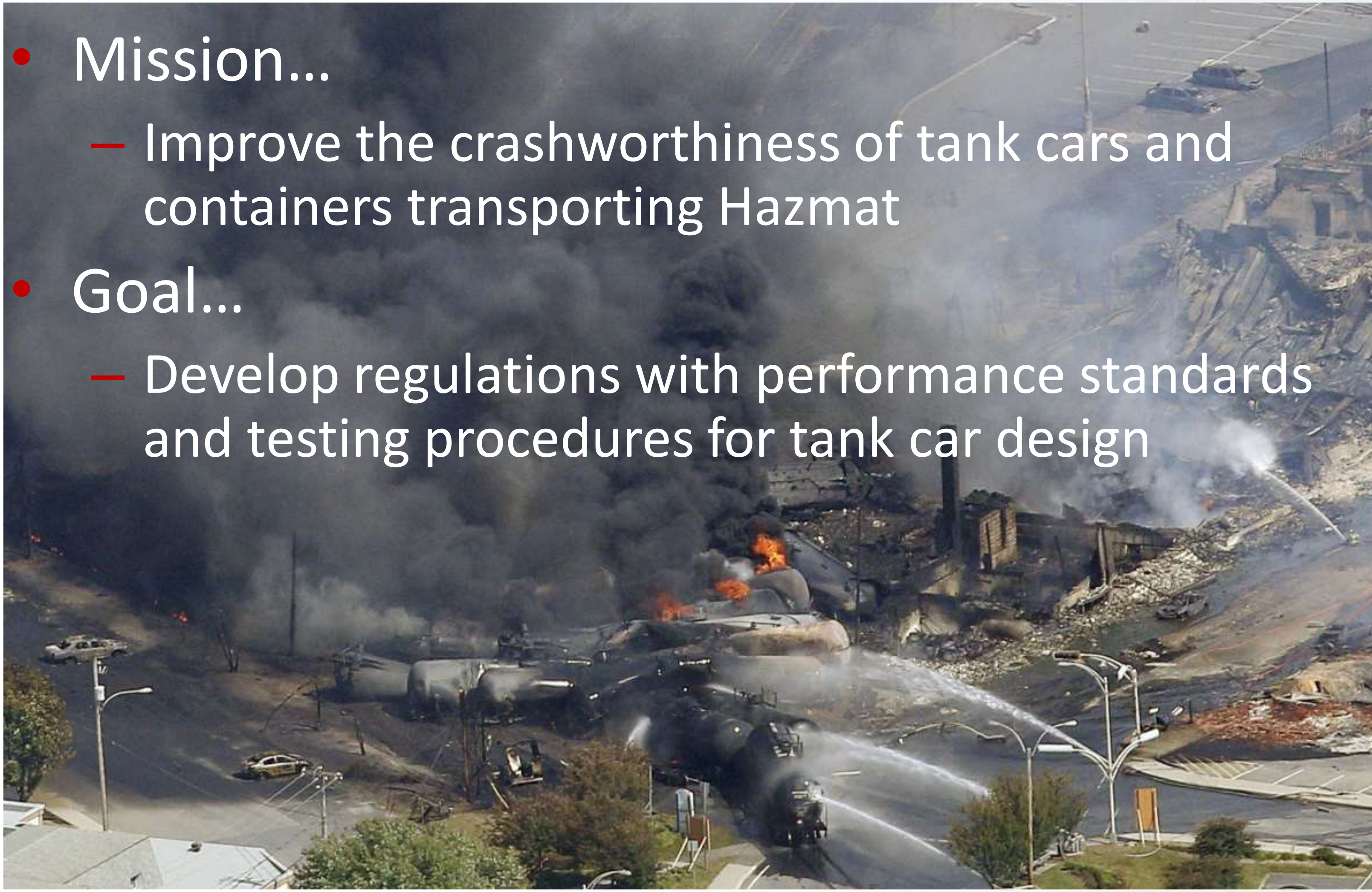
U.S. Department of Transportation
Federal Railroad Administration

OFFICE OF RESEARCH & DEVELOPMENT

Hazardous Materials and Tank Car Program Research Areas
May 2014

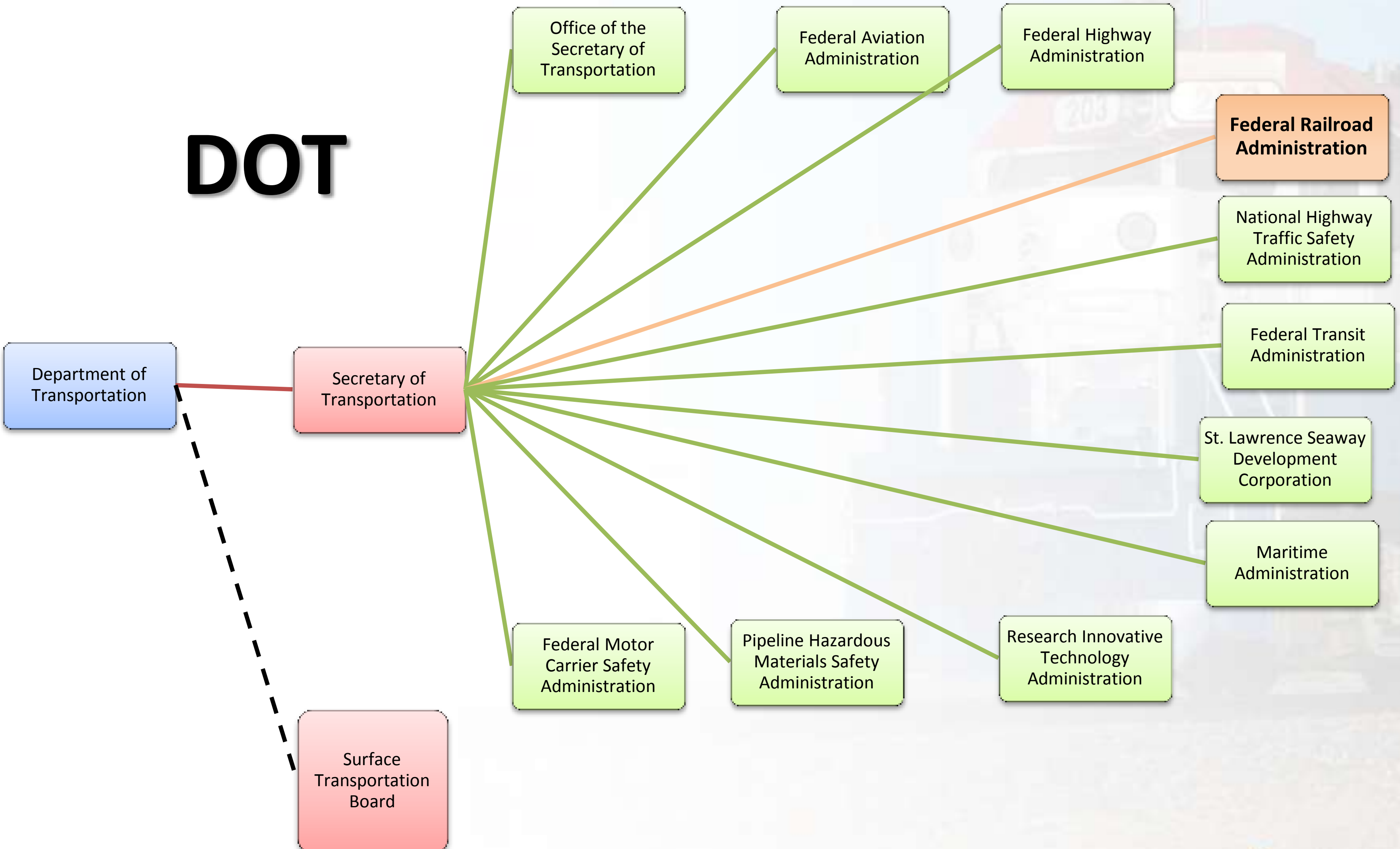
FRANCISCO GONZÁLEZ, III
Hazardous Materials and Tank Car Project Manager
Office of Research and Development
Office of Railroad Policy and Development

