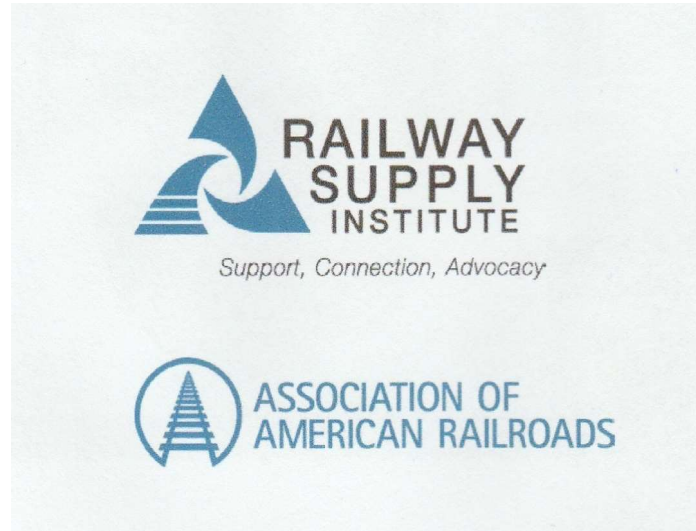


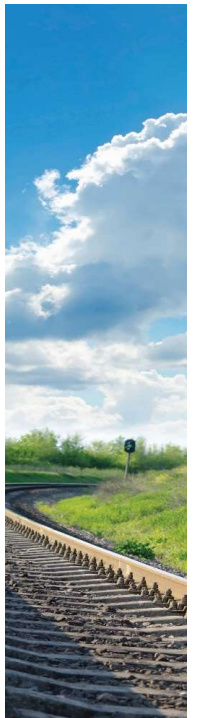
# RSI-AAR Railroad Tank Car Safety Research and Test Project

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FRA Hazmat Seminar - Houston, TX  
August 2018

John Byrne



# RSI – AAR Safety Project

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- Formation of the Safety Project
- Initial Focus and Outcomes – Design Features
  - Protection for pressure tank cars
  - Protection for general purpose tank cars
- Stub sill inspections & TCID
- AFFTAC
- Tank Car Accident Data
- Recent Analysis – Conditional Probability of Release
- Changes in Fleet CPR for Flammable Liquids
- Flammable Liquids Progress Reports



# RSI – AAR Safety Project

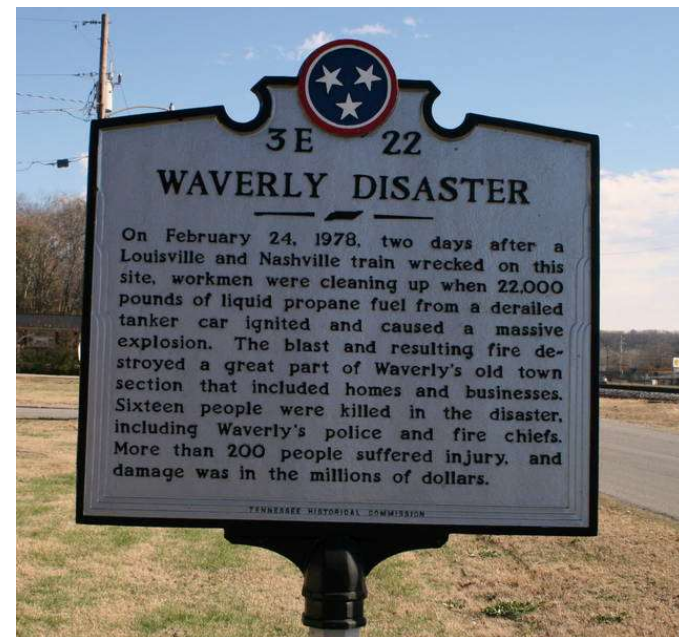
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## 1970s - Significant Derailments / Accidents Involving LPG

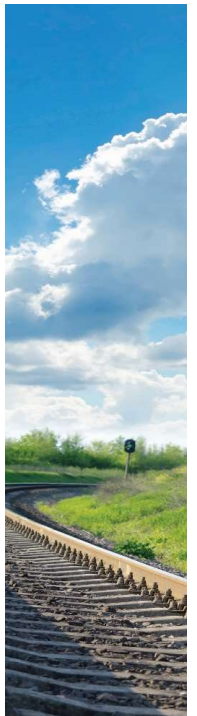
1970 - Crescent City, Illinois

1974 - Decatur, Illinois

1978 – Waverly, Mississippi



Tank punctures – Fires - Explosions



# RSI – AAR Safety Project

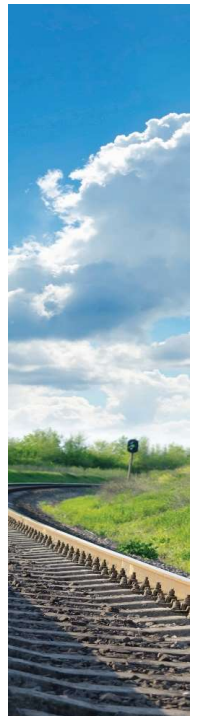
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## AAR Tank Car Committee – Taskforce

- Tank Car Builders / NTSB / DOT
- DOT Class 112A / 114A Accident Review
- 10 Year Period

### Key Findings:

Majority of significant fires and explosions were caused by the couplers of adjacent cars impacting tank heads.



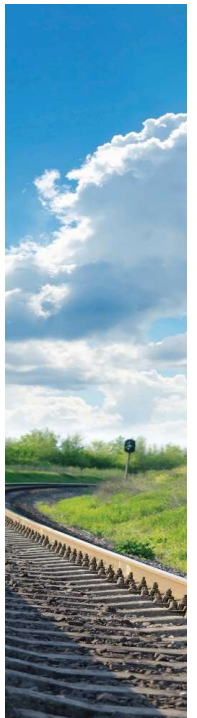
# RSI – AAR Safety Project

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## 1970 - Railroad Tank Car Safety Research and Test Project

- Collaborative Effort between
  - Railway Progress Institute
  - Association of American Railroads
- Formed to conduct and oversee accident analysis
  - Data Collection
  - Statistical Analysis
  - Engineering Design
  - Testing

Focus: Improve damage resistance of tank cars



# RSI – AAR Safety Project

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Statistical Analysis – RA 01-2-3

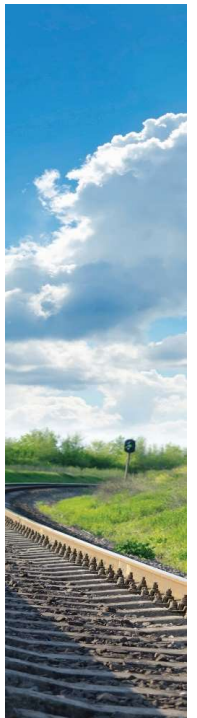
December 4, 1970

Scope: Ruptured Tank Cars 1958 – 1970

- 28 Accidents
- 64 Tank Cars - 63 exposed to fire

## Key Findings

- No single feature of car design appears to represent a critical deficiency that can be corrected by immediate remedial action.
- Fire is a prerequisite to violent rupture.
- Commodity = LPG, Propane, Butane
- Primary failures cause by head and shell punctures

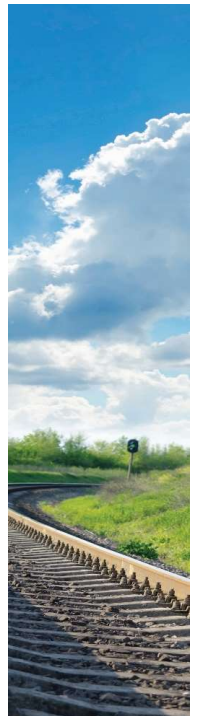
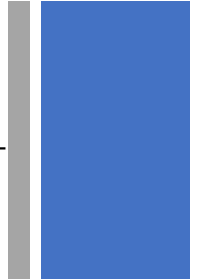
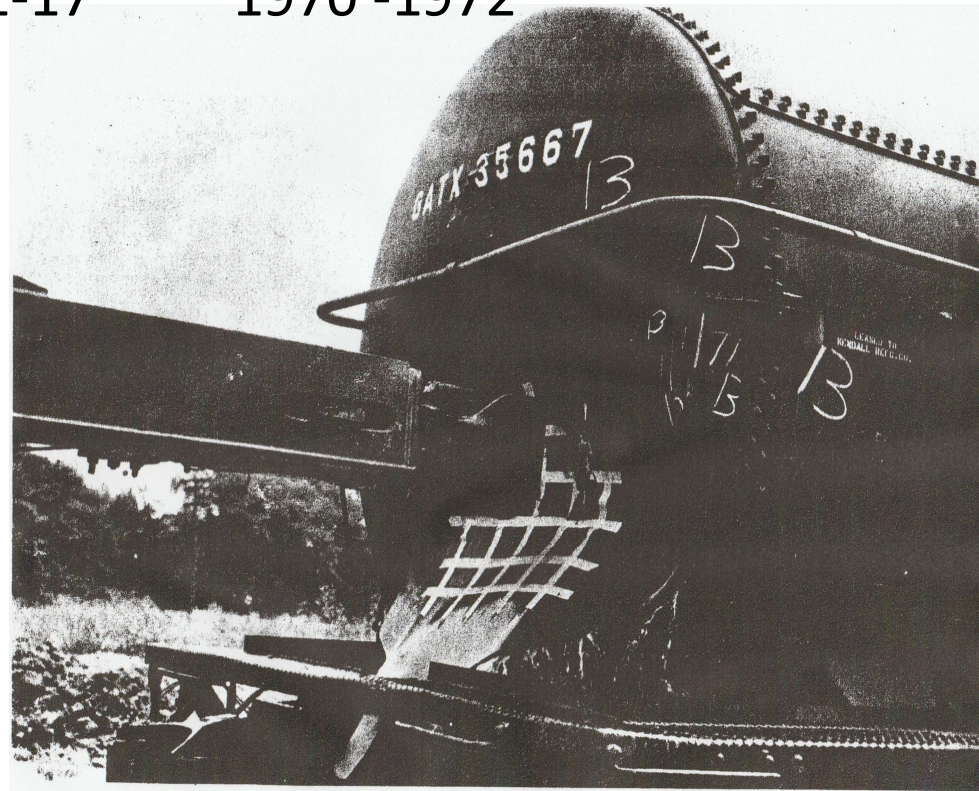


# RSI – AAR Safety Project - History

## Tank Car Head Study RA 05-1-17

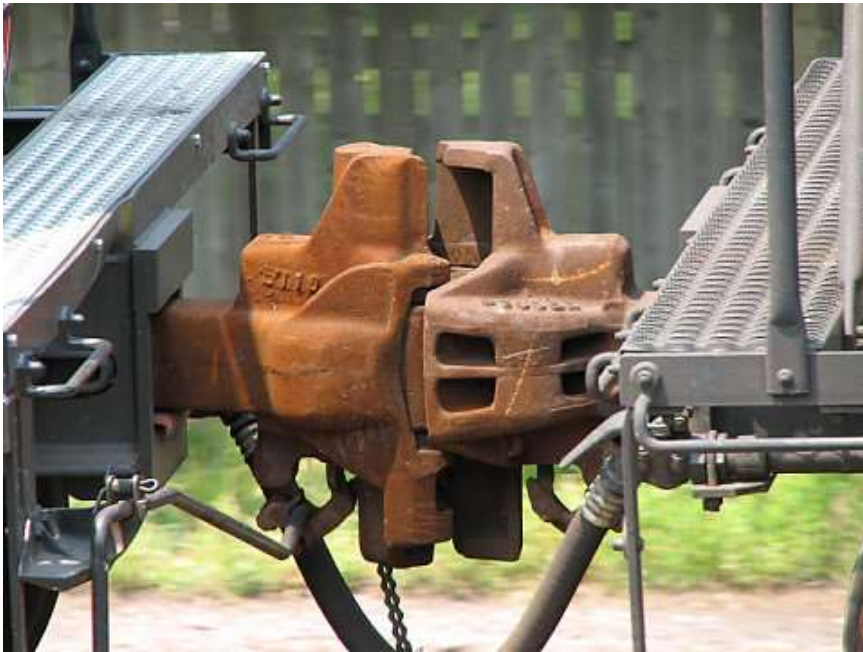
1970 -1972

- Drop weight test on 1/12 scale Heads
- 1/5 scale impact tests
- Full scale impact tests
  - Without head shields
  - With head shields
  
