302
NPV 7%	$836,547,207	$116,749,585	$51,304,086	$8,384,297	$324,222,172	$56,897,181	$1,268,970,646	$125,133,882	$18,219,058	$331,030,067
NPV 3%	$1,015,437,919	$142,927,493	$59,231,114	$9,437,431	$387,644,765	$70,604,808	$1,532,918,606	$152,364,924	$19,661,608	$510,631,020

The total costs of the Option 3 tank car standard over 20 years are $1.743 billion at a 7 percent discount rate and $2.216 billion discounted at 3 percent.

Costs of the AAR 2014 Standard (Option 2)

PHMSA also considered another standard that mandates all cars to meet or exceed the performance achieved by an Option 2 - AAR 2014 tank car. The costs for mandating this standard are developed in this section.

The cost analysis is similar to that for the Final Rule car, with the following change:

The retrofit costs for the DOT-111 unjacketed, DOT-111 Jacketed, and CPC-1232 unjacketed would be higher, because the Option 2 requires extra shell thickness, full height head shields, a

thermal blanket, and full jacket. In addition, the CPC-1232 with a jacket would have to have a thicker jacket applied to meet the puncture resistance standards of this car standard, which means removal of the old jacket and replacement with a new thicker jacket.

Table TC23: Retrofit Costs for the Non-Jacketed DOT-111 to AAR 2014 Tank Car	
Retrofit Option	**Cost**
Bottom outlet valve handle retrofit cost	$1,200
Pressure relief valve retrofit cost	$1,500
Thermal protection retrofit cost	$4,000
Full-jacket retrofit cost (assumed to include full-height head shield cost)	$23,400
Increased 1/8-inch thickness (assumed to be added to jacket)	$3,000
ECP brakes retrofit cost	$0
Wheel bearings	12000
Unadjusted Total	**$45,100**
Learning curve cost reduction	10%
Adjusted Total	**$40,590**

Table TC24: Retrofit Costs for the Jacketed DOT-111 to AAR 2014 Tank Car	
Retrofit Option	**Cost**
Bottom outlet valve handle retrofit cost	$1,200
Pressure relief valve retrofit cost	$1,500
Thermal protection retrofit cost	$4,000
Full jacket retrofit cost (assumed to include full-height head shield cost)	$23,400
Increased 1/8-inch thickness (assumed to be added to jacket)	$3,000
ECP brakes retrofit cost	$0
Wheel bearings	$0
Unadjusted Total	**$33,100**
Learning curve cost reduction	10%
Adjusted Total	**$29,790**

Table TC25: Retrofit Costs for the Non-Jacketed CPC-1232 to AAR 2014 Tank Car	
Retrofit Option	**Cost**
Bottom outlet valve handle retrofit cost	$1,200
Pressure relief valve retrofit cost	$1,500
Thermal protection retrofit cost	$4,000
Full jacket retrofit cost (assumed to include full-height head shield cost)	$23,400
Increased 1/16-inch thickness (assumed to be added to jacket)	$1,500
ECP brakes retrofit cost	$0
Wheel bearings	0
Unadjusted Total	**$31,600**
Learning curve cost reduction	10%
Adjusted Total	**$28,440**

Table TC26: Retrofit Costs for the Jacketed CPC-1232 to AAR 2014 Tank Car	
Retrofit Option	**Cost**
Bottom outlet valve handle retrofit cost	$1,200
Pressure relief valve retrofit cost	$1,500
Thermal protection retrofit cost	$4,000
Full jacket retrofit cost (assumed to included full-height head shield cost)	$23,400
Increased 1/8-inch thickness (assumed to be added to jacket)	$3,000
ECP brakes retrofit cost	$0
Wheel bearings	$0
Unadjusted Total	**$33,100**
Learning curve cost reduction	10%
Adjusted Total	**$29,790**

We continued all other assumptions listed in the cost analysis for the final rule designed car.

Table TC27: Increased Fuel and Maintenance Costs, AAR Tank Car

Tank Car	Increased weight to achieve PHMSA and FRA designed car standard (tons)	Miles Per Year, Per Car	Additional Fuel Costs per Ton-Mile	Additional Maintenance Cost per Ton-Mile	Annual Additional Fuel and Maintenance Costs
Retrofitted Non-Jacketed DOT-111	10.25	15,400	$0.0063	$0.00083	$1,125
Retrofitted Jacketed DOT-111	4.75	15,400	$0.0063	$0.00083	$522
Retrofitted Non-Jacketed CPC-1232	7	15,400	$0.0063	$0.00083	$769
Enhanced Jacketed CPC-1232	2.25	15,400	$0.0063	$0.00083	$247
Replacement of jacketed CPC-1232 with a New AAR Tank Car	2.25	15,400	$0.0063	$0.00083	$247
Replacement of retired unjacketed DOT-111 with a New AAR Tank Car	10.25	15,400	$0.0063	$0.00083	$1,125
Replacement of retired jacketed DOT-111 with a New AAR Tank Car	4.75	15,400	$0.0063	$0.00083	$522

Table TC28: Summary of Cost Estimates for AAR Tank Car

Variable	Formula/Input	Source
Number of DOT-111 Non-Jacketed Retrofitted 2016-2018	30,475 tank cars	DOT Estimate
Unit Cost Per Retrofit of DOT-111 Non-Jacketed	$40,590	DOT Adaptation of Watco Companies, L.L.C. Public Comment on the 2013 APRM

Table TC28: Summary of Cost Estimates for AAR Tank Car		
Variable	**Formula/Input**	**Source**
Time Out-of-Service Cost of DOT-111 Non-Jacketed	$1,033	DOT Adaptation of Watco Companies, L.L.C. Public Comment on the 2013 APRM
Additional Fuel and Maintenance Costs Per Year, Relative to AAR 2014 car (based on 11.5 tons of extra weight)	$1,125	DOT Adaptation of EIA and CSX Corporation Data
Number of DOT-111 Jacketed Retrofitted 2016-2018	2,356	
Unit Cost Per Retrofit of DOT-111Jacketed	$29,970	DOT Adaptation of Watco Companies, L.L.C. Public Comment on the 2013 APRM
Time Out-of-Service Cost of DOT-111 Non-Jacketed	$1,033	DOT Adaptation of Watco Companies, L.L.C. Public Comment on the 2013 APRM
Additional Fuel and Maintenance Costs Per Year, Relative to AAR 2014 car	$522	N/A
Number of CPC-1232NJ 2021-2025	15,895 tank cars	DOT Estimate
Unit Cost Per Retrofit of CPC-1232 Non-Jacketed	$28,440	DOT Adaptation of Watco Companies, L.L.C. Public Comment on the 2013 APRM
Time Out-of-Service Cost of CPC-1232 Non-Jacketed	$944	DOT Adaptation of Watco Companies, L.L.C. Public Comment on the 2013 APRM
Additional Fuel and Maintenance Costs Per Year, Relative to AAR 2014 car (based on 7.07 tons of extra weight)	$769	DOT Adaptation of EIA and CSX Corporation Data
Number of CPC-1232 Jacketed Retrofitted 2016-2018	24,933	DOT Estimate
Unit Cost Per Retrofit of CPC-1232 Jacketed	$29,790	N/A
Time Out-of-Service Cost of CPC-1232 Jacketed		N/A
Additional Fuel and Maintenance Costs Per Year, Relative to AAR 2014 car	$247	N/A
Number of New AAR 2014 Constructed, 2015-2019	6,953 tank cars	DOT Estimate
Incremental Cost of AAR 2014 Cars, Relative to AAR 2014 car	$3,000	DOT Estimate
Other Costs from Factory Re-Tooling or Capacity Issues	Not Estimated	N/A
Additional Fuel and Maintenance Costs Per Year, Relative to AAR 2014 car (based on 2.57 tons of extra weight)	$247	DOT Adaptation of EIA and CSX Corporation Data
Tank Car Capacity Loss from Enhanced Tank Car Standards	None	DOT Estimate
Number of DOT-111NJ Tank Car Early Retirements (as a result of the cost of retrofits), 2015-2034	11,851	DOT Estimate
Cost of retirement	$14,167	DOT Estimate

Table TC28: Summary of Cost Estimates for AAR Tank Car		
Variable	**Formula/Input**	**Source**
Number of DOT-111J Tank Car Early Retirements (as a result of the cost of retrofits), 2015-2034	916	DOT Estimate
Cost of retirement	$11,297	DOT Estimate
Percentage of Track Capable of Handling 286,000 pounds of Gross Rail Load (GRL)	100%	DOT Estimate
Percentage of DOT-111 Non-Jacketed and CPC-1232 Non-Jacketed in PG II and PG III service	100%	DOT Estimate

The 20 year undiscounted and discounted costs for this option are presented in the tables below.

Table TC29: Costs of Option 2 Tank Car

	DOT 111 Unjacketed		DOT 111 Jacketed		CPC 1232 Unjacketed	CPC 1232 Jacketed	**Total**		**Planned New Construction (Additional Cost)**	**Fuel and track Maintenance**
Year	Retrofits	Retirements*	Retrofits	Retirements*	Retrofits	Retrofits	**Retrofits**	**Retirements***	**New Construction**	**Fuel and track Maintenance**
2015	$0	$0	$0	$0	$0	$19,997,151	$19,997,151	$0	$0	$160,747
2016	$183,682,299	$0	$0	$0	$0	$79,988,604	$263,670,903	$0	$20,859,000	$7,488,204
2017	$300,684,552	$64,112,759	$22,100,091	$10,073,786	$0	$79,988,604	$402,773,247	$74,186,544	$0	$22,193,951
2018	$0	$0	$48,577,048	$0	$195,756,208	$79,988,604	$324,321,860	$0	$0	$28,779,421
2019	$0	$0	$0	$0	$248,147,880	$79,988,604	$328,136,484	$0	$0	$35,913,353
2020	$208,239,869	$0	$0	$0	$1,087,208	$79,988,604	$289,315,681	$0	$0	$42,215,507
2021	$363,743,397	$101,885,129	$0	$0	$0	$79,988,604	$443,732,001	$101,885,129	$0	$60,788,051
2022	$211,278,348	$0	$1,941,849	$276,777	$22,067,384	$79,988,604	$315,276,185	$276,777	$0	$67,766,792
2023	$822,054	$0	$0	$0	$0	$79,988,604	$80,810,658	$0	$0	$68,432,006
2024	$0	$1,899,362	$0	$0	$0	$79,988,604	$79,988,604	$1,899,362	$0	$69,225,884
2025	$0	$0	$0	$0	$0	$26,396,239	$26,396,239	$0	$0	$69,438,069
2026	$0	$0	$0	$0	$0	$0	$0	$0	$0	$69,438,069
2027	$0	$0	$0	$0	$0	$0	$0	$0	$0	$69,438,069
2028	$0	$0	$0	$0	$0	$0	$0	$0	$0	$69,438,069
2029	$0	$0	$0	$0	$0	$0	$0	$0	$0	$69,438,069
2030	$0	$0	$0	$0	$0	$0	$0	$0	$0	$69,438,069
2031	$0	$0	$0	$0	$0	$0	$0	$0	$0	$69,438,069
2032	$0	$0	$0	$0	$0	$0	$0	$0	$0	$69,438,069
2033	$0	$0	$0	$0	$0	$0	$0	$0	$0	$69,438,069
2034	$0	$0	$0	$0	$0	$0	$0	$0	$0	$69,438,069
NPV 7%	$894,576,584	$116,749,585	$56,229,628	$8,384,297	$339,835,354	$518,280,364	$1,808,921,931	$125,133,882	$18,219,058	$498,132,967
NPV 3%	$1,085,876,539	$142,927,493	$64,917,705	$9,437,431	$406,312,113	$643,144,089	$2,200,250,446	$152,364,924	$19,661,608	$767,051,450

The total costs of the Option 2 tank car standard over 20 years are $2.45 billion at a 7 percent discount rate and $3.139 billion discounted at 3 percent.

PHMSA also considers another standard that mandates all cars to meet or exceed the performance achieved by Option 1 – PHMSA FRA design tank car (described above). The costs for mandating this standard are developed in this section.

The cost analysis is similar to that for the Option 2 car, with the following changes:

1) The incremental cost for newly constructed car—relative to the baseline Option 3 tank car—would be higher, because the Option 1 car requires ECP brakes and roll-over protection for newly constructed cars. PHMSA estimates the cost of ECP brakes on a new car at $7,800, and rollover protection to cost $5,000 for an Option 1 car. The thicker

shell plus the rollover protection cost and the ECP brake cost raises the new car cost differential for this option to $14,800.

2) The retrofit costs for all tank cars currently in the fleet would be higher, because the Option 1 car requires ECP brakes, a thicker shell, full height head shields, a thermal blanket, and full jacket. Retrofitting rollover protection on older car designs is not feasible, so PHMSA did not propose requiring rollover protection for this car standard.

Table TC30: Retrofit Costs for the Non-Jacketed DOT-111, Jacketed DOT-111, and Jacketed CPC-1232 to PHMSA-FRA Designed Car

Retrofit Option	Cost
Bottom outlet valve handle retrofit cost	$1,200
Pressure relief valve retrofit cost	$1,500
Thermal protection retrofit cost	$4,000
Full-jacket retrofit cost (assumed to included full-height head shield cost)	$23,400
Increased 1/8-inch thickness (assumed to be added to jacket)	$3,000
ECP brakes retrofit cost	$7,800
Truck upgrade	$12,000
Unadjusted Total	**$52,600**
Learning curve cost reduction	10%
Adjusted Total	**$47,340**

Table TC31: Retrofit Costs for the Jacketed DOT-111

Retrofit Option	Cost
Bottom outlet valve handle retrofit cost	$1,200
Pressure relief valve retrofit cost	$1,500
Thermal protection retrofit cost	$4,000
Full jacket retrofit cost (assumed to included full-height head shield cost)	$23,400
Increased 1/8-inch thickness (assumed to be added to jacket)	$3,000
ECP brakes retrofit cost	$7,500
Unadjusted Total	**$40,600**
Learning curve cost reduction	10%
Adjusted Total	**$36,540**

The retrofit costs for the CPC-1232NJ are slightly lower than the other car configurations, because this car has an 8/16ths inch thick tank. Thus, only 1/16th thickness needs to be added to the thickness of the enhanced jacket, rather than a full eighth inch as with the other cars. As a result, the costs of adding shell thickness to this car are half what they would be for the other car configurations.

Table TC32: Retrofit Costs for the Non-Jacketed CPC-1232 to PHMSA-FRA Designed Car

Retrofit Option	Cost
Bottom outlet valve handle retrofit cost	$1,200
Pressure relief valve retrofit cost	$1,500

Thermal protection retrofit cost	$4,000
Full jacket retrofit cost (assumed to included full-height head shield cost)	$23,400
Increased 1/16-inch thickness (assumed to be added to jacket)	$1,500
ECP brakes retrofit cost	$7,800
Truck upgrade	0
Unadjusted Total	**$39,400**
Learning curve cost reduction	10%
Adjusted Total	**$35,460**

Table TC33: Retrofit Costs for the Jacketed CPC-1232 to PHMSA-FRA Designed Car

Retrofit Option	Cost
Bottom outlet valve handle retrofit cost	$1,200
Pressure relief valve retrofit cost	$1,500
Thermal protection retrofit cost	$4,000
Full jacket retrofit cost (assumed to included full-height head shield cost)	$23,400
Increased 1/8-inch thickness (assumed to be added to jacket)	$3,000
ECP brakes retrofit cost	$7,500
Unadjusted Total	$40,600
Learning curve cost reduction	10%
Adjusted Total	$36,540

Table TC34: Extra Fuel and Track Maintenance Costs Associated with the Heavier Cars

Tank Car	Weight Increase in Tons	Miles Per Year, Per Car	Additional Fuel Costs per Ton-Mile	Additional Maintenance Cost per Ton-Mile	Additional Annual Fuel and Maintenance Costs
Retrofitted Non-Jacketed DOT-111	10.75	15,400	$0.0063	$0.00083	$1,180
Retrofitted Jacketed DOT-111	5.25	15,400	$0.0063	$0.00083	$576
Retrofitted Non-Jacketed CPC-1232	7.5	15,400	$0.0063	$0.00083	$824
Enhanced Jacketed CPC-1232	2.75	15,400	$0.0063	$0.00083	$302
Replacement of Jacketed CPC-1232 with Option 1 New construction	2.75	15,400	$0.0063	$0.00083	$302
Replacement of Retired Non-Jacketed DOT-111 with an Option 1 New Car	10.75	15,400	$0.0063	$0.00083	$1,180
Replacement of retired jacketed DOT-111 with an Option 1 New Car	5.25	15,400	$0.0063	$0.00083	$576

As noted in the NPRM, the Agency was unable to model the safety improvement attributable to rollover protection for this car. In addition, because this car option requires all cars in HHFT

service to be retrofit or built with ECP brake technology, regardless of whether they are operated in true unit train service or are being shipped in relatively large volumes in manifest trains. Shipping in manifest trains along with cars that are not ECP equipped prevents the deployment of ECP technology. The costs of equipping cars with ECP technology are therefore incurred but without the accompanying benefit, for some portion of the fleet. This is obviously wasteful, and was a reason for the decision by the Agency to require only cars operating in true unit train service to be equipped with ECP technology.

As presented above, the Option 1 car is marginally more expensive than the Option 2 car but would produce the same safety benefits as that car. Higher costs accompanied by equivalent benefits obviously makes the Option 1 car inferior to the Option 2 car from a cost benefit standpoint. The Option 1 car is also not demonstrably safer. As a result, the Agency drops consideration of this car from the rest of the analysis.

Table TC35: Tank Car Option 1, FRA and PHMSA Designed Car

Variable	Formula/Input	Source
Number of DOT-111NJ Retrofitted 2016-2020	30,130 tank cars	DOT Estimate
Unit Cost Per Retrofit of DOT-111 Non-Jacketed	$47,340	DOT Adaptation of Watco Companies, L.L.C. Public Comment on the 2013 APRM
Time Out-of-Service Cost of DOT-111 Non-Jacketed	$1,033	DOT Adaptation of Watco Companies, L.L.C. Public Comment on the 2013 APRM
Additional Fuel and Maintenance Costs Per Year, Relative to FRA and PHMSA Designed Car(based on 11.93 tons of additional weight)	$1,180	DOT Adaptation of EIA and CSX Corporation Data
Number of DOT-111 Jacketed Retrofitted 2016-2018	2,356	DOT Estimate
Unit Cost Per Retrofit of DOT-111 Jacketed	$36,540	N/A
Time Out-of-Service Cost of DOT-111 Jacketed	$1033	N/A
Additional Fuel and Maintenance Costs Per Year, Relative to FRA and PHMSA Designed Car	$576	N/A
Number of CPC-1232 Non-Jacketed Retrofitted 2016-2018	15,895 Tank Cars	DOT Estimate
Unit Cost Per Retrofit of CPC-1232 Non-Jacketed	$35,640	DOT Adaptation of Watco Companies, L.L.C. Public Comment on the 2013 APRM
Time Out-of-Service Cost of CPC-1232 Non-Jacketed	$944	DOT Adaptation of Watco Companies, L.L.C. Public Comment on the 2013 APRM
Additional Fuel and Maintenance Costs Per Year, Relative to FRA and PHMSA Designed Car (based on 7.5 tons of extra weight)	$824	DOT Adaptation of EIA and CSX Corporation Data
Number of CPC-1232 Jacketed Retrofitted 2016-2018	24,933	DOT Estimate
Unit Cost Per Retrofit of CPC-1232 Jacketed	$36,540	N/A
Time Out-of-Service Cost of CPC-1232 Jacketed	0	N/A

Table TC35: Tank Car Option 1, FRA and PHMSA Designed Car		
Variable	**Formula/Input**	**Source**
Additional Fuel and Maintenance Costs Per Year, Relative to FRA and PHMSA Designed Car	$302	N/A
Number of New PHMSA and FRA Designed Cars Constructed, 2015-2019	6,953 Tank Cars	DOT Estimate
Incremental Cost of New PHMSA and FRA Designed Cars, Relative to Enhanced Jacketed CPC-1232	$14,800	DOT Estimate
Other Costs from Factory Re-Tooling or Capacity Issues	Not Estimated	N/A
Additional Fuel and Maintenance Costs Per Year, Relative to FRA and PHMSA Designed Car (based on 3 tons of extra weight)	$302	DOT Adaptation of EIA and CSX Corporation Data
Tank Car Capacity Loss from Enhanced Tank Car Standards	None	DOT Estimate
Number of DOT-111 NJ Tank Car Early Retirements (as a result of the cost of retrofits), 2015-2034	11,851	DOT Estimate
Cost of retirements	$14,167	DOT Estimate
Number of DOT-111 J Tank Car Early Retirements (as a result of the cost of retrofits), 2015-2034	916	DOT Estimate
Cost of Retirement	$11,297	DOT Estimate
Percentage of Track Capable of Handling 286,000 pounds of Gross Rail Load (GRL)	100%	DOT Estimate
Percentage of DOT-111 Non-Jacketed and CPC-1232 Non-Jacketed in PG II and PG III service	100%	DOT Estimate

C. Tank Car Benefits

This section analyzes the benefits for the three tank car Options considered at the NPRM stage as well as the Final Rule Option promulgated by the final rule that this document accompanies. We assess benefits by considering the expected effectiveness of the enhancements in reducing the expected damages of crude oil and ethanol accidents. All of the Options are designed to address the survivability of the tank car and would mitigate the damages of rail accidents better than the current DOT-111. Specifically, the tank car Options incorporate several enhancements to increase puncture resistance; provide thermal protection to survive a 100-minute pool fire; and protect top fitting and bottom outlets during a derailment. Under all Options, the proposed system of design enhancements would reduce the consequences of a derailment of tank cars carrying crude oil or ethanol. There would be fewer car punctures, fewer releases from the service equipment (top and bottom fittings), and delayed release of flammable liquid from the tank cars through the pressure relief devices.

We explain the benefits calculation for the Final Rule Option first, as the benefits to the other Options were calculated in a similar way. We begin by presenting the expected lower

consequence event damages over 20 years. The explanation of how these damages were derived is in the societal damages section. These are the damages for events that are more typical of the average crude and ethanol incident, with lower quantities released, lower environmental damages because no particularly valuable or difficult to remediate environmental asset has been affected, and a low number of injuries and fatalities. Table TC36 below presents the figures arrived at in the societal damages section of this document.

Table TC36: Tank Car Damages with Societal Factors

Year	Total Damages
2015	$179,915,412
2016	$176,427,442
2017	$182,777,809
2018	$196,334,749
2019	$208,471,811
2020	$221,509,522
2021	$222,699,151
2022	$223,063,891
2023	$208,678,220
2024	$223,774,639
2025	$223,247,669
2026	$219,084,383
2027	$201,212,338
2028	$212,100,606
2029	$208,330,088
2030	$204,293,980
2031	$200,686,778
2032	$196,924,311
2033	$193,606,475
2034	$190,456,652
Total	$4,093,595,927

1. Using Marginal Effectiveness Rates

PHMSA mandates that all DOT jacketed, non-jacketed legacy DOT-111 cars, and non-jacketed CPC-1232 cars be retrofit to meet the NPRM Option 3 standard by being equipped with a jacket and full height head shields (where needed), thermal protection, a better PRV and an enhanced BOV handle. These enhancements significantly improve the survivability of legacy car designs in the event of an incident such as a collision or derailment. We calculate benefits by adjusting the likelihood of release of the existing car design in question relative to the release rate of that same car with the enhancements just listed. Thus, the benefits of retrofitting existing cars are the effectiveness differential/expected release rate between existing cars and the DOT-117.

For the final rule, new construction – those cars that are built to satisfy growing demand going forward – the benefits are calculated using the effectiveness differential between an Option 3 tank car and the Option 2 tank car. For cars that are retired rather than retrofit, the effectiveness differential is the difference between the car configuration being retired (e.g. a DOT-111NJ) and the new car design (the Option 2 tank car).

2. Determining Effectiveness Rates

Table TC37: Effectiveness of Existing Tank Car Options Relative to the Non-Jacketed DOT-111

Tank Car	Total	Head puncture	Shell puncture	Thermal damage	Top fittings	BOV
Option 1	51	21	17	12	N/A	<1
Option 2	50	21	17	12	N/A	<1
Option 3	40	19	9	12	N/A	0

Table TC37 summarizes the effectiveness of the proposed elements of each option. The effectiveness was calculated using the following assumptions:

1) PHMSA examined the 16 accidents provided in Appendix B.
2) DOT-111 tank cars composed the vast majority of the type of tank cars involved in the derailments listed in Appendix B. The type of damages these tank cars experienced were used to design the tank car options in the final rule.
3) The volume of lading lost from each tank car in the derailments indicated in Appendix B compiled relative to the documented damage to each tank car that lost lading. These values were used as the baseline for tank cars constructed to the current DOT-111.
4) Improvement in performance was based on the following assumptions.
    a. The ratio of puncture force (DOT-111/option) was used as a multiplier to determine the reduction in lading loss.
    b. Thermal protection prevented thermal damage that results in loss of containment.
    c. Top fittings protection halves the damage to service equipment.
    d. BOV modification prevents lading loss through valve.
5) The reduced volume of lost lading relative to each enhancement was compared to the baseline to calculate the respective reduction or effectiveness.

E.I. DuPont de Nemours and Company developed the analytical method to determine the ratio of puncture force. Transportation Technology Center in Pueblo, CO validated this ratio by performing full-scale testing. FRA calculated the shell puncture resistance of all three Options, which also provide the necessary effectiveness for the Final Rule Option, compared to the other

tank car configurations.[134] These results are available for review in the public docket for this rulemaking.

The rollover protection for the Option 1 tank car is based on the load conditions described in 179.102-3. The top fittings protection for the Option 2 and Option 3 tank cars must meet the load conditions in M-1002 Appendix E, 10.2.1. The former is a dynamic load and the latter is a static load. Rollover protection should provide some safety benefit compared to static load top fittings, but the modelling conducted to estimate effectiveness rates is unable to estimate the extent of the decrease in likelihood of release for rollover protection. As a result, we assume no marginal safety benefit for that feature.

The proposed materials, minimum thickness of 9/16 inch, and jacket provide a 44.9 percent improvement in the puncture force for Options 1 and 2 relative to the current specification requirements for a non-jacketed DOT-111 tank car. A tank car constructed to the proposed requirements of Option 3 would have a 35 percent improvement in puncture force relative to the current unjacketed DOT-111 tank car.[135]

The combination of the shell thickness and head shield of Options 1 and 2 provide a head puncture resistance velocity of 18.4 mph (21% effectiveness rate). Because the Option 3 tank car has a 7/16 inch shell, as opposed to the 9/16 inch shell in Options 1 and 2, it has a head puncture resistance velocity of 17.8 mph.

For a detailed description of how tank car enhancements effectiveness rates were developed, the reader is referred to that section of the document. We reproduce the rates used to calculate benefits in the Tables below.

Table TC38: Shell and Head Puncture Velocities by Tank Car Option

Tank Car	Shell Puncture Velocity*	Head Puncture Velocity*
Option 1	12.3 mph (66%)	18.4 mph (114%)
Option 2	12.3 mph (66%)	18.4 mph (114%)
Option 3	9.6 mph (30%)	17.8 mph (107%)
CPC-1232 Non-Jacketed	8.5 mph (15%)	Top – 10.3 (20%) Bottom – 17.6 (105%)

[134] "Detailed Puncture Analyses Tank Cars: Analysis of Different Impactor Threats and Impact Conditions" can be found at: http://www.fra.dot.gov/eLib/details/L04420

[135] Modeling and simulation of puncture velocity indicate a puncture velocity of approximately 7.4 mph for a legacy DOT Specification 111; 9.6 mph for Option 3; and 12.3 mph for the cars under Options 1 and 2. Puncture velocity is based on an impact with a rigid 12" x 12" indenter with a weight of 297,000 pounds.

Table TC38: Shell and Head Puncture Velocities by Tank Car Option		
DOT-111 Jacketed	9.3 mph (26%)	11.6 mph (35%)
*improvement relative to DOT-111 non-jacketed		

The proposed changes for existing tank cars are based on commenter input, simulations, and modeling. Modeling and simulation of puncture velocity of DOT-111 tank cars currently used to transport ethanol or crude oil indicate that a velocity of approximately 7.4 mph will puncture the shell of the tanks when struck with a rigid 12" x 12" indenter with a weight of 297,000 pounds. Validation of this model has been accomplished using the results of puncture tests performed at the Transportation Technology Center in Pueblo, CO.[136] Further, based on modeling and simulation, the head of an unjacketed DOT-111 tank car, when struck with a 12" x 12" indenter weighing 286,000 pounds, will puncture at 7.6 mph. Table TC38 provides the tank car shell and head puncture velocities of the DOT-117 tank car Options proposed in the NPRM.

Similar to the methodology for estimating the effectiveness of new cars, PHMSA uses these puncture velocities to arrive at risk reduction estimates for retrofits.

In evaluating train accidents involving HHFTs, we examined derailments that occurred at a variety of speeds. Some of the documented derailment speeds exceed the puncture velocity of both the DOT-111 tank car and the options proposed in this rule. However, during a derailment, the speeds of impacts will vary considerably between cars, and many of those impacts will not result in a puncture. The portion of those impacts that could result in a puncture would decline with the higher puncture velocity of the DOT-117 tank car options proposed in this NPRM. Because of use of the proposed DOT-117 tank cars, we would expect the volume of flammable liquid released into the environment, and the overall consequences of a train accident, to be reduced.

Cars can be upgraded by either being retrofit, in which case the marginal safety improvement is from the car type being altered to a jacketed CPC-1232, or retired and replaced, in which case the safety improvement is the difference between the type of car being retired and the Option 2 tank car. In addition, new cars that are built to expand the size of the fleet are evaluated at the difference between the Option 2 car and the CPC-1232J. As a result, a combination of effectiveness rates for the Option 2 and 3 cars are needed to compute the estimated benefits of the final rule. These effectiveness rates are presented in the two tables below. We also present the Option 1 tank car effectiveness without ECP – this car is equivalent to the Option 2 car so they can both be presented in the same table.

[136] "Detailed Puncture Analyses Tank Cars: Analysis of Different Impactor Threats and Impact Conditions" can be found at: http://www.fra.dot.gov/eLib/details/L04420

Table TC39: Relative Effectiveness of the Options 1 and 2 Tank Car		
AAR 2014 Car		
Variable	**Formula/Input**	**Source**
Risk Reduction, DOT-111 Non-Jacketed to AAR 2014 Car	50.4%	Applied Research and Associates, Puncture Resistance Model; DOT Estimate for Top Fittings, Bottom Outlet Valve, Pressure Release Valve, and Thermal Protection Enhancements
Risk Reduction, CPC-1232 Non-Jacketed to AAR 2014 Car	36.8%	Applied Research and Associates, Puncture Resistance Model; DOT Estimate for Top Fittings, Bottom Outlet Valve, Pressure Release Valve, and Thermal Protection Enhancements
Risk Reduction, DOT-111 Jacketed to AAR 2014 Car	42.8%	Applied Research and Associates, Puncture Resistance Model; DOT Estimate for Top Fittings, Bottom Outlet Valve, Pressure Release Valve, and Thermal Protection Enhancements
Risk Reduction, CPC-1232 Jacketed to AAR 2014 Car	16.2%	Applied Research and Associates, Puncture Resistance Model; DOT Estimate for Top Fittings, Bottom Outlet Valve, Pressure Release Valve, and Thermal Protection Enhancements

Table TC40: Relative Effectiveness of the Option 3, Enhanced Jacketed CPC-1232 Tank Car		
Variable	**Formula/Input**	**Source**
Risk Reduction, DOT-111 Non-Jacketed to Enhanced Jacketed CPC-1232 Car	45.9%	Applied Research and Associates, Puncture Resistance Model; DOT Estimate for Top Fittings, Bottom Outlet Valve, Pressure Release Valve, and Thermal Protection Enhancements
Risk Reduction, CPC-1232 Unjacketed to Enhanced Jacketed CPC-1232 Car	31.0%	Applied Research and Associates, Puncture Resistance Model; DOT Estimate for Top Fittings, Bottom Outlet Valve, Pressure Release Valve, and Thermal Protection Enhancements
Risk Reduction, DOT-111 Jacketed to Enhanced Jacketed CPC-1232 Car	37.6%	Applied Research and Associates, Puncture Resistance Model; DOT Estimate for Top Fittings, Bottom Outlet Valve, Pressure Release Valve, and Thermal Protection Enhancements
Risk Reduction, CPC-1232 Jacketed to Enhanced Jacketed CPC-1232 Car	1.0%	/Estimate from FRA subject matter expert

PHMSA did not impose additional top fittings protection requirements on retrofits of existing DOT-111 Non-Jacketed cars, or on the new car standard. In other words, all effectiveness rates presented do not include any benefits from additional top fittings protection, because those benefits are relatively small and uncertain and would apply only to new construction.

HCE Effectiveness Rates

The Agency applies the same effectiveness/mitigation rates to projected HCE damages as to LCE damages. The Agency consulted available information and research on tank car integrity, the interaction of trains with human-built structures such as buildings, and subject matter experts to determine whether it was appropriate to use the same mitigation/prevention factors for HCEs, which are more likely to involve collisions with human-built structures, as to LCEs, which are less likely to involve direct contact with human built structures. The following section summarizes the research findings and reasoning for using the same mitigation factor for both types of incidents.

Research on Tank Car Integrity

In recent years there has been a great deal of research into railroad tank car integrity and developing analytical techniques to determine the effects of safety improvements. Three railroad accidents that resulted in fatalities from the release of hazardous material Minot, ND on January 18, 2002, Macdona, TX, on June 28, 2004 and Graniteville, SC on January 6, 2005 focused attention on improving the structural integrity of tank cars. Based on the circumstances surrounding those events car-to-car impacts were of greatest concern. Specifically head impacts where railroad equipment impacts the tank head and shell impact where the tank is impacted on its side. Results from dynamic, nonlinear finite element analysis are compared to data obtained from full-scale tests to validate the analysis. The intent of this research is to examine the structural integrity of railroad tank cars under a range of conditions varying from normal operating conditions to rare and extreme circumstances such as accidents. The results of that research would provide a technical basis for ongoing tank car rail safety initiatives. While much of that research has been focused on improving the safety of rail tank cars transporting materials toxic by inhalation, many of the safety features examined in this work (head shields and increased shell thickness) are applied to improving DOT-111 tank cars.

Further Information including the full text of these articles may be obtained through the following URLs:

- **Improved Tank Car Safety Research:** https://www.fra.dot.gov/eLib/Details/L02880
- **Next Generation Tank Car Project**: https://www.fra.dot.gov/Page/P0605
- **Engineering Analysis for Railroad Tank Car Head Puncture Resistance:** https://www.fra.dot.gov/eLib/Details/L02877
- **Analyses of Full-Scale Tank Car Shell Impact Tests:** https://www.fra.dot.gov/eLib/Details/L02879

Impact Resistance of Structures

Research into impact resistance of structures has focused on the impacts of windblown debris on buildings. With respect to residential and light commercial structures, missile impact resistance is usually quantified based on the ability of a wall system to withstand the impact of a 2 × 4 in. (50 × 100 mm) wood stud. The testing focused primarily on hurricane-generated missiles. This research is not pertinent to this investigation because the forces to which tank cars are subjected in a derailment are much greater than the impact resistance of any normal structure.

Development of Crash Wall Design Loads from Theoretical Train Impact (2014) considered the impacts of a derailed train to determine ta reasonable impact load for the design of a crash wall. Two impact modes were considered, a glancing blow from a derailed train in the direction of the track and a direct impact as a result of cars piling up in an accordion fashion. The paper compared energy load cases for a freight train with a speed of 50 mph and passenger train speed of 70 mph.

Potential Combustion Hazards Associated with Rail Accidents of Flammable Liquids

The behavior of a flammable liquid and the hazards it poses upon release depends upon the type of release and environmental factors. The proximity of an ignition source is unrelated to population. This is evidenced in the numerous accidents in unpopulated areas where fires have occurred. Common types of hazards posed by flammable liquids involved in rail tank car accidents include: BLEVE, pool fire, fire ball, flash fire, and radiant heat impacts. These combustion hazards are described more thoroughly in the Sandia report but indicate that fragments generated from a BLEVE have the potential to provide the largest hazard footprint in the immediately after an accident. The severity of other thermal hazards e.g. pool fires and flash fires can vary depending on wind speed and direction and the proximity of surrounding infrastructure.

Application of Effectiveness Rates to HCEs

The Sharma model did not to test whether the rule's tank car standards and ECP requirements effectiveness rates would be the same or different in an HCE compared to an LCE, and PHMSA was unable to identify existing studies on this issue. However, PHMSA believes it is reasonable to assume the tank car standards and ECP requirements would have the same effectiveness at mitigating damages in HCEs as for LCEs.

A high consequence event can be expected to entail derailed cars colliding with significant places of congregation, buildings or infrastructure. The Agency believes the forces in play when a derailed car impacts a building are similar to the forces in play when tank cars collide with one another in an LCE derailment that does not involve interaction with other human-made structures. An HCE is likely to resemble a somewhat severe LCE with regard to most of the dynamic forces impacting the tank cars – it is the exacerbating factors of the presence of significant numbers of people, infrastructure or other valuable resources that are damaged by an event that distinguishes an HCE from an LCE. Tank car collisions are explicitly accounted for in the Sharma model used to determine effectiveness rates of the rule's provisions. As a result, the enhancements adopted by the final rule are likely to have the same relative effectiveness whether or not a derailment involves a collision with a building.

PHMSA believes that mitigating the quantity released could be expected to reduce the consequences of HCEs at the same rate as in LCEs. The distinguishing feature of an HCE is the proximity of a high concentration of people, valuable infrastructure, or an area of particular environmental sensitivity that would be impacted by the derailment. Given the presence of such aggravating factors, a smaller quantity release of flammable liquid in the event of a HCE would

mean a smaller area impacted by the consequent fire, which in turn may mean less property damage and a reduction in total fatalities, as more paths of egress would be available to those fleeing the event.

A larger quantity released may block avenues to escape the event that would continue to be available if the quantity released is reduced, thereby increasing the number of fatalities. In addition, the non-fatality damages associated with an HCE are likely to be mitigated by a smaller fire/quantity released. While even a single-car release could result in catastrophic loss of life if it occurs in the wrong place at the wrong time, mitigating the quantity released has the potential to mitigate the damages and lives lost during an HCE event, just as for an LCE event. Furthermore, whether a car will release is determined by the individual dynamics of each derailment. It is likely that in some cases, the tank car enhancements may reduce the quantity released by only a small amount, while, due to different dynamics the same enhancements may completely prevent any release in another derailment. On average, the Agency believes that the reductions in the relative probability of release estimated by its modelling would apply to HCE as well as LCE events.

Calculating Tank Benefits

The tank car benefits are calculated by multiplying the percentage of the fleet upgraded via retrofit in a given year from one of the three inferior designs by the marginal effectiveness of the Option 3 tank car relative to each of these cars. This value is then multiplied by the societal damages to get the estimated reduction in societal damages – i.e., benefits. Retirements are treated analogously; the percentage of the fleet that it gets upgraded via retirement is multiplied by the marginal effectiveness between the car retired and the Option 2 car. Finally, fleet expansion benefits are calculated based on the percentage of the fleet accounted for by new cars in each year multiplied by the marginal effectiveness of the Option 2 tank car relative to the Option 1 tank car, multiplied by societal damages. It should be noted that the percentage of upgraded cars is cumulative. For example, if 10,000 cars of the DOT-111NJ type were upgraded in year 1 to a CPC-1232J standard, and that amount comprised 20 percent of the fleet, the weighted benefit effectiveness calculation for those cars would yield 0.2 x 0.35 = 0.07. If an equal number of DOT-111s underwent this same upgrade in Year 2, and the fleet did not expand so the percentage of the total fleet remains constant, the percentage of upgraded cars would double, and the cumulative upgrade percent in Year 2 would be 0.4. The weighted effectiveness for these upgrades would then be 0.4 x 0.35 = 0.14. A comprehensive discussion of effectiveness rates is provided in Sharma's full report, entitled *Objective Evaluation of Risk Reduction from Tank Car Design & Operations Improvements – Extended Study*. The report is available in the public docket for this proceeding (PHMSA-2012-0082). The table below presents the expected fleet composition in each year.

Table TC41: Projected Fleet Composition, 2015-2034

	DOT 111 Unjacketed		DOT 111 Jacketed		CPC 1232 Unjacketed		CPC 1232 Jacketed		Planned New Construction	Unjacketed DOT 111 Un-Planned New Construction	Jacketed DOT 111 Un-Planned New Construction	Total Cars
Base Year Fleet	42,326	11,851	3,272	916	15,895	0	24,933	0				
Year												
2015	0	0	0	0	0	0	651	0	0	0	0	651
2016	4,413	0	0	0	0	0	3,253	0	6,953	0	0	14,619
2017	11,637	4,526	717	892	0	0	5,856	0	6,953	0	0	30,580
2018	11,637	4,526	2,293	892	6,662	0	8,458	0	6,953	0	0	41,421
2019	11,637	4,526	2,293	892	15,107	0	11,061	0	6,953	0	0	52,468
2020	16,640	4,526	2,293	892	15,144	0	13,664	0	6,953	0	0	60,111
2021	25,379	11,717	2,293	892	15,144	0	16,266	0	6,953	0	0	78,644
2022	30,455	11,717	2,356	916	15,895	0	18,869	0	6,953	0	0	87,161
2023	30,475	11,717	2,356	916	15,895	0	21,472	0	6,953	0	0	89,784
2024	30,475	11,851	2,356	916	15,895	0	24,074	0	6,953	0	0	92,520
2025	30,475	11,851	2,356	916	15,895	0	24,933	0	6,953	0	0	93,379
2026	30,475	11,851	2,356	916	15,895	0	24,933	0	6,953	0	0	93,379
2027	30,475	11,851	2,356	916	15,895	0	24,933	0	6,953	0	0	93,379
2028	30,475	11,851	2,356	916	15,895	0	24,933	0	6,953	0	0	93,379
2029	30,475	11,851	2,356	916	15,895	0	24,933	0	6,953	0	0	93,379
2030	30,475	11,851	2,356	916	15,895	0	24,933	0	6,953	0	0	93,379
2031	30,475	11,851	2,356	916	15,895	0	24,933	0	6,953	0	0	93,379
2032	30,475	11,851	2,356	916	15,895	0	24,933	0	6,953	0	0	93,379
2033	30,475	11,851	2,356	916	15,895	0	24,933	0	6,953	0	0	93,379
2034	30,475	11,851	2,356	916	15,895	0	24,933	0	6,953	0	0	93,379

The next table presents the cumulative percentages of the fleet that are upgraded via new construction, retirement replacement, or retrofit, made up by each of the tank car types currently in service.

Table TC42: Projected Fleet Composition Percentages, 2015-2034

	DOT-111 Non-Jacketed		DOT-111 Jacketed		CPC-1232 Non-Jacketed	CPC-1232 Jacketed	Planned New Construction	Total Cars
Year	Retrofit	Retire-ment	Retrofit	Retire-ment	Retrofit	Retrofit	New	Total Upgrades
2015	0.00	0.00	0.00	0.00	0.00	0.008	0.00	0.008
2016	0.047	0.00	0.00	0.00	0.00	0.035	0.074	0.157
2017	0.125	0.048	0.01	0.01	0.00	0.063	0.074	0.327
2018	0.125	0.048	0.02	0.01	0.07	0.091	0.074	0.444
2019	0.125	0.048	0.02	0.01	0.16	0.118	0.074	0.562
2020	0.178	0.048	0.025	0.010	0.162	0.146	0.074	0.644
2021	0.272	0.125	0.025	0.010	0.162	0.174	0.074	0.842
2022					0.170	0.202		

Table TC42: Projected Fleet Composition Percentages, 2015-2034								
	0.326	0.125	0.025	0.010			0.074	0.933
2023	0.326	0.125	0.025	0.010	0.170	0.230	0.074	0.961
2024	0.326	0.127	0.025	0.010	0.170	0.258	0.074	0.991
2025	0.326	0.127	0.025	0.010	0.170	0.267	0.074	1.000
2026	0.326	0.127	0.025	0.010	0.170	0.267	0.074	1.000
2027	0.326	0.127	0.025	0.010	0.170	0.267	0.074	1.000
2028	0.326	0.127	0.025	0.010	0.170	0.267	0.074	1.000
2029	0.326	0.127	0.025	0.010	0.170	0.267	0.074	1.000
2030	0.326	0.127	0.025	0.010	0.170	0.267	0.074	1.000
2031	0.326	0.127	0.025	0.010	0.170	0.267	0.074	1.000
2032	0.326	0.127	0.025	0.010	0.170	0.267	0.074	1.000
2033	0.326	0.127	0.025	0.010	0.170	0.267	0.074	1.000
2034	0.326	0.127	0.025	0.010	0.170	0.267	0.074	1.000

In order to calculate benefits, we multiply the effectiveness rate for each car relative to the Option 3 or Option 2 car presented above, depending on whether a car is retrofit or retired, by the percentage of cars of that type to get weighted effectiveness rates, which are applied to the damage pool.

For newly constructed cars, we make a similar adjustment. Beginning in mid- to late 2015, we expect all new cars to be built to the new standard promulgated by this rule. New cars get evaluated at the difference between a CPC-1232J and an Option 2 car if built for continued fleet growth, and the difference between the car being replaced and the Option 2 car for cars being retired rather than retrofit. No benefits are claimed for retired cars until the year they are retired, or retrofit cars until the year they are retrofit. Estimated benefits are presented below.