Tank Car Structural Integrity

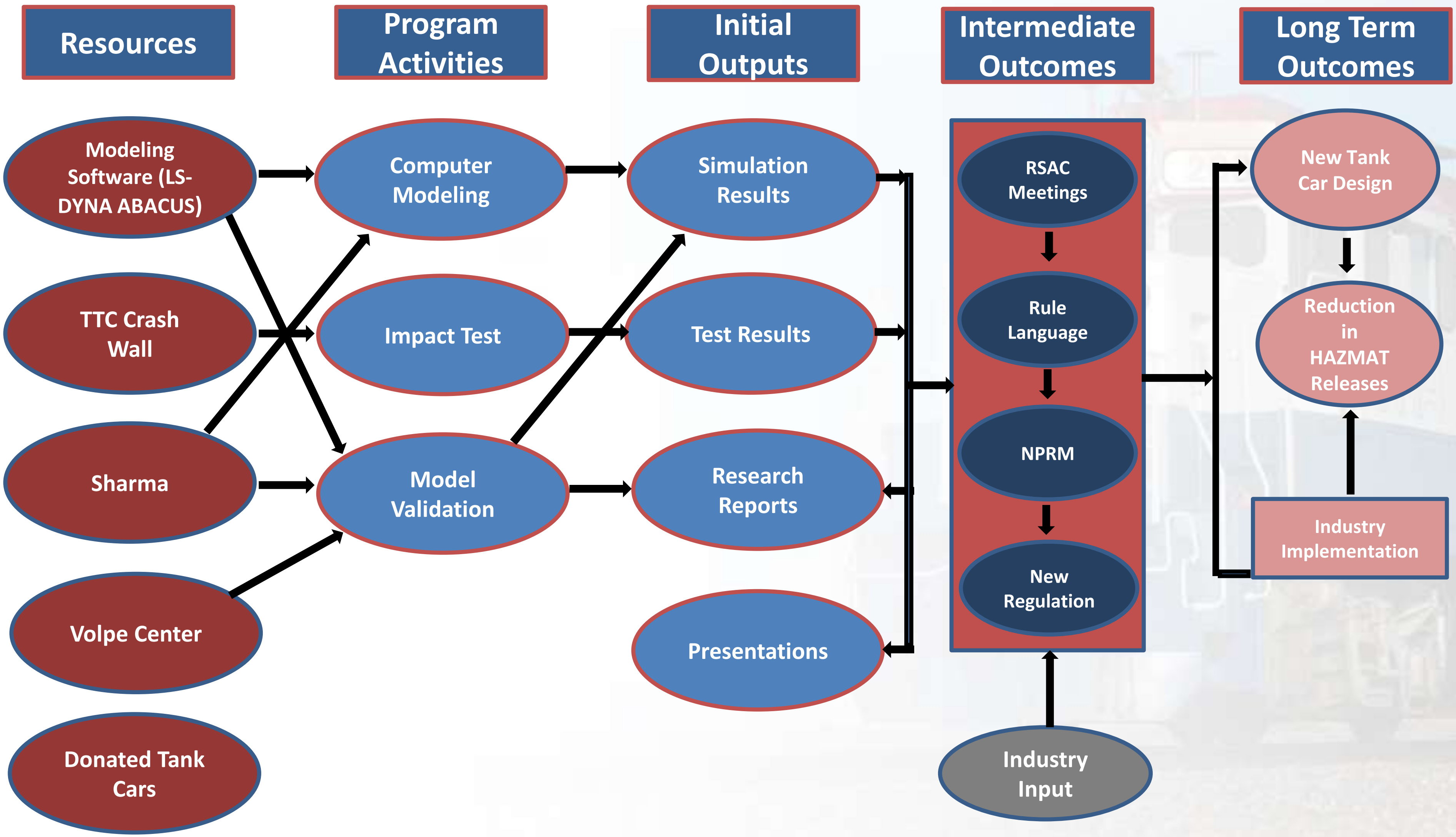


- Mission…
  - Improve the crashworthiness of tank cars and containers transporting Hazmat
- Goal…
  - Develop regulations with performance standards and testing procedures for tank car design