- Study estimated that ½” steel plate head shields would increase puncture speed by 100%
  
- Would have prevented 36% – 58% of head punctures that occurred to 112A tank cars between 1965 -1970

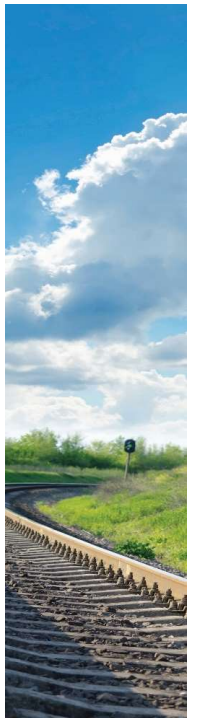


# RSI – AAR Safety Project

## Development of Double Shelf Couplers - 1974



- Accident analysis suggested that couplers of adjacent cars were one of the leading causes of shell punctures.
- Top and bottom coupler shelves considered as a solution to coupler disengagement during derailments.
- ASF initiated initial design and testing.
- Full scale testing of shelf couplers lead to redesign of shelves and recommendations
- Retrofit of all 112A tanks and new tank cars

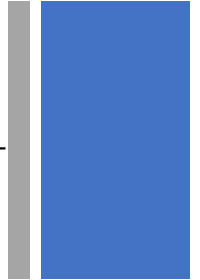
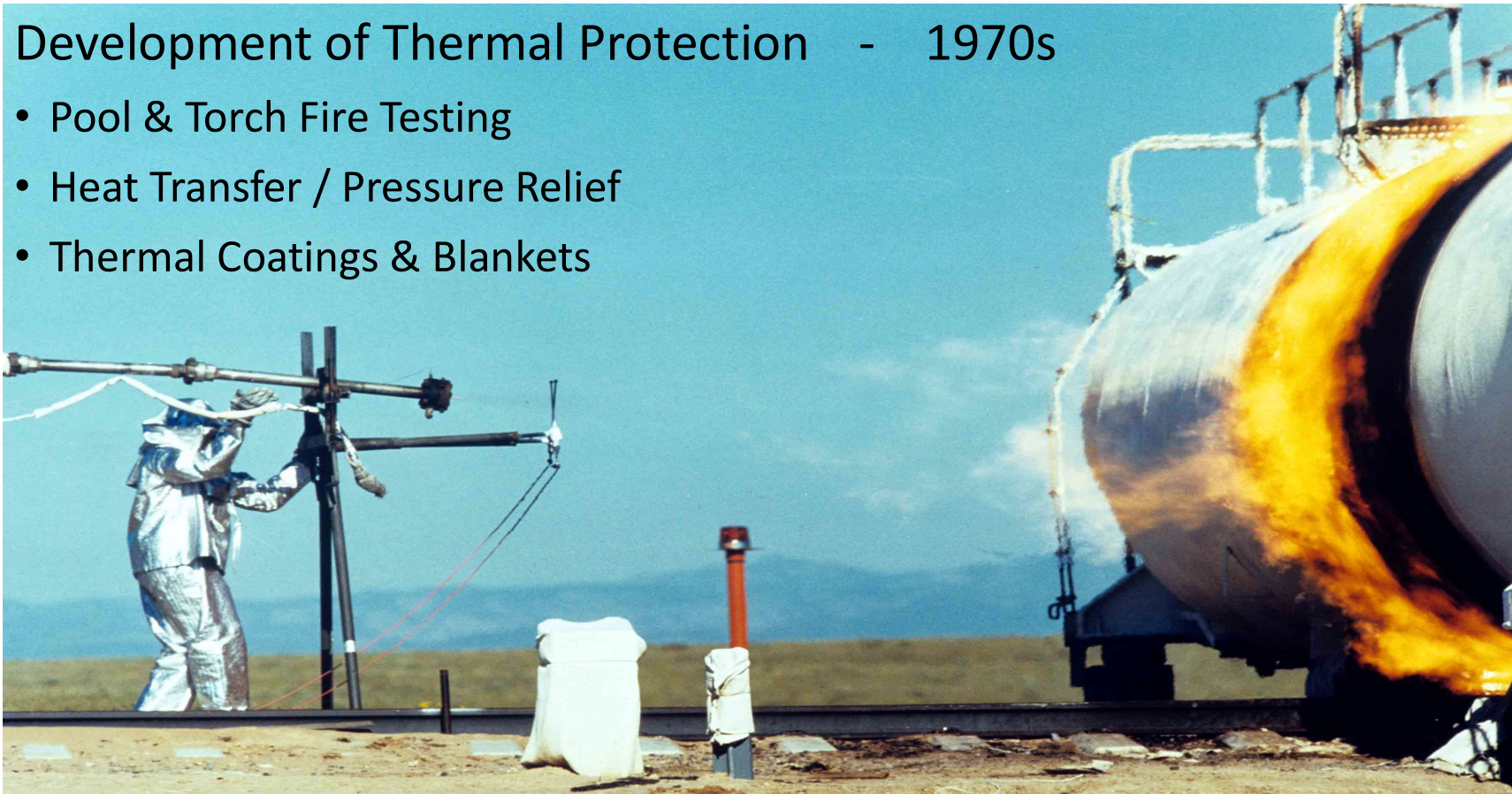




# RSI – AAR Safety Project

## Development of Thermal Protection - 1970s

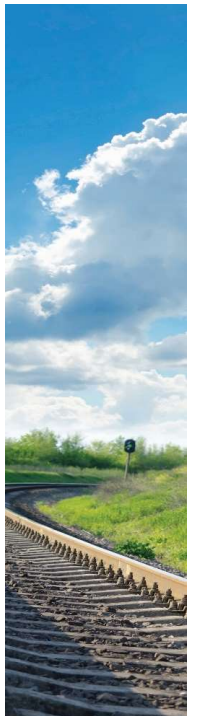
- Pool & Torch Fire Testing
- Heat Transfer / Pressure Relief
- Thermal Coatings & Blankets



# RSI – AAR Safety Project

## HM-144 -

- Implemented 1977
- DOT 112 /114
- Flammable Compressed Gas
- Head Shields
- Shelf Couplers
- Thermal Protection
- Retrofit of 20,000 tank cars
- Estimated \$200 Million



# RSI – AAR Safety Project

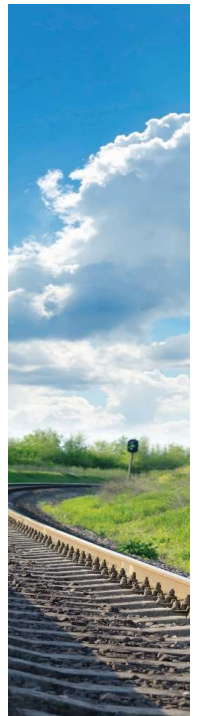
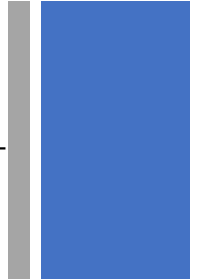
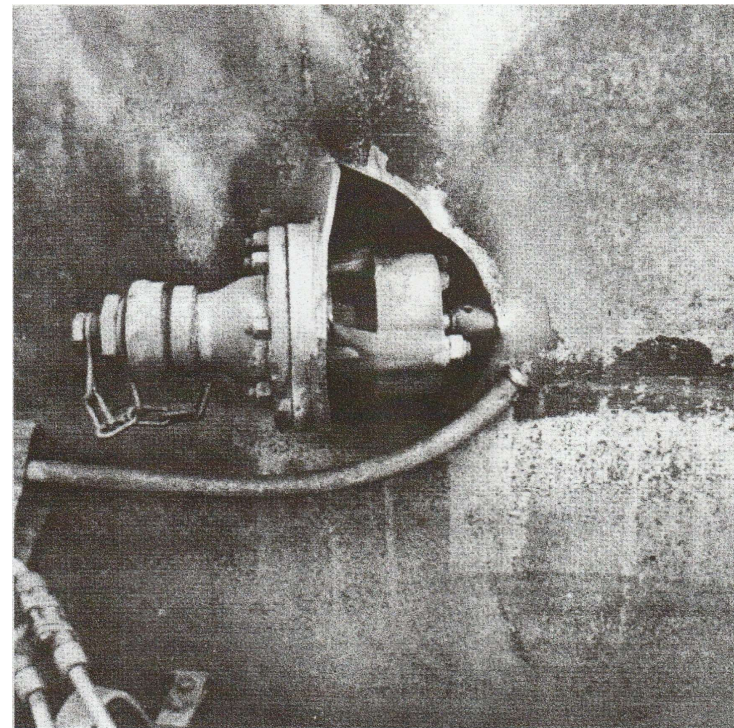
## Improving Puncture Resistance of DOT 111s

Based on accident analysis 1965 – 1970

- Bottom Outlets, non-pressure cars
- Safety valve nozzles, non-pressure cars
- Bottom washout
- Brake Reservoir bracket
- Sump
- Top unloading valves
- Manway or protective housing
- Stub sills and bolsters
- Shell punctures
- Welds

RA-09-1-24 1973

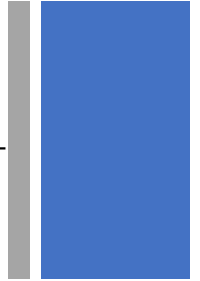
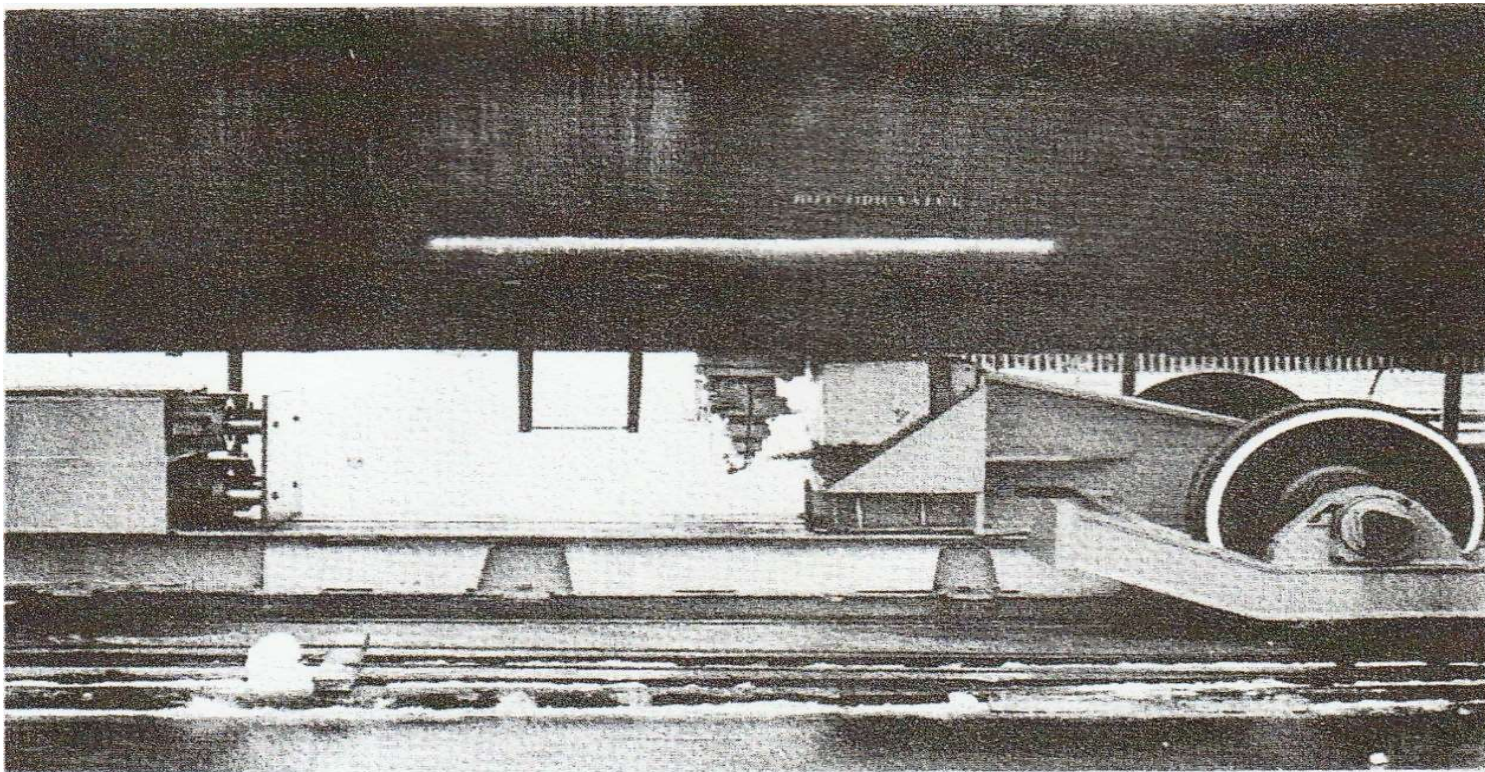
“The tank car appurtenance which has shown the highest vulnerability is the bottom outlet on non-pressure non-insulated stub sill cars.”