Table TC43: LCE Benefits of the Final Rule Tank Car								
Year	**Retrofit DOT-111 No Jacket**	**Retirement DOT-111 No Jacket**	**Retrofit DOT-111 Jacketed**	**Retirement DOT-111 Jacketed**	**Retrofit CPC 1232 No Jacket**	**Retrofit CPC 1232 Jacketed**	**New Construction**	**Total Lower Consequence Benefits**
2015	$0	$0	$0	$0	$0	$13,545	$0	$13,545
2016	$3,827,034	$0	$0	$0	$0	$61,466	$2,128,153	$6,016,653
2017	$10,455,065	$4,464,472	$527,691	$747,044	$0	$114,621	$2,204,755	$18,513,649
2018	$11,230,535	$4,795,610	$1,812,753	$802,454	$4,342,232	$177,844	$2,368,285	$25,529,713
2019	$11,924,786	$5,092,066	$1,924,814	$852,060	$10,455,308	$246,942	$2,514,688	$33,010,664

2020	$18,117,904	$5,410,521	$2,045,191	$905,348	$11,136,385	$324,123	$2,671,955	$40,611,427
2021	$27,781,475	$14,083,913	$2,056,175	$910,210	$11,196,194	$387,933	$2,686,305	$59,102,205
2022	$33,392,591	$14,106,979	$2,116,128	$936,749	$11,770,666	$450,740	$2,690,705	$65,464,559
2023	$31,259,319	$13,197,203	$1,979,656	$876,337	$11,011,561	$479,832	$2,517,178	$61,321,087
2024	$33,520,714	$14,313,856	$2,122,871	$939,734	$11,808,171	$576,914	$2,699,278	$65,981,538
2025	$33,441,775	$14,280,148	$2,117,872	$937,521	$11,780,364	$596,089	$2,692,922	$65,846,691
2026	$32,818,129	$14,013,841	$2,078,376	$920,038	$11,560,675	$584,973	$2,642,702	$64,618,734
2027	$30,140,954	$12,870,647	$1,908,830	$844,985	$10,617,601	$537,253	$2,427,121	$59,347,390
2028	$31,771,981	$13,567,121	$2,012,123	$890,709	$11,192,154	$566,325	$2,558,460	$62,558,875
2029	$31,207,170	$13,325,938	$1,976,354	$874,875	$10,993,191	$556,258	$2,512,979	$61,446,764
2030	$30,602,574	$13,067,766	$1,938,065	$857,926	$10,780,213	$545,481	$2,464,293	$60,256,318
2031	$30,062,227	$12,837,029	$1,903,844	$842,777	$10,589,868	$535,850	$2,420,781	$59,192,377
2032	$29,498,622	$12,596,361	$1,868,151	$826,977	$10,391,329	$525,803	$2,375,397	$58,082,641
2033	$29,001,621	$12,384,134	$1,836,676	$813,044	$10,216,253	$516,945	$2,335,375	$57,104,048
2034	$28,529,788	$12,182,654	$1,806,795	$799,816	$10,050,043	$508,534	$2,297,381	$56,175,011
							Total	$980,193,889
							NPV 7%	$450,032,434
							NPV 3%	$688,875,430

The benefits for the final rule tank car presented above do not include the benefits of reduced higher consequence event risk. The costs presented do include the cost of retrofitting or equipping new cars with ECP brakes. Those are considered in the braking section of this analysis.

To account for higher consequence event risk, we calculate an overall effectiveness ratio for the Final Rule tank car using total non-catastrophic societal damages and non-catastrophic benefits. We divide the total discounted non-catastrophic benefits in each year by the total discounted expected lower consequence event societal damages for that year to get a total weighted effectiveness ratio for that year. This calculation is a shorthand way to arrive at the same total effectiveness rates for all fleet upgrades rather than directly replicating the calculations described above again. Implicit in the use of these effectiveness rates is the assumption that tank car enhancements would be as effective in mitigating high consequence event damages as they are in mitigating lower consequence event damages (see earlier explanation, HCE Effectiveness Rates). The effectiveness ratio for each year is multiplied by the catastrophic damages for that year to get the higher consequence event benefits. We conduct this calculation for two HCE scenarios presented in the societal damages section, the mean and 95th percentile.

The aggregate effectiveness rate for the final rule presented below, along with the HCE benefits at mean HCE damages and HCE benefits at the 95th percentile.

Table TC44: HCE and Total Benefits of Enhanced CPC-1232 J Standard

Year	Aggregate Effectiveness	HCE Benefits, Mean Damages	HCE Benefits, 95th Percentile Damages
2015	0.007	$10,559	$630,900,000
2016	0.032	$4,782,905	$630,900,000
2017	0.118	$14,205,987	$630,900,000
2018	0.157	$18,236,926	$630,900,000

Table TC44: HCE and Total Benefits of Enhanced CPC-1232 J Standard			
2019	0.196	$22,208,018	$630,900,000
2020	0.223	$25,713,354	$630,900,000
2021	0.244	$37,220,996	$630,900,000
2022	0.264	$41,160,424	$630,900,000
2023	0.276	$41,213,129	$630,900,000
2024	0.277	$41,353,706	$630,900,000
2025	0.277	$41,366,606	$630,900,000
2026	0.277	$41,366,606	$630,900,000
2027	0.277	$41,366,606	$630,900,000
2028	0.277	$41,366,606	$630,900,000
2029	0.277	$41,366,606	$630,900,000
2030	0.277	$41,366,606	$630,900,000
2031	0.277	$41,366,606	$630,900,000
2032	0.277	$41,366,606	$630,900,000
2033	0.277	$41,366,606	$630,900,000
2034	0.277	$41,366,606	$630,900,000
	Total	$659,772,064	$2,967,915,831
	7% Discount Rate	$300,935,655.00	$1,353,727,663.03
	3% Discount Rate	$462,092,789.89	$2,078,676,229.19

The net benefits for the final rule tank car standard are presented below.

Table TC45: Final Rule Tank Car Standards Benefits Estimates		
	7% Discount	**3% Discount**
LCE Benefits	$450,032,434	$688,875,430
HCE Benefits, Mean	$300,935,655	$462,092,790
HCE Benefits, 95th Percentile	$1,353,727,663	$2,078,676,229

3. Benefits of the Enhanced Jacketed CPC-1232 (Option 3)

Benefits for the Option 3 tank car are calculated analogously to those for the Option 1 car. However, because ECP braking is not required for this standard, no ECP braking benefits are estimated for this standard. The Option 3 tank car produces lower safety benefits for two reasons. First, it is more likely to release the lading if involved in an accident because it lacks rollover protection, lacks ECP brakes, and has a thinner shell that is less puncture resistant. Secondly, there are no benefits (or costs) associated with construction of an Option 3 tank car to satisfy new demand, because this is the car PHMSA assumes would be built for HHFT service in absence of regulation. The benefits therefore are only attributed to upgrading the safety of the cars that are retrofit. Higher consequence event benefits are also estimated as described above for the Option 1 tank car. The effectiveness rates for upgrading other cars to this standard are presented in the table below.

Table TC46: Relative Effectiveness of the Option 3, Enhanced Jacketed CPC-1232 Tank Car		
Variable	**Formula/Input**	**Source**
Risk Reduction, DOT-111 Unjacketed to Enhanced Jacketed CPC-1232 Car	45.9%	Applied Research and Associates, Puncture Resistance Model; DOT Estimate for Top Fittings, Bottom Outlet Valve, Pressure Release Valve, and Thermal Protection Enhancements
Risk Reduction, CPC-1232 Unjacketed to Enhanced Jacketed CPC-1232 Car	31.0%	Applied Research and Associates, Puncture Resistance Model; DOT Estimate for Top Fittings, Bottom Outlet Valve, Pressure Release Valve, and Thermal Protection Enhancements
Risk Reduction, DOT-111 Jacketed to Enhanced Jacketed CPC-1232 Car	37.6%	Applied Research and Associates, Puncture Resistance Model; DOT Estimate for Top Fittings, Bottom Outlet Valve, Pressure Release Valve, and Thermal Protection Enhancements
Risk Reduction, CPC-1232 Jacketed to Enhanced Jacketed CPC-1232 Car	1.0%	N/A

These effectiveness rates are used analogously to the way they were applied above for the Option 1 tank car standard. The fleet composition and all other parameters affecting benefits are assumed to be the same for this standard as for the Option 1 car and thus, those tables are not repeated here. 20 Year benefits are presented below.

Table TC47: LCE Benefits of Enhanced CPC-1232 J Standard

Year	Retrofit DOT-111 No Jacket	Retirement DOT-111 No Jacket	Retrofit DOT-111 Jacketed	Retirement DOT-111 Jacketed	Retrofit CPC 1232 No Jacket	Retrofit CPC 1232 Jacketed	New Construction	Total Lower Consequence Benefits
2015	$0	$0	$0	$0	$0	$13,545	$0	$13,545
2016	$3,827,034	$0	$0	$0	$0	$61,466	$131,367	$4,019,867
2017	$10,455,065	$4,065,859	$527,691	$656,282	$0	$114,621	$136,096	$15,955,614
2018	$11,230,535	$4,367,430	$1,812,753	$704,959	$4,342,232	$177,844	$146,190	$22,781,944
2019	$11,924,786	$4,637,417	$1,924,814	$748,539	$10,455,308	$246,942	$155,228	$30,093,034
2020	$18,117,904	$4,927,438	$2,045,191	$795,352	$11,136,385	$324,123	$164,936	$37,511,330
2021	$27,781,475	$12,826,420	$2,056,175	$799,624	$11,196,194	$387,933	$165,821	$55,213,643
2022	$33,392,591	$12,847,428	$2,116,128	$822,939	$11,770,666	$450,740	$166,093	$61,566,584
2023	$31,259,319	$12,018,881	$1,979,656	$769,866	$11,011,561	$479,832	$155,381	$57,674,498
2024	$33,520,714	$13,035,833	$2,122,871	$825,561	$11,808,171	$576,914	$166,622	$62,056,686
2025	$33,441,775	$13,005,135	$2,117,872	$823,617	$11,780,364	$596,089	$166,230	$61,931,081
2026	$32,818,129	$12,762,606	$2,078,376	$808,257	$11,560,675	$584,973	$163,130	$60,776,145
2027	$30,140,954	$11,721,482	$1,908,830	$742,323	$10,617,601	$537,253	$149,822	$55,818,265
2028	$31,771,981	$12,355,771	$2,012,123	$782,492	$11,192,154	$566,325	$157,930	$58,838,777
2029	$31,207,170	$12,136,122	$1,976,354	$768,582	$10,993,191	$556,258	$155,122	$57,792,799
2030	$30,602,574	$11,901,001	$1,938,065	$753,692	$10,780,213	$545,481	$152,117	$56,673,143
2031	$30,062,227	$11,690,866	$1,903,844	$740,384	$10,589,868	$535,850	$149,431	$55,672,470

2032	$29,498,622	$11,471,686	$1,868,151	$726,503	$10,391,329	$525,803	$146,629	$54,628,725
2033	$29,001,621	$11,278,408	$1,836,676	$714,263	$10,216,253	$516,945	$144,159	$53,708,325
2034	$28,529,788	$11,094,917	$1,806,795	$702,642	$10,050,043	$508,534	$141,814	$52,834,533
							Total	$915,561,007
							NPV 7%	$418,338,960
							NPV 3%	$642,234,605

Table TC48: HCE and Total Benefits of Enhanced CPC-1232 J Standard

Year	Aggregate Effectiveness	HCE Benefits, Mean Damages	HCE Benefits, 95th Percentile Damages
2015	0.007	$10,559	$47,497
2016	0.032	$3,195,571	$14,374,942
2017	0.118	$12,243,143	$55,074,503
2018	0.157	$16,274,081	$73,207,258
2019	0.196	$20,245,173	$91,070,802
2020	0.223	$23,750,510	$106,839,190
2021	0.244	$34,772,083	$156,418,589
2022	0.264	$38,709,598	$174,131,088
2023	0.276	$38,762,303	$174,368,177
2024	0.277	$38,893,819	$174,959,787
2025	0.277	$38,906,718	$175,017,814
2026	0.277	$38,906,718	$175,017,814
2027	0.277	$38,906,718	$175,017,814
2028	0.277	$38,906,718	$175,017,814
2029	0.277	$38,906,718	$175,017,814
2030	0.277	$38,906,718	$175,017,814
2031	0.277	$38,906,718	$175,017,814
2032	0.277	$38,906,718	$175,017,814
2033	0.277	$38,906,718	$175,017,814
2034	0.277	$38,906,718	$175,017,814
	Total	$615,924,020	$2,770,669,975
	7% Discount Rate	$279,424,202	$1,256,960,635
	3% Discount Rate	$430,471,100	$1,936,429,354

Table TC49: CPC-1232 J Standard Benefits Summary

	7% Discount	3% Discount
LCE Benefits	$418,338,960	$915,561,007
HCE Benefits, Mean	$279,424,202	$430,471,100
HCE Benefits, 95th Percentile	$1,256,960,635	$1,936,429,354

Benefits of the AAR 2014 Tank Car (Option 2)

The Option 2 car benefits were calculated analogously to the Final Rule and Option 3 tank cars using the third group of effectiveness ratings. The only differences between the Option 2 car and the Option 1 car are rollover protection and ECP brakes. Accordingly, the effectiveness

differences between this car and the Option 1 tank car are very slight until ECP effects are factored in. The differences in cost between the two cars, excluding ECP brakes, are also minimal. The effectiveness rates of upgrading other tank car designs to this standard are presented in the table below.

Table TC50: Relative Effectiveness of the Option 2, AAR 2014 Tank Car

Variable	Formula/Input	Source
Risk Reduction, DOT-111 Unjacketed to AAR 2014 Car	50.4%	Applied Research and Associates, Puncture Resistance Model; DOT Estimate for Top Fittings, Bottom Outlet Valve, Pressure Release Valve, and Thermal Protection Enhancements
Risk Reduction, CPC-1232 Unjacketed to AAR 2014 Car	36.8%	Applied Research and Associates, Puncture Resistance Model; DOT Estimate for Top Fittings, Bottom Outlet Valve, Pressure Release Valve, and Thermal Protection Enhancements
Risk Reduction, DOT-111 Jacketed to AAR 2014 Car	42.8%	Applied Research and Associates, Puncture Resistance Model; DOT Estimate for Top Fittings, Bottom Outlet Valve, Pressure Release Valve, and Thermal Protection Enhancements
Risk Reduction, CPC-1232 Jacketed to AAR 2014 Car	16.2%	N/A

Benefits for this car are calculated analogously to the methodology described for the Final Rule and Option 3 tank cars. Estimated benefits for this tank car standard are presented below.

Table TC51: LCE Benefits of the Option 2 Tank Car, 2015-2034

Year	Retrofit DOT-111 No Jacket	Retirement DOT-111 No Jacket	Retrofit DOT-111 Jacketed	Retirement DOT-111 Jacketed	Retrofit CPC 1232 No Jacket	Retrofit CPC 1232 Jacketed	New Constructio n	Total Lower Consequence Benefits
2015	$0	$0	$0	$0	$0	$219,425	$0	$219,425
2016	$4,202,233	$0	$0	$0	$0	$995,749	$2,128,153	$7,326,135
2017	$11,480,071	$4,464,472	$600,670	$747,044	$0	$1,856,862	$2,204,755	$21,353,874
2018	$12,331,568	$4,795,610	$2,063,453	$802,454	$5,154,650	$2,881,072	$2,368,285	$30,397,091
2019	$13,093,883	$5,092,066	$2,191,012	$852,060	$12,411,462	$4,000,459	$2,514,688	$40,155,630
2020	$19,894,169	$5,410,521	$2,328,036	$905,348	$13,219,967	$5,250,798	$2,671,955	$49,680,794
2021	$30,505,150	$14,083,913	$2,340,539	$910,210	$13,290,966	$6,284,521	$2,686,305	$70,101,603
2022	$36,666,374	$14,106,979	$2,408,784	$936,749	$13,972,920	$7,301,984	$2,690,705	$78,084,496
2023	$34,323,958	$13,197,203	$2,253,439	$876,337	$13,071,789	$7,773,286	$2,517,178	$74,013,190
2024	$36,807,058	$14,313,856	$2,416,459	$939,734	$14,017,442	$9,346,009	$2,699,278	$80,539,837
2025	$36,720,381	$14,280,148	$2,410,769	$937,521	$13,984,432	$9,656,640	$2,692,922	$80,682,812
2026	$36,035,592	$14,013,841	$2,365,811	$920,038	$13,723,640	$9,476,556	$2,642,702	$79,178,180
2027	$33,095,950	$12,870,647	$2,172,817	$844,985	$12,604,119	$8,703,496	$2,427,121	$72,719,135
2028	$34,886,882	$13,567,121	$2,290,396	$890,709	$13,286,170	$9,174,471	$2,558,460	$76,654,209
2029	$34,266,697	$13,325,938	$2,249,679	$874,875	$13,049,982	$9,011,376	$2,512,979	$75,291,525
2030	$33,602,827	$13,067,766	$2,206,095	$857,926	$12,797,156	$8,836,793	$2,464,293	$73,832,855

2031	$33,009,504	$12,837,029	$2,167,142	$842,777	$12,571,198	$8,680,762	$2,420,781	$72,529,195
2032	$32,390,643	$12,596,361	$2,126,513	$826,977	$12,335,514	$8,518,016	$2,375,397	$71,169,420
2033	$31,844,917	$12,384,134	$2,090,684	$813,044	$12,127,681	$8,374,502	$2,335,375	$69,970,338
2034	$31,326,826	$12,182,654	$2,056,671	$799,816	$11,930,374	$8,238,255	$2,297,381	$68,831,977
							Total	$1,192,731,724
							NPV 7%	$546,104,661
							NPV 3%	$837,260,304

Table TC52: HCE and Total Benefits of the Option 2 Tank Car, 2015-2034

Year	Aggregate Effectiveness	HCE Benefits, Mean Damages	HCE Benefits, 95th Percentile Damages
2015	0.009	$171,049	$769,447
2016	0.052	$5,823,870	$26,198,072
2017	0.150	$16,385,364	$73,707,850
2018	0.197	$21,713,895	$97,677,691
2019	0.245	$27,014,814	$121,523,323
2020	0.279	$31,455,674	$141,500,071
2021	0.307	$44,148,124	$198,595,733
2022	0.336	$49,095,129	$220,849,320
2023	0.355	$49,743,332	$223,765,190
2024	0.360	$50,478,071	$227,070,339
2025	0.361	$50,687,044	$228,010,382
2026	0.361	$50,687,044	$228,010,382
2027	0.361	$50,687,044	$228,010,382
2028	0.361	$50,687,044	$228,010,382
2029	0.361	$50,687,044	$228,010,382
2030	0.361	$50,687,044	$228,010,382
2031	0.361	$50,687,044	$228,010,382
2032	0.361	$50,687,044	$228,010,382
2033	0.361	$50,687,044	$228,010,382
2034	0.361	$50,687,044	$228,010,382
	Total	$802,899,763	$3,611,760,861
	7% Discount Rate	$365,168,143	$1,642,670,813
	3% Discount Rate	$561,651,532	$2,526,530,849

Table TC53: Option 2 Tank Car Benefits Summary

	7% Discount	3% Discount
LCE Benefits	$546,104,661	$837,260,304
HCE Benefits, Mean	$365,168,143	$561,651,532
HCE Benefits, 95th Percentile	$1,642,670,813	$2,526,530,849

D. Requirement Area 3 – Speed Restrictions

Final Action: PHMSA is restricting the speed of HHFTs to 50 mph in all areas and 40 mph in HTUAs unless all tank cars meet the DOT-117 standard.

PHMSA is requiring a 50-mph maximum speed limit for HHFTs in all areas. PHMSA is also requiring a 40-mph speed limit for HHFTs within the limits of a *High-Threat Urban Area* (HTUA), unless all tank cars containing flammable liquids meet or exceed the new construction, performance, or retrofit standards for the DOT-117 tank car.

1. Determination of Need

Speed is a factor that may contribute to derailments. Speed can influence the probability of an accident, as slower speeds may allow for braking applications to stop the train before a collision. Speed also increases the kinetic energy of a train, resulting in a greater possibility of the tank cars being punctured in the event of a derailment. Under the current packaging requirement and until the new tank cars are fully in use, PHMSA believes reduced speed for HHFTs is warranted.

Further, despite existing voluntary action, additional regulatory action on the 50-mph speed limit is necessary because AAR OT-55-N is a recommended practice and, as such, does not carry the weight of law. A subscribing railroad can, without concern of a penalty, move these trains at speeds exceeding this voluntary industry standard and increase the energy and likelihood of catastrophic damage to tank cars involved in a train accident. Codifying this voluntary commitment will ensure that the benefits of these speed restrictions are realized indefinitely. Without codification of these requirements, the speed restrictions could be subsequently lifted prematurely and increase risk.

2. Action by the United States and Canada

U.S. Action

In the NPRM, PHMSA proposed to require a 50-mph speed restriction for HHFTs in all areas. This action aligns with the existing requirements imposed by AAR Circular No. OT-55-N. PHMSA believes that there will be no costs associated with a speed restriction of 50 mph, as this codifies current industry best practices.

PHMSA also proposed to limit any HHFT to a speed of 40 mph in select areas unless the tank cars meet the new DOT-117 standard. In the NPRM, PHMSA considered three Options for implementation of the 40-mph speed restriction and requested comments on which Option would have the greatest net social benefits and whether the 40-mph speed restriction is necessary. Further, in line with the NPRM, any HHFT that does not meet the braking requirements in the braking section would be restricted to 30 mph. This section will look at the costs associated with the slowdown of the rail network and the benefits from reducing the potential harm of HHFT accidents.

A train collision or derailment that occurs at 40 mph rather than 50 mph would be less severe.[137] PHMSA anticipates the efforts made by reducing the speed of trains with less safe tank cars and braking systems will prevent fatalities and other injuries, and limit the amount of environmental and property damage in an accident. PHMSA anticipates additional safety benefits will be realized as the tank car fleet meets the proposed integrity standards. The trains will no longer be subject to the speed restrictions discussed here, in but will accrue the benefits discussed in the tank car section, and the braking section. PHMSA believes that with enhanced braking, and greater car integrity, the risk from a derailment of a train that is authorized to travel at 50 mph is less than the risk from a train not so equipped with a maximum authorized speed of 40 mph. PHMSA believes the enhanced braking is likely to reduce the speed at which the train enters an accident from the maximum authorized speed, and to do so more effectively than conventional braking would allow. Once the tank cars have enhanced integrity and braking systems, they will be less likely to release product when involved in a derailment or collision. PHMSA expects reduced benefits attributable to speed restrictions as new tank cars make up a larger portion of the fleet and the reduction in risk is realized by the new tank cars. As a result, PHMSA phases out the speed restriction as the new tank cars are introduced.

Canadian Action

On April 23, 2014, Transport Canada issued an Emergency Directive restricting companies from operating a *key train*[138] at a speed that exceeds 50 miles per hour (mph).

3. Specific Comments

Comments addressing the proposed speed restriction focused mainly on the cost associated with reducing speeds from 50 mph to 40 mph. Comments from environmental groups and the concerned public generally supported a 40-mph speed limit in all areas, whereas comments from rail network users and operators generally supported a 40-mph speed limit in HTUAs, but not in other areas. The commenters affiliated with industry were concerned with the economic impacts of delays and reduced network fluidity.

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[137] Kinetic energy varies directly with the square of speed (velocity). [Kinetic energy = ½ Mass x (Velocity)^2] Forty mph is 80% of 50 mph. Assuming equal mass, the resulting change in energy is the square of the difference in velocity ($0.8^2 = 0.64$) or a reduction of 36% (1.00 - 0.64 = 0.36).

[138] "Key Train" means an engine with cars that includes one or more loaded tank cars of dangerous goods that are included in Class 2.3, Toxic Gases and of dangerous goods that are toxic by inhalation subject to Special Provision 23 of the Transport of Dangerous Goods Regulations; or that includes 20 or more loaded tank cars or loaded intermodal portable tanks containing dangerous goods, as defined in the Transportation of Dangerous Goods Act, 1992 or any combination thereof that includes 20 or more loaded tank cars and loaded intermodal portable tanks.

For example, the American Fuel & Petrochemical Manufacturers (AFPM) supports the proposal to establish a 40-mph speed limit in high-threat urban areas (HTUAS) unless the tank cars meet DOT-117 standards. AFPM has substantial concerns that any other speed limit would unduly restrict all types of rail traffic without any commensurate improvement in safety. The AFPM, quoting from an Association of American Railroads (AAR) presentation, states, "83 percent of the U.S. rail network is single track with passing track spaced every 5 to 50 miles." Thus, these tracks are shared by various types of trains, including passenger, premium, manifest, and unit bulk trains. AFPM is concerned that a blanket speed restriction would significantly restrict rail capacity and speeds for all these major traffic groups. If an overly restrictive speed limit were adopted, AFPM states shippers will require more tank cars to move the same volume of commodity, which may increase risk.

AAR notes that the Class I railroads committed to a 40-mph speed limit for crude oil trains in HTUAs in a February 2014 letter to Secretary Foxx and have since complied with the restriction. AAR asserts that expanding speed restrictions beyond the HTUAs would have a ripple effect on other rail traffic and degrade the fluidity of the rail network. Adverse impacts include reduced customer service, increased costs, and diversion of traffic to less safe and less environmentally friendly modes of transportation. Several freight railroads, including the Alaska Railroad Corporation, Burlington Northern Santa Fe, and Union Pacific, also reported that significant disruptions could occur if a uniform national speed limit were to be implemented. Passenger railroads commented that reducing the maximum allowable speed for crude oil trains beyond the voluntary USDOT-AAR agreement of 40 mph will increase freight train interference and reduce Amtrak's on-time performance (OTP). Poor OTP can have ongoing negative economic impacts for passenger trains, with operating costs, such as fuel, labor, and maintenance costs, increasing just as ridership and ticket revenues decline. Other commenters including shippers, manufacturers, freight forwarders, and logistical operations support the agreements between the AAR and DOT, but advocate for no further speed restrictions. Homeland Energy Solutions, LLC, an ethanol producer from Iowa, supports the 40-mph speed restrictions for trains that are transporting a continuous block of 20 or more cars containing crude oil through HTUAs, but strongly discourages any speed limits on ethanol trains.

Environmental groups refer to railroad accident records and research showing that serious accidents and extreme damage have resulted at speeds far lower than 50 mph and even lower than 40 mph. Some commenters have asserted that the only way to protect the public and avoid costly accidents is for PHMSA to impose a 40-mph speed limit in all areas and a 30-mph speed limit during the transition periods to higher tank car standards and ECP braking.

PHMSA reviewed all the comments and technical analyses submitted in response to the NPRM. Many commenters concerned with the risks of HHFTs propose nationwide speed restrictions below the 50-mph speed restriction. To assess the potential for such a speed restriction, the FRA uses simulation software to quantify the hours of delay that speed restrictions would impose on other trains, including passenger, intermodal, grain, and general merchandise trains. FRA found that the costs of a uniform HHFT speed restrictions below 50 mph, except in HTUAs, are cost prohibitive. Thus, this rule codifies the railroad's voluntary agreement to operate all HHFTs at 50 mph nationwide. In addition, this rule requires all HHFTs to travel at 40 mph within HTUAs unless all tank cars containing a Class 3 flammable liquid meet or exceed the retrofit or

performance standards or the new construction standards for the DOT-117. The 40-mph speed limit for HHFTs within the limits of HTUAs is in line with Option 3 proposed in the NPRM.

The Brattle Group (Brattle) questions the length of haul estimates for crude and ethanol shipments that informed the NPRM cost benefit analysis. In its analysis, Brattle finds that crude oil cars have longer trip times than ethanol cars. Brattle uses trip times to estimate the additional tank cars required, if uniform speed restrictions were imposed. Brattle finds that in 2012, the average rail shipment of crude oil traveled 1,397 miles, whereas the average rail shipment of ethanol traveled 950 miles. In deriving these estimates, it appears that Brattle utilized a 2012 waybill sample and a review of crude oil and ethanol origins and destinations by region, as delineated by the Bureau of Economic Analysis.

In determining its estimate for crude oil and ethanol movements, Brattle selected crude oil and ethanol records from the 2012 and 2013 Surface Transportation Board (STB)'s Confidential Waybill Sample, but only for those segments that occur on a Class I railroad. The STB Confidential Waybill Sample "total distance field" is calculated by routing traffic on a rail network between originating and terminating railroad stations[139]. The mileage is calculated by ALK Technologies, Inc., using PC Miler software and the Princeton Transportation Network Model.

In both years and for each Class I railroad, the combined average "total distance field" for crude oil traffic is 1,000 miles and includes over 2,000 trips, with a reported distance of 1,098 miles from the Bakken area. Other pairs of originating and terminating railroad stations range from 241 to 981 miles. Ethanol movements averaged 1,300 miles for 2012 and 2013 and include 2,700 moves by the western Class I railroads, which range in distance between 1,375 and 1,650 miles. The eastern Class I railroads conducted another 1,500 moves, averaging 850 miles in length.

E. Speed Restriction Alternatives

1. Restrict Speed to 50 mph in All Areas

Currently, there is no regulatory prohibition on speeds of HHFTs in excess of 50 mph (up to 79 mph). Nevertheless, for purposes of this rulemaking and analysis, PHMSA reasonably assumes that, in the absence of any regulatory action, all affected railroads will continue indefinitely to abide by the voluntary agreement currently in place to limit HHFT speeds to no more than 50 mph. Therefore, codification of the current 50 mph speed will result in the same level of damages occurring from derailments and the same probability of higher consequence events. As such, there will be no marginal costs or benefits resulting from this specific requirement.

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[139] These are fields from the waybill sample database.

PHMSA believes the 50-mph speed limit is a current industry best practice adopted to reflect market pressures. Under these circumstances, this alternative would be, in effect, a status quo or "no action" alternative.

PHMSA asked several questions regarding AAR Circular No. OT-55-N in the September 6, 2013, ANPRM. Specifically, PHMSA asked if the Circular adequately addressed speed restrictions. The majority of the commenters indicated that the current self-imposed 50-mph speed restriction is acceptable. Further, during the recent industry Call-to-Action, the rail and crude oil industries agreed to voluntarily consider additional safety improvements, including speed restrictions in HTUAs, similar to the requirements that are established by the routing requirements in Part 172, Subpart I of the HMR.

2. Additional Speed Reductions

The laws of physics indicate that if an accident occurred at 40 mph instead of 50 mph, we should expect a reduction of kinetic energy by 36 percent. After consultations with engineers and subject matter experts, we can assume that this would translate to the severity of an accident being reduced by 36 percent. In addition, a slower speed may allow a locomotive engineer to identify a safety problem ahead and stop the train before an accident results, leading to accident prevention. With respect to prevention, PHMSA also notes that while reduced speeds will reduce the risk of accidents on net, some risks could increase under limited circumstances. For the purposes of this analysis, PHMSA only quantifies the benefits of mitigating the severity of accidents.

PHMSA uses a ten-mile speed differential in calculating an effectiveness rate for the 40-mph speed restriction options. This speed differential assumes that at the time of an accident, trains would be going 10 mph slower if the speed restriction were at 40 mph rather than 50 mph. Braking is often applied before an accident occurs, so the speed differential at the time of an accident that results from trains operating at maximum speeds of 50 mph and 40 mph could be different by more than 10 mph. Furthermore, congestion and/or other restrictions on speed may apply, which would also affect speed at the time of an accident.

FRA used simulation software to estimate the effects of a 40-mph speed restriction on crude oil and ethanol trains[140] on different types of train traffic traversing typical crude and ethanol corridors. The simulation software is based on long-standing, industry standard approaches to analyzing train movements along a network. Reference material regarding this simulation software has been placed in the docket for public review. The initial data entered into the simulation is based on data from the STB's 2012 Confidential Waybill Sample, the U.S. Energy

[140] Crude and ethanol trains are referred to as High-Hazard Freight Trains or HHFT's.

Information Administration, and observations from FRA inspectors in the field. Separate simulations were conducted for crude oil (STC Code 13111) and ethanol (STC code 28184).

The waybill sample's total distance field was used to estimate the average length of haul of both crude oil and ethanol for Class I railroads. FRA found that an average crude oil train travels over 1,000 miles and an average ethanol train travels over 1,300 miles on the Class I rail network.[141] However, FRA estimated that each type of train is on a transcontinental corridor for five-sevenths, or 71 percent, of each trip. FRA estimated the delay costs for each fuel train move by combining the results of two separate simulations to account for the different conditions applicable to entering and exiting the major transcontinental corridors. FRA assumed that three hundred miles of each trip, at the origin and destination, takes place on double-track territory with Centralized Traffic Control (CTC) signaling and six HHFTs operating at reduced speeds. FRA assumed that the remainder of the trip takes place on the major transcontinental corridors, also with CTC signaling, and with a range of one to ten HHFTs operating at lower speeds. In both cases, FRA assumed that track grade and curvature have minor effects on train speed. FRA expertise provides the basis for these assumptions.

During simulation, passenger and intermodal trains are granted priority, so that initially, fuel and general merchandise trains bear the majority of the delay. As the number of HHFTs increases, rail sidings fill up and all trains experience main line delay. Taking into consideration the close proximity of waybill originations, and assuming that crude oil/ethanol trains would be routed to move as quickly as possible to major corridors, FRA grouped crude oil and ethanol traffic into sixteen and six separate smaller corridors, respectively, for the first two-sevenths or 29 percent of the trip. FRA assumed crude oil trains travel across six major transcontinental corridors and ethanol trains are restricted to two.

Further, FRA assumed moderate traffic densities for each of the subdivisions on the corridor, but does not account for seasonal variation or extraordinary circumstances. As the number of fuel trains increased, net delay[142] increased exponentially.

This analysis provides an estimate of train delay at the corridor level. FRA does not have sufficient data to estimate the full impact of speed restrictions on the U.S. railroad network. To the extent that HHFTs traverse all the major U.S. railroad transcontinental corridors, the network

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[141] The average length of haul for each fuel type for the industry was calculated averaging the length of haul each origin-destination pair that occurred on the Class I railroad using 2012 Confidential Waybill. Interchange traffic on Class II and III rail networks was not included, as these railroads are not subject to this regulation.

[142] Net delay is the delay encountered in sidings, while stopped on the main line, due to schedule delay, or time spent waiting to be authorized to enter the territory.

impact could be significant. Other factors such as the supply and demand of crude oil and ethanol would also affect the outcome of this analysis.

The following table shows the total daily train hours of delay per corridor as estimated by FRA's simulation. The number of trains is the number of crude oil or ethanol trains traversing the corridor on a single day. For example, if one crude oil train on the representative corridor is subjected to a 40-mph speed limit, then all of the trains traveling the length of the corridor will experience a total of 84 hours of delay that day. Ten crude oil trains will result in 770 hours of delay for all trains on the corridor per day, while 10 ethanol trains will impose 1,522 hours of delay per day on all trains sharing the corridor.

Table S1: Time Impacts of a 40 mph Maximum Speed

Crude Oil Trains per Day	Daily Hours of Delay for All Trains	Ethanol Trains per Day	Daily Hours of Delay for All Trains
1	84	1	92
2	181	2	228
4	233	4	250
6	385	6	576
8	534	8	721
10	770	10	1,522

The beginning years of the restriction would be the most burdensome as the industry works to build or retrofit tank cars to the required specifications.

Restrict Speed to 40 mph in High-Threat Urban Areas (HTUAs)

PHMSA estimates that HHFTs traverse only two percent of the entire Class I rail network located within HTUAs. For this analysis, PHMSA assumes that only these track miles would have costs associated with them and affirms that any accident prevented or mitigated within these locations would have a greater impact on the total benefit pool than accidents in other areas. Population densities in HTUAs are 10 to 100 times greater than the average for smaller communities, and property values in HTUAs are much higher. As a result, an evacuation notice would affect more people in these areas, and damage to the transportation network, buildings, and other infrastructure would be higher. We estimate the effectiveness rates of the speed restriction in HTUAs by determining the value of a 36 percent reduction in kinetic energy attributable to speed restrictions along the entire rail network and then, multiplying this value by seven percent to remove the uncovered miles outside the HTUAs. After, we multiply the damages avoided by 3.5 (to account for the potentially greater harm that might result in these

HTUAs). [143] In subsequent years, we subtract the benefits attributable to the voluntary slowing of select crude oil trains. The effectiveness rates are presented in the table below.

PHMSA assumes the 40-mph speed restriction will reduce accident severity by 0.0882, which is the effectiveness rate from when the rule is initially implemented until the different sets of trains are DOT-117 compliant. Starting in 2017, the effectiveness rates are reduced based on the percent of the fleet that meets the DOT 117 standard.

Table S2. Speed Benefits Effectiveness Rates 40 mph, HTUA

Year	Effectiveness Rate
2015	0.0875
2016	0.0744
2017	0.0593
2018	0.0491
2019	0.0386
2020	0.0314
2021	0.0139
2022	0.0059
2023	0.0034

To calculate the total annual cost of delay from a 40-mph HHFT speed limit in all areas for HHFTs, PHMSA multiplied the daily cost of delay by the number of days in a week and by the number of weeks in a year. The total daily cost is determined by multiplying the total hours of delay by $500 per hour, which PHMSA estimates is the average cost of an hour of delay. The economic impact of slowing trains depends upon multiple factors including other types of trains, other train speeds, dispatching requirements, work zones, and topography. Looking at numerous variables, for purposes of this particular analysis, DOT estimated the average cost of a train delay to be $500 per hour. This cost estimate was determined by reviewing costs associated with crewmembers, supply chain logistic time delays based on various freight commodities, and passenger operating costs for business and other travel. PHMSA removes from the cost calculation the voluntary costs of slowing crude DOT-111 HHFTs to 40 mph in HTUAs.

Tables S2 and S3 demonstrate how the HTUA 40-mph speed limit costs are calculated for 2015 and 2016 before any train sets are compliant. The 2015 costs are reduced by 50 percent based on the assumption that the rule is not implemented until mid-year. During these initial years, the total delay hours for the 40-mph speed limit are calculated by multiplying the number of corridors by the daily hours of delay for all trains times the percentage of usage. This value is

[143] Reduced kinetic energy times percent rail network within HTUAs times the increased damages or .36*.07*3.5=0.0882

multiplied by the percent of the rail network within the HTUAs after removing voluntary compliance. Note that for voluntary compliance adjustment is only applied to crude oil trains. The Class I railroads are not slowing the ethanol trains within HTUAs as required by the rule.

Table S3 "number of hours" of delay column is determined by referencing Table S1 above. The "percentage of usage" column is based on the proportion of time that crude oil and ethanol trains spend on each type of track; the column shows that trains spend 29 percent of their time on start-end corridors and 71 percent of their time in the middle of the corridor. This ratio or percentage was calculated by considering the use of the rail network, defining two segments (i.e., the start/end of a corridor and the middle of a corridor), and then quantifying the proportion of time that traffic within our sample spent on each type of corridor. PHMSA assumed that the crude and ethanol routes would have similar start-middle-end ratios. The distances were based on the average corridor mileage for ethanol and crude oil trains.

Table S3: Cost of 40 mph Speed Limit, HTUAs Only, 2015 and 2016

	Number of Corridors	Number of Trains	Number of Hours	Percent of Usage	Voluntary Action Reduction	Total Hours[144]	Total Daily Cost
Crude Traffic at 40 mph							
Start-End	16	6	385	29%	4.57%[145]	43	$21,412
Middle	6	10	770	71%	4.57%	80	$40,148
					Total	123	$61,560
Ethanol Traffic at 40 mph							
Start-End	6	6	576	2/7	0%	69	$34,560
Middle	2	10	1,522	5/7	0%	152	$76,100
					Total	221	$110,660

[144] For the start-end corridors' crude oil traffic in year one, the daily hours of delay is calculated as follows: 16 corridors x 385 hours of delay x 2/7 percentage of usage x (100% minus 98% track miles covered reduction x 4.57% voluntary action reduction) = 43 total hours of delay per day

[145] PHMSA took account of the voluntary compliance with a 40 mph speed limit for crude oil in HTUA. The voluntary compliance is limited to 7 percent of trackage, the proportion of trackage in HTUAs, and is limited to those shipments made in cars that do not comply with CPC-1232, which are not subject to the voluntary compliance. PHMSA's estimate of the proportion of CPC-1232 cars is based on the proportion in effect at the effective date of the rule, which PHMSA estimates will be 35 percent of the HHFT fleet in 2015, in the NPRM we noted that 11 percent of the fleet would be CPC-1232 cars. For the purposes of this analysis the number of CPC-1232 cars is held constant. PHMSA believes that the voluntary compliance amounts to 4.57 percent of crude oil shipments. This percentage is deducted from burdens (i.e., costs) estimated below and is also used to reduce the benefit estimates.

Table S4: Cost of 40-mph Speed Limit	
HTUAs Only, 2015 and 2UAs Only, 2015 and 2016	
Total Daily Cost	$172,220
Total Weekly Cost	$1,205,540
Total Annual Cost 2015	$62,688,065
2015 = 0.5 * $62,688,065	$31,344,003

Table S5: Cost of 40-mph Speed Limit			
HTUAs Only			
	Undiscounted	**7% Discount**	**3% Discount**
2015	$31,344,033	$29,293,489	$30,431,100
2016	$52,873,753	$46,181,984	$49,838,583
2017	$42,158,808	$34,414,146	$38,581,282
2018	$34,881,209	$26,610,707	$30,991,503
2019	$27,464,645	$19,581,913	$23,691,244
2020	$22,333,952	$14,882,055	$18,704,333
2021	$9,892,017	$6,160,251	$8,043,115
2022	$4,174,247	$2,429,450	$3,295,189
2023	$804,595	$437,646	$616,655
Total	$225,957,259	$179,991,640	$204,193,004

Speed Analysis Limitations

This is a simplified analysis with several limitations. First, the analysis extrapolates from the geometric characteristics of a single 124-mile subdivision, which may not be representative. It is also possible that slower traffic along crude oil and ethanol corridors would lead to delays for the network overall. Further, the analysis does not take into account the potential diversion of rail traffic from the rail line on which the speed restriction occurs to other rail lines. Such diversion would slow down the traffic on other lines, but speed up the traffic on the line with the speed restrictions (and speed up the traffic diverted). Overall, the effect of the diversion would be to reduce delays, because the railroad would presumably only divert traffic if it reduced delays.

This analysis also does not take into account the possibility of rail traffic, particularly time-sensitive intermodal traffic, being diverted onto truck or other modes of transit because of rail delays. This could have adverse safety, environmental, and state-of-good-repair costs. PHMSA does not believe that the speed limitations and potential resulting delays will have a large effect on unit costs of shipping by rail, and therefore, any potential modal diversion would be minimal.

On February 21, 2014, the AAR signed a letter to DOT discussing the transportation of crude oil. One of the commitments that they made was:

> *"Railroad Subscribers commit to continue to adhere to a speed restriction of 50 mph for any Key Crude Oil Train. By no later than July 1, 2014, Railroad Subscribers will adhere to a speed restriction of 40 mph for any Key Crude Oil Train with at least one "DOT-111" tank car loaded with crude oil or one non-DOT specification tank car loaded with crude oil while that train travels within the limits of any high-threat urban area as defined by 49 C.F.R. § 150.3. For purposes of these commitments, "DOT-111" tank cars are those cars that meet DOT Specifications 111 standards but do not meet the requirements of AAR Circular CPC-1232 or any new standards adopted by DOT after the date of this letter."*

In the Call-to-Action, there was voluntary compliance on the transportation of crude oil; however, this did not include jacketed CPC-1232 tank cars, which comprise around 35 percent of the fleet. Therefore, except for jacketed CPC-1232, PHMSA does not anticipate any new costs associated with the slowdown of traffic in a HTUA when transporting crude oil.

F. Requirement Area 4 – Braking

Final Action: PHMSA is requiring HHFTs to be equipped with Advanced Braking Systems.

PHMSA is requiring HHFTs to be equipped and operated with either a *two-way end-of-train* (EOT) device or a *distributed power* (DP) system, or travel at 30 MPH or less. By January 1, 2021, any HHFUT transporting one or more tank car loaded with a Packing Group I flammable liquid will be required operate using an ECP brake system that complies with the requirements of 49 CFR part 232, subpart G. All other HHFUTs (i.e. trains consisting of Packing Group II or Packing Group III flammable liquids) must be equipped with operative ECP brake systems by May 1, 2023, when traveling in excess of 30 mph.

Determination of Need

The 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 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.

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 to the remote locomotives.

ECP brake systems simultaneously send a braking command 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 the train crew 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. 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.

In the NPRM, PHMSA and FRA provided data produced by Sharma & Associates showing a 36 percent effectiveness rate of ECP brakes over conventional air brakes as expressed in number of cars punctured. In March 2015, Sharma & Associates performed additional modeling that takes into account the comments received after publication of the NPRM. See "Letter Report: Objective Evaluation of Risk Reduction from Tank Car Design & Operations Improvement – Extended Study," Sharma & Associates, March 2015. This updated, purpose-built model from Sharma & Associates confirms that ECP brakes provide substantial safety benefits in emergency braking situations compared to air brakes, two-way EOT devices, and DP systems. While a comprehensive discussion of effectiveness rates is provided in March 2015 Letter Report, some highlights are provided below.