DOT


Department of Transportation
Secretary of Transportation
Surface Transportation Board
Office of the Secretary of Transportation
Federal Aviation Administration
Federal Highway Administration
Federal Railroad Administration
National Highway Traffic Safety Administration
Federal Transit Administration
St. Lawrence Seaway Development Corporation
Maritime Administration
Research Innovative Technology Administration
Pipeline Hazardous Materials Safety Administration
Federal Motor Carrier Safety Administration

Roadmap



Resources
Program Activities
Initial Outputs
Intermediate Outcomes
Long Term Outcomes
Modeling Software (LS-DYNA ABACUS)
TTC Crash Wall
Sharma
Volpe Center
Donated Tank Cars
Computer Modeling
Impact Test
Model Validation
Simulation Results
Test Results
Research Reports
Presentations
RSAC Meetings
Rule Language
NPRM
New Regulation
Industry Input
New Tank Car Design
Reduction in HAZMAT Releases
Industry Implementation

NTSB
D

January 18, 2002
Minot, ND

NTSB
C

June 28, 2004
Macdona, TX

NTSB
C

January 6, 2005
Graniteville, SC

NTSB
C

October 15, 2005
Texarkana, AR

2002 | 2003 | 2004 | 2005

NTSB
C

July 10, 2005
Anding, MS

August 2005

President signs SAFETEA-LU

Legend

- Accident
- NTSB — NTSB Investigation
- FRA — FRA Investigation
- TSBC — TSB of Canada Investigation
- D — Derailment
- C — Collision
- GC — Grade Crossing
- Broken Rail
- Broken Joint Bar
- Public Meeting
- Regulatory Action
- Collaboration with Industry

Placards

- Anhydrous Ammonia
- Butadiene
- Chlorine
- Liquefied Petroleum Gas
- Propylene
- Vinyl Chloride
- Ethanol
- Crude Oil
- Toluene
- Diesel Fuel
- Denatured Alcohol
- Phthalic Anhydride
- Sodium Chlorate
- Ferric Chloride
- Terephthalic Acid

May 31-June 1, 2006

FRA/PHMSA Public Meeting

Dow, UP, and UTLX announce NGRTC project at FRA/PHMSA Public Meeting

October 20, 2006 — NTSB D

October 20, 2006
New Brighton, PA

November 16, 2006

FRA/PHMSA initiate NPRM

December 14, 2006

FRA/PHMSA Public Meeting

January 16, 2007

FRA signs Memorandum of Cooperation with Dow, UP, and UTLX

NTSB D

January 16, 2007
Shepherdsville, KY

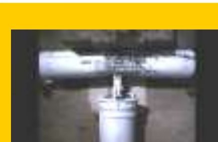
NTSB D

March 12, 2007
Oneida, NY

March 30, 2007

FRA/PHMSA Public Meeting

April 26, 2007
Full-scale Shell Impact Test #1



July 11, 2007
Full-scale Shell Impact Test #2

NTSB D

October 10, 2007
Painesville, OH

April 1, 2008

PHMSA Final Rule on Interim Cars published in Federal Register

October 2008

Rail Safety Improvement Act (RSIA)

November 26, 2008

PHMSA publishes HM-232e

Fall 2008

Government/ Industry collaboration in NGRTC project dissolved

January 13, 2009

PHMSA publishes HM-246

NTSB D

June 19, 2009
Cherry Valley, IL

2009

Advanced Tank Car Collaborative Research Program (ATCCRP) initiated

2006 2007 2008 2009

2010

2011

2012

2013

FRA
D


February 6, 2011
Arcadia, OH


May 18, 2011
Full-scale Shell
Impact Test #3

August to
December 2011

Government/
Industry Task
Force on General
Purpose Tank Cars

NTSB
D


October 7, 2011
Tiskilwa, IL


July 11, 2012
Columbus, OH

NTSB
D

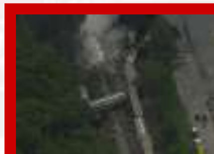
FRA
D


August 5, 2012
Plevna, MT

NTSB
D


November 30, 2012
Paulsboro, NJ

NTSB
GC


May 28, 2013
White Marsh, MD

TSBC
D


July 6, 2013
Lac-Mégantic, Quebec

August 7, 2013

FRA issues Safety
Advisory 2013-06
and Emergency
Order No. 28

August 16, 2013

Government/
Industry Task
Force on General
Purpose Tank Cars
Resurrected

August 29, 2013

Rail Safety Advisory
Committee (RSAC)
convenes first
Emergency Meeting

October 28, 2013

RSAC Hazmat
Working Group
Kick-off Meeting

December 16, 2013

RSAC Hazmat
Working Group
Meeting

August 27-28, 2013

PHMSA/FRA Public
Meeting

FRA
D


Novembe
Alicevil


December 18, 2013
Full-scale Shell
Impact Test #4

February 2014
Full-scale Shell
Impact Test #5

2014 2015 2016 2017

December 30, 2013
Casselton, ND

NTSB

D

January 27, 2014

RSAC Hazmat
Working Group
Meeting

March 4, 2014

RSAC Hazmat
Working Group
Meeting

HM Projects

1. Post Accident Investigation
2. Loading/unloading Ethanol, reducing NAR's
3. Loading and unloading of Sulphur
4. Top Fitting protection non-pressure and **pressure** tank cars- On hold
5. Tank Car Structural Integrity: Impact Resistance, Fracture Toughness
6. Tank Car Operating Spectrum (Valve failures)
7. ATCCRP: Evaluation of different impactors on different tank car designs -**Complete**
8. Steel testing (Task force/VOLPE)
9. Non-destructive Evaluation Techniques
10. Valve testing (VOLPE/ Industry) Determining Effect on Environmental Factors in PRV Testing
11. **Fire test on 1/3 scale containers.**
12. **Test Procedures and evaluating techniques for new tank car designs-TWP 15**
13. **Crude oil Sampling**
14. Determine the benefits of stress relief after major welding repair to the tank car and tank car components
15. Liquid Flow test for valves-two-way flow
16. Emergency response case studies
17. Broad Agency Announcement (BAA)
    1. Rapid test to detect
    2. Probability of puncture
    3. Corrosion stress on valves
    4. Tank car new designs

RFA RENEWABLE FUELS ASSOCIATION

GUIDELINES FOR HINGED AND BOLTED MANWAY ASSEMBLY

Assembly Instructions for the Ethanol Industry

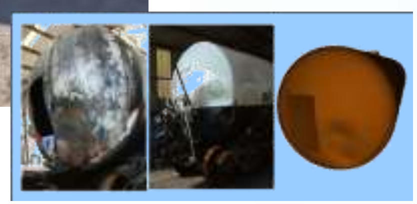
Published by: Renewable Fuels Association

Authored by: Watco Compliance Services, VSP Technologies, and Salco Products, Inc.