# RSI – AAR Safety Project

Bottom Fittings Protection Test Program

1978



# RSI – AAR Safety Project - History

## Bottom Fittings Protection Test Program

- Bottom Discontinuity Mandated on new tanks - 1/1/1978

## Five designs tested (E10)

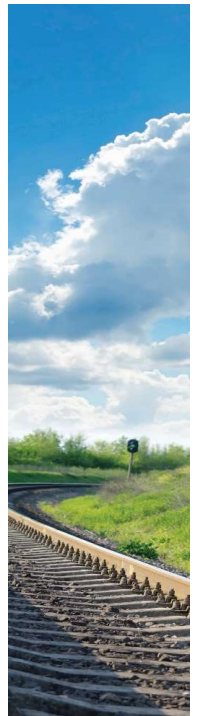
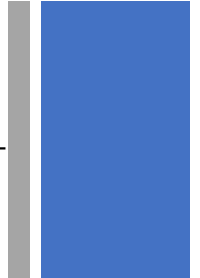
- Fatigue Tests – non-destructive
- Impact Tests - destructive

## Recommendations

- Shallow skids / longer fatigue life
- Need reinforcement pads
- Avoid Transverse welds
- Profile of skid should be continuous
- Lock valve handles or stow separately

All Hazmat Cars Retrofitted by 1994

Estimated Cost = \$70 million



# RSI – AAR Safety Project

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## Stub Sill Inspection Programs (SS-2, SS-3)

- 1991 – AAR creates a program for inspection of pre 1984 built stub sill cars
- 1992 – FRA issues EO-17 (Referenced O&M Circular No.1)
  - Jacketed tanks – 5 years
  - Non-jacketed tanks – 7 years
  - Tanks with greater than 400K miles on accelerated schedule
  - All inspection data submitted to the RPI/AAR Safety Project for Analysis
  - Stub Sill Working Group determined need for design enhancements – head braces / sill pad extensions
  - RSI/AAR Safety Project develop SILSPEC Program and database



# RSI – AAR Safety Project

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## Stub Sill Inspection Programs (SS-2, SS-3)

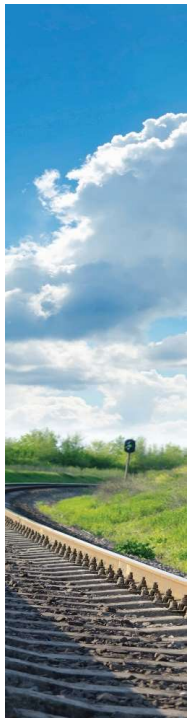
- 1999 SS-3 Program Started
  - Interim program pending development of DTA
  - Recurring inspection requirement
  - Harmonized with Tank Qualification with high mileage exceptions

## RSI/AAR Safety Project

- Managed Upload Program & Databases
- Design Specific Reports
- Quarterly Review of Records

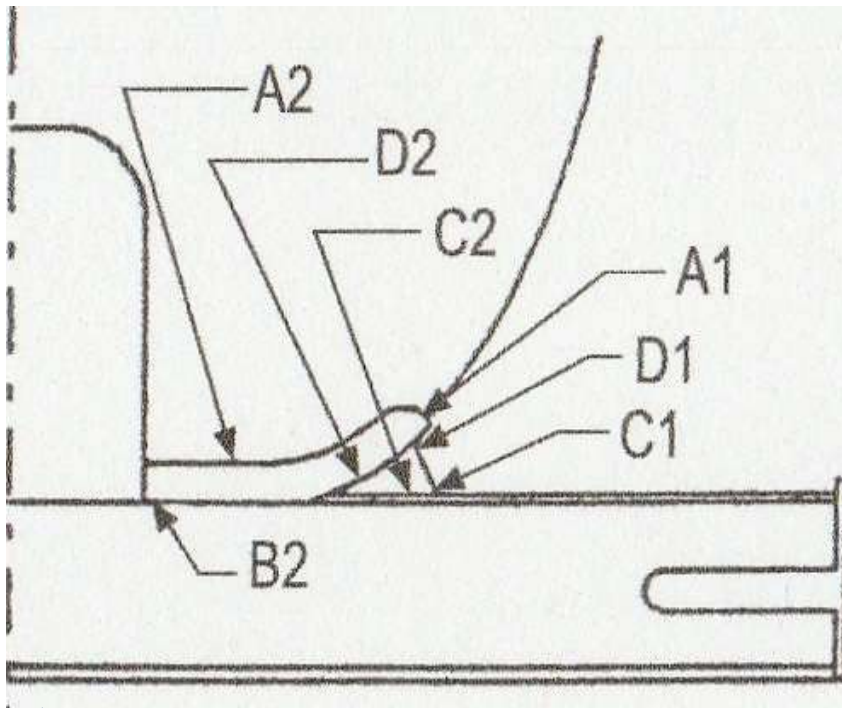
SS-2 = 116,535 Inspection Records

SS-3 = 233,045 Inspection Records



# RSI – AAR Safety Project

## Stub Sill Design and Inspection



← Point of Failure Moved Inboard

**REPORT OF TANK CAR STUB SILL INSPECTION** Form SS-3

1. Car Reporting Mark and Number \_\_\_\_\_ 2. Inspection Performed by (Company) \_\_\_\_\_

3. Stencil Class \_\_\_\_\_ 4. Shop Loc. (Town) \_\_\_\_\_ State or Province \_\_\_\_\_

5. Built Date Mo \_\_\_\_\_ Yr \_\_\_\_\_ 6. Date of Inspection Mo \_\_\_\_\_ Day \_\_\_\_\_ Yr \_\_\_\_\_

7. Car Jacketed? (Y,N) \_\_\_\_\_ 8. Reserved (design specific) \_\_\_\_\_

9. Reserved (design specific) \_\_\_\_\_ 10. Original AAR Certificate of Construction Number \_\_\_\_\_

11. Builder \_\_\_\_\_ 12. Stub Sill Design Style (as inspected) \_\_\_\_\_

13. Total Mileage to Nearest 1,000 Miles \_\_\_\_\_ Note: Lines 10 - 13 Provided By Car Owner

**Transverse Weld Cracks** (if more than one, record longest)  
Enter max crack length to nearest 1/4 inch. (0, .25, .5, .75)  
Enter 0 if no crack.  
Enter N/A if item not applicable

	Inspection Technique	A-END Number of Cracks	Maximum Length	Inspection Technique	B-END Number of Cracks	Maximum Length
14. A-1 Pad to Tank						
15. B-1 Pad to Sill (if no head brace)						
16. C-1 Head Brace to Sill						
17. D-1 Head Brace to Pad						
18. E-1 Other - Car Builder Specified						

**Longitudinal Weld Cracks** (if more than one, record longest)  
Enter max crack length to nearest 1/4 inch. (0, .25, .5, .75)  
Enter 0 if no crack.  
Enter N/A if item not applicable

	Inspection Technique	A-END Number of Cracks	Maximum Length	Inspection Technique	B-END Number of Cracks	Maximum Length
19. A-2 Pad to Tank						
20. B-2 Pad to Sill						
21. C-2 Head Brace to Sill						
22. D-2 Head Brace to Pad						
23. E-2 Other - Car Builder Specified						

**Parent Metal Cracks** (if more than one, record longest)  
Enter max crack length to nearest 1/4 inch. (0, .25, .5, .75)  
Enter 0 if no crack.  
Enter N/A if item not applicable

	Inspection Technique	A-END Number of Cracks	Maximum Length	Inspection Technique	B-END Number of Cracks	Maximum Length
24. Tank						
25. Pad						
26. Sill Webs						
27. Sill Top Flange						
28. Sill Bottom Flange						
29. Head Brace						
30. Other - Design Specific						

31. Inspector's Name: \_\_\_\_\_ 32. Car Owner's Representative: \_\_\_\_\_

SS-3 9/1/99

Fig. Y7 CPC-1097 stub sill inspection program—new Form SS-3 (page 2 of 5)  
(Click [here](#) to access a printable form)







# RSI – AAR Safety Project

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## Tank Car Integrated Database (TCID)

- Safety Project developed in 2012 with FRA funding
- Eliminated use of multiple forms
  - SS-3 Stub Sill Defect Data – Outboard of Body Bolster
  - R-2 Non-accident damage (cracks/dents/buckles/corrosion)
  - R-1 Tank Repairs / Alterations / Conversions
- Improved Scope and Accuracy of Data Collection
  - Stub Sill Design Templates – for Tank Qualification Inspections
  - Include Inboard Sill/Pad Welds and BOV Saddle / Skid / Sump
  - Differentiates Accident Damage / Non-Accident Damage
  - Differentiates Continuous / Non-continuous Sill Pads



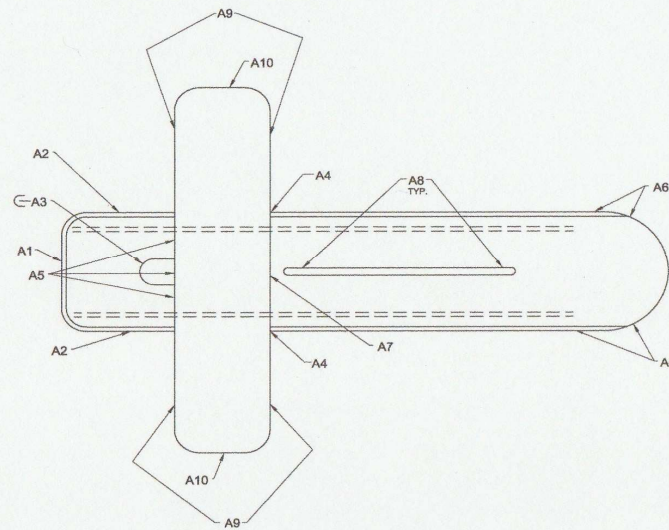
# RSI – AAR Safety Project

## Location Designations:

### Pad-to-Tank (Designated with an 'A' codes)

Code	Description	Location	Includes
A1	Outboard sill pad-to-tank transverse weld.	A- & B-Ends	Full length of weld, including portion around corner of pad.
A2	Front sill pad longitudinal welds.	AR, AL, BR, BL	Full length of weld to termination at bolster pad.
A3	Fillet weld in outboard sill pad-to-tank cutout.	A- & B-Ends	Full length of weld.
A4	Sill pad longitudinal weld.	AR, AL, BR, BL	6" of weld from termination.
A5	Outboard sill pad-to-bolster pad transverse weld.	A- & B-Ends	Full length of weld.
A6	Inboard termination of sill pad longitudinal welds.	AR, AL, BR, BL	Last 6" of weld to termination.
A7	Sill pad-to-bolster pad transverse weld.	A- & B-Ends	Full length of weld.
A8	Sill pad-to-tank slot welds.	A- & B-Ends (2 to 16 places per car)	Last 6" of weld at each end of slot.
A9	Bolster pad-to-tank transverse weld.	ARO, ARI, ALO, ALI, BRO, BRI, BLO, BLI	36" from junction with sill pad.
A10	Top of bolster pad longitudinal weld.	AR, AL, BR, BL	Full length of weld.