Puncture hazards result from a variety of factors, including operating conditions, speed of the train, and the type of tank car involved, 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 braking alternatives considered in the NPRM. 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.

The March 2015 Letter Report from Sharma & Associates used the most probable number of tank cars punctured to evaluate the benefits of the tank car enhancements, brake systems, and speed. The derailment scenarios were simulated for a 100-car train at different speeds with the first car subjected to a brief lateral force to initiate the derailment. At the point of derailment, Sharma & Associates applied a retarding force to all the cars that was equivalent to an emergency brake application. For a train with conventional air brakes, Sharma & Associates modeled a brake initiation of 12 percent net braking ratio, which represents an emergency brake application, propagated from the front (point of derailment) to the rear of the train. For a train with a two-way EOT device or a DP locomotive at the rear of the train, the emergency brake signal propagation was initiated at both ends of the train. For a train with ECP brakes, the model has all cars simultaneously receiving the braking signal with a brake ratio of 12 percent. As reflected in Table BR1, for DOT-117 and DOT-117R tank cars, the ECP braking system was consistently the top performer in terms of preventing the most cars punctured, while two-way EOT devices and DP systems with a locomotive at the rear consistently out-performed conventional air brake systems.

Table BR1: Most Likely Number of Punctures: 100-Car Train, with POD at Head End				
Tank Car Type	**Speed, mph**	**Conventional Brakes**	**2-way EOT (DP: lead + rear)**	**ECP Brakes**
7/16" TC128, 11 gauge jacket, 1/2" full-height head shield	30	4.7	3.9	3.3
	40	8.0	7.1	5.3
	50	12.2	9.8	9.1
9/16" TC128, 11 gauge jacket, 1/2" full-height head shield	30	3.8	3.2	2.6
	40	6.6	5.9	4.3
	50	10.2	8.2	7.6

Based on the analysis in the 2015 Letter Report from Sharma & Associates, PHMSA and FRA believe that ECP brakes, in isolation, can be expected to reduce the number of cars punctured by up to 30 percent compared to conventional air brake systems (minimal variation based on train speed). In addition, a two-way EOT device or DP locomotive at the rear of the train will reduce the number of cars punctured by up to 16 percent. These numbers are reflected in Table BR2 for DOT-117 and DOT-117R cars.

Table BR2 : Risk Improvement Due to Braking with POD at Head-End 100 Cars Behind POD					
		Most-Likely Number of Punctures			**% Improvement Due to ECP Brakes Only Relative to 2-way EOT**
Tank Type	**Speed, mph**	**Conventional Brakes**	**2-way EOT (DP: lead + rear)**	**ECP Brakes**	
7/16" TC128, 11 gauge jacket, ½" full-height head shield	30	4.7	3.9	3.3	15%
	40	8.0	7.1	5.3	25%
	50	12.2	9.8	9.1	7%
9/16" TC128, 11 gauge jacket, ½" full-height head shield	30	3.8	3.2	2.6	19%
	40	6.6	5.9	4.3	27%
	50	10.2	8.2	7.6	7%

The ECP brake system always provides an advantage over conventional the air brake system in terms of 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. However, a number of commenters suggested that the scenarios modeled by Sharma & Associates may overstate the effectiveness of ECP brake systems because its model focused

on measuring derailments at the front of a train. As a result, FRA conducted further analysis based on the simulations of derailments at different points in the train. FRA's simulations considered derailment at locations with 100, 80, 50, and 20 cars trailing the point of derailment. 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 that 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, the ECP brake system reduced the number of cars punctured compared with two-way EOT devices and DP systems with the locomotive at the rear. See Tables BR3 and BR4.

Table BR3 : Most Likely Number of Punctures: 100-Car Train, with POD Distributed Throughout Train

Tank Type	Speed, mph	Conventional Brakes	2-way EOT DP (lead + rear)	ECP Brakes
7/16" TC128, 11 gauge jacket, ½" full-height head shield	30	3.4	2.96	2.34
	40	6.2	5.62	4.19
	50	8.54	7.18	6.55
9/16" TC128, 11 gauge jacket, ½" full-height head shield	30	3.03	2.66	2.12
	40	5.6	5.1	3.8
	50	7.8	6.6	6.0

Table BR4 : Risk Improvement Due to Braking, with POD Distributed Throughout the Train

		Most-Likely Number of Punctures			% Improvement Due to ECP Brakes Only Compared to 2-way EOT
Tank Type	Speed, mph	Conventional Brakes	2-way EOT (DP: lead + rear)	ECP Brakes	
7/16" TC128, 11 gauge jacket, ½" full-height head shield	30	3.4	2.8	2.6	35.4%
	40	6.8	6.2	4.65	24.4%
	50	9.3	7.92	7.2	8.0%
9/16" TC128, 11 gauge	30	2.8	2.4	2.2	20.3%
	40	5.6	5.1	3.8	25.7%

Table BR4 : Risk Improvement Due to Braking, with POD Distributed Throughout the Train					
jacket, ½" full-height head shield	50	7.8	6.6	6.0	8.5%

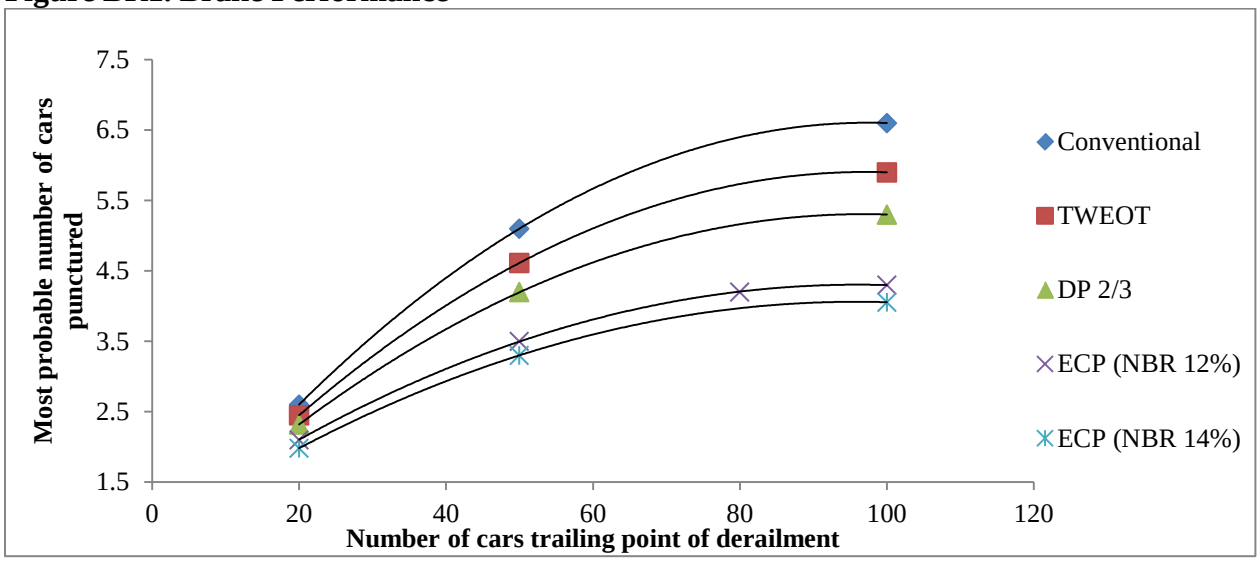
The results of these simulations in the March 2015 Letter report from Sharma & Associates and the FRA analysis of the data show that advanced brake signal propagation systems reduce the rates of puncture in derailing tank cars relative to the conventional air brake system, with ECP braking systems demonstrating the best overall performance. According to the March 2015 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-EOT devices or DP systems with a locomotive at the rear because of the limited time needed to initiate emergency braking.

While PHMSA and FRA are establishing a requirement to implement ECP brake systems for certain operations, we recognize 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). This rulemaking is 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. In the event that a new technology is developed, railroads should apply to FRA to obtain special approval for the technology pursuant to part 232, subpart F.

FRA also conducted simulations to better understand the effect on energy dissipation and stopping distance of different brake signal propagation systems; conventional brakes, two-way end of train devices, 2/3 DP configurations, 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 BR5:

Table BR5: Parameters Evaluated in the FRA's Purpose Built Model		
Parameter Category	**Subcategory**	**Description**
Brake System	**Conventional**	**Without End-of-Train Device**
	TWEOT	Two-way end-of-train device capable of initiating emergency from the rear based on signal from lead locomotive
	DP 2/3	Distributed power locomotive at a location at or near 2/3 back in the consist from the lead locomotive
	ECP (NBR 12 percent)	Electronically controlled pneumatic brakes with a set net brake ratio of 12 percent. This is the same brake ratio as Conventional, TWEOT and DP 2/3 systems in the purpose built model.

Figure BR1. Brake Performance



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

1. Action by the United States and Canada

U.S Action

In the NPRM, PHMSA proposed to require advanced braking systems (electronic controlled pneumatic brakes (ECP), distributed power (DP), and two-way end of train (EOT) device to reduce the number of cars and energy associated with train accidents as follows:

For all three tank car Options, by 10/1/15 HHFTs must be equipped and operated with two-way end of train (EOT) braking devices or distributed power (DP), or travel at 30 mph or lower.

Applicable only to the proposed tank car Option 1 (i.e., the PHMSA and FRA designed car), all HHFT tank cars built after October 1, 2015, and HHFT tank cars retrofitted to the PHMSA and FRA designed car standard, must be equipped with ECP brakes. Trains comprised entirely of PHMSA and FRA designed cars, except required buffer cars, would have been required to operate in ECP mode, or travel at no greater than 30 mph.

Canadian Action

We are not aware of any Canadian completed or proposed actions on this topic.

2. Specific Comments

The NPRM, and the RIA for the NPRM, requested comments and input on the rulemaking and its supporting documents. The following provides a summary of the comments received that pertained to the economic issues, and how those comments were addressed.

Effectiveness of ECP Brakes

PHMSA and FRA received many comments stating the ECP brake system technology was not an effective braking system, or that it was not a proven technology. These commenters noted that DP systems were just as effective as ECP brakes. Many of the comments were directed towards the computer simulations that were run for the NRPM. They believed that the simulations of merely 80-car trains overstated effectiveness of ECP brake systems, and that the models looked at only derailments starting in the first car of the train. However, in the NPRM, PHMSA and FRA looked at 100-car trains. Commenters also stated that pileups are not as likely as the models used in the NPRM indicated. PHMSA and FRA refined analysis of benefits addresses this comment.

FRA has run numerous additional simulations for the final rule. These simulations considered derailment at locations with 100, 80, 50, and 20 cars trailing the point of derailment. 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. (Comparing a two-way end of train device/DP in the rear to ECP brakes)

Modeling

The majority of the discussion of the modeling can be found in the tank car section of this analysis. However, some of the safety benefits corresponding to ECP braking were debated by commenters during the comment period. Their comments noted that the TEDS model[146] used by PHMSA and FRA in the NPRM, derived different results than the TOES model,[147] which was the model used by the AAR.

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[146] Train Energy and Dynamics Simulator (TEDS) is a longitudinal train dynamics and operation simulation software developed by Sharma & Associates for the Federal Railroad Administration.

147 Train Operation and Energy Simulator (TOES) is a train action model developed for and licensed to AAR-member railroads.

Simulations are only as good as the assumptions used to drive the program. Both TEDS and TOES are based on the laws of physics. The TEDS simulator was compared and validated against the TOES simulator and essentially provides identical results in response to the same input assumptions. TEDS was developed through FRA's Research & Development Program only because AAR was unwilling to make TOES available outside its membership.

In the NPRM, we based effectiveness of brake systems, in part, on TEDS results. To reach a conclusion on the effectiveness of various brake systems, we correlated the effectiveness of ECP brakes, calculated using the Sharma model, to an energy dissipation curve calculated using TEDS. We then calculated the areas under the energy dissipation curves for a number of brake systems. Differences in the areas under the curves were then used to calculate the effectiveness of the alternative brake systems. For instance, the difference in area between the ECP brake curve and the conventional brake curve is twice the difference in the area between the two-way end-of-train device (TWEOT) curve and conventional brake curve. Therefore, the effectiveness of TWEOT is half that of ECP brakes. The effectiveness and benefits in the final rule are not based on this relationship. Instead the effectiveness is calculated using the Sharma model exclusively. TEDS is used to determine the time history of the brake signal for the alternative brake systems. These results are then used as input to the LS-Dyna model of the 18 different derailments in the Sharma model.

In its comments, the AAR provided a study using TOES. The study provides simulation results in the form of energy reduction and number of car reaching the point of derailments. AAR also "reproduces" the stopping distance recorded in three derailments. However, none of the results are from an actual simulation of a derailment. The model simply calculates the speed of the train during the braking and the stopping distance. The train does not "derail" in the TOES model, rather it simply slows to a stop. Using the difference in the deceleration, AAR calculated the relative energy dissipation. The difference in stopping distance was used to determine the reduction in the number of cars reaching the point of derailment. Simulations to reproduce stopping distances were performed by applying an opposing (the direction of movement) force they referred to as a blocking force. The blocking force is a surrogate for the force applied to the trailing cars by the derailing cars and minimized the braking force needed to stop the train. These results were provided in an effort to refute the effectiveness basis in the NPRM. Specifically, AAR asserts a blockage force was not included in the TEDS results provided in the NPRM. While this is true, it is irrelevant. As stated above, the TEDS results are not the basis for the effectiveness in the final rule.

In the final rule, the Sharma model is used to calculate effectiveness and blockage force is implicit in the model. In fact, knowing that the event recorder from the Aliceville, Alabama, derailment showed that the rear locomotive traveled about 1240 feet, we compared that to the LS-Dyna derailment simulations (not TEDS). We checked ten of the 18 runs in the 100-car, 40 mph, EOT braking set and found that in most of the runs the distance the rear car traveled was in the range of 1250 to 1300 feet. The LS-Dyna runs had 10 more cars (and 1 less locomotive) than the Aliceville, Alabama train, and started at 40 mph rather than 39 mph. Adjusting the Dyna distance for reduced initial speed brings the range down to 1190 - 1235 feet. So, the rear car distance traveled in the Dyna simulations matched the Aliceville locomotive's event recorder data with a difference of less than four percent. This shows that in spite of all the potential variations, our derailment simulations closely matched the reality as evidenced by the event

recorded download. The results also validate that PHMSA's and FRA's choice of friction coefficients was reasonable (the AAR also asserted the range of friction factors used in simulating the derailments was inappropriate), and the results further indicate how the LS-Dyna simulations implicitly include the blockage force.

Any comparison of results derived from AAR's TOES to those from TEDS is inappropriate because TEDS results are not the basis for the effectiveness in the final rule. The Sharma model is used to calculate the effectiveness. The Sharma model is superior to TOES for three reasons. First, the Sharma model simulates a derailment. TOES simulates slowing and stopping of a train on the tracks. Second, the Sharma model quantifies effectiveness in the form of the number of punctures. TOES indicates energy reduction and stopping distance relative to a stationary point of derailment. These are a poor corollary to the outcome of a derailment. Energy is necessary but insufficient to quantify damages. Other factors, such as location of impact and size of impactors are of equal importance to energy. None of these items are included in TOES. Third, the results of the Sharma model enable us to calculate the effectiveness of the brake system, speed at derailment, and the tank car design. The effectiveness of each variable can be calculated individually or in combination with one or both of the other variables. TOES is not capable of such analysis.

The Sharma model 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, we were able to evaluate 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. A letter report describing the rationale and methodologies employed by the model was posted in the docket to provide an opportunity for public review. A number of comments related to the model were received. These comments are addressed elsewhere in the RIA and Final Rule.

Additionally, after the NPRM, Sharma and Associates published a paper describing the model. The paper has been reviewed. The model generally has received very positive feedback. A few instances are outlined below.

- The paper was presented at the ASME Joint Rail Conference. The paper was reviewed anonymously, and there was positive feedback as well as some constructive criticism. All the feedback and criticism was incorporated into the final letter report which is referenced in the RIA and Final Rule.
- The paper has already been reviewed and accepted for publication at the International Heavy Haul Conference to be held in June 2015.
- The paper was reviewed by FRA Research and Development personnel and their feedback has been incorporated into the final letter report.
- The paper was presented to and well-received by personnel at Transport Canada as well as personnel at the Volpe National Transportation Center.
- An overview of the work was presented at the NTSB Tank Car forum and folks from NTSB have also seen published versions of the paper. All feedback has been positive.

In the July 2014 letter report that supported the NPRM, Section 5: Preliminary ECP Simulations, the authors provided the following caveat to the reported results related to ECP brakes.

> *Nonetheless, given that this is based on a limited simulation set, the results could be a bit optimistic, and should be taken with a grain of salt. Once a larger number of simulations are complete, it is anticipated that the percent improvement due to ECP would likely drop to about 25%, or about a 5-6 mph performance advantage at a 40 mph derailment speed.*

This has been the focus of a number of comments. As stated, the authors understood that the reported results were based on a limited number of simulations that could be run in the time available to inform this rulemaking. The results of the July 2014 letter report were based on 12 derailment simulations while the effectiveness reported in the final rule is based on 18 simulations. The reported effectiveness of ECP brakes in the NPRM was about 36 percent. As the authors predicted this result was optimistic and the effectiveness was likely closer to 25 percent, which is very close to the results indicated in the final rule.

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. However, AAR asserts that many of the benefits claimed in the analysis of the NPRM for wheel savings and fuel savings are currently realized through use of dynamic braking, so the marginal benefit of ECP brakes should be much lower. AAR provided limited data from the current coal trains that operate in the United States with ECP brakes indicating that ECP brakes are utilized only 11 percent of the time that brakes are employed. The remaining 89 percent of the time, dynamic brakes are used. Although PHMSA and FRA did not incorporate the use of dynamic braking into the NRPM analysis, we have adjusted for it in this final rule.

AAR uses the data from coal trains and recommends that fuel and wheel benefits should be reduced by 85 percent. Our analysis, however, indicates that AAR's reasoning behind this recommended adjustment is flawed. Although railroads use dynamic braking for much of their braking, dynamic brakes, in some ways more than conventional pneumatic brakes, create significant in-train forces and can be damaging to both the rolling stock and the rail structure.

The ability to use ECP brakes on top of the dynamic brakes further improves fuel efficiency by as much as five percent above compared to using dynamic braking alone, depending on the

routes and railroad practices.[148] In response to the AAR comments, PHMSA and FRA accept a 50 percent reduction in the fuel efficiency benefits in its analysis. However, 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). Additionally, AAR's contention about an 85 percent reduction in costs related to wheel wear does not account for corresponding stress being placed on the rail when a train employs dynamic braking alone. AAR also does not account for the additional efficiencies that will occur when railroads take advantage of the coordinated use of ECP brakes with dynamic brakes, which are discussed below.

Railroads will continue to experience brake-induced wheel wear where pneumatic brakes are used, but if the railroads rely on dynamic braking they will 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.[149] 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 percent improvement in average wheel life.[150] Once operations "settle in," improvements in wheel life may reach ten percent, thus reducing the estimated wheel wear benefit by 75 percent instead of the 85 percent estimated by AAR.

Most of the rail and infrastructure wear caused by dynamic braking occurs due to power braking. Power braking also uses excess fuel and creates poor in-train forces. PHMSA and FRA expect that ECP brakes will provide further benefits in these areas as the use of ECP brakes with dynamic braking can eliminate power braking. Further, ECP brakes can be operated at a more steady 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.[151] This allows for a more optimum use of dynamic brakes. Modulating the speed over the dynamic braking with ECP brakes also greatly reduces in-train forces by applying the brakes evenly through the train rather than just at the locomotive.

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[148] 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

[149] Wachs, K.,p. 4

[150] Wachs, K., p 6

[151] Wachs, K., p. 3

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. We recognize that 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,[152] are proliferating within the United States rail network that 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 best use of 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 signal spacing existing 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.

Cost of ECP on Tank Cars

Several stakeholders commented that the cost to equip tank cars with ECP brakes in the NPRM was too low. PHMSA and FRA used two different cost estimates in the NPRM. For any car that would be retrofit, PHMSA and FRA assumed the cost would be $5,000. For cars that were considered new construction, the cost would be $3,000. In the comment period, PHMSA and FRA received comments that the costs associated with ECP for tank cars would range from $5,300 - $15,000.

PHMSA and FRA reviewed these comments and have updated their estimate. One of the manufacturers of tank cars provided PHMSA and FRA with an estimate of $7,000, while another commenter, Railway Supply Institute (RSI), provided FRA with an estimate of $7,300 for a newly constructed tank car and $7,800 for a retrofitted tank car. In its December 19, 2014 letter to PHMSA and FRA, RSI provided a detailed total per car labor and material cost estimates for installation for new and modified tank cars. Based on review of the comments and professional judgment, PHMSA and FRA are using an average estimate of $7,633 that relies on RSI's estimates and assumes that approximately one third of the ECP fleet would be new construction tank cars and two thirds of the ECP fleet would be comprised of retrofitted tank cars. This

[152] http://www.up.com/aboutup/corporate_info/sustainability/preserve_environment/fuel_efficiency/index.htm

estimate may be high to the extent that for the crude oil fleet the industry may equip ECP brakes significantly more on new cars than on those in the existing fleet.

Cost of ECP on Locomotives

PHMSA and FRA received comments from several stakeholders that the cost to retrofit locomotives in the NPRM was too low. Some commenters did not see a cost for the locomotive in the NPRM. However, in the NPRM, PHMSA and FRA estimated that it would cost around $79,000 to retrofit a locomotive with ECP brakes. The Association of American Railroads (AAR) noted that this cost would be closer to $88,300 per locomotive.

Class I Railroad's locomotive purchasing projections indicate that over 1,000 locomotives will be purchased in 2015. PHMSA and FRA believe that the railroads will continue this rate over the next 6 years, and the railroads would be able to allocate a portion of new locomotive purchases towards locomotives equipped with ECP. For new locomotives, the ECP add-on over an electronic based locomotive air brake (i.e. CCB-2 or Fastbrake) is estimated, by FRA Motive Power and Equipment Division to cost $40,000 per locomotive.

Additional Locomotives

PHMSA and FRA received comments regarding the number of locomotives that the NPRM had indicated would need to be equipped with ECP brakes to support the proposed ECP brake requirement. In the NPRM, PHMSA and FRA estimated that 300 unit trains would be used in the peak period, and that 900 locomotives would be retrofit with ECP brakes to accommodate three locomotives per train. Some of the commenters noted that all locomotives in the rail industry would need to be equipped with ECP brakes to meet the proposed requirements. Some commenters further explained that if an ECP-equipped locomotive was out-of-service there would not be sufficient replacement locomotives equipped with ECP brakes, thereby causing a bottleneck. Others noted that switching locomotives would also need ECP brakes.

After the NPRM, PHMSA received comments from RSI that updated the forecast of the number of carloads that would be originated. Based on this update, PHMSA and FRA made adjustments and are now estimating that the maximum number of HHFUT on the general network at any given time would be 633. Not all locomotives would need to be retrofit since the equipment with ECP brakes is part of a captive fleet, and therefore the locomotives would be part of that captive fleet. Although the majority of these trains operate with three locomotives, PHMSA and FRA are assuming 2,532 ECP-equipped locomotives (four per train) will be required to meet the final rule requirements for ECP brake operation, which would accommodate for out-of-service locomotives or any additional locomotives needed to operate the HHFUT's with ECP brakes.

One of the major railroads currently operating an ECP-equipped subset of their fleet has 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 envision 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 only traveling 30 mph if they constitute a HHFUT. This would allow switching locomotives to avoid having ECP brakes installed to comply with the rule.

Equipping Short Line Railroad Locomotives

The American Short Line and Regional Railroad Association noted that it believes that the short line railroads would need to equip their locomotives. PHMSA and FRA believe that the majority of short line railroads affected by this rule already transport these commodities on Class III track, which is subject to speed restriction of 30 mph. Since this analysis assumes that tank cars will be equipped with overlay systems, any non-ECP-equipped locomotive from a short line railroad should be able to haul these tank cars. Notwithstanding, FRA expects that the Class I railroads will supply unit crude oil and ethanol trains that will stay intact, including the locomotive (through the use of pooled power arrangements), from origin to destination. Further, FRA anticipates that the Class I crews will continue to operate the train over the smaller railroad's line pursuant to trackage rights or other agreement. Therefore, if a shortline or regional railroad were to receive a crude oil or ethanol unit train at its interchange with a Class I railroad, FRA anticipates that the locomotive (and the Class I operating crew) will pass through interchange with the rest of the train. For the same reason, there will not be additional training costs for the crews of short line railroads.

ECP-Equipped Tank Cars Cannot be intermixed

PHMSA and FRA received comments that an ECP-equipped tank car could not be intermixed with other cars in a train consist. These commenters also believed that cycle times would be increased, as special movements would need to be made to rescue stranded ECP-equipped cars. This would add additional operational costs. PHMSA and FRA have verified with subject matter experts in ECP brakes and determined that an overlay system would be able to be intermixed with non-ECP brake-equipped cars carrying other commodities; however, we do not expect that these cars will be regularly switched into mixed commodity trains. In addition, if a railroad decides to operate with stand-alone ECP brakes, §232.609(h) permits the operation of stand-alone ECP brakes on cars in a conventional train as long as the conventional brakes are 100 percent effective, and the total percentage of effective brakes in the trainset are at least 95 percent. Stand-alone ECP-equipped cars still have vent valves, and can propagate emergency brake signals. Therefore, unless a large number of defective ECP-equipped cars need to be moved, it will be difficult to 'strand' ECP cars. As noted above, PHMSA and FRA have limited the number of tank cars that will need to be equipped with ECP brakes to those cars in a HHFUT that operates in excess of 30 mph. This will minimize the number of times these cars will need to be intermixed, as PHMSA and FRA believe that these trains will stay together for long periods in order to meet the demand for service.

Fleet Management

The PHMSA and FRA analysis assumes that shippers have the ability to predict or control whether a given tank car will be used in manifest train service or unit train service. With respect to unit train service, shippers will typically contract with a railroad to provide these services and will be aware that its tank cars are being operated in unit train service. In fact, shippers currently advertise their ability to have unit train service which implicitly is a benefit to the shippers' customers.[153] Agweek reported that "[u]nit trains are considered more efficient and have access to more destinations."[154] However, some commenters noted that the identification of what type of service—manifest or unit train—a shipper's tank car may be transported in may be a difficult to discern. These commenters argue that it could result in shippers equipping more tank cars with ECP brakes, in order to maintain their current level of fleet flexibility.

Shippers have fleet managers responsible for the logistics, maintenance, and repair of owned and leased tank cars. Business units within each shipper manage the use of the owned or leased tank cars based on the commodity shipped. The shippers purchase or lease tank cars based on the anticipated demand for each business unit. The cars are leased or purchased in groups. The fleet managers or business units assign cars to the specific service to meet supply chain demands. Under the current practices, the fleet managers keep these cars in unit train service. This will be easier as the fleet matures—currently because of the shortage of tank cars, shippers of crude oil and ethanol sometimes cobble together fleets from a variety of sources to meet demand. Based on current energy production forecasts, these cars will likely remain in unit service over the length of their leases or, if owned, over the expected life of the cars. Some shippers also use specialized fleet management companies.

Tank car ownership has been consolidating recently as shippers are opting to lease rather than purchase tank cars. Shippers then contract with railroads to pick up and deliver tank cars containing their products. This service may be in mixed freight, or by unit train. These contracts are usually longer term deals—ranging from five to ten years in length—particularly for unit train operations because both shippers and railroads benefit from locking in the contract terms for major commodity shipments that are likely to stay steady for a multi-year period. A vital consideration of these contracts is whether it is for unit train operations. A contract for unit train service is expected to be of sufficient length to pay for the unique design of the equipment for the service. However, there is flexibility in contracting for rail service, and we expect that this flexibility will allow shippers and carriers to coordinate in a way that helps resolve any fleet management issues. For example, new and retrofitted tank cars may not have ECP brakes

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[153] http://www.csx.com/index.cfm/customers/commodities/agricultural-products/services/ethx-express-ethanol-delivery/

[154] "Ethanol plants depend on rail service improvement to prevent shutdowns." Pates, M. 10/27/14. Agweek.com, http://www.agweek.com/event/article/id/24322/publisher_ID/80/

installed initially, and a shipper may decide to add ECP brakes to a whole train at once. Shippers could upgrade equipment to accommodate for ECP brakes when it becomes clear that equipment will be used in a unit train that is covered by the rule because, unlike with tank car retrofitting, ECP brakes can be installed on tank cars in a yard or other less-sophisticated equipment facility.

Carriers and shippers, through their fleet management, often work to ensure that a unit train stays together for the length of the contract. Coal trains that operate as unit trains are a prime example of this. When a wheel set needs to be replaced on a hopper car that is in a unit coal train, Union Pacific (UP), in particular, stops the entire train and brings machinery to lift the individual car and replace the wheel set while keeping the train together. FRA granted an inline wheel replacement waiver to UP to accommodate this. BNSF has also discussed applying for these waivers in two different locations. When this occurs on manifest trains, the car is typically set out and the train continues on without the car.

Although the shippers and carriers already have fleet managers, PHMSA and FRA have included an extra cost to account for any additional expenses associated with managing the ECP brake system fleet. In our analysis, we have estimated 8,000 man hours in the second year of this rule as a means of accounting for any burden that would be encountered. PHMSA and FRA believe that this is conservative estimate as these positions already exist and the shippers are already managing these small captive fleets. As the crude oil and ethanol fleets mature and permanent unit train sets are established, managing tank cars that make up unit trains will become easier. Moreover, managing cars in unit train services is easier than cars in mixed freight service because the tank cars in unit train service for crude oil and ethanol tend to stay together for an extended period of time.

Reliability and Technological Readiness

AAR has argued that ECP brakes are not reliable and that ECP brakes are an unproven technology that is not ready for wide spread deployment. In making these assertions, AAR relies on its own evidence—developed after publication of the NPRM—while discounting all other sources. PHMSA and FRA have reviewed AAR's evidence, and we have also reviewed FRA studies, analyzed the results of ECP brake system waiver programs, and examined the results of ECP brake operations in other countries. In PHMSA and FRA's view, the evidence firmly establishes that ECP braking is a "mature technology" that can, among other things, reduce derailment frequencies.[155] Therefore, while AAR now contends that ECP braking technology is not ready or unreliable, the actions of AAR and its members outside the context of this

[155] "Assessment of freight train derailment risk reduction measures: A4 – New Technologies and Approaches", Report for European Railway Agency, Report No. BA 000777/05, April 19, 2011, at 9, http://www.era.europa.eu/Document-Register/Documents/DNV%20Study%20-%20Final%20A4%20Report%20-%2020110419%20-%20Public.pdf.

rulemaking in updating AAR Standard S-4200 and continuing to use ECP brake systems in revenue service while also pursuing regulatory relief on brake inspections indicate otherwise.

ECP brakes have been operated in North American fleets since at least 1998, and these fleets have seen varying degrees of success during this time period. PHMSA and FRA recognize that there have been hurdles in the deployment of ECP brakes (e.g. diversion of capital away from ECP brakes to PTC and software issues contributing to crosstalk). However, the technology has continued to improve since 1998 and carriers are in a better position now to ensure that ECP brakes are successfully implemented.

In 2008, FRA promulgated a rule to establish a regulatory process by which railroads could implement ECP brakes. The ECP brake rule incorporates by reference AAR's 2007 ECP brake standards developed by it standards making body. As recently as July 2014, AAR updated its ECP brake standard to resolve issues identified during ECP operations and improve the standard. Also, in 2014, BNSF and Norfolk Southern (NS) began moving forward with a pilot program waiver that allowed the carriers to jointly operate an ECP-equipped train that is permitted to travel up to 5,000 miles between brake inspections.[156] Setting aside AAR's alternative assertions, the carriers' pursuit of this waiver is evidence that they consider ECP brake systems reliable. Otherwise, they would not be pursuing a regime that would allow for fewer inspections of ECP-equipped trains, which would need to be justified with data from the pilot program. FRA has granted this waiver and is currently assessing the efficacy of extending the interval between brake inspections to 5,000 miles on ECP-equipped trains. The success of these pilot programs indicates that this technology is working well, and is ready for further deployment. If ECP braking was not a success, these pilot programs would end, and no additional carriers would seek waivers. As previously discussed, NS would not have expanded their ECP routes within the last three years if this system was not reliable.

AAR has argued that its member railroads have experienced longer delays in train consists operating in ECP brakes versus conventional braking. Its contention is that its members have experienced delays in their ability to respond to en route failures on ECP braking systems because of the lack of available equipment to make routine repairs and lack of personnel to make the repairs. AAR uses this information to argue that ECP brakes may be too complex and not reliable. However, AAR is looking at these issues through the wrong end of the lens. According to a representative from New York Air Brake, the issue with ECP brake systems "is not reliability, but rather, availability of power and shops."[157] These are issues that can arise with any new technology, but they do not evidence a problem with the technology itself. The problem is solved by increasing the availability of ECP braking equipment and training a workforce to

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[156] 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.

[157] William C. Vantuono, "The Science of Train Handling", Railway Age, June 2012, at 25-26.

handle ECP brake issues as they arise. PHMSA and FRA have taken into account the need for investment in these areas and have factored in costs that are designed to mitigate the cause of these types of delays.

The North American railroads have not trained enough employees on the use and maintenance of ECP brakes because of the very small number of trains that have been operated with ECP brakes. If a carrier has not invested sufficiently in training and an ECP-equipped train has any mechanical issues, there likely will be delays associated with locating an employee trained on ECP brakes maintenance and repair who could travel to the site to assess and correct the problem. For example, on Canadian Pacific Railway there was a train stranded for about 18 hours in 2012 during the holiday season, and the employees who were on-duty were not familiar with the ECP technology. ECP brakes are expected to be deployed over 68 percent of the general rail network. As a result, training will be more widespread, which should overcome any potential issue similar to what CP experienced from occurring. 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 section of its operating and maintenance personnel in order to ensure that these 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 68 percent of the mentioned 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.

Some railroads seem to have experienced delays resulting from not having sufficient equipment on hand to address normal operational issues. The extent of this problem is not well-researched, but there is some evidence that ECP brakes are often tabbed as the culprit for delays even when they are not the actual cause of the delay. This was reported in the Sismey and Day study, which noted that, "[t]his is not unique to ECP as it tends to happen whenever new technology or operational aspects are introduced."[158] Notwithstanding, PHMSA and FRA do not question that lack of ECP brake equipment can cause delays. For example, at one point BNSF and NS had an insufficient ratio of ECP-equipped locomotives to ECP-equipped trains. NS, which currently operates six of ECP-equipped trains, solved this issue by outfitting locomotives with run-around cables, which allows any locomotive to be used as a secondary unit to power a train. To account for a sufficient level of extra equipment, PHMSA and FRA have conservatively assumed four locomotives will be outfitted with ECP brakes per trainset, when only three are necessary to power a trainset. We have also assumed that each locomotive will be outfitted with run around cables.

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[158] pg. 229.

Trains equipped with ECP brake systems in the United States typically operate using stand-alone systems. However, to minimize delays, we have assumed in our analysis that the tank cars for HHFUTs will be equipped with more expensive overlay systems. The overlay system is more expensive than the stand alone ECP brake system, but it provides an extra layer of flexibility in operations by allowing the tank cars to be used in a train with either braking system. This will allow some shortline carriers that operate these trains at 30 mph or under to use their own locomotives and use conventional air brakes. Shortlines could also opt to use "through" trains under an arrangement between interchanging railroads in which trackage rights are granted and the initial carrier operates the train to the destination using their equipment and crews. This approach is used with Class I railroads. For example, the NS's ECP locomotives stay with the trainset even when operating on BNSF track with BNSF crews.

PHMSA and FRA recognize that delays will likely occur during the initial implementation of the technology, but there is no reason to believe that these delays would be any longer than the delays that have taken place with the roll-out of any other new technology, such as distributed power. Further, an overly ECP braking system could allow continued safe operation in the event of an ECP braking failure.

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. In 2014, BNSF and NS began moving forward with a pilot program waiver that allowed the carriers to jointly operate an ECP-equipped train that is permitted to travel up to 5,000 miles between brake inspections. Setting aside AAR's alternative assertions, the carriers' pursuit of this waiver is evidence that they consider ECP brake systems reliable. Otherwise, they would not be pursuing a regime that would allow for fewer inspections of ECP-equipped trains, which would need to be justified with data from the pilot program. FRA has granted this waiver and is currently assessing the efficacy of extending the interval between brake inspections to 5,000 miles on ECP-equipped trains. The success of these pilot programs indicates that this technology is working well, and is ready for further deployment. If ECP braking was not a success, these pilot programs would end, and no additional carriers would seek waivers. As previously discussed, NS would not have expanded their ECP routes within the last three years if this system was not reliable.

AAR has raised crosstalk and interoperability as the two primary technological issues that affecting the ability of trains to operate in ECP brake mode. "Crosstalk" occurs when a signal—usually from a passing train—interrupts the signal of an ECP-equipped train causing the train to go into emergency mode. After further investigation into this problem, the ECP brake manufacturers were able to resolve this by updating the ECP brake software program. The new software incorporates a unique code established between the locomotive and the end of train device at initialization. This unique code attaches to all messages within a train and allows two passing trains to continue to operate in ECP brake mode without any interference, as these trains can no longer communicate with each other. This fix requires a railroad that is operating equipment using an older version of ECP braking software to update that software for all freight cars and locomotives that operate with ECP brakes, but the fix has proven effective in eliminating crosstalk problems.

As evidence of the effectiveness of this solution, the software update was incorporated into the AAR Standard S-4200 in July 2014.[159] Any new ECP-equipped freight car or locomotive that has this update should not experience any crosstalk problems. Australian railroads currently are updating their ECP braking software. In the United States, NS has updated its ECP-equipped coal cars; however, its locomotives have not yet been updated. It is expected that NS will update its locomotives in 2015 at the same time its ECP-equipped locomotives are taken to repair shops for PTC upgrades. PHMSA and FRA do not have specific information on BNSF, but any equipment operating in the United States under AAR Standard S-4200 is expected to be updated before July 2016.[160] Once railroads have incorporated the software updates, they will be able to operate more efficiency by avoiding delays related to crosstalk.

Given that the ECP braking requirements in this rulemaking do not take effect until January 1, 2021, PHMSA and FRA expect that the latest software will be included on all HHFUTs that operate in excess of 30 mph. As a result, by the time that ECP brakes are required for HHFUTs, PHMSA and FRA expect that the crosstalk problem will be fully resolved.

Some commenters also have raised the issue of interoperability between the ECP equipment of various manufactures. This argument is misplaced regarding ECP equipment in full interchange service. The issue of interoperability between varying manufactures has been addressed by AAR's ECP standards since 2008. As mentioned earlier, these standards have been updated as recently as July 2014. PHMSA and FRA believe this issue has been raised by commenters using pre-2008 equipment or equipment that has not been updated to comply with the current version of this standard, and therefore those comments do not represent a realistic concern.

Limited Suppliers of ECP Braking Systems

Several commenters noted there are only two companies that manufacture and supply ECP brakes. They discussed that the majority of products they sell are for railroads overseas, and the available supply of ECP brakes will not be sufficient to equip the tank cars. One of the commenters also felt that a lack of suppliers would cause an increase in ECP braking system prices, as the ramp-up period to be ECP-equipped is too fast.

First, there are only two major suppliers of conventional brake equipment in the United States at this time, and within normal commercial constraints, they are sufficiently supplying the car and locomotive building industries. In the NPRM, PHMSA and FRA estimated that every tank car

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[159] The S-4200 update of July 2014 also helped to improve system performance of the trainline connectors and correct the brake cylinder pressure requirements.

[160] "Subject:Implementation: Revisions to AAR MSRP Section E-II, ELECTRONICALLY CONTROLLED BRAKE SYSTEMS, S-4200, S-4210, S-4230 and S-4250", Circular Letter C-12156, Association of American Railroads, July 24, 2014.

(130,000 +) would be equipped with ECP brakes regardless of if it would be part of a unit train. The NPRM also limited the phase in time to a three-year period. As PHMSA and FRA have limited the number of tank cars that would need to be equipped with ECP brakes, the number of tank cars has decreased to 60,231 cars. PHMSA and FRA believe that ECP brake component manufacturing capacity will accommodate this demand over a six to eight -year period, which was increased in the final rule. PHMSA and FRA believe that this ramp up of production could be done with minimal capital investments for the ECP brake manufactures.

Separate Fleets

The AAR commented that having a separate ECP brake system fleet would be daunting and difficult to manage. 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 have employees who already manage the crude oil and ethanol fleets. The additional cost to determining the best way to manage these fleets would be realized in the first year of operation. PHMSA and FRA included the costs of an asset manager to help account for the difficulties of managing separate fleets. These costs can be seen further in the analysis.

Training and Wages

In the NPRM, PHMSA and FRA assumed that 9,000 employees would need to be trained in the use of ECP brakes. Some of the commenters noted that this estimate was too low because all crewmembers and carmen would need to be trained. PHMSA and FRA believe that the commenters' estimate is too high, but note that the original estimate in the NPRM was low.

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 68 percent of the total ton-miles were on routes that had crude or ethanol unit trains. PHMSA and FRA adjusted the estimate to include 68 percent of the total crews as the other 32% of crews work on track that does not carry crude oil or ethanol. Based on these assumptions, around 18,000 engineers and 27,000 conductors would receive additional training. PHMSA and FRA also included 6,500 carmen in the training pool. Training duration was also adjusted to reflect actual experience by railroads currently conducting such training.

The AAR noted that there was an underestimation of wage rates, as they believe that engineers' wages should be $73.10 and conductors' should be $62.16. PHMSA and FRA used the 2012 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. PHMSA and FRA also incorporated a 75 percent overhead cost.

Burden of Costs

PHMSA and FRA received numerous comments debating what entities would bear the costs of this regulation. The various comments noted that the cost would be borne by the rail carriers, car lessors, or car owners. PHMSA and FRA recognize that this rule will have significant costs and that all of these entities will be incurring implementation costs. In the final rule, PHMSA and FRA have tried to minimize the costs to all stakeholders by only requiring ECP brakes on

HHFUT, which should also ensure the highest safety and business benefits return per unit equipped.

Additional Maintenance Costs on Tank Car

During the comment period, PHMSA and FRA were informed of additional costs associated with the use of ECP brakes. The commenters noted that some components, such as batteries and electrical cables, would need to be replaced every five years. PHMSA and FRA have included the replacement costs that would take place during a tank car's normal maintenance services and have included these costs in our analysis.

Out-of-Service Time

RSI commented that PHMSA and FRA did not account for the amount of time a car would be out-of-service for retrofitting for ECP brakes. PHMSA and FRA determined that there is no additional time necessary for including ECP brakes in a retrofit. That is, subject matter experts indicate that ECP brakes can be included in a retrofit without adding out-of-service time. If a bottleneck in retrofits occurs, the outfitting of ECP brakes can be done at any rail car repair facility. This will help to reduce the amount of time a car is out-of-service. PHMSA and FRA also note that fewer cars will have to be equipped under the final rule than would have had to be equipped under the NPRM.

Timeline for Implementing ECP Brake Systems

Numerous commenters asked for clarification regarding the timeline for implementation of ECP braking systems. In the NPRM, PHMSA and FRA expected all tank cars (including ECP-equipped) to be retrofit within three years. PHMSA and FRA reviewed the comments for the tank car portion of the rule, and developed a new phase-out period. The ECP brake requirement begins on January 1, 2021 for any HHFUT operating in excess of 30 mph that contains one or more loaded tank car of a Packing Group I flammable liquid. For all other HHFUTs, the ECP brake requirement would begin on May 1, 2023. This would provide a longer timeline for retrofits to occur.

ECP Brakes Accident Prevention

PHMSA received comments noting that ECP brakes would not be able to prevent any accidents. Like many of the elements of this rule that will mitigate the consequences of an accident, PHMSA and FRA also recognize that the majority of ECP braking system benefits will also help to reduce the severity of accidents. However, FRA specifically looked for derailments (accident types) in which train handling was the cause of the incident. Accidents such as "string line" derailments could also be avoided with ECP brakes. In addition, certain equipment-caused (e.g., wheels) accidents could be prevented. The benefit section of the analysis further discusses this topic.

Background

On March 9, 2011, AAR, on behalf of its members and the Tank Car Committee (TCC or Committee), jointly petitioned PHMSA and Transport Canada (TC) to establish new standards for DOT Class 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. The 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 recent increase in the demand for these cars. 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 a number of 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, DP systems, and two-way EOT devices.

TEDS was used to study the dynamics and energy levels of trains under a variety of operational conditions. Specifically, TEDS was used to determine the stopping distance and the rate of dissipation of kinetic energy (KE) of a generic 100-tank car train on level tangent track equipped with the candidate brake signal propagation systems. The simulations were used to determine the relative performance of the different systems. The model was validated using brake signal propagation data from Wabtec and data from a BNSF test performed in 2008.

This modeling tool was then used to determine the remaining energy to be dissipated and the speed at selected locations in the train when that tank car reached a defined point specified as the Point of Derailment (POD). By comparing the results for each technology, assumptions were made for the difference in number of cars reaching the POD, remaining kinetic energy of all of the cars in the train at a set time interval, and conditional probability of release (CPR) of hazardous material on the train.