Molten Sulphur Rail Tank Car Loading and Unloading Operations

Leading Practices in Industry

Tank Car Structural Integrity: Current & Next Steps



<u>Current</u>:

- Full Scale Side Impact Testing with different type of tank cars
  - DOT 111
  - DOT 112
  - DOT 113
  - DOT 105
- Head test
- Developing Puncture Models with different tank cars

  Verify the models with the actual testing data

<u>Next Steps</u>:

- Evaluate the different protection methods
  - Head protection
  - Side protection
- Select options that provide the best results
- Testing procedures for pressure tank cars
- Modeling and simulations
- Continue improvements

<u>Project Partners</u>:

- Sharma
- VOLPE
- TTC

Resources

- Modeling software (LS-DYNA ABACUS)
  - Using dimensions and measures of the tank car and create simulations of the impact
- TTC crash wall
  - Use the repeatable testing procedures to perform the crash
- Sharma
  - Analyze the model and make an impact speed prediction to puncture
- Volpe Center
  - Help develop the testing procedures
- Donated tank cars
  - Industry providing tank cars to test and obtain the test results

Timeline of FRA/Volpe Hazmat Tank Car Research

1980

1980: Switchyard Impact Tests

1986-87: Investigation of Stub Sill Tank Car Failures

1992: Chlorine Tank Car Puncture Resistance

1993: Stress Analysis of Stub Sill Tank Cars

1997: Residual Stresses Near Weld Ends

2001: Engineering Analyses for Tank Car Head Puncture

2004: Research Addressing NTSB Recommendations from Minot, ND Derailment

2007-2008: Next-Generation Rail Tank Car (NGRTC) Project

2008-2011: Research on Shell Protection

2007- present: Full-scale Testing and Interpretation of Tank Car Shell Impacts

2014

Head impact testing conducted by Government and Industry in 1970s and '80s

Toxic by Inhalation Hazard (TIH) Tank Cars

Crude Oil and Ethanol

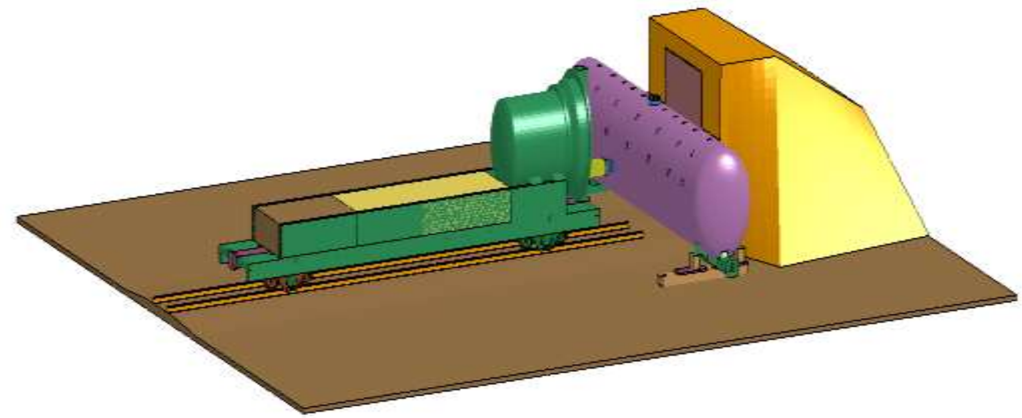
Project Overview

- Project Objective:
  - Provide the technical basis for rule-making on enhanced and alternative performance standards for tank cars and review of new and innovative designs
- Two project phases
- Each phase includes at least two full-scale tests
- Period of performance: 8-6-2013 to 12-31-2015
- Two types of tests are in the project scope:
  - With no modification to the tank car
  - With protective components
  - Head test

Test Objectives

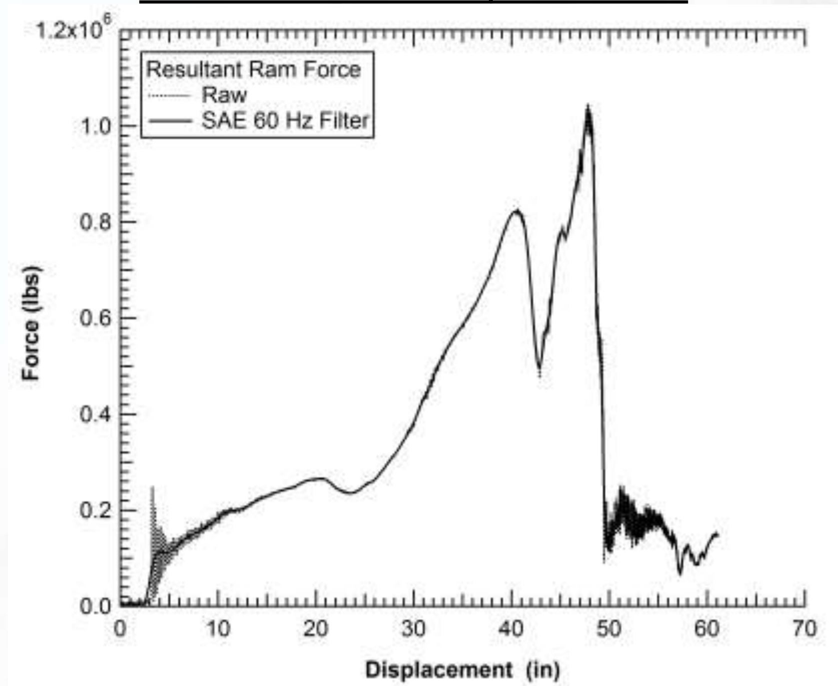
- Provide reliable data for finite element model validation
- Evaluate crashworthiness of existing equipment
- Simulate close to real event conditions
- Repeatable test conditions