## Sketch/Description:

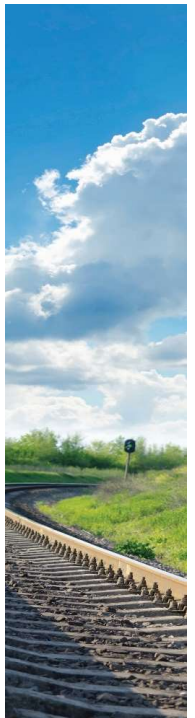


Use the "Generic Tank Head Brace." template for head brace defects.

Use the "Generic Body Bolster." template for body bolster defects.

Use the TCID "Record Shell/Sill Damage" button for:

- All parent metal defects.
- All structural defects outside the scope of these templates.



# RSI – AAR Safety Project

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## Tank Car Integrated Database (TCID)

### Enables Recording and Retention of Alterations and Conversions

- Change Category (Alteration / Conversion)
- Drawing / Part / Document / Commodity
- Approval Reference
- Comments – scope of alteration or conversion

TCID Program and Database funded by Safety Project - managed by Sims Professional Engineering



# RSI – AAR Safety Project

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## 2018 - TCID Transition to Railinc

- Improve integration with existing industry data – improve accuracy
  - UMLER file – link TCID Updates
  - Synchronize TCID data values (Specification / Components)
  - Link TCID to AAR Approvals 4-2, 4-5
  - Manage access to data – current owner – Link to EIN
  - Potential integration with component tracking
- Railinc - dedicated user support
- Tank car owners share cost of enhancements



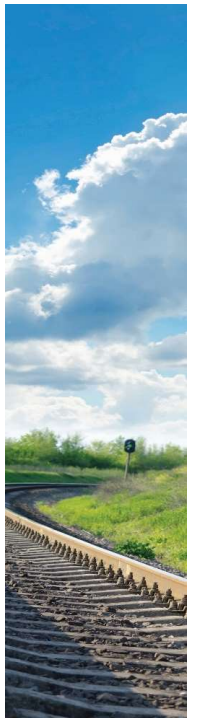
# RSI – AAR Safety Project

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## AFFTAC – Analysis of Fire Affects on Tank Cars

A Model that performs.....

- a Transient
- Physics-based simulation of the Heat exchange
- Stresses, Expansions
- Flow through safety relief device
- Deterioration of insulation for a tank car exposed to fire.



# RSI – AAR Safety Project

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AFFTAC Model - RA 16-01

Analysis of Tank Cars with Flammable Commodities

- Ladings included crude oil, ethanol and propane
- API provided thermodynamic properties for 7 crude oils
- 6 different tanks modeled 117J, (4) 117R, 1 Pressure Tank
- 4 different PRDs – 75psi – 294psi start to discharge
- 3 Thermal Protection Materials
  - Degraded Fiberglass, Ceramic Fiber, Degraded fiberglass + ceramic fiber

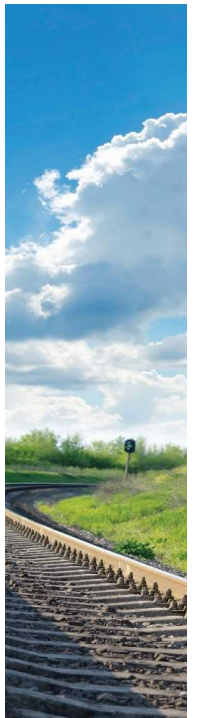


# RSI – AAR Safety Project

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## AFFTAC Model - RA 16-01

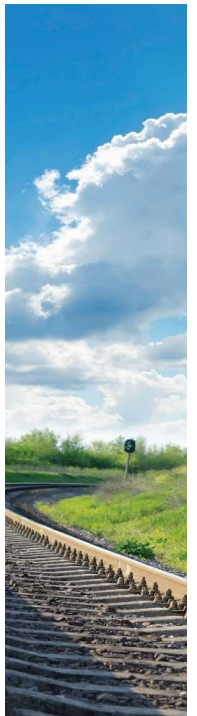
- 200 simulations run – to final time
- Final time = tank burst or tank empty
- Results
  - All cars equipped with degraded fiberglass exceeded 100 minutes
  - Met 49CFR 179.18 performance requirement





# RSI – AAR Safety Project

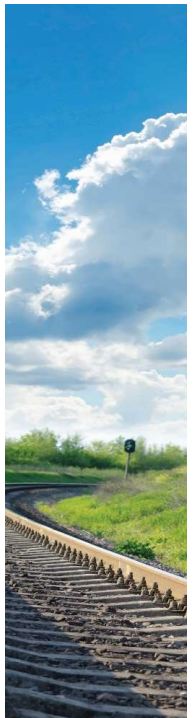
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# RSI – AAR Safety Project

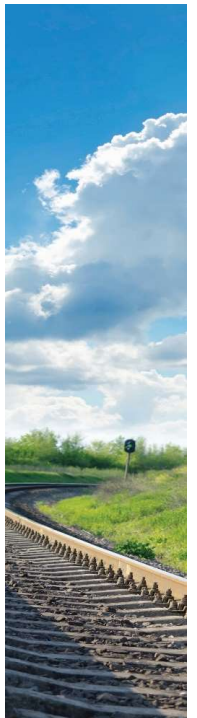
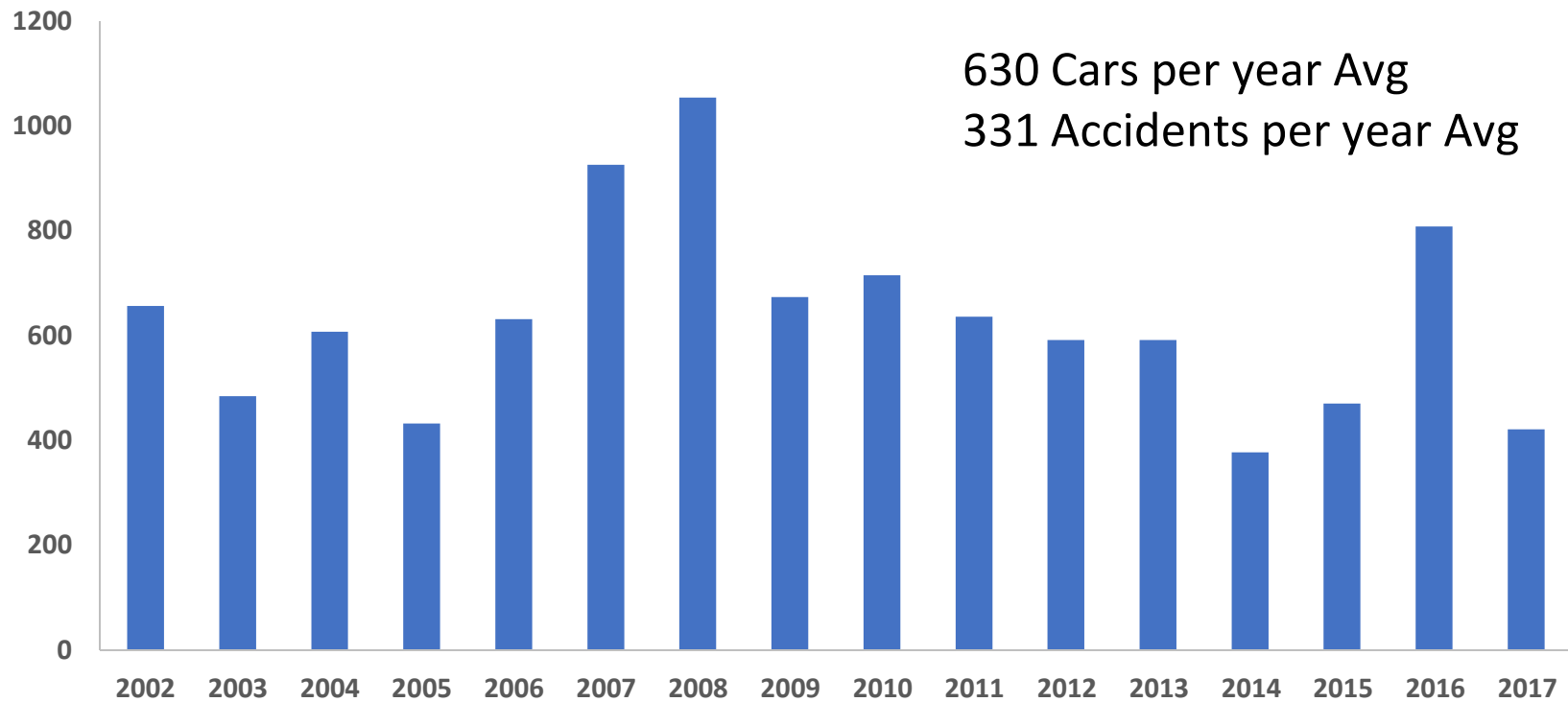
Location of Accident	Corpus Christi Texas	Melville, Sas.	Crescent City, Illinois			
Date of Accident	Feb. 4, 1970	June, 1970	June 21, 1970			
Car Number	CELX 2022	UTLX 90179	NATX 32025	SOEX 3252	NATX 33990	SCMX 3445
ICC/DOT Class	111A100W1	112A340W	112A340W	112A340W	112A340W	112A400W
Date Built	-66	1-69	3-66	9-69	3-66	11-69
Insulation?	No	No	No	No	No	No
Full Underframe?	Yes	No	No	No	No	No
Capacity: U S Gallons	20,850	33,800	32,700	33,680	33,800	33,600
Lading	Ethylacetate	Propane	Propane	Propane	Propane	Propane
Exposed to fire prior to rupture	Yes	Yes	Yes	Yes	Yes	Yes
Type of Failure	Rupture	Rocketing	Rocketing	Rocketing	Rocketing	Rocketing
Tank Material: Type of steel	A212GrB	TC128GrB	A212GrB	TC128GRB	M128GrB	TC128GrB
Tank inside diameter	104"	117.925	120-3/8/102.614	119	118.616/102.8	118.537
Weld joint efficiency		.9	.9	1.0	.9	1.0
Shell thickness		.687	.812	.625	.692	.732
Head thickness		.687	.693	.687	.600	.782
Valve setting-psig	75	280.5	280.5	280.5	280.5	330

61932.14



# RSI – AAR Safety Project

## Tank Cars Added to Accident Database since 2002



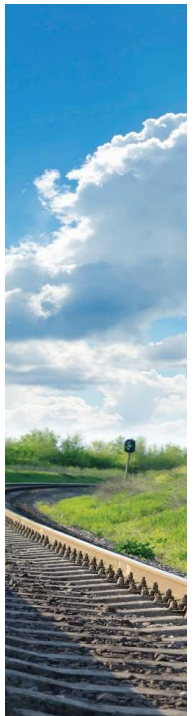
# RSI – AAR Safety Project

## Accident Data Collection – Information Sources

- University of Illinois
- News Articles
- Railroads
- Car owners
- FRA
- NTSB / TSB