Informed by a 2008 FRA rule on ECP braking systems,[161] the task force 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. The group found:

Based on the simulation results and analysis of the data it was concluded the alternatives considered provided marginal benefits. Moreover, the identified obstacles to implementation represent a considerable time and cost investment and the predicted benefits would not be realized for months or years in the future. As such, this working group will not make a recommendation related to alternative brake signal propagation systems.[162]

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 energy associated with derailments. In addition, FRA and RSAC have considered and evaluated the usefulness of advanced brake signal propagation systems.

The totality of these efforts show that 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. The evidence collected is inclusive and supports the regulatory change.

Fleet Forecast

In the NPRM, PHMSA and FRA forecasted that 133,010 tank cars would be required to meet the demand of crude oil and ethanol production levels in the peak year (2020) of the twenty-year period analyzed. This demand was primarily based on: (1) comments that RSI made in the ANPRM regarding the demand for tank cars and (2) the US Energy Information Administration's (2014 EIA Forecast) forecast production for US crude oil and ethanol.[163] PHMSA and FRA received minimal comments after the publication of the NPRM addressing this estimate. One of the few comments that were made came from RSI.

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

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

[163] Source of both crude oil and ethanol production forecast was the Energy Information Administration's Annual Energy Outlook 2013.

RSI projected that as the production of crude oil increases, other modes transporting oil (such as pipeline or barge) would already be at capacity. This would cause rail to increase their market share of the transportation of crude oil. RSI projects that there will be 419,099 carloads of ethanol in 2024, which will be its peak year. Crude oil's peak year will be in 2021 when 1,131,980 carloads will be produced. RSI's comments noted that around 160,000 tank cars would be required for this North American service: 30,000 for ethanol and 130,000 for crude oil.

AAR Annual Report

Every year, the Association of American Railroads (AAR) produces an Annual Report of Hazardous Materials Transported by Rail. Exhibit 2 of the 2013 edition of this report lists the top 125 hazardous commodities, measured by carload. In 2013, the AAR reported that there were 483,701 crude oil tank cars originating in North America, with 401,813 originating in the US and 81,888 in Canada. This gives us average shipments per car of 11.2[164] per year for crude oil. In 2013, the AAR reported that there were 290,710 alcohols NOS (ethanol) tank cars originating in North America, with 290,709 originating in the US and one in Canada. This gives us average shipments per car of 10.8[165] per year for ethanol.

These two utilization estimates (shipments per tank car per year) are likely too low resulting in an artificially high estimate of cars needed in the future to meet demand. As noted in RSI's comments, any tank car that shipped at least one carload of this commodity during the year would be included in the crude oil tank car fleet numbers. RSI does not account for partial year service for tank cars, which leads to an underestimated average utilization rate. In the first 4 months of 2014, over 600 tank cars moved from other services into crude oil service, creating artificially low utilization rates for these 600 cars since they are listed separately and not pro-rated to reflect partial-year service in each commodity category. In addition, the UMLER database shows over 4,100 cars built during the course of the year in 2013. Not adjusting for the partial year service of these cars also results in underestimates of the average utilization rates, as they were not in-service the entire year. However, for the purposes of this analysis, FRA is using the RSI's conservative (artificially low) estimate that was calculated using the data provided by the Brattle Group.

Using RSI's projected peak carloads for ethanol service results in 419,099 carloads transported by roughly 30,000 tank cars, which would translate to 14.0[166] shipments per car in the peak year. This is an increase of 29.6 percent from 2013. Using RSI's projected peak carloads for crude oil service results in 1,004,852 carloads transported by roughly 96,590 tank cars, which would

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[164] 483,701 (Carloads of Crude oil) / 43,288 (number of cars used in 2013) = 11.174

[165] 290,710 (Carloads of Ethanol) / 27,024 (number of cars used in 2013) = 10.757

[166] 419,099 (RSI Forecast of carloads of Ethanol in 2024) / 30,000 (RSI estimate of number of cars used) = 13.970

translate to 10.4[167] shipments per car in the peak year. This shows a 7.1 percent decrease in utilization rate (efficiency) from 2013.

If we were to predict the number of tank cars required by looking at the 2013 AAR average shipments per car of crude oil, and using RSI's forecast, industry would need 101,069 tank cars. Even using a conservative AAR estimate, FRA believes that RSI has overestimated the cars required for crude service.

Unit Trains (HHFUTs)

PHMSA and FRA received many comments discussing the costs associated with ECP brakes. In the NPRM, it was proposed that every HHFT tank car would be equipped with ECP brakes. The final rule mandates that only HHFUTs would be required operate in ECP brake mode.

PHMSA and FRA have considerably narrowed the ECP brake requirement from that proposed. The final rule will require the use of ECP brakes only on certain long unit trains of Class 3 flammable materials, classified as HHFUT 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. This closely aligns with FRA's research into per unit crashworthiness, which estimated that the safety benefit of a 100-car unit train with ECP brakes is approximately equivalent to 64-car train using a two-way EOT device. The mandate for operating HHFUTs with ECP brakes would be January 1, 2021 or May 1, 2023, depending on the consist of the train (if there is one or more tank car load of Packing Group I flammable liquids, the earlier date applies).

Crude Oil Traffic

The peak crude oil production from the 20-year period analyzed is in 2021 with an estimated 1,131,980 carloads. Using RSI's 10.4 shipments per year average, the rail industry would need 96,590[168] tank cars to meet forecasted demand for crude traffic.

From the 2013 waybill sample, FRA estimated that 84 percent of crude oil shipments traveled in trains of 70 or more crude oil carloads. FRA believes that these trains are unit trains, traveling from the loading facilities to the oil refineries and back. The experience of FRA's regional staff

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[167] 1,004,852 (RSI Forecast of carloads of Crude in 2021) / 965,90 (RSI estimate of number of cars used) = 10.403

[168] 1,004,852 (Carloads) / 10.4 (Utilization rate) = 96,590 (Number of cars required)

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. We can then assume that 84 percent of the shipments in 2021 would travel in unit trains giving us 844,076[169] carloads for HHFUTs and 160,776[170] carloads for non-unit trains.

Ethanol Traffic

The peak ethanol production for the 20-year period analyzed is an estimated 419,099 carloads in 2024. RSI believes that the current 30,000 cars would be able to transport those carloads. Looking at the 2013 waybill sample, FRA determined that 0.285 percent of ethanol shipments traveled in trains of 100 or more carloads. However, the waybill also found that roughly 47 percent of the ethanol trains transported 70 or more tank cars. After discussions with ethanol stakeholders and FRA regional staff, PHMSA and FRA believe that all of these trains were operating as unit trains. In the peak ethanol year, there would be 197,400[171] carloads for HHFUTs and 222,600[172] carloads for non-unit trains.

Utilization Rates for HHFUT

In the NPRM, PHMSA and FRA noted that a unit train would travel 220 miles in one day. This translates to a 14-day cycle time for an average unit train. No comment was made to dispute this assumption. FRA also talked to individuals at the loading facilities, who indicated that a 14-day cycle time would be accurate for crude oil unit trains. A news article[173] stated that cycle time from the Bakken has improved from 23-24 days down to 18-19 days for one railroad. Bridger LLC comments indicate a 15-day round trip cycle time between North Dakota and the East Coast. Finally, FRA reached out to its regional inspectors, who estimated that the crude oil from the Bakken regions would have cycle times ranging from 6-14 days, with an average cycle time of 10 days. The cycle time would vary based on if the shipment were going to the east coast, gulf region other locations such as Kansas City. In this analysis, PHMSA and FRA wanted to

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[169] 1,004,852 (carloads of crude) * .84 (percent of carloads on unit trains) = 844,076 (carloads of crude on unit trains)

[170] 1,004,852 (carloads of crude) – 844,076 (carloads of crude on unit trains) = 160,776 (carloads of crude not on unit trains)

[171] 419,099 (carloads of ethanol) * .47 (percent of carloads on unit trains) = 197,400 (carloads of ethanol on unit trains)

[172] 419,099 (carloads of ethanol) – 197,400 (carloads of ethanol on unit trains) = 222,122 (carloads of ethanol not on unit trains)

[173] http://www.reuters.com/article/2014/11/12/uk-railways-crude-bnsf-eases-congestion-idUSKCN0IW2D320141112

use a conservative cycle time and estimated that the utilization rate of 16.0 (or number of completed round trips annually), or 22.8 days in a cycle time would be appropriate. This is well above the average days that we have seen in our research and in our discussions with various stakeholders.

Assuming a utilization rate of 16.0 for HHFUTs, the rail industry would need:

- 52,755 tank cars to annually transport 844,076 carloads of crude traffic; and
- 12,311 tank cars to annually transport 196,977 carloads of ethanol.

PHMSA and FRA have kept the same utilization rate that RSI used for the non-unit trains. For crude traffic, which is in non-unit trains, the rail industry would need:

- 15,459 tank cars to transport 160,776 carloads of crude oil, assuming 10.4 average shipments per year, as RSI indicated. For ethanol traffic, which is in non-unit trains, the rail industry would need 17,689 tank cars to transport 222,122 carloads of ethanol, assuming 14.0 average shipments per year, as RSI indicated.

ECP Efficiencies

Certain business benefits were discussed and monetized in terms of labor cost savings in the NPRM's RIA. For instance, fewer brake tests were monetized in terms of labor time savings. 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. 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. This permits faster cycle times for ECP-equipped trains as each brake test generally takes about three hours, but in some cases can take up to eight hours to perform.

NS and BNSF currently operate under a pilot waiver an ECP-equipped unit coal train that permits brake inspections every 5,000 miles instead of the 3,500 miles permitted by 49 CFR § 232.607. If the safety data collected from this pilot waiver is positive, it is reasonable to assume that other railroads would apply to extend ECP brake inspections to every 5,000 miles as well. This could further increase the utilization rates of ECP brake operated unit trains.

The modern conventional air brake valves are fast-acting and sensitive. 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 benefit and support safer operation of longer trains in cold weather conditions where brake pipe pressure is harder to maintain than 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 originate. Railroads would benefit from using ECP brakes because they will be able to maintain normal train lengths, eliminating the need for addition 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. For the purpose of this rule, a HHFUT is defined to be 70 tank cars or more in a consist. 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.

Under current FRA regulations, due to the real time equipment health monitoring requirements of AAR standard S-4200 in ECP-equipped locomotives, FRA regulations permit 95 percent operative brake operations 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 several times 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; 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 the locomotive engineer can ease into the brakes instead of applying and releasing full brakes under conventional braking.

PHMSA and FRA have reviewed reports and other research on the efficiency rate of ECP brakes. Stakeholders have discussed that that a reduction in equipment used can be seen between about 5 -15 percent. A Booz Allen Hamilton report[174] discussed that this topic. This report was relied on in FRA's 2008 ECP brake rule saying, "[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."

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[174] 'Benefit-Cost Analysis and Implementation Plan for Electronically Controlled Pneumatic Braking Technology in the Railroad Industry,' Booz Allen Hamilton, August 2006, p. II-6.

In a BNSF analysis[175] 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[176] 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. With ECP as the only contributing factor to improved efficiencies, this would translate to a 14 percent increase in cycle times, allowing them to have 14 percent few cars to provide the same service as was rendered. Even though the rail network is larger in the United States, these efficiencies would still be seen as they are based on cycle times.

In a public hearing[177] 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[178] 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

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[175] Maryott, D. 2008. ECP Perspectives. Proceedings of the 100th Annual Convention and Technical Conference, pp.57-62 Chicago, IL: Air Brake Association

[176] 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

[177] United States Department of Transportation, Federal Railroad Administration. Public Hearing on Electronically Controlled Pneumatic Brake Systems. October 19, 2007. Rosemont, Illinois.

[178] Forrester, J. 2010. Norfolk Southern ECP Brake Pilot Project Update. National Coal Transportation Association. Coeur d'Alene ID.

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 on the train).

Based upon this and other anecdotal evidence we determined that ECP brakes will deliver a 5-15 percent reduction of equipment used. For this analysis we used an improved utilization rate of eight percent for crude oil traffic instead of the high end of 15 percent. As the ethanol HHFUT are only 47 percent of the total ethanol fleet, PHMSA and FRA are estimating a smaller reduction to 5 percent.[179] Again, this percentage is appropriate as some studies have shown a much more significant reduction in the amount of equipment required. Using an eight percent reduction from the 52,755 tank cars required for crude service, ECP braked equipment would require only 48,535[180] cars to transport 884,076 car loads. A 5 percent reduction to the ethanol HHFUT fleet would permit 11,696[181] cars to transport 197,977 carloads annually. Multiplying the above tank car reduction estimates by the estimated cost of equipping a car with ECP results in an undiscounted cost savings of $36.9 million over 20 years.

In total PHMSA and FRA estimate that 4,835 fewer tank cars would need to be purchased over the 20 year period. The incremental cost difference between a CPC 1232 and a DOT-117 is $3,000. The total costs savings of ECP brakes are estimated to be $14.5 million.[182] PHMSA estimates that the reduction in demand for tank cars will be reflected by a reduction in the number of tank cars manufactured at the end of the time frame considered. Therefore, over a 20-year period the cost savings, discounted at 3 and 7 percent, are $12.1 million and $9.7 million respectively. These costs savings are discussed in further detail in Section 3. PHMSA and FRA did not use these tank car reduction estimates to reduce the number the number tank cars that would be retrofitted. Any impact of ECP in reducing the number of cars that would need to be built and purchased in the future is an additional benefit that is not monetized in this analysis.

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[179] 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.

[180] 52,755 (tank cars for crude) *.08 (ECP efficiency reduction) = 4,220.38 (number of tank cars not need for service)

[181] 12,311 (tank cars for ethanol) *.05 (ECP efficiency reduction) = 615.55 (number of tank cars not need for service)

[182] 4,835 (fewer tank cars) * $3,000 (incremental cost difference) = $14,505,000

G. Braking Components

1. Status Quo

PHMSA expects all Class I and Class II railroads' HHFTs currently have two-way EOT devices or Distributed Power. PHMSA also expects all Class III railroads' HHFTs to either have EOT devices or operate over track with a maximum authorized speed of 30 mph.

2. End-of-Train Devices or Distributed Power, or 30 MPH in All Areas

This rule will require that every HHFT be equipped with a two-way EOT device or DP system, or would be required to travel at a speed no greater than 30 mph. With longer, heavier trains it is necessary to factor in train control issues. For all HHFT that are transporting less than 70 loaded tank cars of Class 3 flammable liquids, PHMSA and FRA believe that there would be no costs or benefits associated with this portion of the rule.

In most instances, existing FRA regulations require all Class I and Class II railroads transporting HHFTs to use two-way EOT devices or DP systems. See 49 CFR 232.407.

PHMSA and FRA therefore expect all Class III railroads that operate HHFTs on tracks with a maximum authorized speed in excess of 30 mph to operate using a two-way EOT device or DP. Class III railroads are likely to be equipped with two-way EOT devices when trains do not qualify for at least one of the exceptions to 49 CFR §232.407. Railroads operating over track with a maximum authorized speed of 30 mph or less would not be affected. PHMSA and FRA believe that codifying explicitly that all HHFT operating over 30-mph must use two-way EOT devices or DP systems will increase clarity for railroads. Therefore, PHMSA and FRA estimate no costs or benefits associated with braking for Class III railroads.

3. ECP Brakes on HHFUT

The final rule establishes 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 car load of a Packing Group I flammable liquid while traveling in excess of 30 mph. All other HHFUTs must be equipped with and operate in ECP brake mode on May 1, 2023. This schedule is based on feedback received during the comment period and estimates based on the new/retrofitted tank cars and new locomotive construction. PHMSA and FRA believe that this schedule supports installation of ECP brakes predominantly on new equipment. However, we 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, PHMSA and FRA are assuming that the construction of equipment with ECP brakes would begin in 2015. However, PHMSA and FRA believe that starting in 2017 enough tank cars would be available to begin making up a unit train meeting the

DOT-117 tank car specifications and operating with ECP brakes. 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 633 trains, as described in our ECP brake system forecast section.

Tank Car Costs for ECP Brakes

As previously discussed, PHMSA and FRA are using a weighted average estimate of $7,633 (the weighted average of $7,300 and $7,800 based on the assumption that around one third of the ECP-equipped fleet would be new construction and two thirds of the ECP-equipped fleet would be retrofits.[183] PHMSA and FRA estimated that 60,231 tank cars would be required to have ECP brakes. In accordance with the phase-in schedule, all HHFUT's would be equipped with ECP brakes by the May 1, 2023 deadline. The total cost to equip these tank cars with ECP would be $459.8 million. Discounted at 3 and 7 percent over a 20-year period costs are $409.8 and $354.7 million respectively.

Buffer cars are required for the transportation of these commodities by train. 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. In total, 1,266[184] buffer cars would be needed. The total cost of those additional buffer cars would be $1.3 million. Twenty-year discounted costs at 3 and 7 percent are $1.1 and $1.0 million, respectively.

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. From comments received from the NPMR, 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. Over a twenty year period, the total cost of batteries and cable replacement is $64.7 million. Costs discounted at 3 and 7 percent over a 20 year period are $43.9 and $27.2 million, respectively.

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[183] [(1/3) (Fleet to be new construction) * $7,300 (cost of new construction)] + [(2/3) (Fleet to be retrofit) * $7,800 (cost of retrofit)] = $7,633

[184] 633 (estimated number of HHFUT at peak year) *2 (number of buffer cars required for each train) = 1,266 (buffer cars needed)

As earlier discussed, due to the efficiencies of ECP brakes, fewer tank cars will be needed to provide the same service. PHMSA and FRA estimate that 4,835 less tank cars would need to be purchased over the 20 year period. The incremental cost difference between a CPC 1232 and a DOT-117 is $3,000. The total costs savings of ECP brakes would be $14.5[185] million. PHMSA believes that these would be the last tank cars to be manufactured. Therefore, over a 20-year period the cost discounted at 3 and 7 percent, are $12.1 million and $9.7 million respectively.

Summary of Tank Car Costs for ECP Brakes

For the 20-year period of analysis, the estimated total cost related to ECP brakes on tank cars is $511.2 million. Total discounted costs are $442.7 million (3 percent) and $373.2 million (7 percent).

Locomotive Costs for ECP Brakes

As earlier discussed, 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 633 trains. Although the majority of these trains operate with three locomotives, PHMSA and FRA are estimating the cost to retrofit 2,532 locomotives, which would accommodate for out-of-service locomotives or any additional locomotives needed to operate the HHFUT's with ECP brakes. Class I Railroad's locomotive purchasing projections indicate that over 1,000 locomotives will be purchased in 2015. PHMSA and FRA believe that the railroads will continue this rate over next six to eight years, and the railroads would able allocate a portion of new locomotive purchases towards locomotives equipped with ECP brakes. The ECP brake add-on is estimated to cost $40,000 per locomotive. Over a 20-year period, the total cost to equip the locomotives with ECP brakes is $101.3 million. Discounted at 3 and 7 percent the costs are $89.5 and $76.5 million, respectively.

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. PHMSA and FRA believe that other railroads would follow this business practice, and purchase one set for each locomotive in 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. PHMSA and FRA estimate it would cost $2.5 million to purchase these additional cables. Over a 20-year period, that total would be discounted to $2.2 million and $1.9 million using a 3 and a 7 percent discount rate.

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[185] 4,835 (fewer tank cars) * $3,000 (incremental cost difference) = $14,505,000

For the 20-year period of analysis, the estimated total cost of ECP brakes on locomotives is $103.8 million. Discounted at 3 and 7 percent the total cost is $91.7 million and $78.4 million, respectively.

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.[186] 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 $62.30,[187] in 2016. The total cost of this burden would be $498,418. Discounted at 3 and 7 percent the total would be $469,807 and $435,338 respectively.

Summary of Locomotive Costs for ECP Brakes

For the 20-year period of analysis, the estimated total cost ECP brakes on locomotives is $104.3 million. Discounted values at 3 and 7 percent are $92.3 million and $79.9 million respectively.

Training Costs for ECP Brakes

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 the routes of the HHFUT's to determine how many crews could be affected. Using the waybill sample, FRA determined that approximately 68 percent of the total ton-miles were on routes that had crude or ethanol unit trains. PHMSA and FRA adjusted the

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[186] The first year we estimate the fleets would be operating with ECP is 2017; therefore, the cost to initially manage these fleets would take place in the prior year (i.e. 2016).

[187] PHMSA used the 2012 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. These wages were adjusted in accordance with the "Guidance on Treatment of the Economic Value of a Statistical Life in U.S. Department of Transportation Analyses." http://www.dot.gov/regulations/economic-values-used-in-analysis.

estimate to include 68 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 four years following the publication of the 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.[188] PHMSA and FRA are using the burdened hourly wage rate of $61.89. The total cost for each trainer of locomotive engineers and conductors would be $54,459.[189] 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 $7,148 per employee.[190] For 200 supervisors, the total cost would be approximately $1.4 million[191] 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.[192] PHMSA and FRA assume the burdened hourly wage rate to be $61.89. The total cost for the training of carmen supervisors would be $54,459.[193] 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,

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

[189] [$61.89 (Wage rate)*80 (Hours of training)*7 (Number of classes)]+[61.89 (Wage rate)*80(Hours to prepare for training)*4(Number of trainers)]=$54,459

[190] [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) * $61.89 (Wage rate)] = $7,147.80

[191] 200 (Number of supervisors) * 7,147.80 (Cost of training) = $1,429,560

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

[193] [$61.89 (Wage rate)*80 (Hours of training)*7 (Number of classes)]+[61.89 (Wage rate)*80(Hours to prepare for training)*4(Number of trainers)]=$54,459

hotel, food, and wages would is $7,148 per employee.[194] For 98 supervisors the total cost would be $700,485,[195] which would take place in the first year of this analysis.

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 68 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 68 percent of the total crews. Based on these assumptions, around 18,000 engineers, 27,000 conductors, and 6,500 carmen would receive additional training.[196] An adjustment to the duration of training was also done upon recommendations of the FRA's ECP brake specialists. In the NPRM we estimated that it would take two weeks to train the locomotive engineers. We believe that a more accurate estimate is two days. We also estimated in the NPRM it would take two days to train the conductors. This estimate was reduced to one day.

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 18,000 locomotive engineers, there would be around 597 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 $599,307.[197] 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 $14.7 million.[198]

Conductors

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[194] [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) * $61.89 (Wage rate)] = $7,147.80

[195] 98 (Number of supervisors) * 7,147.80 (Cost of training) = $770,485

[196] 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.

[197] 597 (Number of classes) * 16 (Hours of training) * $61.89 (Wage rate) = $591,173. This cost increases to $599,307 as the classes are spread over a three year period, and wage rates increase each year.

[198] 17,914 (Number of engineers) *16 (Hours of training) * $50.56 (Wage Rate) = $14,491,709. This cost increases to $14,687,760 as the classes are spread over a three year period, and wage rates increase each year.

PHMSA and FRA estimate that there are 27,070 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 902 classes taught with over 27,000 conductors. Training classes are estimated to last one day. The costs associated with conductor supervisory trainers would be $452,798.[199] 27,070 conductors would need to be trained in order to ensure safe operations of the trains. The cost to train these conductors would be $11.1 million.[200]

Carmen

PHMSA and FRA estimate that there are 6,500 carmen who would also need to be trained.[201] 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 6,500 carmen to be trained, there would be approximately 217 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 $761,117.[202] 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 $18.7 million.[203]

Summary of Training Costs for ECP Brakes

For the 20-year period of analysis, the estimated total training costs for ECP brakes is $48.5 million. Discounted at 3 and 7 percent, the total cost values are $44.5 million and $39.9 million respectively. PHMSA and FRA assume that any additional future training required for ECP

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[199] 902 (Number of classes) * 8 (Hours of training) * $61.89 (Wage rate) = $446,598. This cost increases to $452,798 as the classes are spread over a three year period, and wage rates increase each year.

[200] 27,070 (Number of conductors) *8 (Hours of Training) * $50.56 (Wage Rate) = $10,949,273.60 This cost increases to $11,097,124 as the classes are spread over a five year period, and wage rates increase each year.

[201] 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.

[202] 217 (Number of classes) * 56 (Hours of training) * $61.89 (Wage rate) = $752,087. This cost increases to $761,117 as the classes are spread over a three year period, and wage rates increase each year.

[203] 6,500 (Number of conductors) *56 (Hours of Training) * $50.56 (Wage Rate) = $18,403,840. This cost increases to $18,653,396 as the classes are spread over a five year period, and wage rates increase each year.

would be tied into the current refresher training programs and would therefore have minimal additional costs.

Summary of Costs

For the 20-year period of analysis, the estimated total cost for ECP brakes is $664.0 million. Discounted values at 3 and 7 percent are $579.4 million and $492.0 million respectively.

Phase-in

In analyzing the NPRM, PHMSA and FRA assumed that all train related benefits will accrue at 100 percent once brakes have been installed on all HHFTs by year 2018 and thereafter. PHMSA and FRA also assumed that one-third of the HHFT fleet will be equipped with ECP brakes in 2016, two-thirds in 2017, and all of the fleet in 2018 and subsequent years.

In this final rule analysis, PHMSA and FRA assume that benefits will accrue the year after ECP brakes are installed on a tank car for an HHFUT, and that 20 percent of the cars used in crude oil unit trains will be equipped with ECP brakes each year starting in 2016, 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 20 percent of the full performance level in 2017, rising to the full performance level at the beginning of 2021. Ethanol unit trains will need to be equipped with ECP brakes by May 1, 2023. In this final rule analysis PHMSA and FRA assume that 15 percent of the cars used in ethanol unit trains will be equipped with ECP brakes each year from 2016 through 2020, and that 10 percent of the cars used in unit trains will be equipped with ECP brakes in each of the years 2021 and 2022, and the last 5 percent of cars used in ethanol unit trains will be equipped in the first four months of 2023. Thus, the benefits from operations involving ECP brakes on crude oil unit trains will start at 15 percent of the full performance level in 2017, rising to the full performance level at the beginning of 2024.

Table BR6: Phase-In

	Benefit Percentage (%)	
Year	**Crude Oil Unit Trains**	**Ethanol Unit Trains**
2015	0%	0%
2016	0%	0%
2017	20%	15%
2018	40%	30%
2019	60%	45%
2020	80%	60%
2021	100%	75%
2022	100%	85%
2023	100%	95%
2024	100%	100%

Safety Benefits of ECP Brakes (Other Than Accident Avoidance)

The potential violence and destruction of a HHFUT accident is substantial. ECP brakes would help to mitigate the magnitude of many of the horrific accidents we have seen over the last decade. When looking at the mitigation or avoidance of these incidents, it is important to understand how long it can take to apply the brakes. What ECP brakes do is replace the air pressure controlled valves, which are used on conventional triple valves, and substitute them with electronically controlled valves. This allows the response time for braking to occur essentially at the speed of light, instead of 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. Brake shoe wear can also be reduced by 20 to 25 percent.[204] As a result, ECP brakes would reduce the damages associated with HHFUT accidents. Safety benefits include both reductions in property damage caused as well as the number of fatalities and/or injuries.

The survivability of tank cars can 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 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 quantity 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. Our modeling and simulations indicate that 19.7 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 or DP in the rear (see table BR4). PHMSA and FRA used this effectiveness rate of 19.7 percent to estimate the benefits that would result from deployment of ECP braking on HHFUT.

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

Table BR7: 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 Rate at 30, 40, 50 mph	Cumulative Effectiveness Rate
Below 34 mph	33	798,433	22.8%	20.10%	4.6%
35-44 mph	8	1,488,350	49.2%	25.80%	12.7%
45 mph and above	5	980,180	28%	8.60%	2.4%
Total	46	3,499,656	100%		19.7%

To derive benefits, the estimated 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 19.7 percent. We have also broken out the percentage of crude oil traffic and ethanol traffic that would be transported on HHFUT.

As explained in more detail in section VII of this analysis, "*Estimation of Expected Benefits*" there are expected benefits for low consequence events (LCE), and for high consequence events (HCE). The 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 might occur in absence of the final rule and an estimation of expected damages from those higher-consequence events.

ECP brakes will gradually be implemented over approximately eight years, as the rule mandates a date of May 1, 2023.[205] One third of the tanks cars that will be equipped with ECP brakes will be the new construction tank cars. This will maximize the value of the return on investment. Table BR8 and BR9 show the benefits[206] by year for HHFUT transporting crude oil for LCE and HCE, while Tables BR10 and BR11 show the benefits by year for ethanol.

[205] There is a January 1, 2021, deadline for HHFUTs transporting one or more tank car load 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.

[206] Total Damages for LCE and HCE are described in detail in the Benefits Section of this document.

Table **BR8**: Total LCE ECP Benefits for Crude Oil Traffic by Year

Year	Total Damages	Percentage of Crude HHFUT of Total Carloads	Percent of Operating Equipped with ECP	ECP Effectiveness Ratio	ECP Benefits	Present Value Discounted at 7%	Present Value Discounted at 3%
2015	$ 179,915,412	54.3%	0%	19.7%	$ -	$ -	$ -
2016	$ 176,427,442	54.3%	0%	19.7%	$ -	$ -	$ -
2017	$ 182,777,809	54.9%	20%	19.7%	$ 3,955,803	$ 3,229,114	$ 3,620,120
2018	$ 196,334,749	56.8%	40%	19.7%	$ 8,785,860	$ 6,702,690	$ 7,806,123
2019	$ 208,471,811	58.3%	60%	19.7%	$ 14,359,423	$ 10,238,070	$ 12,386,565
2020	$ 221,509,522	59.6%	80%	19.7%	$ 20,800,121	$ 13,859,999	$ 17,419,774
2021	$ 222,699,151	59.6%	100%	19.7%	$ 26,143,997	$ 16,281,167	$ 21,257,462
2022	$ 223,063,891	59.2%	100%	19.7%	$ 26,006,132	$ 15,135,806	$ 20,529,481
2023	$ 208,678,220	59.2%	100%	19.7%	$ 24,335,284	$ 13,236,782	$ 18,650,969
2024	$ 223,774,639	59.2%	100%	19.7%	$ 26,117,072	$ 13,276,595	$ 19,433,554
2025	$ 223,247,669	59.2%	100%	19.7%	$ 26,030,711	$ 12,367,003	$ 18,805,139
2026	$ 219,084,383	58.7%	100%	19.7%	$ 25,340,467	$ 11,251,470	$ 17,773,294
2027	$ 201,212,338	58.3%	100%	19.7%	$ 23,109,493	$ 9,589,618	$ 15,736,440
2028	$ 212,100,606	57.9%	100%	19.7%	$ 24,175,297	$ 9,375,597	$ 15,982,719
2029	$ 208,330,088	57.4%	100%	19.7%	$ 23,555,277	$ 8,537,516	$ 15,119,236
2030	$ 204,293,980	56.9%	100%	19.7%	$ 22,883,191	$ 7,751,329	$ 14,260,048
2031	$ 200,686,778	56.4%	100%	19.7%	$ 22,285,382	$ 7,054,981	$ 13,483,023
2032	$ 196,924,311	55.9%	100%	19.7%	$ 21,668,654	$ 6,410,973	$ 12,728,051
2033	$ 193,606,475	55.4%	100%	19.7%	$ 21,116,256	$ 5,838,821	$ 12,042,306
2034	$ 190,456,652	54.8%	100%	19.7%	$ 20,579,575	$ 5,318,153	$ 11,394,412
				Total	**$ 381,247,995**	**$ 175,455,685**	**$ 268,428,715**

Table **BR9**: Total HCE ECP Benefits for Crude Oil Traffic by Year

Year	Total Damages	Percentage of Crude HHFUT of Total Carloads	Percent of Operating Equipped with ECP	ECP Effectiveness Ratio	ECP Benefits	Present Value Discounted at 7%	Present Value Discounted at 3%
2015	$ 140,250,000	54.3%	0%	19.7%	$ -	$ -	$ -
2016	$ 140,250,000	54.3%	0%	19.7%	$ -	$ -	$ -
2017	$ 140,250,000	54.9%	20%	19.7%	$ 3,035,387	$ 2,477,780	$ 2,777,809
2018	$ 140,250,000	56.8%	40%	19.7%	$ 6,276,102	$ 4,788,008	$ 5,576,235
2019	$ 140,250,000	58.3%	60%	19.7%	$ 9,660,343	$ 6,887,691	$ 8,333,096
2020	$ 140,250,000	59.6%	80%	19.7%	$ 13,169,714	$ 8,775,536	$ 11,029,428
2021	$ 140,250,000	59.6%	100%	19.7%	$ 16,464,793	$ 10,253,446	$ 13,387,384
2022	$ 140,250,000	59.2%	100%	19.7%	$ 16,351,190	$ 9,516,541	$ 12,907,780
2023	$ 140,250,000	59.2%	100%	19.7%	$ 16,355,438	$ 8,896,274	$ 12,535,081
2024	$ 140,250,000	59.2%	100%	19.7%	$ 16,368,787	$ 8,321,061	$ 12,179,915
2025	$ 140,250,000	59.2%	100%	19.7%	$ 16,353,171	$ 7,769,274	$ 11,813,878
2026	$ 140,250,000	58.7%	100%	19.7%	$ 16,222,062	$ 7,202,790	$ 11,377,828
2027	$ 140,250,000	58.3%	100%	19.7%	$ 16,107,891	$ 6,684,202	$ 10,968,690
2028	$ 140,250,000	57.9%	100%	19.7%	$ 15,985,741	$ 6,199,546	$ 10,568,458
2029	$ 140,250,000	57.4%	100%	19.7%	$ 15,857,660	$ 5,747,546	$ 10,178,428
2030	$ 140,250,000	56.9%	100%	19.7%	$ 15,709,555	$ 5,321,370	$ 9,789,675
2031	$ 140,250,000	56.4%	100%	19.7%	$ 15,574,144	$ 4,930,375	$ 9,422,613
2032	$ 140,250,000	55.9%	100%	19.7%	$ 15,432,471	$ 4,565,911	$ 9,064,950
2033	$ 140,250,000	55.4%	100%	19.7%	$ 15,296,776	$ 4,229,686	$ 8,723,538
2034	$ 140,250,000	54.8%	100%	19.7%	$ 15,154,553	$ 3,916,224	$ 8,390,708
				Total	**$ 255,375,776**	**$ 116,483,261**	**$ 179,025,496**

Table BR10: Total LCE ECP Benefits for Ethanol Traffic by Year

Year	Total Damages	Percentage of Ethanol HHFUT of Total Carloads	Percent Operating Equipped with ECP	ECP Effectiveness Ratio	ECP Benefits	Present Value Discounted at 7%	Present Value Discounted at 3%
2015	$ 179,915,412	16.6%	0%	19.7%	$ -	$ -	$ -
2016	$ 176,427,442	16.6%	0%	19.7%	$ -	$ -	$ -
2017	$ 182,777,809	16.3%	15%	19.7%	$ 878,485	$ 717,105	$ 803,938
2018	$ 196,334,749	15.2%	30%	19.7%	$ 1,766,667	$ 1,347,782	$ 1,569,661
2019	$ 208,471,811	14.4%	45%	19.7%	$ 2,660,253	$ 1,896,723	$ 2,294,757
2020	$ 221,509,522	13.7%	60%	19.7%	$ 3,577,118	$ 2,383,585	$ 2,995,780
2021	$ 222,699,151	13.7%	75%	19.7%	$ 4,493,644	$ 2,798,416	$ 3,653,744
2022	$ 223,063,891	13.9%	85%	19.7%	$ 5,187,070	$ 3,018,922	$ 4,094,721
2023	$ 208,678,220	13.9%	95%	19.7%	$ 5,420,078	$ 2,948,163	$ 4,154,039
2024	$ 223,774,639	13.9%	100%	19.7%	$ 6,106,170	$ 3,104,067	$ 4,543,564
2025	$ 223,247,669	13.9%	100%	19.7%	$ 6,105,699	$ 2,900,774	$ 4,410,887
2026	$ 219,084,383	14.1%	100%	19.7%	$ 6,106,429	$ 2,711,327	$ 4,282,926
2027	$ 201,212,338	14.4%	100%	19.7%	$ 5,699,939	$ 2,365,272	$ 3,881,381
2028	$ 212,100,606	14.6%	100%	19.7%	$ 6,111,741	$ 2,370,239	$ 4,040,581
2029	$ 208,330,088	14.9%	100%	19.7%	$ 6,109,545	$ 2,214,380	$ 3,921,484
2030	$ 204,293,980	15.2%	100%	19.7%	$ 6,111,889	$ 2,070,308	$ 3,808,727
2031	$ 200,686,778	15.5%	100%	19.7%	$ 6,112,387	$ 1,935,025	$ 3,698,095
2032	$ 196,924,311	15.7%	100%	19.7%	$ 6,109,094	$ 1,807,460	$ 3,588,449
2033	$ 193,606,475	16.0%	100%	19.7%	$ 6,110,975	$ 1,689,736	$ 3,485,004
2034	$ 190,456,652	16.3%	100%	19.7%	$ 6,119,619	$ 1,581,426	$ 3,388,285
				Total	**$ 90,786,803**	**$ 39,860,711**	**$ 62,616,023**

Table BR11: Total HCE ECP Benefits for Ethanol Traffic by Year

Year	Total Damages	Percentage of Ethanol HHFUT of Total Carloads	Percent Operating Equipped with ECP	ECP Effectiveness Ratio	ECP Benefits	Present Value Discounted at 7%	Present Value Discounted at 3%
2015	$ 140,250,000	16.6%	0%	19.7%	$ -	$ -	$ -
2016	$ 140,250,000	16.6%	0%	19.7%	$ -	$ -	$ -
2017	$ 140,250,000	16.3%	15%	19.7%	$ 674,084	$ 550,253	$ 616,882
2018	$ 140,250,000	15.2%	30%	19.7%	$ 1,262,003	$ 962,776	$ 1,121,273
2019	$ 140,250,000	14.4%	45%	19.7%	$ 1,789,693	$ 1,276,026	$ 1,543,805
2020	$ 140,250,000	13.7%	60%	19.7%	$ 2,264,872	$ 1,509,180	$ 1,896,795
2021	$ 140,250,000	13.7%	75%	19.7%	$ 2,829,978	$ 1,762,368	$ 2,301,031
2022	$ 140,250,000	13.9%	85%	19.7%	$ 3,261,337	$ 1,898,128	$ 2,574,530
2023	$ 140,250,000	13.9%	95%	19.7%	$ 3,642,766	$ 1,981,423	$ 2,791,877
2024	$ 140,250,000	13.9%	100%	19.7%	$ 3,827,022	$ 1,945,464	$ 2,847,663
2025	$ 140,250,000	13.9%	100%	19.7%	$ 3,835,759	$ 1,822,342	$ 2,771,034
2026	$ 140,250,000	14.1%	100%	19.7%	$ 3,909,118	$ 1,735,695	$ 2,741,776
2027	$ 140,250,000	14.4%	100%	19.7%	$ 3,972,999	$ 1,648,653	$ 2,705,419
2028	$ 140,250,000	14.6%	100%	19.7%	$ 4,041,345	$ 1,567,303	$ 2,671,805
2029	$ 140,250,000	14.9%	100%	19.7%	$ 4,113,009	$ 1,490,744	$ 2,639,984
2030	$ 140,250,000	15.2%	100%	19.7%	$ 4,195,877	$ 1,421,289	$ 2,614,732
2031	$ 140,250,000	15.5%	100%	19.7%	$ 4,271,643	$ 1,352,293	$ 2,584,414
2032	$ 140,250,000	15.7%	100%	19.7%	$ 4,350,912	$ 1,287,278	$ 2,555,703
2033	$ 140,250,000	16.0%	100%	19.7%	$ 4,426,837	$ 1,224,057	$ 2,524,563
2034	$ 140,250,000	16.3%	100%	19.7%	$ 4,506,414	$ 1,164,543	$ 2,495,092
				Total	**$ 61,175,668**	**$ 26,599,815**	**$ 41,998,379**

The safety benefits (excluding accident prevention benefits) of ECP will range from $472.0 million to $788.6 million; discounted at 7 percent, the range is $215.3 million to $358.4 million and discounted at 3 percent, the range is $331.0 million to 552.1 million.

Accident Prevention Benefits Related to ECP Brakes

FRA evaluated derailments that occurred over the last twenty years which may have been avoidable if a train was operating with ECP brakes. FRA specifically looked for derailments (accident types) in which train handling was the cause of the incident. FRA also looked for the term "emergency" to be in the narrative of the accident/incident reports in order to find trains that went into emergency mode while operating.

FRA identified 478 accident/incident records in which a train incident may have occurred due to train handling. The focus was on cause codes (such as human factor or mechanical) where ECP brakes would have avoided or reduced the consequences of a derailment. After reviewing the records, FRA removed duplicate events, non-train handling events and events that occurred off of main track, FRA identified 252 incidents as candidates for ECP brake accident avoidance benefits.

FRA also identified 86 accident/incident records in which a train incident may have occurred due to string lining.[207] As above, FRA removed duplicate events and events that occurred off of main track. FRA identified 44 incidents as candidates for measuring ECP brake accident avoidance benefits.

FRA technical experts reviewed the records using professional judgment to determine how likely a train accident could have been avoided. These incidents were categorized as "LIKELY," "UNLIKELY," and "NOT SURE." FRA assigned effectiveness rates of 90 percent, 0 percent, and 50 percent respectively to each of these incidents.

FRA reviewed the damages to equipment associated with these incidents. Since the commodities carried were generally not hazardous materials, it is reasonable to assume that this represents the lower bound of the consequences that could be prevented with ECP brakes. The total unadjusted values from these reports showed that damages over the 20-year period amounted to $44.8 million. While PHMSA and FRA elsewhere in this analysis estimate the cost of a derailment based on the cost per gallon of crude or ethanol spilled, it is more appropriate here to use the accident/incident report estimate because these accidents primarily occurred when a train was pulling a light load (often, a train that has a large number of empty or residue cars). Therefore, damages were predominantly to equipment (excluding injuries and fatalities), and this category of damage is accurately captured in the accident/incident reports.

There was one fatality and five injuries in four of these accidents. FRA reviewed the F 6180.54 form (accident/incident reports) and read the narratives of each of these events. FRA also looked at the F 6180.55A reports which indicated the type and severity of these injures. FRA then made

[207] String lining occurs when the brakes are applied and the train is on a curve. The pulling motion from the back and the front of the train can cause the cars to derail inside the curve.

its best judgment in putting them into one of the five categories of the AIS (Abbreviated Injury Scale). FRA has no rail-type injury standard/average, as it tries to be as specific as possible.

FRA applied DOT's 2014 "Guidance on Treatment of the Economic Value of a Statistical Life in United States Department of Transportation Analyses." This policy updated the value of a statistical life (VSL) to $9.2 million in 2014 and revised guidance used to compute benefits based on AIS injury and fatality avoidance in each year of the analysis based on forecasts from the Congressional Budget Office (CBO) of a 1.18 percent annual growth rate in median real wages over the next 30 years (2014–2044). The total damage for injuries and fatalities over the twenty-year period was $12.6 million.

The impact on unit trains covered by the requirement was estimated by determining the number of locomotives that would be implemented with ECP brakes. There are approximately 25,500 locomotives in the current fleet. FRA estimated that at the peak year, 2024, of the next 20-year period, a total of 633 unit trains for both crude oil and ethanol would be on the network at any given time. With each unit train requiring three or more locomotives and extra locomotives required to cover for when a locomotive is out-of-service, FRA estimated that 1,899 locomotives equipped with ECP brakes would be required. This would account for 7.4 percent of the total locomotive fleet.

Incidents were categorized into three likelihood categories. FRA assigned the appropriate effectiveness rate to each incident. For the purposes of this analysis, FRA looked at the 7.4 percent effectiveness. FRA took 7.4 percent as this will focus on the locomotive fleet that would be identified for crude oil or ethanol unit train traffic. FRA determined that the annual property damages would be $78,812 and the injury prevention would also be $40,635. Full benefits of the avoidable incidents for ECP brake trains would be staggered over a six year period. Over a twenty year period, FRA believes that the total benefits of ECP accident avoidance would be $1.9 million, discounted at 7 percent and 3 percent the totals would be $0.8 million and $1.3 million, respectively. Given that property damage estimates for the 20-year accident pool were not updated and the likelihood for omission of relevant accidents without a narrative including the terms searched for, estimated accident avoidance benefits are understated.

Business Benefits of ECP Braking

ECP braking systems also have additional potential operational benefits. In 2008, FRA issued a final rule permitting the use of ECP brake systems. In an accompanying analysis,[208] FRA found that ECP brakes offered major benefits in train handling, car maintenance, fuel savings, and

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

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 and reduce emissions, 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.

Of the business benefits identified in the 2008 analysis, PHMSA and FRA are including in this analysis a subset of those benefits, adjusted as shown in tables below. The benefits are adjusted for differences in application and scale, differences in cost levels, and differences in fuel efficiency.

Flow Assumptions

In the NPRM, PHMSA and FRA assumed there would be 900 locomotives (three each in 300 sets), 100 trailing cars behind each set of locomotives, and that each train will travel an average of 220 miles per day. This resulted in an estimate of 23,760,000 unit train miles per year (assuming each unit train, and thus every unit train car, travels 360 days/year), which using 100 cars per train, implied 2,376,000,000 unit train car miles per year.