Program Activities



- Computer Modeling
  - Analyzing the problem and making predictions
- Impact Test
  - Perform the side impact and record results
- Model Validation
  - Use the data to validate and calibrate the model for better confidence

Predicted Ram Impact Force

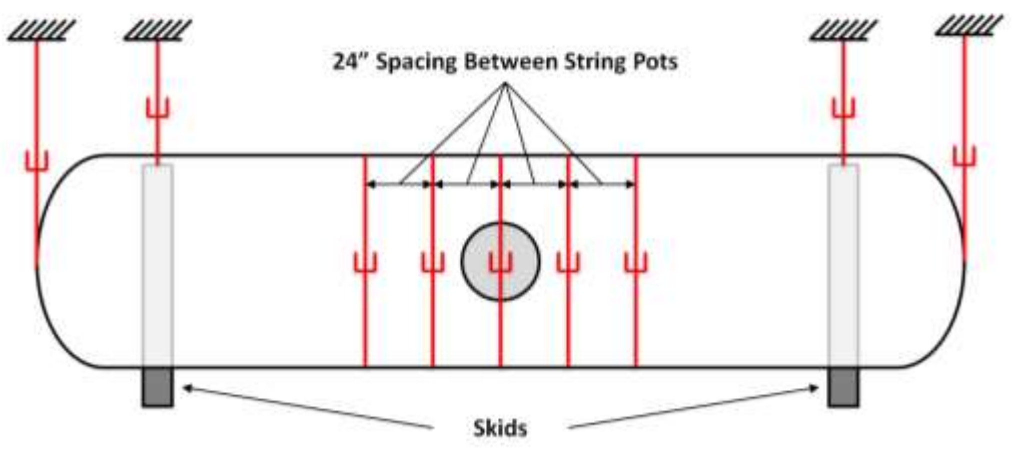


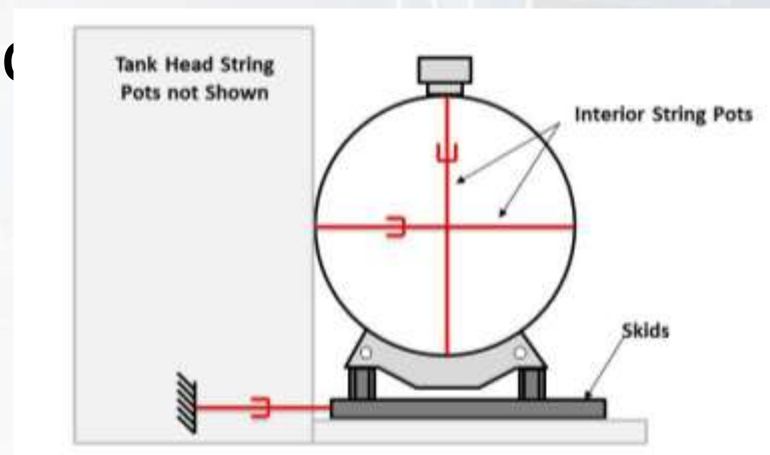
Test 1 - Overview

- Test 1 was performed on December 18th , 2013
- Tested tank car DOT 111
- Filled with water with about 3% of outage
- Tank car was not pressurized
- Impact speed:
  - Target speed: 14 mph
  - Actual speed: 14.04 mph
- Indenter size: 12” x 12”

Instrumentation

- Accelerometers on the ram car
- Speed sensors
- Pressure transducers inside the tank car and on the safety pressure relief valve
- String potentiometers inside and outside of the tank car
- Total of 32 channels





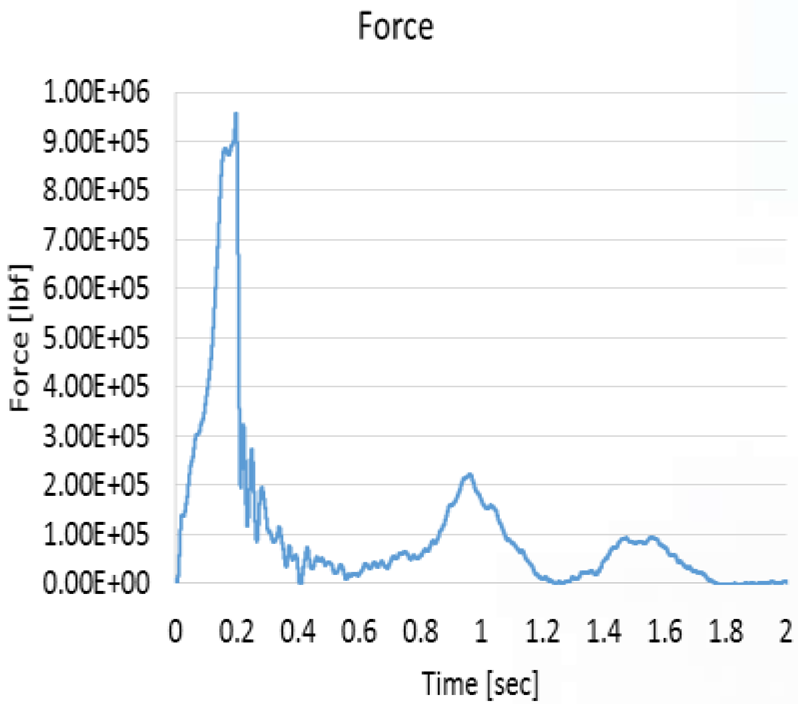
Second Test

- Test 2 was performed on February 26, 2014
- Tested tank car DOT 112J340
- Tank car was not pressurized
- Filled with water with about 3% of outage
- Impact speed:
  - Target speed: 15 mph
  - Actual speed: 14.7 mph
- Indenter size: 12” x 12