Date	Carrier Code	Location of RR Station	State or Province	Reporting Marks Initials
11/23/2017	CSX	Waycross	GA	TILX
11/24/2017	CN	Edmonton	ON	TILX
11/24/2017	UP	La Marque	TX	GBRX
11/24/2017	UP	La Marque	TX	TILX
11/24/2017	UP	La Marque	TX	UTLX
11/24/2017	UP	La Marque	TX	TAEX
11/24/2017	UP	La Marque	TX	TAEX
11/24/2017	UP	La Marque	TX	GBRX
11/27/2017	CSX	Lakeland	FL	PGTX
11/27/2017	CSX	Lakeland	FL	DVLX
11/27/2017	CSX	Lakeland	FL	CPDX
11/27/2017	CSX	Lakeland	FL	CPDX
11/27/2017	CN	Surrey	BC	PROX
11/27/2017	CN	Winnipeg	MB	GATX
11/28/2017	CN	Chicago	IL	UTLX
11/28/2017	CN	Chicago	IL	UTLX
11/28/2017	CN	Chicago	IL	UTLX
11/28/2017	CN	Chicago	IL	UTLX

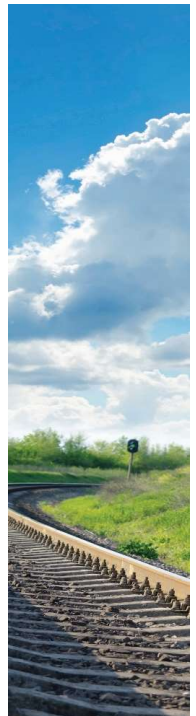
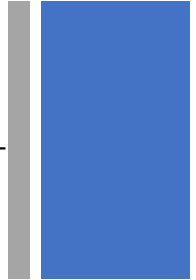
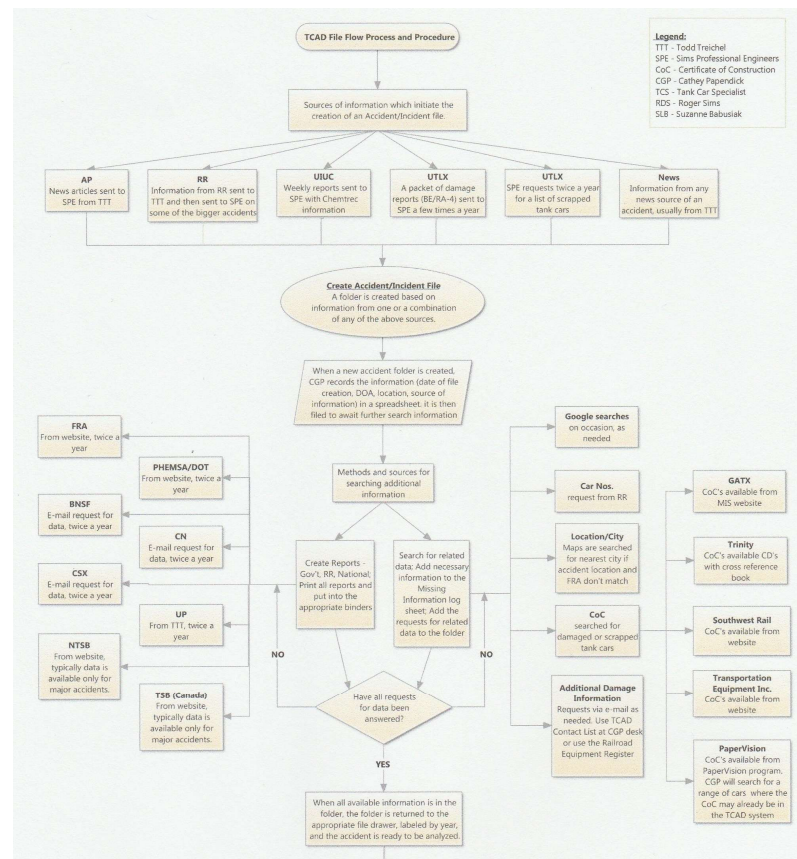
Information collected both car damage and accident information



# RSI – AAR Safety Project

## TCAD - Data Acquisition and Processing Flow

- File Creation
- Analysis & Coding
- Data Entry
- Data Review & Edit
- Quality Control
- Add UMLER Data
- File Completion
- Quarterly Reports



# RSI – AAR Safety Project

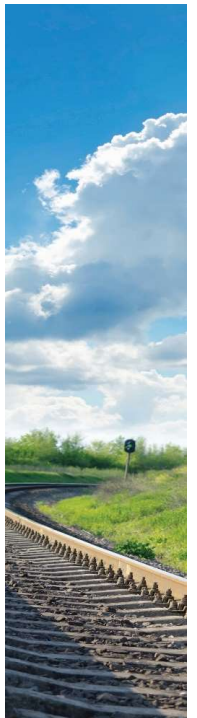
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As of 6/30/2018:

- 48,588 Tank Car Records – 66 data fields (attributes & damage)
- 30,695 Accident Records – 24 data fields

Latest New Fields:

- Unit train yes/no (definition: train was all tank cars except buffer cars)
- Presence of fire at derailment
- Top nozzles (number)
- Top fittings protection (detail in the new UMLER field)
- Car exposure to fire (was previously left to catch-all Narrative field)
- Bottom outlet valve type
- Bottom outlet valve handle securement



## RSI – AAR Safety Project

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### Statistical Analysis of Tank Car Safety

# Conditional Probability of Release

$$CPR_{CAR} = 1 - (1 - CPR_H)(1 - CPR_S)(1 - CPR_T)(1 - CPR_B)$$



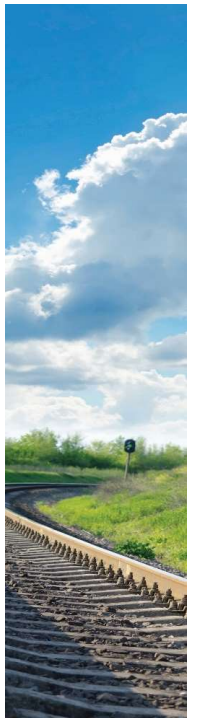
# RSI – AAR Safety Project

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## Latest CPR Study – TWP – 17

### Data Included:

- Accident occurred 1980 through 2011
- Car was built 1970 or later
- Loaded cars only
- Stub-sill cars
- Tank car classes DOT/TC-111, 211, 105, 112, 114, 120
- Tank steel specs TC128, A515, A516 only
- Truck capacity 100 tons or more and 4 axles only
- Damaged by impact (as opposed to strictly by fire exposure).



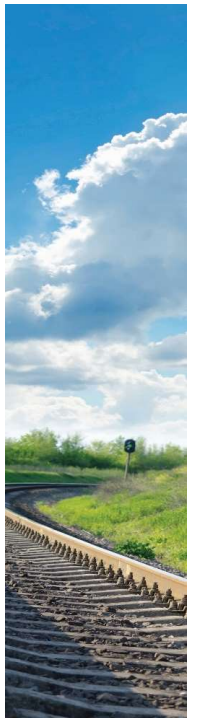


# RSI – AAR Safety Project

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The Number of Tank Car Records Used in Each Component Regression  
And the Number of Accidents Damaging Those Cars

Component	Tank Cars	Accidents
Shell	7,165	4,993
Head	4,467	2,464
Bottom Fittings	5,484	3,905
Top Fittings	4,467	2,175



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### CPR – Average Mainline Conditions

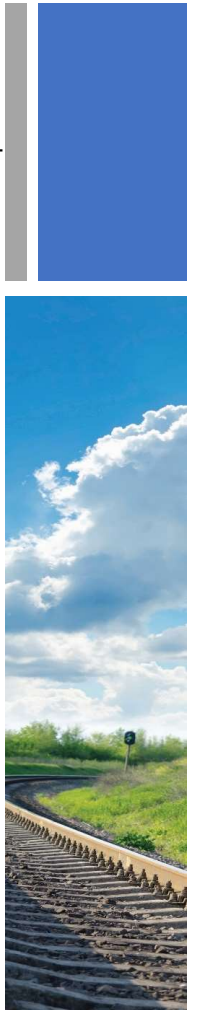
- Derailment Speed = 26 mph
- 11 Cars Derailed
- Car is Halfway Back in Derailment String – 6<sup>th</sup> Car

Source: FRA mainline and siding freight train accidents for the period 2003-2012



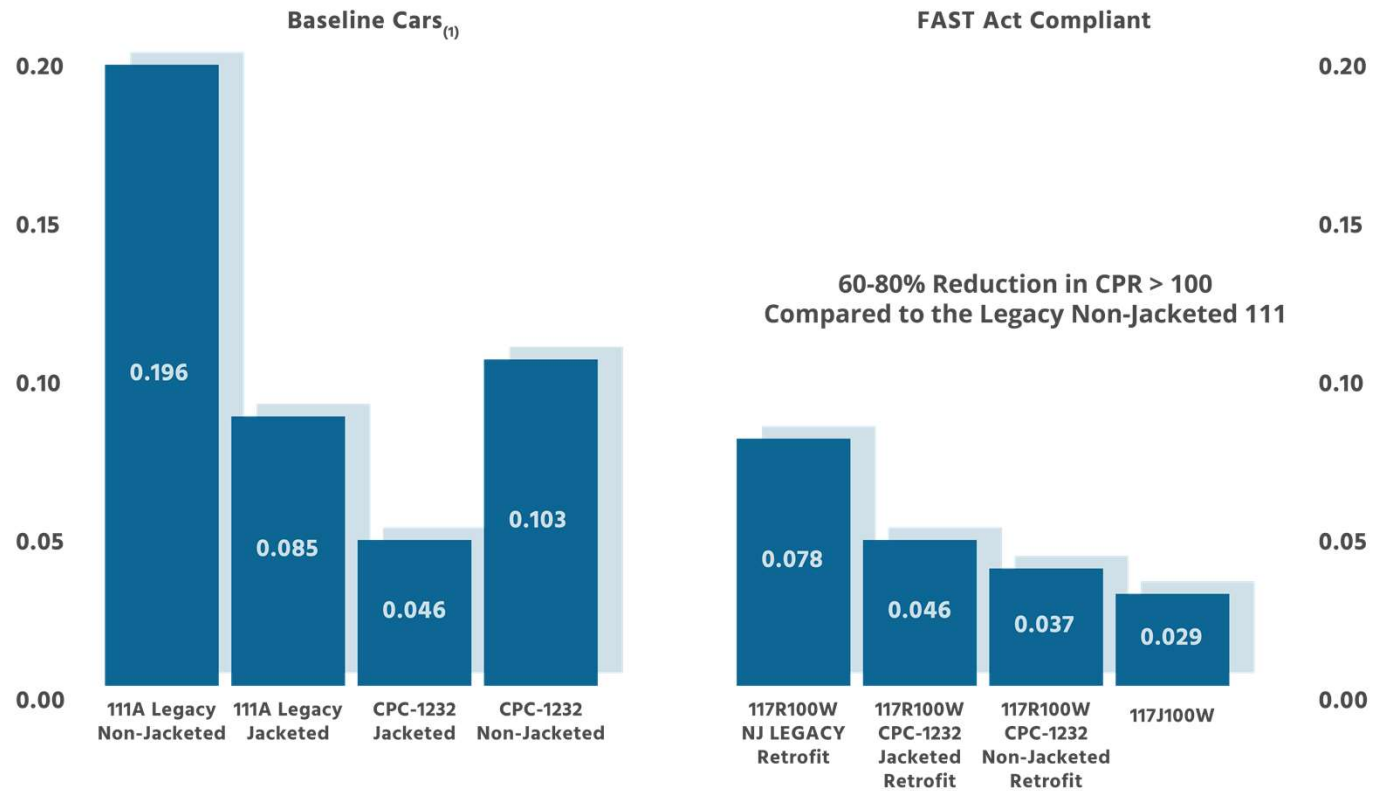
**CPR > 100**

Released Quantity is greater than 100 gals.  
Adjusted to filter out minor releases that  
Would not be expected to cause a pool  
fire

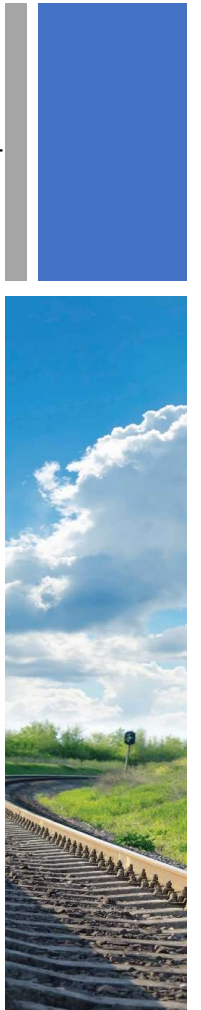


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## RELATIVE CPR > 100 OF FLAMMABLE LIQUIDS CARS