In this final rule analysis, PHMSA and FRA forecast that much greater numbers of carloads of crude oil will be shipped, with 84 percent hauled by unit trains, and an average length of haul by crude oil unit trains of 1,000 miles. This is a reduced estimate of length of haul from the analysis of the NPRM, and reflects a reexamination of the original data that showed some shipments included in the estimate used in analyzing the NPRM included mileage in Canada. For example, in the table below PHMSA and FRA are forecasting that there will be 761,028 crude oil car loads in 2017. PHMSA and FRA multiply 761,028 car loads times 1,000 miles, times 2 for the train making a round trip, times 84 percent to arrive at an estimate of 1,278,527,006 crude oil carload miles in unit trains in 2017. 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 final rule analysis, PHMSA and FRA assume that 47 percent of ethanol car loads 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. For example, in the table below PHMSA and FRA are forecasting that there will be 402,736 ethanol car loads in 2017. PHMSA and FRA multiply 402,736 car loads times 1,300 miles, times 2 for the train making a round trip, times 47 percent to arrive at an estimate of 492,143,392 ethanol carload miles in unit trains in 2017. PHMSA and FRA then add the 1,278,527,006 crude oil carload miles plus the 492,143,392 ethanol carload miles, to arrive an estimated 1,770,670,398 total affected carload miles in 2017.

Table BR12- HHFUT Car Miles

Year	Crude Car Loads	Crude Unit Car Miles	Ethanol Car Loads	Ethanol Unit Car Miles	Unit Car Miles
2014	569,387	956,570,244	387,665	473,726,630	1,430,296,874
2015	723,699	1,215,813,967	394,977	482,661,894	1,698,475,861
2016	726,742	1,220,926,207	396,882	484,989,804	1,705,916,011
2017	761,028	1,278,527,006	402,736	492,143,392	1,770,670,398
2018	844,901	1,419,433,277	404,852	494,729,144	1,914,162,421
2019	920,347	1,546,182,288	406,310	496,510,820	2,042,693,108
2020	999,596	1,679,320,776	409,649	500,591,078	2,179,911,854
2021	1,004,852	1,688,151,377	411,575	502,944,650	2,191,096,027
2022	999,277	1,678,785,730	419,078	512,113,316	2,190,899,046
2023	999,486	1,679,136,110	418,797	511,769,934	2,190,906,044
2024	1,002,977	1,685,000,570	419,099	512,138,978	2,197,139,548
2025	999,375	1,678,949,244	418,947	511,953,234	2,190,902,478
2026	972,594	1,633,957,147	418,876	511,866,472	2,145,823,619
2027	950,327	1,596,549,007	418,923	511,923,906	2,108,472,913
2028	927,328	1,557,910,570	418,994	512,010,668	2,069,921,238

2029	903,274	1,517,500,589	418,718	511,673,396	2,029,173,985
2030	877,236	1,473,756,900	418,752	511,714,944	1,985,471,844
2031	854,058	1,434,816,902	418,658	511,600,076	1,946,416,978
2032	830,166	1,394,678,040	418,303	511,166,266	1,905,844,306
2033	808,749	1,358,698,639	418,301	511,163,822	1,869,862,461
2034	787,945	1,323,747,180	418,760	511,724,720	1,835,471,900

Set Out Relief

The set out 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. Under the 2008 rule, trains equipped with ECP brakes were given relief from set-out requirements. The benefit of set-out relief was described the analysis:[209]

"Additional regulatory flexibility is provided by the rule. The removal of equipment with defective or inoperative brakes en route, known as set-outs, is eliminated. The defective equipment is permitted to remain in the train consist to destination, not to exceed 3,500 miles. ECP brake systems monitor in real time the health of the train's brake system, thus eliminating the safety concern that exists in conventionally-braked trains. Locomotive engineers operating trains equipped with ECP brakes have the ability to monitor the condition and the location of defective or inoperable brakes. ECP brake-equipped trains are not required to stop and set out a defective car. FRA requested and received comments and information on the cost per set-out. The AAR provided comments on the cost per set-out ($400) and the quantity of set-outs (10 percent). While FRA agrees that the original set-out percentage was high, the 10 percent long-haul train figure offered by AAR is too low. This figure does not address the extended mileage that the rule permits ECP brake trains to travel (3,500 miles versus 1,000 miles). FRA estimates, on average, 20 percent of trains must stop en route for one set-out due to the increased length of haul of ECP brake trains. FRA accepts the $400 figure provided by the AAR for the cost of a set-out. The number of ECP brake-equipped trains annually, as estimated above, is 178,071 + 14,000 unit trains = 192,071 trains per year. Approximately, half of these trains will likely avoid one set-out valued at $400 each."

For purposes of this analysis, there is no reason to increase the value of avoided set-outs from 10 percent to 20 percent, because only about half of set-outs are related to brake issues, so the value

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

from the original analysis is halved. For example, a car may need to be set out because of a defective hand hold, and the likelihood of such a set-out is not affected by the presence of ECP brakes. In this analysis FRA assumes one brake caused set-out avoided on 10 percent of 1,000 miles trips or one brake induced set-out avoided for every 10,000 miles of unit train travel. To update the numbers from 2008 to 2014, 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 Q2 2014 Class I railroads reported their labor cost index to be 388.1, and they had reported the labor cost index in Q2 2008 to have been 313.6. The ratio is 1.2376, which when multiplied by the 2008 estimate of $400, yields a 2014 estimate of $495.

In the NPRM, PHMSA and FRA estimated that when all ECP-equipped locomotives have joined the fleet, each set of locomotives will operate 220 miles per day, 360 days per year, for a total of 79,200 miles per year. PHMSA and FRA estimate that 900 locomotives will be equipped, and that unit trains will require three locomotives each, thus there will be 300 sets, operating a total of 23,760,000 miles per year. If one set-out is avoided every 10,000 miles, these sets will avoid 2,376 set-outs a year, for an annual savings of $1,176,181 at full installation. PHMSA and FRA also increased the estimated real cost each year after 2014 to account for increased real wages, which are estimated to grow at 1.18 percent per year from the base year of 2015.[210] There is no reason to believe that the labor hours required for setting out a car will decrease because of improved productivity. As discussed above, PHMSA and FRA estimates one-third of full benefit in 2016, two-thirds of full benefit in 2017 and full benefit from 2018 onward. In the NPRM 10,000 train-miles with 100 cars per train implied 1,000,000 car-miles per setout avoided. In this analysis of the final rule, where the average length of ethanol unit trains is estimated at 80 cars instead of 100 cars, the value had to be converted to car-miles, but remained at an estimated 1,000,000 car-miles per set-out avoided.

Table BR13: Set Out Relief Values Estimated for the NPRM Analysis

			Discounted Value	
			Discount Factor	
Year	**Wage Inflator**	**Benefit**	**7% Discount**	**3% Discount**
2015	101.18%	0	$0	$0
2016	102.37%	$401,367	$350,570	$378,327
2017	103.58%	$812,207	$663,003	$743,285
2018	104.80%	$1,232,687	$940,411	$1,095,226

[210] These wages were adjusted in accordance with the "Guidance on Treatment of the Economic Value of a Statistical Life in U.S. Department of Transportation Analyses." http://www.dot.gov/regulations/economic-values-used-in-analysis.

Table BR13: Set Out Relief Values Estimated for the NPRM Analysis				
2019	106.04%	$1,247,232	$889,259	$1,075,874
2020	107.29%	$1,261,950	$840,890	$1,056,863
2021	108.56%	$1,276,841	$795,152	$1,038,188
2022	109.84%	$1,291,907	$751,902	$1,019,844
2023	111.14%	$1,307,152	$711,004	$1,001,823
2024	112.45%	$1,322,576	$672,331	$984,121
2025	113.77%	$1,338,183	$635,761	$966,732
2026	115.12%	$1,353,973	$601,180	$949,650
2027	116.47%	$1,369,950	$568,481	$932,869
2028	117.85%	$1,386,116	$537,560	$916,386
2029	119.24%	$1,402,472	$508,320	$900,193
2030	120.65%	$1,419,021	$480,672	$884,287
2031	122.07%	$1,435,765	$454,527	$868,662
2032	123.51%	$1,452,707	$429,804	$853,313
2033	124.97%	$1,469,849	$406,426	$838,235
2034	126.44%	$1,487,194	$384,319	$823,423
Total			$11,621,571	$17,327,300

Previous analyses had used one set out avoided per 10,000 train-miles, assuming 100 cars per train. This works out to one set out avoided per 1,000,000 car-miles, This final rule analysis uses the car miles estimates shown in Table BR 11, above, the unit savings estimate of $495 per set out avoided in 2014, and one set out avoided per 1,000,000 car-miles, inflated by growth in real wages. The results, used to calculate the business benefits in this analysis, are presented in Table BR14.

Table BR14– Set-Out Relief Final Rule Estimates				
			Discounted Value	
			Discount Factor	
Year	**Wage Inflator**	**Benefit**	**7%**	**3%**
2015	$0	$0	-	-
2016	$0	$0	-	-
2017	$137,920	$154,621	$148,220	$166,167
2018	$283,451	$330,114	$303,031	$352,918
2019	$430,812	$521,219	$458,684	$554,941
2020	$581,731	$731,142	$617,162	$775,673
2021	$691,158	$902,408	$733,235	$957,346
2022	$668,982	$907,375	$693,290	$940,345
2023	$647,925	$912,943	$655,582	$923,732
2024	$621,687	$909,992	$621,687	$909,992
2025	$586,203	$891,374	$586,203	$891,374
2026	$542,913	$857,608	$542,913	$857,608
2027	$504,446	$827,790	$504,446	$827,790
2028	$468,286	$798,295	$468,286	$798,295
2029	$434,098	$768,752	$434,098	$768,752
2030	$401,646	$738,904	$401,646	$738,904
2031	$372,329	$711,570	$372,329	$711,570
2032	$344,738	$684,426	$344,738	$684,426
2033	$319,832	$659,639	$319,832	$659,639
2034	$296,873	$636,066	$296,873	$636,066
Total			$8,335,030	$12,944,239

The total discounted value of this benefit is $8,335,030 at 7 percent and $12,944,239 at 3 percent.

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 requires ECP brakes, equipped trains could, but as explained below, will not, realize

the potential benefits permitted by the 2008 rule, which allowed, but did not require ECP brakes. The item shown as "Single Brake Test" in the table below was described in the 2008 analysis: [211]

"The [2008] rule also modifies periodic maintenance requirements, including certain SCABTs, in order to tailor the requirements more specifically for ECP brake systems. Due to the ECP brake system's ability to continuously monitor the condition of a car's air brakes, FRA believes that less frequent SCABTs are justified on ECP brake equipment. Railroads may retrofit ECP brake systems on existing cars equipped with conventional pneumatic brake systems. Accordingly, the performance of a SCABT is required prior to returning the car to revenue service after the application of the ECP brake system. This is already required when installing a new brake system, thus the cost of this test is not avoided with ECP brake systems. However, the self-monitoring capabilities of ECP brake systems may extend the time period to perform SCABTs. This would reduce the number of single car tests that must be performed on cars equipped with ECP brakes. Freight cars with conventional brakes receive a SCABT every time they are on the repair track if they haven't received one within the past 12 months. It has been estimated by the AAR that more than 99 percent of cars are on a repair track every 2 years. FRA estimates the benefits of SCABT avoidance once at the beginning of a five year period coinciding with the ECP brake installation rate, and once every 5 years thereafter. This estimate is conservative, and it is possible that these cars may avoid up to 2.5 SCABTs every 5-year period. Because this estimate is so conservative, this benefit is taken at the beginning of the 5-year period. The cost of the SCABT is either $89.22 for a manual test or $100.85 for an instrument test. FRA used the average value of these two tests, $95.04, to calculate this benefit."

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, because the railroads will need the flexibility to haul the cars in trains not equipped with ECP, whether moving them for repairs, or hauling commodities in a train not equipped with ECP brakes, perhaps because a short haul is involved, or the car has been shifted into service carrying a commodity not affected by the proposed rule. Thus, there is no benefit estimated for this provision.

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

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

benefits permitted by the 2008 rule, which allowed, but did not require ECP brakes. The 2008 analysis[212] 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.[213] 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

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

[213] 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

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 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."

As described above, in analyzing the NPRM, PHMSA and FRA assumed that ECP-equipped trains will travel 23,760,000 miles per year. PHMSA and FRA assumed 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. PHMSA and FRA, in analyzing the NPRM, further assumed that each train will avoid 2 Class IA brake tests every three thousand miles, or 15,840 brake tests per year.

In this analysis of the final rule PHMSA and FRA have changed the assumption to reflect that extended haul trains are allowed by regulation to go as far as 1500 miles before requiring a Class I brake test, and that some unit trains are being broken up at the unloading facility. 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 value per brake test, $500 is updated to 2014 values using the same multiplier for labor costs, 1.2376, yielding a savings per test of $618.78. Because this estimate is based on data from 1998 that is updated only to account for inflation (as measured by wage growth since this primarily a labor function, and there is no reason to assume that the hours of labor required to perform a brake test will be reduced by increased productivity), PHMSA and FRA sought, but did not receive comment on this. This number largely represents wage costs, and is increased by a real factor of 1.18 percent per year past 2014. The total cost of brake tests avoided over 20 years will be $51,480,542, discounted at 7 percent per year, or $80,261,134, discounted at 3 per cent per year.

Table BR 15: Class I Brake Test Relief Values from the NPRM Analysis				
Values Estimated for the NPRM Analysis			Discounted Value	
			Discount Factor	
Year	Wage Inflator	Benefit	7% Discount	3% Discount
2015	101.18%	-	$0	$0
2016	102.37%	$3,344,728	$2,921,415	$3,152,727
2017	103.58%	$6,768,393	$5,525,024	$6,194,038
2018	104.80%	$10,272,389	$7,836,757	$9,126,885
2019	106.04%	$10,393,604	$7,410,496	$8,965,614
2020	107.29%	$10,516,248	$7,007,420	$8,807,192
2021	108.56%	$10,640,340	$6,626,269	$8,651,570
2022	109.84%	$10,765,896	$6,265,849	$8,498,698
2023	111.14%	$10,892,933	$5,925,034	$8,348,526
2024	112.45%	$11,021,470	$5,602,756	$8,201,009
2025	113.77%	$11,151,523	$5,298,008	$8,056,098
2026	115.12%	$11,283,111	$5,009,836	$7,913,747
2027	116.47%	$11,416,252	$4,737,339	$7,773,912
2028	117.85%	$11,550,964	$4,479,663	$7,636,548
2029	119.24%	$11,687,265	$4,236,003	$7,501,611
2030	120.65%	$11,825,175	$4,005,596	$7,369,058
2031	122.07%	$11,964,712	$3,787,721	$7,238,847
2032	123.51%	$12,105,896	$3,581,698	$7,110,938
2033	124.97%	$12,248,745	$3,386,880	$6,985,288
2034	126.44%	$12,393,280	$3,202,659	$6,861,859
Total			$96,846,424	$144,394,164

Table BR16- Class I Brake Test Relief Final Rule Estimates				
Adjusted for Both Phase-In and Flows				
Year	**Wage Inflator**	**Benefit**	**Discounted Value**	
			Discount Factor	
			7%	**3%**
2015	101.18%	$0	$0	$0
2016	102.37%	$0	$0	$0
2017	103.58%	$1,006,720	$821,784	$921,292
2018	104.80%	$2,118,600	$1,616,270	$1,882,349
2019	106.04%	$3,496,442	$2,492,915	$3,016,061
2020	107.29%	$5,056,942	$3,369,654	$4,235,110
2021	108.56%	$6,852,822	$4,267,593	$5,571,971
2022	109.84%	$7,133,806	$4,151,940	$5,631,492
2023	111.14%	$7,380,862	$4,014,700	$5,656,816
2024	112.45%	$7,553,682	$3,839,909	$5,620,649
2025	113.77%	$7,664,708	$3,641,447	$5,537,148
2026	115.12%	$7,732,963	$3,433,528	$5,423,745
2027	116.47%	$7,661,777	$3,179,365	$5,217,297
2028	117.85%	$7,615,992	$2,953,613	$5,035,068
2029	119.24%	$7,563,625	$2,741,406	$4,854,803
2030	120.65%	$7,500,827	$2,540,790	$4,674,268
2031	122.07%	$7,424,279	$2,350,337	$4,491,811
2032	123.51%	$7,362,662	$2,178,346	$4,324,788
2033	124.97%	$7,292,736	$2,016,502	$4,158,945
2034	126.44%	$7,238,029	$1,870,444	$4,007,521
Total			$51,480,542	$80,261,134

Impact of Dynamic Braking

In the NPRM, 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 meetings with the Office of Information and Regulatory Affairs of the Office of Management and Budget held under Executive Order 12866, AAR asserts that a significant portion the benefits claimed in the analysis of the NPRM for wheel savings and fuel savings are currently realized through 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 analyzed data from a small number of trips of ECP-equipped trains and found that 89 percent of the time that the train was braking, it was not using ECP brakes in whole or in part. AAR therefore estimated that 85 percent of the fuel and wheel

savings benefits are currently 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, but the reduction should be smaller than 85 percent. The ability to use ECP brakes on top of the dynamic brakes further improves 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.[214] Because not all terrain will be as advantageous as this test region, PHMSA is reducing estimated fuel efficiency benefits by 50 percent, corresponding to a fuel improvement rate of 2.5 percent. However, this estimate is conservative and likely understates the fuel efficiency benefits. 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 will 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. PHMSA and FRA view this as a conservative assumption.

Wheel Savings

The Wheel Savings 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. "Wheel Savings" were described in the 2008 analysis:

"Wheels are but one component of a freight car that could provide maintenance savings under ECP brake operation. Wheel damage is reduced due to more uniform braking and better train handling. One of the ways in which ECP brakes contribute to a reduction in premature wheel wear is by lowering the average brake friction temperature on the wheels through more consistent braking. Excessive buildup of heat in the wheels is a major contributor to wheel failure. The industry expenditure on wheel replacements warrants singling them out as a significant benefit of conversion to ECP brake systems. A recent study by the TTCI found that the rail freight industry spends 37 percent of its annual freight car repair cost of $1.5 billion on

[214] 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.

wheel replacements—representing $555 million. These data are for calendar year (CY) 2000, and the costs are undoubtedly higher now. Wheelsets need to be replaced because they are either worn out or damaged. Brake-related failures were found to reduce the life of wheelsets by more than 50 percent."

Per wheelset replacement costs are now at least $1,250 and could range as high as $1,500. Using the lower end of this range ($1,250), the resulting 25 percent increase in per unit wheel replacement costs translates into a conservative estimate of $700 million in annual wheel repair expenditures, when applied to the CY 2000 data. Assuming that ECP brakes would eliminate half of all brake-related wheel defects, this would translate into $175 million annually for the entire freight car fleet. Heavy-haul, high-mileage cars would account for a disproportionately high share of these savings. Using the same adjustment of 61 percent for ECP brake-related savings, the annual savings for the entire fleet of $175 million (× 0.61) = $106,750,000. The 20-year wheel savings discounted at 7 percent equals $714,495,572.

PHMSA and FRA assume that wheel replacement cost in freight cars is proportional to their mileage. In analyzing the NPRM, PHMSA and FRA used locomotive numbers as a surrogate for share of total miles. In this final analysis, the estimates are based on the ratio of carload miles in this final analysis to carload miles implied in the analysis of the NPRM. This analysis estimates that the industry will equip far more locomotives, but there is no longer an assumption that these locomotives will be used almost exclusively to haul HHFT unit trains. In the NPRM analysis PHMSA and FRA estimate there would be 900 locomotives out of an industry wide fleet of 24,250 mainline locomotives, or 3.71 percent. The number of locomotives estimated in this analysis reflects that the locomotives will not be used exclusively in service affected by the final rule.

This analysis continues to use estimates from the NPRM, adjusting those estimates to take into account relative car miles, thus the number of locomotives is no longer a direct input to the estimates of business benefits in this analysis. If the industry wide cost of wheelset replacement was $555 million in year 2000 (as noted above), and according to the AAR fact book, there were 34,950,000,000 car miles in 2000, the cost per car-mile was $0.01588. This number was adjusted for labor costs. The labor index submitted by Class I railroads to the STB for Q2 2000 was 242.6, while the 2014 value was 388.1. The ratio of the 2014 value to the Q2 2000 value, used here as a multiplier, is 1.598. Thus the cost per car mile, in 2014 dollars would be $0.02538. Since brake-related failures account for only half of wheelset life reduction, the addressable value of wheelset life reduction is $0.01269 per car mile. Saving half of that would save $0.006348 per car mile. Car miles were those shown in Table BR12, above.

There were no comments to the docket regarding the various multipliers, but as noted above, the total savings were reduced by 75 percent to account for use of dynamic braking. Although these values are largely labor costs, unlike other costs, PHMSA and FRA believe that shop labor costs subject to real wage growth are also subject to offsetting increases in productivity, so they are not multiplied by an annual real wage growth factor.

Table BR 17: Wheel Savings Values Estimated for the NPRM Analysis			
		Discounted Value	
		Discount Factor	
Year	**Benefit**	**7% Discount**	**3% Discount**
2015	0	$0	$0
2016	$2,718,987	$2,374,869	$2,562,906
2017	$5,437,974	$4,439,007	$4,976,517
2018	$8,156,962	$6,222,907	$7,247,355
2019	$8,156,962	$5,815,801	$7,036,267
2020	$8,156,962	$5,435,328	$6,831,327
2021	$8,156,962	$5,079,746	$6,632,356
2022	$8,156,962	$4,747,426	$6,439,181
2023	$8,156,962	$4,436,847	$6,251,632
2024	$8,156,962	$4,146,586	$6,069,546
2025	$8,156,962	$3,875,314	$5,892,763
2026	$8,156,962	$3,621,789	$5,721,129
2027	$8,156,962	$3,384,849	$5,554,494
2028	$8,156,962	$3,163,410	$5,392,713
2029	$8,156,962	$2,956,458	$5,235,643
2030	$8,156,962	$2,763,045	$5,083,149
2031	$8,156,962	$2,582,285	$4,935,096
2032	$8,156,962	$2,413,351	$4,791,355
2033	$8,156,962	$2,255,468	$4,651,801
2034	$8,156,962	$2,107,914	$4,516,312
Total		$71,822,399	$105,821,542

Table BR 18: Wheel Savings Final Rule Estimates			
		Discounted Value	
		Discount Factor	
Year	**Benefit**	**7% Discount**	**3% Discount**
2015	$0	$0	$0
2016	$0	$0	$0
2017	$502,793	$410,429	$460,127
2018	$1,045,542	$797,639	$928,951
2019	$1,704,282	$1,215,130	$1,470,129
2020	$2,434,935	$1,622,500	$2,039,220
2021	$3,259,738	$2,030,001	$2,650,466
2022	$3,356,336	$1,953,418	$2,649,523
2023	$3,435,085	$1,868,459	$2,632,707
2024	$3,475,718	$1,766,879	$2,586,261
2025	$3,485,607	$1,655,987	$2,518,077
2026	$3,475,712	$1,543,258	$2,437,795
2027	$3,404,198	$1,412,621	$2,318,093
2028	$3,344,944	$1,297,227	$2,211,402
2029	$3,283,784	$1,190,194	$2,107,736
2030	$3,219,141	$1,090,435	$2,006,063
2031	$3,149,811	$997,150	$1,905,688
2032	$3,087,853	$913,584	$1,813,788
2033	$3,023,488	$836,020	$1,724,253
2034	$2,966,405	$766,575	$1,642,427
Total		$23,367,506	$36,102,703

Fuel Savings

In the 2008 analysis, fuel savings were calculated as a proportion of fuel used. This remains a reasonable assumption today, because even though locomotives use fewer gallons per ton-mile, ECP braking still improves fuel efficiency by 5 percent when it is used instead of dynamic braking;[215] therefore, improved ECP braking still improves fuel efficiency by 5 percent of the

[215] 'Benefit-Cost Analysis and Implementation Plan for Electronically Controlled Pneumatic Braking Technology inthe Railroad Industry,' Booz Allen Hamilton, August 2006, p. III-2. The Booz Allen figures were confirmed by tests performed on Canadian Pacific cited by "Electronically-Controlled Pneumatic (ECP) Brake Experience at

new fuel consumption rate. A simple way to account for both factors at one time is to estimate the total expenditure on fuel, and then calculate the fuel savings assuming that ECP brakes will continue to save the same percentage of fuel. According to their reports to the STB, Class I railroads spent $3,202,554,000 on fuel in Q2 2014, or an annual rate of $12,810,216,000. In analyzing the NPRM, PHMSA and FRA estimated that 900 locomotives will be affected by the final rule, of out of a potential fleet of 24,250, and PHMSA and FRA assume that these locomotives use fuel in proportion to their share of the total locomotive fleet. Thus, the fuel expenditure total is multiplied by 0.03711 (= 900 /24,250). The estimated quarterly fuel use of the 900 locomotives is $475,430,697. (.03711 * $12,810,216,000) The savings from ECP brakes would be 5 percent of $475,430,697; or $23,771,535 per year. While benefits in the NPRM analysis were based on locomotives, that analysis assumed that locomotives assigned to unit train service hauling crude oil and ethanol would not be used for other purposes, so in this analysis it is appropriate to base benefits on relative car-miles. This savings might be greater if the added weight of the enhanced tank cars causes more fuel use, but PHMSA and FRA are not certain that fuel use will increase, because aerodynamic effects may offset increases in weight. Therefore, the measure of ECP induced fuel savings does not take into account the impacts of increased weight, which assumption, when used to estimate business benefits, is a conservative assumption. This savings is not adjusted for any changes in real wages, and, in the NPRM analysis, accrued at full value beginning in year 2018.

In this analysis, fuels savings estimates are based on car-miles. Class I railroads used $11,597,000,000 in fuel, and hauled 35,253,000,000 car-miles in 2013, according to the AAR fact book. Thus the cost of fuel per car-miles was $0.3290, and saving 5 percent would save $0.0164 per car mile. These savings are reduced by 50 percent to account for savings already generated by dynamic braking, as discussed above. The car-miles are those derived for Table BR12. The savings estimated are presented in Table BR20, below.

Canadian Pacific", Wachs, K., Aronian, A., Bell, S. *Proceedings from the 2011 International Heavy Haul Conference*, Calgary AB, 2011, p. 2-4. http://www.ihha.net/IHA/uploads/assets/fin00258.pdf

Table BR19: Fuel Savings, NPRM Estimates			
Values Estimated for the NPRM Analysis			
		Discount Factor	
Year	**Benefit**	**7% Discount**	**3% Discount**
2015	0	$0	$0
2016	$7,923,845	$6,920,993	$7,468,984
2017	$15,847,690	$12,936,436	$14,502,881
2018	$23,771,535	$18,135,190	$21,120,701
2019	$23,771,535	$16,948,776	$20,505,535
2020	$23,771,535	$15,839,977	$19,908,286
2021	$23,771,535	$14,803,717	$19,328,433
2022	$23,771,535	$13,835,250	$18,765,469
2023	$23,771,535	$12,930,140	$18,218,902
2024	$23,771,535	$12,084,243	$17,688,254
2025	$23,771,535	$11,293,685	$17,173,063
2026	$23,771,535	$10,554,846	$16,672,876
2027	$23,771,535	$9,864,342	$16,187,259
2028	$23,771,535	$9,219,011	$15,715,785
2029	$23,771,535	$8,615,898	$15,258,044
2030	$23,771,535	$8,052,241	$14,813,635
2031	$23,771,535	$7,525,459	$14,382,170
2032	$23,771,535	$7,033,139	$13,963,271
2033	$23,771,535	$6,573,027	$13,556,574
2034	$23,771,535	$6,143,016	$13,161,722
Total		$209,309,387	$308,391,844

Table BR20- Fuel Savings, Final Rule Estimates			
		Discounted Value	
		Discount Factor	
Year	Benefit	7% Discount	3% Discount
2015	$0	$0	$0
2016	$0	$0	$0
2017	$2,606,502	$2,127,682	$2,385,318
2018	$5,420,140	$4,134,998	$4,815,724
2019	$8,835,077	$6,299,288	$7,621,215
2020	$12,622,814	$8,411,114	$10,571,408
2021	$16,898,632	$10,523,619	$13,740,134
2022	$17,399,401	$10,126,610	$13,735,248
2023	$17,807,639	$9,686,176	$13,648,072
2024	$18,018,280	$9,159,580	$13,407,293
2025	$18,069,545	$8,584,711	$13,053,824
2026	$18,018,251	$8,000,319	$12,637,639
2027	$17,647,517	$7,323,092	$12,017,100
2028	$17,340,340	$6,724,883	$11,464,008
2029	$17,023,286	$6,170,022	$10,926,600
2030	$16,688,176	$5,652,863	$10,399,520
2031	$16,328,764	$5,169,269	$9,879,171
2032	$16,007,572	$4,736,063	$9,402,762
2033	$15,673,898	$4,333,963	$8,938,605
2034	$15,377,978	$3,973,962	$8,514,414
Total		$121,138,213	$187,158,053

Table BR21: Total ECP Business Benefits		
Benefit	Discounted Value	
	Discount Factor	
	7% Discount	3% Discount
Set Out Relief	$8,335,030	$12,944,239
Class IA brake test	$51,480,542	$80,261,134
Wheel Savings	$23,367,506	$36,102,703
Fuel Savings	$121,138,213	$187,158,053
Total	$204,321,291	$316,466,129

Reduction in Locomotives

As discussed earlier, due to the efficiencies of ECP brakes, fewer tank cars will be needed to meet demand. PHMSA and FRA estimate that 4,835 less tank cars would need to be purchased. As fewer tank cars are required, there would be a commensurate reduction in the number of locomotives needed. There would be 4,220 fewer crude cars. Assuming 100 cars per train, ECP brakes help to reduce the number of trains it takes to make the same number of movements over time – in this case 42.2 trains.[216] There would also be 615 fewer ethanol cars. Using an 80-car train, ECP brakes help to reduce the number of trains by 7.7.[217] Most trains require three locomotives per trainset. The 49.9 trainsets [218] would result in the rail industry needing 149.7 fewer locomotives [219] to operate.

The current cost of a new locomotive is approximately $2,000,000. If we used the full cost of a locomotive, we would see a savings of over $299.3 million.[220] However, the railroads may continue to purchase these locomotives in order to update their fleet, or move these locomotives into other services. PHMSA and FRA believe it would be conservative to use only 25 percent of the cost of a locomotive to attribute to the locomotive savings that would occur due to ECP brakes. In this analysis, PHMSA and FRA realized all of the costs for the locomotive savings in year six, given that that is the final year for allowed retrofits/new construction. Over a twenty year period, the total business benefit attributed to a reduction of locomotives would be $74.8 million; discounted at 7 percent, the value is $49.9 million and is $62.7 million discounted at 3 percent.

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 are both safety and business benefits.

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[216] 4,220 (tank cars) / 100 (cars per train) = 42.2 (number of train sets)

[217] 615 (tank cars) / 80 (cars per train) = 7.7 (number of train sets)

[218] 42.2 (crude oil trains reduced) + 7.7 (ethanol trains avoided) = 49.9 (total trains avoided)

[219] 49.9 (total trains reduced) * 3 (average number of locomotives on a train) = 149.7 (total locomotives reduced)

[220] 149.7 (locomotives) * $2,000,000 = $299,325,000

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, trains sets that operate in 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. 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 looking at the impact ECP brakes will have on the rail network.

Summary of Benefits

Over a twenty-year period, the total benefits of the ECP braking systems would range between $470.3million and $613.4 million, discounted at 7 percent. Total benefits would range between $711.5 million and $932.5 million, discounted at 3 percent.

1. Alternatives Considered

The NPRM included a proposal for broad implementation of ECP brakes on HHFTs and presented cost estimates of $500.2 with benefits ranging from $737.3 million to $1,758.6 million. Commenters responded that the installation costs that had taken into account efficiencies based on economies of scale resulting from broad application analyzed by FRA in 2006 were too low and provided other cost estimates. However, no basis was provided for most of the cost estimates provided. Commenters also responded that the benefits had been overstated in the NPRM, particularly because the analysis of tank car derailment and puncture was based on the assumption that all derailments would occur at the head end of the train, which would allow for the mitigation benefits of ECP to apply to all the tank cars in the consist. As discussed earlier in this RIA and the final rule, FRA has since updated its analysis to take into account points of derailment along the train consist based on actual past history of relevant accidents. Prompted by the input provided by commenters and reviewers, FRA conducted further analysis of the costs and benefits of ECP brakes and based on actual in-service experience identified additional business benefits that would result from such technology when applied high-utilization cars in dedicated trainsets. Thus, PHMSA and FRA reevaluated the alternative of the broader application approach proposed in the NPRM.

PHMSA and FRA also considered requiring that all tank cars travelling in trains in excess of 30 mph covered by the final rule be equipped with ECP brakes by no later than the outermost compliance date for full implementation of the tank car structural requirements. This would maximize safety benefits and provide maximum flexibility for tank car owners to move their cars between services and railroads to manage train consists. Under this alternative the demand for ECP brakes would be strongest, thereby increasing the likelihood that economies of scale in manufacture would result in lower unit prices. The safe transport of high hazard flammable materials requires a system safety approach that includes accident mitigation and avoidance through structural and operational requirements. ECP brake systems enhance safety in both of these areas. ECP brakes provide accident prevention safety benefits without imposing the negative impacts on velocity that commenters noted the more stringent speed restrictions proposed in the NPRM would. The following analysis estimates the costs and benefits of an alternative under which all HHFT trainsets, including those with 70 or fewer crude and/or ethanol cars, are equipped and may utilize ECP brakes.

ECP Installation Costs (Tank Cars)

For the HHFUT ECP requirement of the final rule, PHMSA and FRA use a weighted average unit cost estimate of $7,633 (one third new construction at $7,300 and two thirds retrofit at $7,800)[221] for ECP brakes. Applying the ECP brake requirement to the larger tank car population alters the relative composition of the impacted fleet because more ethanol cars are included and we assume that they will be retrofits versus new construction. Accordingly, under the alternative considered scenario, that average is raised to $7,700 (20% new construction and 80% retrofit).[222] PHMSA and FRA estimate that all 93,379 tank cars would be required to have ECP brakes – the entire US fleet of crude oil and ethanol cars. It is reasonable to assume that all HHFUT's (70+ tank car unit trains) would be still be equipped with ECP brakes by the January 1, 2021 for PG I and May 1, 2023 for PG II deadlines as both railroads and shippers seek to take advantage of the ECP brake business benefits. The remainder of the tank cars would be equipped over the next one and a half years. Cars used outside of HHFUTs are probably not used in such high-service dedicated trainsets. The total estimated cost to equip these tank cars with ECP brakes would be $719.0 million. Discounted at 3 and 7 percent over a 20-year period costs are $614.3 and $506.20 million respectively.

Buffer cars are required for the transportation of the impacted commodities by train. However, PHMSA and FRA do not expect that additional buffer cars would be equipped with ECP brakes

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[221] [(1/3) (Fleet to be new construction) * $7,300 (cost of new construction)] + [(2/3) (Fleet to be retrofit) * $7,800 (cost of retrofit)] = $7,675

[222] [.20 (Fleet to be new construction) * $7,300 (cost of new construction)] + [.80 (Fleet to be retrofit) * $7,800 (cost of retrofit)] = $7,700

for the additional service impacted since these additional cars would not operate exclusively in ECP brake mode like those in HHFUTs. Any additional buffer cars that are required for the added service would simply operate using runaround cables that would be kept onboard the ECP-equipped locomotives. In total, 1,266[223] buffer cars would be needed. The total cost of those additional buffer cars would be $1.3 million. Twenty-year discounted costs at 3 and 7 percent are $1.1 and $1.0 million, respectively. The per-unit and total costs are the same under both the actual requirement and the alternative considered since we assume that runaround cables will be used to meet the requirements for trains not covered by the HHFUT definition.

As previously discussed, the batteries and cables would need to be replaced on all cars ever five years regardless of use. The per-tank car cost for batteries is $87 and for cables is $300. Over a twenty-year period, the total cost of batteries and cable replacement is $91.3 million. Costs discounted at 3 and 7 percent over a 20 year period are $60.7 and $36.6 million, respectively.

PHMSA and FRA do not assume that the additional tank cars that are retrofitted under the alternative considered will benefit from the same in-service efficiencies of ECP brakes as the cars in exclusive HHFUTs. In general, most of these additional cars will continue to operate with conventional air brakes, using a two-way EOT or DP yielding nominal business benefits. Therefore, the total cost savings of ECP efficiencies, with a reduction of tank cars, will remain the same under both scenarios. The total costs savings of ECP brakes would be $14.5[224] million. Over a 20-year period the cost are $12.1 million discounted at 3 percent and $9.7 million discounted at 7 percent.

Summary of ECP Installation Costs (Tank Cars)

For the 20-year period of analysis, the estimated total cost related to ECP brakes on tank cars is $797.1 million. Total discounted costs are $664.1 million (3 percent) and $534.2 million (7 percent).

ECP Installation Costs (Locomotives)

As discussed in the previous section, it is reasonable to assume that all equipment in HHFUT's would still be equipped with ECP brakes by the January 1, 2021 or May 1, 2023 deadline. The remainder of the locomotives would be equipped over the next one and a half years. For the final rule ECP brake requirement analysis, we estimate the locomotive cost based on equipping 2,532 locomotives. In order to capture the additional ECP installation costs that would result from the broader alternative considered, the alternative scenario assumes approximately 5,000

[223] 633 (estimated number of HHFUT at peak year) *2 (number of buffer cars required for each train) = 1,266 (buffer cars needed)

[224] 4,835 (fewer tank cars) * $3,000 (incremental cost difference) = $14,505,000

locomotives would need to be equipped or about twice as many. To meet this higher rate of installations, it is no longer realistic to assume that all would be on new locomotives. The Class I Railroad's locomotive purchasing projections of over 1,000 new locomotives per year would likely be insufficient since they may be needed for other service. Therefore, PHMSA and FRA assume that 20 percent of the ECP brake installations on locomotives would be retrofits, and 80 percent would be add-ons for new locomotives. The ECP brake add-on for new locomotives is estimated to cost $40,000 per locomotive. AAR commented that the cost for retrofit is $83,300 and this analysis is using that as its estimate. This results in a weighted average cost of $48,660.[225] Over a 20-year period, the total cost to equip the locomotives with ECP brakes is $243.3 million. Discounted at 3 and 7 percent the costs are $204.4 and $164.6 million, respectively.

PHMSA and FRA believe that each locomotive would be equipped with run around cables. Over a 20-year period, it would cost $5.0 million to purchase these additional cables. These totals discounted are $4.2 million and $3.4 million using a 3 and a 7 percent discount rate.

In the original analysis, PHMSA and FRA included cost for and asset manager to oversee the two fleets, one with ECP and one non-ECP. With all tank cars equipped with ECP, there would be no need for an additional asset manager.

For the 20-year period of analysis, the estimated total cost of ECP brakes on locomotives is $248.3 million. Discounted at 3 and 7 percent, the total cost is $208.6 million and $168.0 million, respectively.

Training Costs for ECP Brakes

In the previous sections PHMSA and FRA analyzed the routes of the HHFUT's to determine how many crews could be affected. Using the waybill sample, FRA estimated that approximately 68 percent of the total ton-miles were on routes that had crude or ethanol unit trains. Commenters noted that the under a full fleet equipped scenario all crews would have to be trained. Accordingly, the cost to train all supervisors and crews is $70.9 million. Discounted at 3 and 7 percent, the total cost is $65.0 million and $58.2 million, respectively.

Summary of Costs

For the 20-year period, the total cost for installation and operation of ECP brakes is $1,116.3 million. Discounted values at 3 and 7 percent are $937.6 million and $760.4 million respectively.

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[225] [$83,300 (cost to retrofit a locomotive) * .20 (percent of retrofitted locomotives)] + [$40,00 (cost of add on for new locomotives) * .80 (percent of new locomotives)] = $48,660

Benefits of ECP Brakes

Benefits for ECP brakes are attained only when entire trains operate in ECP mode. Based on PHMSA and FRA's assumptions that the utilization rate for HHFUT is 16.0 cycles per year, 45 percent of the tank cars would likely operate in manifest trains – thus they were not included in the benefits estimate for the HHFUT ECP brake analysis. If these additional tank cars were equipped with ECP brakes to meet the alternative considered these cars would not often operate in ECP mode. A small percentage of the carloads originated might shift from manifest trains to dedicated ECP train service. That would be a business decision based on the particular circumstances surrounding those moves. These would likely include a portion of trains with 69 or fewer tank cars that only carry a single commodity.

Crude Oil Service -- After evaluating the waybill sample PHMSA and FRA found that 84 percent of the crude oil carloads were on trainsets that had 70+ tank cars. Additional crude oil trains with fewer than 70 cars would be equipped with ECP brakes and benefit from the accident prevention and mitigation benefits. Because the additional number of trains captured would be small the corresponding increase in safety benefits would also be small. In addition, because the trains themselves would have fewer crude oil cars, the opportunity for derailment and puncture would be reduced and thus the overall potential safety benefit per train in this category. For the purposes of this analysis, PHMSA and FRA have increased the estimate of crude oil tank cars that would operate using ECP brakes by 2 percentage points. We have slightly adjusted our phase in for ECP braking benefits based on these trainsets that would operate under with ECP braking systems. Tables 22 and 23 shows the resulting accident mitigation safety benefits for crude oil traffic for LCE and HCE.

Table BR22: Total LCE ECP Benefits for Crude Oil Traffic by Year

Year	Total Damages	Percentage of Crude HHFUT of Total Carloads	Percent of Operating Equipped with ECP	ECP Effectiveness Ratio	ECP Benefits	Present Value Discounted at 7%	Present Value Discounted at 3%
2015	$ 179,915,412	55.6%	0.0%	19.7%	$ -	$ -	$ -
2016	$ 176,427,442	55.6%	0.0%	19.7%	$ -	$ -	$ -
2017	$ 182,777,809	56.2%	18.0%	19.7%	$ 3,644,990	$ 2,975,398	$ 3,335,682
2018	$ 196,334,749	58.1%	38.0%	19.7%	$ 8,545,295	$ 6,519,164	$ 7,592,384
2019	$ 208,471,811	59.7%	58.0%	19.7%	$ 14,211,271	$ 10,132,440	$ 12,258,767
2020	$ 221,509,522	61.0%	78.0%	19.7%	$ 20,762,978	$ 13,835,249	$ 17,388,667
2021	$ 222,699,151	61.0%	98.0%	19.7%	$ 26,231,143	$ 16,335,438	$ 21,328,320
2022	$ 223,063,891	60.6%	98.5%	19.7%	$ 26,225,946	$ 15,263,739	$ 20,703,004
2023	$ 208,678,220	60.6%	99.0%	19.7%	$ 24,665,549	$ 13,416,424	$ 18,904,089
2024	$ 223,774,639	60.7%	99.5%	19.7%	$ 26,605,212	$ 13,524,741	$ 19,796,777
2025	$ 223,247,669	60.6%	100.0%	19.7%	$ 26,650,490	$ 12,661,456	$ 19,252,881
2026	$ 219,084,383	60.1%	100.0%	19.7%	$ 25,943,811	$ 11,519,362	$ 18,196,467
2027	$ 201,212,338	59.7%	100.0%	19.7%	$ 23,659,719	$ 9,817,942	$ 16,111,117
2028	$ 212,100,606	59.2%	100.0%	19.7%	$ 24,750,899	$ 9,598,825	$ 16,363,260
2029	$ 208,330,088	58.8%	100.0%	19.7%	$ 24,116,117	$ 8,740,791	$ 15,479,218
2030	$ 204,293,980	58.2%	100.0%	19.7%	$ 23,428,029	$ 7,935,884	$ 14,599,573
2031	$ 200,686,778	57.7%	100.0%	19.7%	$ 22,815,986	$ 7,222,957	$ 13,804,047
2032	$ 196,924,311	57.2%	100.0%	19.7%	$ 22,184,575	$ 6,563,615	$ 13,031,099
2033	$ 193,606,475	56.7%	100.0%	19.7%	$ 21,619,024	$ 5,977,840	$ 12,329,027
2034	$ 190,456,652	56.2%	100.0%	19.7%	$ 21,069,565	$ 5,444,776	$ 11,665,707
				Total	**$ 387,130,598**	**$ 177,486,041**	**$ 272,140,087**

Table BR23: Total HCE ECP Benefits for Crude Oil Traffic by Year

Year	Total Damages	Percentage of Crude HHFUT of Total Carloads	Percent of Operating Equipped with ECP	ECP Effectiveness Ratio	ECP Benefits	Present Value Discounted at 7%	Present Value Discounted at 3%
2015	$ 140,250,000	55.6%	0.0%	19.7%	$ -	$ -	$ -
2016	$ 140,250,000	55.6%	0.0%	19.7%	$ -	$ -	$ -
2017	$ 140,250,000	56.2%	18.0%	19.7%	$ 2,796,892	$ 2,283,097	$ 2,559,553
2018	$ 140,250,000	58.1%	38.0%	19.7%	$ 6,104,256	$ 4,656,908	$ 5,423,552
2019	$ 140,250,000	59.7%	58.0%	19.7%	$ 9,560,672	$ 6,816,627	$ 8,247,120
2020	$ 140,250,000	61.0%	78.0%	19.7%	$ 13,146,196	$ 8,759,866	$ 11,009,733
2021	$ 140,250,000	61.0%	98.0%	19.7%	$ 16,519,676	$ 10,287,624	$ 13,432,008
2022	$ 140,250,000	60.6%	98.5%	19.7%	$ 16,489,396	$ 9,596,979	$ 13,016,882
2023	$ 140,250,000	60.6%	99.0%	19.7%	$ 16,577,404	$ 9,017,010	$ 12,705,200
2024	$ 140,250,000	60.7%	99.5%	19.7%	$ 16,674,727	$ 8,476,586	$ 12,407,563
2025	$ 140,250,000	60.6%	100.0%	19.7%	$ 16,742,532	$ 7,954,256	$ 12,095,161
2026	$ 140,250,000	60.1%	100.0%	19.7%	$ 16,608,302	$ 7,374,285	$ 11,648,729
2027	$ 140,250,000	59.7%	100.0%	19.7%	$ 16,491,412	$ 6,843,350	$ 11,229,849
2028	$ 140,250,000	59.2%	100.0%	19.7%	$ 16,366,354	$ 6,347,154	$ 10,820,088
2029	$ 140,250,000	58.8%	100.0%	19.7%	$ 16,235,223	$ 5,884,392	$ 10,420,772
2030	$ 140,250,000	58.2%	100.0%	19.7%	$ 16,083,592	$ 5,448,069	$ 10,022,763
2031	$ 140,250,000	57.7%	100.0%	19.7%	$ 15,944,957	$ 5,047,765	$ 9,646,961
2032	$ 140,250,000	57.2%	100.0%	19.7%	$ 15,799,911	$ 4,674,624	$ 9,280,782
2033	$ 140,250,000	56.7%	100.0%	19.7%	$ 15,660,985	$ 4,330,393	$ 8,931,241
2034	$ 140,250,000	56.2%	100.0%	19.7%	$ 15,515,376	$ 4,009,468	$ 8,590,487
				Total	**$ 259,317,864**	**$ 117,808,451**	**$ 181,488,444**

Ethanol Service – Evaluation of the 2013 waybill sample data for ethanol shipments indicates that 47 percent of the carloads were on trains that had 70 or more tank cars. In addition, 13 percent of the ethanol carloads were on trains carrying between 16-60 carloads. Given the distribution of ethanol carloads and crude oil carloads across the different carload groups, a larger percentage increase would be seen in ethanol traffic captured by the broader application of ECP brakes. For the purposes of evaluating this alternative, PHMSA and FRA have increased the ethanol traffic car that would use ECP brakes by 8 percentage points. We have slightly adjusted our phase in for ECP braking benefits based on these trainsets that would operate under with ECP braking systems. Tables 24 and 25 shows the new accident mitigation safety benefits that would accrue from trains carrying ethanol cars and operating in ECP brake mode for LCE and HCE.

