Hazardous Materials and Tank Car Program Research Areas

May 2014

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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
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
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

Current:
- 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

Next Steps:
- 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

Project Partners:
- 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: 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

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
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

Impact Force

Force [million lbf]

Time [sec]
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 Meetings
  – 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

<table>
<thead>
<tr>
<th>Test</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 0</td>
<td>Testing of a bare (non-insulated) tank, 98% full with water, to calibrate the fire</td>
</tr>
<tr>
<td>Test 1</td>
<td>Insulated tank, 98% full with water</td>
</tr>
<tr>
<td>Test 2</td>
<td>Insulated tank, 50% full with water</td>
</tr>
<tr>
<td>Test 3</td>
<td>Insulated tank, 98% full with NaOH (or KOH)</td>
</tr>
<tr>
<td>Test 4</td>
<td>Insulated tank, 50% full with NaOH (or KOH)</td>
</tr>
<tr>
<td>Test 5</td>
<td>Insulated tank – Fill volume &amp; commodity TBD</td>
</tr>
</tbody>
</table>

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
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.
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### 2013

#### April

#### 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

#### 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
Hazardous Materials Transportation

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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 Car 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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