(1) Baseline Cars - Includes tank cars authorized for flammable liquid transport prior to the FAST Act



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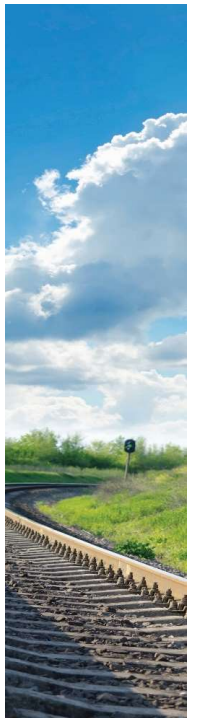
## Fleet Average CPR Calculation

Sum of (CPR > 100 for each Car Specification X Number of Trips Made for that Specification)

= Fleet Average

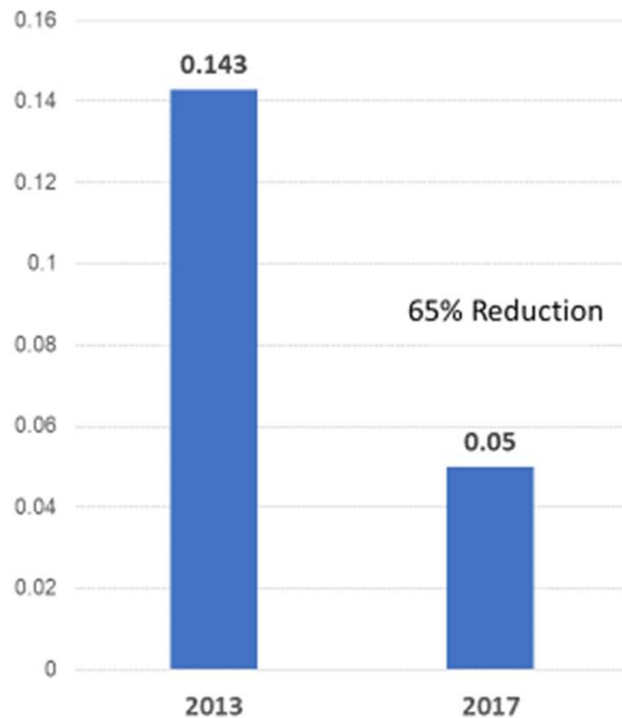
CPR > 100

total Number of Trips Made for all Car Specifications



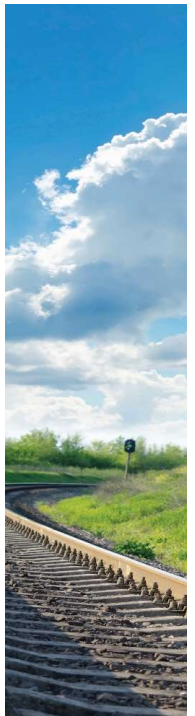
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## Change In Average Fleet CPR $>_{100}$ for Crude Oil (2013 vs. 2017)



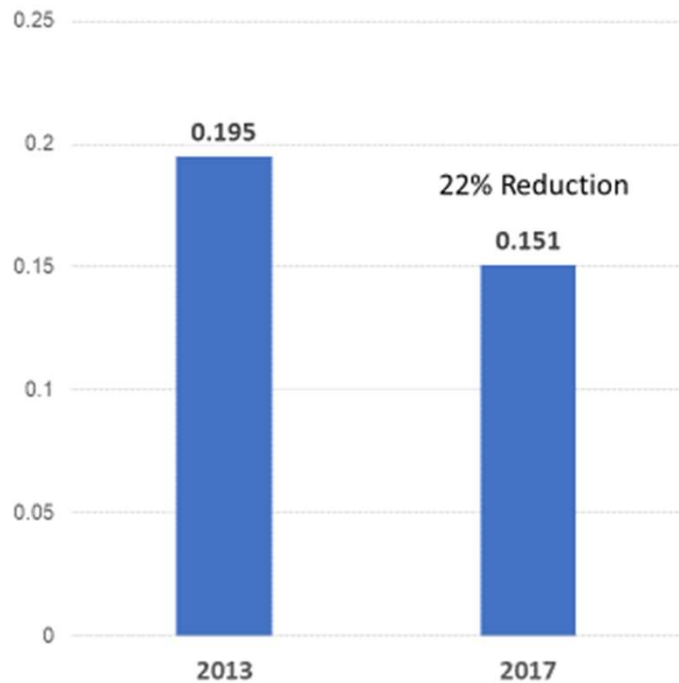
### Key Factors:

- 99.6% Reduction in DOT 111 Shipments
- 86% Reduction in Non-Jacketed CPC-1232 Shipments
- 272% Increase in Jacketed CPC-1232 Shipments
- 31% of Crude Oil Shipments in 117J, 117R and 120J Specification Tanks
- 3/1/2018 Deadline for DOT 111 Removal



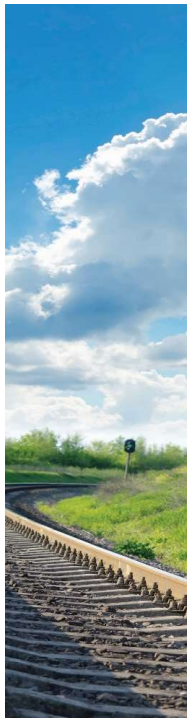
# RSI – AAR Safety Project

## Change In Average Fleet CPR <sub>>100</sub> for Ethanol (2013 vs. 2017)



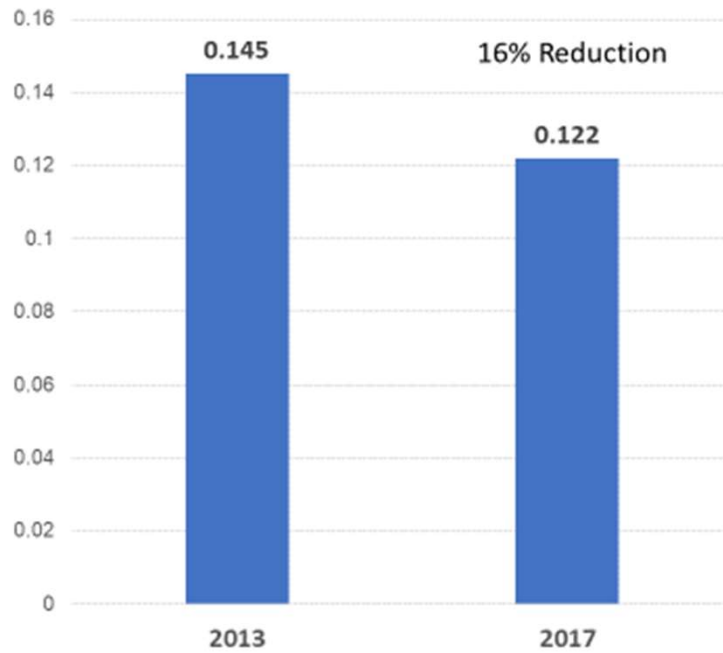
### Key Factors:

- Total Shipments Increased by 22%
- 15% Reduction in DOT 111 Shipments
- CPC-1232 shipments Increased by 1220%
- 10% of Shipments Made by CPC-1232 Tanks
- Use of DOT 117 & 120 Car specifications Increased to 21% of Shipments
- 5/1/2023 Deadline for DOT 111 Removal



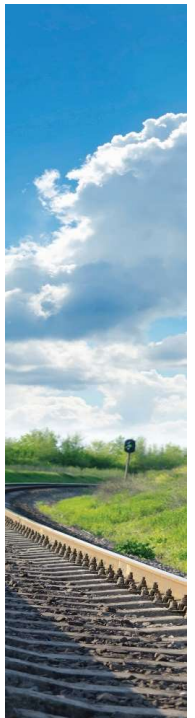
# RSI – AAR Safety Project

Change In Average Fleet CPR > 100 for Other Flammable Liquids (2013 vs. 2017)



Key Factors:

- Total Shipments Increased by 32%
- 3% Reduction in DOT 111 Shipments
- Use of CPC-1232 Specification Tanks Increased by 433%
- 24% of Shipments Made by CPC-1232 Tanks
- DOT 117/120 Specification Tanks Made over 23K Shipments or 7% of Total Shipments
- 5/1/2025 Deadline for DOT 111 Removal (packing group I)
- 5/1/2029 Deadline for DOT 111 Removal (packing group II & III)





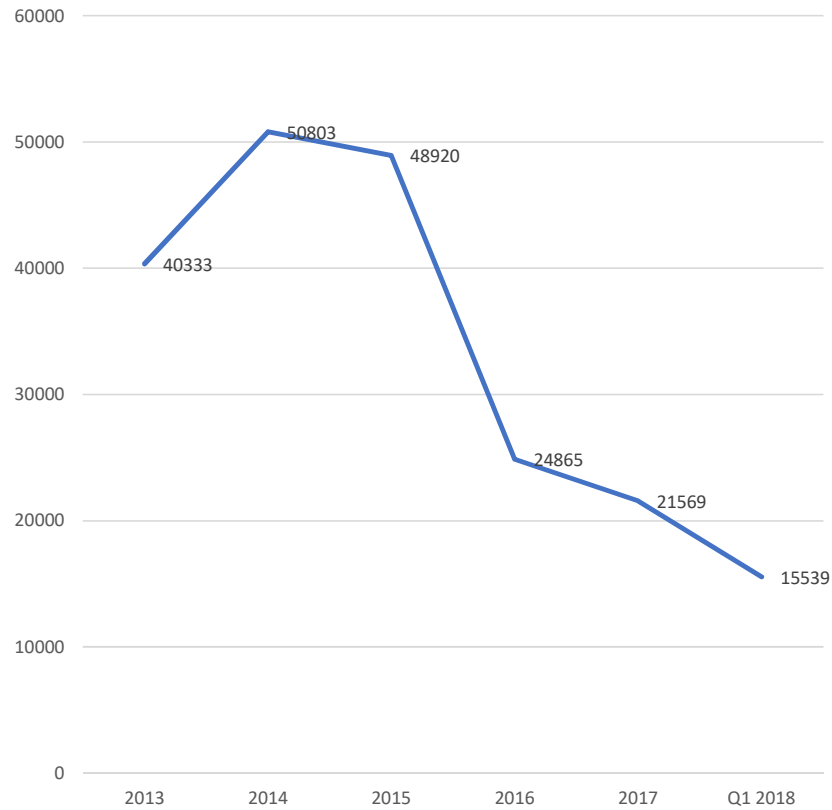
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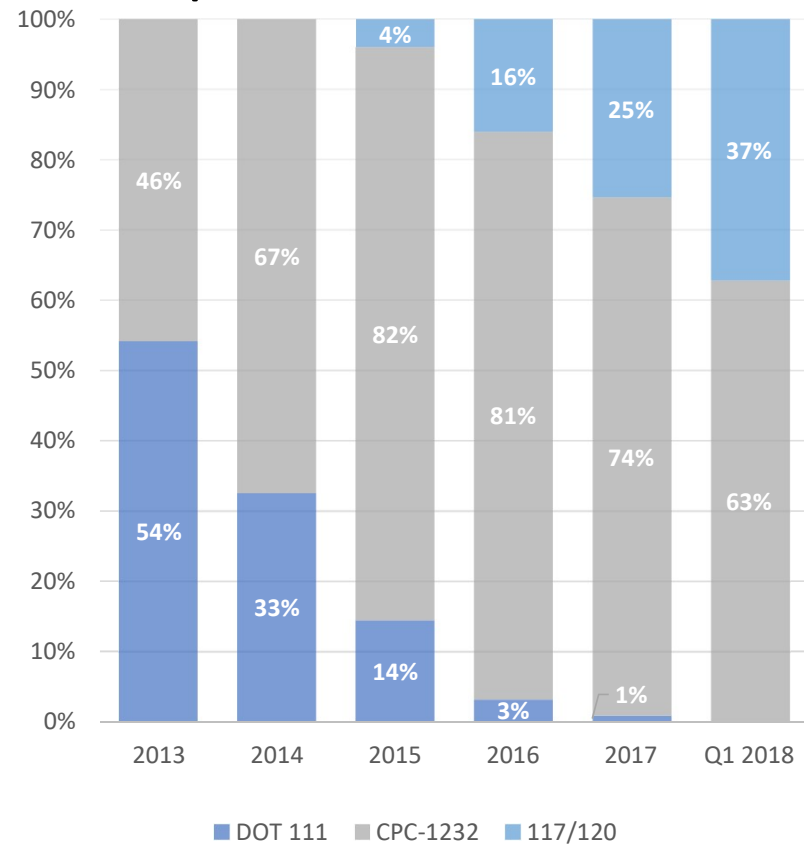
# 2018 Flammable Liquid Fleet Progress Report