Table BR24: Total LCE ECP Benefits for Ethanol Traffic by Year

Year	Total Damages	Percentage of Ethanol HHFUT of Total Carloads	Percent Operating Equipped with ECP	ECP Effectiveness Ratio	ECP Benefits	Present Value Discounted at 7%	Present Value Discounted at 3%
2015	$ 179,915,412	19.1%	0.0%	19.7%	$ -	$ -	$ -
2016	$ 176,427,442	19.1%	0.0%	19.7%	$ -	$ -	$ -
2017	$ 182,777,809	18.7%	15.0%	19.7%	$ 1,009,323	$ 823,908	$ 923,674
2018	$ 196,334,749	17.5%	35.0%	19.7%	$ 2,368,086	$ 1,806,601	$ 2,104,013
2019	$ 208,471,811	16.5%	55.0%	19.7%	$ 3,735,674	$ 2,663,484	$ 3,222,425
2020	$ 221,509,522	15.7%	75.0%	19.7%	$ 5,137,350	$ 3,423,233	$ 4,302,450
2021	$ 222,699,151	15.7%	96.0%	19.7%	$ 6,608,525	$ 4,115,458	$ 5,373,336
2022	$ 223,063,891	16.0%	97.0%	19.7%	$ 6,800,970	$ 3,958,226	$ 5,368,748
2023	$ 208,678,220	15.9%	98.0%	19.7%	$ 6,423,976	$ 3,494,217	$ 4,923,443
2024	$ 223,774,639	15.9%	99.0%	19.7%	$ 6,945,444	$ 3,530,711	$ 5,168,063
2025	$ 223,247,669	16.0%	100.0%	19.7%	$ 7,015,059	$ 3,332,804	$ 5,067,828
2026	$ 219,084,383	16.3%	100.0%	19.7%	$ 7,015,897	$ 3,115,142	$ 4,920,809
2027	$ 201,212,338	16.5%	100.0%	19.7%	$ 6,548,866	$ 2,717,547	$ 4,459,459
2028	$ 212,100,606	16.8%	100.0%	19.7%	$ 7,022,000	$ 2,723,253	$ 4,642,369
2029	$ 208,330,088	17.1%	100.0%	19.7%	$ 7,019,477	$ 2,544,181	$ 4,505,535
2030	$ 204,293,980	17.4%	100.0%	19.7%	$ 7,022,171	$ 2,378,652	$ 4,375,985
2031	$ 200,686,778	17.8%	100.0%	19.7%	$ 7,022,743	$ 2,223,220	$ 4,248,875
2032	$ 196,924,311	18.1%	100.0%	19.7%	$ 7,018,959	$ 2,076,657	$ 4,122,899
2033	$ 193,606,475	18.4%	100.0%	19.7%	$ 7,021,121	$ 1,941,398	$ 4,004,047
2034	$ 190,456,652	18.7%	100.0%	19.7%	$ 7,031,052	$ 1,816,957	$ 3,892,923
				Total	**$ 108,766,691**	**$ 48,685,651**	**$ 75,626,880**

Table BR25: Total HCE ECP Benefits for Ethanol Traffic by Year

Year	Total Damages	Percentage of Ethanol HHFUT of Total Carloads	Percent Operating Equipped with ECP	ECP Effectiveness Ratio	ECP Benefits	Present Value Discounted at 7%	Present Value Discounted at 3%
2015	$ 140,250,000	19.1%	0.0%	19.7%	$ -	$ -	$ -
2016	$ 140,250,000	19.1%	0.0%	19.7%	$ -	$ -	$ -
2017	$ 140,250,000	18.7%	15.0%	19.7%	$ 774,479	$ 632,206	$ 708,758
2018	$ 140,250,000	17.5%	35.0%	19.7%	$ 1,691,621	$ 1,290,530	$ 1,502,983
2019	$ 140,250,000	16.5%	55.0%	19.7%	$ 2,513,185	$ 1,791,866	$ 2,167,896
2020	$ 140,250,000	15.7%	75.0%	19.7%	$ 3,252,742	$ 2,167,439	$ 2,724,120
2021	$ 140,250,000	15.7%	96.0%	19.7%	$ 4,161,874	$ 2,591,806	$ 3,383,984
2022	$ 140,250,000	16.0%	97.0%	19.7%	$ 4,276,066	$ 2,488,710	$ 3,375,566
2023	$ 140,250,000	15.9%	98.0%	19.7%	$ 4,317,473	$ 2,348,419	$ 3,308,984
2024	$ 140,250,000	15.9%	99.0%	19.7%	$ 4,353,034	$ 2,212,862	$ 3,239,066
2025	$ 140,250,000	16.0%	100.0%	19.7%	$ 4,407,043	$ 2,093,754	$ 3,183,741
2026	$ 140,250,000	16.3%	100.0%	19.7%	$ 4,491,327	$ 1,994,203	$ 3,150,126
2027	$ 140,250,000	16.5%	100.0%	19.7%	$ 4,564,722	$ 1,894,198	$ 3,108,354
2028	$ 140,250,000	16.8%	100.0%	19.7%	$ 4,643,247	$ 1,800,731	$ 3,069,733
2029	$ 140,250,000	17.1%	100.0%	19.7%	$ 4,725,585	$ 1,712,770	$ 3,033,173
2030	$ 140,250,000	17.4%	100.0%	19.7%	$ 4,820,795	$ 1,632,970	$ 3,004,160
2031	$ 140,250,000	17.8%	100.0%	19.7%	$ 4,907,845	$ 1,553,698	$ 2,969,327
2032	$ 140,250,000	18.1%	100.0%	19.7%	$ 4,998,921	$ 1,479,000	$ 2,936,339
2033	$ 140,250,000	18.4%	100.0%	19.7%	$ 5,086,153	$ 1,406,364	$ 2,900,562
2034	$ 140,250,000	18.7%	100.0%	19.7%	$ 5,177,582	$ 1,337,986	$ 2,866,702
				Total	**$ 73,163,695**	**$ 32,429,510**	**$ 50,633,575**

Although the majority of benefits associated with accident avoidance would be captured by the final rule HHFUT requirement, a small number of accidents may also be avoided as additional smaller unit trains operate in ECP mode. In the final rule we project that 7.4 percent of the locomotive fleet would operate with ECP brakes. Crude shipments impacted increase by 2 percentage points and the ethanol shipments by 8 percentage points under the broader alternative, this equates to an additional 21 ECP trains, which in turn translates to a 3 percent increase in accident avoidance benefits results or a total of 7.7 percent of the locomotives in the fleet would operate with ECP brakes. Under the broader ECP brake scenario, the total ECP accident avoidance would be to be $2.0 million under the broader ECP brake scenario, discounted at 7 percent and 3 percent the totals would be $.8 million and $1.4 million, respectively.

ECP Business Benefits

As noted above, for the analysis of the alternative considered no additional business benefits (excluding equipment reduction) are included, given the more limited opportunity for cars in non-HHFUT trains to be operated in ECP brake mode. Total discounted benefits (excluding reduction in equipment, which is discussed below) are presented in the table below:

Table BR26: Total ECP Business Benefits

Benefit	Discounted Value	
	Discount Factor	
	7% Discount	3% Discount
Set Out Relief	$8,335,030	$12,944,239
Class IA brake test	$51,480,542	$80,261,134
Wheel Savings	$23,367,506	$36,102,703

Table BR26: Total ECP Business Benefits		
Benefit	**Discounted Value**	
	Discount Factor	
	7% Discount	**3% Discount**
Fuel Savings	$121,138,213	$187,158,053
Total	$204,321,291	$316,466,129

Locomotives would still be eliminated under the alternative. Over a twenty year period, the total business benefit attributed to a reduction of locomotives would be $74.8 million; discounted at 7 percent, the value is $49.9 million and is $62.7 million discounted at 3 percent.

Summary of Benefits

Over a twenty-year period, the total benefits of the broader ECP brake requirement would range between $485.4 million and $635.7 million, discounted at 7 percent. Total benefits would range between $733.6 million and $965.7 million, discounted at 3 percent.

Conclusion for Alternatives Considered

The alternative of equipping all of the covered tank cars with ECP brakes allows for additional flexibility for car owners and railroads and results in higher safety benefit, however compliance costs are significantly higher. The total costs for this alternative is $760.4 million with benefits ranging from and $485.4 million and $635.7 million, discounted at 7 percent. This provides net benefits (both negative) ranging between -$275.4 million and -$126.6 million, discounted at 7 percent.

The total cost for the final rule as presented in Section 3 of this analysis is $492.0 million, with benefits ranging from $470.3 million to $613.4 million. This provides net benefits ranging between -$21.7 million and $121.4 million, discounted at 7 percent.

The costs for the alternative of requiring ECP brakes for all covered tank cars would exceed the costs of the final rule by $268.4 million over a twenty-year period, discounted at 7 percent. This is a 55 percent increase in costs. The benefits for this alternative also exceed the costs of the final rule, but not by the same margin. In this alternative, the benefits would increase between $15.1 million and $22.3 million, discounted at 7 percent. This is only a 3.2 – 3.6 percent increase over the benefits in the final rule.

PHMSA and FRA believe that the approach focused on HHFUT for ECP brakes results in a better return on investment per unit equipped. This limits the costs of this regulation and ensures optimal utilization of ECP brakes. Under the final rule operational requirements for ECP brakes on HHFUTs, 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.

H. Requirement Area 5 – Classification of Unrefined Petroleum-Based Products

Final Action: PHMSA is requiring any offeror of unrefined petroleum-based products for transportation to develop, implement, and update a sampling and testing program related to the classification and identification of properties for packaging selection of these materials.

1. Determination of Need

Under § 173.22 of the HMR, it is the offeror's responsibility to properly "class and describe the hazardous material in accordance with parts 172 and 173 of the HMR." A hazardous material must be classified in accordance with the appropriate hazard class definitions included in Part 173 of the HMR. The offeror must also identify relevant properties to follow packaging requirements. Once an offeror has determined the hazard class of the material, the offeror must select the most appropriate shipping name from the § 172.101 Hazardous Materials Table (HMT).

Relevant properties to properly classify describe, and package unrefined petroleum-based products include, but are not limited to the following: flash point; boiling point; corrosivity; specific gravity at loading; reference temperatures; and the presence and concentration of specific compounds such as sulfur. This information enables an offeror to properly classify a hazardous material, select the most appropriate shipping description, and the proper HMR-authorized packaging for transportation of that hazardous material. Proper classification and characterization is especially important when dealing with a material such as unrefined petroleum-based products, including crude oil, as these materials' properties are variable. Such information and determination of the authorized packaging also ensures that the required tank car outage, or unfilled capacity, can be maintained in accordance with § 173.24(a).

Crude oil transported by rail is often derived from different sources and is then blended, complicating proper classification and characterization of the material. PHMSA and FRA audits of crude oil loading facilities indicate that the classification of crude oil being transported by rail is often based solely on a generic Safety Data Sheet (SDS). The data on these sheets only provides a material classification and a range of material properties. This SDS information is typically provided by the consignee (the person to whom the shipment is to be delivered) to the offeror. In these instances, it is possible that there has been no validation of the crude oil properties. Further, FRA's audits indicate that SDS information is often not assembled from any recently conducted tests or from testing for the many different sources (wells) of the crude oil.

In the rail environment, it is critical that the existence and concentration of specific elements or compounds be identified, along with the corrosivity of the materials to the tank cars and service equipment. Proper identification of these elements will enable a shipper to ensure the reliability of the tank car. Proper identification also enables a shipper to determine if there is a need for an interior coating or lining, alternative materials of construction for valves and fittings, and performance requirements for fluid sealing elements, such as gaskets and o-rings.

In addition, recommendation R-14-6, issued by the NTSB, recognized the importance of sufficient testing and documentation of the physical and chemical characteristics of hazardous materials to ensure the proper classification, packaging, and record-keeping of products offered in transportation. Correct classification decisions are essential for the selection of proper equipment (tank, service equipment, interior lining or coating) and use, or maintenance and qualification of the equipment. The statement on a shipping paper is the offeror's certification that a hazardous material, is properly classified, described, packaged, marked and labeled, and in proper condition for transportation according to the applicable regulations of DOT. Packaging decisions are based on the information provided by the offeror. Incorrect classification and characterization of hazardous material may lead to failures throughout the transportation system.

2. Action by the United States and Canada

U.S. Action

Any improper classification of crude oil and subsequent shipment in an unauthorized tank car diminishes industry efforts to improve the safety of transporting hazardous materials, and violates the requirements of the HMR. The proper classification of a hazardous material is a key requirement under the HMR, as it dictates exactly which other requirements apply, such as specific operational controls and proper packaging selection. Classification is simply ensuring that the proper hazard class and Packing Group (if applicable) have been assigned to a particular material. Characterization is a complete description of the properties necessary to comply with all requirements during the transportation cycle. Characterization includes the identification of the effects that a material has on both the reliability and safety of the packaging. Proper classification and characterization is especially important when dealing with a material such as unrefined petroleum-based products, including crude oil, as these materials are variable. The characterization of crude oil may vary greatly depending on time, temperature, and the methods used to extract and process the material. In contrast, the classification and characterization of manufactured products is generally well understood and consistent.

Improper classification and characterization can also affect operational requirements under the HMR. Offerors and carriers must ensure that outage is considered when loading a tank car. Section 173.24b(a) of the HMR sets the minimum tank car outage for hazardous materials at one percent at a reference temperature that is based on the existence of tank car insulation. A crude oil offeror must know the specific gravity of the hazardous material at the reference temperature as well as the temperature and specific gravity of the material at that temperature when loaded. This information is then used to calculate the total quantity that can be safely loaded into the car to comply with the one percent outage requirement. If the outage is not properly calculated because the material's specific gravity is unknown (or is provided only as a range), the tank car could be loaded such that if the temperature increases during transportation, the tank will become shell-full, increasing the likelihood of a leak from the valve fittings or manway.

The final sampling and testing program is intended to ensure that:

1) the proper regulatory requirements are applied to shipments to minimize the risk of incident;
2) first responders have accurate information in the event of a train accident; and

3) the characteristics of the material are known and fully considered so that offerors and carriers are aware of and mitigate and potential threats to integrity of rail tank cars.

Canadian Action

On July 2, 2014 Canada published "SOR/2014-152, Published". The final rule requires that consignors and carriers present classification assessment information upon request and also requires a shipper's certification on the shipping paper so that there is someone to hold responsible for that classification. The shipper's certification is something we currently require under the HMR already. In accordance with this rule:

1) The consignor must classify these dangerous goods on the basis of samples.
2) The consignor must make available to the Minister, on reasonable notice given by the Minister, a document that explains the sampling method and includes the following information:

    a. the scope of the method;
    b. the sampling apparatus;
    c. the sampling procedures;
    d. the frequency and conditions of sampling; and
    e. a description of the quality control management system in place.

I. Alternatives Considered to Classification of Unrefined Petroleum-Based Products

1. Status Quo

The industry would continue the status quo and sample the material based on the existing classification and characterization methods. Rail derailment and accidents involving crude oil shipments that have been improperly classified may create potential risks for emergency responders. If PHMSA chose to take no action, then there would be no added costs or benefits to the rule.

2. Require Sampling and Testing Program

The properties of unrefined petroleum-based products, including crude oil, are variable based on time, method, and location of extraction. Whereas manufactured goods that undergo strict quality assurance tests to fall within defined parameters, unrefined petroleum-based products do not. The challenge they provide to classification is that the chemical makeup of raw material can vary over time and geographic location. While organic materials from oil and gas production pass through a "separator" to remove gas, sediment and water from crude, multiple hazardous materials can be commonly shipped from the well site: crude, natural gas condensate, and natural gas liquid.

Under this alternative, PHMSA requires a documented sampling and testing plan for shippers of these unrefined petroleum-based products in commerce. This plan will enable PHMSA and shippers of this commodity to more easily ascertain the specific classification and characteristics of the commodity and help to minimize potential risks when responding to a derailment and accident. In Recommendation R-14-6, the NTSB recognized the importance of sufficient testing and documentation of the physical and chemical characteristics of hazardous materials. The testing and sampling plan is required to address the following areas:

1) A frequency of sampling and testing that accounts for any appreciable variability of the material;
2) Sampling prior to the initial offering of the material for transportation and when changes that may affect the properties of the material occur;
3) Sampling methods that ensures a representative sample of the entire mixture, as offered, is collected;
4) Testing methods that enable classification of the material under the HMR;
5) Quality control measures for sample frequencies;
6) Duplicate samples or equivalent measures for quality assurance;
7) Criteria for modifying the sampling and testing program;
8) Testing or other appropriate methods used to identify properties of the mixture relevant to packaging requirements

Section 173.41(c) requires that the sampling and testing program be documented in writing and retained for as long as it remains in effect. The final requirement specifies that the sampling and testing program must be reviewed annually, at a minimum, and revised and/or updated as necessary to reflect changing circumstances § 173.41(d) mandates that each offeror required to develop and implement a sampling and testing program must maintain a copy of the sampling and testing program documentation (or an electronic file thereof) that is accessible at, or through, its principal place of business and must make the documentation available upon request, at a reasonable time and location, to an authorized official of DOT. Additionally, if any changes are made to the sampling and testing program, documentation that was updated, revised, or superseded must be retained for five additional years.

During the comment period, the majority of issues raised by commenters could have either been addressed by editorial revisions to the regulatory text or were outside of the scope of what was proposed in the rulemaking. Our focus centered on the applicability of which hazardous materials should be covered by the rulemaking:

Alternative 2a): Limit Applicability to Petroleum Crude Only

This option supports AAR comments. It does not fully address the risk posed by gaseous petroleum products, which have the same variability and classification risks as petroleum crude oil. The estimated number of offerors affected by this requirement is 1,748 offerors.[226] This dataset does not allow for separation of crude oil from petroleum gases and natural gas.

Alternative 2b): Limit Applicability to Unrefined Petroleum-Based Products

PHMSA has adopted this option. The majority of hazardous liquids and gases extracted from the earth are petroleum-based products. This option addresses the risks posed by unrefined petroleum-based products, which potentially have significant variability in their properties as a function of time, location, method of extraction, temperature at time of extraction, and the type and extent of conditioning or processing of the material. It further addresses commenter requests to clarify which hazardous materials are subject to the sampling and testing plan. Many commenters also supported inclusion of materials beyond petroleum crude oil only. The RIA for the NPRM only included petroleum-based products when analyzing mined liquids and gases. Therefore, this option was analyzed in the RIA for the NPRM. While, they savings from the proposed definitions are not quantified, the clarification ensures that additional offerors will not be inadvertently impacted. This option has been adjusted to reflect an updated dataset. The total number offerors affected by this requirement has increased from 1,538 offerors originally stated in the NPRM to 1,801.[227]

Alternative 2c): All Mined Liquids and Gases

This option was proposed in rulemaking, but no data was provided by commenters to describe benefits from expanding the definition beyond petroleum-based liquids and gases. Petroleum-based products were the only mined liquids and gases analyzed in the RIA for the NPRM, thus we have no additional information on the number of offerors and the costs and benefits of this requirement.

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[226] Offerors are determined using a subset of PHMSA registrants. The number of offerors reflects numbers from the latest data pull from the Active PHMSA Registration list, December 15th, 2014. Source designation and codes for the offerors are Crude Petroleum and Natural Gas Extraction (211111) and Petroleum Bulk Stations and Terminals (424710). Crude Petroleum and Natural Gas Extraction (186 Offerors) & Petroleum Bulk Stations and Terminals (1,562 Offerors).

[227] Offerors are determined using a subset of PHMSA registrants. The increased number of offerors reflects numbers from the latest data pull from the Active PHMSA Registration list, December 15th, 2014. Source designation and codes for the offerors are Crude Petroleum and Natural Gas Extraction (211111), Natural Gas Liquid Extraction (211112), & Petroleum Bulk Stations and Terminals (424710).

Costs

First Year - Development and Implementation

The costs are attributed to the time cost of developing then implementing the sampling plan. Costs associated with additional equipment for sampling or testing or changes in shipping behavior or equipment (such as increased use of lined tank cars) are not estimated. Since sampling and testing of these materials are already required to properly classify them, PHMSA assumes that shippers already have sampling methods and testing protocols in place and are compiling and organizing the testing results in some form. Therefore, PHMSA attributes low costs to the development of a testing and sampling plan. The final rule requires that a report compiling sampling and testing procedures and tracking testing results be produced and updated as necessary. The time necessary to document a sampling and testing program report is estimated at 40 hours per shipper.

PHMSA assumes a Chemical Engineer is the labor category most appropriate to describe sampling methodologies, testing protocols, and present test results. The median hourly wage for a Chemical Engineer is $46.02.[228] To calculate the hourly wage rates for every year of the analysis PHMSA takes into consideration the 1.18 percent annual growth rate in median real wages. [229] Inflating the 2013 wage by 1.18 percent gives us a 2014 wage of $46.56. We then inflate this wage by 60 percent to account for fringe benefits and overhead of $27.94 per hour, for a total weighted hourly wage of $74.50 in 2014. Following the same series of calculations (and holding fringe benefits constant at $27.94), the total weighted hourly wage in 2015, the first year of the analysis, is estimated at $75.05. PHMSA estimates there are 1,801 entities that offer unrefined petroleum-based products for transportation to which sampling and testing requirement could apply.[230]

These comprise of 186 offerors of petroleum/natural gas extraction, 53 offerors of natural gas liquid extraction, and 1,562 offerors of petroleum bulk stations/terminals. PHMSA assumes that the 1,801 entities include a modest number of offerors of ‘refined’ petroleum-based products. Thus the total number of 1,801 offerors subject to this requirement will yield a conservative cost estimate. Additionally, PHMSA estimates that each offeror would spend 40 hours for

[228] BLS May 2013 National Occupational Employment and Wage Estimates, available online at http://www.bls.gov/oes/current/oes_nat.htm#17-0000.

[229] Based on real wage growth forecasts from the Congressional Budget Office, DOT's guidance estimates that there will be an expected 1.18 percent annual growth rate in median real wages over the next 30 years (2013-2043). The wage rate in 2014 is calculated as follows: $46.02*1.0118 +$46.02*1.0118*0.6 = $74.50.

[230] Source: PHMSA Hazmat Intelligence Portal (HIP) based on NACIS Codes for 211111 – Crude Petroleum and Natural Gas Extraction; 211112 – Natural Gas Liquid Extraction; and 424710 – Petroleum Bulk Stations and Terminals. The data are for active PHMSA registrations.

development and implementation of the sampling and testing program. Thus, for offerors subject to the sampling and testing program, for alternative 2 b) PHMSA estimate the cost to develop and implement a sampling and testing program will be $5,407,000 (1,801 offerors x 40 hours/entity x $75.05/hour). The classification requirements already exist. The impact of this action is related only to the development and maintenance of the sampling and testing plan. We do not account for the time to collect and analyze samples.

As discussed above, for alternative 2a), PHMSA assumes that there are 1,748 offerors. As previously mentioned this dataset does not allow for separation of crude oil from petroleum gases and natural gas thus yielding a conservative cost estimate. PHMSA estimates the costs of this option for the initial year of the sampling and testing program to be $5,248,000 (1,748 offerors x 40 hours/entity x $75.05/hour).

Subsequent Year – Update

This final rule requires companies that offer unrefined petroleum-based products for transportation to update their sampling and testing program as necessary to account for changing circumstances. PHMSA assumes that companies will review and update their sampling and testing programs once a year. PHMSA estimates the costs with alternative 2b), the adopted alternative, to update a sampling and testing program will be on average $1,459,263 per year.[231] The costs to develop, implement and update sampling and testing program for alternatives 2a and 2b are shown in the table below.

Table CL1: Costs to Develop, Implement and Update Sampling and Testing Program

Sampling and Testing Plan		
	Alternative 2a	**Alternative 2b**
Offerors	1,748	1,801
Initial Year Cost	$5,248,000	$5,407,000
Later Year Cost (Average over years 2-20)	$1,416,211	$1,459,263
20 Years Total, Undiscounted	$32,156,000	$33,133,000
7% Discount Rate	$18,377,913	$18,936,060
3% Discount Rate	$24,656,717	$25,405,702

[231] $1.46 million = 1,801 entities x 10 hours/company x $81.02/hour (average hourly rate calculated for the subsequent years of the analysis (years 2-20) is based on the expected 1.18 percent annual growth rate in median real wages as mentioned above).

Benefits

The sampling and testing program is intended to minimize the risk of incident by ensuring the proper regulatory requirements are applied to each shipment and mitigate the potential threats to the integrity of packagings, such as rail tank cars when the offerors and carriers know and fully consider the properties of the material. Proper classification and characterization is especially important when dealing with a material such as unrefined petroleum-based products, including crude oil, as these materials' properties are variable. Such information and determination of the authorized packaging also ensures that the required tank car outage, or unfilled capacity, can be maintained in accordance with § 173.24b(a).

In calculating the benefits for the change, we focused on crude oil, as we assume the vast majority of unrefined petroleum-based products transported by highway and rail is crude oil. Further, any unrefined petroleum-based products moving by highway or rail are required to be transported in more robust packaging than for liquids, such as crude oil. Further, crude oil accounted for most non-accident releases (NARs) by commodity in 2012, nearly doubling the next highest commodity (alcohols not otherwise specified, which accounts for a comparable annual volume transported by rail). FRA's data indicates that 98 percent of the NARs involved loaded tank cars. Also, less than 2 percent of the NARs occurred at the bottom outlet valve. Product releases through the top valves and fittings of tank cars when the hazardous material expands during transportation suggest that loading facilities may not know the specific gravity of the hazardous materials loaded into railroad tank cars, resulting in a lack of sufficient outage. We anticipate some reduction in NARs as a result of improved testing and characterization but did not include this reduction.

FRA's review of the One-Time Movement Approval (OTMA) data indicates an increasing number of derailment and accidents involving damage to tank cars in crude oil service in the form of severe corrosion of the internal surface of the tank, man way covers, and valves and fittings. A possible cause is contamination of the crude oil by materials used in the fracturing process that are corrosive to the tank car and service equipment. Therefore, when crude oil is loaded into tank cars, it is critical that that the existence and concentration of specific elements or compounds be identified, along with the corrosivity of the materials to the tank cars and service equipment. Proper identification of these elements will enable a shipper to ensure the reliability of the tank car. Proper identification also enables a shipper to determine if there is a need for an interior coating or lining, alternative materials of construction for valves and fittings, and performance requirements for fluid sealing elements, such as gaskets and o-rings. Thus, by requiring offerors to properly classify these materials, PHMSA expects the maintenance time for the tank cars to be reduced.

DOT assumes that the sampling and testing program will affect all projected lower-consequence damages associated with crude oil incidents. DOT has not limited this estimate to accidents that would have been prevented through appropriate classification and packaging of materials. PHMSA expects the final requirements to reduce the expected lower-consequence damages. PHMSA conducted a break-even analysis to determine the effectiveness rates for which the final sampling and testing requirement will be beneficial to society. The lower-consequence event damage estimates with the sampling and testing requirement over the next 20 years, a total of $ 4.1 billion (undiscounted) are as seen in the table below:

Table CL2: Total Undiscounted Estimated Damages over 20-Years						
Year	**Crude Carloads**	**Ethanol Carloads**	**Total carloads**	**Ratio of crude oil carloads to total carloads**	**Total Lower-Consequence Damages**	**Total Lower-Consequence Damages - Sampling and Testing**
1	723,699	394,977	1,118,676	$116,391,702.11	$116,391,702.11	$116,391,702.11
2	726,742	396,882	1,123,624	$114,110,442.69	$114,110,442.69	$114,110,442.69
3	761,028	402,736	1,163,764	$119,525,118.86	$119,525,118.86	$119,525,118.86
4	844,901	404,852	1,249,753	$132,732,968.65	$132,732,968.65	$132,732,968.65
5	920,347	406,310	1,326,657	$144,623,972.77	$144,623,972.77	$144,623,972.77
6	999,596	409,649	1,409,245	$157,119,615.22	$157,119,615.22	$157,119,615.22
7	1,004,852	411,575	1,416,427	$157,988,860.20	$157,988,860.20	$157,988,860.20
8	999,277	419,078	1,418,355	$157,155,730.27	$157,155,730.27	$157,155,730.27
9	999,486	418,797	1,418,283	$147,058,774.16	$147,058,774.16	$147,058,774.16
10	1,002,977	419,099	1,422,076	$157,826,175.32	$157,826,175.32	$157,826,175.32
11	999,375	418,947	1,418,322	$157,304,292.82	$157,304,292.82	$157,304,292.82
12	972,594	418,876	1,391,470	$153,133,130.00	$153,133,130.00	$153,133,130.00
13	950,327	418,923	1,369,250	$139,651,281.75	$139,651,281.75	$139,651,281.75
14	927,328	418,994	1,346,322	$146,091,968.16	$146,091,968.16	$146,091,968.16
15	903,274	418,718	1,321,992	$142,345,151.79	$142,345,151.79	$142,345,151.79
16	877,236	418,752	1,295,988	$138,283,713.92	$138,283,713.92	$138,283,713.92
17	854,058	418,658	1,272,716	$134,671,166.42	$134,671,166.42	$134,671,166.42
18	830,166	418,303	1,248,469	$130,944,274.60	$130,944,274.60	$130,944,274.60
19	808,749	418,301	1,227,050	$127,606,082.11	$127,606,082.11	$127,606,082.11
20	787,945	418,760	1,206,705	$124,362,927.69	$124,362,927.69	$124,362,927.69
				Total	$4,093,595,926	$2,798,927,349.52

Table CL3: Prevented Damages at the Break-Even Point		
Year	**Total Lower Consequence Damages - Sampling and Testing - 3% discounted**	**Total Lower Consequence Damages - Sampling and Testing - 7% discounted**
2015	$1,382,116	$1,401,495
2016	$1,315,560	$1,284,137
2017	$1,337,850	$1,257,075
2018	$1,442,413	$1,304,659
2019	$1,525,857	$1,328,540

Table CL3: Prevented Damages at the Break-Even Point		
2020	$1,609,411	$1,348,904
2021	$1,571,179	$1,267,633
2022	$1,517,372	$1,178,456
2023	$1,378,528	$1,030,600
2024	$1,436,371	$1,033,700
2025	$1,389,923	$962,881
2026	$1,313,658	$876,026
2027	$1,163,110	$746,636
2028	$1,181,313	$729,973
2029	$1,117,491	$664,721
2030	$1,053,987	$603,509
2031	$996,556	$549,293
2032	$940,754	$499,151
2033	$890,069	$454,604
2034	$842,183	$414,065
Total	$25,405,702	$18,936,060

To break even, the sampling and testing plan must achieve an overall effectiveness rate of 1.22% and 1.29% to be beneficial at three percent respectively seven percent discount rates. While it is ideal to consider damages that specifically resulted from improper classification, such information has not been developed. PHMSA believes that this provision will reduce the risk of release of these materials to the environment. As a result, we expect the sampling and testing plan to result in net benefits.

X. Comprehensive Benefits and Costs

A. Integration of Benefits for Entire Rule Options

To this point in the analysis, costs and benefits of the various provisions of the rule have been estimated on a stand-alone basis. If there were no overlap in either benefits or costs, total benefits and costs could be obtained by adding the costs of the various provisions together and adding benefits together to calculate totals for each. There is, however, some overlap, for both costs and benefits, between the effects of the tank car standard and the effects of ECP brakes and the speed restriction. The benefit estimate for each individual provision is obtained by multiplying the effectiveness of the provision by the total societal damages expected from unit train derailments. Because of this, adding the benefits for each provision to the benefits of other provisions results in some double counting of benefits.

A stylized example may help illustrate this issue. Consider a proposed rule that involves two provisions that are each expected to reduce expected damages by 30 percent. If the total

expected damages are $100 in the absence of the rule, each provision enacted on its own would be expected to generate $30 in benefits. However, those provisions together would not generate $60 in benefits. Instead, one provision should be applied first, generating $30 in benefits and leaving $70 in expected damages. The second provision would generate benefits equal to 30 percent of the $70 that remains of expected damages, or $21. Total benefits for this example would then be $51 ($30 + $21).

In this section, we make a series of calculations to eliminate these overlaps and develop and benefits of the final rule. We begin with the tank car standard, although it does not matter in which order these calculations are carried out—the total benefits for the final rule would be the same regardless of the order of calculation. We begin by presenting with lower-consequence damages, and higher consequence damages below. This is the pool of incidents that would be prevented or mitigated by the requirements of the final rule. We conduct these calculations using the mean HCE damages plus LCE damages. The final benefit figures for the 95th percentile benefit scenarios presented below are calculated exactly the same way, except the aggregate effectiveness of the rule is multiplied by the 20-year stream of 95th percentile HCE societal damage estimates rather than the mean HCE societal damage estimates.

Table CBC1. Low- and High-Consequence Baseline Damages, 2015-2034

Year	LCE Damages	Mean HCE
2015	$179,915,412	$140,250,000
2016	$176,427,442	$140,250,000
2017	$182,777,809	$140,250,000
2018	$196,334,749	$140,250,000
2019	$208,471,811	$140,250,000
2020	$221,509,522	$140,250,000
2021	$222,699,151	$140,250,000
2022	$223,063,891	$140,250,000
2023	$208,678,220	$140,250,000
2024	$223,774,639	$140,250,000
2025	$223,247,669	$140,250,000
2026	$219,084,383	$140,250,000
2027	$201,212,338	$140,250,000
2028	$212,100,606	$140,250,000
2029	$208,330,088	$140,250,000
2030	$204,293,980	$140,250,000
2031	$200,686,778	$140,250,000
2032	$196,924,311	$140,250,000
2033	$193,606,475	$140,250,000
2034	$190,456,652	$140,250,000
Total, Undiscounted	$4,093,595,927	$2,805,000,000
7% Discount Rate	$2,151,588,358	$1,485,810,498
3% Discount Rate	$3,037,792,406	$2,086,565,849

The series of calculations used to generate benefits for the comprehensive packages, starting with the tank car standard, then adding speed, then ECP braking as follows:

Equation CBC 1:

$$(\text{total low} - \text{consequence baseline damages}) - (\text{benefits of tank car standard}) = (\text{remaining damages})$$

Equation CBC 2:

$$(\text{remaining damages 1}) \text{ x } (\text{Speed effectiveness})) = (\text{marginal Speed benefits})$$

Equation CBC 3:

$$(\text{remaining damages 1}) - (\text{marginal Speed benefits}) = (\text{remaining damages 2})$$

Equation CBC 4:

$$(\text{remaining damages 2}) \text{ x } (\text{ECP effectiveness}) = (\text{marginal ECP benefits})$$

To obtain total LCE benefits, marginal speed benefits and marginal ECP brake benefits are added to the tank car benefits.

First, we subtract the benefits of the tank car option in question. For the Final Rule tank car, we subtract only the benefits of the tank car itself, not the ECP braking benefits, which are handled later in the calculations for options that include that car. This leaves us with a remaining damages pool, which provides the opportunity to achieve benefits from the next provision of the set of proposals. The calculations for estimating the benefits of the Option 1 tank car are presented in the tank car benefits section, but the dollar figures discounted at seven percent are presented below.

Table CBC2. Benefits of Final Rule Tank Car, 2015-2034 (7 Percent Discount)

Year	Total LCE Benefits
2015	$13,545
2016	$6,016,653
2017	$18,513,649
2018	$25,529,713
2019	$33,010,664
2020	$40,611,427
2021	$59,102,205
2022	$65,464,559
2023	$61,321,087
2024	$65,981,538
2025	$65,846,691
2026	$64,618,734
2027	$59,347,390
2028	$62,558,875
2029	$61,446,764
2030	$60,256,318

Table CBC2. Benefits of Final Rule Tank Car, 2015-2034 (7 Percent Discount)	
2031	$59,192,377
2032	$58,082,641
2033	$57,104,048
2034	$56,175,011
Total Undiscounted	$980,193,889
7% Discount Rate	$450,032,434.38
3% Discount Rate	$688,875,430.36

These benefit figures are subtracted from the discounted low-consequence baseline damages to arrive at the remaining damages pool, which provides opportunities to achieve benefits from other provisions. Then, Speed effectiveness is applied to this remaining damage pool to generate speed benefits. These benefits are then subtracted from the damages minus tank car benefits to obtain damages minus tank car and marginal speed benefits. ECP braking effectiveness is then applied to these values to obtain marginal ECP benefits. Marginal ECP benefits are added to marginal speed benefits and tank car benefits to get the total LCE benefits of the rule. These calculations are carried out in the table below.

Table CBC3: Speed Marginal Effectiveness Benefits, 2015-2034 (Seven Percent Discount)

Year	LCE Damages - Tank Car Benefits	Speed Effectiveness	Speed Marginal Benefits
2015	$179,901,868	8.75%	$15,747,889
2016	$170,410,789	7.44%	$12,677,130
2017	$164,264,160	5.93%	$9,743,497
2018	$170,805,036	4.91%	$8,382,546
2019	$175,461,146	3.86%	$6,780,140
2020	$180,898,095	3.14%	$5,684,382
2021	$163,596,946	1.39%	$2,276,899
2022	$157,599,332	0.59%	$925,585
2023	$147,357,133	0.34%	$500,442
2024	$157,793,101	0.00%	$0
2025	$157,400,978	0.00%	$0
2026	$154,465,650	0.00%	$0
2027	$141,864,947	0.00%	$0
2028	$149,541,731	0.00%	$0
2029	$146,883,324	0.00%	$0
2030	$144,037,662	0.00%	$0
2031	$141,494,401	0.00%	$0
2032	$138,841,670	0.00%	$0
2033	$136,502,426	0.00%	$0
2034	$134,281,641	0.00%	$0
		Total Undiscounted	$62,718,509
		7% Discount Rate	$50,989,684
		3% Discount Rate	$57,177,815

Table CBC4: ECP Braking Marginal Effectiveness Benefits, 2015-2034 (Seven Percent Discount)				
Year	**LCE Damages - Tank Car and Speed**	**ECP Effectiveness**	**Marginal ECP Benefits**	**Total LCE Benefits**
2015	$164,153,979	0.0%	$0	$15,761,434
2016	$157,733,659	0.0%	$0	$18,693,783
2017	$154,520,663	2.6%	$4,086,915	$32,344,061
2018	$162,422,491	5.4%	$8,729,823	$42,642,082
2019	$168,681,006	8.2%	$13,771,148	$53,561,952
2020	$175,213,712	11.0%	$19,282,361	$65,578,171
2021	$161,320,048	13.8%	$22,193,464	$83,572,568
2022	$156,673,747	14.0%	$21,909,220	$88,299,364
2023	$146,856,692	14.3%	$20,940,250	$82,761,779
2024	$157,793,101	14.4%	$22,721,991	$88,703,529
2025	$157,400,978	14.4%	$22,657,806	$88,504,497
2026	$154,465,650	14.4%	$22,171,663	$86,790,397
2027	$141,864,947	14.3%	$20,312,117	$79,659,507
2028	$149,541,731	14.3%	$21,353,904	$83,912,779
2029	$146,883,324	14.2%	$20,915,210	$82,361,974
2030	$144,037,662	14.2%	$20,443,009	$80,699,327
2031	$141,494,401	14.2%	$20,021,874	$79,214,251
2032	$138,841,670	14.1%	$19,584,727	$77,667,368
2033	$136,502,426	14.1%	$19,196,585	$76,300,633
2034	$134,281,641	14.0%	$18,824,292	$74,999,303
Total Undiscounted			$339,116,360	$1,382,028,759
7% Discount Rate			$156,306,575	$657,328,693
3% Discount Rate			$238,841,097	$984,894,343

Once total LCE benefits for the final rule have been obtained, they can be used to generate an aggregate effectiveness rate by dividing benefits by LCE damages in each year. These values can then be multiplied by the HCE damages to obtain HCE benefits. HCE benefits are then added to LCE benefits to get total safety benefits for the rule. These calculations are presented in the table below.

Table CBC5: Total Benefits, Mean HCE + LCE				
Year	**Aggregate Effectiveness**	**HCE Damages**	**HCE Benefits**	**Total Benefits**
2015	9%	$140,250,000	$12,286,557.52	$28,047,991
2016	11%	$140,250,000	$14,860,517.56	$33,554,301
2017	18%	$140,250,000	$24,818,409.96	$57,162,471
2018	22%	$140,250,000	$30,460,995.81	$73,103,078
2019	26%	$140,250,000	$36,033,954.73	$89,595,907
2020	30%	$140,250,000	$41,521,187.58	$107,099,358
2021	38%	$140,250,000	$52,631,779.86	$136,204,348
2022	40%	$140,250,000	$55,517,662.33	$143,817,026
2023	40%	$140,250,000	$55,623,147.69	$138,384,926

2024	40%	$140,250,000	$55,594,637.54	$144,298,167
2025	40%	$140,250,000	$55,600,829.90	$144,105,327
2026	40%	$140,250,000	$55,560,113.06	$142,350,510
2027	40%	$140,250,000	$55,524,656.25	$135,184,163
2028	40%	$140,250,000	$55,486,721.64	$139,399,501
2029	40%	$140,250,000	$55,446,944.92	$137,808,919
2030	40%	$140,250,000	$55,400,949.89	$136,100,276
2031	39%	$140,250,000	$55,358,896.91	$134,573,148
2032	39%	$140,250,000	$55,314,899.23	$132,982,267
2033	39%	$140,250,000	$55,272,758.06	$131,573,391
2034	39%	$140,250,000	$55,228,589.37	$130,227,892
			Total Undiscounted	$2,315,572,968
			7% Discount Rate	$1,100,206,522
			3% Discount Rate	$1,648,909,232

The remaining tank car options are considered analogously. To these benefits we other ECP benefits, such as business benefits, as presented in the Braking section of the RIA. We also add in costs for braking, classification, and routing in addition to the tank car costs to present comprehensive costs and benefits in the tables below.

CBC6: Table CBC6: Final Rule Costs and Benefits

	7% Discount	3% Discount
Total Cost	$2,481,971,599	$3,094,967,161
LCE Benefits + Other ECP Benefits	$912,334,141	$1,365,368,402
LCE + Mean HCE Benefits + Other ECP	$1,355,211,969	$2,029,383,291
LCE + 95th Percentile HCE + Other ECP	$2,904,573,871	$4,352,370,139
Net Benefits, LCE+ Other ECP	-$1,569,637,459	-$1,729,598,759
Net Benefits, LCE + Mean HCE + Other ECP	-$1,126,759,630	-$1,065,583,870
Net Benefits, LCE + 95th Percentile HCE + Other ECP	$422,602,272	$1,257,402,977

The next table presents costs, benefits, and net benefits for the Option 3.

Table CBC 7: Option 3, Final Rule ECP Costs, and Benefits

	7% Discount	3% Discount
Total Cost	$2,443,099,630	$3,036,632,698
LCE Benefits + Other ECP Benefits	$884,795,934	$1,324,967,696
LCE + Mean HCE Benefits + Other ECP	$1,308,953,852	$1,961,558,925
LCE + 95th Percentile HCE + Other ECP	$2,792,826,100	$4,188,606,958
Net Benefits, LCE+ Other ECP	-$1,558,303,696	-$1,711,665,002
Net Benefits, LCE + Mean HCE + Other ECP	-$1,134,145,777	-$1,075,073,773

Table CBC 7: Option 3, Final Rule ECP Costs, and Benefits		
Net Benefits, LCE + 95th Percentile HCE + Other ECP	$349,726,470	$1,151,974,260

The next table presents these figures for the Option 2 tank car.