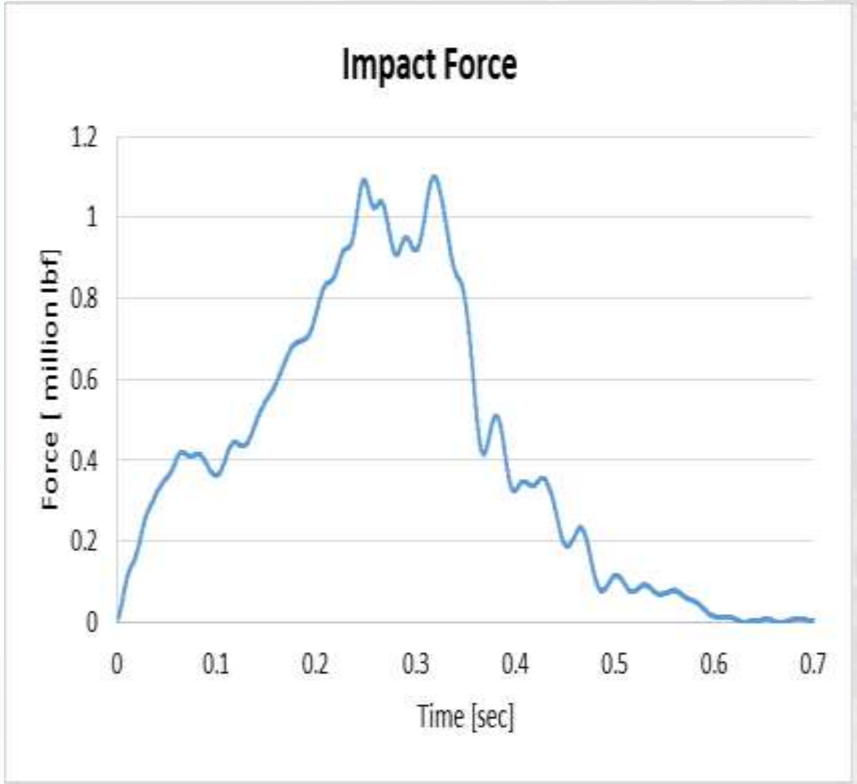
Videos

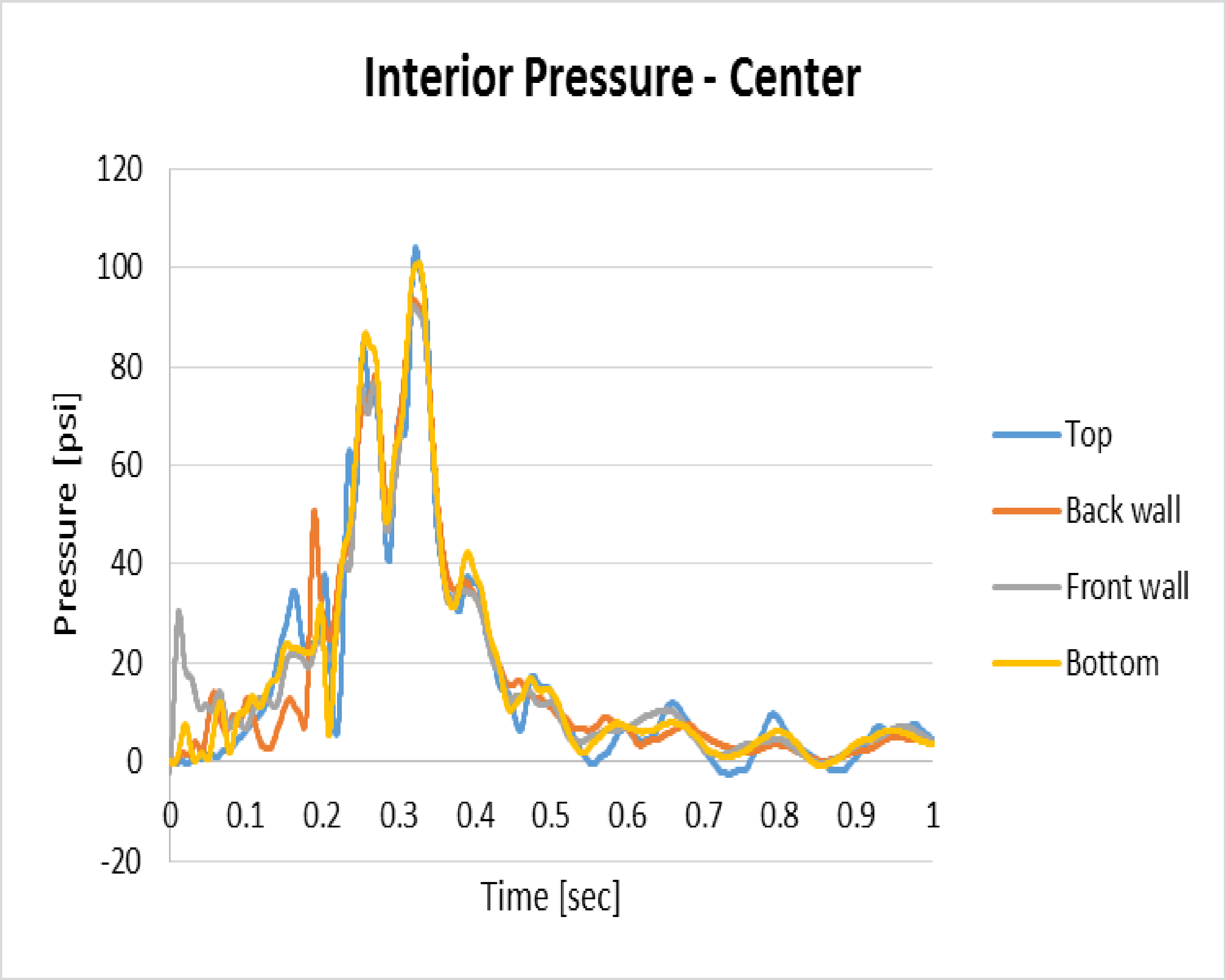
Analysis (Comparison)

First Test



Second test





Interior Pressure - Center
Pressure [psi]
120
100
80
60
40
20
0
-20
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Time [sec]
Top
Back wall
Front wall
Bottom