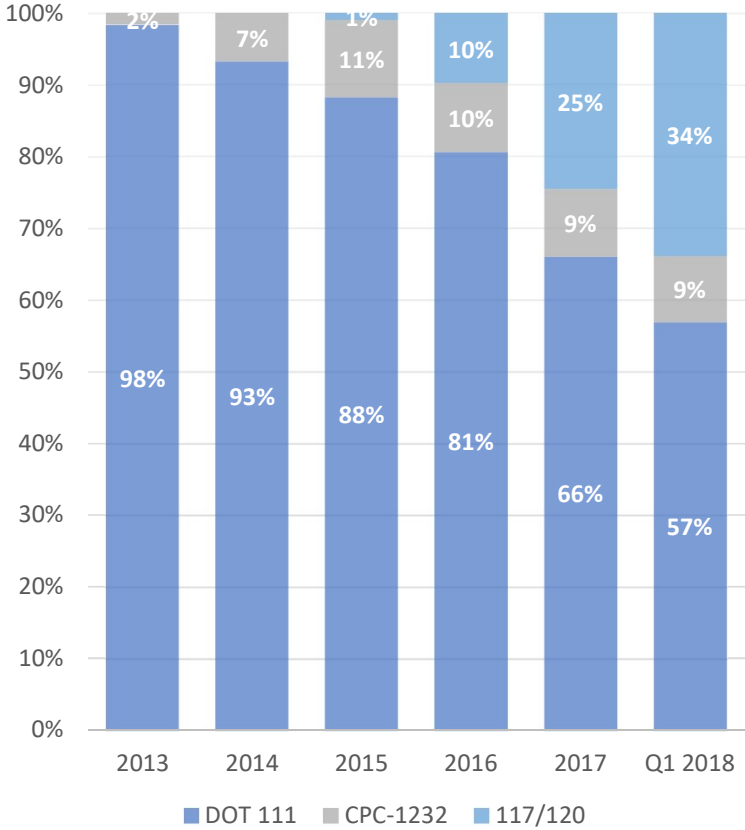
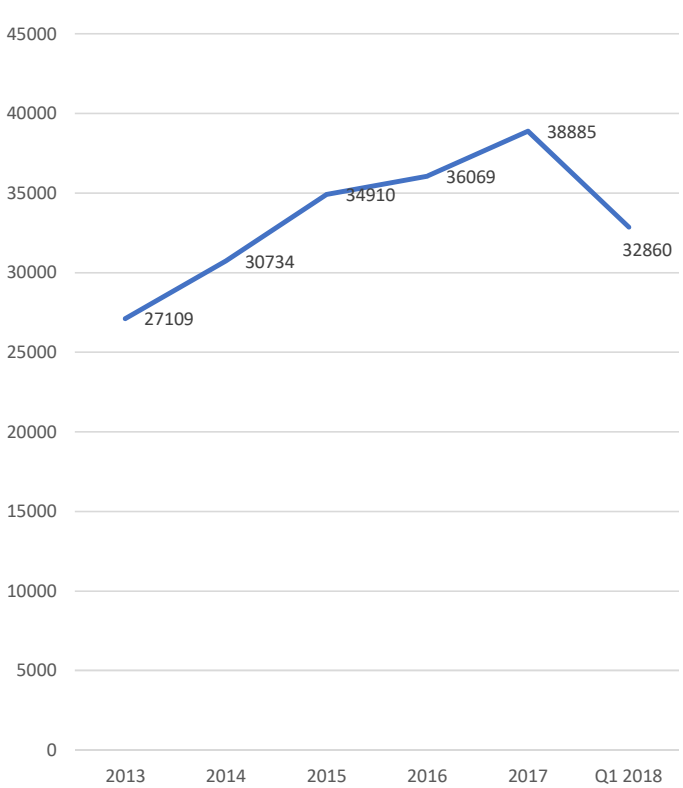
# Crude Oil Fleet Size & Composition