Table CBC 8: Option 2, Final Rule ECP Costs, and Benefits		
	7% Discount	**3% Discount**
Total Cost	$3,150,153,815	$3,960,384,968
LCE Benefits + Other ECP Benefits	$995,160,213	$1,493,115,679
LCE + Mean HCE Benefits + Other ECP	$1,493,450,261	$2,242,883,389
LCE + 95th Percentile HCE + Other ECP	$3,236,666,034	$4,865,867,538
Net Benefits, LCE+ Other ECP	-$2,154,993,602	-$2,467,269,289
Net Benefits, LCE + Mean HCE + Other ECP	-$1,656,703,554	-$1,717,501,579
Net Benefits, LCE + 95th Percentile HCE + Other ECP	$86,512,219	$905,482,570

The following three tables present the same figures above except that instead of presenting the tank car options in combination with the final rule ECP mandate, the tank car options are combined with the other ECP option considered in this document.

First, we present the final rule tank car with the Alternative ECP braking option:

Table CBC 9: Final Rule Tank Car plus Alterative 1 ECP Costs and Benefits		
	7% Discount	**3% Discount**
Total Cost	$2,750,399,536	$3,453,193,619
LCE Benefits + Other ECP Benefits	$869,495,357	$1,313,388,944
LCE + Mean HCE Benefits + Other ECP	$1,317,541,782	$1,985,382,790
LCE + 95th Percentile HCE + Other ECP	$2,884,985,478	$4,336,283,185
Net Benefits, LCE+ Other ECP	-$1,880,904,179	-$2,139,804,675
Net Benefits, LCE + Mean HCE + Other ECP	-$1,432,857,754	-$1,467,810,829
Net Benefits, LCE + 95th Percentile HCE + Other ECP	$134,585,942	$883,089,566

Next, we present the Option 3 tank car with the alternative ECP braking option.

Table CBC 10: Option 3 Tank Car, Alternative 1 ECP Costs and Benefits		
	7% Discount	**3% Discount**
Total Cost	$2,711,527,567	$3,394,859,156
LCE Benefits + Other ECP Benefits	$842,139,570	$1,273,271,605
LCE + Mean HCE Benefits + Other	$1,271,586,410	$1,918,030,014

ECP		
LCE + 95th Percentile HCE + Other ECP	$2,773,961,401	$4,173,650,071
Net Benefits, LCE+ Other ECP	-$1,869,387,997	-$2,121,587,551
Net Benefits, LCE + Mean HCE + Other ECP	-$1,439,941,156	-$1,476,829,142
Net Benefits, LCE + 95th Percentile HCE + Other ECP	$62,433,834	$778,790,915

Finally, we present the Option 2 tank car with the alternative ECP braking option.

Table CBC 11: Option 2 Tank Car, Alternative 1 ECP Costs and Benefits

	7% Discount	3% Discount
Total Cost	$3,418,581,752	$4,318,611,426
LCE Benefits + Other ECP Benefits	$951,693,996	$1,440,145,047
LCE + Mean HCE Benefits + Other ECP	$1,454,737,493	$2,197,231,312
LCE + 95th Percentile HCE + Other ECP	$3,214,582,712	$4,845,818,662
Net Benefits, LCE+ Other ECP	-$2,466,887,756	-$2,878,466,380
Net Benefits, LCE + Mean HCE + Other ECP	-$1,963,844,259	-$2,121,380,115
Net Benefits, LCE + 95th Percentile HCE + Other ECP	-$203,999,041	$527,207,236

Based on the figures presented above, the Final Rule produces the highest net benefits/lowest net costs when compared to the other options under consideration. One option examined presents a more stringent tank car standard than that adopted by the final rule. Although this option produces higher benefits, it also comes at a higher cost, resulting in lower net benefits/higher net costs than the Final Rule. The less stringent option produces lower cost but commensurately lower benefits, and also produces lower net benefits/higher net costs than the Final Rule. The Final Rule appears to be the best compromise between enhanced safety and cost.

XI. Conclusions

Hazardous materials such as crude oil and ethanol are essential to the economy of the U.S. and the well-being of its people. These materials are an important part of the U.S. economy and have many manufacturing and other industrial applications. The need for these hazardous materials to support essential services means transportation of hazardous materials is unavoidable; rail transportation of hazardous materials in the United States is generally recognized to be a safe method of moving large quantities of hazardous materials over long distances.

PHMSA, in coordination with FRA, is requiring new operational requirements for HHFTs comprised of 20 or more tank car loads of a Class 3 flammable liquid in a continuous block or 35 or more tank car loads of a Class 3 flammable liquid across the entire train. This ensures that the

requirements are closely aligned with the risks posed by the operation of trains that are transporting large quantities of flammable liquids.

PHMSA is mandating improvements in tank car standards for HHFTs and revision of the general requirements for offerors to ensure proper classification and characterization of unrefined petroleum-based products. These new requirements are designed to lessen the frequency and consequences of derailments involving ethanol and crude oil, when moved as a HHFT. The growing reliance on trains to transport large volumes of flammable liquids poses a significant risk to life, property, and the environment. These significant risks have been highlighted by the recent derailments of trains carrying crude oil in Lynchburg, Virginia, Casselton, North Dakota, Aliceville, Alabama, and Lac-Mégantic, Quebec, Canada.

Shipments of flammable liquids in large volumes pose a risk of catastrophic consequences during transportation. In addition, both the number of shipments and accidents involving large flammable liquids has increased.

Consistent with the final rule, the following table provides the five (5) requirement areas considered in this analysis and their costs.

Table CBC12 shows the costs and benefits by affected section and rule provision over a 20-year period, discounted at a 7% rate. Table CBC12 also shows an explanation of the comprehensive benefits and costs (i.e., the combined effects of individual provisions), and the estimated benefits, costs, and net benefits of each amendment.

Please also note that, given the uncertainty associated with the risks of HHFT shipments, Table CBC12 contains a range of estimated benefits. The low-end of the range of estimated benefits estimates risk from 2015 to 2034, based on the U.S. safety record for crude oil and ethanol from 2006 to 2013, adjusting for the projected increase in shipment volume over the next 20 years. The upper end of the range of estimated benefits is the 95th percentile from the Monte Carlo simulation.

Table CBC12. 20 Year Costs and Benefits by Stand-Alone Proposed Regulatory Amendments 2015-2034[232]			
Affected Section[233]	**Provision**	**Benefits (7%)**	**Costs (7%)**
49 CFR 172.820	Rail Routing+	Cost effective if routing were to reduce risk of an incident by 0.41%	$8.8 million
49 CFR 173.41	Classification Plan	Cost effective if this requirement reduces risk by 1.29%	$18.9 million
49 CFR 174.310	Speed Restriction: 40 mph speed limit in HTUA*	$56 million – $242 million	$180 million
	Advanced Brake Signal Propagation Systems	$470.3 million - $1,1144 million	$492 million
49 CFR part 179	New Tank Car Construction and Existing Tank Car Retrofit	$450 million - $1,804 million	$1,782 million
Cumulative Total		$912 million-$2,905 million	$2,482 million
"*" indicates voluntary compliance regarding crude oil trains in high-threat urban areas (HTUA) "+" indicates voluntary actions that will be taken by shippers and railroads			

[232] All costs and benefits are in millions over 20 years, and are discounted to present value using a 7 percent rate.

[233] All affected sections of the Code of Federal Regulations (CFR) are in Title 49.

Appendix A: 2011 U.S. Business Statistics for Selected Industries that Ship Class 3 Hazardous Materials

NAICS CODE	NAICS DESCRIPTION	ENTERPRISE EMPLOYMENT SIZE	NUMBER OF FIRMS	NUMBER OF ESTABLISHMENTS	EMPLOYMENT
211111	Crude petroleum and natural gas extraction	1: Total	6,523	7,757	108,954
211111	Crude petroleum and natural gas extraction	2: 0-4	4,519	4,531	7,361
211111	Crude petroleum and natural gas extraction	3: 5-9	946	963	6,099
211111	Crude petroleum and natural gas extraction	4: 10-19	496	514	6,685
211111	Crude petroleum and natural gas extraction	5: <20	5,961	6,008	20,145
211111	Crude petroleum and natural gas extraction	6: 20-99	388	458	13,989
211111	Crude petroleum and natural gas extraction	7: 100-499	87	216	11,507
211111	Crude petroleum and natural gas extraction	8: <500	6,436	6,682	45,641
211111	Crude petroleum and natural gas extraction	9: 500+	87	1,075	63,313
211112	Natural gas liquid extraction	1: Total	136	338	10,005
211112	Natural gas liquid extraction	2: 0-4	58	58	0
211112	Natural gas liquid extraction	3: 5-9	11	11	67
211112	Natural gas liquid extraction	4: 10-19	6	6	0
211112	Natural gas liquid extraction	5: <20	75	75	250
211112	Natural gas liquid extraction	6: 20-99	15	16	536
211112	Natural gas liquid extraction	7: 100-499	9	21	947
211112	Natural gas liquid extraction	8: <500	99	112	1,733
211112	Natural gas liquid extraction	9: 500+	37	226	8,272
324191	Petroleum lubricating oil and grease manufacturing	1: Total	248	289	9,285
324191	Petroleum lubricating oil and grease manufacturing	2: 0-4	64	64	125
324191	Petroleum lubricating oil and grease manufacturing	3: 5-9	36	36	241
324191	Petroleum lubricating oil and grease manufacturing	4: 10-19	37	37	493
324191	Petroleum lubricating oil and grease manufacturing	5: <20	137	137	859
324191	Petroleum lubricating oil and grease manufacturing	6: 20-99	67	73	2,695
324191	Petroleum lubricating oil and grease manufacturing	7: 100-499	22	34	2,528
324191	Petroleum lubricating oil and grease manufacturing	8: <500	226	244	6,082
324191	Petroleum lubricating oil and grease manufacturing	9: 500+	22	45	3,203
325110	Petrochemical manufacturing	1: Total	43	60	10,398
325110	Petrochemical manufacturing	2: 0-4	14	14	0
325110	Petrochemical manufacturing	3: 5-9	2	2	0
325110	Petrochemical manufacturing	4: 10-19	1	1	0
325110	Petrochemical manufacturing	5: <20	17	17	49
325110	Petrochemical manufacturing	6: 20-99	4	4	260
325110	Petrochemical manufacturing	7: 100-499	5	5	433
325110	Petrochemical manufacturing	8: <500	26	26	742
325110	Petrochemical manufacturing	9: 500+	17	34	9,656
324110	Petroleum refineries	1: Total	198	296	63,150
324110	Petroleum refineries	2: 0-4	75	75	0
324110	Petroleum refineries	3: 5-9	23	23	148
324110	Petroleum refineries	4: 10-19	18	18	249
324110	Petroleum refineries	5: <20	116	116	490
324110	Petroleum refineries	6: 20-99	15	18	662
324110	Petroleum refineries	7: 100-499	23	25	2,766
324110	Petroleum refineries	8: <500	154	159	3,918
324110	Petroleum refineries	9: 500+	44	137	59,232
325192	Cyclic crude and intermediate manufacturing	1: Total	25	28	3,166
325192	Cyclic crude and intermediate manufacturing	2: 0-4	1	1	0
325192	Cyclic crude and intermediate manufacturing	3: 5-9	1	1	0
325192	Cyclic crude and intermediate manufacturing	4: 10-19	1	1	0
325192	Cyclic crude and intermediate manufacturing	5: <20	3	3	0
325192	Cyclic crude and intermediate manufacturing	6: 20-99	7	7	243
325192	Cyclic crude and intermediate manufacturing	7: 100-499	3	3	338
325192	Cyclic crude and intermediate manufacturing	8: <500	13	13	605
325192	Cyclic crude and intermediate manufacturing	9: 500+	12	15	0
325193	Ethyl alcohol manufacturing	1: Total	168	219	10,299
325193	Ethyl alcohol manufacturing	2: 0-4	19	19	30
325193	Ethyl alcohol manufacturing	3: 5-9	8	8	0
325193	Ethyl alcohol manufacturing	4: 10-19	12	13	175
325193	Ethyl alcohol manufacturing	5: <20	39	40	257
325193	Ethyl alcohol manufacturing	6: 20-99	97	99	4,038
325193	Ethyl alcohol manufacturing	7: 100-499	17	37	2,299
325193	Ethyl alcohol manufacturing	8: <500	153	176	6,594
325193	Ethyl alcohol manufacturing	9: 500+	15	43	3,705

Source: U.S. Census Bureau, Statistics of U.S. Businesses, 2011

Appendix B: Crude Oil/ Ethanol Derailment Accidents Research

Appendix B summarizes the impacts of recent accidents involving HHFTs of crude oil and ethanol. While not all accidents involving crude oil and ethanol release have significant consequences, these accidents indicate the potential harm from future releases. The following includes an accounting of the rail accidents involving crude oil and ethanol, including their location, a sample of major accidents including number of cars punctured, location of puncture, and amount of product released, and finally a list of literature examining the economic and social impacts of crude oil and ethanol spills.

Table B1: Mainline Derailments of Crude Oil and Ethanol from 2006-2013
Geographic locations of mainline crude oil and ethanol rail accidents in the United States (2006-2013)

Incident Date	Product	UN No.	Speed at Derailment (mph)	Cars Releasing	No. Main Line Incidents	Qty. Released per derailment	Unit of Measure	City	State or Province
4/22/2006	Ethanol	UN1268	5	1	1	9,000	LGA	CHILLICOTHE	OHIO
5/30/2006	Ethanol	UN1987	50	0	1	0	LGA	TRIBES HILL	NEW YORK
10/20/2006	Ethanol	UN1987	37	20	1	485,278	LGA	NEW BRIGHTON	PENNSYLVANIA
11/11/2006	Ethanol	UN1987	10	1	1	1,000	LGA	PORTAGE	INDIANA
11/22/2006	Ethanol	UN1987	24	7	1	24877	LGA	CAMBRIDGE	MINNESOTA
2006 Total				29cars	5 cars	520155	LGA		
6/30/2007	Ethanol	UN1987	20	1	1	29357	LGA	PLUMAS	CALIFORNIA
10/10/2007	Ethanol	UN1987	48	5	1	55200	LGA	PAINESVILLE	OHIO
12/28/2007	Ethanol	UN1987	23	2	1	16000	LGA	NEW FLORENCE	PENNSYLVANIA
2007 Total				8 cars	3cars	100557	LGA		
8/16/2008	Ethanol	UN1987	17	1	1	12,447	LGA	COUNCIL	NORTH CAROLINA
8/22/2008	Crude Oil	UN1267	19	5	1	80746	LGA	LUTHER	OKLAHOMA
12/7/2008	Crude Oil	UN1267	55	6	1	140	LGA	PAGE	NORTH DAKOTA
2008 Total				12cars	3cars	93333	LGA		
1/12/2009	Ethanol	UN1987	44	1	1	1	LGA	DEFIANCE	OHIO
3/8/2009	Ethanol	UN1987	10	2	1	85	LGA	JESUP	IOWA
5/28/2009	Ethanol	UN1987	18	1	1	100	LGA	GREEN MOUNTAIN	NORTH CAROLINA
6/19/2009	Ethanol	UN1987	19	13	1	232693	LGA	CHERRY VALLEY	ILLINOIS
7/23/2009	Ethanol	UN1987	11	1	1	174	LGA	MAX	NORTH DAKOTA
9/15/2009	Ethanol	UN1987	2	2	1	8204	LGA	KNOXVILLE	TENNESSEE

Table B1: Mainline Derailments of Crude Oil and Ethanol from 2006-2013
Geographic locations of mainline crude oil and ethanol rail accidents in the United States (2006-2013)

10/28/2009	Crude Oil	UN1267	30	1	1	1	LGA	LODI	OHIO
12/13/2009	Ethanol	UN1170	15	1	1	1	LGA	CARBONDALE	ILLINOIS
2009 Total				22	8	241259	LGA		
2/20/2010	Ethanol	UN1987	20	1	1	24175	LGA	KEENE	CALIFORNIA
3/11/2010	Ethanol	NA1987	10	1	1	5	LGA	WINDHAM	CONNECTICUT
4/19/2010	Ethanol	UN1987	41	8	1	57613	LGA	BRYAN	OHIO
2010 Total				10	3	81793	LGA		
1/8/2011	Ethanol	UN1987	5	0	1	0	LGA	ROANOKE	VIRGINIA
2/6/2011	Ethanol	UN1987	46	31	1	834840	LGA	ARCADIA	OHIO
5/4/2011	Ethanol	NA1987	24	1	1	28000	LGA	BURLINGTON	OREGON
7/6/2011	Ethanol	UN1987	28	1	1	1	LGA	MORRISTOWN	INDIANA
7/19/2011	Ethanol	UN1987	10	1	1	366	LGA	AURORA	SOUTH DAKOTA
10/7/2011	Ethanol	UN1987	34	10	1	143534	LGA	TISKILWA	ILLINOIS
2011 Total				44 cars	6 cars	1006741	LGA		
1/6/2012	Ethanol	UN1987	44	5	1	2.25	LGA	WESTVILLE	INDIANA
6/1/2012	Ethanol	UN1170	25	2	1	40099	LGA	OAKLAND CITY	INDIANA
7/11/2012	Ethanol	UN1987	23	3	1	53347	LGA	COLUMBUS	OHIO
8/5/2012	Ethanol	UN1987	23	12	1	245336	LGA	PLEVNA	MONTANA
11/30/2012	Ethanol	UN1987	8	1	1	1	LGA	PAULSBORO	NEW JERSEY
12/30/2012	Ethanol	UN1987	15	1	1	16000	LGA	MOUNT VERNON OUTLAND AIRPORT	ILLINOIS
2012 Total				24 cars	6 cars	354785	LGA		
3/27/2013	Crude Oil	UN1267	40	3	1	15000	LGA	PARKERS PRAIRIE	MINNESOTA
5/23/2013	Crude Oil	UN1267	23	0	1	0	LGA	BEAR CREEK	ALABAMA
7/17/2013	Ethanol	UN1170	28	1	1	1	LGA	BUFFALO	NEW YORK
10/21/2013	Crude Oil	UN1267	20	1	1	1	LGA	SMITHBORO	ILLINOIS
11/7/2013	Crude Oil	UN1267	39	25	1	455520	LGA	ALICEVILLE	ALABAMA

Table B1: Mainline Derailments of Crude Oil and Ethanol from 2006-2013
Geographic locations of mainline crude oil and ethanol rail accidents in the United States (2006-2013)

12/30/2013	Crude Oil	UN1267	42	18	1	474936	LGA	CASSELTON	NORTH DAKOTA
2013 Total				48 cars	6 cars	945458	LGA		
1/20/2014	Crude Oil	UN1267	7	0	1	0	LGA	PHILADELPHIA	PENNSYLVANIA
1/31/2014	Crude Oil	UN1267	45	4	1	90000	LGA	NEW AUGUSTA	MISSIPPI
2/11/2014	Ethanol	UN1987	10	1	1	25	LGA	JACKSONVILLE	FLORIDA
2/13/2014	Crude Oil	UN1267	31	4	1	10000	LGA	VANDERGRIFT	PENNSYLVANIA
4/30/2014	Crude Oil	UN1267	23	2	1	30000	LGA	LYNCHBURG	VIRGINIA
5/9/2014	Crude Oil	UN1267	9	1	1	7932	LGA	EVANS	COLORADO

Table B2: Major Crude Oil/Ethanol Train Accidents in the U.S. and Canada (2006-2014) used in tank car modeling

Incident	Date	Tank Cars Derailed	Lost Containment	Cars Punctured	Speed at Derailment	Puncture only breach	SE only breach	Material	Product loss	Shell Puncture	Top Head Puncture	Bottom Head Puncture	Top fittings damage	BOV Damage	Thermal Damage	CPC1232	CPC-1232 w/ jacket	legacy
LaSalle, CO	May-14	5	1	0	9	0	1	Crude Oil (unit)	<5,000	0	0	0	1	0	0	0	0	5
Lynchburg. VA	May-14	17	2	1	23	1	1	Crude Oil (unit)	30,000	1	0	0	1	0	0	13	0	4
Vandergrift, PA	Feb-13	21	4	1	30	1	3	Crude Oil, LPG	10,000	1	0	0	2	1	0	0	0	18
New Augusta, MS	Jan 2014	20	9	5	45	4	0	Crude Oil (unit)	90,000	1	1	3	0	0	0	0	13	0
Plaster Rock	Jan 2014	9	2	2	47 (EB)	2	0	LPG, Crude Oil	~30,000	0	1	1	0	1	0	1	2	2
Casselton, ND	Dec 2013	20	18	18	42	3	0	Crude Oil (unit)	476,436	13	3	4	10	3	3	0	0	
Aliceville, AL	Nov 2013	26	20	16	38	2	1	Crude Oil (unit)	350,000	12	4	9	18	0	4	0	0	
Lac-Mégantic	July 2013	63	59	55	65	-	-	Crude Oil (unit)	1,580,000	33	10	16	20	7	4	0	0	

Plevna, MT	Aug 2012	17	11	2	25	2	1	Ethanol	245,336	1	0	1	0	0	6	0	0	
Columbus, OH	July 2012	3	3	1	23	1	0	Ethanol	53,347	0	1	0	0	0	2	0	0	
Tiskilwa, IL	Oct 2011	10	7	4	34	2	0	Ethanol	143,534	2	0	3	3	1	3	0	0	
Arcadia, OH	Feb 2011	31	31	23	46	14	4	Ethanol (unit)	834,840	16	6	7	16	2	5	0	0	
Rockford, IL	June 2009	19	12	10	36	10	2	Ethanol (unit)	232,963	4	4	5	2	1	0	0	0	
Luther, OK	Aug 2008	8	8	2	19	3	4	Crude Oil		3			4		1			
Painesville, OH	Oct 2007	7	2	1	48	1	1	Ethanol	76,153	1	0	0	1	0	0	0	0	
New Brighton, PA	Oct 2006	23	19	11	37	5	7	Ethanol (unit)	485,278	5	3	6	14	0	1	0	0	

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Appendix C: Lac-Mégantic Accident Non-Fatalities Potential Damage Estimates

On July 6, 2013, a catastrophic railroad accident occurred in Lac-Mégantic, Quebec, Canada when an unattended freight train containing crude oil rolled down a descending grade and subsequently derailed. The derailment resulted in multiple releases and subsequent fires, which caused the confirmed deaths of forty-seven individuals. In addition, according to many news reports this derailment caused extensive damage to the town, the destruction of over 30 buildings and approximately half of the downtown area, a release of hazardous materials that would require clean-up costs, and the evacuation of approximately 2,000 people. Although the event took place in Canada, PHMSA believes it presents a unique data point that can be used to characterize the magnitude of a potential future catastrophic event that could occur in the U.S.

The costs of the Lac-Mégantic train accident are still being estimated as cleanup and reconstruction efforts continue and lawsuits and insurance cases still need to be resolved. Therefore, it probably won't be possible to obtain a final tally for several more years. PHMSA compiled different costs reported in the media, and have developed estimates of other costs on our own in order to produce and a very rough preliminary estimate of what we think the final cost of such an occurrence might be. These costs consist of property damage to the town, environmental and other cleanup costs, the costs associated with re-routed train traffic, evacuation and emergency response costs, and the value of the rail cars and oil that was lost. These costs exceed $450 million and include about $200 million in property damage and $200 million in environmental cleanup, as seen in the table below:

Inputs into Non-Fatalities Damages Estimates[234]

[234] Note: Estimates based on analysis of Waybill data, where products are sourced and where they go, and train routes to estimate diverted traffic volumes through Lac-Mégantic. The figures reflect the marginal increase in transportation costs. Network effects are assumed to be marginal given the low volume of trains on the particular track that runs through Lac-Mégantic.

Cost Item	Units	Number of Units	Cost per Unit	Total Cost	Notes and Sources
Evacuation	Person Days	8400	217	$1,822,800	1200 people at 3 days, 800 people at 6 days, exlcudes long-term living costs for people whose homes were damaged
Emergency Response	Person Hours	7200	50	$360,000	150 firefighters (http://newsinfo.inquirer.net/439937/at-least-80-missing-in-canada-train-blaze-firefighter), assume 48 hours per person, assume $50 per hour including benefits and overhead
Property Damage and Survivor assistance to town				$200,000,000	Bangor Daily News, Oct 14, 2013
Environmental Cleanup				$400,000,000	http://www.thestar.com/news/canada/2014/06/16/quebec_claims_400_million_for_lacmgantic_train_disaster.html
Loss of Tank Cars	Number	74	115,000	$8,510,000	Assume all tank cars unusable
Loss of Product	Barrels	44,982	92	$4,138,344	$85 per barrel for Bakken Crude + $7 for transportation (from waybill), 714 barrels per tank car, 63 cars destroyed
Delay/Reroute Crude from Bakken	Barrels	9,510,480	4.2	$39,944,016	74 cars per day: assuming large daily shipments to Irving refinery based on Dec 26 2012 Bloomberg News article "Irving Refinery Said to Get 90,000 Barrels a Day by Rail": http://www.bloomberg.com/news/2012-12-26/irving-refinery-said-to-get-90-000-barrels-a-day-by-rail.html; 714 barrels per car (AAR), 6 months since accident happened, 30 days per month, 4.2 dollar rail differential on crude shipped from Alberta vs Bakken (waybill). Within 6 days of the accident, Irving was already rerouting Bakken crude through Southern Maine and (Pan Am Railway) and on CN tracks (CBS News - New Brunswick, July 12). The total cost increase should not exceed $4.2 per carload as Irving would just switch to using Alberta oil instead of Bakken oil at that point.
Dealy/Reroute Lumber from New Brunswick	Carloads	1,500	1000	$1,500,000	Waybill, cost increase based on figure reported by Lumber shipper who cited $500-$1500 per carload increase (WLBZ2 News, Augusta Maine, July 31)
Dealy/Reroute Other products Canada to Maine	Carloads	2,000	1000	$2,000,000	Waybill, cost increase based on figure reported by Lumber shipper who cited $500-$1500 per carload increase (WLBZ2 News, Augusta Maine, July 31)
Total Costs to Date				$658,275,160	

Appendix D: HCE Model – Calculation of Population Density and Wetland Damages

Population Density Calculation

1) We selected appropriate records from the Confidential Surface Transportation Board 2012 Waybill Sample using Surface Transportation Commodity Codes "1311110" for crude oil and "28184" for ethanol.
2) We assigned selected fuel waybill records to a routable rail network (scale 1:100,000) based on railroad ownership, trackage rights, and historical route densities. We identified all crude and ethanol rail corridors within the United States. The resulting rail fuel network includes all originating, terminating, and intermediate stations (nodes) and all rail links traversed by fuel cars. The process identified 20,420 rail links totaling 36,500 railroad miles. Rail link length ranged from 0.005 to 25 miles, with average link length at 1.8 miles. Over 10,500 rail links are less than one-mile long.
3) The 2010 Census Block data provides GIS population data down to the block level and includes over 11 million records. A one-kilometer-wide buffer zone (1/2 kilometer on either side of the track) was imposed over the fuel rail network using GIS software. A half kilometer on either side was chosen to reflect the impact zone for the Lac-Mégantic incident.[235] Then the Census Blocks that overlap with that buffer zone are identified. Density was calculated for each Block by dividing population by the area, which yields the population per square km.
4) For Census Blocks that include an entire rail link, the population density of that Block was applied to the rail link. For rail links that include more than one Census Blocks, the population density along the rail link is taken as a weighted average of the population density of the Census Blocks—the weighting is for the proportion of the rail link's buffer zone area that each Census Block occupies.
5) For verifications, these results were compared to Census maps and 2006 Census Track Data.

[235] http://www.bloomberg.com/news/2013-07-06/train-carrying-crude-derails-in-quebec-town-sparking-explosions.html. This article reports that explosions and fires were concentrated in an area about one square kilometer, which indicates that a half-kilometer on either side of the track is a reasonable assumption. PHMSA used measurements taken with GIS of the blast area showing a radius of .37 km and a new diameter of .49 km with a significant portion of all the damage occurring on one side of the track. At the time of this analysis PHMSA does not have access to another tool such as georeferenced imagery to more accurately determine the blast area. Thus, PHMSA maintained that a half-kilometer on either side of the track is a reasonable assumption to reflect the impact zone.

Costs of Wetland Damages

With regards to wetlands, the majority of the cost documentation relates to the restoration costs of the impacted wetlands rather than just the cleanup costs. There was one report related to a 1973 oil spill that broke down cleanup costs, but more recent documentation of incidents, specifically in the post Oil Pollution Act of 1990 era, focus on restoration costs. Below is a list of examples of oil spills where damage to wetlands was significant and the damage was also documented in the damage assessment and settlement documents, and a table calculating the per gallon costs for wetland damages of each incident.

Incident Examples:

1. **Motor Vessel Westchester Grounding in 2000:** The vessel grounded along the Mississippi River, releasing approximately 500,000 gallons of crude oil. The responsible party did not pay the natural resource trustees for restoration of the impacted area, but rather took the projects on themselves and acquired contractors to complete the restoration projects. However, the responsible party did have to pay the federal and state government a total of $968,175 ($1,204,432 in 2014 dollars)[236] for the response costs incurred from the oil spill.

2. **Equinox Well Spill in 1998**: An oil well belonging to the Equinox Oil Company released approximately 63,000 gallons of oil into Lake Grande Ecaille and the Gulf of Mexico. As a result over 1,200 acres of wetlands in Louisiana were exposed to oil. In 2006, a settlement of $1.2 million ($1,365,867 in 2014 dollars)[237] was awarded to trustees of the damaged wetlands.

3. **The Apex Barge Spill in 1990**: A tanker vessel collided with the Apex tank barges, spilling approximately 694,000 gallons of partially refined crude. The spill impacted shorelines, birds, and marsh wetlands. In 1994 the trustees responsible for the natural resources that were damaged by the oil spill agreed on a settlement of $1.3 million dollars ($1,899,427 in 2014 dollars).[238] The settlement was used to fund four wetland restoration projects, which collectively developed 298 acres of new wetlands and marsh areas. This translates to a per acre restoration cost of $4,362 ($6,374 in 2014 dollars).

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[236] The settlement was finalized in 2003, therefor the cost estimates were converted using the GDP deflator, where deflator index for 2003 is 86.754.

[237] Cost estimates were converted using the GDP deflator, where deflator index for 2006 is 94.818.

[238] Cost estimates were converted using the GDP deflator, where the deflator index for 1994 is 73.865 and for 2014 it is 107.924 (US Dollar Implicit Price Deflators for Gross Domestic Product 1929-2014, 2009=100, BEA).

4. **The Zoe Colocotroni Spill in 1973**: Occurred 3 miles off the shore of Puerto Rico, spilling approximately 50,000 barrels of crude oil. Cost claims for the spill with regard to wetlands and wildlife were broken down as follows:

1) Direct cost of removing dead and dying mangrove trees and removing and replacing soiled sediments = $7.17 million ($29.35 in 2014 dollars)[239]
2) Direct cost of replanting 23 acres (where the mangrove trees were removed) = $0.56 million ($2.29 in 2014 dollars)
3) Direct cost of environmental damages for marine animals killed = $5.5 million ($22.51 in 2014 dollars)
4) Direct cost of a scientific evaluation/assessment of the long term effects of the environmental damages the spill created = $1.39 million ($5.69 in 2014 dollars)

The costs of the lost wildlife was estimated using a replacement cost method, which estimates the cost of replacing damaged wildlife (biota) based on the price lists from firms that supply labs and zoos with those plants/animals. However, it is noted that the replacement cost method may overestimate costs of wildlife because the costs paid by labs and zoos includes/accounts for transport and collection costs, and in most cases a level of profit for the supplier.

Table D1. Per gallon Cost Estimates of Wetland Oil Spills*

	Gallons Spilled	Costs (in 2014 $)	Cost per gallon (total spill volume)	Cost per gallon (50% spill volume)
Westchester	500,000	$1,204,432	$2.41	$4.82
Equinox	63,000	$1,365,867	$21.68	$43.36
Apex Barge	694,000	$1,899,427	$2.74	$5.47
Zoe Colocotroni	2,100,000	$54,150,000[240]	$25.79	$51.57

*Note: these are likely underestimating the cost per gallon, as not all gallons of the spills directly affect wetlands, but the estimate for the percent of oil from a spill that directly impacts wetlands is not known. However, in an analysis conducted by Mark Cohen, he breaks down the impact of deepwater oil spills on various natural resources and industries. The study estimates that for any given oil spill, on average 59.7 percent of the spill directly impacts the fishing industry (e.g. if 100 gallons were spilled, 59.7 gallons of oil would impact fishing), 51.5 percent of the spill directly impacts the water supply, 16.5 percent of the spill directly impacts bird wildlife in the

[239] Cost estimates were converted using the GDP deflator; where the deflator index for 1973 is 26.366.

[240] Does not include the long term effect costs, since those are not part of the cleanup costs.

area of the spill, and 0.7 percent of the spill directly impacts recreational activities[241]. Since his focus was on deepwater, wetlands are not one of the categories, however, it provides some evidence that we can assume approximately 50 percent of an oil spill would directly impact any one resource. Thus, the cost per incident is estimated at $14.7 million.[242]

NOAA's Habitat Equivalency Analysis (HEA) Model: a methodology established to determine the claims for damages to natural resources resulting from "discharges of oil, releases of hazardous substances, or physical injury." This model estimates the restoration costs of wetlands and other natural resources, rather than the explicit cleanup costs. Specifically, "In the case of a wetland damaged by an oil spill, an HEA would not necessarily estimate or value the damages to the wetlands or its services; instead, it calculates the natural resource service losses in discounted terms and then determines the scale of restoration projects needed to provide equal natural resource service gains in the future in discounted terms, thereby fully compensating the public for the natural resource injuries."[243]

It is noted that this method is now preferred over the replacement cost method, which was the common approach prior to the Oil Pollution Act of 1990. All oil spill events described above (except the Zoe Colocotroni spill, which occurred prior to 1990) used the HEA model to estimate restoration needs in the filed settlements.

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[241] Cohen, Mark. "The Costs and Benefits of Oil Spill Prevention and Enforcement." Journal of Environmental Economics and Management, 1986: 167-188.

[242] $14, 654931.5 = $58,619,726/4

[243] Barbier, Edward B. "Coastal Wetland Restoration and the Deepwater Horizon Oil Spill." Vanderbilt Law Review 64, no. 6 (2011): 1821-1849.

Appendix E: Cost Effectiveness Calculations and Methodologies

This document will describe the methodologies and calculation used to determine effectiveness of the proposed tank car and operational enhancements proposed in the final rule (HM-251). This document is divided into the following 5 sections.

Section 1: Calculation of most probable number of cars punctured based on tank car enhancements, brake system, and speed
Section 2: Intermediate specifications
Section 3: Thermal protection effectiveness
Section 4: Definition of "unit train"
Section 5: Equivalency of 20-car block and 35 cars throughout at consist

Section 1: Calculation of most probable number of cars punctured based on tank car enhancements, brake system, and speed

The benefit of the tank car enhancements, brake systems, and speed were evaluated using the calculated values for most probable number of tank cars derailed and punctured. Sharma & Associates, Inc. using a purpose built model calculated these values for FRA.[244] The parameters evaluated by the purpose built model are provided in Table AE1.

Table AE1: Parameters evaluated in the FRA's purpose built model

Parameter category	Subcategory	Description
Tank Car Enhancements	Legacy DOT-111	7/16" A516-70, non-jacketed
	DOT-111 (CPC1232)	7/16, TC-128, jacket, thermal protection, head shield
	DOT-117 (retrofit)	8/16", TC-128, jacket, thermal protection, head shield
	DOT-117 (new)	9/16", TC-128, jacket, thermal protection, head shield
Brake System	Conventional	End-of-train device
	TWEOT (for brake pipe induced emergency, TWEOT is equivalent to a distributed power locomotive at the rear of the train)	Two-way end-of-train device capable of initiating emergency from the rear based on signal from lead locomotive
	DP 2/3	Distributed power locomotive at a location at or near 2/3

[244] Sharma and Associates, Inc. Letter Report submitted to FRA March 2015.

Table AE1: Parameters evaluated in the FRA's purpose built model		
		back in the consist from the lead locomotive
	ECP (NBR 12%)	Electronically controlled pneumatic brakes with a set net brake ratio of 12%. This is the same brake ratio as Conventional, TWEOT and DP 2/3 systems in the purpose built model.
	ECP (NBR 14%)	Electronically controlled pneumatic brakes with a set net brake ratio of 14%. Maximum allowed by the AAR Standards and Recommended practices.
Speed	50 mph	Proposed maximum speed
	40 mph	Proposed maximum speed in High Threat Urban Areas
	30 mph	Speed in the range at which most of derailments under consideration in this rulemaking occurred.

The intent of the evaluation was to consider the effect of the location of derailment within the train on the resulting number of cars punctured. Accordingly, results of simulations of derailments at locations with 100 cars trailing, 50 cars trailing and 20 cars trailing were used to develop trend lines that allowed for consideration of a derailment at all location in the train (Figure 1). For this analysis a polynomial line fit was assumed.

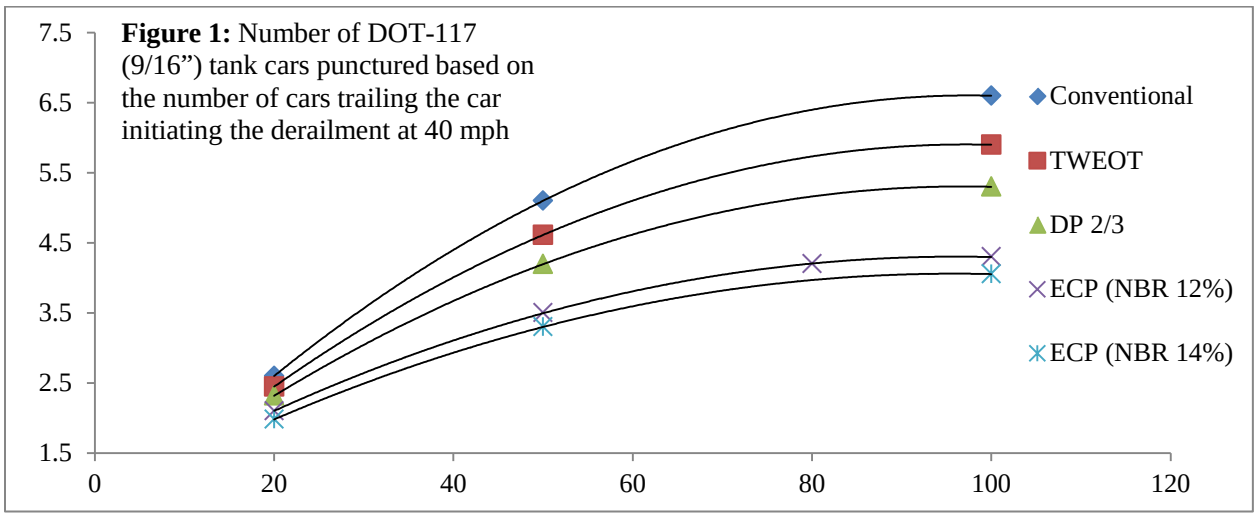

Figure 1: Number of DOT-117 (9/16") tank cars punctured based on the number of cars trailing the car initiating the derailment at 40 mph

Figure 2 summarizes the FRA data (Jan. 2000 - Nov 2014) of all freight train derailments. This will include all commodities, all car types and derailments from all causes indicating the location

of first car derailed in the first 100 cars of a train. The data provided below accounts for 96% of all the incidents. To facilitate calculations the data was organized into bins. Each bin is comprised of five sequential cars. For example, the first bin has cars 1-5, or cars with 100 (inclusive) through 96 cars trailing the point of derailment.

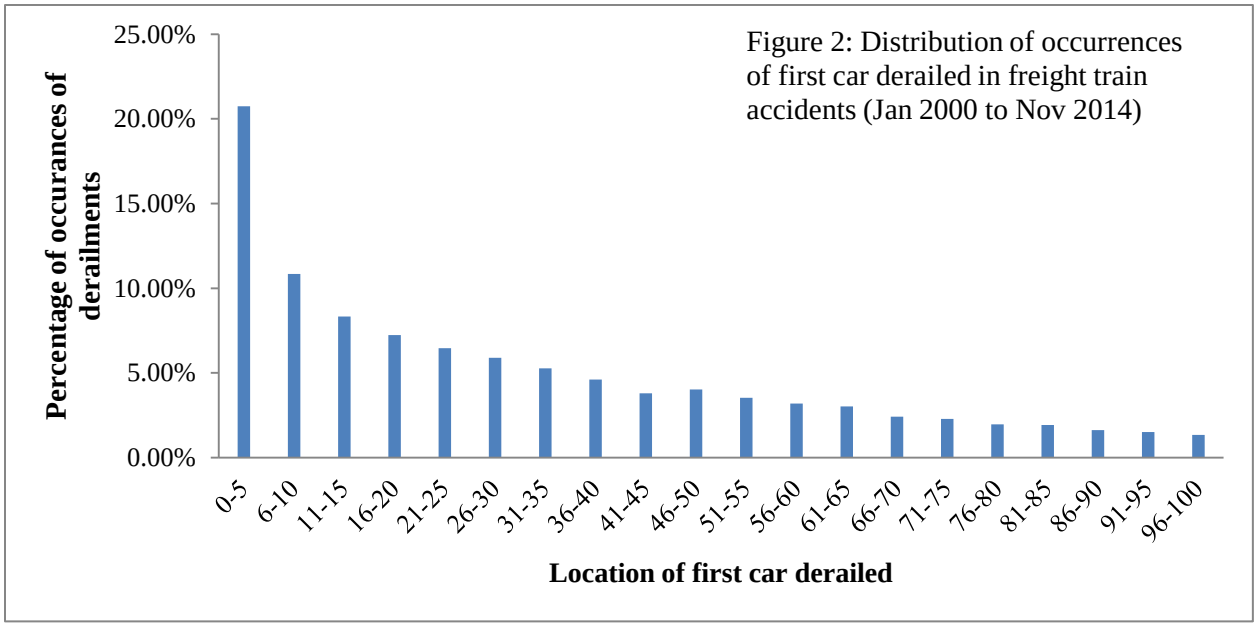

Figure 2: Distribution of occurrences of first car derailed in freight train accidents (Jan 2000 to Nov 2014)

The most probable number of cars punctured was calculated for the first and last car in each bin and the average was taken. An example of this calculation for the DOT-117 in a train equipped with a two-way end-of-train device and derailing at 40 mph is provided in Equation 1.

$$Puncture_a = ((-0.000585{x_l}^2 + 0.113x_l + 0.424) + \left(-0.000585{x_f}^2 + 0.113x_f + 0.424\right))/2 \quad (1)$$

Where x_f and x_l are the locations of the first and last cars in bin a.

The number of cars punctured for a particular bin is multiplied by the percentage of derailments that occur at locations within each bin. These values are summed for the 100 car train to provide the most likely number of DOT-117 tank cars punctured in a train equipped with EOT brakes that derails at 40 mph. These calculations are made according to Equation 2:

$$CP_{i,j,k} = \sum_{a-1}^{20} Puncture_a * P_a \quad (2)$$

Where $CP_{i,j,k,}$ is the calculated number of cars punctured, P_a is the probability of a derailment at a location within bin a (shown in Figure 2) . This number will be dependent on tank car specification (i), brake system (j), and initial speed (k). An example of the calculation for a DOT-117, TWEOT braking, at 40 mph is provided in Table AE2.

Table AE2: Example calculation of most probable number of car punctured (DOT-117, TWEOT brakes, 40 mph)					
			Polynomial Coefficients		
			-0.00058	**0.113**	**0.424**
Bin	Cars trailing point of derailment		Calculated per (1)	Calculated per (2)	
1	100	95	5.92	1.23	
2	95	90	5.91	0.64	
3	90	85	5.87	0.49	
4	85	80	5.80	0.42	
5	80	75	5.69	0.37	
6	75	70	5.56	0.33	
7	70	65	5.41	0.28	
8	65	60	5.22	0.24	
9	60	55	5.00	0.19	
10	55	50	4.75	0.19	
11	50	45	4.48	0.16	
12	45	40	4.18	0.13	
13	40	35	3.84	0.12	
14	35	30	3.48	0.08	
15	30	25	3.09	0.07	
16	25	20	2.67	0.05	
17	20	15	2.22	0.04	
18	15	10	1.74	0.03	
19	10	5	1.24	0.02	
20	5	0	0.70	0.01	
			Most probable number of cars punctured	5.09	

A similar analysis was performed for each tank car specification, brake system and speed presented in the Braking section of the Final Rule, Table BR5:

Table AE3 shows the results of the analysis for the DOT-117 tank car.

Table AE3: Results of calculation to determine the most probable number of cars punctured for the DOT-117 considering different brake systems and speeds			
Tank Car	**Brake System**	**Speed (mph)**	**Most Probable number of cars punctured**
DOT-117	Conventional	30	2.81
		40	5.64
		50	7.82
	TWEOT	30	2.35
		40	5.09
		50	6.57
	DP2/3	30	2.43
		40	4.66

Table AE3: Results of calculation to determine the most probable number of cars punctured for the DOT-117 considering different brake systems and speeds			
		50	6.77
	ECP (12% NBR)	30	2.15
		40	3.78
		50	6.01
	ECP (14% NBR)	30	2.02
		40	3.57
		50	5.63

Section 2: Intermediate specifications

An intermediate specification is one that has not been specifically modelled in the Sharma simulations or related analyses. In order to determine the benefit of the tank cars proposed in the final rule, we needed to determine the most probable number of cars punctured for the intermediate specification tank car. The following describes the methodology used to develop those results.