Initial Outputs

- Simulation Results
  - Ideas and forecast
- Test Results
  - Data, pictures, videos
- Research Reports
  - Share the wealth
- Presentations
  - Spread the word

Intermediate Outcomes

- Rail Safety Advisory Committee Mee
  - Input
- Rule Language
  - DOT develop
- Notice of Proposed Rule Making
  - Receive comments
- New Regulation
  - Performance standard and testing procedures
- Industry Input
  - Involved

Long Term Outcomes

- New Tank Car Design
  - Industry will use innovated ways
- Reduction in HAZMAT Releases
  - Better package and improved operations
- Industry Implementation

Tank car Total Containment Fire Testing

Project Update

Background

- Current regulations require the use of pressure relief devices (PRDs) on rail tank cars transporting hazardous materials.
- Industry has applied to the FRA and TC for a waiver from using PRDs on tank cars transporting Sodium Hydroxide (NaOH) and Potassium Hydroxide (KOH) solutions (total containment).
  - The technical bases for the waiver request have been the results of AFFTAC modeling suggesting that such total containment conditions are acceptable for these commodities (i.e. no failure in 100% engulfing fire for 100 minutes)

Program Objectives

- To conduct a series of 1/3 scale fire tests that can address:
  - Whether a full-scale tank car carrying NaOH or KOH solutions can survive 100 minutes in a full engulfment fire under total containment conditions
  - Validate the fidelity and performance of the AFFTAC model

General Test Plan

- Conduct multiple full engulfment fire tests on 1/3 scale tanks, representing an appropriate variety of conditions, so that the stated objectives can be reached.
- Six tests (using six tanks) will be conducted as outlined.
- Several thermocouples and pressure transducers will be used to monitor the test.

Tests

Test 0	Testing of a bare (non-insulated) tank, 98% full with water, to calibrate the fire
Test 1	Insulated tank, 98% full with water
Test 2	Insulated tank, 50% full with water
Test 3	Insulated tank, 98% full with NaOH (or KOH)
Test 4	Insulated tank, 50% full with NaOH (or KOH)
Test 5	Insulated tank – Fill volume & commodity TBD

The test sequence has been planned in a manner that increases confidence in the setup as we progress to the hazardous materials, and also to generate valuable data for validating AFFTAC.

Project Phases

- Phase I Develop of a detailed framework for the testing
- Phase II Tank Design & Construction
- Phase III Development of a representative pool fire
- Phase IV Instrumentation & Data Collection
- Phase V Fire Testing of the tanks
- Phase VI Reporting

Project Status – Phase I

- The overall project plan has been developed by the SA team, and reviewed/approved by the FRA.
- BAM in Berlin, Germany has been identified as the test facility
  - A contract with BAM has been signed and is in place.
- BAM strengths
  - Experienced team
  - Ground level fire system
  - Remote data acquisition and control
  - Safe in-ground bunker with viewing ports for test personnel

Project Status – Phase II

- Detailed design of the specimen tank is complete
  - Includes jacket, insulation, loading/unloading ports, and ports for instrumentation
- Tanks are constructed

Tanks

Project Status – Phase III

- In the process of finalizing the details for the pool fire and burner system
- The system will be fine-tuned and validated using a bare tank filled with water, to ensure that the heat input to the tank is as-specified in the test plan.

Support from CI

- Provide product for use in the test
  - Deliver to test site outside of Berlin, Germany
- Be available during the tests to provide spill cleanup or emergency response capabilities
- Participate in cost-sharing for building the test tanks
  - CI & Sharma have an agreement in-place.

Tank Details

- A 1/3 scale tank with the following dimensions is being considered for this effort:
  - 36” ID
  - 2:1 elliptical heads
  - 0.1345” Shell Thickness (gage 10) – Burst pressure ~ 500 psi
  - 0.1644” Head Thickness (gage 8)
  - Material equivalent to ASTM A516 – Grade 70
  - Overall length: 14’-4”
  - 4” of fiberglass insulation with a 11 gage jacket
  - Reinforced penetrations for thermocouples and pressure transducers
  - Fill on top and drain on bottom
    - Could use CI help in ensuring the fittings chosen are compatible with the systems used in Germany

Potential for Tank Failure

- The test setup will be designed to shut down the fuel to fire if the pressures rise to dangerous levels.

- The initial tests being done with water will help calibrate this system and minimize the possibility of release during the hazmat tests.

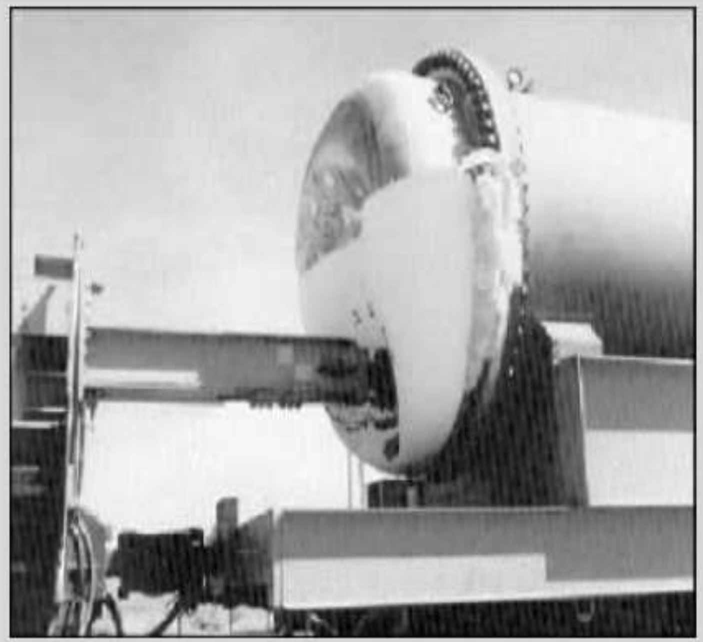
Engulfing fire with no wind effects

Example: A Tank in test facility

Reports
http://www.fra.dot.gov/Page/P0151

Hazardous Materials Transportation

The production, transportation, and use of hazardous materials are essential to the economy of the United States, Canada, and Mexico, and to their technology-dependent societies. The increased harmonization of regulations, better data, and new technology, and cooperative efforts between shippers, carriers, tank car builders, and governments influence safe transport practices for hazardous materials.