Source :Association of American Railroads

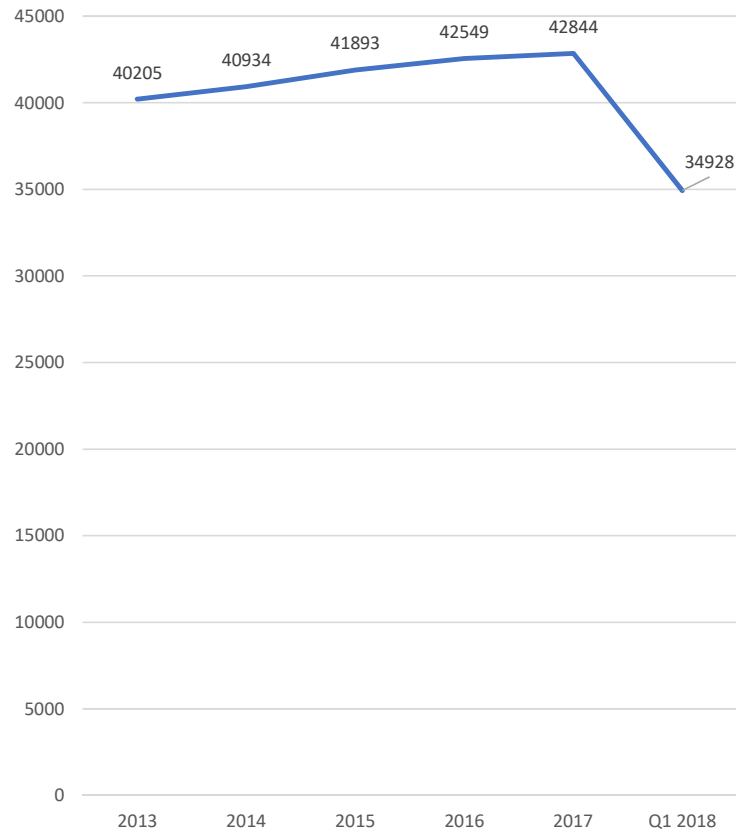


# Ethanol Fleet Size & Composition

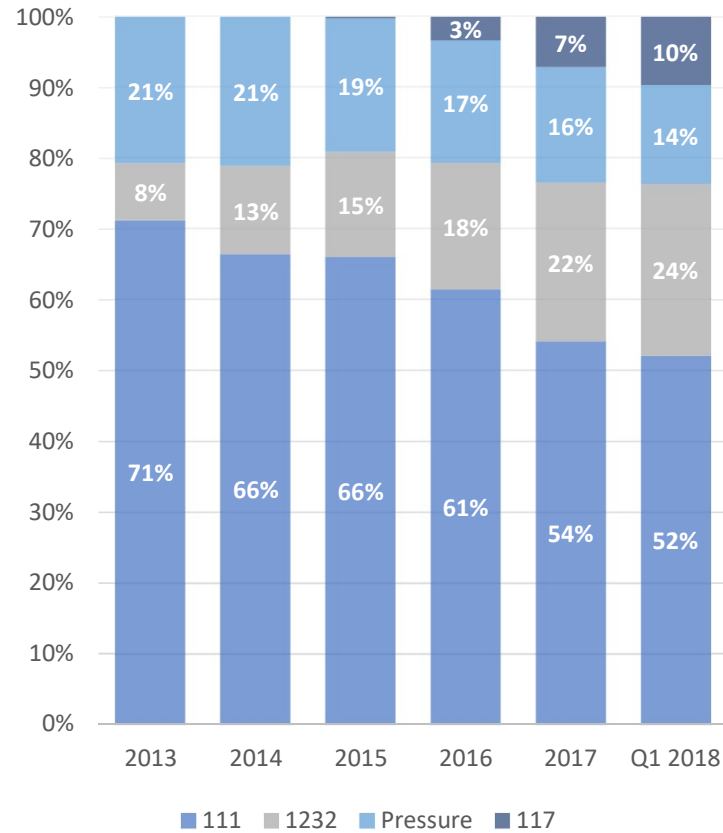


Source :Association of American Railroads

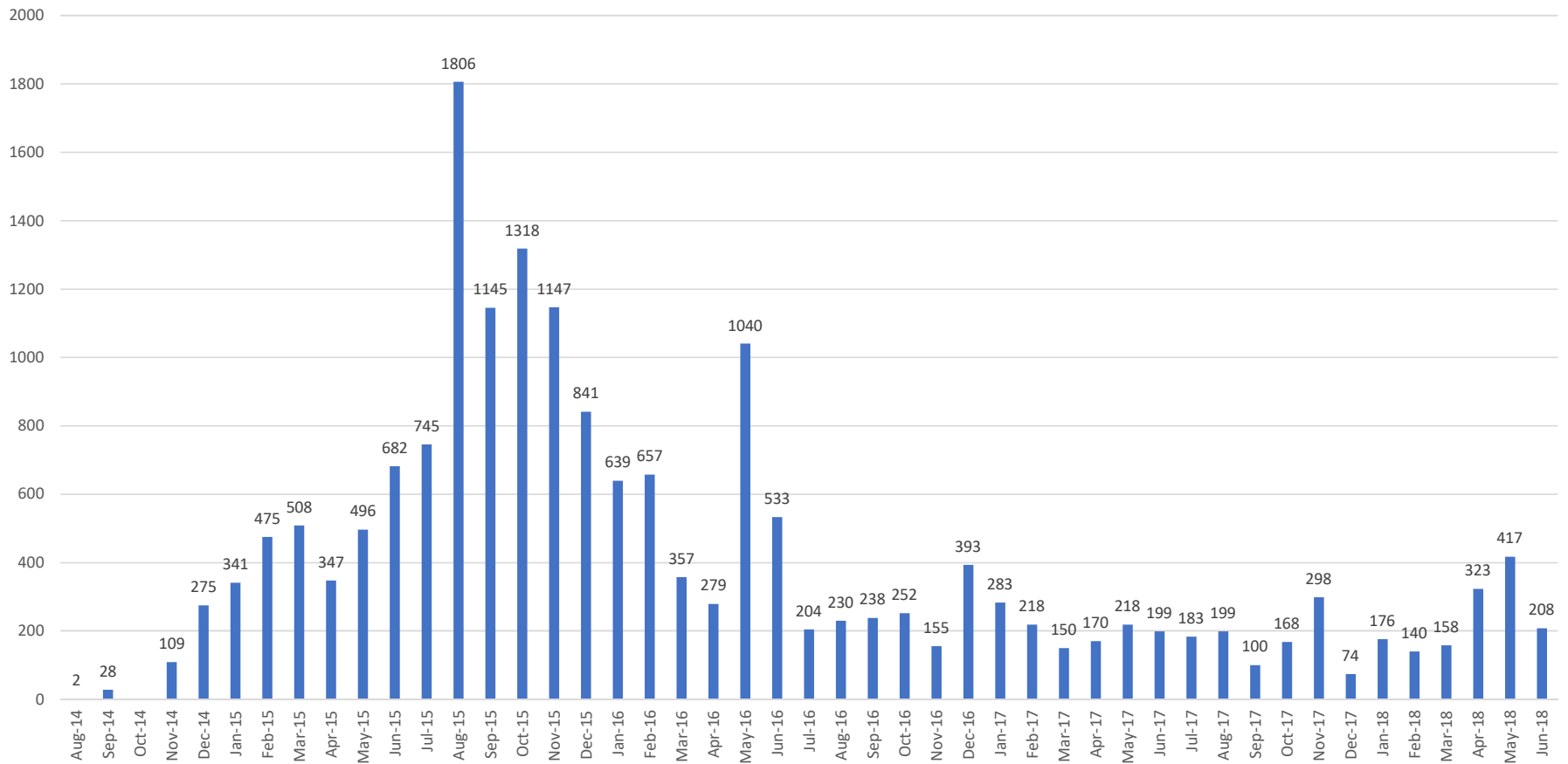
# Other Flammable Liquids



Source :Association of American Railroads

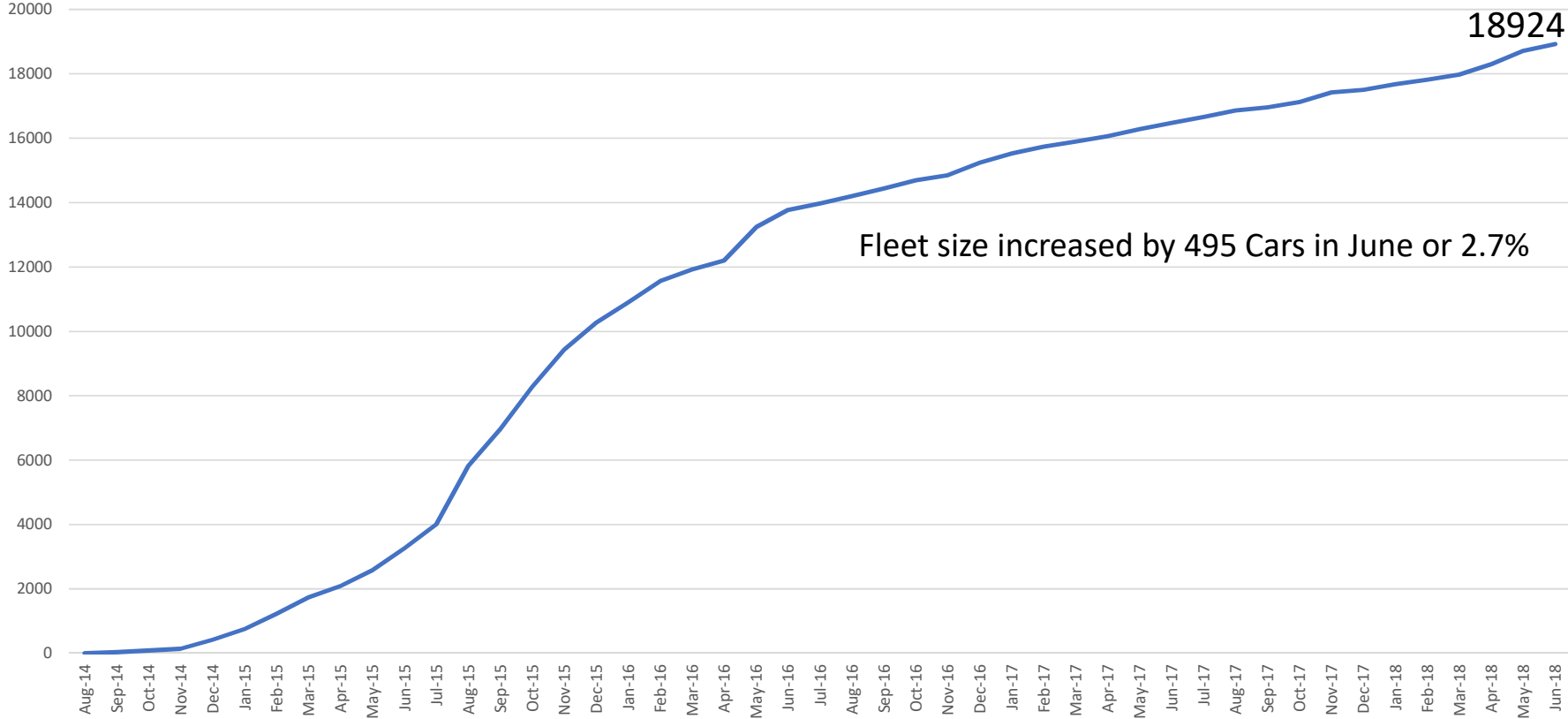


# DOT 117J & 120J200 Monthly Production



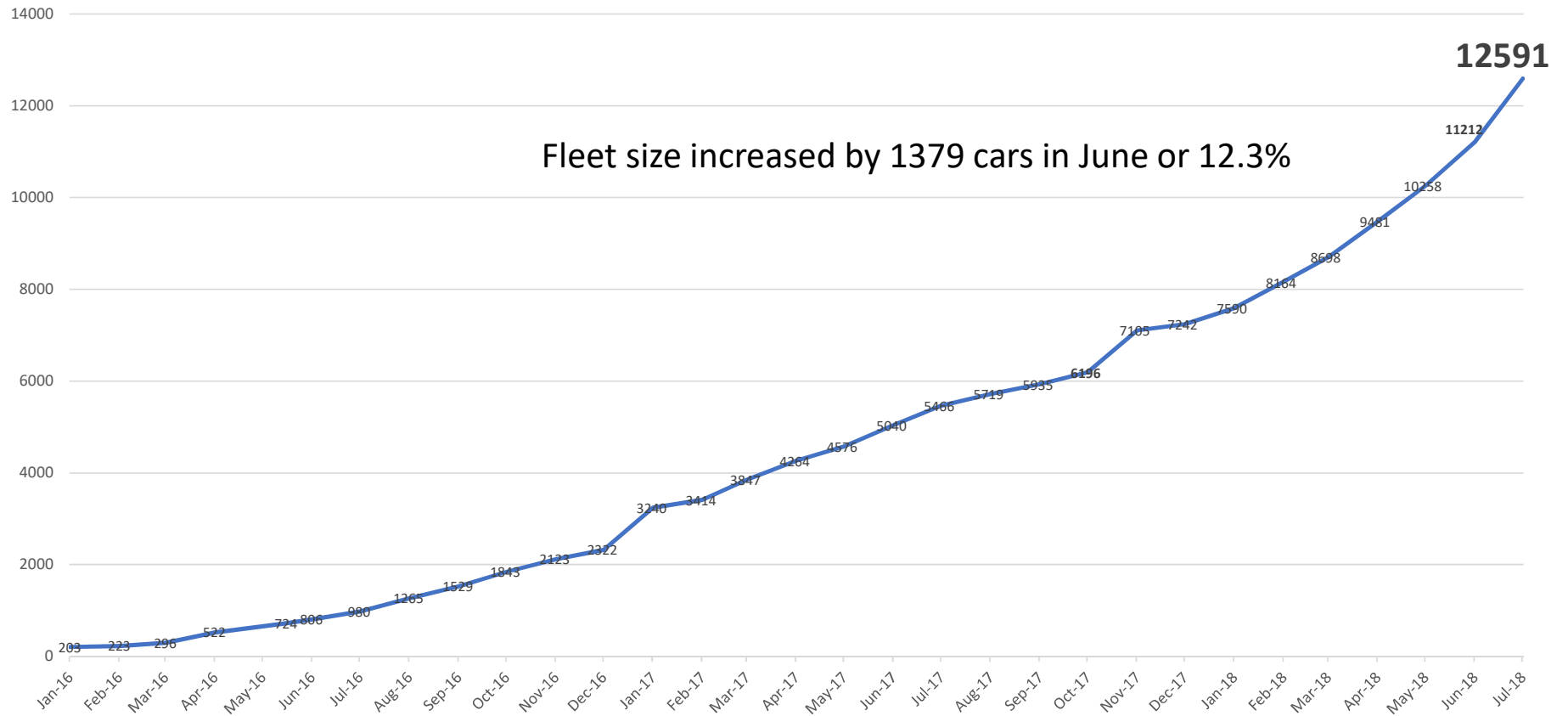
Based on 7/1/2018 UMLER File

# DOT 117J & 120J200 Fleet Growth



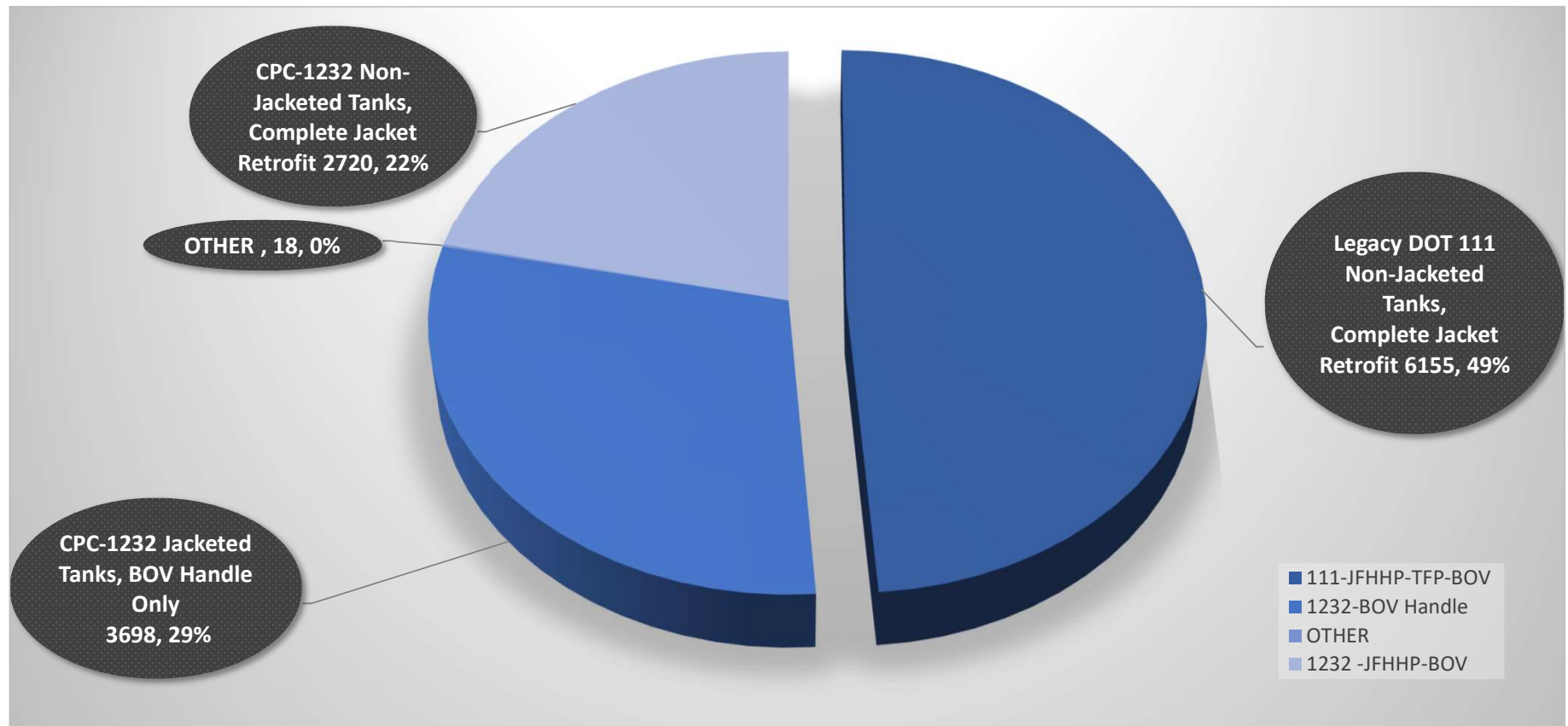
Based on 7/1/2018 UMLER

# DOT 117R Fleet Growth



Based on 7/1/2018 UMLER

# DOT 117R Fleet Composition



Based on 7/1/2018 UMLER



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**Thank You**

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