Table AE4 provides the calculated number of tank car punctures for a variety of tank car configurations that include the enhancements considered in this final rule; grade of steel, additional thickness of shell and head, 11-gauge jacket, and ½" thick full height head shield. These calculations used the same force distribution of the 18 derailments described in the Sharma letter report. This analysis assumed a 40-mph derailment speed and the train being equipped with conventional and ECP brakes. The brake system under consideration bound the expected range of performance. This analysis is intended to determine the contribution of the enhancement on an individual basis, not the effectiveness of the brake system.

Table AE4 Results of analysis of alternative designs to determine the contribution of safety enhancements to the reduction in the most probable number of cars punctured			
100 Cars Behind POD at 40 mph		**Probable No. of Punctures**	
Tank Type		**Conventional Brakes**	**ECP Brakes**
Alternative 0	7/16" A516-70, no jacket, no head shield	13.7	9.8
Alternative 1	7/16" TC128, 11 gauge jacket, 1/2" full-height head shield	8.0	5.3
Alternative 1a	7/16" TC128, 11 gauge jacket, no head shield	12.2	8.6
Alternative 1b	7/16" TC128, no jacket, 1/2" full-height head shield	8.7	5.8
Alternative 1c	7/16" TC128, no jacket, no head shield	12.9	9.2
Alternative 3	9/16" TC128, 11 gauge jacket, 1/2" full-height head shield	6.6	4.3
Alternative 3a	9/16" TC128, 11 gauge jacket, no head shield	10.0	6.8
Alternative 3b	9/16" TC128, no jacket, 1/2" full-height head shield	7.2	4.8

Alternative 3c	9/16" TC128, no jacket, no head shield	10.6	7.3

Table AE5 indicates the contribution of each enhancement to the reduction in the number of punctures to tank cars involved in the derailments specified above. The calculated number of cars punctured for each of the Alternatives in Table AE4 was then used to calculate the reduction attributed to each enhancement.

The values in Table AE5 were calculated as follows using the values from Table AE4. Alternatives 0 and 1 are constructed of different steel. The contribution of the steel (C_s) was calculated according to (3).

$$C_s = P_b - P_{1c} \qquad (3)$$

Where P_b is the most likely number of car punctured for the Alternative 0 in Table AE4 and P_{1c} is the most likely number of cars punctured in Alternative 1c in Table AE4.

The contribution of the jacket and head shield ($C_{J/HS}$), head shield (C_{HS}), and jacket (C_J) for the 7/16" tank operating with conventional brakes were calculated per (4), (5), and (6).

$$C_{J/HS} = P_b - P_1 - C_s \ (4)$$

$$C_{HS} = P_b - P_{1b} - C_s \ (5)$$

$$C_J = P_b - P_{1a} - C_s \ (6)$$

Where P_1 is the most likely number of cars punctured for Alternative 1, P_{1b} is the most likely number of cars punctured in Alternative 1b, and P_{1a} is the most likely number of cars punctured in Alternative 1a in Table AE4. All of the other (rounded) values in were calculated in a similar manner.

Table AE5: Contribution of enhancements to the reduction in the calculated number of cars punctured at 40 mph

	Tank Component	Likely % Reduction in No. of Punctures	
		Conventional Brakes	ECP Brakes
7/16" tank	jacket and full height head shield	4.9	3.9
	head shield	4.2	3.3
	jacket	0.7	0.5
	TC128B over A516-70	0.8	0.6
9/16" tank	jacket and head shield	4.0	3.0
	head shield	3.4	2.5
	jacket	0.6	0.5
	TC128B over A516-70	0.8	0.6
	from 7/16" to 9/16", TC128B	2.3	1.9

Table AE6 indicates the percent reduction in number of cars punctured for each enhancement. The percentages were used to calculate both the benefits of adding enhancement to a legacy DOT-111 specification car and removing enhancements from the other car specifications indicated in Table BR5:

Table AE6: Relative reduction in the number of cars punctured for individual tank car enhancements in 40-mph derailments

	Tank component	Conventional Brakes	ECP Brakes
7/16" tank	puncture reduction of Alternative 1 compared to Alternative 0	5.7	4.5
	head shield	Overall Percent Reduction	
		74%	73%
	Jacket	12%	11%
	stronger material, TC128B over A516-70	14%	13%
9/16" tank	puncture reduction of Alternative 3 compared to Alternative 0	7.1	5.5
	head shield	Overall Percent Reduction	
		48%	45%
	Jacket	8%	9%
	stronger material, TC128B over A516-70	11%	11%
	thicker tank wall: from 7/16" to 9/16", TC128B	32%	35%

For the purpose of an analysis the values for the half-inch thick shell is the average of 7/16” and the 9/16” values. To date only the specifications as outlined in Table BR5 have been considered in the benefits analysis. These values were used to calculate the benefits of the DOT-117 (new and retrofit) to a variety of existing cars.

The final rule proposes the DOT-117 (both retrofit and new) as indicated in Table BR5:

The effectiveness of these tank cars was calculated relative to four existing tank car specifications described in Table AE7.

Table AE7: Existing Tank Car Specifications

Tank Car Specification	Shell Material	Shell/Head Thickness	Jacket	Head Shield
DOT111	TC-128	7/16"	no jacket	no HS
CPC1232	TC-128	8/16"	no jacket	Half
Jacketed DOT111	TC-128	7/16"	jacket	no HS
Jacketed CPC1232	TC-128	7/16"	jacket	Full

The intermediate specifications include the DOT-111 constructed to the CPC-1232 Non-jacketed standard (equipped with a half-height head shield) and a legacy Jacketed DOT-111 (constructed of TC-128) (Table AE8, line 1). In order to calculate the benefit of the proposed tank car specifications (new and retrofit) relative to the intermediate specification, the most probable number of intermediate standard tank cars punctured was calculated as follows.

1) The base car is Alternative 0 in Table AE4 . These calculations of punctures of intermediate specification tank cars are relative to Alternative 0 (Table AE8, line 2 and 3).

2) Determine the most probable number of cars punctured for a tank car specification that has the same shell thickness as the intermediate specification car but also has all of the safety enhancements (high grade steel, jacket, and head shield). This will be referred to Base 2 car (Table AE8, lines 4 and 5).

3) The difference in the number of cars punctured is a result of the differences in the values of between the Base and Base 2 car (Table AE8, line 6).

4) Take account of the differences between the features of Base 2 car and the intermediate specification car (Table AE8, lines 8-12). These will be the steel specification and/or jacket and/or head shield. These features correlate to a respective contribution indicated in Table 4 for 7/16" and 9/16" thick tank cars. As indicated above the values for the 8/16" car are the average of the values indicated in Table AE7. The sum of the contribution of features (Table AE8, line 12) is multiplied by the difference in the cars punctured between the Base Car and Base Car 2 (Table AE8, line 6). This value (Table AE8, line13) is added to Base Car 2 to give the number of cars punctured of the intermediate specification car (Table AE8, line 14).

Table AE8: Calculation Summary			
1	Intermediate car	CPC-1232 (1/2 HS)	DOT-111(J)
2	Base car	DOT-111 legacy	DOT-111 legacy
3	Cars punctured	10.45	10.45
4	Base Car 2	CPC1232 (TC128, 8/16", J, HS)	CPC-1232 (TC128, 7/16", J, HS)
5	Cars Punctured	6.17	6.68
6	Difference in cars punctured	4.67	4.16
7	Features removed from Base Car 2		
8	Head shield	0.31 (1/2 HS Contribution)[245]	0.56 (1/4 HS Contribution)[246]

[245] The contribution of a half-height head shield is assumed to be half that of a full height head shield. This is based on derailment data which indicates that the head punctures are equally distributed between top and bottom halve of the tank head.

Table AE8: Calculation Summary			
9	jacket	0.1	0
10	Material	0	0
11	Thickness	0	0
12	Total	0.41	0.56
13	Adjustment of cars punctures	1.91	2.31
14	Corrected cars punctured	8.08	8.99

Using the calculated value of the most probable number of cars punctured for the intermediate specification tank cars as well as those explicitly modeled the effectiveness of the proposed cars relative to the existing cars ($E_{p/e}$) were calculated per (7).

$$E_{p/e} = 1 - \frac{CP_{i,j,k}}{CP_{i,j,k}} \quad (7)$$

The results are summarized in Table AE9.

Table AE9: Effectiveness regarding puncture resistance of proposed cars relative to existing specifications equipped with TWEOT and operating at 40 mph.		
	Cars punctured	**Effectiveness**
DOT-117 (new)	5.66	0
DOT-111	10.45	0.448
CPC-1232	8.08	0.299
DOT-111 (J)	8.99	0.370
CPC-1232 (J)	6.17	0.152
DOT-117 (retrofit)	6.17	0
DOT-111	10.45	0.398
CPC-1232	8.08	0.236
DOT-111 (J)	8.99	0.314
CPC-1232 (J)	6.17	0

Section 3: 100-Minute Thermal Protection[247]

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[246] The contribution of the jacket head is assumed to be a quarter of the full height head shield. This is based on the jacket head being a quarter of the thickness of the head shield.

[247] Thermal protection prevents release of lading from anywhere on the tank other than the pressure relieve device during exposure to a 100 minute pool fire or 30-minute torch fire.

The benefit of thermal protection is prevention of the thermal tear and high-energy (separation) events.[248] It is assumed the thermal protection system required will prevent these events. In other words a thermal protection system will basically provide 100% benefit for 100 minutes.[249] However, the benefit is only realized in derailments in which a portion of the cars does not lose containment in the derailment and which involve fire. This is a small percentage of the cars. Accordingly, the portion of derailed cars benefiting from thermal protection (P_{TP}) is calculated using (8).

$$P_{TP} = \left(\frac{Incident\ involving\ fire}{total\ incidents}\right) \times \left(\frac{no\ loss\ of\ containment}{total\ car\ involved}\right) \times \left(\frac{cars\ with\ thermal\ damage}{cars\ derailing\ no\ loss\ of\ containment}\right) \quad (8)$$

The data used for this calculation is provided in Table AE10. The calculated value of 3.36 is applied to the number of cars derailed but not punctured.

Table AE10: Data Related to Thermal Damage	
Events (Crude oil/EtOH)	46
Events involving fire	13
Cars involved	244
Cars not losing containment	81
Cars with thermal damage	29

The benefit of the thermal protection was allied to the overall tank car benefits by multiplying the effectiveness of the thermal protection, weighted by the expected portion of cares that could be affected, by the difference between the cars derailed and the cars punctured per (9).

$$Benefit\ of\ TP = (Cars\ derailed - cars\ punctured) \times P_{TP} \quad (9)$$

[248] A thermal tear is typically a longitudinal failure that occurs in the portion of the shell surrounding the vapor space of the tank following exposure of the tank to pool fire conditions. The tank shell fails when the pressure in the tank (and resulting tensile or hoop stress) exceeds the tensile strength of the shell material that is diminishing with time of exposure to the pool fire. The length of thermal tears measured during FRA investigations ranged from 2-16 feet. The length of the tear may be a function of the volume of vapor escaping through the failure, flaws in the shell material, and the existence of crack arresters such as welds or stronger, non-heat effected steel.

A separation occurs when a thermal tear propagates circumferentially from each end of the tear and result in the tank completely or nearly fragmenting into multiple pieces.

[249] The 100 minute threshold achieves to things. First, based on research in support of HM-144 the contents of a tank car loaded with LPG and exposed to pool fire condition will be evacuated through the pressure relieve valve in 100 minutes. As such, when a breach of the tank occurs (after 100 minutes) resulting from exposure to the fire the release will have limited energy. Second, 100 minutes is time for first responders to assess the situation and initiate evacuations.

The number of cars derailed was calculated in a manner similar to that used to calculate the number of cars punctured above. These values are independent of tank car specification. The results are provided in Table AE11.

The calculated vales were used in (9).

Table AE1: Most probable number of cars derailed based on initial speed and brake system			
Brakes system	**30 mph**	**40 mph**	**50 mph**
Conventional	14.89	22.90	28.53
TWEOT	14.04	22.11	28.05
DP 2/3	13.21	20.30	26.77
ECP (12% NBR)	12.25	19.08	24.50

This value, *Benefit of TP*, represents the derailed cars that do not lose containment when exposed to pool fire conditions. This number was added to the value of the number of cars punctured in a derailment to tank cars that do not have thermal protection to give the total number of cars losing containment in a derailment.

The benefit of a particular tank car, brake system and initial speed relative to another was calculated in accordance with (10).

$$Benefit_{u/v} = 1 - \frac{LC_{i,j,k}}{LC_{i,j,k}} \quad (10)$$

Where $LC_{i,j,k}$ is the number of cars losing containment (puncture and thermal damage) based on tank car specification (i), brake system (j), and initial train speed (k). The calculations are summarized in Table 12.

Table AE12: Calculation of effectiveness of puncture resistance and thermal protection of existing cars[250] relative to proposed cars equipped with TWEOT operating at 40 mph			
Tank Car Specification	**Cars punctured**	**Total cars loosing containment per (9)**	**Effectiveness**
DOT-117 (new)	5.66	5.66	0
DOT-111	10.45	11.19	0.494
CPC-1232	8.08	8.82	0.358
DOT-111 (J)	8.99	9.73	0.418
CPC-1232 (J)	6.17	6.91	0.181
DOT-117 (retrofit)	6.17	5.66	0
DOT-111	10.45	11.19	0.494

[250] It is assumed that none of the existing cars are equipped with thermal protection.

CPC-1232	8.08	8.82	0.358
DOT-111 (J)	8.99	9.73	0.418
CPC-1232 (J)	6.17	6.91	0.181

Section 4: Definition (length) of a unit train

Polynomial fits to the output from the simulations for 100-, 50- and 20-car trains and for each brake system under evaluation (conventional, TWEOT, DP at 2/3 back in the train, and ECP brakes) were developed. The polynomial fit was used to predict probable number of cars derailed and the number of cars punctured if a derailment occurred at each car location in the train.

The predicted number of cars punctured in a derailment originating at each location in the train was calculated using (11).

$$Puncture_i = (-.000142{x_i}^2 + 0.0753x_i + 1.49) \quad (11)$$

Where x_i is the locations of the car in the train. An example of the calculation for a 100 car train equipped with ECP (15 net brake ratio) operating at a maximum speed of 50 mph is provided in Table AE13.

Following equation (2) the predicted number is weighted by multiplying it by the percentage of derailments at each location in a 100-car train, in order to account for derailment location throughout a train. The scaled number of cars punctured for each location in the train is summed (from car 1 to car 100) to provide a predicted number of cars punctured for a 100-car unit train (Table AE13).

Table AE13: Example calculation to determine the most probable number of cars derailed throughout a train equipped with ECP (12% net brake ratio) and operating at 50 mph

				Coefficients used in (11)		
				-0.000142	0.0753	1.49
Location	Cars trailing	Occurrences of derailment	% of total	Cars punctured	Scaled number of cars punctured	Cumulative
1	99	1254	0.09	7.55	0.66	0.66
2	98	455	0.03	7.51	0.24	0.89
3	97	522	0.04	7.46	0.27	1.16
4	96	412	0.03	7.41	0.21	1.37
5	95	354	0.02	7.36	0.18	1.55
6	94	350	0.02	7.31	0.18	1.73
7	93	324	0.02	7.26	0.16	1.89
8	92	320	0.02	7.22	0.16	2.05
9	91	285	0.02	7.17	0.14	2.19
10	90	286	0.02	7.12	0.14	2.34
						Rows 11-98 deleted

99	1	31	0.00	1.57	0.00	5.96
100	0	31	0.00	1.49	0.00	5.96

We assert that the acceptable risk is a 100-car unit train made up of DOT-117 tank cars (9/16", jacket, head shield, and thermal protection) operating ECP brake mode with a 12-percent-net braking ratio moving at 50 mph. Similar calculations were performed for TWEOT[251] (current practice representing both two-way end-of-train devices and distributed power at the rear of the train) and ECP.

The calculated number of cars punctured in a train operating in ECP mode was 5.96. The length of the train operating in TWEOT mode with the same number of cars punctured was 64 cars. This means that a 64-car train operating in TWEOT mode presents the same risk as a 100-car train operating in ECP mode. A 65-car train in TWEOT poses a greater risk. Accordingly, the threshold can be set so that a train with 65 or more cars containing a flammable liquid must be equipped with ECP brakes and operated in ECP mode.

The largest incremental benefit of this requirement was calculated by subtracting the number of cars punctured in the TWEOT train from the ECP train. The calculated difference was 0.42 cars at 50 mph and 1.31 at 40 mph. It makes sense that the benefits of a brake system with faster brake signal propagation would have higher benefits at lower speeds. For the faster propagation system the brakes are fully applied for a longer time period. As the speed of the train at the time of derailment decreases, the time of full application is a greater percentage of the entire derailment time. This is particularly relevant because the average speed of derailment for the trains considered in this rule is 24.6 mph. In addition, the results presented in this RIA are based on ECP with a net brake ratio of 12 percent. The current AAR standards for ECP brakes allow that ratio to be as high as 14 percent. At that ratio the benefits increase to 0.79 for 50 mph and 1.52 for 40 mph.

Section 5: Equivalency of risk: 20-car block and 35 cars in manifest train

A proposed definition of a HHFT was 20 cars in a block or 35 throughout a train. We assert that the 20-car block represents the acceptable risk for a manifest train. This section describes how we determined the number of tank cars distributed randomly throughout a train that would have the equivalent level of risk to a 20-car block of tank cars.

To perform the calculations the following assumptions were made.

- Data regarding the first car derailed in freight trains provided in Table AE14 was used.
- Assumed a 100-car train

[251] TWEOT is a device that monitors the train line (brake pipe) pressure that is capable of receiving a signal from the lead locomotive and initiating an emergency brake application at the rear of the train.

- Assumed 20 cars derailed

The first step was calculating the risk of a derailment of a train comprised of a single, 20-car block of tank cars loaded with flammable liquids. In order to simplify the calculations, twenty bins of five cars each were created to represent an entire 100-car train. The first car of the 20-car block was placed at the first car of each bin. The 20-car block spanned four consecutive bins. The probability of a derailment at any of the locations within a particular block was calculated using (12).

$$P_m = \sum_{x=z}^{n+4} p_x \quad (12)$$

Where P_m is the probability of a derailment in Block m, p_x is the probability of a derailment at location x, and z is the location within the train of the cars in Block m.

$$P_{FL} = \sum_{m=i}^{i+3} P_m \times 20 \times \left(\frac{4-(m-i)}{4}\right) \quad (13)$$

Where P_{FL} is the probability of a tank car containing a flammable liquid derails, m is the block identifier, i is the initial block in the set of 20 cars that derail. Table AE14 provides the result of the calculation. The column on the right provides the calculated number of cars derailed. The largest number is from a block of cars located at the front of the train. Based on the probability distribution of location of first car derailed, the probable number of cars derailed is 6.5.

Table AE14: Number of cars derailed from a 20-car block based on location of first car in block

Bins	# of incidents	% of total	Block	First	Last	Derailed
0-5	2997	20.74%	1	1	20	6.50
6-10	1565	10.83%	2	6	25	4.13
11-15	1204	8.33%	3	11	30	3.41
16-20	1045	7.23%	4	16	35	3.02
21-25	932	6.45%	5	21	40	2.71
26-30	850	5.88%	6	26	45	2.42
31-35	761	5.27%	7	31	50	2.15
36-40	666	4.61%	8	36	55	1.91
41-45	549	3.80%	9	41	60	1.73
46-50	582	4.03%	10	46	65	1.67
51-55	509	3.52%	11	51	70	1.49
56-60	461	3.19%	12	56	75	1.34
61-65	437	3.02%	13	61	80	1.20
66-70	350	2.42%	14	66	85	1.03
71-75	331	2.29%	15	71	90	0.95
76-80	284	1.97%	16	76	95	0.85
81-85	278	1.92%	17	81	100	0.78
86-90	234	1.62%	18	86	100	0.42
91-95	218	1.51%	19	91	100	0.19
96-100	194	1.34%	20	96	100	0.05

A slightly different set of calculations were performed to determine the number of cars derailed in a manifest trains with tank car containing flammable liquid throughout the train. The same

five-car blocks were established to facilitate the calculations. A unique number generator was developed to list non-repeating numbers between 0 and 100. Numbers 1-35 were designated as representing tank car transporting flammable liquids. Once again, a 20-car derailment at the first car of each 5-car bock was assumed. The numbers of cars (identified as 1-35) were counted for each 20-car derailment occurring at each of the blocks in the train. For example, after refreshing the unique number (with numbers 1-35 highlighted), the number of highlighted cars in the twenty cars after each point of derailment was counted. For each block (point of derailment) the number of flammable liquid cars in the trailing 20 cars was recorded. This was repeated five times for 35 flammable liquid cars in the train and five times for both 40 and 45 cars in the train. The probability of a flammable liquid car derailed was calculated using (26).

$$P_{FL} = \sum_{i=1}^{20} P_{d\ (i)} \times N_i \quad (14)$$

Where P_d is the probability of a derailment initiating in the ith block, N_i is the number of flammable liquid cars counted in the 20 cars following the point of derailment. The results are summarized in Table AE15.

Table AE15: Results of calculations for manifest trains

Train	Flammable liquid cars derailed
20-car block (head end)	6.5
35 cars	6.32
40 cars	8.81
45 cars	8.66

Appendix F: Count Model for Low Consequence Events

Many historical models of oil spills develop probabilistic estimates of oil spill occurrence. Frequently, researchers have modeled spill occurrence as a Poisson process.[252,253,254] In these models, a stochastic process *N(t)* is a counting process if *N(t)* represents the total number of events that have occurred up to time *t*. These models generally model spills as a function of oil handled, or similar variables such as number of trips.

Instead of spills we are modelling derailments that can lead to spills. To do so, we also employ a count model. We can use these models when the dependent variable (y) takes integer values that represent the number of events that occur. In these cases, the dependent variable assumes discrete values, but is not a categorical value. Classic examples include the number of accidents on a pipeline. In the pipeline case, an explanatory variable could be the amount of product shipped. In such a case, a Poisson regression model would be appropriate.[255] This, of course, is similar to what we are trying to model here.

With a Poisson model, the explanatory variables ($Y_1, Y_2, \ldots, Y_n$) have independent Poisson distributions with parameters $\lambda_1, \lambda_2, \ldots, \lambda_n$, respectively.

$$\text{Prob}(Y_i = r) = \exp(-\lambda_i)\,[(\lambda_i)^r / y_i]$$

$$\text{In } \lambda_i = \beta_0 + \sum \beta_j X_{ij}$$

With Poisson models, the conditional variance is equal to the mean. This is not always true in actual data so it can limit the usefulness somewhat. The usefulness may also be limited if process does not have independent increments (i.e., independence of past events). This violation would occur if a derailment event were not independent of a prior derailment; however, this does not appear to be the case here. To measure for over-dispersion between the variance and the mean,

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[252] Smith RA, Slack JR, Wyant T, Lanfear KJ. The Oil Spill Risk Analysis Model of the US Geological Survey. US Geological Survey Professional, 1982, Paper 1227

[253] Anderson CM, LaBelle RP. Estimated Occurrence Rates for Analysis of Accidental Oil Spills on the US Outer Continental Shelf. *Oil & Chemical Pollution* 1990; 6:21–35.

[254] Homan A, Steiner, T. OPA 90's Impact at Reducing Oil Spills, *Marine Policy* 2008; 711-718

[255] Maddala GS. *Limited-dependent and Qualitative Variables in Econometrics*. Cambridge: Cambridge University Press; 1989.

we use the Wooldridge test.[256] The test is a regression with the fitted values of y_i as the independent variable on es_i - 1 (the squared standardized residuals - 1). A significant t-statistic suggests over-dispersion and the value of the coefficient is an estimate of the necessary adjustment for it using an alternate Count Model framework (Negative Binomial). Otherwise, the Poisson specification is fine.

Data

We used actual historical data (1995-2013) from the Surface Transportation Board's (STB) Waybill Sample to derive total annual carloads of ethanol and crude (for more information on this data source see http://www.stb.dot.gov/stb/industry/econ_waybill.html). As discussed earlier in the RIA, the STB collects cargo waybill data under the requirement that all U.S. railroads that terminate more than 4,500 revenue carloads submit a yearly sample of terminated waybills. This data provides an indication of the annual volume of freight rail traffic in ethanol and crude.

We used available rail accident and incident reports from FRA Form 6180.54 (Rail Equipment Accident/Incident Report) and PHMSA Form 5800.1 (Hazardous Materials Incident Report), to derive total annual derailments from 2000-2013 (for more information on data submitted by these forms see http://safetydata.fra.dot.gov/OfficeofSafety/publicsite/Forms.aspx and http://www.phmsa.dot.gov/hazmat/incident-report). Rail carriers are required to report accidents that occur on the following types of track: main, yard, siding and industry. As previously discussed in the RIA, we only used main and siding accidents and incidents involving ethanol and crude given the scope of the rule.

Results

We ran a Poisson count model where the annual number of derailments of crude and ethanol trains (DRCR) is a function of a constant and the total number of crude and ethanol carloads in that year (CLCR). We would expect that derailments are an increasing function of carloads shipped. Due to data limitations in earlier years, we only have data available for derailments from 2000-2013. We ran the model using EVIEWS7 statistical software. The results are below.

Dependent Variable: DRCR
Method: ML/QML - Poisson Count (Quadratic hill climbing)
Date: 02/03/15 Time: 17:22
Sample: 2000 2013
Included observations: 14
Convergence achieved after 7 iterations

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[256] Wooldridge JM. Quasi-likelihood Methods for Count data. In: Pesaran MH, Schmidt P, editors. *Handbook of Applied Econometrics*, vol. 2. Oxford: Blackwell; 1997 p. 352–406.

GLM Robust Standard Errors & Covariance
Variance factor estimate = 0.858061802535
Covariance matrix computed using second derivatives

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	1.159386	0.193635	5.987494	0.0000
CLCR	9.42E-07	4.64E-07	2.029572	0.0424

R-squared	0.257159	Mean dependent var	4.214286
Adjusted R-squared	0.195256	S.D. dependent var	2.044827
S.E. of regression	1.834364	Akaike info criterion	4.241095
Sum squared resid	40.37871	Schwarz criterion	4.332389
Log likelihood	-27.68767	Hannan-Quinn criter.	4.232644
Restr. log likelihood	-29.36192	LR statistic	3.348502
Avg. log likelihood	-1.977691	Prob(LR statistic)	0.067266

As expected, the coefficient for carloads shipped is positive. It is also significant at the 95 percent level of confidence. The R^2 for the model was about .26 but more importantly the LR statistic was significant at a 90 percent level of confidence (nearly 95) indicating the model as a whole had adequate explanatory power. We also ran a comparison between the actual number of derailments and the forecast number of derailments ("Fitted") during the estimation period (2000-2013). The table below shows the results. With the exception of certain outlier years on both the high and the low end (e.g. 2002 and 2009) the model did a reasonable job of predicting the number of derailments in the estimation period. The model also did not have a systematic bias in over or under predicting derailments as forecast errors residuals ("Residual") are fairly evenly split between positive residuals (under predict) or negative residuals (over predict). To ensure that there was not an over-dispersion issue with the Poisson specification, we ran a Wooldridge test (see Model). The results showed that the coefficient for the fitted values of y_i was not statistically significant and as such the use of the Poisson was fine. The biggest issue with the model is the limited sample size of 14 years followed by lack of additional explanatory variables; the latter which might be picked up in the constant term.

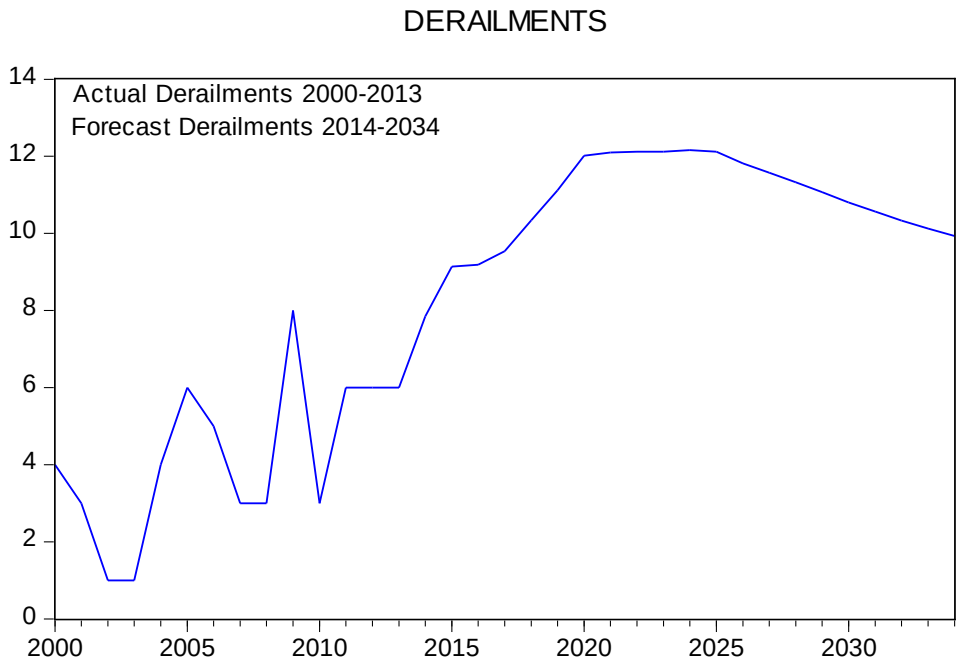
While there are strong reasons for using the Poisson framework (see Model), the results for carloads are robust to other methods. For example, the results for carloads are still positive and significant when running an ordinary least squares model or as a Negative Binomial model.

ACTUAL & FORECAST NUMBER OF DERAILMENTS

obs	Actual	Fitted	Residual
2000	4.00000	3.34235	0.65765
2001	3.00000	3.33821	-0.33821
2002	1.00000	3.35401	-2.35401
2003	1.00000	3.38114	-2.38114
2004	4.00000	3.41878	0.58122
2005	6.00000	3.44825	2.55175
2006	5.00000	3.65176	1.34824

2007	3.00000	3.87245	-0.87245
2008	3.00000	4.23517	-1.23517
2009	8.00000	4.51326	3.48674
2010	3.00000	4.85479	-1.85479
2011	6.00000	4.98631	1.01369
2012	6.00000	5.64621	0.35379
2013	6.00000	6.95731	-0.95731

We next forecast the number of derailments using the aforementioned Count Model and the forecast number of crude and ethanol carloads. The annual number of derailments range from between about 8 and 12 derailments. The graph below shows actual number of derailments (2000-2013) and the forecasted number using the Count Model (2014-2034).



The forecast number using the count model is less than using the forecast from the Simple Average forecast that we use in the main body of the analysis. As such, the Count Model forecast would produce a more conservative estimate of benefits. The table below shows forecast carloads, and forecast derailments using both methods. The final column shows the difference between the two methods.

		DERAILMENTS		
	Carloads Crude/Ethanol	Simple Average Forecast	Count Model Forecast	Δ
2014	957,052	10.18	7.85	2.33
2015	1,118,676	11.90	9.14	2.76
2016	1,123,624	11.95	9.18	2.77
2017	1,163,764	12.38	9.54	2.84
2018	1,249,753	13.29	10.34	2.95
2019	1,326,657	14.11	11.12	2.99
2020	1,409,245	14.99	12.02	2.97
2021	1,416,427	15.06	12.10	2.97
2022	1,418,355	15.09	12.12	2.96
2023	1,418,283	15.08	12.12	2.96
2024	1,422,075	15.13	12.16	2.96
2025	1,418,321	15.09	12.12	2.96
2026	1,391,469	14.80	11.82	2.98
2027	1,369,250	14.56	11.57	2.99
2028	1,346,322	14.32	11.33	2.99
2029	1,321,993	14.06	11.07	2.99
2030	1,295,989	13.78	10.80	2.98
2031	1,272,716	13.54	10.57	2.97
2032	1,248,469	13.28	10.33	2.95
2033	1,227,050	13.05	10.12	2.93
2034	1,206,705	12.83	9.93	2.90

Appendix G: Illustrative Approach to Higher-Consequence Event Damages

This information is included for illustrative purposes only to show higher-consequence damages using different assumptions. This appendix contains the same basic method for estimating higher-consequence event damages as used in the main analysis, employing a Monte Carlo simulation to run a large number of scenarios where the inputs are allowed to vary. See section VII.B.2 for a fuller discussion of the methods employed—this appendix focuses on the differences between the estimation here and the estimation in the main text. Where methodology is not fully described, it is the same as in the main analysis.

PHMSA used the estimated damages of the accident at Lac-Mégantic, Quebec, to illustrate the potential damages of a higher-consequence event, but because this accident was unique in many ways, PHMSA adjusted the damages downward to reflect the lower speeds and force that are more typical of derailments. For the main analysis, PHMSA adjusted the severity of Lac-Mégantic using the amount of energy dissipation that resulted from slowing the accident speed to a more typical derailment, but here uses another method. For this analysis, PHMSA looked at the FRA accident database which contains approximately 65,000 records for all types of accidents (e.g., derailments, grade crossings, collisions) on mainline and sidings from 1995 to 2013 and examined them to get a factor that includes severity as a function of train speed. Extracting only those accidents where the speed was greater than zero (0) and the number of cars derailed were greater the zero (0), the impact was binned by speed groups:

Table AG1: Average Number of Tank Car Derailments by MPH

Speed (mph)		Number of accidents	Number of tank cars derailed	Average number of Derailed Tank Cars	Ratio of the average number of derailed tank cars
Min	Max				
25	<40	2,083	18,957	9.1	N/A
40	<65	1,598	19,047	11.9	1.31

Here, PHMSA assumes the reduction in severity of an accident is given by the ratio of the average number of derailed cars in the speed bin from 40 to 64 mph to the average number of tank cars derailed at 25 to 39 mph. A slower speed, below 40 mph,[257] results in a 31 percent[258]

[257] In addition to applying a 50-mph speed limit to HHFTs, which is already in effect due to universal compliance with AAR's Circular OT-55-N, railroad subscribers agreed to adhere to a speed restriction of 40 mph for any HHFTs carrying crude oil in HTUAs, unless the tank cars all meet the CPC-1232 standard. This rulemaking will extend that speed restriction for HHFTs carrying ethanol, and will change the threshold tank car standard to the DOT-117 or DOT-117p.

reduction in severity, as measured by the average number of cars derailed. PHMSA considered whether derailment severity is an increasing function of speed, but the data support the 31 percent reduction. Thus PHMSA applies this factor to scale down the damages from Lac Mégantic from $1.1 billion to approximately $765 million[259] to account for a smaller expected number of cars derailed and lower speeds.

In the main analysis, PHMSA used two higher-consequence events as the central input for the Monte Carlo simulation, and allowed the number to vary between one and five. Here, PHMSA projects the number of higher consequence events over the next 20 years in the absence of this rule based on carloads shipped and an estimate of expected carloads over the next 20 years. There were approximately 5 million carloads of crude oil and ethanol shipped in Canada and the United States from 1995 – 2013, and over that time there was one higher-consequence event, the accident at Lac-Mégantic. PHMSA divides the total number of carloads shipped in US and Canada into the carloads we forecast to be shipped from 2015-2034 in the U.S. only: 26.2/5.3 = 4.94. Thus for this analysis, PHMSA estimates the number of higher consequence events that are likely to occur over the next 20 years in the absence of this rule at five events.

The table below presents the other input values that are used here:

Table AG2. Assumed Distribution of Input Values for Appendix XX Monte Carlo Analysis

Risk Variables	Probability Distribution	Point Estimate	Low	Mode	High
Number of events	Triangular*	5	50%	100%	150%
Percent of Population Fatalities	Triangular*	24%	75%	100%	110%
Baseline Non-Fatality Damage Value ($)	Triangular*	454,412,030	75%	100%	125%
Random Selection of Population Density	Custom**				
Wetlands ($)	Triangular*	14,654,932	75%	100%	125%
Wetlands Probability	Uniform	6%	2%		10%

*****We chose a triangular distribution for most elements because of its ease of use, only 3 parameters (lower limit, an upper limit and a mode) and allows for skewed distributions, like

[259] $1,108,022,645 x (1- 0.3097) = $764,875,920.

Table AG2. Assumed Distribution of Input Values for Appendix XX Monte Carlo Analysis

the percent fatalities above. Additionally, with definite lower and upper limits we can avoid extreme values.

**The random selection of a population density is based on custom distributions with points given by the population densities in HTUAs and the rest of the HHFT rail network as illustrated in the table above titled "Population Densities along Crude Oil and Ethanol Rail Routes." The fuel network rail link lengths are used within HTUA/HHFT as a scaling factor to develop the population density custom distributions for HTUAs and HHFT networks, assuming the probability of having an accident is proportional to the link length. PHMSA uses the average annual tons transported on the fuel network to select in which area the accident occurs and is a proxy for the usage of the rail track in the HTUAs versus the rest of the HHFT network. Thus the probability of an accident occurring in the HTUA portion of the network is given by the ratio between the average annual tons transported in the HTUA network to the total tons transported in the entire HHFT network: 8,009,851,408 / 49,800,510,555.7 = 16.08%.

HTUAs account for 16.08% of the HHFT network. In each run of the simulation, a new, random number between 0 and 1 is generated. If this number is less than 0.1608, the incident is modeled as if taking place in a HTUA; otherwise, it is modeled as if taking place outside of a HTUA.

Below is the table showing a sampling of 30 possible sets of alternative outcomes (and the damages resulting from those outcomes) that might occur over the 20-year analysis period.

Table AG3. Sample Outputs of the Risk Model Showing 20-Year Values for Fatality and Non-Fatality Damages

Trial values	No. of Events	Percent Fatalities	Population Density per half-square km	Scaling Factor	Non-Fatality Damages* (million)	Damages Non-Fatality (million)	Damages Fatality (million)	Wetlands (million)	Total Damages (million)
1	6.1	23.1%	306.20	224.7%	$468.8	$6,457.6	$4,648.0	$0.0	$11,105.7
2	3.5	22.2%	55.06	40.4%	$387.7	$541.1	$451.8	$0.0	$992.9
3	3.4	24.2%	33.66	24.7%	$472.8	$397.8	$297.0	$0.0	$694.8
4	4.3	25.7%	1.46	1.1%	$425.5	$19.8	$17.4	$0.0	$37.2
5	7.0	23.0%	132.90	97.5%	$466.7	$3,176.9	$2,282.1	$0.0	$5,459.0
6	6.4	11.4%	0.05	0.0%	$245.6	$0.6	$0.4	$0.0	$1.0
7	4.1	24.9%	22.85	16.8%	$487.7	$336.4	$250.9	$0.0	$587.4
8	5.1	20.2%	36.84	27.0%	$378.7	$526.3	$410.5	$0.0	$936.8
9	4.1	22.2%	395.68	290.4%	$494.2	$5,943.8	$3,896.6	$0.0	$9,840.4
10	5.1	11.2%	0.00	0.0%	$199.2	$0.0	$0.0	$0.0	$0.0
11	5.9	20.7%	39.05	28.7%	$445.1	$756.2	$512.8	$0.0	$1,268.9
12	3.4	10.5%	2,741.63	2012.3%	$250.4	$17,208.4	$10,535.5	$0.0	$27,743.8
13	4.5	20.9%	273.15	200.5%	$523.4	$4,743.0	$2,761.2	$12.5	$7,516.6
14	4.3	22.5%	1.01	0.7%	$449.2	$14.4	$10.5	$0.0	$24.9

Table AG3. Sample Outputs of the Risk Model Showing 20-Year Values for Fatality and Non-Fatality Damages									
Trial values	No. of Events	Percent Fatalities	Population Density per half-square km	Scaling Factor	Non-Fatality Damages* (million)	Damages Non-Fatality (million)	Damages Fatality (million)	Wetlands (million)	Total Damages (million)
15	4.2	9.3%	0.13	0.1%	$212.3	$0.8	$0.5	$0.0	$1.4
16	4.7	23.7%	173.61	127.4%	$378.7	$2,243.9	$2,048.7	$0.0	$4,292.7
17	5.5	20.1%	182.03	133.6%	$404.9	$2,987.1	$2,169.5	$0.0	$5,156.6
18	5.3	24.1%	7.57	5.6%	$543.9	$158.8	$103.0	$0.0	$261.7
19	4.7	19.3%	332.90	244.3%	$396.4	$4,510.2	$3,205.9	$0.0	$7,716.1
20	4.5	24.2%	179.23	131.6%	$472.0	$2,789.2	$2,086.3	$0.0	$4,875.5
21	6.0	23.2%	77.92	57.2%	$364.3	$1,247.8	$1,160.4	$0.0	$2,408.2
22	6.5	10.2%	0.07	0.1%	$232.2	$0.8	$0.5	$0.0	$1.2
23	4.6	24.2%	298.66	219.2%	$426.9	$4,344.1	$3,601.3	$12.9	$7,958.2
24	5.1	23.5%	260.01	190.8%	$390.9	$3,836.1	$3,368.7	$0.0	$7,204.8
25	5.2	22.7%	198.82	145.9%	$475.0	$3,578.0	$2,498.5	$0.0	$6,076.5
26	4.6	24.0%	2.41	1.8%	$432.7	$35.3	$28.6	$0.0	$63.9
27	3.0	11.1%	1,391.93	1021.7%	$219.4	$6,659.9	$4,915.4	$0.0	$11,575.3
28	3.3	23.4%	519.31	381.2%	$556.3	$6,904.6	$4,250.5	$0.0	$11,155.0
29	5.4	18.9%	666.92	489.5%	$484.8	$12,768.7	$7,266.8	$0.0	$20,035.5
30	5.3	22.2%	122.89	90.2%	$549.1	$2,621.6	$1,547.1	$0.0	$4,168.7
Note: *The values represent the Lac-Mégantic baseline non-fatality damages and vary randomly according to the triangular distribution of non-fatality damages set forth in table titled *Assumed Distribution of Input Values for Monte Carlo Analysis*.									

The distribution of total estimated damages from higher-consequence events over 20 years is shown as a percentile distribution from 0 percent to 100 percent in 5-percentile increments as follows:

Table AG4. Distribution of Total Estimated Damages From High-Consequence Events Over 20 Years								
Percentiles	No. of Events	Percent Fatalities	Population Density per half-square km	Scaling Factor relative to Lac-Mégantic	Damages Non-Fatality (million)	Damages Fatality (million)	Wetlands (million)	Total Damages (million)
0%	2.4	8.5%	0.0	0.0%	$0.0	$0.0	$0.0	$0.0
5%	3.2	10.4%	0.0	0.0%	$0.1	$0.0	$0.0	$0.1
10%	3.5	11.1%	0.1	0.1%	$1.0	$0.7	$0.0	$2.2
15%	3.7	11.8%	0.7	0.5%	$9.3	$6.5	$0.0	$18.1
20%	3.9	19.2%	2.7	2.0%	$42.5	$30.8	$0.0	$75.4
25%	4.1	20.0%	6.5	4.8%	$103.0	$73.2	$0.0	$177.9
30%	4.3	20.6%	13.1	9.6%	$201.6	$146.6	$0.0	$346.6
35%	4.4	21.1%	22.5	16.5%	$357.9	$259.6	$0.0	$618.5
40%	4.6	21.5%	35.8	26.3%	$551.4	$406.9	$0.0	$963.5
45%	4.7	21.9%	51.0	37.4%	$793.3	$576.9	$0.0	$1,369.2
50%	4.8	22.3%	72.3	53.1%	$1,121.1	$810.1	$0.0	$1,930.1
55%	4.9	22.6%	97.5	71.5%	$1,515.5	$1,110.1	$0.0	$2,630.2
60%	5.1	22.9%	127.0	93.2%	$2,036.7	$1,467.8	$0.0	$3,520.0
65%	5.2	23.2%	174.2	127.9%	$2,699.9	$1,962.2	$0.0	$4,668.6
70%	5.4	23.4%	231.6	170.0%	$3,588.0	$2,651.5	$0.0	$6,263.9
75%	5.5	23.7%	305.4	224.2%	$4,817.5	$3,488.7	$0.0	$8,290.7
80%	5.7	24.0%	412.7	302.9%	$6,457.6	$4,686.5	$0.0	$11,133.3
85%	5.9	24.3%	547.7	402.0%	$8,666.3	$6,308.5	$0.0	$14,945.3
90%	6.2	24.7%	845.9	620.8%	$12,779.3	$9,210.3	$0.0	$21,944.4
95%	6.5	25.1%	1,512.4	1110.1%	$20,572.6	$14,870.9	$13.0	$35,601.9
100%	7.2	26.2%	21,526.0	15799.7%	$224,785.5	$144,504.1	$18.2	$369,289.6

The median of the distribution (i.e., the 50th percentile) is approximately $1.9 billion. The mean, $7.8 billion, represents the average of all possible future outcomes (including some with extremely high damages); the median represents the outcome that has an equal probability that the actual outcome will be higher or lower than the median. The 80th percentile value ($11.1 billion) indicates that there is a 20-percent chance that the damages could be higher than $11.1 billion.