Rail transportation of hazardous materials in the United States is recognized to be the safest method of moving large quantities of chemicals over long distances. Recent statistics show that the rail industry's safety performance, as a whole, is improving. In particular, the vast majority of hazardous materials shipped by rail tank car every year arrive safely and without incident, and railroads generally have an outstanding record in moving shipments of hazardous materials safely.

See Also

- FRA Hazmat Technical Reports
- Miscellaneous Hazmat Papers
- Hazardous Materials Rail Vehicle Security Monitoring System

Reports
http://www.fra.dot.gov/Page/P0151

Research & Development

Program Areas

HazMat Transportation

- Overview
- HazMat Transportation Safety
- Tank Car Integrity
- Damage Assessment and Improved Inspection Systems
- Miscellaneous Hazmat Papers
- Next Generation Tank Car Project (NGRTC)

Home Page // Research & Development // Program Areas // HazMat Transportation // Overview

Hazardous Materials Transportation

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http://www.fra.dot.gov/eLib/Find#p1_z10_IRT_s23

http://www.fra.dot.gov/Page/P0505

Technical Reports

eLibrary Overview

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Document Type

- Civil Penalties (1)
- Compliance Manuals (1)
- Conference & Workshop (10)
- Emergency Orders (12)
- Fact Sheets (2)
- Final Rule (3)
- Forms and Templates (1)
- Interim Rule (1)
- Notices (1)
- Other Reports (26)
- Policy and Guidance (8)
- Proposed Rule (2)
- Safety Advisories (4)
- Technical Bulletins (9)
- [x] Technical Reports (51)
- Testimony (2)

Year

Month

Subject

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eLibrary Search

Your Selections: Technical Reports Hazardous Materials

5 25 50 **1 - 10** of **51** « »

2013

April

16 APR 2013

TECHNICAL REPORTS

Detailed Puncture Analyses Tank Cars: Analysis of Different Impactor Threats and Impact Conditions

SUBJECT: Hazardous Materials
AUTHOR: Steven W. Kirkpatrick
OFFICE: RPD
REPORT NUMBER: DOT/FRA/ORD-13/17
KEYWORDS: Tank car, Impactor, derailment, hazardous materials, hazmat

2010

November

01 NOV 2010

TECHNICAL REPORTS

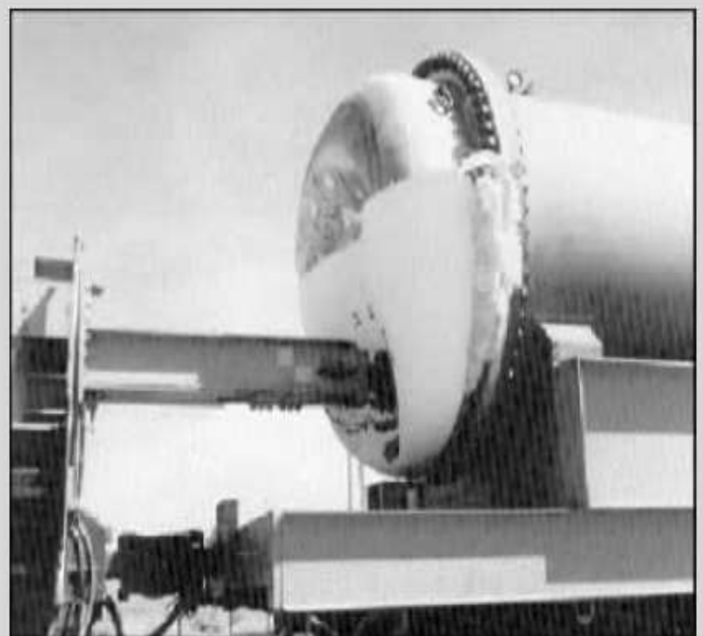
Torsional Stiffness of Railroad Coupler Connections

SUBJECT: Freight Operations, Hazardous Materials
AUTHOR: Robert Trent, Anand Prabhakaran, and Vinaya Sharma
OFFICE: RPD
REPORT NUMBER: DOT/FRA/ORD-10/13
KEYWORDS: coupler torque; coupler stiffness; rollover; shelf coupler; tank car; tank car safety

Reports http://www.fra.dot.gov/Page/P0151

Home Page // Research & Development // Program Areas // HazMat Transportation // Overview

Hazardous Materials Transportation



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http://www.fra.dot.gov/Page/P0605

See Also

FRA Hazmat Technical Reports

Miscellaneous Hazmat Papers

Hazardous Materials Rail Vehicle Security Monitoring System

NGRTC

Research & Development

Program Areas

HazMat Transportation

- Overview
- HazMat Transportation Safety
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- Damage Assessment and Improved Inspection Systems
- Miscellaneous Hazmat Papers
- Next Generation Tank Car Project (NGRTC)

Home Page // Research & Development // Program Areas // HazMat Transportation // Next Generation Tank Car Project (NGRTC)

Next Generation Tank Car Project (NGRTC)

The following reports and papers were produced and published under this cooperative effort with FRA, VOLPE, The Chlorine Institute, Tank Ca and Railroad industries:

ARA Applied Research Associates, Inc.

Detailed Puncture Analyses of Various Tank Car Designs: Final Report - Revision 1

Detailed Impact Analyses for Development of the Next Generation Rail Tank Car:
Part 1 – Model Development and Assessment of Existing Tank Car Designs
Part 2 –Development of Advanced Tank Car Protection Concepts

Structural Reliability Technology, Inc. &Applied Research Associates, Inc

Quantifying and Enhancing Puncture Resistance in Railroad Tank Cars Carrying Hazardous Materials
Phase I: Preliminary Study

Quest

Quantifying and Enhancing Puncture Resistance in Railroad Tank Cars Carrying Hazardous Materials
Phase II: Development and Validation of a Puncture Resistance Evaluation Methodology

Questions?

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Office of Research and Development

U.S. Department of Transportation

Federal Railroad Administration

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